APPENDIX A. LABORATORY CONDITIONING EXPERIMENT

PREVIOUS RESEARCH ON LABORATORY CONDITIONING PROTOCOLS FOR WMA

The standard practice for laboratory mix design of asphalt concrete paving materials is to simulate the binder absorption and aging that occurs during construction by short-term oven aging (STOA) or conditioning of the loose mix prior to compaction for a specified time and temperature. For hot mix asphalt (HMA), the recommended procedure when preparing samples for volumetric mix design is 2 h at compaction temperature (T_c), while the recommended procedure for performance testing is 4 h at 275°F (135°C; AASHTO R 30). In the past few years, a number of studies have been conducted to evaluate the effect of different conditioning protocols on the performance of warm mix asphalt (WMA). In general, the majority of these studies have concluded that an increase in laboratory conditioning temperature, time, or both may reduce the difference in performance between WMA and HMA.

A recent study by Estakhri et al. (2010) evaluated the effect of three conditioning protocols on WMA mixtures prepared with Evotherm DAT™: 2 h at 220°F (104°C), 2 h at 275°F (135°C), and 4 h at 275°F (135°C). Performance was evaluated using the Hamburg Wheel-Tracking Test (HWTT; AASHTO T 324) and compared against HWTT results of HMA cured at 250°F (121°C). In addition, WMA mixtures prepared with Advera® and Sasobit® conditioned for 2 h at 220°F (104°C) and 4 h at 275°F (135°C) were also tested and compared against the results of HMA conditioned for 2 h at 250°F (121°C). The results for WMA Evotherm DAT™ showed that the number of passes to generate a 0.5 inch (12.5 mm) rut depth increased with higher conditioning temperature and longer conditioning time, and that the mixture conditioned for 4 h at 275°F (135°C) showed equivalent performance to the control HMA conditioned at 250°F (121°C). The HMA showed only a slight decrease in the number of passes to a 0.5 inch (12.5 mm) rut depth when conditioned at 250°F (121°C) versus 275°F (135°C). However, the change for the WMA mixtures prepared with the three different WMA technologies was significant for the two conditioning temperatures. The number of passes for all of the WMA mixtures was similar when conditioned at 220°F (104°C), and all three mixtures sustained much higher numbers of passes to a 0.5 inch (12.5 mm) rut depth when conditioned at 275°F (135°C). Based on these observations, a recommendation to condition WMA for 4 h at 275°F (135°C) was made and was incorporated in the WMA specifications for the Texas Department of Transportation (TxDOT).

Another study by Estakhri (2012) evaluated the effect of curing time and temperature on HMA and WMA properties using HWTT (AASHTO T 324) and the Overlay Test (OT). Two field projects with three different WMA mixtures were included in the study. HWTT results indicated equivalent rutting characteristics between WMA and HMA when both types of mixtures were cured for 2 h at the standard HMA compaction temperature of 275°F (135°C). In addition, the WMA mixtures conditioned with increased curing time and temperature had significantly higher resistance to rutting in the HWTT tests. Mixture performance measured in the OT was also sensitive to curing time and temperature. Specifically, a significant reduction in mixture cracking resistance was shown by both HMA and WMA when the curing time increased from 2 to 4 h. Based on results from both tests, it was concluded that curing time and temperature have a significant effect on mixture stiffness.

A study by Al-Qadi et al. (2012) focused on the short-term characterization and performance of WMA with the following technologies: Evotherm DAT™, Sasobit®, and Foaming. The effect of loose-mix reheating on mixture properties was evaluated on the basis of comparison of reheated plant-mixed laboratory-compacted (PMLC) specimens versus on-site PMLC specimens. Laboratory tests used in the study included dynamic modulus (AASHTO TP 79-10), flow number (AASHTO TP 62-03), HWTT (AASHTO T 324), indirect tensile (IDT) creep and strength (AASHTO T 322-07), and semi-circular bending fracture tests (ASTM D7313-07a). Test results indicated that the effect of reheating on the mixture's complex modulus, tensile strength, and rutting resistance was significant. In addition, an elevated reheating temperature had a more significant effect on test results.

In a separate study, the University of California Pavement Research Center utilized the conditioning protocol of 4 h at T_c for preparing laboratory-mixed laboratory-compacted (LMLC) specimens as part of a comprehensive accelerated pavement testing (APT) program (Jones, 2011). Results showed no difference in rut depth between WMA and the control HMA after HWTT (AASHTO T 324) and full-scale accelerated load tests (using the heavy vehicle simulator) with this conditioning protocol. However, WMA without conditioning prior to compaction was more susceptible to rutting. These results confirmed that additional laboratory conditioning significantly increases the stiffness of WMA such that equivalent performance to HMA is eventually achieved.

Research performed at the University of Kentucky (Clements, 2011) explored the differences in flow number test (AASHTO TP 62-03) and disc-shaped compact tension test (ASTM D7313-07a) performed on HMA and WMA conditioned at several intervals (0.5 h, 2 h, 4 h, and 8 h) at 275°F (135°C) and 240°F (114°C), respectively. Since no differences were observed between the performance of HMA and WMA at the various conditioning times, the author proposed considering WMA and HMA as equivalent with respect to conditioning time. A complementary study by Clements (2012) evaluated the performance of WMA as compared to HMA with different conditioning times prior to compaction. Evotherm® 3G was used as the WMA additive, and four aging times for loose mix were included in the study (0.5 h, 2 h, 4 h, and 8 h). WMA performances were evaluated and compared to those of HMA, on the basis of test results in dynamic modulus (AASHTO TP 79-10), flow number (AASHTO TP 62-03), HWTT (AASHTO T 324), and disc-shaped compact tension (ASTM D7313-07a) tests. Test results indicated that WMA had lower stiffness and higher susceptibility to rutting than HMA, yet it had greater fracture energy when tested at 28°F (-2°C). The lower production temperature of WMA and the incorporation of chemical additives in mixture were attributed to the difference in mixture properties. In addition, it was shown in the study that generally, increasing the aging period corresponded with an increase in mixture stiffness and rutting resistance for both HMA and WMA.

The recently completed National Cooperative Highway Research Project (NCHRP) on mix design practices for WMA (Bonaquist, 2011a) recommended a conditioning protocol for WMA of 2 h at T_c for both volumetric mix design and performance testing as listed in the draft appendix to AASHTO R 35. This conditioning protocol was selected based on comparisons of maximum specific gravity (AASHTO T 209) and IDT strength (AASHTO T 283) of LMLC specimens subjected to the mentioned conditioning protocol versus the results obtained for plant-mixed field-compacted (PMFC) cores. The specific gravity comparison showed equivalent maximum theoretical density for LMLC specimens and PMFC cores, indicating the same binder absorption level. The difference in IDT strength between LMLC specimens and PMFC cores was

also insignificant based on a paired t-test comparison with a 5 percent significance level (i.e., alpha = 0.05). In addition, further research was recommended to develop a two-step WMA conditioning procedure for the evaluation of moisture susceptibility and rutting resistance, similar to the conditioning protocol applied to HMA. The first step would be the conditioning for 2 h at T_c to simulate binder absorption and aging during construction, and the second step would consist of an extended conditioning time at a representative high in-service temperature but no longer than 16 h (Bonaquist, 2011a).

TEST RESULTS AND DATA ANALYSIS FOR WMA LABORATORY CONDITIONING

This section provides performance test results for HMA and WMA after following the different conditioning protocols listed in Chapter 3, Section 3.2. Volumetrics, resilient modulus (M_R) stiffness, binder stiffness, aggregate orientation, and number of gyrations (N) to 7 percent air voids (AV) are discussed. Complete M_R results for the Iowa, Texas, and Montana field projects are provided in Table A.1, Table A.2, Table A.3, Table A.4, and Table A.5, respectively.

Table A.1. M_R Results for PMFC Cores versus LMLC Specimens for the Iowa Field Project

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
PMFC Cores	At construction	HMA+RAP	Average	8.2%	269.3
			Standard Deviation	1.2%	27.1
			COV%	14.6%	10.1%
		Evotherm 3G+RAP	Average	8.5%	247.8
			Standard Deviation	1.1%	16.3
			COV%	12.9%	6.6%
		Sasobit+RAP	Average	8.5%	203.7
			Standard Deviation	1.5%	26.9
			COV%	17.6%	13.2%
PMFC Cores	After winter at 6 months	HMA+RAP	Average	7.5%	275.5
			Standard Deviation	0.0%	15.6
			COV%	0.1%	5.7%
		Evotherm 3G+RAP	Average	7.2%	293.4
			Standard Deviation	0.1%	16.0
			COV%	1.9%	5.5%
		Sasobit+RAP	Average	6.9%	293.8
			Standard Deviation	0.2%	25.6
			COV%	2.8%	8.7%
LMLC	2h at Tc	HMA+RAP	Average	7.2%	309.4
			Standard Deviation	0.1%	32.9
			COV%	1.4%	10.6%
		Evotherm 3G+RAP	Average	7.4%	211.4
			Standard Deviation	0.1%	9.7
			COV%	1.4%	4.6%
		Sasobit+RAP	Average	7.2%	213.5
			Standard Deviation	0.2%	18.5
			COV%	2.8%	8.6%
LMLC	4h at Tc	HMA+RAP	Average	7.3%	477.8
			Standard Deviation	0.2%	23.4
			COV%	2.7%	4.9%
		Evotherm 3G+RAP	Average	7.5%	237.2
			Standard Deviation	0.2%	3.7
			COV%	2.7%	1.6%
		Sasobit+RAP	Average	7.6%	278.8

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
			Standard Deviation	0.2%	14.9
			COV%	2.6%	5.3%
LMLC	2h at Tc + 16h at 140°F + 2h at Tc	HMA+RAP	Average	6.9%	525.4
			Standard Deviation	0.2%	2.4
			COV%	2.9%	0.5%
		Evotherm 3G+RAP	Average	7.2%	299.9
			Standard Deviation	0.4%	19.4
			COV%	5.6%	6.5%
		Sasobit+RAP	Average	6.8%	357.5
			Standard Deviation	0.5%	10.4
			COV%	7.4%	2.9%
LMLC	2h at 275°F	HMA+RAP	Average	7.0%	344.1
			Standard Deviation	0.2%	31.3
			COV%	2.9%	9.1%
		Evotherm 3G+RAP	Average	8.0%	301.0
			Standard Deviation	0.2%	10.4
			COV%	2.5%	3.5%
		Sasobit+RAP	Average	7.4%	288.0
			Standard Deviation	0.1%	15.7
			COV%	1.4%	5.5%
LMLC	4h at 275°F	HMA+RAP	Average	7.1%	376.8
			Standard Deviation	0.1%	3.2
			COV%	1.4%	0.8%
		Evotherm 3G+RAP	Average	7.1%	349.9
			Standard Deviation	0.2%	4.3
			COV%	2.8%	1.2%
		Sasobit+RAP	Average	7.0%	302.6
			Standard Deviation	0.5%	32.8
			COV%	7.1%	10.8%

Table A.2. M_R Results for PMFC Cores versus PMLC Specimens for the Iowa Field Project

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
PMFC Cores	At construction	HMA+RAP	Average	8.2%	269.3
			Standard Deviation	1.2%	27.1
			COV%	14.6%	10.1%
		Evotherm 3G+RAP	Average	8.5%	247.8
			Standard Deviation	1.1%	16.3
			COV%	12.9%	6.6%
		Sasobit+RAP	Average	8.5%	203.7
			Standard Deviation	1.5%	26.9
			COV%	17.6%	13.2%
PMFC Cores	After winter at 6 months	HMA+RAP	Average	7.5%	275.5
			Standard Deviation	0.0%	15.6
			COV%	0.1%	5.7%
		Evotherm 3G+RAP	Average	7.2%	293.4
			Standard Deviation	0.1%	16.0
			COV%	1.9%	5.5%
		Sasobit+RAP	Average	6.9%	293.8
			Standard Deviation	0.2%	25.6
			COV%	2.8%	8.7%
On-Site PMLC	1 to 2h at Tc	HMA+RAP	Average	6.7%	361.3
			Standard Deviation	0.5%	26.8
			COV%	7.5%	7.4%
		Evotherm 3G+RAP	Average	6.2%	351.2
			Standard Deviation	0.2%	36.7
			COV%	3.2%	10.5%
		Sasobit+RAP	Average	6.3%	414.5
			Standard Deviation	0.6%	31.2
			COV%	9.5%	7.5%
Off-Site PMLC	Reheat to Tc	HMA+RAP	Average	7.0%	505.3
			Standard Deviation	0.2%	16.1
			COV%	2.9%	3.2%
		Evotherm 3G+RAP	Average	7.0%	490.4
			Standard Deviation	0.1%	23.7
			COV%	1.4%	4.8%
		Sasobit+RAP	Average	7.0%	520.7
			Standard Deviation	0.1%	19.1

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
			COV%	1.4%	3.7%
Off-Site PMLC	Reheat to Tc + 2h at Tc	HMA+RAP	Average	7.1%	735.0
			Standard Deviation	0.4%	49.8
			COV%	5.6%	6.8%
		Evotherm 3G+RAP	Average	6.9%	522.4
			Standard Deviation	0.5%	86.9
			COV%	7.2%	16.6%
		Sasobit+RAP	Average	7.1%	557.7
			Standard Deviation	0.3%	23.5
			COV%	4.2%	4.2%
Off-Site PMLC	16h at 140°F + Reheat to Tc + 2h at Tc	HMA+RAP	Average	6.7%	669.9
			Standard Deviation	0.2%	46.8
			COV%	3.0%	7.0%
		Evotherm 3G+RAP	Average	7.0%	583.5
			Standard Deviation	0.0%	21.2
			COV%	0.0%	3.6%
		Sasobit+RAP	Average	7.5%	562.1
			Standard Deviation	0.1%	35.6
			COV%	1.3%	6.3%
Off-Site PMLC	Reheat to Tc + 4h at 275°F	HMA+RAP	Average	6.9%	701.2
			Standard Deviation	0.1%	33.1
			COV%	1.4%	4.7%
		Evotherm 3G+RAP	Average	7.2%	788.8
			Standard Deviation	0.2%	33.8
			COV%	2.8%	4.3%
		Sasobit+RAP	Average	7.1%	846.2
			Standard Deviation	0.1%	79.5
			COV%	1.4%	9.4%

Table A.3. M_R Results for PMFC Cores versus LMLC Specimens for the Texas Field Project

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
PMFC Cores	At construction	HMA	Average	7.0%	494.3
			Standard Deviation	0.5%	62.1
			COV%	7.1%	12.6%
		Evotherm DAT	Average	9.9%	305.1
			Standard Deviation	0.3%	12.4
			COV%	3.0%	4.1%
		Foaming	Average	7.0%	403.9
			Standard Deviation	0.1%	32.8
			COV%	1.4%	8.1%
LMLC	2h at Tc	HMA	Average	6.8%	482.0
			Standard Deviation	0.2%	28.1
			COV%	2.9%	5.8%
		Evotherm DAT	Average	6.7%	412.1
			Standard Deviation	0.5%	20.0
			COV%	7.5%	4.9%
		Foaming	Average	7.2%	507.9
			Standard Deviation	0.1%	11.6
			COV%	1.4%	2.3%
LMLC	4h at Tc	HMA	Average	6.9%	587.2
			Standard Deviation	0.0%	52.5
			COV%	0.0%	8.9%
		Evotherm DAT	Average	6.7%	519.1
			Standard Deviation	0.5%	45.0
			COV%	7.5%	8.7%
		Foaming	Average	7.3%	524.4
			Standard Deviation	0.1%	39.9
			COV%	1.4%	7.6%
LMLC	2h at 275°F	HMA	Average	7.4%	482.0
			Standard Deviation	0.1%	28.1
			COV%	1.4%	5.8%
		Evotherm DAT	Average	6.8%	573.0
			Standard Deviation	0.3%	32.9
			COV%	4.4%	5.7%
		Foaming	Average	6.9%	642.5
			Standard Deviation	0.2%	53.4

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
			COV%	2.9%	8.3%
LMLC	4h at 275°F	HMA	Average	7.1%	587.2
			Standard Deviation	0.3%	52.5
			COV%	4.2%	8.9%
		Evotherm DAT	Average	6.9%	621.1
			Standard Deviation	0.4%	91.5
			COV%	5.8%	14.7%
		Foaming	Average	6.8%	708.9
			Standard Deviation	0.3%	29.8
			COV%	4.4%	4.2%

Table A.4. M_R Results for PMFC Cores versus PMLC Specimens for the Texas Field Project

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
PMFC Cores	At construction	HMA	Average	7.0%	494.3
			Standard Deviation	0.5%	62.1
			COV%	7.1%	12.6%
		Evotherm DAT	Average	9.9%	305.1
			Standard Deviation	0.3%	12.4
			COV%	3.0%	4.1%
		Foaming	Average	7.0%	403.9
			Standard Deviation	0.1%	32.8
			COV%	1.4%	8.1%
On-Site PMLC	1 to 2h at Tc	HMA	Average	6.3%	504.4
			Standard Deviation	0.3%	24.6
			COV%	4.8%	4.9%
		Evotherm DAT	Average	6.5%	308.1
			Standard Deviation	0.1%	54.7
			COV%	1.5%	17.7%
		Foaming	Average	5.4%	402.2
			Standard Deviation	0.1%	19.2
			COV%	1.9%	4.8%
Off-Site PMLC	Reheat to Tc	HMA	Average	6.7%	645.8
			Standard Deviation	0.1%	72.5
			COV%	1.5%	11.2%

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
		Evotherm DAT	Average	7.0%	440.9
			Standard Deviation	0.3%	56.9
			COV%	4.3%	12.9%
		Foaming	Average	6.8%	469.0
			Standard Deviation	0.1%	13.1
			COV%	1.5%	2.8%
Off-Site PMLC	Reheat to Tc + 2h at Tc	HMA	Average	7.0%	556.5
			Standard Deviation	0.1%	39.6
			COV%	1.4%	7.1%
		Evotherm DAT	Average	6.7%	401.8
			Standard Deviation	0.1%	9.1
			COV%	1.5%	2.3%
		Foaming	Average	6.3%	523.5
			Standard Deviation	0.2%	29.1
			COV%	3.2%	5.6%
Off-Site PMLC	16h at 140°F + Reheat to Tc + 2h at Tc	HMA	Average	6.4%	570.4
			Standard Deviation	0.2%	27.3
			COV%	3.1%	4.8%
		Evotherm DAT	Average	6.6%	468.8
			Standard Deviation	0.3%	41.0
			COV%	4.5%	8.7%
		Foaming	Average	6.5%	523.5
			Standard Deviation	0.0%	29.1
			COV%	0.0%	5.6%
Off-Site PMLC	Reheat to Tc + 4h at 275°F	HMA	Average	6.8%	734.4
			Standard Deviation	0.1%	40.1
			COV%	1.5%	5.5%
		Evotherm DAT	Average	6.6%	656.5
			Standard Deviation	0.0%	23.8
			COV%	0.0%	3.6%
		Foaming	Average	6.3%	630.6
			Standard Deviation	0.2%	16.5
			COV%	3.2%	2.6%

Table A.5. M_R Results for PMFC Cores versus PMLC Specimens for the Montana Field Project

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
PMFC Cores	At construction	HMA	Average	6.0%	292.5
			Standard Deviation	0.1%	29.7
			COV%	1.7%	10.1%
		Evotherm 3G	Average	4.9%	248.6
			Standard Deviation	0.5%	32.9
			COV%	10.2%	13.2%
		Sasobit	Average	4.7%	256.0
			Standard Deviation	0.1%	8.6
			COV%	2.1%	3.4%
PMFC Cores	After winter at 6 months	HMA	Average	4.1%	277.9
			Standard Deviation	0.1%	13.4
			COV%	2.4%	4.8%
		Evotherm 3G	Average	3.6%	189.7
			Standard Deviation	0.5%	12.1
			COV%	13.9%	6.4%
		Sasobit	Average	4.4%	241.4
			Standard Deviation	0.1%	0.6
			COV%	2.3%	0.3%
On-Site PMLC	1 to 2h at Tc	HMA	Average	6.5%	312.8
			Standard Deviation	0.4%	23.9
			COV%	6.2%	7.6%
		Evotherm 3G	Average	6.2%	329.9
			Standard Deviation	0.4%	45.9
			COV%	6.5%	13.9%
		Sasobit	Average	7.1%	429.9
			Standard Deviation	0.2%	17.3
			COV%	2.8%	4.0%
Off-Site PMLC	Reheat to 275°F - HMA Reheat to 240°F - WMA	HMA	Average	6.8%	309.7
			Standard Deviation	0.4%	48.8
			COV%	5.9%	15.7%
		Evotherm 3G	Average	7.9%	200.2
			Standard Deviation	0.2%	5.3
			COV%	2.5%	2.6%
		Sasobit	Average	7.2%	369.7
			Standard Deviation	0.1%	21.8

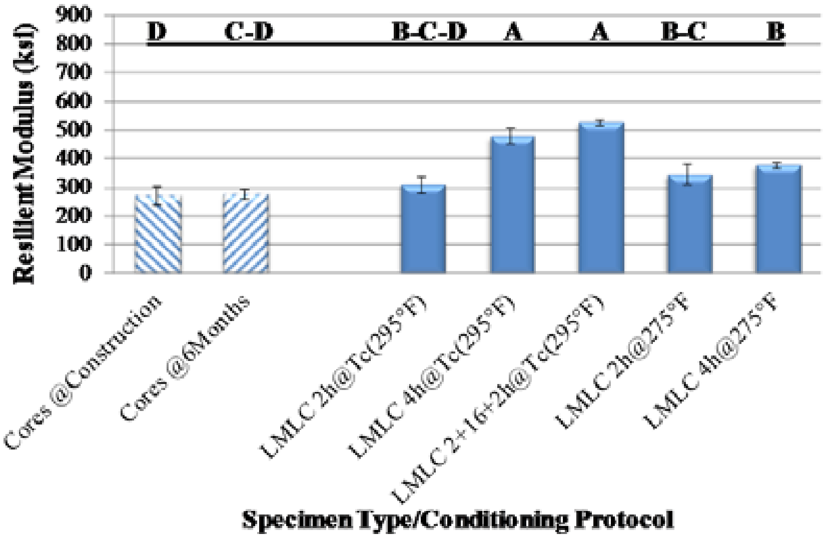
Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
			COV%	1.4%	5.9%
Off-Site PMLC	Reheat to Tc	HMA	Average	7.2%	449.6
			Standard Deviation	0.2%	41.2
			COV%	2.8%	9.2%
		Evotherm 3G	Average	6.9%	277.9
			Standard Deviation	0.3%	29.4
			COV%	4.3%	10.6%
		Sasobit	Average	6.7%	490.3
			Standard Deviation	0.1%	40.1
			COV%	1.5%	8.2%

Resilient Modulus

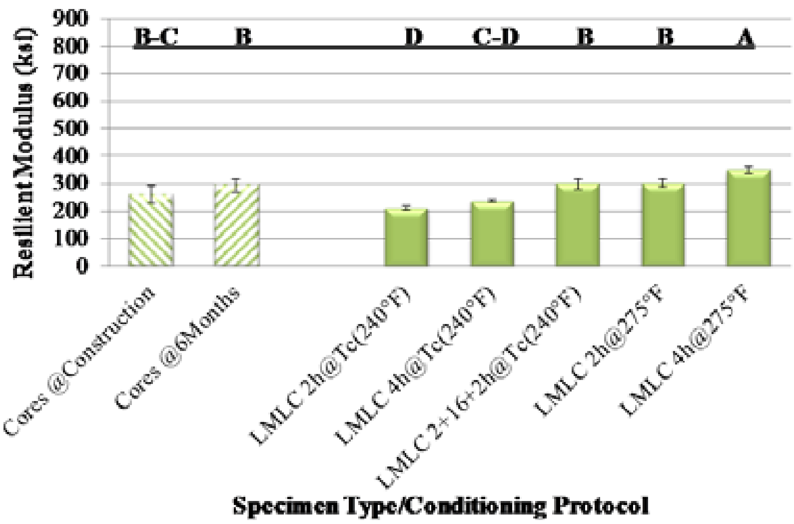
Laboratory Conditioning Protocols for LMLC Specimens

Figure A.1 and Figure A.2 present the M_R results of PMFC cores and LMLC specimens from the Iowa and Texas field projects, respectively. In each graph, PMFC cores are presented on the left side of the figure, and the LMLC specimens with different conditioning protocols are shown on the right side of the figure. Each bar in these figures represents the average value of three replicate specimens, and the error bars represent ± one standard deviation from the average value.

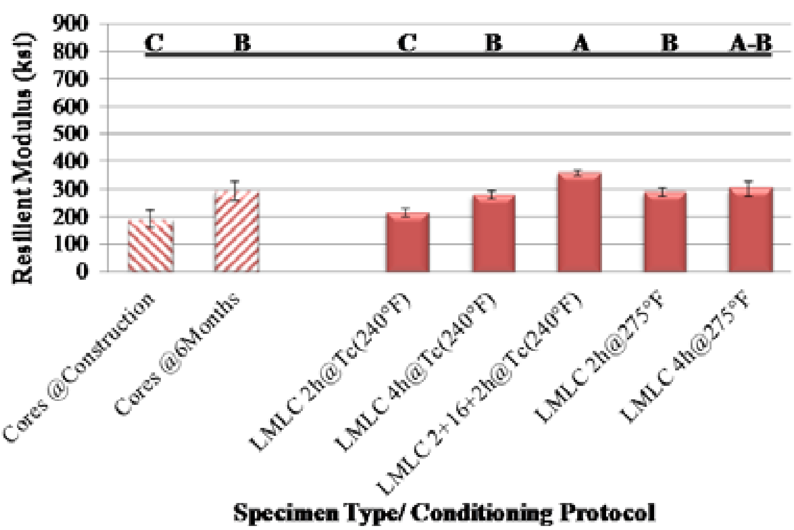
As illustrated in Figure A.1 for the Iowa field project, the stiffness of HMA with reclaimed asphalt pavement (RAP) and WMA Evotherm® 3G with RAP PMFC cores increased slightly after 6 months in service, while PMFC cores of WMA Sasobit® with RAP increased significantly. A general trend was shown that the longer conditioning protocols for LMLC specimens resulted in specimens with equivalent or higher stiffness than the M_R values measured in the early life of the pavement. Among the five conditioning protocols applied to LMLC specimens, several protocols applied for WMA Evotherm® 3G with RAP were able to produce enough aging such that the stiffness of the LMLC specimens was equivalent to the stiffness of PMFC cores at construction. In the case of HMA with RAP and WMA Sasobit® with RAP, equivalent stiffnesses were obtained between PMFC cores at construction and the LMLC specimens conditioned with 2 h at T_c. Additionally, WMAs with RAP specimens conditioned with 2 h at 275°F (135°C) had significantly higher stiffness than those conditioned with 2 h at T_c, while WMA Sasobit® with RAP specimens conditioned with 2 h and 4 h at T_c had similar stiffness. Thus, it can be inferred that WMAs with RAP specimens are more susceptible to conditioning temperature than conditioning time in terms of changes in M_R.



(a) HMA+RAP

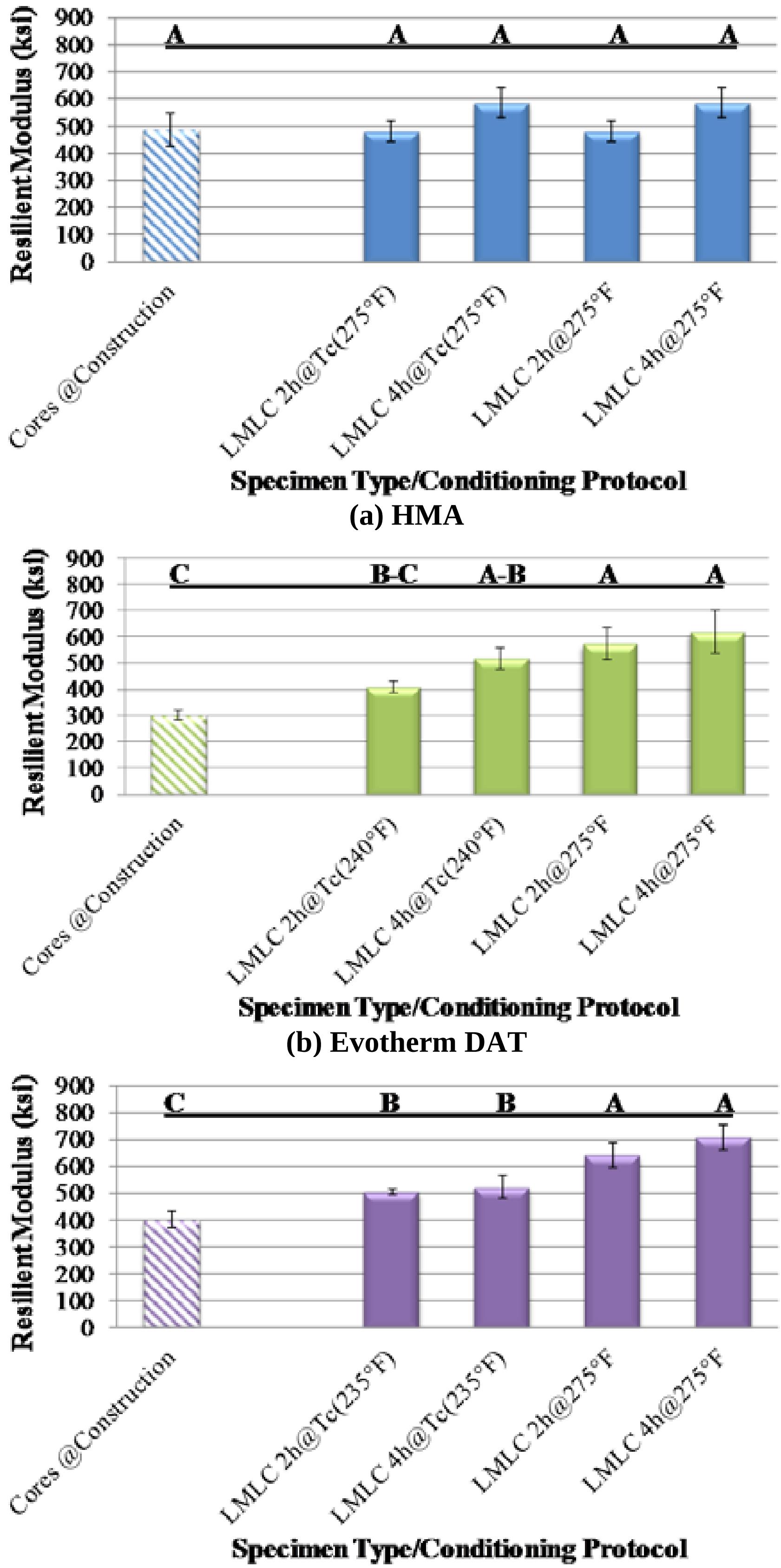


(b) Evotherm 3G+RAP



(c) Sasobit+RAP

Figure A.1. M_R Comparison for the Iowa PMFC Cores versus LMLC Specimens



(a) HMA

(b) Evotherm DAT

(c) Foaming

Figure A.2. M_R Comparison for the Texas PMFC Cores versus LMLC Specimens

In the case of the Texas field project, the conditioning protocol of 2 h at T_c followed by 16 h at 140°F (60°C) plus 2 h at T_c was not performed on LMLC specimens given the high stiffness values obtained for the same protocol in the Iowa field project and the impractical nature of this protocol. Among the four conditioning protocols applied to the LMLC specimens, 2 h at T_c more closely represented the stiffness of the pavement in its early life. Similar trends to the ones obtained for the Iowa field project were observed, with the stiffness increasing with higher conditioning temperature and longer conditioning time, and the stiffness of the mixtures being more sensitive to conditioning temperature versus conditioning time (see Figure A.2).

Based on the results shown, 2 h at T_c was the recommended conditioning protocol for LMLC (mix design) specimens to simulate the stiffness of both WMA and HMA pavements in their early life. A statistical analysis was completed to further justify this recommendation and account for the variability in the M_R results. An analysis of variance (ANOVA) and Tukey-Kramer Honest Significant Differences (Tukey's HSD) test were conducted with a 5 percent significance level (i.e., alpha = 0.05) to verify the difference in M_R between the conditioned LMLC specimens versus the PMFC cores at construction. Detailed results from these statistical analyses are provided in Appendix H by corresponding figure or table number. In addition to the main factor of interest, which is conditioning protocol, the effect of orientation (i.e., rotating the specimen 90 degrees after the first measurement) as well as the interaction effect between orientation and conditioning protocol was also tested by utilizing a split plot design analysis. The results confirmed that neither the interaction effect between orientation and conditioning protocol nor the main effect of orientation were statistically significant for any of the mixtures considered. The effect of conditioning protocol was statistically significant for all mixtures except for Texas HMA.

The results of Tukey's HSD test on conditioning protocols are shown in Figure A.1 and Figure A.2 with different capital letters above the M_R results. The M_R values decrease as letters change from A to E. Conditioning protocols with different letters have M_R values that are statistically different from each other. A summary of the statistical comparison between all conditioning protocols versus PMFC cores is listed in Table A.6. In this table, the stiffness achieved after the LMLC protocols is compared against the stiffness of PMFC cores at construction. When equivalent stiffness was achieved, the result is marked as *PMFC*. When the stiffness of the LMLC mixture after the conditioning protocol was higher or lower than the cores or on-site specimens, the result is marked as *High* or *Low* in the table.

As shown by Tukey's HSD results, for all HMA and WMA mixtures except Iowa WMA Evotherm® 3G with RAP and Texas WMA Foaming, LMLC specimens conditioned for 2 h at T_c had statistically equivalent stiffness as corresponding PMFC cores at construction. For Texas WMA Foaming, the least difference in mixture M_R stiffness as compared to that of PMFC core at construction was shown by LMLC specimens conditioned with 2 h at T_c, although significantly higher M_R stiffness were indicated by Tukey's HSD results. In general, conditioning protocol of 2 h at T_c was able to represent the stiffness of HMA and WMA pavements at their early life.

Table A.6. Summary of Statistical Analysis Results for LMLC Specimens

Mixture Type		Conditioning Protocols for LMLC Specimens				
		2 h @ T_c	4 h @ T_c	2 + 16 + 2 h @ T_c	2 h @ 275°F	4 h @ 275°F
Iowa	HMA+RAP	PMFC	High	High	High	High
	Evotherm 3G+RAP	Low	PMFC	PMFC	PMFC	High
	Sasobit+RAP	PMFC	High	High	High	High
Texas	HMA	PMFC	PMFC		PMFC	PMFC
	Evotherm DAT	PMFC	High		High	High
	Foaming	High*	High		High	High

* Least difference in mixture stiffness versus PMFC cores at construction.

It is important to note, however, that in most instances, T_c is not specified in the mix design, and it is sometimes arbitrarily selected with different values used for LMLC specimens, on-site PMLC specimens, and placement temperatures during pavement construction. Besides, standard conditioning temperatures for HMA and WMA are desired. Table 5 in Chapter 2 shows that T_c, monitored after the paver during construction for the Iowa HMA with RAP was 295°F (146°C) and that used for the Texas HMA was 275°F (135°C). Since the conditioning protocol of 2 h at 275°F (135°C) was able to provide enough compactability for Iowa HMA with RAP and Texas HMA, the standard laboratory conditioning protocol for preparing HMA LMLC specimens is ultimately recommended as 2 h at 275°F (135°C). In the case of WMA, T_c for most of the Iowa and Texas mixtures was approximately 240°F (116°C) with the exception of WMA Foaming in the Texas field project (Table 5 in Chapter 2). Therefore, 2 h at 240°F (116°C) was ultimately recommended as the standard laboratory conditioning protocol for WMA LMLC specimens.

Laboratory Conditioning Protocols for PMLC Specimens

Figure A.3 and Figure A.4 present the M_R results for PMFC cores, on-site PMLC specimens, and off-site PMLC specimens for the Iowa and Texas field projects, respectively. In each graph, PMFC cores are located on the left side of the figure, and on-site and off-site PMLC specimens subjected to different conditioning protocols are shown on the right side of the figure. Each bar represents the average value of three replicate specimens, and the error bars represent ± one standard deviation from the average value.

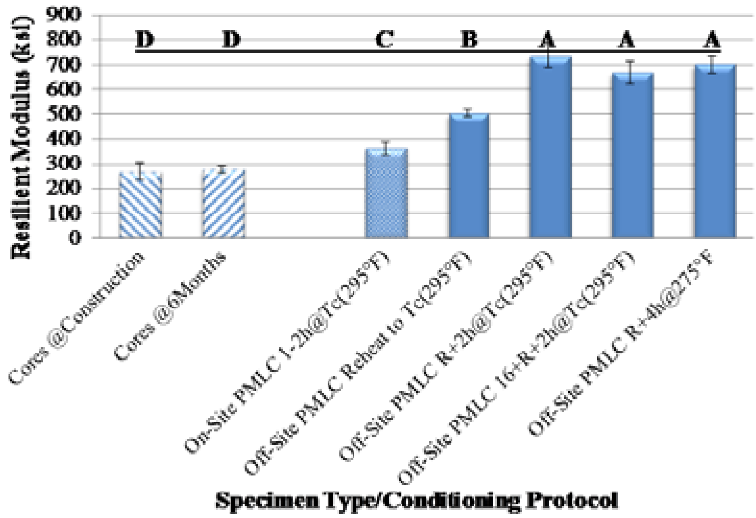
A statistical analysis similar to that used for the LMLC specimens was utilized to verify the difference in M_R stiffness between PMFC cores versus on-site PMLC specimens and off-site PMLC specimens subjected to the different conditioning protocols. The interaction effect between conditioning protocol and orientation was statistically insignificant for all mixtures. The

main effect orientation was statistically insignificant for all mixtures except for Texas WMA Evotherm DAT™, but the difference was practically insignificant. The effect of conditioning protocol, on the other hand, was statistically significant for all mixtures. The general results of Tukey's HSD test are shown in Figure A.3 and Figure A.4 with capital letters above the bars. Conditioning protocols with different letters have M_R values that are statistically different from each other. A summary of the statistical comparison between conditioning protocols for PMLC specimens versus PMFC cores is listed in Table A.7.

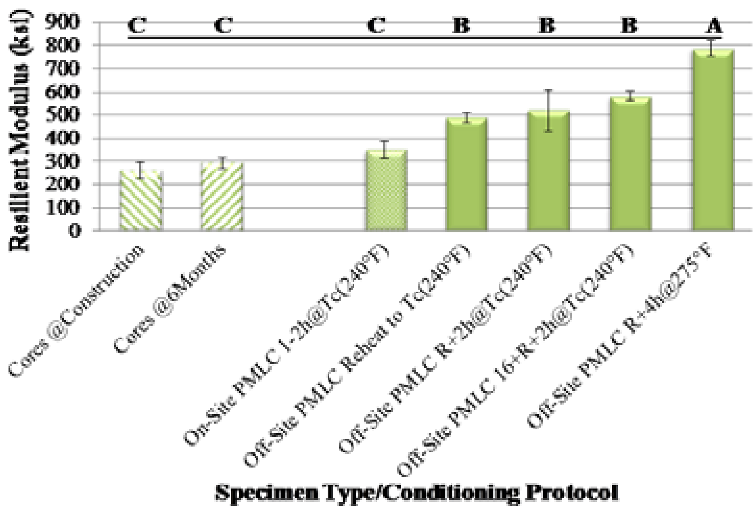
Figure A.3 and Figure A.4 show that for all Iowa and Texas mixtures, on-site PMLC specimens had equivalent mixture stiffness or mixture stiffness with the least difference (i.e., Iowa HMA with RAP and Iowa WMA Sasobit ® with RAP) as compared to those of PMFC cores at construction. In the case of the Texas field project, besides the 1-2 h conditioning at T_c for the on-site PMLC specimens, a separate set was prepared with 0-1 h of conditioning time at T_c. The M_R stiffness of both sets of specimens was compared using a student t-test. The results of the comparison indicated equivalent stiffness between the two sets of on-site PMLC specimens for HMA and WMA Evotherm DAT™, demonstrating an insignificant effect on stiffness from the increase in on-site conditioning time by 1 or 2 h.

In contrast, the conditioning protocols used on the off-site PMLC specimens yielded specimens with statistically higher stiffness as compared to the PMFC cores at construction. This indicates that even reheating the off-site PMLC to T_c is enough to increase significantly the stiffness of the mixture. In addition, the stiffness of the off-site PMLC specimens reheated at T_c was in most cases equivalent to the stiffness of the off-site PMLC conditioned for longer periods after being reheated to T_c.

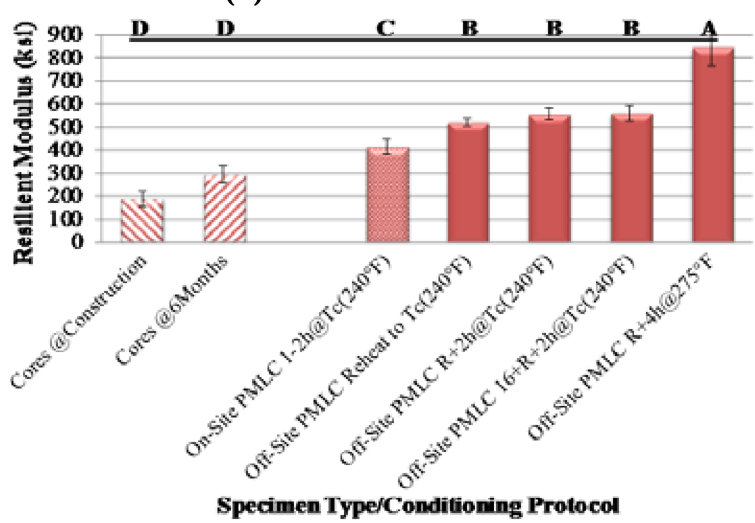
The smallest difference in mixture stiffness between PMFC cores versus PMLC specimens corresponded to the on-site PMLC specimens, followed by the off-site PMLC specimens with the conditioning protocol of reheating to T_c. The latter also required the least amount of aging prior to compaction. Therefore, the use of on-site PMLC specimens is recommended as the best alternative, especially when preparing quality assurance (QA) specimens. In cases where on-site PMLC specimens are not available, the next best option is to employ off-site PMLC specimens reheated to T_c.



(a) HMA+RAP

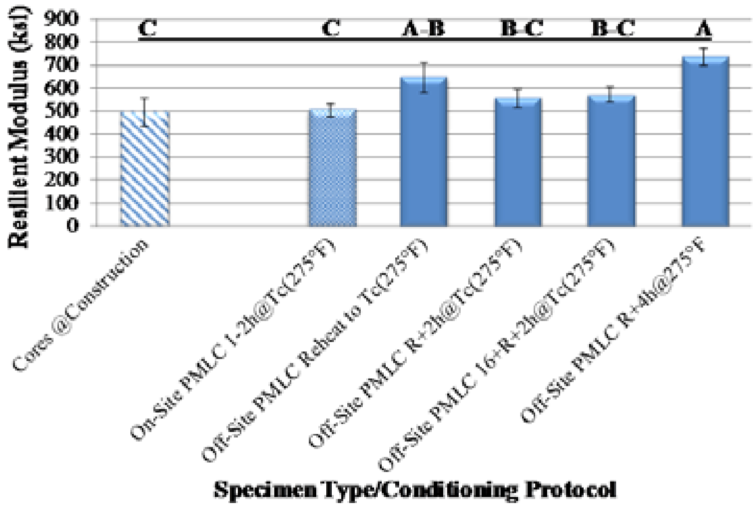


(b) Evotherm 3G+RAP

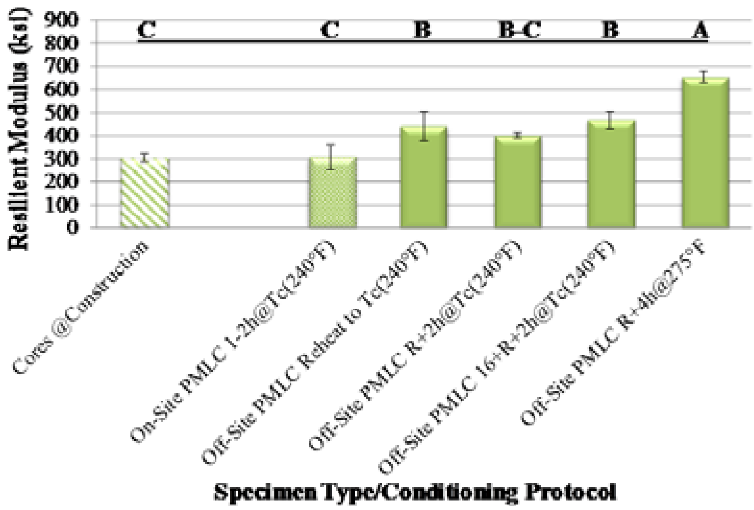


(c) Sasobit+RAP

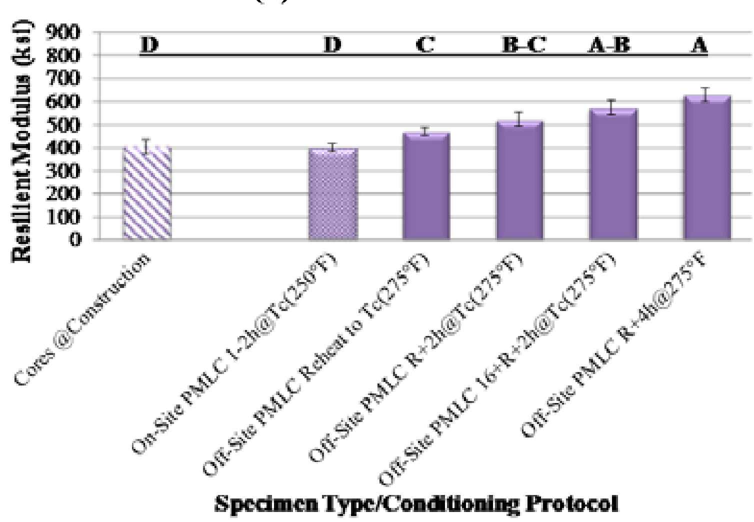
Figure A.3. M_R Comparison for the Iowa PMFC Cores versus On-Site and Off-Site PMLC Specimens



(a) HMA



(b) Evotherm DAT



(c) Foaming

Figure A.4. M_R Comparison for the Texas PMFC Cores versus On-Site and Off-Site PMLC Specimens

Table A.7. Summary of Statistical Analysis Results for Off-Site PMLC Specimens

Mixture Type		Conditioning Protocols for PMLC Specimens				
		On-Site PMLC	Off-Site PMLC			
		1-2 h @ T_c	R to T_c	R + 2 h @ T_c	16 + R + 2 h @ T_c	R + 4 h @ 275°F
Iowa	HMA+RAP	High*	High	High	High	High
	Evotherm 3G+RAP	PMFC	High	High	High	High
	Sasobit+RAP	High*	High	High	High	High
Texas	HMA	PMFC	High	PMFC	PMFC	High
	Evotherm DAT	PMFC	High	PMFC	High	High
	Foaming	PMFC	High	High	High	High
		On-Site PMLC	**R to T_c**	**Recommended Protocol**		
Montana	HMA		PMFC	PMFC		
	Evotherm 3G		PMFC	PMFC		
	Sasobit		High	High*		

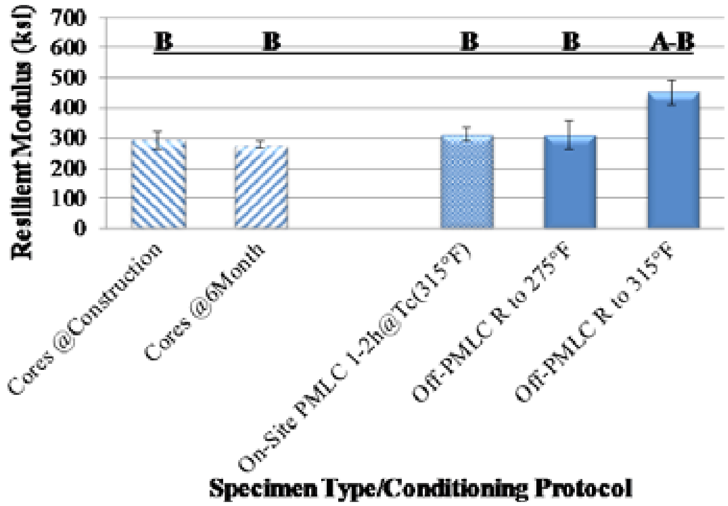
Note: R: reheat.
* Least difference in mixture stiffness versus PMFC cores at construction.

As previously mentioned, the T_c of 275°F (135°C) was able to provide enough compactability for the loose HMA from both field projects, and most T_c for WMA from the Iowa and Texas field projects were approximately 240°F (116°C). Therefore, the T_c in the recommended conditioning protocol for preparing off-site HMA and WMA PMLC specimens was standardized at 275°F (135°C) and 240°F (116°C), respectively. WMA Foaming of off-site PMLC specimens required a different conditioning protocol as compared to WMA with additives because the foaming effect during production is assumed lost after mixing and cooling of the loose mix. Therefore, the conditioning protocols recommended for preparing PMLC specimens are on site with (a) 1 h at 240°F (116°C) for WMA, and (b) 1 h at 275°F (135°C) for HMA. When compacting PMLC specimens on site is not viable, the recommended conditioning protocol for off-site PMLC specimens is to (a) reheat to 240°F (116°C) for WMA with additives, and (b) reheat to 275°F (135°C) for HMA and WMA Foaming.

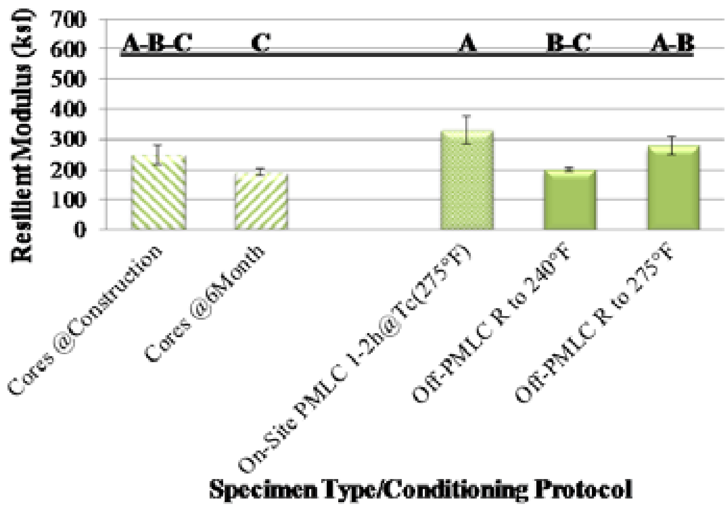
Compaction temperatures for WMAs from the Montana field project were significantly higher than the ones used in the Iowa and Texas field projects. Therefore, to validate further the recommended off-site conditioning protocol for PMLC specimens, the Montana off-site PMLC

specimens were fabricated following the recommended protocol as well as reheating to the actual compaction temperature of 315°F (157°C) for HMA and 275°F (135°C) for WMA with additives. Then, the stiffness of the off-site PMLC specimens was compared against PMFC cores at construction. The M_R values are shown in Figure A.5 along with Tukey's HSD test results noted with capital letters above the bars. Conditioning protocols with different letters have M_R values that are statistically different from each other. A summary of the statistical comparison between conditioning protocols for off-site PMLC specimens versus PMFC cores at construction is listed in Table A.7.

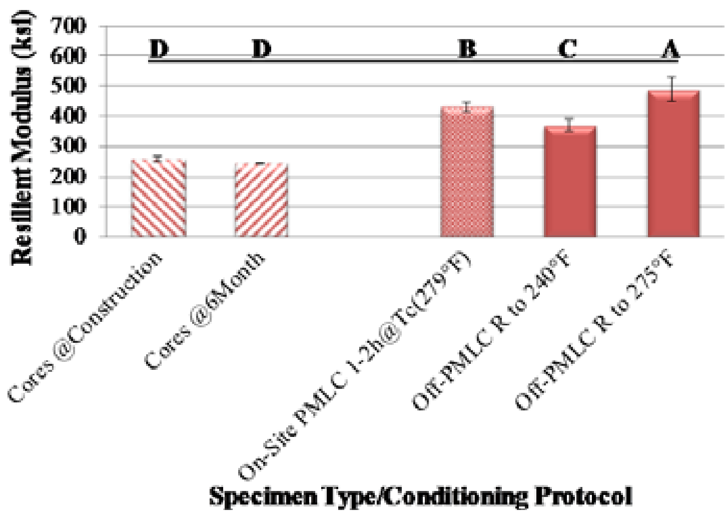
As shown, for Montana HMA and WMA Evotherm® 3G, the recommended conditioning protocols as well as reheating to actual T_c were able to yield the off-site PMLC specimens with equivalent mixture stiffness as PMFC cores at construction. However, in the case of Montana Sasobit®, higher stiffness was shown for both sets of off-site PMLC specimens, while a smaller difference in mixture stiffness was shown by the recommended conditioning protocol. Therefore, the recommended conditioning protocol for off-site PMLC specimens of reheating plant mix to 275°F (135°C) for HMA and WMA Foaming and to 240°F (116°C) for all WMA mixtures except WMA Foaming was verified for the Montana field project.



(a) HMA



(b) Evotherm 3G



(c) Sasobit

Figure A.5. M_R Comparison for Montana PMFC Cores versus Off-Site PMLC Specimens

Other Factors Affecting Mixture Stiffness

On-site PMLC specimens and PMFC cores at construction were expected to have similar stiffness as they experienced approximately the same level of binder aging, with the PMFC cores possibly aging more during transportation to the pavement site. M_R results from the Texas field project followed this expected behavior, while M_R results from the Iowa field project showed a different trend. For the Iowa field project, the on-site PMLC specimens showed higher stiffness as compared to the PMFC cores at construction. These differences were evaluated with respect to binder stiffness, aggregate orientation, and total specimen AV.

Asphalt Binder Stiffness To verify the expectation that binder stiffness has an increasing effect on mixture stiffness, asphalt binder was extracted and recovered (ASTM D2172 and ASTM D5404) from HMA and WMA Evotherm® 3G with RAP/Evotherm DAT™ on-site PMLC specimens and PMFC cores obtained from both field projects. The stiffness of the extracted binders was then evaluated with the dynamic shear rheometer (DSR). The difference in mixture stiffness between these two specimen types was attributed to difference in binder aging that occurred during loose-mix reheating prior to compaction.

DSR tests were performed on the extracted and recovered binders in accordance with AASHTO T 315 at 77°F (25°C) to match the M_R test temperature. The complex modulus (G*) was selected as the test parameter to compare the stiffness of the extracted binders. DSR and M_R results of on-site PMLC specimens versus off-site PMLC specimens and PMFC cores at construction versus on-site PMLC specimens from both projects are summarized in Figure A.6 and Figure A.7, respectively. The bars in Figure A.7 and Figure A.7 represent the average M_R of three replicate specimens, the dots indicate the average G* of three measurements, and the error bars represent ± one standard deviation from the average values.

As illustrated in Figure A.6, for both Texas HMA and WMA Evotherm DAT™, on-site PMLC specimens had lower binder stiffness and mixture stiffness than corresponding off-site PMLC specimens. Considering the same compactor was used to prepare both on-site and off-site specimens and that they had an equivalent total AV content, the difference in mixture stiffness (M_R) was likely due to the higher binder stiffness (G*) of the off-site PMLC specimens caused by the additional aging that occurred during the reheating of the loose plant mix. Thus, this set of results validated the expectation that binder stiffness has an increasing effect on mixture stiffness.

The results in Figure A.7 show that all PMFC cores had higher G* values than corresponding on-site PMLC specimens. Therefore, PMFC cores were expected to be stiffer than on-site PMLC specimens, assuming an equivalent aggregate orientation and specimen AV. However, the trend for the M_R results was opposite to the G* results, as illustrated in Figure A.7. M_R results indicate that the stiffness of the PMFC cores was lower or equivalent to that of corresponding on-site PMLC specimens. Therefore, factors other than binder aging, such as different compaction methods and different specimen AV, affected the stiffness of the mixtures.

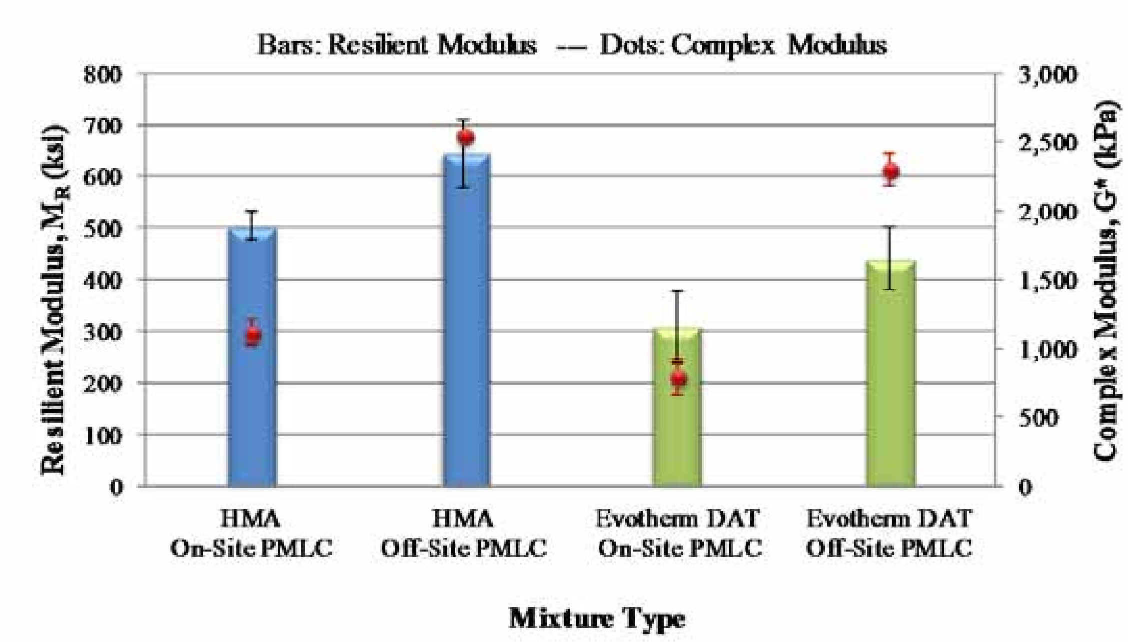
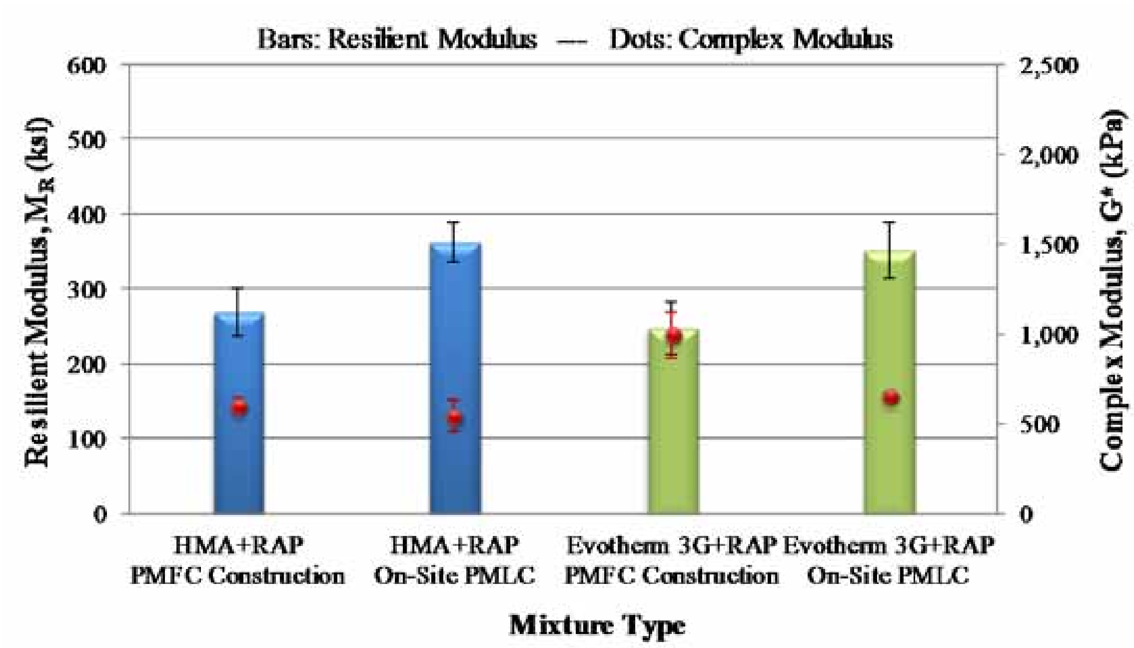
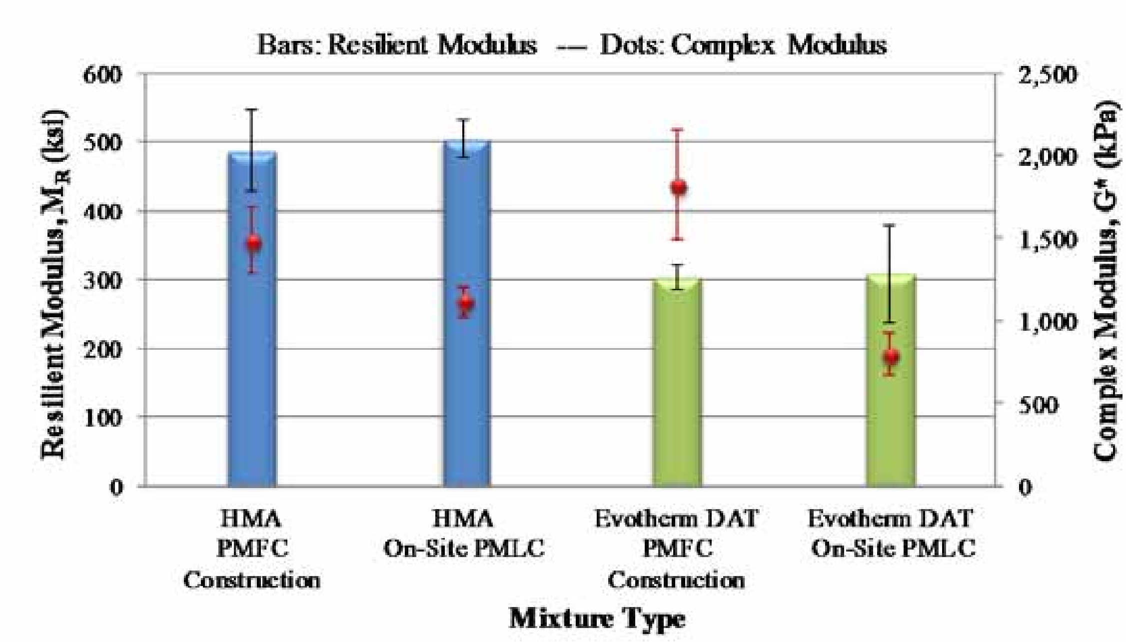


Figure A.6. M_R and DSR Results for Texas On-Site PMLC and Off-Site PMLC Specimens at 77°F (25°C)



(a) Iowa Field Project

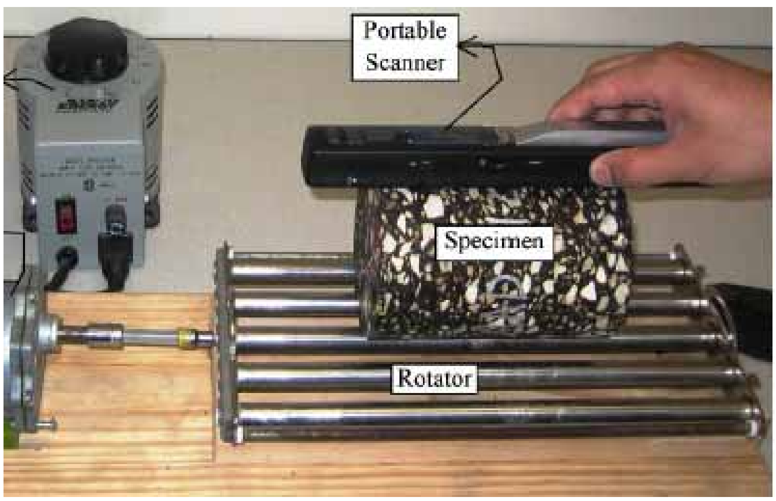


(b) Texas Field Project

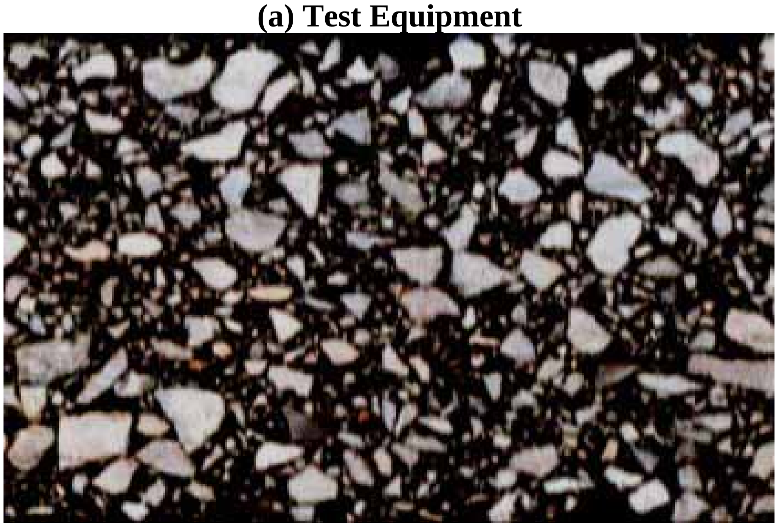
Figure A.7. M_R and DSR Results for PMFC Cores and On-Site PMLC Specimens at 77°F (25°C)

Aggregate Orientation A previous study indicated that different compaction methods may induce differences in specimen anisotropy and aggregate interlock and that both factors may have a significant effect on mixture stiffness (Boudreau et al., 1992). Specifically, field compaction is expected to give rise to cross-anisotropic materials, indicating that most aggregates orient along the horizontal direction in the field. These cross-anisotropic materials will exhibit lower MR values than isotropic ones when tested in the horizontal direction due to the aggregate orientation.

The difference in aggregate orientation was evaluated via image analysis using a portable scanner to capture a continuous image of the lateral surface of the specimen, as shown in Figure A.8. Four on-site PMLC specimens and PMFC cores from the Iowa and Texas field projects were scanned. The specimens were laid horizontally on an automatic constant speed rotator while the portable scanner was placed on top of the specimen to scan its lateral surface (Figure A.8a).



(a) Test Equipment



(b) Scanned Image of Lateral Surface of Asphalt Mixture Sample

Figure A.8. Image Analysis Technique Used to Capture Aggregate Orientation

Using image analysis software, several aggregate characteristics including the inclination angle, cutting surface area, and aspect ratio were measured and used in a modified vector magnitude, Δ′, to evaluate the overall aggregate orientation of the asphalt mixture (Zhang et al., 2011). The parameter Δ′ has a range from zero to one, with zero indicating full isotropy (i.e., complete random distribution of particles) and larger values indicating more anisotropy (i.e., preferential orientation of the long dimension of the aggregates in the horizontal direction, which is perpendicular to the direction of compaction).

The results for the on-site PMLC specimens and PMFC cores from the Iowa and Texas field projects are summarized in Figure A.9. As expected, the Δ' parameter for the PMFC cores was higher than for the on-site PMLC specimens, indicating higher anisotropy in the horizontal direction. Therefore, PMFC cores could have less resistance to the diametral load as applied in the M_R test.

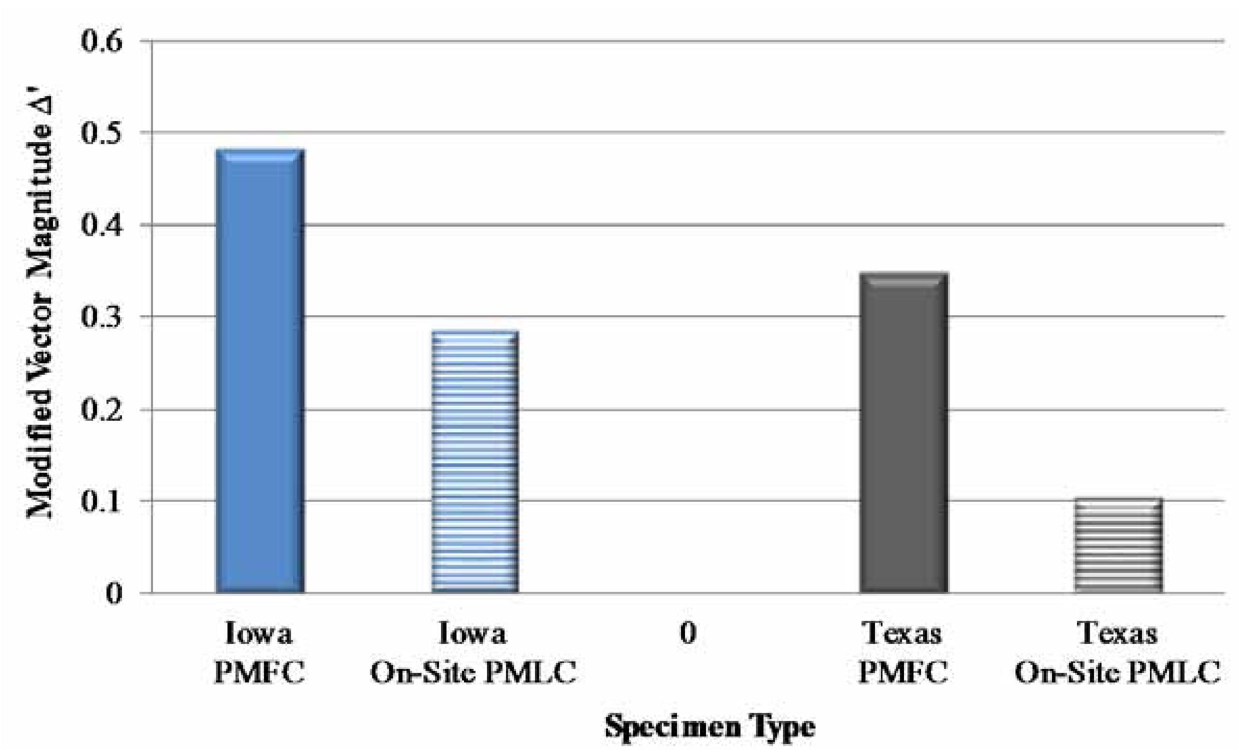


Figure A.9. Overall Aggregate Orientation for On-Site PMLC and PMFC Cores from the Iowa and Texas Field Projects

Total AV Content Another factor to consider in the comparison of mixture properties conditioned using the selected protocols is AV content. It is well known that AVs have a significant effect on mixture stiffness. In this study, all laboratory specimens (LMLC and off-site PMLC) had a target AV of 7±0.5 percent, while the PMFC cores had higher AV, in the range of 7 percent to 9 percent. To evaluate the effect of AV in stiffness, several LMLC specimens of WMA Sasobit® with RAP with AV ranging from 5 percent to 9 percent were fabricated and tested to determine MR. These results are presented in Figure A.10 and show that the mixture stiffness reduced significantly as the AV increased from 6 percent to 9 percent, while MR was relatively constant between 5 percent and 6 percent AV. Therefore, the higher AV of PMFC cores as compared to the on-site PMLC specimens could also explain some of the differences in mixture stiffness.

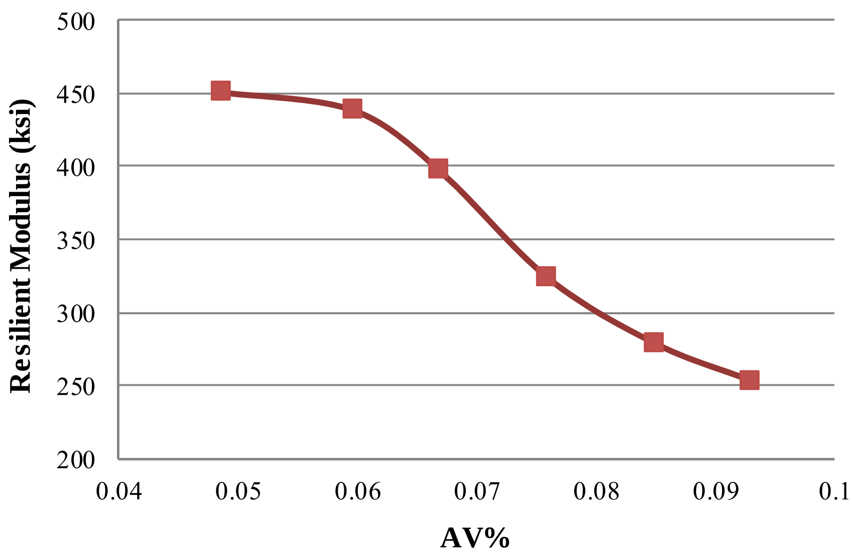


Figure A.10. Effect of Total AV on Mixture Stiffness for the Iowa WMA Sasobit® with RAP LMLC Specimens

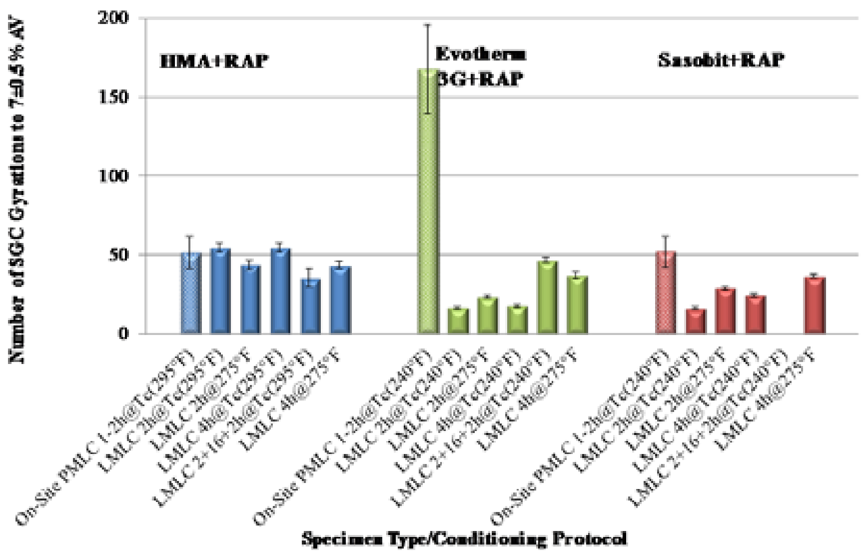
In general, for the HMA and WMA evaluated, both the compaction method (i.e., anisotropy) and overall AV had a significant effect on mixture stiffness. These factors help explain the discrepancy in the mixture and binder stiffness observed between on-site PMLC specimens versus PMFC cores (Figure A.7).

Number of Gyrations

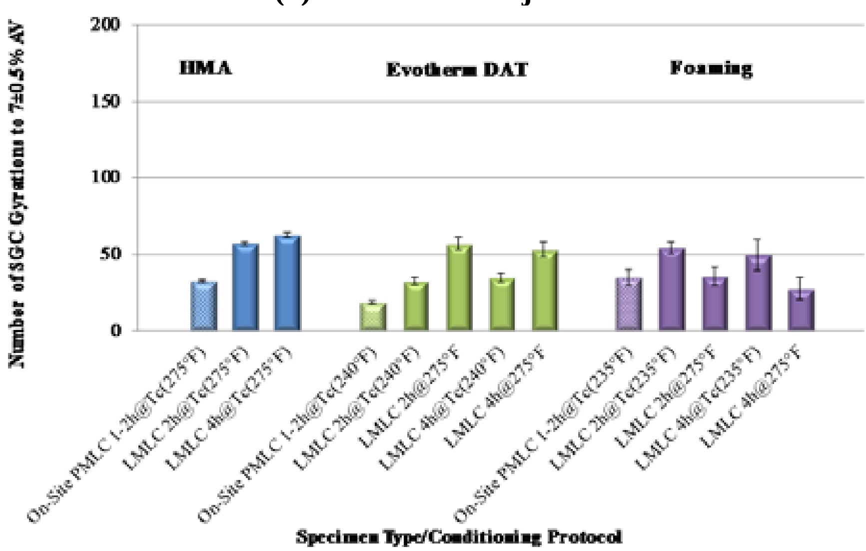
Figure A.11 and Figure A.12 present the comparison between LMLC and off-site PMLC specimens versus on-site PMLC specimens from the Iowa and Texas field projects in terms of the number of gyrations, N, to 7±0.5 percent AV as recorded in the Superpave gyratory compactor (SGC). Each bar in these figures represents the average value of three replicate specimens, and the error bars represent ± one standard deviation from the average value.

As illustrated in Figure A.11, for most HMA and WMA mixtures from Iowa and Texas field projects, N increased as the laboratory conditioning temperature, time, or both increased, as expected. A different trend was observed for the Texas WMA Foaming; higher conditioning temperature and longer conditioning time resulted in smaller N values. This could be caused by

the loss of the moisture in the mixture during conditioning prior to compaction. The comparison between HMA and WMA indicated that more gyrations (higher N) were required to compact HMA to the target AV range as compared to WMA. This trend was also expected due to the compaction aid of the water (i.e., foaming) and WMA additives at the lower production temperature. Additionally, the comparison between on-site PMLC specimens versus LMLC specimens showed differences, probably caused by the fact that different SGCs were used to prepare these specimens in the laboratory and in the field.



(a) Iowa Field Project

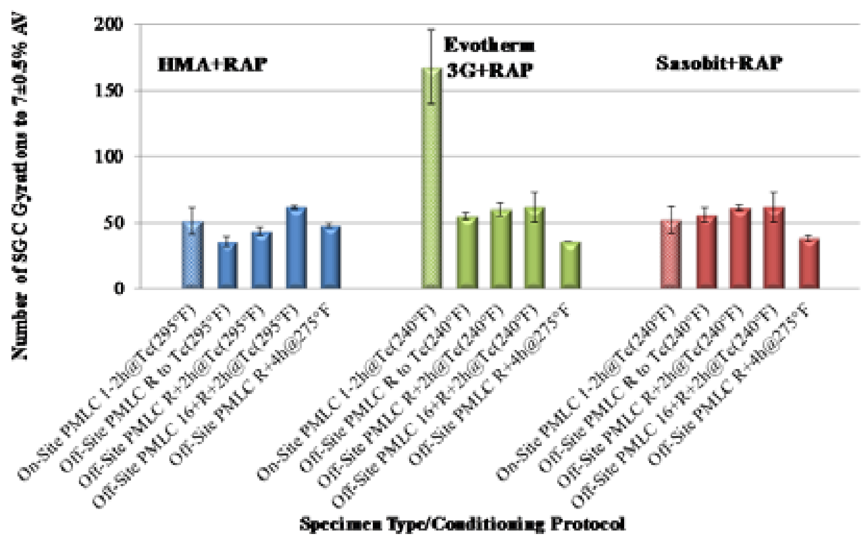


(b) Texas Field Project

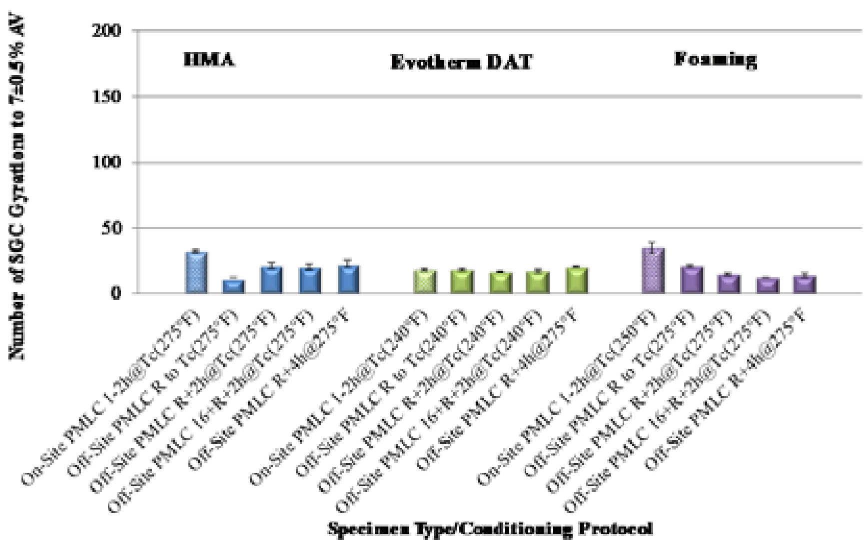
Figure A.11. Comparison of HMA and WMA On-Site PMLC Specimens versus LMLC Specimens with Different Conditioning Protocols in Terms of N

As shown in Figure A.12, for the majority of mixtures, the difference in N values for HMA and WMA off-site PMLC specimens conditioned with different protocols was not remarkable, which could be explained by the aging of the loose mixture during reheating. This

result agrees with the M_R results, which indicates that reheating the loose mix significantly increases the mixture stiffness regardless of the conditioning time or temperature beyond reheating. In addition, equivalent N values were observed between on-site PMLC and off-site PMLC specimens for HMA and WMA Sasobit® with RAP from the Iowa field project and WMA Evotherm DAT™ and WMA Foaming from the Texas field project. The N values for the on-site PMLC specimens were higher than the off-site PMLC specimens for WMA Evotherm® 3G with RAP from the Iowa field project and HMA from the Texas field project.



(a) Iowa Field Project



(b) Texas Field Project

Figure A.12. Comparison of HMA and WMA On-Site PMLC Specimens versus Off-Site PMLC Specimens with Different Conditioning Protocols in Terms of N

In general, an increase in laboratory conditioning temperature, time, or both significantly increased the stiffness of the mixture, and therefore a greater number of gyrations (higher N value) was required to achieve the same AV level. The results shown in Figure A.11 and Figure

A.12 agree with the M_R results. Therefore, the number of gyrations can be used as an alternative method to assess the stiffness of HMA and WMA specimens.

APPENDIX B. MOISTURE CONDITIONING EXPERIMENT

BACKGROUND

Moisture Susceptibility Mechanisms

To take effective measures to preclude moisture damage in asphalt pavements, a comprehensive understanding of the chemical and mechanical causes is needed. There are two major sources of moisture damage: (a) the loss of adhesion between the binder or mastic and the aggregates, and (b) the loss of cohesion within the binder or mastic due to the presence of moisture (Little and Jones, 2003). Research over many years has identified the following six processes that contribute, usually in combination, to these causes (Santucci, 2010; Sebaaly et al., 2010; Taylor and Khosla, 1983):

- Detachment of the binder film from the aggregate without film rupture.
- Displacement of the binder film from the aggregate through film rupture.
- Spontaneous emulsification and formation of an inverted emulsion of water in binder.
- Pore pressure-induced damage due to repeated traffic loading.
- Hydraulic scour at the surface due to tire-pavement interaction.
- pH instability of the contact water that affects the binder-aggregate interface.
- Environmental factors such as excessive rainfall, large temperature fluctuations, and freeze-thaw (F/T) conditions.

The physical and chemical interaction between binder and aggregate, including the non-uniform opposite charge distributions on their surfaces, determines the strength of the adhesive bond between these two components. The binder-aggregate adhesive bond is also affected by aggregate mineralogy and corresponding surface charge and adsorbed cations on the aggregate surface, with clay particles degrading the adhesive bond (Tarrer and Wagh, 1991). Functional groups that are strongly adsorbed to the aggregate surface, however, are also oftentimes more prone to moisture damage (Caro et al., 2008).

Researchers have focused on calculating adhesive bond strengths from measured surface energies of the binder and the aggregate in both wet and dry conditions as part of a tiered approach to select compatible combinations with adequate resistance to moisture damage (Howson et al., 2006). Physical properties of the aggregate (such as surface texture, porosity, shape, and gradation) and of the binder (such as viscosity and modification) are also important in terms of their effect on binder film thickness and wettability, with thicker films providing a physical barrier to moisture damage and lower viscosity providing deeper penetration into the aggregate surface and a stronger mechanical bond (Santucci, 2010). Anti-stripping agents such as hydrated lime, Portland cement, and chemical liquid agents can be added to improve adhesive bond strengths between binders and aggregates, and polymer modified binders can also result in improved adhesion due to thicker binder films (Santucci, 2010). Thus, both favorable chemical bonding and the ability of the binder to wet and permeate the aggregate surface are required for favorable adhesive bonding between aggregate and binder and a subsequent improved resistance to moisture damage.

Moisture damage, however, is not limited to adhesive failure; weakening of the cohesive strength of the binder or mastic due to moisture infiltration is equally important. Some research suggests that the incorporation of anti-stripping agents can also enhance mixture cohesion

(Sebaaly et al., 2010). Lytton et al. (1993) used micromechanics to assess the relationship between the binder film thickness and the failure type due to moisture. They found that mixtures with thin binder films fail in tension by adhesive bond rupture, while those with thicker binder films fail due to cohesive damage within the mastic.

Laboratory Characterization

To evaluate the moisture susceptibility of asphalt mixtures and the effectiveness of the use of anti-stripping agents, various laboratory tests can be performed on (a) loose mixtures or component materials, (b) compacted unconditioned or dry versus conditioned or wet specimens, and (c) compacted specimens subjected to cyclic loads in the presence of water. These different approaches along with the most common test methods in each category are summarized in Table B.1 and described in more detail in this section. The list of tests included in Table B.1 is not exhaustive but includes commonly used tests that are currently available as national standards or that have been recently developed and show promise. Solaimanian et al. (2003) and Santucci (2010) provide a more extensive list that includes less commonly used and older test methods.

The most common categories of laboratory tests currently used to evaluate moisture susceptibility are the second and third listed in Table B.1. These are used in the mix design stage on laboratory-mixed laboratory-compacted (LMLC) specimens or as part of the quality assurance (QA) program using plant-mixed laboratory-compacted (PMLC) or plant-mixed field-compacted (PMFC) cores. As part of the second category listed in Table B.1, laboratory moisture-conditioning protocols are performed before testing mixtures in a wet state, and the measured properties are compared with corresponding properties measured in dry state. An ideal laboratory moisture-conditioning protocol should accelerate the penetration of moisture through the binder film while at the same time minimize complicating effects such as damaging the structure of the mixture.

Relationship with field performance is the ultimate goal of laboratory characterization methods for identifying moisture-susceptible asphalt mixtures and the effectiveness of materials (binder-aggregate compatibility, anti-stripping agents, or both) and methods (increased density) to combat the deteriorative effects of moisture.

Uncompacted Loose Mixtures or Component Materials

The test methods under this category provide a qualitative or quantitative measure of the compatibility or stripping potential of specific binder-aggregate combinations. They are generally simpler and less costly than those described subsequently that include measurement of mixture properties. However, as Aschenbrener et al. (1995) and Solaimanian et al. (2003) indicate, they do not account for mixture mechanical behavior, the internal structure of the mixture (air voids, aggregate gradation, etc.), or the effects of traffic.

The Boiling Water Test (ASTM D3625) is a national test standard from the first category that visually evaluates a loose mixture after boiling in water for 10 min. Numerous prior research studies have indicated that the Boiling Water Test is not an ideal test method since the results are subjective, but some reasonable correlation to field performance has been shown for Alabama mixtures (Parker and Wilson, 1986).

Table B.1. Laboratory Tests for Characterizing Moisture Susceptibility

Category	Tests & Standards	Moisture Conditioning	Output
Uncompacted Loose Mixtures or Component Materials	Boiling Water Test ASTM D3652	Boiling water, 10 min	Level of stripping by visual rating
	Ultrasonic Accelerated Moisture Conditioning (UAMC)	Ultrasonic conditioning in 140°F (60°C) water bath, 5 h	Mass loss
	Net Adsorption Test (NAT)	Wet condition (presence of water)	Amount of asphalt remaining on the aggregate surface after desorption
	Surface Free Energy (SFE)	Wet condition (calculated)	Conditioned to unconditioned adhesive bond strength ratio
	Bitumen Bond Strength (BBS)	Wet condition (presence of water) or conditioned specimens	Maximum pullout tensile force
Comparison of Conditioned vs. Unconditioned Mixture Properties	Modified Lottman Test AASHTO T 283	Partial vacuum saturation, 1 F/T cycle, and 140°F (60°C) water bath	Conditioned indirect tensile strength (IDT), unconditioned IDT strength, conditioned to unconditioned tensile strength ratio (TSR)
	Immersion-Compression Test AASHTO T 165	140°F (60°C) water bath	Conditioned and unconditioned compressive strength ratio
	Energy Ratio (ER)	Vacuum saturation and cyclic pore pressure with hot water	Dissipated creep strain energy (DCSE)
	Dynamic modulus (E*)/ Environmental Conditioning System (ECS) AASHTO TP 62 AASHTO TP 34	ECS	Conditioned to unconditioned E* stiffness ratio (ESR)
	Resilient Modulus ASTM D4123	Partial vacuum saturation, 1 F/T cycle, and hot water bath	Conditioned M_R, unconditioned M_R, conditioned to unconditioned M_R-ratio
	Dynamic Mechanical Analyzer (DMA)	Partial vacuum saturation, 1 h	Conditioned to unconditioned crack growth index ratio at 10,000 cycles
Repetitive Loading in the Presence of Water	Hamburg Wheel-Track Testing (HWTT) AASHTO T 324	122°F (50°C) water bath	Rut depth at 20,000 load cycles and stripping inflection point (SIP)
	Asphalt Pavement Analyzer (APA) AASHTO TP 63	Partial vacuum saturation, 1 F/T cycle, 140°F (60°C) water bath and testing water bath at performance grade (PG) high temperature	Conditioned to unconditioned rut depth ratio
	Model Mobile Load Simulator 3 (MMLS3)	140°F (60°C) water bath	Visual stripping evaluation, conditioned to unconditioned rut depth ratio, and conditioned to unconditioned TSR
	Moisture Induced Stress Tester (MIST)	Unsaturated specimen with water at 140°F (60°C) under compressed air and vacuum cycles	Visual stripping evaluation, change in bulk specific gravity, and conditioned to unconditioned TSR

More recent developments include the use of ultrasonic energy to more quantitatively assess displacement and detachment of the binder from the aggregate (McCann and Sebaaly, 2001; McCann et al., 2006). In applying the Ultrasonic Accelerated Moisture Conditioning (UAMC), ultrasonic energy is utilized on a loose mixture in a 140°F (60°C) water bath, and the loss of weight through a fine sieve (No. 16 [1.18 mm]) over a 5 h period is continuously monitored. The rate of material lost is a repeatable result that quantifies mixture moisture susceptibility: larger rates are associated with a greater susceptibility to moisture damage. In a

research study, the UAMC method was able to distinguish between different aggregate type, binder types and contents, and the use of lime as an anti-stripping agent (McCann and Sebaaly, 2001). In addition, this testing method was correlated with the retained tensile strength ratio (TSR) after one F/T cycle and with the decay rate of the TSR after multiple F/T cycles (McCann et al., 2006).

Approaches that are more theoretical involve evaluating the adsorption characteristics of different aggregate-binder combinations with and without the presence of water. The Net Adsorption Test (NAT) was developed during the Strategic Highway Research Program (SHRP) to assess moisture susceptibility of asphalt concrete mixtures (Curtis et al., 1991; Curtis et al., 1993; Perry and Curtis, 1993). This test is based on adsorption of a binder of varying concentrations in solutions of toluene onto an aggregate surface and subsequent desorption of the binder from the aggregate surface in the presence of water. A specific fraction of the fine aggregate is used in the NAT, and initial and net adsorptions are reported. Adequate correlation to field performance has been reported for some Minnesota mixtures (Stroup-Gardiner et al., 1995).

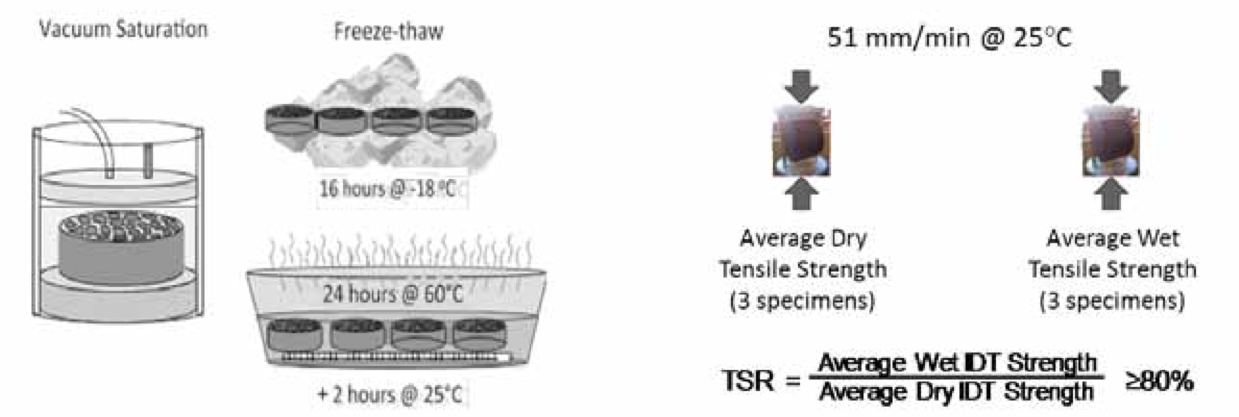
More recent advances utilize a calculated energy ratio of the strength of the adhesive bond between a specific binder and a specific aggregate with and without water present based on measured surface energies of the binder and the aggregate (Howson et al., 2007). This calculation is part of the first tier in a three-tiered approach to select binder and aggregate components with adequate moisture susceptibility. Successful correlation to field performance has been shown for multiple mixtures from multiple states, and limits on the ratio have been suggested (Bhasin et al., 2006).

To assess more directly the adhesive bond between specific binders and aggregates, the Bitumen Bond Strength (BBS) Test was recently developed as a draft American Association of State Highway and Transportation Officials (AASHTO) standard and submitted for review during the 2009 Federal Highway Administration (FHWA) Emulsion Task Force meeting in Scottsdale, Arizona. This test utilizes the Pneumatic Adhesion Tensile Testing Instrument (PATTI) to pull an aggregate stub off a solid substrate coated with binder (Copeland et al., 2006; Kanitpong and Bahia, 2003; Youtcheff and Aurilio, 1997). This test successfully showed increased adhesion with anti-stripping agents, especially in the presence of water, that correlated with improved overall pavement performance and specific distresses associated with moisture damage (raveling and rutting; Kanitpong and Bahia, 2008). This test was also utilized to compare the strength of a binder-coated substrate after being subjected to a heated water bath at 147°F (64°C) overnight and compared against the dry test results (Wasiuddin et al., 2011). An additional test to measure cohesion of the mastic as a function of moisture and allow comparison to the adhesive (through BBS testing) and cohesive causes of failure predicted for specific binder-aggregate combinations was also recently developed (Kringos et al., 2011).

Comparison of Conditioned Versus Unconditioned Mixture Properties

Compared to more subjective, qualitative, and pass-fail tests on uncompacted loose mixtures or component materials, quantitative tests provide a more objective ratio of a measured mechanical parameter (stiffness or strength) after moisture conditioning to that in an unconditioned or dry state. The most common national test standard in this category is the Modified Lottman Test (AASHTO T 283) included in AASHTO M 323 as part of the Superpave volumetric mix design method and a similar American Society for Testing and Materials (ASTM) method (ASTM D4867). These methods utilize a value of 70 or 80 percent (Superpave

criteria) for the retained indirect TSR measured at 77°F (25°C) and 2 inch/min (50 mm/min) after moisture conditioning. The moisture conditioning protocol consists of partial vacuum saturation (70 to 80 percent), a F/T cycle for 16 h at 0°F (-18°C), and soaking for 24 h at 140°F (60°C) before bringing the conditioned specimens to the test temperature of 77°F (25°C). A schematic of this moisture conditioning and testing protocol is presented in Figure B.1 The specimen fabrication protocol also calls for loose-mix conditioning/curing of 16 h at 140°F (60°C) followed by 2 h at 275°F (135°C) and a compacted air void (AV) content of 7 percent. The loose-mix conditioning/curing and the use of a F/T cycle were recommended to transition from smaller specimens for which the test was originally developed to larger specimens compacted in the Superpave gyratory compactor (SGC) and utilized in the Superpave mix design (Epps et al., 2000).



(a) Moisture-Conditioning Sequence **(b) IDT Test**

Figure B.1. Modified Lottman Test AASHTO T 283

Experience shows that this common test method is able to distinguish highly moisture-resistant mixtures from those that are extremely susceptible to moisture damage (Lottman, 1982; Aschenbrener et al., 1995; Scherocman et al., 1986; Sebaaly et al., 2010). Multiple mixtures in Colorado with large differences in performance were identified by differences in TSR measured on conditioned specimens with high saturation levels (Aschenbrener et al., 1995). Successful use of this test to discriminate the effectiveness of different anti-stripping agents has also been shown with multiple F/T cycles for mixtures from multiple states (Scherocman et al., 1985; Scherocman et al., 1986). A more recent extensive laboratory testing program for the National Lime Association (NLA) determined TSR results reliably predicted moisture susceptibility for mixtures from multiple states with a range in performance (Sebaaly et al., 2010).

However, there are also some disadvantages to the Modified Lottman Test, including a lack of correlation with field performance for mixtures that are marginally moisture susceptible (especially when the AV content is less than 6 percent) and variability in test results (Aschenbrener et al., 1995; Epps et al., 2000; Kanitpong and Bahia, 2008; Stuart, 1998). A recent study to develop a precision and bias statement for this test method identified large variability in test results when comparing two different compaction methods and two different aggregate types (a moisture-resistant limestone and a moisture-susceptible sandstone) and their corresponding field performance (Azari, 2010). The reasons for the associated variability were also evaluated using analysis of X-ray computed tomography (CT) images and finite element simulation of the

moisture infiltration process, and it was found that they were caused by variation in inside pore-space distribution, outside porosity and connectivity of the inside pores within the sample, and non-uniform micro-cracking damage due to suction. Results indicated that moisture infiltrates to the center of smaller specimens compacted with the Marshall compactor faster than to that of larger SGC specimens due to differences in air void size and distribution or internal structure. In addition, the lack of correspondence between laboratory and field results was attributed to the fact that the laboratory moisture-conditioning protocol was not representative of the moisture damage time frame that occurred in the field. This moisture-conditioning protocol and resulting micro-cracking due to the vacuum saturation process may also contribute to the variability of the test results. Other related research demonstrated that there are likely differences in the long-term damage processes in the field and damage processes in the laboratory caused by volumetric expansion when water turns to ice and embrittlement of materials that could also contribute to the variability in the test results (Kringos et al., 2009). In general, the AASHTO T 283 moisture-conditioning method is highly dependent on the saturation level, the specimen diameter and height, and the compaction method used. Therefore, improved precision of the test is needed since it is commonly used by many state agencies for mixture selection and payment.

The Immersion-Compression Test (AASHTO T 165/ASTM D1075) is another standard method that employs a value of 75 percent for the index of retained stability (or ratio of direct compressive strength) after static soaking of compacted specimens in heated water to those without moisture conditioning. This is no longer a popular method for characterizing moisture susceptibility because tensile properties (stiffness or strength) are more likely related or sensitive to the adhesive and cohesive causes of failure due to moisture damage rather than compressive strength.

The Environmental Conditioning System (ECS) was developed during SHRP in an effort to simulate field conditions using repeated hydraulic and mechanical loading. The ECS was utilized with a retained resilient modulus ratio (ECS–M_R-ratio) with and without multiple moisture-conditioning cycles (vacuum saturation, hot water, and optional F/T cycle; AASHTO TP 34; Terrel and Al-Swailmi, 1994). This non-destructive test parameter (i.e., M_R) was measured after each moisture-conditioning cycle, and specifications required a minimum unconditioned to conditioned retained resilient modulus of 70 percent. Several subsequent modifications to the original ECS conditioning parameters and M_R measurement protocols have been made to provide a better correlation between test results and field performance (Alam et al., 1998; Aschenbrener et al., 1995).

More recently, the ECS was evaluated along with the dynamic modulus (E*) test (AASHTO TP 62), to assess the effects of moisture conditioning on the same test specimen (Solaimanian et al., 2006). An unconditioned to conditioned E* stiffness ratio (ESR) between 75 percent and 80 percent showed good correlation to field performance for mixtures from multiple states. Yet, further work to simplify and shorten the testing protocol, add an evaluation of the effects of moisture and load separately, continuously monitor mixture response during conditioning, or a combination of these was recommended (Solaimanian et al., 2007). Nadkarni et al. (2009) also utilized the ESR following the AASHTO T 283 moisture-conditioning protocol and recommended a minimum ESR of 70 percent for conventional mixtures in Arizona. Bausano and Williams (2009) also utilized and recommended the ESR with AASHTO T 283 moisture conditioning but with tests performed on saturated specimens after conditioning. Their suggested minimum ESR was 60 percent based on an equivalent percentage of AASHTO T 283 results below the 80 percent limit for different mixtures from Iowa.

A recently completed extensive laboratory testing program for the NLA tracked E* with up to 15 multiple F/T cycles per AASHTO T 283 for mixtures from multiple states with a range in performance and found that these results correlated with other moisture-susceptibility results (Sebaaly et al., 2010). This study also utilized more advanced tools like the Dynamic Mechanical Analyzer (DMA) to characterize the effect of lime on the fine aggregate matrix (FAM; binder combined with the aggregate fraction passing the No. 16 sieve [1.18 mm)]), as recommended in the three-tiered approach for moisture-susceptibility evaluation (Howson et al., 2007). The DMA and associated analysis identified both good and poor field performance in multiple states, and the NLA study showed consistent results between the DMA G* results and E* with multiple F/T cycles (Lytton et al., 2005; Sebaaly et al., 2010).

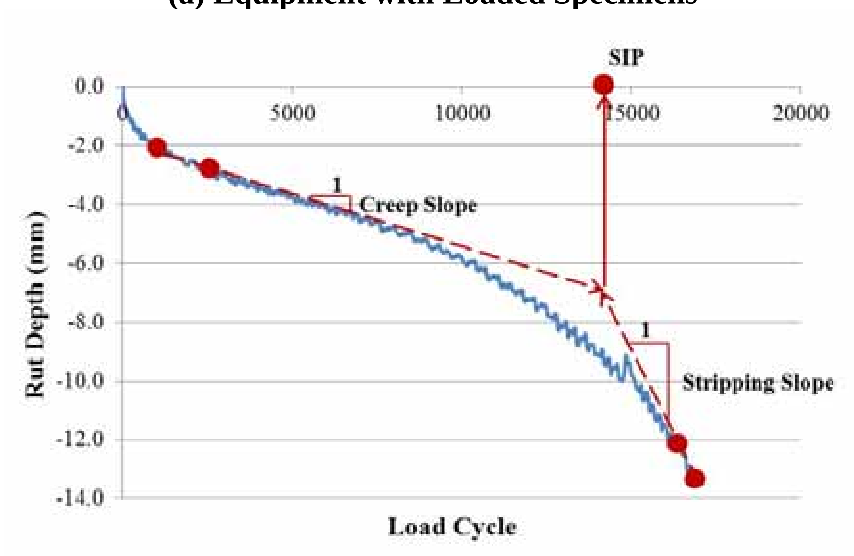
Other recent advances include development of the energy ratio (ER) by Birgisson et al., (2004; Birgisson et al., 2007). The ER quantifies the effects of moisture damage on the fracture resistance of mixtures measured using the Superpave Indirect Tensile (IDT) Test (AASHTO T 322) that includes both creep and strength testing. The ER is calculated from parameters including the dissipated creep strain energy (DCSE), and a minimum DCSE threshold for adequate cracking performance as well as creep and strength parameters are recommended. While originally developed using the moisture-conditioning protocol from AASHTO T 283, a new protocol using application of cyclic pore pressure is now included (Birgisson et al., 2007). This technique creates a more representative mechanism that accelerates both long-term moisture intrusion through the binder film and the effects of expansive water pressure while minimizing other confounding damage effects. Results indicated that the ER was capable of detecting moisture susceptibility in terms of the effects on mixture fracture resistance and detecting the positive contribution of anti-stripping agents in improving moisture susceptibility.

Repetitive Loading in the Presence of Water

Laboratory tests that utilize repetitive loading in the presence of water include wheel-tracking tests that measure combined mixture resistance to moisture susceptibility and rutting. These tests are more objective in nature but may confound resistance to rutting and moisture susceptibility. Some states have switched from a comparison of conditioned and unconditioned mixtures to this type of test (especially the Hamburg Wheel-Tracking Test [HWTT]) based on good repeatability, a significantly improved relationship with field performance, and an ability to identify premature failures (Epps Martin et al., 2003; Izzo and Tahmoressi, 1999).

Figure B.2 shows the HWTT setup. In this test, specimens are submerged in hot water between 113°F (45°C) and 122°F (50°C) and subjected to about 50 to 52 passes of a steel wheel per minute. Each sample is loaded for a maximum number of passes (usually 20,000) or until a maximum deformation of usually 0.5 inch (12.5 mm) occurs. Different states have different water temperature, number of passes, and maximum rutting requirements, often dependent on the performance grade (PG) of the binder, the traffic level of the pavement, or both.

(a) Equipment with Loaded Specimens



(b) Typical Deformation Behavior with Load Cycles

Figure B.2. Hamburg Wheel-Tracking Test

Izzo and Tahmoressi (1999) evaluated the laboratory repeatability, testing configuration, test temperature, and capability of the HWTT to assess the effects of anti-stripping agents. Their results showed that the test was capable of detecting the use of anti-stripping agents, yielding improved performance in terms of moisture susceptibility. Recommended changes by Aschenbrener et al. (1995) to the rut depth threshold (from 0.16 to 0.40 inch [4 to 10 mm]) under variable testing temperatures depending on the binder type resulted in improved correlation with field performance. According to Claros (2011), laboratory HWTT results in terms of moisture susceptibility are very sensitive to short-term conditioning/curing of mixtures, and an increase in conditioning/curing time, temperature, or both may significantly improve HWTT performance.

The Asphalt Pavement Analyzer (APA; AASHTO TP 63) also utilizes a repeated loading test device on specimens in saturated conditions and compares them to unconditioned specimens tested dry. Similar to the HWTT, the APA loads the sample to a maximum rut depth; however, the steel wheels run on top of a rubber hose instead of directly in contact with the specimen. The

test criteria include the ratio of conditioned rut depth to unconditioned rut depth, with values greater than 1 suggesting the mixture is moisture susceptible. Bausano et al. (2006) indicated that the APA testing of saturated mixtures is capable of identifying moisture susceptibility, simulating the repeated hydraulic loading that pavements undergo with desirable testing efficiency.

The Model Mobile Load Simulator 3 (MMLS3) can also be used to provide accelerated loading in the presence of water. This device applies traffic to mixture specimens in a hot-wet environment. A tire pressure of 100 psi (690 kPa), load of 607 lbf (2.7 kN), and water temperature of 140°F (60ºC) were used in previous research (Mallick et al., 2005). Specimens were put in a test bed that was then placed in a 140°F (60ºC) water bath. An electronic profilometer recorded the rut depth of the specimens during the test process. Visual stripping was also considered for comparison of mixtures after loading. In addition, 4 inch (100 mm) cores extracted from 6 inch (150 mm) specimens after loading were used to determine conditioned IDT strength. Results indicated that the MMLS3 is a promising moisture-susceptibility test method (Mallick et al., 2005).

A recently developed moisture-conditioning equipment named the Moisture Induced Stress Tester (MIST) is designed to evaluate the resistance of a compacted asphalt mixture specimen to stripping and moisture damage and to simulate the action of traffic on a wet pavement (InstroTek, 2012a). This equipment replicates the condition of water being forced in and out of the pavement as tires roll over it by cyclically applying and removing high pressure on a specimen submerged in water. The user specifies the number of cycles to be applied to the specimen, which is usually between 1,000 and 3,500. To accelerate further the potential moisture damage from this action, the test is performed at an elevated temperature of up to 140°F (60°C). The change in bulk specific gravity of the sample before and after conditioning measured using ASTM D2726 or AASHTO T 166 is used as an indicator of moisture damage. Other mechanical tests such as TSR can also be performed after the conditioning protocol and compared to unconditioned properties. Good correlation between TSR before and after MIST and field performance has been reported (InstroTek, 2012b). In addition, the use of MIST as a moisture-conditioning protocol prior to E* or Superpave IDT creep and strength tests has also shown promise in characterizing moisture susceptibility (Chen and Huang, 2008). The reported advantages of MIST as compared to other moisture sensitivity tests are the reduced conditioning time and its automated operation.

Previous Research on Moisture Susceptibility of WMA

Despite the attractive economic, environmental, and safety advantages of warm mix asphalt (WMA), a number of changes in the production process as compared to hot mix asphalt (HMA) have raised concerns regarding the long-term performance of WMA pavements. Factors that can potentially increase the moisture susceptibility of WMA are described in this section. In addition, results from prior research studies regarding moisture-susceptibility characterization of WMA, minimization strategies, and comparison of specimen types are discussed.

Bonaquist (2011b), who evaluated mix design practices for WMA through laboratory and field study, indicated that the effect of WMA processes on moisture susceptibility is mixture and process specific. He pointed out that different WMA processes have different effects on moisture susceptibility and that most of them provide a mixture with less resistance to moisture damage, while some processes, such as the low emission/energy asphalt (LEA), may be beneficial in terms of moisture susceptibility. Thus, moisture susceptibility of WMA mixtures should be

evaluated comprehensively, considering all factors, such as binder grade and contents, aggregate gradations, and properties of different WMA additives. Solaimanian et al. (2011) agrees that mix design should be evaluated for WMA, despite having an equivalent HMA design meeting specifications.

WMA Moisture-Susceptibility Factors

Besides the moisture-susceptibility mechanisms explained in the previous section, there are several factors related to the lower production temperature of the WMA and the use of certain foaming and additive technologies that can increase the moisture susceptibility of WMA. These factors include:

- Introduction of additional moisture with the free water foaming WMA technologies.
- Use of wet/damp aggregates in the production process.
- Reduced binder absorption by the aggregates at lower production temperatures.
- Reduced binder-aggregate bond strength in the presence of certain WMA additives.

While the first listed factor has not been addressed extensively to date in previous research, the remaining factors have been investigated. This section provides a summary of selected research studies on these topics. From the performance evaluation of various WMA technologies in the laboratory, the conclusion of several studies is that WMA has increased moisture susceptibility as compared to HMA (Austerman et al., 2009; Buss et al., 2011; Diefenderfer and Clark, 2011; Goh and You, 2011; Kim et al., 2011; Kim et al., 2012). However, documented field performance indicates that WMA pavements are not exhibiting moisture-susceptibility-related distresses (Diefenderfer and Clark, 2011; Jones et al., 2011; Kim et al., 2012). This could be due to the limited time that field sections have been monitored or other causes that are not being adequately represented in the laboratory evaluations.

Use of Wet Aggregates Aggregates used in WMA production may not dry completely due to the lower production temperatures, especially if absorptive aggregates are employed (Prowell et al., 2011). Bennert (2011) stated that higher absorptive aggregates are more prone to a higher degree of moisture damage potential when used in WMA mixtures due to incomplete drying of the aggregate during mixture production. The residual moisture in the mixture may disrupt the adhesive bond between the binder and the aggregate and increase the moisture susceptibility and stripping potential of the mixture. Even if the dwell time in the drum at lower temperatures is enough to dry the moisture on the aggregate surface, it may not be enough to dry the internal moisture, especially for the coarser aggregate fractions. Parker and West (1992) observed that the moisture content of coarse aggregates in stockpiles was always higher than the finer fractions and that the variation was highly dependent on the environmental conditions before production, during production, or both (i.e., rainy and cool days versus hot and dry days).

Researchers have studied the effect of residual aggregate moisture on the stripping potential of HMA. Their results show that the moisture susceptibility of HMA prepared with aggregates having varying levels of moisture content and measured in terms of the IDT strength and TSR depends on the aggregate type, with gravel and sandstone being more susceptible to the initial level of moisture content than limestone (Joslin et al., 1998; Parker and West, 1992). In addition, the initial moisture content of the aggregate during production had an effect on the

correlation between observed field performance and test predictions in the laboratory (Parker and West, 1992).

In a study aimed at investigating the relationship between the tender behavior of HMA during compaction and the initial moisture content in the aggregates, Huber et al. (2002) developed a method to introduce and measure moisture in laboratory specimens. They placed aggregates that were soaked overnight in a bucket mixer and mixed while heating using a propane tank with a nozzle attachment to simulate the burner flame at the production plant. The binder was added once the aggregate reached a temperature of 290°F (143°C; measured with an infrared probe). The procedure was successful in trapping moisture, with residual moisture values in the mixture ranging from about 0.8-1.8 percent. The recommended method for measuring moisture content in the mixture was drying at constant mass using a forced draft oven at 230°F (110°C). In a later study, Mallick et al. (2011) developed a laboratory method to simulate incomplete aggregate drying during HMA production. To prepare aggregate batches with various moisture contents, an oven-dried aggregate blend was vacuum sealed in a bag, soaked with water introduced in the bag with a syringe, vacuum sealed again, left soaking overnight, and oven dried at 194°F (90°C) for different periods. After mixing at 194°F (90°C) using Sasobit® as a compaction aid, the mixture was short-term aged at the same temperature (i.e., 194°F]90°C]). The compacted mixtures were placed in sealed bags to preserve the moisture content until testing.

Similar work evaluating the effect of the initial aggregate moisture content in WMA performance has been done. Hurley and Prowell (2006) used the same bucket mixer and propane torch method developed by Huber et al. (2002) to prepare WMA mixtures with limestone and granite aggregates containing 3 percent moisture content beyond their absorption capacities and evaluated the effect on the moisture susceptibility of Aspha-min®, Sasobit®, and Evotherm™ technologies. The use of moist aggregates decreased the IDT strength in all cases versus the HMA control. The TSR values were dependent on the type of aggregate and technology; the combination of granite and Evotherm™ yielded acceptable values of TSR (i.e., 96 percent), as did limestone and Sasobit® with a TSR of 91 percent. All other combinations were below the recommended threshold, ranging from 51-71 percent.

In a separate study, Bennert et al. (2011) proposed a modified mixing procedure to simulate incomplete aggregate drying during WMA production and measure the moisture susceptibility of the mixture. The procedure consisted of pre-wetting the aggregate blend for 24 h, mixing the aggregate while heating with a propane torch until the mixing temperature was reached (measured with an infrared probe), adding the pre-heated binder, mixing until the aggregates were fully coated, and conditioning for 2 h at the compaction temperature. The aggregates were pre-wet at 3 and 6 percent moisture content, and a blend of dry aggregates was also used. Highly absorptive (i.e., gravel) and low absorptive aggregates (i.e., trap rock) were used to prepare the aggregate blends. The moisture susceptibility was measured using IDT strength, TSR, and HWTT. The TSR results showed that all mixtures with the exception of the ones prepared at a higher mixing temperature (315°F [157°C]) with the dry aggregate blend failed to meet the recommended TSR threshold of 80 percent. The reported TSR values for the mixtures prepared with the moist aggregates ranged from 38.7-71.5 percent, while the TSR range for the mixtures prepared with the dry aggregate blends was 62.6-93.9 percent. Also, for both aggregate types, the lower mixing temperature (270°F [132°C]) and increased moisture content had a significant negative effect on both the unconditioned and conditioned IDT strength. For HWTT, only the WMA mixtures prepared at the lower mixing temperature and 6 percent

moisture content exceeded the rutting threshold of 0.5 inch (12.5 mm) at 20,000 passes. The rutting values for all other mixtures at that load level varied between 0.27-0.46 inch (6.89-11.62 mm).

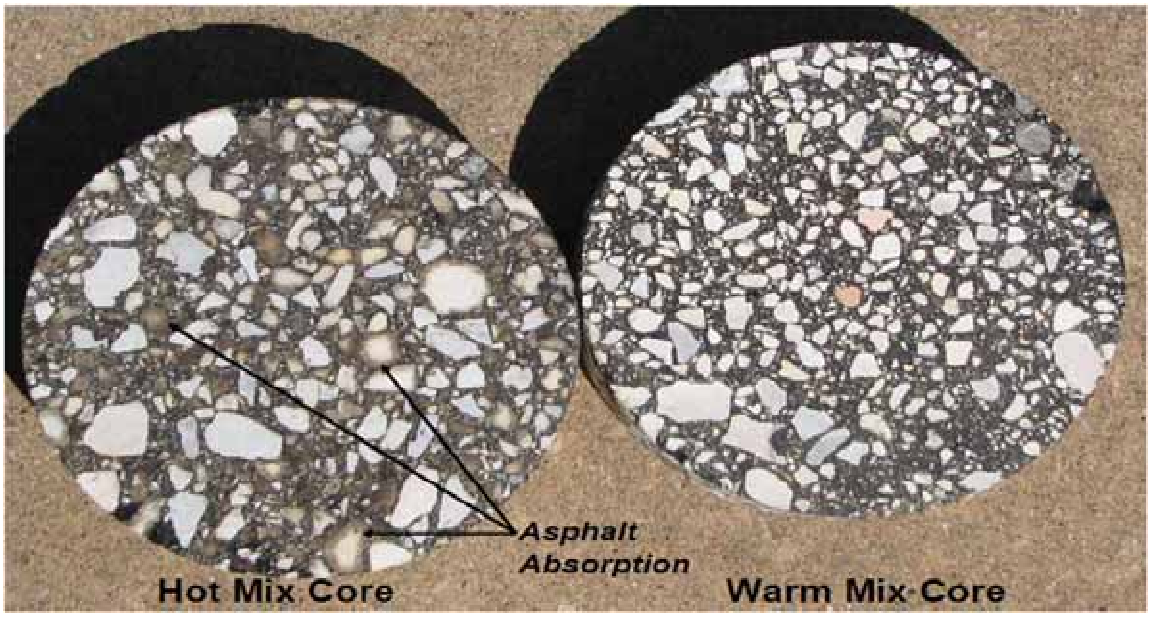
Xiao et al. (2009) also investigated the influence of initial aggregate moisture content on the moisture susceptibility of WMA. They prepared mixtures using three aggregate sources, dry and moist aggregate blends (0.5 percent moisture content), two WMA additives, and various quantities of hydrated lime and evaluated the performance of the mixture with IDT strength, TSR, deformation, and toughness. The 0.5 percent aggregate moisture content was achieved by drying aggregate blends soaked with specific amounts of water at 349°F (176°C) for 140 min. The IDT strength values of all unconditioned mixtures prepared with the moist aggregates were lower compared to their dry counterparts and highly dependent on the aggregate source. A follow-up study confirmed that the moisture susceptibility of WMA was dependent on the aggregate type and that the addition of hydrated lime improved the resistance to moisture damage (Xiao et al., 2011). A study by Gong et al. (2012) calculated fracture energy parameters from M_R, creep compliance, and IDT strength. The ER appeared to be more sensitive to identify moisture-susceptibility issues than TSR, and results from this study corroborated that moisture susceptibility is aggravated in mixtures that include incompletely dried aggregates.

Instead of simulating in the laboratory initial moisture content of the aggregates and evaluating the effect on moisture susceptibility, Bennert and Brouse (2011) tried to quantify the influence on mixture performance of plant-produced WMA. In the study, WMA plant mixtures produced at different temperatures and with different initial moisture contents were tested using IDT strength and HWTT. Test results showed that production temperature had a larger effect on mixture stiffness as compared to the initial aggregate moisture content. Nevertheless, results from the overlay tester revealed that fatigue resistance decreased with the increase in initial moisture content and as the production temperature raised 10°F (~5°C). The author proposed evaluating field cores acquired after certain periods from the test sections that employed these mixtures in order to have a better assessment of the effect of initial aggregate moisture content and production temperature on plant-produced WMA.

Another study by Jones et al. (2011) measured the moisture content of WMA (Advera®, Sasobit®, and Evotherm™) and HMA mixtures at the plant, and in all cases, the moisture content of the WMA mixtures was higher. The authors noted this could create a potential for moisture distress if the aggregate moisture contents during production were not closely monitored. In addition, laboratory tests on WMA and HMA LMLC and PMLC specimens and field-accelerated load tests via heavy vehicle simulator (HVS) were performed on a custom-built test track. Moisture-susceptibility laboratory tests included HWTT (AASHTO T 324) and TSR (Caltrans CT 371). The HWTT and TSR test results performed on WMA LMLC specimens with no conditioning were generally poor, although the results obtained on PMLC specimens showed similar performance for WMA and HMA and little evidence of moisture damage. In agreement with the PMLC laboratory results, the forensic investigations performed on the test track after HVS trafficking showed no indication of moisture damage on either the WMA or HMA sections.

Reduced Binder Absorption Due to the lower temperatures used during WMA production, less binder is often absorbed by the aggregate. Figure B.3 shows the difference in binder absorption by the aggregate in HMA and WMA field cores obtained from Loop 368 in San Antonio, Texas, after 1 year in service. The binder absorption in the HMA field core is evident in Figure B.3(a), which implies that the lighter and less polar fractions of the binder were absorbed by the aggregate, leaving behind the thicker, more polar fraction of the binder to coat the aggregate. In contrast, binder absorption is not visible in the WMA core (Figure B.3[b]).

This phenomenon could potentially increase the moisture susceptibility of WMA if lower binder absorption weakens the binder-aggregate bond or if the lighter fractions of the binder coating the aggregate provide less protection from moisture. On the other hand, a thicker binder film could provide a better physical barrier against moisture damage that could yield a more moisture-resistant mixture. Additional research in this area is needed to fully understand the effects of reduced binder absorption in WMA and if the level of absorption changes with time.



(a) **(b)**

Figure B.3. HMA and WMA Field Cores (Estakhri et al., 2010)

Reduced Binder-Aggregate Bond Strength Another factor affecting the moisture susceptibility of WMA is the effect that certain additives may have on the binder-aggregate bond strength. The additives used in some of the WMA technologies have an impact on binder rheology, which in turn may weaken the adhesive bond between the binder and the aggregate, especially in the presence of water. The surface free energy (SFE) and work of adhesion are commonly used to estimate the binder-aggregate bond strength. In a recent research study, the work of adhesion was calculated for combinations of two types of aggregates, two types of binders, two binder sources, and three WMA additives: Evotherm™, Sasobit®, and Rediset™ WMX (Estakhri et al., 2010). The results showed that in a dry condition, the work of adhesion between the aggregates and the binder plus additives decreased with respect to the control case (i.e., virgin binder-aggregate combination); that is, the binder-aggregate bond was weakened when the additives were included. In addition, in the presence of water, the values obtained for the work of adhesion were negative, which means that debonding between the two materials was likely to occur in the presence of water. Also, higher negative work of adhesion magnitudes were obtained for the cases where the binder was combined with the additives, which implied that debonding could have been a likely occurrence.

In another study, SFE was also used to evaluate the adhesive bond strength between two types of aggregates and two types of binders prepared with various levels of Sasobit® (Wasiuddin et al., 2008). The results showed that although the additive promoted better aggregate wettability, it had a negative effect on the binder-aggregate bond (regardless of the quantity of additive in the binder). This effect was more critical when PG 70-28 was used versus PG 64-22.

The adhesive bond strength has also been measured with the BBS test using PG 64-22 binder specimens prepared with Advera®, Sasobit®, and Evotherm™ and applied on top of a limestone surface (Mogawer et al., 2010). The tests were performed at room temperature (i.e., 68°F [20°C]) on unconditioned specimens and moisture-conditioned specimens soaked for 24 h at 104°F (40°C). The pull-off tensile strength results showed that the unconditioned values were equal to or higher for the WMA binders versus the HMA control. The conditioned tensile strengths for the WMA binder specimens, although lower than their dry counterparts, were also similar to the unconditioned HMA tensile strength values. The unconditioned to conditioned tensile strength percent drop was between 5-10 percent higher for WMA versus HMA. Besides the WMA additive, Alavi et al. (2012) found the bond strength measured by BBS to be dependent on the production temperature; at lower production temperatures, the adhesive bond strength decreased.

Nazzal and Qtaish (2013) used the atomic force microscopy (AFM) for evaluating adhesive and cohesive bond strength of WMA and healing characteristics of the binder. Traditional Dynamic Shear Rheometer (DSR) and TSR measurements were also incorporated into this study. Two binders (polymer modified and unmodified) and four different WMA technologies (Foaming, Sasobit®, Evotherm™, and Advera®) were evaluated. It was found that for the unconditioned samples, all WMAs exhibited an increase in adhesive bond strength for both types of asphalt binder. After moisture conditioning, the unmodified binder experienced a greater decrease in adhesive bond strength as compared to the polymer modified for all HMAs and WMAs. Between the WMAs, Evotherm™ exhibited similar performance as compared to HMA, while Advera® and Sasobit® experienced a greater loss of adhesive bond strength after moisture conditioning. Additionally, Advera® and Sasobit® showed a reduction in the cohesive bond strength with both types of binders after moisture conditioning.

Minimization Strategies

Common strategies used to minimize moisture damage in asphalt pavements are (a) assuring complete aggregate drying during mixture production, (b) incorporating anti-stripping agents in the mixture, and, to some extent (c) using reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS).

In addition, good construction practices are important for alleviating moisture damage issues in the field. The primary factor during construction is achieving target density during compaction (93 to 96 percent maximum theoretical density or 3-7 percent AV) to reduce the access of moisture into the mixture and minimize other types of distress that are exacerbated by the effects of moisture (Santucci, 2010). In addition, construction should avoid entrapment of moisture between pavement layers such as placement of a drainage layer over a distressed pavement or placement of an impermeable surface treatment over a moisture-susceptible layer.

Anti-Stripping Agents Commonly used anti-stripping agents include hydrated lime and chemical liquid agents. Hydrated lime is widely used throughout the United States by agencies to improve the moisture damage resistance of asphalt concrete paving materials. It is generally added at a rate of 1.0 to 2.0 percent by weight of dry aggregate or 20 to 40 percent by weight of binder in powder form to dry or damp aggregate or as slurry (Santucci, 2010). Most chemical liquid anti-stripping agents are amine-based compounds that are usually added at a rate of 0.25 to 1.00 percent by weight of binder. They are designed to act as coupling agents to promote better adhesion at the binder-aggregate interface (Curtis et al., 1993). Other, less common chemical liquid anti-stripping agents include silane-based additives that are added at a rate of 0.40 percent by weight of binder directly to the heated binder (Kim and Moore, 2009a, 2009b).

Some studies have verified that adding hydrated lime to asphalt mixtures helps stiffen the mixture and reduce the probability of moisture damage by loss of adhesion or cohesion, therefore extending the service life of the pavement (Sebaaly et al., 2010). It is commonly accepted that higher hydrated lime dosages result in better moisture resistance; however, a study by Granite Construction Inc. indicated that anti-stripping agents have an optimum dosage that maximizes the resistance to moisture damage (Hand, 2010). The optimization of anti-stripping agents should be based on a comprehensive consideration of specifications, performance, and cost.

In a study by Xiao el al. (2009), the effect of hydrated lime in mixtures employing moist aggregates was explored. The addition of hydrated lime in the unconditioned mixtures where moist aggregates were used provided no significant improvement in the IDT strength. However, for the mixtures subjected to moisture conditioning (prepared both with dry and moist aggregates), the addition of hydrated lime was beneficial in increasing the IDT strength. With regard to the TSR results, only the mixtures containing hydrated lime (prepared both with dry and moist aggregates) were above the 85 percent threshold established by the agency.

Research studies on moisture susceptibility of WMA also indicate better performance when anti-stripping agents are added to the mixture. Hurley and Prowell (2006) evaluated Aspha-min® and Sasobit®; Aspha-min® benefited from the addition of hydrated lime, while Sasobit® benefited from adding either hydrated lime or an anti-stripping agent. Hearon and Diefenderfer (2008) also found that both hydrated lime and liquid anti-stripping agents enhanced the moisture resistance of WMA Sasobit®.

It is known that some WMA technologies include anti-stripping agents within their chemical composition. Therefore, different WMA technologies could exhibit different

performance upon combination with various types of aggregates and binders. In their research study, Prowell et al. (2007) found that granite exhibited enhanced moisture resistance with the use of Evotherm™, while limestone showed better performance when combined with Sasobit®. Other research studies support the need for optimizing the WMA additive/aggregate type combination for producing WMA to achieve enhanced moisture resistance (Abbas and Ayman, 2011; Alavi et al., 2012; Bennert et al., 2011; Hurley and Prowell, 2006).

Inclusion of RAP, RAS, or Both Some studies have demonstrated that in some instances, the incorporation of RAP, RAS, or both in WMA has a similar effect to the use of anti-stripping agents. In a recent study, HWTT was used to assess the moisture susceptibility of WMA mixtures with 35-40 percent RAP, 5 percent RAS, or both and compared to WMA without the addition of these materials. The results showed that WMA with RAP and RAS had a better resistance to moisture damage due to the stiffening effect that these materials provide (Mogawer et al., 2011; Mogawer et al., 2012). A separate study by Doyle et al. (2011) based on TSR values concluded that high RAP (up to 50 percent) WMA surface mixtures had a better moisture resistance as compared to WMA mixtures with no RAP.

Another study focusing on moisture damage potential of WMA containing RAP was conducted by the US Army Corps of Engineers (Mejias-Santiago et al., 2011). Various aggregate types, RAP contents, production temperatures, and WMA technologies were used to prepare WMA mixtures with different characteristics. These mixtures were evaluated in terms of moisture susceptibility per ASTM D4867 without an F/T cycle. Increased moisture susceptibility of WMA due to lower production temperature compared with HMA was observed. However, the results also showed that several WMA additives did not negatively affect the resistance to moisture damage if mixed and compacted at higher production temperatures. Key finds in terms of properties of WMA with RAP indicated that the incorporation of RAP significantly reduced the moisture susceptibility of the mix at even at the lowest production temperature.

Laboratory versus Field Specimens

As explained in previous sections, production temperature and WMA specimen conditioning/curing have a significant effect on measured performance. This is particularly apparent when LMLC specimens, PMLC specimens, and PMFC cores are compared, since they are often subjected to different conditions in the laboratory and the field. In addition, several dissimilarities between laboratory evaluations and observed field performance have been noted. Anderson (2010) stated that in order to better simulate field performance in terms of moisture susceptibility, the differences should be minimized by saving material during the production process.

Differences between specimen types is not exclusive to WMA specimens; in a study by Parker and West (1992), HMA PMLC specimens prepared with limestone aggregates had higher strengths and TSR values than HMA LMLC specimens did. The authors noted that the differences could be explained by the residual aggregate moisture in the case of the PMLC specimens, while in the laboratory, the aggregates were dried completely. They hypothesized that the residual moisture could form a weaker but more moisture-resistant binder-aggregate adhesive bond versus an initially stronger but more moisture-susceptible bond between the binder and the dry aggregates.

A similar study by Bennert (2011) evaluated the moisture damage of WMA Sasobit® cores and reheated loose mix as part of a test study conducted on Rt. 38. The results showed

significant differences within each specimen type (i.e., cores and reheated loose mix), with higher TSR values when the mixtures were produced at 315°F (157°C) as compared to when the production temperature was 270°F (132°C). In addition, within each production temperature, the TSR for the cores were lower than the values obtained for the reheated loose mix. The author's explanation for the results was that trapped moisture in the field cores could have resulted in lower TSR values and that additional drying/stiffening could have occurred after reheating the loose mixture in the laboratory, therefore improving the TSR values.

Another study with similar objectives but different conclusions was performed by Hajj et al. (2011). Their results indicated that foamed WMA mixtures made using plant loose mix with and without reheating at compaction temperature for 2 to 4 h had similar moisture resistance. A dynamic modulus ratio of foamed WMA mixtures with a certain number of F/T cycles similar to that without moisture conditioning was used as the moisture-susceptibility index. Laboratory results showed that the reheating protocol had no effect on improving the mixture resistance to moisture damage. Instead, the incorporation of RAP and polymer modifiers into WMA mixtures seemed to improve this property.

In a WMA demonstration project built in Birmingham, Alabama, the performance of PMLC and LMLC specimens prepared with Evotherm DAT™ were compared using IDT strength and the HWTT (Kvasnak et al., 2009). The WMA specimens were also compared to the HMA control. LMLC specimens were prepared at 290°F (143°C) for HMA and 248°F (120°C) for WMA. Both HMA and WMA mixtures contained RAP and RAS and were compacted to 7 percent air voids and conditioned/cured for 2 h after mixing. The PMLC specimens were prepared from a mixture obtained from the trucks and compacted right after sampling in the National Center for Asphalt Technology (NCAT) mobile laboratory (without reheating the mixture) with the compaction temperature and target air voids the same as those used for LMLC specimens. To evaluate moisture susceptibility, a subset of the specimens were conditioned using Alabama Department of Transportation (ALDOT) moisture-conditioning protocol (ALDOT 361: partial vacuum saturation, 140°F [60°C] water bath for 24 h, and 77°F [25°C] water bath for 1 h before testing). The LMLC specimens' TSR results were lower for the WMA than for the control HMA, and all WMA specimens failed to meet the 80 percent TSR threshold. Conversely, all the TSR results for WMA PMLC specimens (as well as the control HMA) were greater than 80 percent. The number of passes to the stripping inflection point (SIP) for the PMLC specimens was higher for the control HMA versus the WMA, although in some cases the WMA exceeded 10,000 passes. Overall, with respect to moisture susceptibility, the WMA PMLC specimens performed better than the LMLC specimens.

Ongoing NCHRP Project 9-48 is investigating the differences in volumetrics and mechanical properties of LMLC, PMLC, and PMFC specimens (Mohammad and Elseifi, 2010). Existing datasets published in the literature were used to investigate possible sources of variability between specimen types. These factors include compaction methods, silo storage time, baghouse fines, mixture reheating, aggregate absorption, plant type/settings, sampling location, gradation density, aggregate degradation, and aggregate moisture content. With respect to moisture sensitivity, preliminary conclusions based on the analysis of data collected during the original and rehabilitation construction cycles of the WesTrack study showed that the TSR of PMLC specimens and PMFC cores were lower than the LMLC specimens. However, analysis of research data from the University of Nevada showed the opposite trend, with larger TSR values for PMLC versus LMLC specimens. When combining both datasets, the largest absolute average

difference was for PMFC cores versus LMLC specimens, followed by PMLC versus LMLC specimens.

TEST RESULTS AND DATA ANALYSIS

Moisture Susceptibility of WMA

This appendix provides the test results for comparing HMA versus multiple WMA technologies in terms of moisture susceptibility for different specimen types. The main test parameters used are IDT strength, TSR, resilient modulus (M_R), resilient modulus ratio (M_R-ratio), HWTT stripping inflection point (SIP), and HWTT stripping slope.

Dry and Wet IDT Strength and TSR

For the results presented in this section, three replicate specimens were tested in dry condition and three replicate specimens were tested after saturation and one F/T cycle as specified in AASHTO T 283 conditioning protocol. The test parameters used as indicators of moisture susceptibility were TSR and the difference between the wet IDT strength of the WMA specimens versus that of the HMA specimens. An analysis of variance (ANOVA) and Tukey's Honest Significant Differences (HSD) were performed on the wet IDT strength values to assess moisture susceptibility of the WMA specimens as compared to their HMA counterparts. The analysis was done independently for each specimen type (i.e., on-site PMLC specimens, PMFC cores at construction, LMLC specimens, etc.). Since only one TSR result was generated using the average of the three dry and three wet replicate results, a statistical analysis like the one performed for the wet IDT strength was not suitable for this particular variable. Therefore, to compare the differences in TSR results of different mixture types and different specimen types, AASHTO T 283 precision and bias statement, which indicates a d2s of 9.3 percent is an acceptable range of two results not being different with more than a 95 percent confidence level, was used (Azari, 2010). In the figures presented in this section, the statistical groups based on Tukey's HSD analysis of the WMA vs. HMA wet IDT strength are indicated by capital letters in the center of the bars. In these same graphs, the solid part of the bar represents the wet IDT strength value, and the portion that extends beyond the solid part with no fill represents the dry IDT strength.

Iowa Field Project Wet and dry IDT strengths are shown for all Iowa specimen types in Table B.2 and Figure B.4(a), with mixture types compared within the same specimen type. In the majority of the cases, the wet IDT strength of the HMA with RAP specimens was higher than the WMA with RAP values. The wet IDT strength of WMA Evotherm® 3G with RAP and Sasobit® with RAP was statistically equivalent for every specimen type, except the on-site PMLC specimens, where WMA Evotherm® 3G with RAP had a higher wet IDT strength as compared to WMA Sasobit® with RAP. PMFC cores after summer at 12 months in service and off-site PMLC specimens were statistically equivalent between HMA with RAP and both WMAs with RAP in terms of wet IDT strength. It is interesting to note that after a summer at 12 months in service, both dry and wet strengths for the HMA with RAP and WMA with RAP mixtures increased significantly.

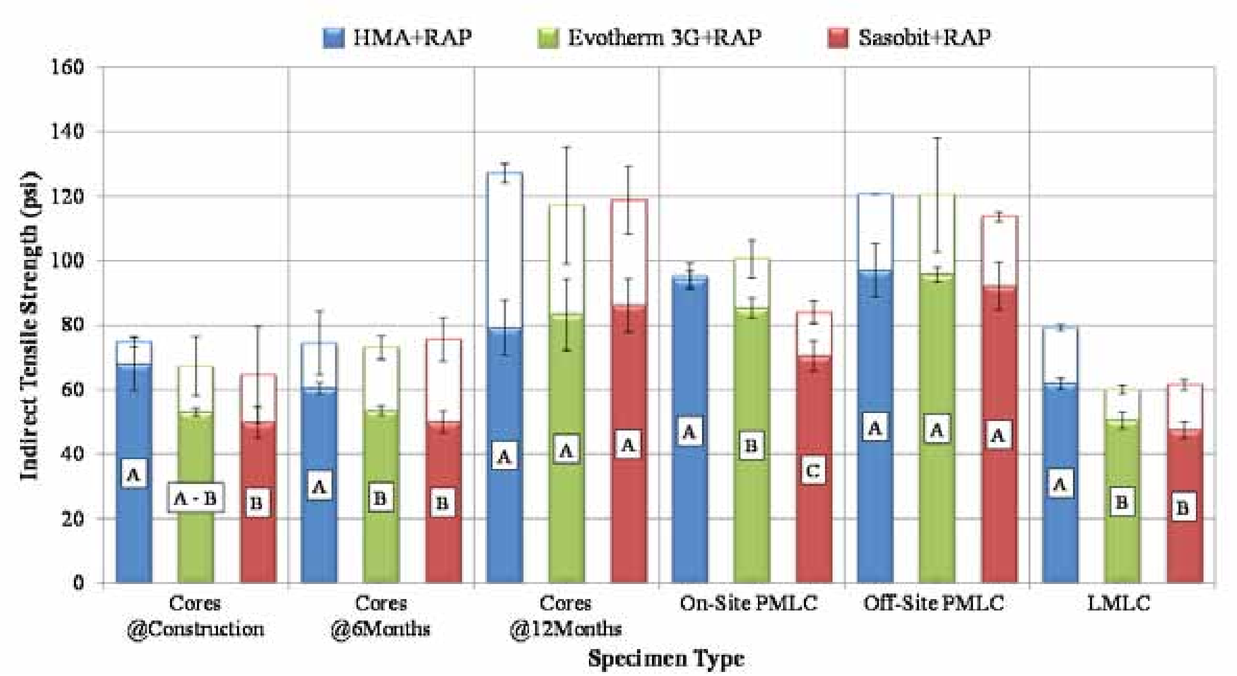
Table B.2 and Figure B.4(b) show the wet to dry TSR for the different specimen and mixture types. All TSR values except for WMA Sasobit® with RAP PMFC cores after winter at 6 months in service and HMA PMFC cores after summer at 12 months in service were higher

than 70 percent. TSR values for different specimen types showed mixed conclusions regarding moisture susceptibility of WMA as compared to HMA with RAP. For off-site PMLC and LMLC specimens, HMA with RAP and both WMAs with RAP were equivalent based on the 9.3 percent d2s value. For PMFC cores at construction and on-site PMLC specimens, HMA with RAP had higher TSR values than both WMAs with RAP. For PMFC cores after winter at 6 months in service and after summer at 12 months in service, on the other hand, HMA with RAP exhibited different values than WMA Sasobit® with RAP (larger in the case of cores after winter at 6 months in service and smaller in the case of cores after summer at 12 months in service) but equivalent values to WMA Evotherm® 3G with RAP.

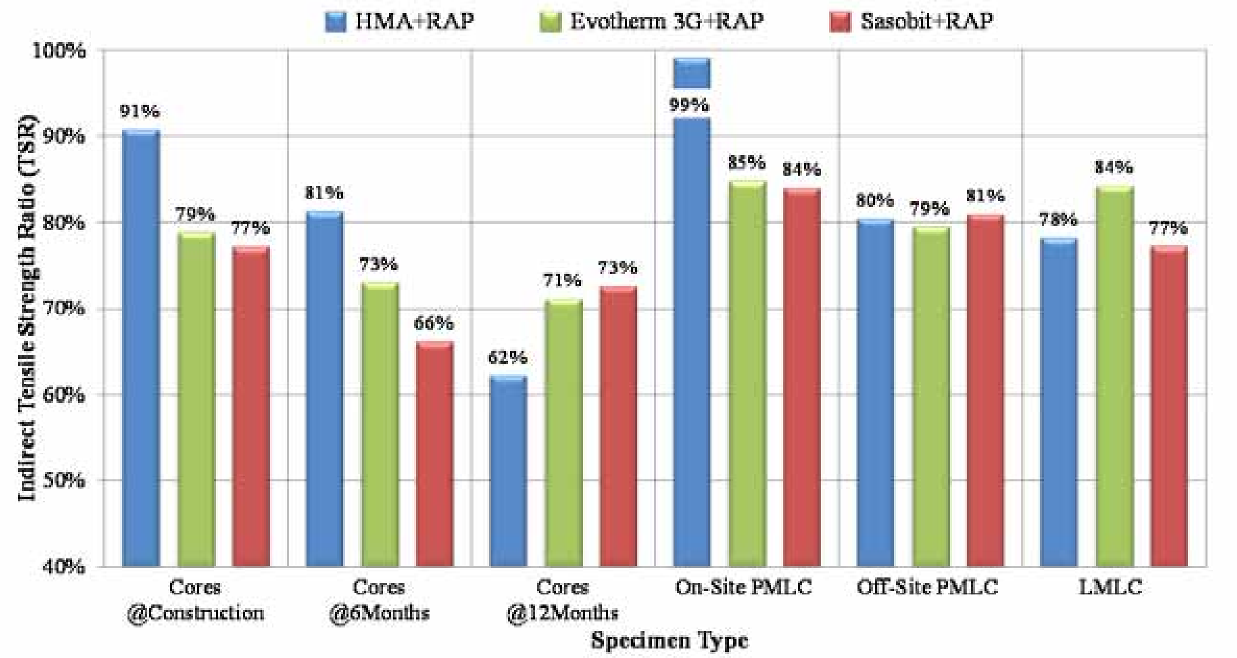
Table B.2. Indirect Tensile Strength Results for the Iowa Field Project

Specimen Type	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
Cores @Construction	HMA + RAP	Average	8.2%	7.6%	74.9	68.0	90.8%
		Std. Dev.	1.2%	0.5%	1.6	8.1	
		COV%	14.6%	6.2%	2.2%	11.9%	
	Evotherm 3G + RAP	Average	9.4%	7.9%	67.2	53.0	78.9%
		Std. Dev.	1.3%	1.2%	9.3	1.1	
		COV%	13.4%	15.8%	13.8%	2.2%	
	Sasobit + RAP	Average	8.7%	9.2%	64.6	49.8	77.2%
		Std. Dev.	2.3%	0.5%	15.1	4.9	
		COV%	26.5%	5.8%	23.4%	9.8%	
Cores @6Months	HMA + RAP	Average	7.9%	7.5%	74.4	60.4	81.3%
		Std. Dev.	0.3%	0.1%	9.8	1.8	
		COV%	4.4%	1.3%	13.2%	3.0%	
	Evotherm 3G + RAP	Average	8.1%	8.2%	73.1	53.4	73.0%
		Std. Dev.	0.7%	0.6%	3.6	1.5	
		COV%	8.5%	7.2%	4.9%	2.7%	
	Sasobit + RAP	Average	7.4%	7.7%	75.6	50.0	66.1%
		Std. Dev.	0.4%	0.4%	6.7	3.4	
		COV%	5.7%	5.6%	8.9%	6.8%	
Cores @12Months	HMA + RAP	Average	7.0%	7.0%	127.2	79.2	62.2%
		Std. Dev.	0.3%	0.3%	2.9	8.5	
		COV%	4.5%	4.5%	2.2%	10.7%	
	Evotherm 3G + RAP	Average	7.7%	7.4%	117.2	83.3	71.1%
		Std. Dev.	0.7%	0.9%	18.2	11.1	
		COV%	9.7%	11.5%	15.5%	13.3%	

Specimen Type	Mixture Type		Air Voids %		IDT (psi)		TSR
			Dry	Wet	Dry	Wet	
	Sasobit + RAP	Average	7.1%	6.8%	118.8	86.2	72.6%
		Std. Dev.	0.7%	0.9%	10.6	8.3	
		COV%	10.0%	12.8%	8.9%	9.6%	
On-Site PMLC	HMA + RAP	Average	6.3%	6.2%	95.2	94.4	99.1%
		Std. Dev.	0.2%	0.1%	4.0	2.5	
		COV%	2.5%	1.9%	4.2%	2.6%	
	Evotherm 3G + RAP	Average	5.9%	5.9%	100.6	85.3	84.8%
		Std. Dev.	0.2%	0.1%	5.9	3.1	
		COV%	2.8%	2.5%	5.8%	3.6%	
	Sasobit + RAP	Average	6.2%	6.1%	84.0	70.5	84.0%
		Std. Dev.	0.0%	0.0%	3.5	4.6	
		COV%	0.6%	0.8%	4.2%	6.5%	
Off-Site PMLC	HMA + RAP	Average	7.1%	6.9%	120.6	97.0	80.4%
		Std. Dev.	-	0.1%	-	8.2	
		COV%	-	1.5%	-	8.4%	
	Evotherm 3G + RAP	Average	6.5%	6.7%	120.5	95.8	79.5%
		Std. Dev.	0.5%	0.6%	17.8	2.4	
		COV%	7.9%	9.2%	14.8%	2.5%	
	Sasobit + RAP	Average	6.7%	6.6%	113.7	92.1	81.0%
		Std. Dev.	0.4%	0.6%	1.5	7.4	
		COV%	6.5%	9.3%	1.3%	8.0%	
LMLC	HMA + RAP	Average	7.2%	7.3%	79.2	62.0	78.2%
		Std. Dev.	0.1%	0.1%	1.0	1.7	
		COV%	1.6%	2.1%	1.3%	2.8%	
	Evotherm 3G + RAP	Average	6.8%	6.4%	59.9	50.5	84.3%
		Std. Dev.	0.6%	0.1%	1.3	2.5	
		COV%	9.0%	1.8%	2.2%	4.9%	
	Sasobit + RAP	Average	5.9%	5.7%	61.5	47.5	77.2%
		Std. Dev.	0.2%	0.1%	1.5	2.5	
		COV%	2.7%	1.0%	2.5%	5.3%	



(a) Dry and Wet Indirect Tensile Strength (the Statistical Comparisons Are Only Valid within Each Specimen Type)



(b) Tensile Strength Ratio

Figure B.4. Indirect Tensile Strength Results by Specimen Type for the Iowa Field Project

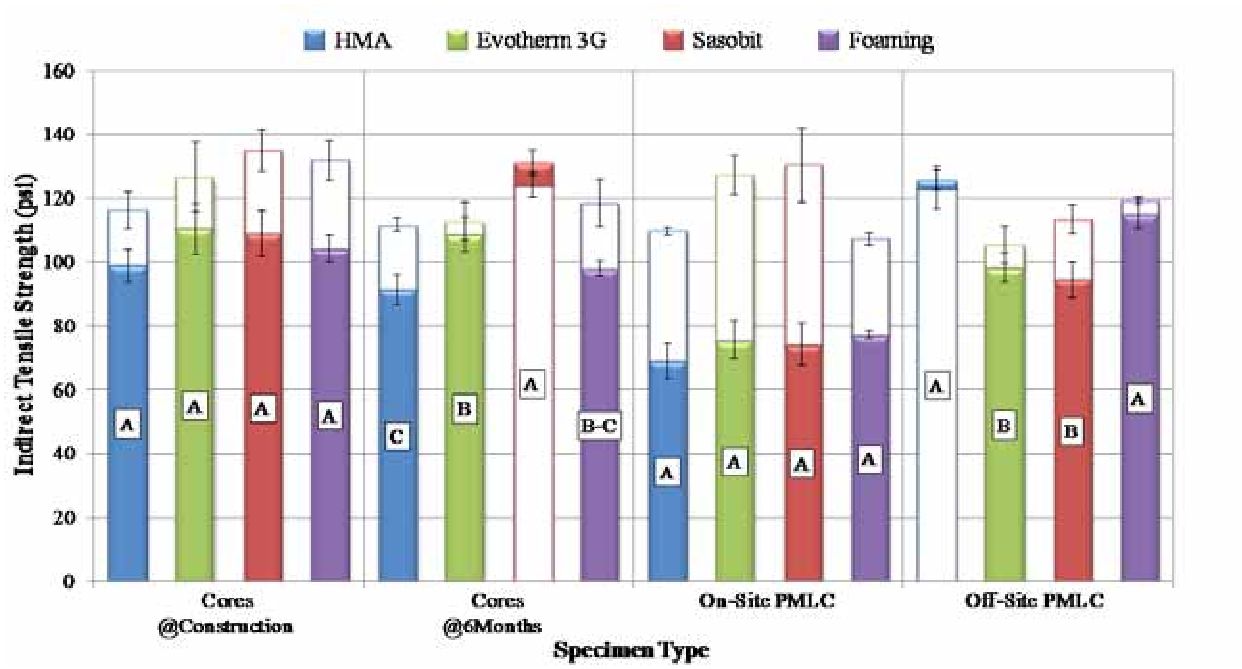
Montana Field Project Wet and dry IDT strengths are shown for all Montana specimen types in Table B.3 and Figure B.5(a), with mixture types compared within the same specimen type. In the case of the on-site PMLC specimens and PMFC cores at construction, the wet IDT strength of the HMA specimens was equivalent to the wet IDT strength of all WMA specimens. In the case of the off-site PMLC specimens, the wet IDT strength was equivalent to the HMA and WMA foaming specimens but higher than the WMA Evotherm® 3G and Sasobit® specimens. For the PMFC cores after winter at 6 months in service, the trend was different, with WMA Sasobit® specimens recording the highest wet IDT strength, followed by WMA Evotherm® 3G, WMA Foaming, and finally HMA specimens. Low AV content of around 2.8 percent for the WMA Sasobit® PMFC cores after winter at 6 months in service likely contributed to this change in the trends.

Based on the 9.3 percent d2s value, a comparison of the TSR values presented in Table B.3 and Figure B.5(b) indicated that WMAs exhibited similar performance as compared to HMA for PMFC cores at construction and on-site PMLC specimens. The WMAs showed equivalent or better performance as compared to HMA for PMFC cores after winter at 6 months in service, and for off-site PMLC specimens, HMA and all WMAs exhibited adequate performance (TSR > 80 percent), with WMA Sasobit® exhibiting a lower TSR than HMA or WMA Foaming.

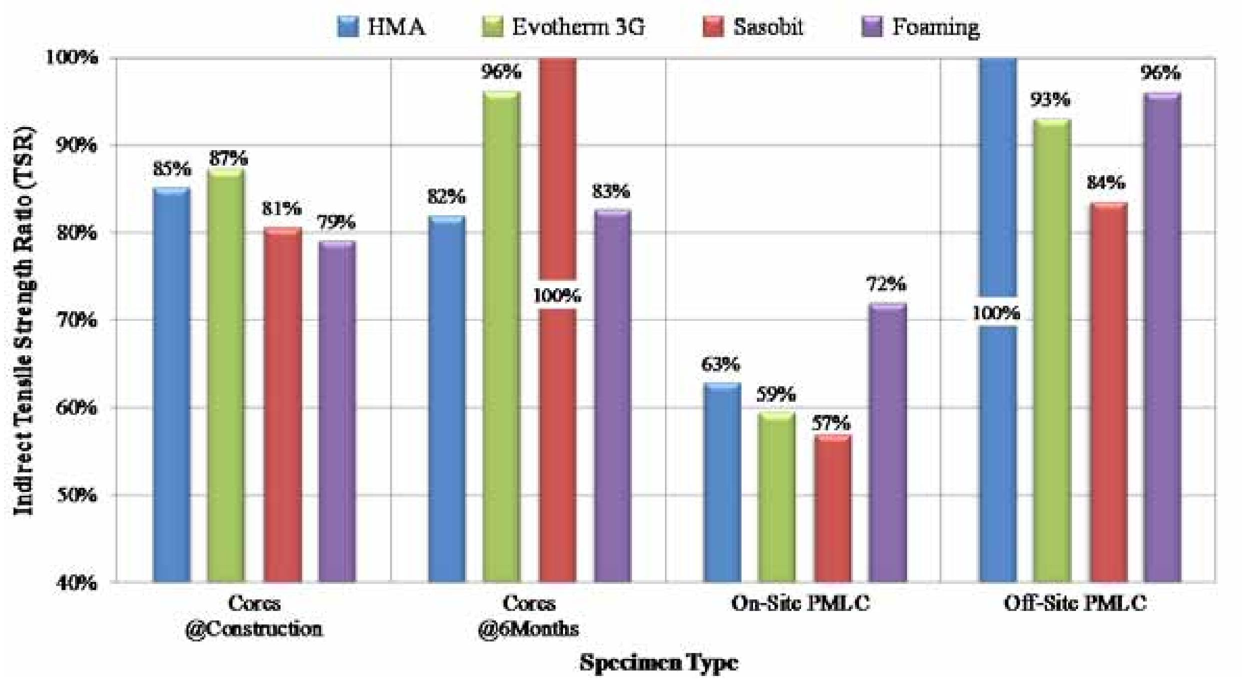
Table B.3. Indirect Tensile Strength Results for the Montana Field Project

Specimen Type	Mixture Type		Air Voids %		IDT (psi)		TSR
			Dry	Wet	Dry	Wet	
Cores @Construction	HMA	Average	5.5%	5.3%	116.2	99.0	85.2%
		Std. Dev.	0.2%	0.4%	5.6	5.2	
		COV%	3.9%	6.8%	4.8%	5.2%	
	Evotherm 3G	Average	4.0%	3.9%	126.6	110.6	87.4%
		Std. Dev.	0.2%	0.1%	11.0	8.0	
		COV%	5.2%	3.7%	8.7%	7.2%	
	Sasobit	Average	4.3%	4.2%	135.0	109.0	80.7%
		Std. Dev.	0.3%	0.4%	6.8	7.2	
		COV%	6.6%	8.6%	5.0%	6.6%	
	Foaming	Average	3.8%	3.5%	131.8	104.3	79.1%
		Std. Dev.	0.1%	0.2%	6.3	4.1	
		COV%	1.8%	4.6%	4.8%	3.9%	
Cores @6Months	HMA	Average	3.7%	3.8%	111.6	91.4	82.0%
		Std. Dev.	0.1%	0.0%	1.9	4.8	
		COV%	2.1%	0.7%	1.7%	5.2%	
	Evotherm 3G	Average	3.0%	3.2%	112.8	108.7	96.3%
		Std. Dev.	0.1%	0.0%	6.1	5.4	
		COV%	3.6%	1.4%	5.4%	5.0%	

Specimen Type	Mixture Type		Air Voids %		IDT (psi)		TSR
			Dry	Wet	Dry	Wet	
	Sasobit	Average	2.6%	2.9%	117.3	124.3	105.9%
		Std. Dev.	0.1%	0.2%	3.8	3.7	
		COV%	3.6%	6.6%	3.3%	2.9%	
	Foaming	Average	3.0%	3.5%	118.7	98.1	82.7%
		Std. Dev.	0.2%	0.1%	7.4	2.4	
		COV%	6.3%	2.8%	6.2%	2.5%	
On-Site PMLC	HMA	Average	7.3%	7.2%	109.8	69.0	62.9%
		Std. Dev.	0.4%	0.4%	1.2	5.5	
		COV%	5.6%	6.1%	1.1%	8.0%	
	Evotherm 3G	Average	6.5%	6.5%	127.3	75.7	59.5%
		Std. Dev.	0.2%	0.3%	6.2	5.9	
		COV%	3.8%	4.3%	4.9%	7.7%	
	Sasobit	Average	6.6%	7.0%	130.5	74.3	56.9%
		Std. Dev.	0.1%	0.2%	11.5	6.7	
		COV%	1.9%	2.7%	8.8%	9.1%	
	Foaming	Average	6.4%	6.6%	107.4	77.3	72.0%
		Std. Dev.	0.4%	0.1%	1.9	1.2	
		COV%	6.9%	1.7%	1.8%	1.6%	
Off-Site PMLC	HMA	Average	6.1%	5.9%	120.8	123.2	102.1%
		Std. Dev.	0.2%	0.2%	3.1	6.9	
		COV%	2.5%	3.6%	2.6%	5.6%	
	Evotherm 3G	Average	8.0%	7.5%	105.4	98.2	93.2%
		Std. Dev.	0.4%	0.1%	5.7	4.7	
		COV%	5.1%	1.3%	5.4%	4.7%	
	Sasobit	Average	7.5%	7.5%	113.4	94.7	83.5%
		Std. Dev.	0.1%	0.1%	4.6	5.6	
		COV%	1.8%	1.2%	4.0%	5.9%	
	Foaming	Average	6.3%	6.4%	119.6	115.0	96.2%
		Std. Dev.	0.2%	0.3%	1.0	4.5	
		COV%	3.6%	4.8%	0.8%	3.9%	



(a) Dry and Wet IDT Strength
(the Statistical Comparisons Are Only Valid within Each Specimen Type)



(b) Tensile Strength Ratio

Figure B.5. Indirect Tensile Strength Results by Specimen Type for the Montana Field Project

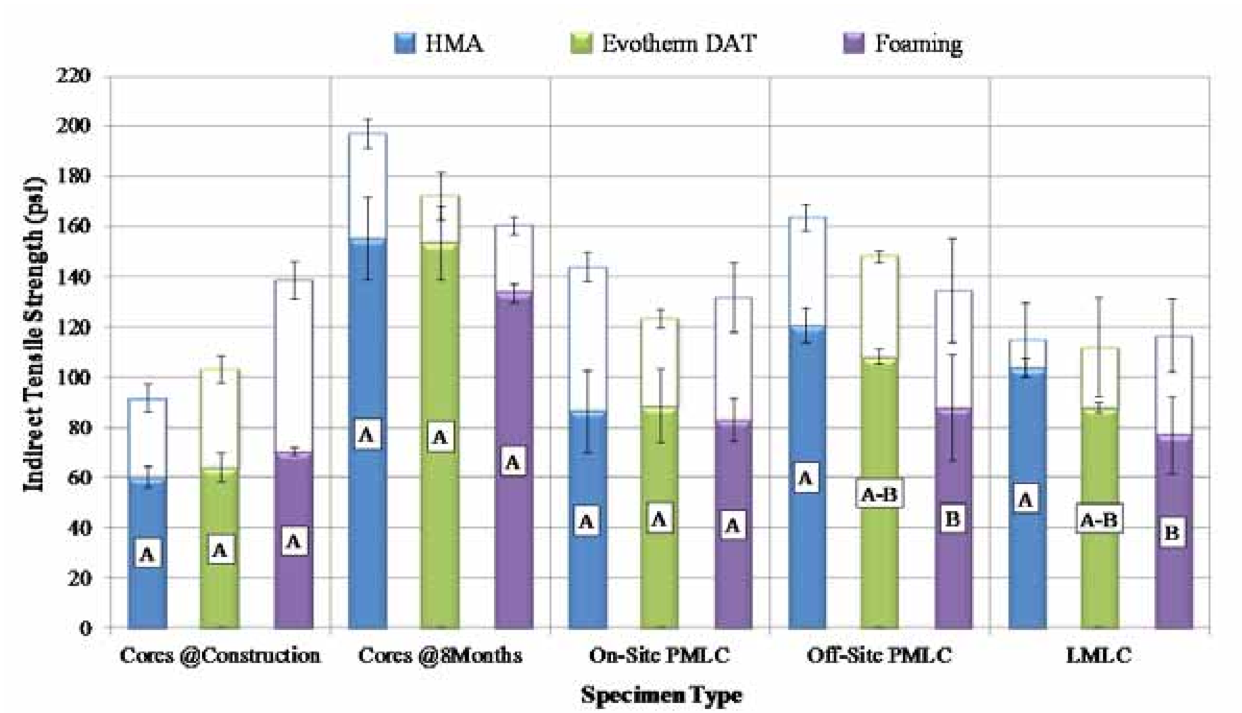
Texas Field Project The dry and wet IDT strength results for the Texas specimens are presented in Table B.4 and Figure B.6(a). In the case of the off-site PMLC and LMLC specimens, the wet IDT strength of the HMA was statistically higher than that of the WMA Foaming; in all other cases, the wet IDT strengths were statistically equivalent for both WMAs and the HMA.

Table B.4 and Figure B.6(b) show the wet to dry TSR for the different mixture types. Overall, WMA Foaming specimens had the lowest TSR values, all lower than 70 percent except for the PMFC cores after summer at 8 months in service. WMA Evotherm DAT™ exhibited, for most specimen types, equivalent or better TSR as compared to HMA based on the 9.3 percent d2s value. For LMLC specimens, WMA Evotherm DAT™ had a lower TSR than HMA.

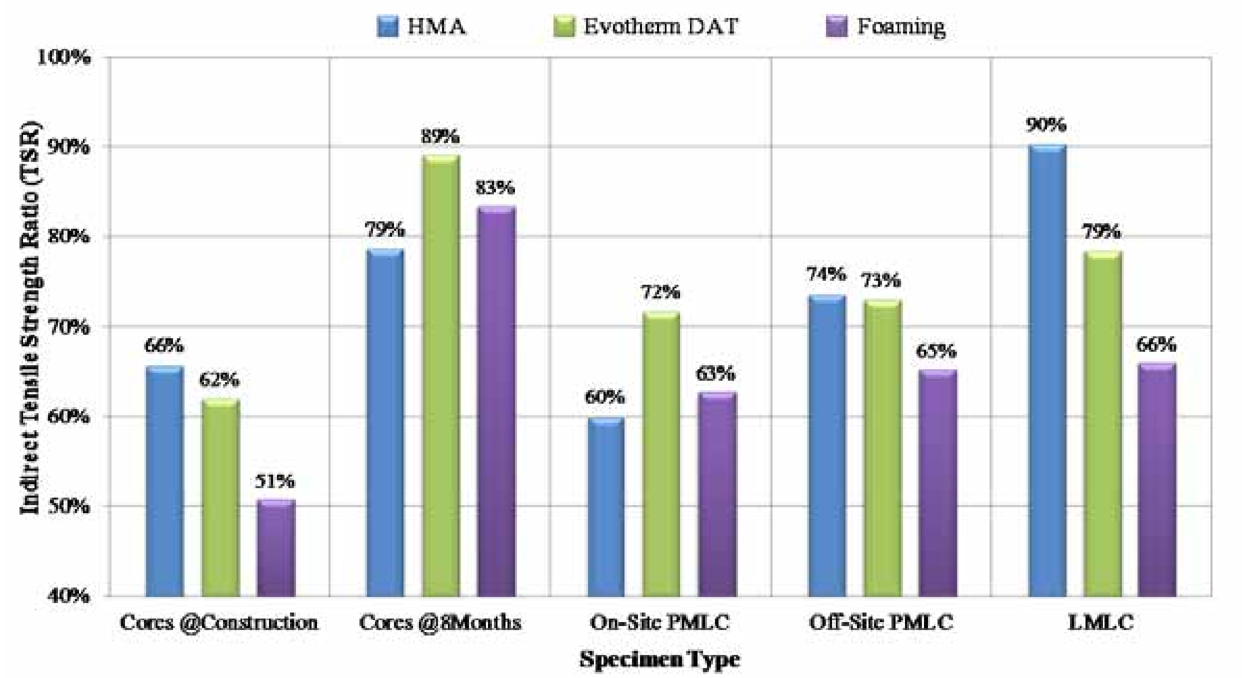
Table B.4. Indirect Tensile Strength Results for the Texas Field Project

Specimen Type	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
Cores @Construction	HMA	Average	9.6%	10.2%	91.6	60.3	65.8%
		Std. Dev.	0.1%	0.4%	5.7	4.2	
		COV%	1.3%	3.6%	6.2%	6.9%	
	Evotherm DAT	Average	7.6%	8.1%	103.0	63.9	62.1%
		Std. Dev.	0.1%	0.1%	5.3	5.6	
		COV%	2.0%	1.2%	5.2%	8.8%	
	Foaming	Average	6.1%	6.7%	138.5	70.3	50.8%
		Std. Dev.	0.4%	0.5%	7.5	1.5	
		COV%	5.7%	6.8%	5.4%	2.2%	
Cores @8Months	HMA	Average	6.6%	6.3%	196.9	155.2	78.8%
		Std. Dev.	0.8%	0.9%	5.7	16.3	
		COV%	12.6%	14.7%	2.9%	10.5%	
	Evotherm DAT	Average	6.3%	6.1%	172.0	153.4	89.1%
		Std. Dev.	0.5%	0.5%	9.6	14.6	
		COV%	8.4%	8.0%	5.6%	9.6%	
	Foaming	Average	7.2%	6.9%	160.1	133.6	83.4%
		Std. Dev.	0.4%	0.4%	3.6	3.7	
		COV%	6.0%	5.9%	2.2%	2.8%	
On-Site PMLC	HMA	Average	5.7%	6.2%	143.7	86.4	60.1%
		Std. Dev.	0.1%	0.1%	5.8	16.5	
		COV%	0.9%	1.9%	4.0%	19.1%	
	Evotherm DAT	Average	6.4%	6.1%	123.1	88.4	71.8%
		Std. Dev.	0.0%	0.1%	3.6	14.5	

Specimen Type	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
		COV%	0.7%	0.9%	2.9%	16.4%	
	Foaming	Average	4.9%	5.9%	131.8	82.8	62.8%
		Std. Dev.	0.2%	0.1%	13.6	8.5	
		COV%	3.7%	2.5%	10.3%	10.3%	
Off-Site PMLC	HMA	Average	6.8%	6.8%	163.6	120.6	73.7%
		Std. Dev.	0.2%	0.1%	5.3	6.7	
		COV%	2.7%	1.1%	3.2%	5.6%	
	Evotherm DAT	Average	6.9%	6.8%	147.9	108.1	73.0%
		Std. Dev.	0.1%	0.2%	2.2	3.1	
		COV%	1.2%	2.5%	1.5%	2.8%	
	Foaming	Average	7.1%	6.9%	134.6	87.9	65.3%
		Std. Dev.	0.2%	0.6%	20.6	21.2	
		COV%	3.1%	8.6%	15.3%	24.1%	
LMLC	HMA	Average	5.7%	6.0%	114.7	103.7	90.4%
		Std. Dev.	0.4%	0.2%	14.8	3.9	
		COV%	7.3%	3.7%	12.9%	3.8%	
	Evotherm DAT	Average	7.8%	6.5%	111.8	87.8	78.5%
		Std. Dev.	1.8%	0.4%	20.0	2.3	
		COV%	23.4%	6.5%	17.9%	2.7%	
	Foaming	Average	6.6%	6.5%	116.5	76.8	66.0%
		Std. Dev.	0.2%	0.3%	14.5	15.4	
		COV%	3.0%	4.6%	12.5%	20.0%	



(a) Dry and Wet IDT Strength
(the Statistical Comparisons Are Only Valid within Each Specimen Type)



(b) Tensile Strength Ratio

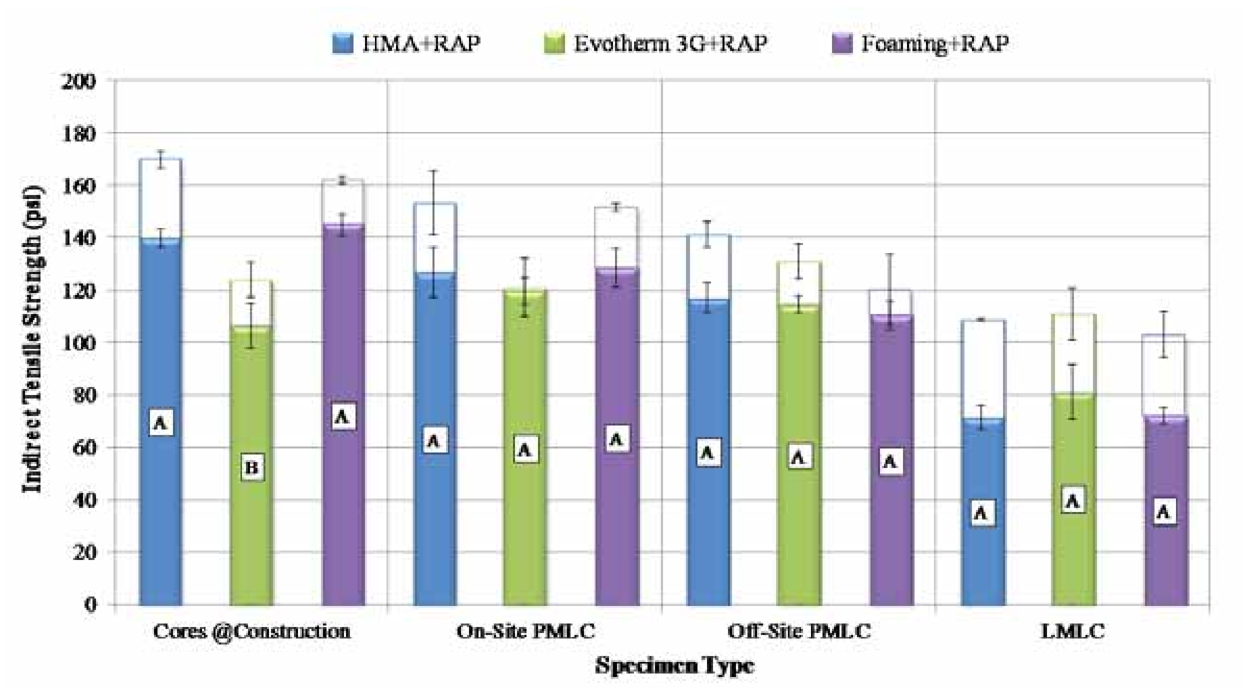
Figure B.6. Indirect Tensile Strength Results by Specimen Type for the Texas Field Project

New Mexico Field Project Wet and dry IDT strengths are shown for all New Mexico specimen types in Table B.5 and Figure B.7. All WMA mixtures with RAP exhibited equivalent performance to HMA with RAP for each specimen type except for WMA Evotherm® 3G with RAP PMFC cores at construction, which had a lower yet acceptable wet IDT based on the common threshold of 80 psi obtained from the limits enforced by various states. The TSR for Evotherm® 3G was also higher than 80 percent. The LMLC specimens showed the lowest IDT strength and TSR values among all specimen types.

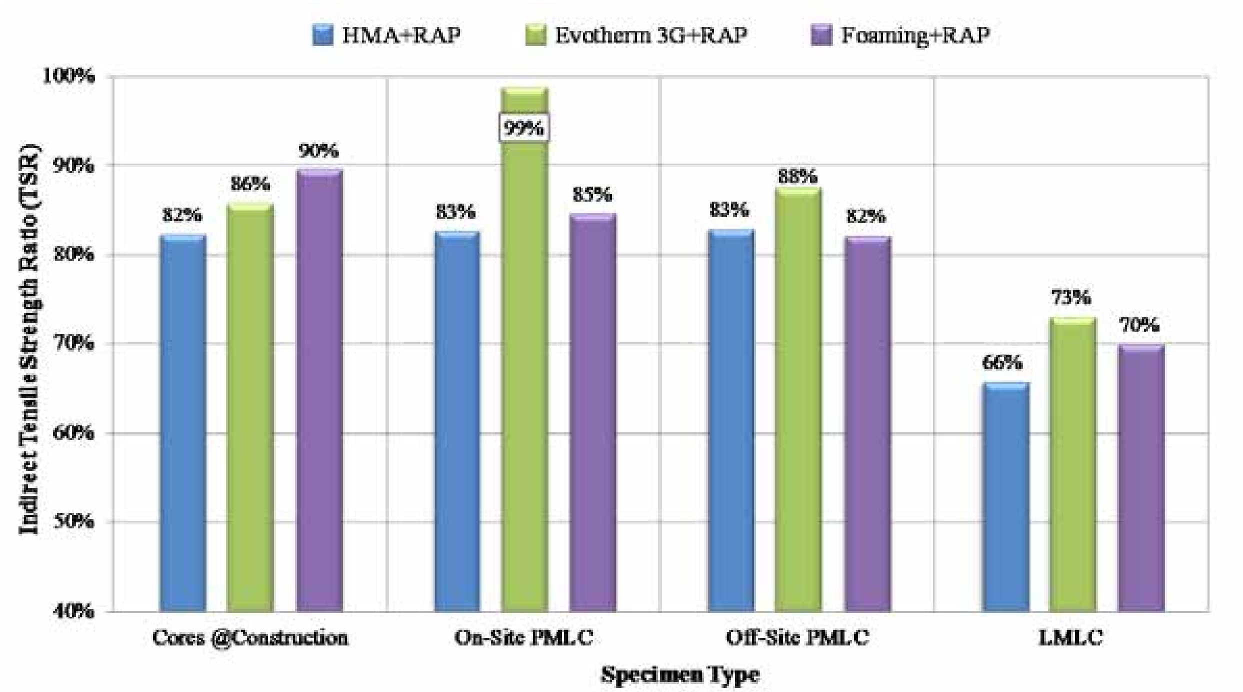
Table B.5. Indirect Tensile Strength Results for the New Mexico Field Project

Specimen Type	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
Cores @Construction	HMA + RAP	Average	6.3%	6.5%	169.8	139.9	82.4%
		Std. Dev.	0.5%	0.5%	3.3	3.5	
		COV%	7.5%	8.3%	2.0%	2.5%	
	Evotherm 3G + RAP	Average	7.4%	7.4%	124.0	106.3	85.8%
		Std. Dev.	0.2%	0.2%	6.7	8.3	
		COV%	2.2%	2.2%	5.4%	7.8%	
	Foaming + RAP	Average	4.6%	4.7%	161.9	145.0	89.6%
		Std. Dev.	0.2%	0.2%	1.4	4.3	
		COV%	4.5%	3.5%	0.9%	3.0%	
On-Site PMLC	HMA + RAP	Average	6.8%	6.8%	153.2	126.7	82.7%
		Std. Dev.	0.3%	0.3%	12.0	9.3	
		COV%	4.6%	4.4%	7.8%	7.4%	
	Evotherm 3G + RAP	Average	6.7%	6.7%	121.1	119.7	98.9%
		Std. Dev.	0.2%	0.2%	11.0	5.2	
		COV%	3.3%	3.1%	9.1%	4.3%	
	Foaming + RAP	Average	6.4%	6.1%	151.7	128.4	84.6%
		Std. Dev.	0.3%	0.5%	1.5	7.2	
		COV%	5.2%	8.8%	1.0%	5.6%	
Off-Site PMLC	HMA + RAP	Average	7.8%	8.0%	141.1	117.0	82.9%
		Std. Dev.	0.6%	0.2%	4.9	5.6	
		COV%	7.5%	2.0%	3.5%	4.8%	
	Evotherm 3G + RAP	Average	7.2%	6.2%	130.9	114.5	87.5%
		Std. Dev.	0.2%	0.0%	6.8	3.3	
		COV%	2.6%	0.5%	5.2%	2.8%	
	Foaming +	Average	7.6%	7.6%	134.5	110.5	82.2%

Specimen Type	Mixture Type		Air Voids %		IDT (psi)		TSR
			Dry	Wet	Dry	Wet	
	RAP	Std. Dev.	0.4%	0.2%	13.3	5.5	
		COV%	5.2%	3.0%	9.9%	5.0%	
LMLC No LTOA	HMA + RAP	Average	6.9%	7.0%	108.9	71.6	65.8%
		Std. Dev.	0.4%	0.6%	0.5	4.7	
		COV%	5.1%	8.6%	0.4%	6.6%	
	Evotherm 3G + RAP	Average	7.5%	7.0%	110.9	81.1	73.1%
		Std. Dev.	0.4%	0.7%	9.8	10.3	
		COV%	5.5%	10.1%	8.8%	12.7%	
	Foaming + RAP	Average	6.1%	6.4%	103.2	72.2	70.0%
		Std. Dev.	0.2%	0.4%	8.8	2.8	
		COV%	3.0%	6.2%	8.5%	3.9%	



(a) Dry and Wet IDT Strength
(the Statistical Comparisons Are Only Valid within Each Specimen Type)



(b) Tensile Strength Ratio

Figure B.7. Indirect Tensile Strength Results by Specimen Type for the New Mexico Field Project

Summary In the case of Iowa, all WMA mixtures for specimen types representative of the pavement in its early life (i.e., cores at construction, cores after winter, on-site PMLC, and LMLC specimens) exhibited lower performance in terms of wet IDT strength or TSR as compared to HMA. In addition, the Texas LMLC WMA specimens showed reduced wet IDT strength or TSR values as compared to the HMA mixtures, while the Montana and New Mexico WMA mixtures exhibited equivalent performance to HMA. Both the Montana and New Mexico projects included an anti-strip agent in their mixtures.

Dry and Wet M_R and M_R-ratio

For the results presented in this section, three replicate specimens were tested in dry condition, and three replicate specimens were tested after saturation and one F/T cycle as specified in AASHTO T 283 conditioning protocol. The wet/dry M_R-ratio was considered together with the wet M_R for comparing different mixture types within the same specimen type. ANOVA and Tukey's HSD were performed on the wet M_R results to assess moisture susceptibility of the WMA specimens as compared to their HMA counterparts. The analysis was performed comparing the moisture susceptibility by mixture type within each specimen type. The statistical groups are indicated with letters in the middle of the bars in the figures below, with different letters indicating that the wet M_R values are significantly different from each other. The solid part of the bar represents the average wet M_R, and the part of the bar with no fill extends up to the average dry M_R. The error bars represent ± one standard deviation from the

average value. For PMFC cores, no wet M_R was measured, and thus only the dry results are shown (bars with no fill).

Because the average of the three replicate wet and three replicate dry M_R results were used to calculate the M_R-ratio, an ANOVA and Tukey's HSD was not applicable to this result. In addition, contrary to TSR, a precision and bias statement was not available for M_R-ratio. Therefore, a d2s value of 10 percent was assumed to compare the differences between M_R-ratios. This d2s value was generated taking as baseline the precision and bias d2s of 9.3 percent applicable to TSR values (Azari 2010). A larger d2s could be expected when considering the smaller sample size and single laboratory source of data applicable to the M_R-ratios in this study (as compared to the multiple laboratories and larger sample size used in the study by Azari [2010]). However, a smaller d2s could result because the wet and dry M_R measurements were conducted on the same replicate specimens. Therefore, a 10 percent difference was deemed reasonable for identifying significant differences in M_R-ratio within mixture types and specimen types.

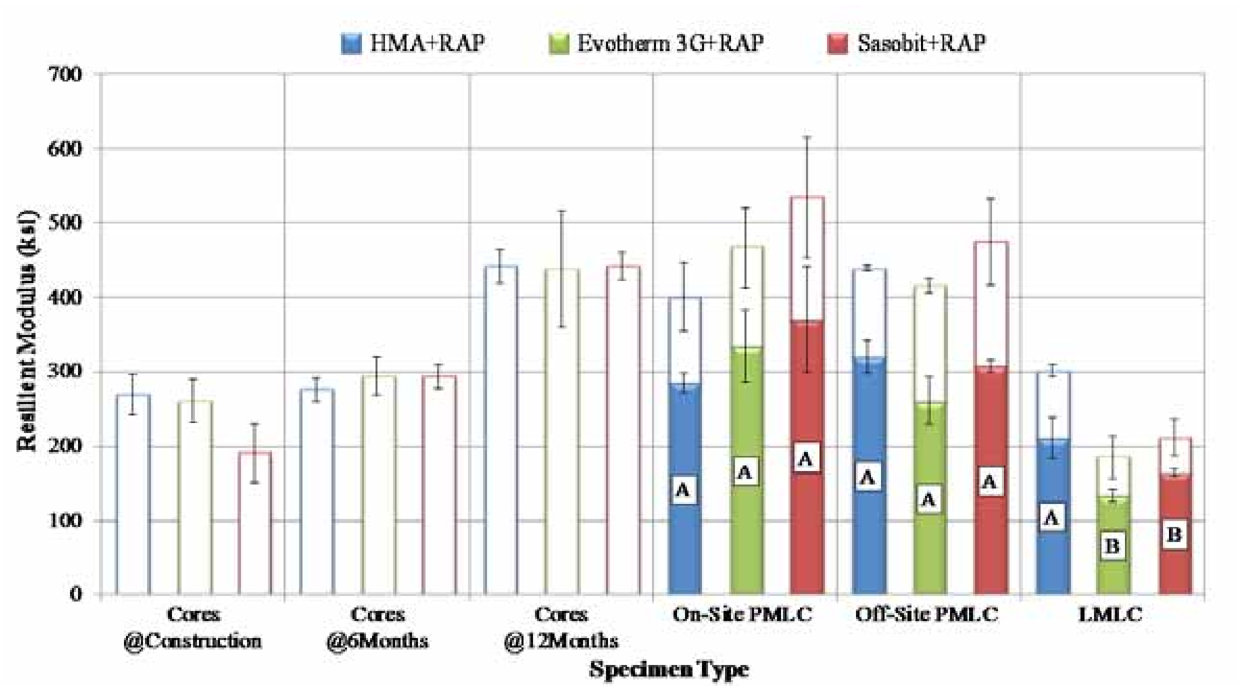
Iowa Field Project The results shown in Table B.6 and Figure B.8 indicate that within each specimen type, HMA with RAP, WMA Evotherm® 3G with RAP, and WMA Sasobit® with RAP had equivalent wet M_R stiffness except for with the LMLC specimens, in which HMA with RAP exhibited higher wet M_R stiffness than its WMA with RAP counterparts (Figure B.8[a]). In terms of dry M_R stiffness, PMFC cores at construction showed WMA Sasobit® with RAP to be less stiff than the other two mixtures. With time, equivalent dry M_R stiffness was achieved by HMA and WMA PMFC cores after winter at 6 months in service and after summer at 12 months in service. In addition, LMLC specimens' HMA with RAP had higher dry M_R stiffness resulting in a lower M_R -ratio than both WMAs with RAP (Figure B.8[b]). M_R -ratios ranged between 63 and 77 percent and were likely equivalent across mixture types for each specimen type based on the assumed d2s value of 10 percent.

Table B.6. M_R Results for the Iowa Field Project

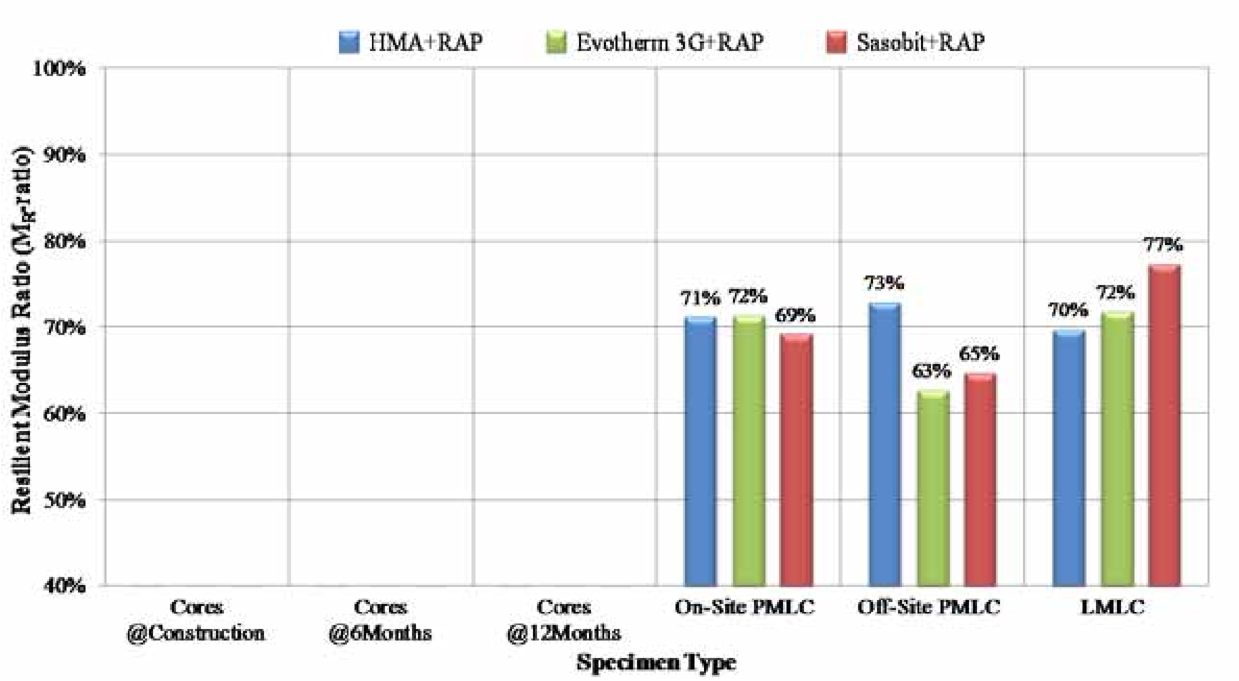
Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
Cores @Construction	HMA + RAP	Average	8.2%	269.3	-	-
		Std. Dev.	1.2%	27.1	-	
		COV%	14.6%	10.1%	-	
	Evotherm 3G + RAP	Average	8.5%	260.6	-	-
		Std. Dev.	1.1%	28.8	-	
		COV%	12.9%	11.1%	-	
	Sasobit + RAP	Average	8.5%	190.4	-	-
		Std. Dev.	1.5%	40.0	-	
		COV%	17.6%	21.0%	-	
Cores @6Months	HMA + RAP	Average	7.5%	275.5	-	-
		Std. Dev.	0.0%	15.6	-	

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
		COV%	0.1%	5.7%	-	
	Evotherm 3G + RAP	Average	7.2%	293.8	-	-
		Std. Dev.	0.1%	25.6	-	
		COV%	1.9%	8.7%	-	
	Sasobit + RAP	Average	6.9%	293.4	-	-
		Std. Dev.	0.2%	16.0	-	
		COV%	2.8%	5.5%	-	
Cores @12Months	HMA + RAP	Average	7.0%	440.6	-	-
		Std. Dev.	0.3%	22.5	-	
		COV%	4.5%	5.1%	-	
	Evotherm 3G + RAP	Average	7.7%	437.9	-	-
		Std. Dev.	0.7%	77.8	-	
		COV%	9.7%	17.8%	-	
	Sasobit + RAP	Average	7.1%	441.3	-	-
		Std. Dev.	0.7%	18.6	-	
		COV%	10.0%	4.2%	-	
On-Site PMLC	HMA + RAP	Average	7.1%	399.6	285.0	71.3%
		Std. Dev.	0.1%	45.7	13.4	
		COV%	1.4%	11.4%	4.7%	
	Evotherm 3G + RAP	Average	6.1%	467.0	334.0	71.5%
		Std. Dev.	0.1%	53.5	48.6	
		COV%	1.8%	11.5%	14.6%	
	Sasobit + RAP	Average	6.5%	533.8	370.3	69.4%
		Std. Dev.	0.3%	81.0	70.1	
		COV%	5.1%	15.2%	18.9%	
Off-Site PMLC	HMA + RAP	Average	6.9%	438.4	320.1	73.0%
		Std. Dev.	0.1%	3.4	21.8	
		COV%	1.5%	0.8%	6.8%	
	Evotherm 3G + RAP	Average	7.2%	414.9	260.8	62.9%
		Std. Dev.	0.1%	9.8	31.4	
		COV%	1.7%	2.4%	12.0%	
	Sasobit + RAP	Average	6.8%	474.2	307.6	64.9%
		Std.	0.1%	58.1	8.2	

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
		Dev.				
		COV%	1.0%	12.3%	2.7%	
LMLC	HMA + RAP	Average	7.2%	301.0	210.3	69.9%
		Std. Dev.	0.1%	7.7	27.4	
		COV%	0.7%	2.6%	13.0%	
	Evotherm 3G + RAP	Average	6.8%	185.1	133.1	71.9%
		Std. Dev.	0.0%	28.8	8.3	
		COV%	0.6%	15.5%	6.2%	
	Sasobit + RAP	Average	7.6%	211.3	163.7	77.4%
		Std. Dev.	0.2%	24.6	5.4	
		COV%	2.1%	11.6%	3.3%	



(a) Dry and Wet Resilient Modulus
(the Statistical Comparisons Are Only Valid within Each Specimen Type)



(b) Resilient Modulus Ratio

Figure B.8. Resilient Modulus Test Results by Specimen Type for the Iowa Field Project

Montana Field Project M_R test results for the Montana field project are shown in Table B.7 and Figure B.9. When comparing Tukey's HSD statistical results by mixture type, WMA Sasobit® had the largest wet M_R stiffness for both on-site and off-site PMLC specimens (Figure B.9[a]). For on-site PMLC specimens, all WMAs exhibited equivalent or better wet M_R stiffness as compared to HMA. For off-site PMLC specimens, WMA Evotherm® 3G resulted in the lowest wet M_R stiffness, but this same mixture showed the best TSR value within this specimen type (Figure B.9[b]). With regard to the PMFC cores, HMA had higher dry M_R values as compared to any of the WMAs, and this difference was more pronounced for the PMFC cores after winter at 6 months in service.

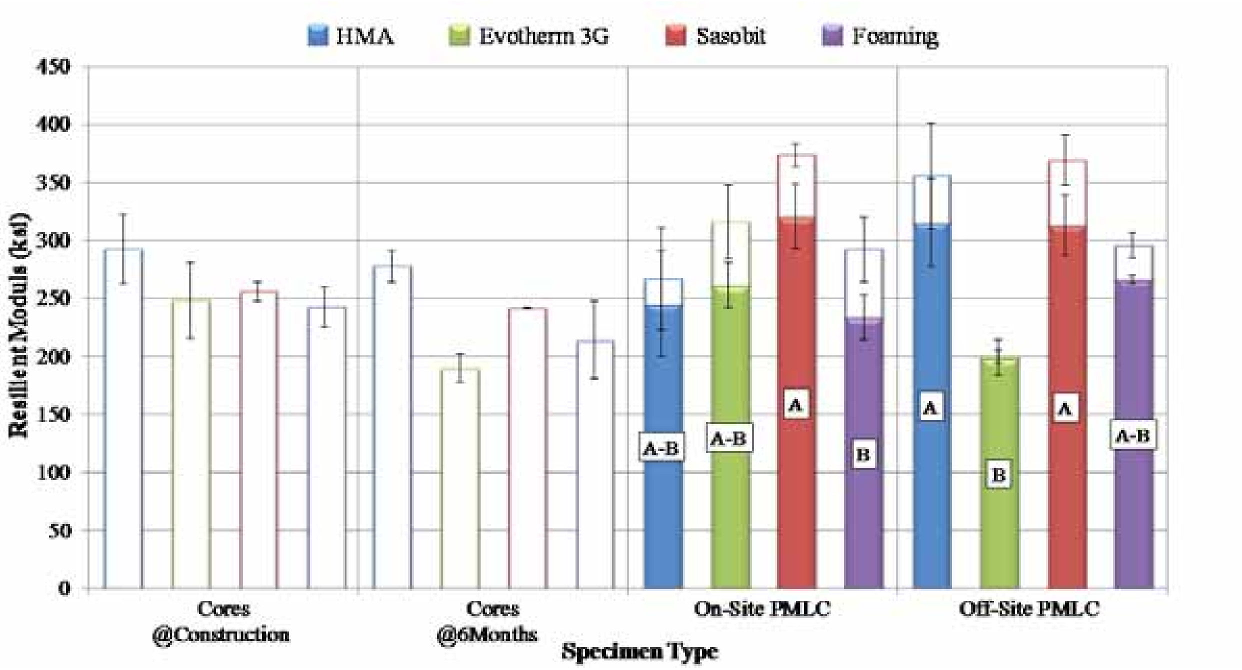
With respect to the M_R-ratios, all values ranged between 80 and 99 percent, with HMA showing equivalent performance to WMA Evotherm® 3G and WMA Sasobit® for on-site PMLC specimens based on the assumed d2s value of 10 percent, and better performance than foaming. In the case of off-site PMLC specimens, HMA was equivalent to all WMAs when considering this same assumed d2s value.

Table B.7. M_R Results for the Montana Field Project

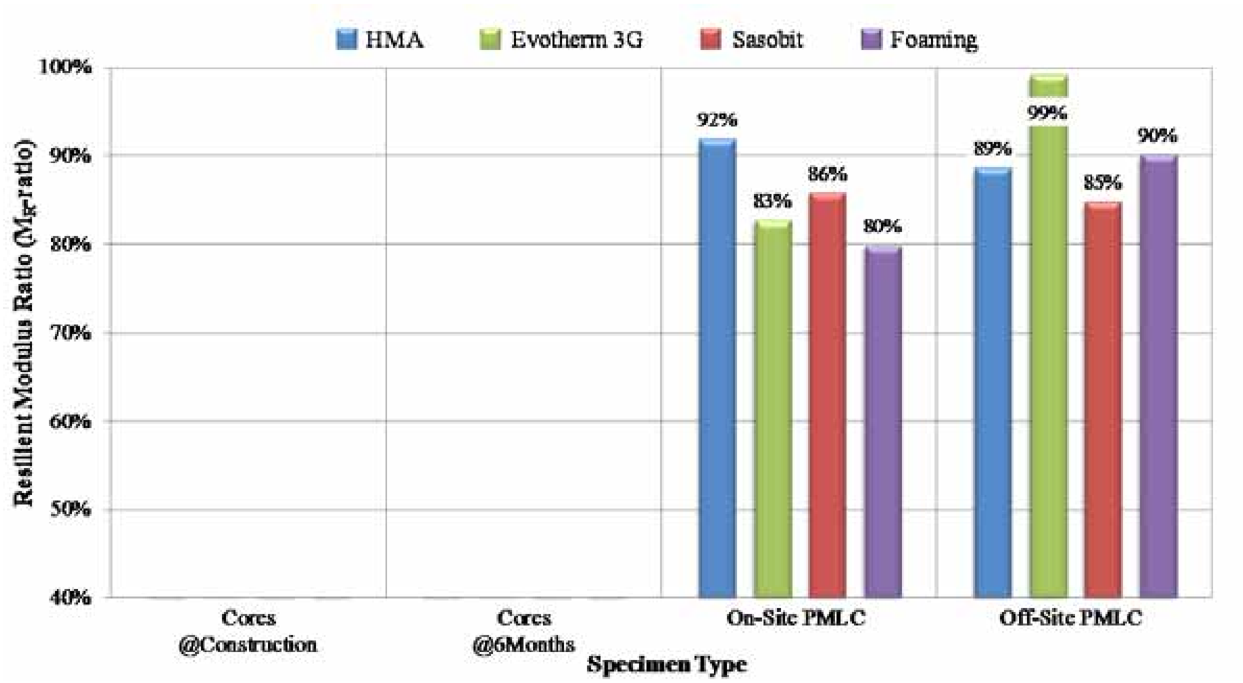
Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
Cores @Construction	HMA	Average	6.0%	292.5	-	-
		Std. Dev.	0.1%	29.7	-	
		COV%	1.7%	10.1%	-	
	Evotherm	Average	4.9%	248.6	-	-

Specimen Type	Mixture Type		Air Voids %	M_R (ksi)		M_R-ratio
				Dry	Wet	
	3G	Std. Dev.	0.5%	32.9	-	
		COV%	10.2%	13.2%	-	
	Sasobit	Average	4.7%	256.0	-	-
		Std. Dev.	0.1%	8.6	-	
		COV%	2.1%	3.4%	-	
	Foaming	Average	4.3%	243.2	-	-
		Std. Dev.	0.2%	17.3	-	
		COV%	3.6%	7.1%	-	
Cores @6Months	HMA	Average	4.1%	277.9	-	-
		Std. Dev.	0.1%	13.4	-	
		COV%	2.4%	4.8%	-	
	Evotherm 3G	Average	3.6%	189.7	-	-
		Std. Dev.	0.5%	12.1	-	
		COV%	13.9%	6.4%	-	
	Sasobit	Average	4.4%	241.4	-	-
		Std. Dev.	0.1%	0.6	-	
		COV%	2.3%	0.3%	-	
	Foaming	Average	3.9%	214.3	-	-
		Std. Dev.	0.0%	33.0	-	
		COV%	1.1%	15.4%	-	
On-Site PMLC	HMA	Average	6.5%	267.2	245.7	92.0%
		Std. Dev.	0.4%	43.5	45.1	
		COV%	5.6%	16.3%	18.3%	
	Evotherm 3G	Average	6.2%	315.6	261.4	82.8%
		Std. Dev.	0.4%	31.7	19.3	
		COV%	5.8%	10.0%	7.4%	
	Sasobit	Average	7.1%	373.4	320.7	85.9%
		Std. Dev.	0.2%	9.8	27.9	
		COV%	2.7%	2.6%	8.7%	
	Foaming	Average	6.8%	292.6	233.7	79.9%
		Std. Dev.	0.3%	27.7	19.6	
		COV%	4.1%	9.5%	8.4%	

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
Off-Site PMLC	HMA	Average	6.8%	355.9	315.6	88.7%
		Std. Dev.	0.4%	45.6	37.7	
		COV%	5.9%	12.8%	11.9%	
	Evotherm 3G	Average	8.0%	200.2	198.7	99.2%
		Std. Dev.	0.3%	5.3	15.4	
		COV%	3.4%	2.6%	7.8%	
	Sasobit	Average	6.9%	369.6	313.6	84.9%
		Std. Dev.	0.2%	21.8	25.3	
		COV%	2.9%	5.9%	8.1%	
	Foaming	Average	6.8%	295.9	266.8	90.2%
		Std. Dev.	0.0%	10.6	3.5	
		COV%	0.7%	3.6%	1.3%	



(a) Dry and Wet Resilient Modulus
(the Statistical Comparisons Are Only Valid within Each Specimen Type)



(b) Resilient Modulus Ratio

Figure B.9. Resilient Modulus Test Results by Specimen Type for the Montana Field Project

Texas Field Project Dry and wet M_R values and M_R -ratios for the Texas field project are summarized in Table B.8 and Figure B.10. HMA, WMA Foaming, and WMA Evotherm DAT™ had statistically equivalent wet M_R stiffness for the off-site PMLC specimens. For the on-site PMLC specimens, conversely, Evotherm DAT™ had a statistically significant lower wet M_R stiffness than the other two mixture types, but equivalent TSR value. For LMLC specimens, WMA Foaming had the lowest wet M_R stiffness and was significantly different from HMA (Figure B.10[a]). For PMFC cores at construction, HMA showed higher dry M_R stiffness than the WMA mixtures did, but at 8 months after construction, the WMA mixtures reached an equivalent M_R stiffness to HMA.

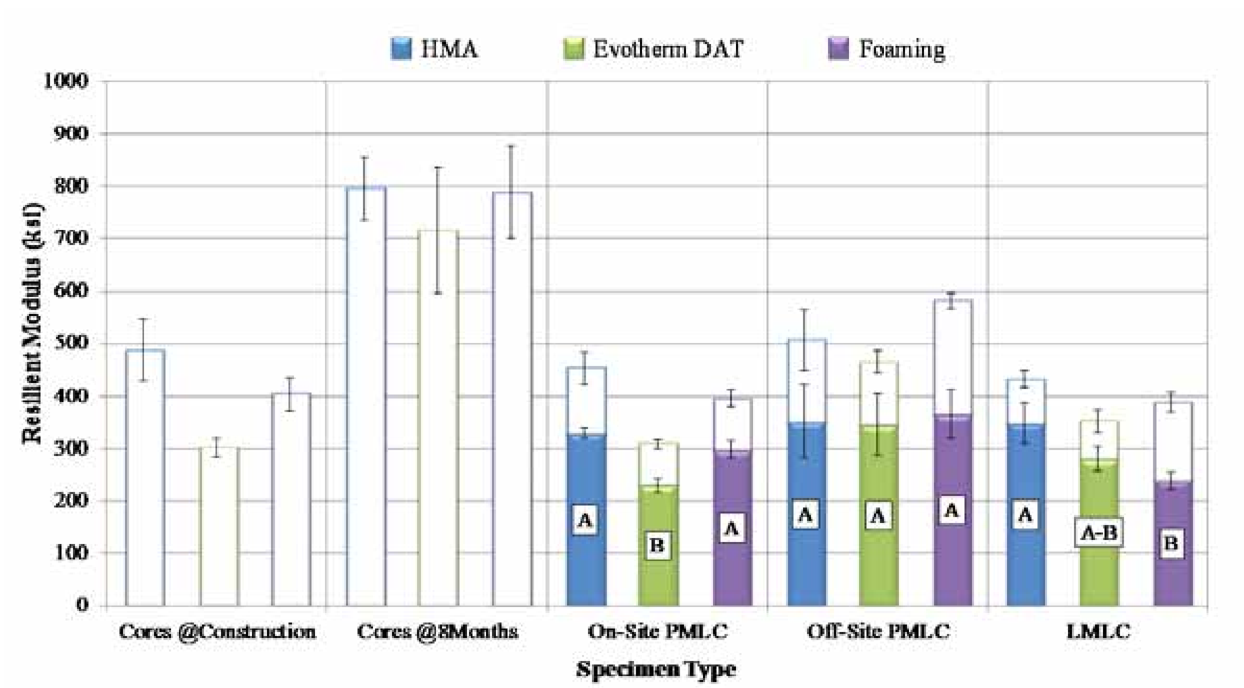
M_R-ratios ranged between 62 and 80 percent, with HMA equivalent to both WMAs for on-site PMLC specimens and off-site PMLC specimens based on the assumed d2s value of 10 percent. For LMLC specimens, HMA was equivalent to WMA Evotherm DAT™ but exhibited an M_R-ratio greater than that for WMA Foaming.

Table B.8. M_R Results for the Texas Field Project

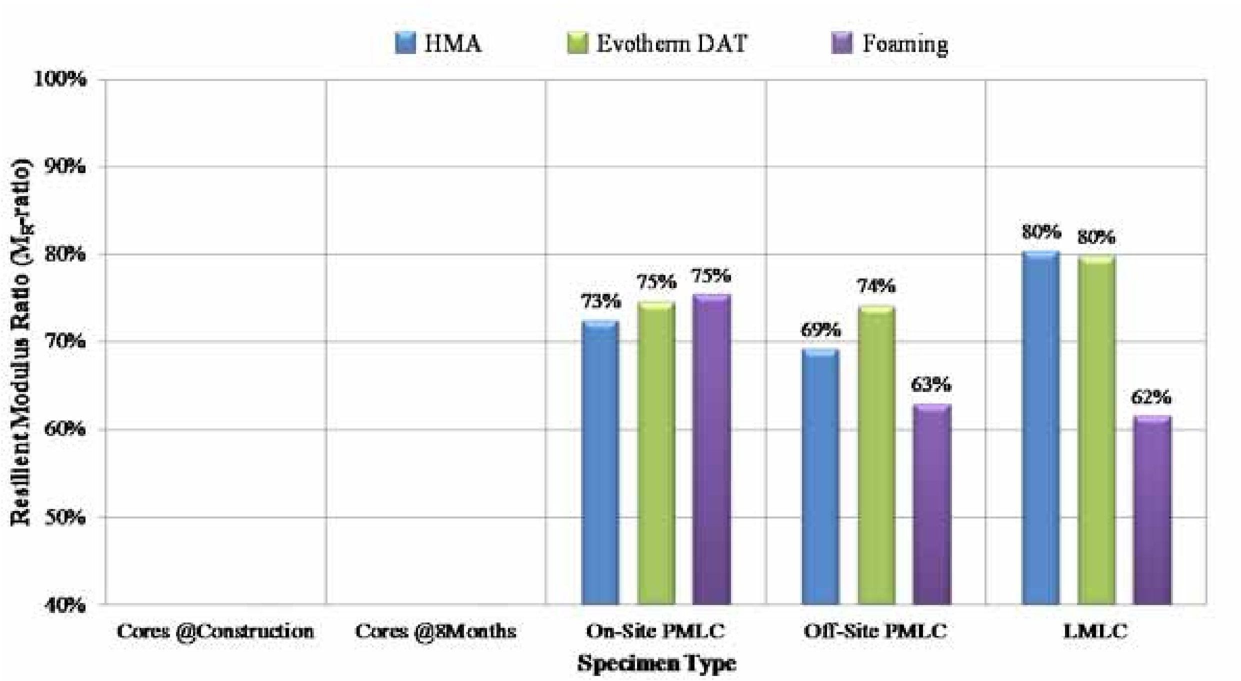
Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
Cores @Construction	HMA	Average	7.0%	487.1	-	-
		Std. Dev.	0.5%	59.0	-	
		COV%	7.1%	12.1%	-	
	Evotherm	Average	9.9%	303.0	-	-

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
	DAT	Std. Dev.	0.3%	17.4	-	
		COV%	3.0%	5.7%	-	
	Foaming	Average	7.0%	403.9	-	-
		Std. Dev.	0.1%	31.0	-	
		COV%	1.4%	7.7%	-	
Cores @8Months	HMA	Average	7.0%	796.2	-	-
		Std. Dev.	0.7%	59.5	-	
		COV%	10.2%	7.5%	-	
	Evotherm DAT	Average	7.1%	715.7	-	-
		Std. Dev.	0.3%	120.4	-	
		COV%	3.6%	16.8%	-	
	Foaming	Average	7.0%	789.3	-	-
		Std. Dev.	0.1%	88.9	-	
		COV%	1.5%	11.3%	-	
On-Site PMLC	HMA	Average	6.3%	453.3	328.8	72.5%
		Std. Dev.	0.3%	31.9	9.4	
		COV%	4.1%	7.0%	2.9%	
	Evotherm DAT	Average	6.5%	308.9	230.7	74.7%
		Std. Dev.	0.1%	8.9	12.5	
		COV%	0.9%	2.9%	5.4%	
	Foaming	Average	5.4%	395.2	298.3	75.5%
		Std. Dev.	0.1%	16.6	15.8	
		COV%	2.2%	4.2%	5.3%	
Off-Site PMLC	HMA	Average	8.0%	507.5	351.5	69.3%
		Std. Dev.	0.1%	57.6	70.6	
		COV%	1.7%	11.4%	20.1%	
	Evotherm DAT	Average	7.1%	465.5	345.3	74.2%
		Std. Dev.	0.3%	21.8	59.6	
		COV%	3.9%	4.7%	17.3%	
	Foaming	Average	7.1%	580.8	365.8	63.0%
		Std. Dev.	0.0%	15.5	46.7	
		COV%	0.7%	2.7%	12.8%	

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
LMLC	HMA	Average	6.6%	433.0	348.5	80.5%
		Std. Dev.	0.4%	16.4	39.4	
		COV%	5.4%	3.8%	11.3%	
	Evotherm DAT	Average	6.5%	351.5	280.7	79.9%
		Std. Dev.	0.2%	22.8	23.6	
		COV%	2.9%	6.5%	8.4%	
	Foaming	Average	7.6%	387.6	238.6	61.6%
		Std. Dev.	0.2%	18.9	16.1	
		COV%	3.0%	4.9%	6.8%	



(a) Dry and Wet Resilient Modulus
(the Statistical Comparisons Are Only Valid within Each Specimen Type)



(b) Resilient Modulus Ratio

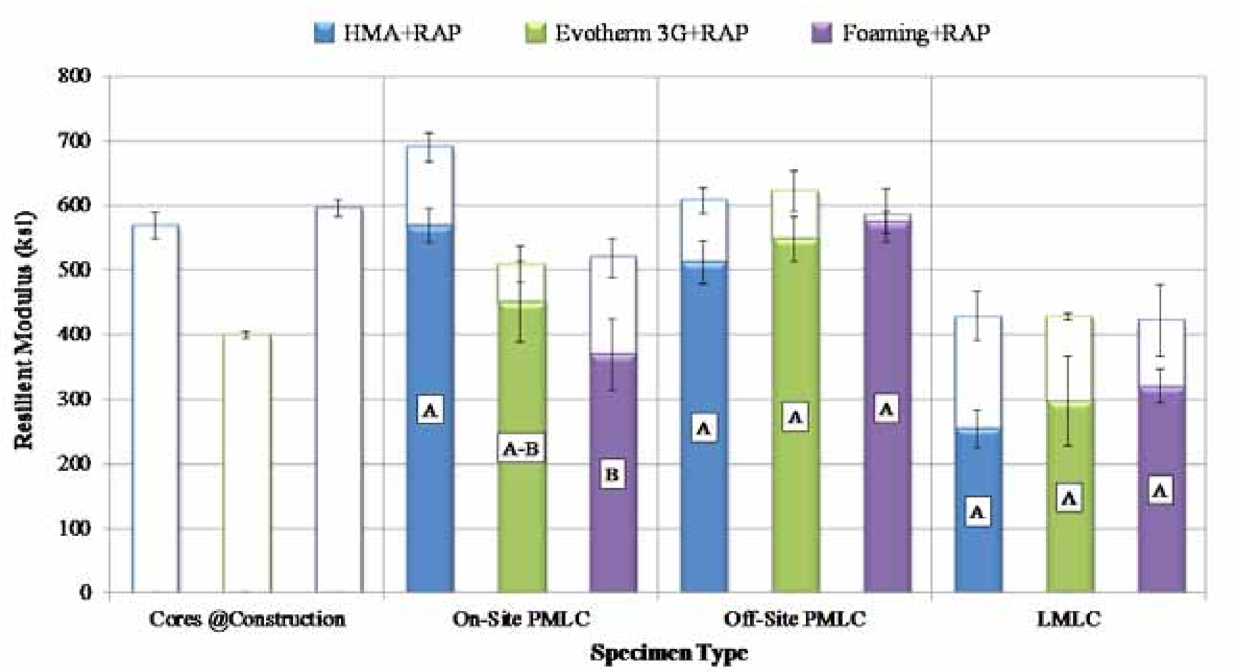
Figure B.10. Resilient Modulus Test Results by Specimen Type for the Texas Field Project

New Mexico Field Project Dry and wet M_R values and M_R -ratios for the New Mexico field project are summarized in Table B.9 and Figure B.11. WMA Evotherm® 3G with RAP exhibited equivalent performance to HMA with RAP in terms of wet M_R stiffness for all specimen types. WMA Foaming with RAP showed lower wet M_R stiffness for on-site PMLC specimens and equivalent performance to HMA with RAP for the other specimen types.

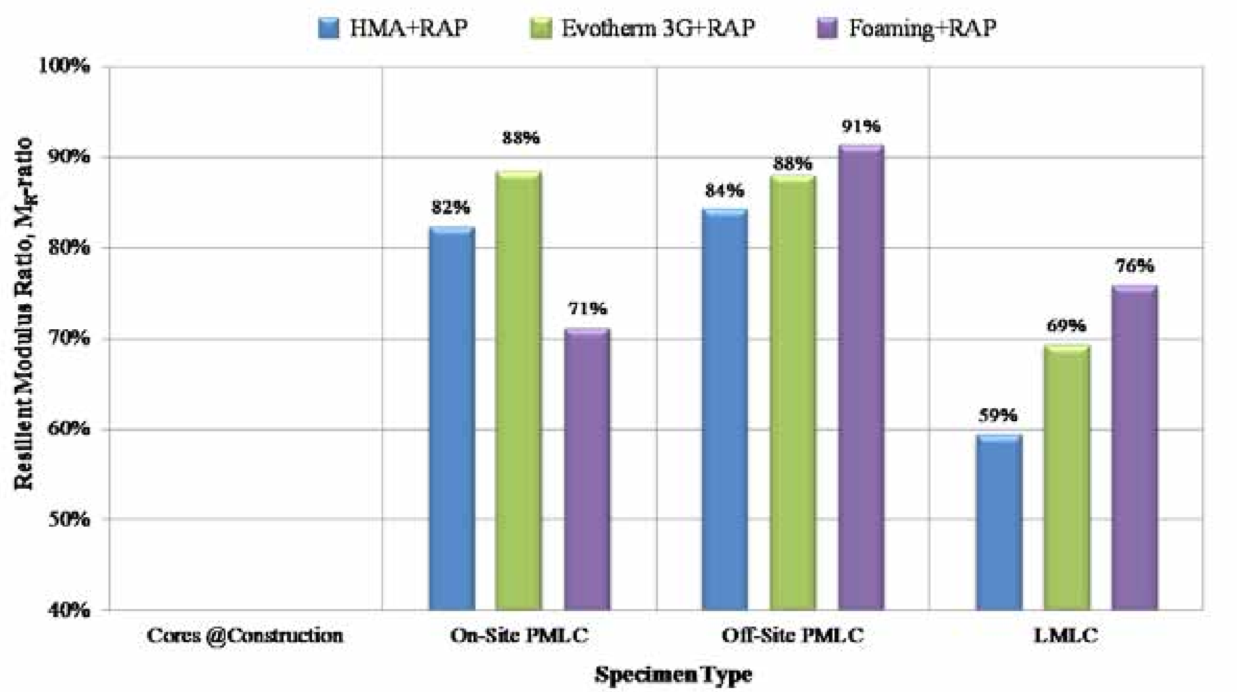
Table B.9. M_R Results for the New Mexico Field Project

<table>
<tr><th rowspan="2">Specimen Type</th><th rowspan="2">Mixture Type</th><th rowspan="2"></th><th rowspan="2">Air Voids %</th><th colspan="2">M_R (ksi)</th><th rowspan="2">M_R-ratio</th></tr>
<tr><th>Dry</th><th>Wet</th></tr>
<tr><td rowspan="9">Cores @Construction</td><td rowspan="3">HMA + RAP</td><td>Average</td><td>6.3%</td><td>568.1</td><td>-</td><td rowspan="3">-</td></tr>
<tr><td>Std. Dev.</td><td>0.5%</td><td>20.1</td><td>-</td></tr>
<tr><td>COV%</td><td>7.5%</td><td>3.5%</td><td>-</td></tr>
<tr><td rowspan="3">Evotherm 3G + RAP</td><td>Average</td><td>7.4%</td><td>398.5</td><td>-</td><td rowspan="3">-</td></tr>
<tr><td>Std. Dev.</td><td>0.2%</td><td>5.2</td><td>-</td></tr>
<tr><td>COV%</td><td>2.2%</td><td>1.3%</td><td>-</td></tr>
<tr><td rowspan="3">Foaming + RAP</td><td>Average</td><td>4.9%</td><td>596.4</td><td>-</td><td rowspan="3">-</td></tr>
<tr><td>Std. Dev.</td><td>0.6%</td><td>12.9</td><td>-</td></tr>
<tr><td>COV%</td><td>13.0%</td><td>2.2%</td><td>-</td></tr>
<tr><td rowspan="2">On-Site PMLC</td><td rowspan="2">HMA + RAP</td><td>Average</td><td>6.8%</td><td>689.6</td><td>568.4</td><td rowspan="2">82.4%</td></tr>
<tr><td>Std.</td><td>0.3%</td><td>21.6</td><td>25.9</td></tr>
</table>

		Std. Dev.				
		COV%	4.0%	3.1%	4.6%	
	Evotherm 3G + RAP	Average	6.9%	508.8	450.2	88.5%
		Std. Dev.	0.2%	27.3	61.9	
		COV%	2.6%	5.4%	13.7%	
	Foaming + RAP	Average	7.1%	519.4	370.0	71.2%
		Std. Dev.	0.1%	30.3	55.3	
		COV%	0.8%	5.8%	15.0%	
Off-Site PMLC	HMA + RAP	Average	6.8%	607.3	512.4	84.4%
		Std. Dev.	0.1%	20.6	33.1	
		COV%	1.7%	3.4%	6.5%	
	Evotherm 3G + RAP	Average	7.2%	622.0	547.9	88.1%
		Std. Dev.	0.2%	30.8	35.0	
		COV%	2.4%	4.9%	6.4%	
	Foaming + RAP	Average	6.7%	627.3	573.3	91.4%
		Std. Dev.	0.2%	41.1	17.3	
		COV%	2.8%	6.6%	3.0%	
LMLC	HMA + RAP	Average	7.2%	428.3	254.5	59.4%
		Std. Dev.	0.4%	38.7	29.5	
		COV%	5.5%	9.0%	11.6%	
	Evotherm 3G + RAP	Average	7.3%	427.3	296.5	69.4%
		Std. Dev.	0.2%	5.2	69.7	
		COV%	2.7%	1.2%	23.5%	
	Foaming + RAP	Average	5.8%	421.1	319.7	75.9%
		Std. Dev.	0.6%	54.4	26.4	
		COV%	9.7%	12.9%	8.3%	



(a) Dry and Wet Resilient Modulus
(the Statistical Comparisons Are Only Valid within Each Specimen Type)



(b) Resilient Modulus Ratio

Figure B.11. Resilient Modulus Test Results by Specimen Type for the New Mexico Field Project

Summary Considering the wet M_R stiffness and M_R -ratio results, foaming was the WMA technology that most commonly exhibited poor performance as compared to HMA. The instances when other WMA technologies exhibited lower wet M_R or M_R -ratio values as

compared to HMA corresponded to specimen types representative of the pavement in its early life (i.e., cores at construction, cores after winter, on-site PMLC, and LMLC specimens).

Hamburg Wheel-Tracking Test Results

The moisture-susceptibility test parameters obtained from the HWTT were the SIP and the stripping slope. A precision and bias statement was not available for HWTT test results; therefore, using the data generated in this study, the average differences in SIP and the stripping slope for all Texas mixtures that exhibited stripping were calculated to be approximately 2,000 load cycles and 0.2 μm/cycle, respectively. These two thresholds were used as d2s values to compare results between mixture types and specimen types.

Iowa Field Project HWTT results for the Iowa field project are summarized in Table B.10 and Figure B.12 through Figure B.16. In general, this field project exhibited poor performance for all WMAs with RAP and HMA with RAP. Figure B.17 shows the SIP and stripping slope to give a representative comparison of the test results in terms of moisture susceptibility. Figure B.17(a) shows that the SIP for all mixture types was low, less than about 5,000 load cycles. Considering the variability of the SIP observed in Figure B.17(a) when compared to the d2s threshold of 2,000 load cycles, all WMA with RAP mixtures within each specimen type were considered equivalent to their respective HMA with RAP. However, for the stripping slope results (Figure B.17[b]), it is clear that Sasobit® with RAP was the weakest within the PMFC cores at construction and that HMA showed better performance than both WMAs for the PMFC cores after winter at 6 months in service. The difference between HMA with RAP and both WMAs with RAP was significantly reduced for the PMFC cores after summer at 12 months in service. Both WMAs with RAP were more moisture susceptible than HMA for LMLC specimens.

Table B.10. HWTT Results for the Iowa Field Project

Specimen Type	Mixture Type	Air Voids %		SIP	Stripping Slope (μm/cycle)
Cores at construction	HMA+RAP	Average	8.5%	3,393	4.48
		Std. Dev.	1.7%		
		COV%	19.8%		
	Evotherm 3G+RAP	Average	7.9%	3,716	3.63
		Std. Dev.	0.5%		
		COV%	6.2%		
	Sasobit+RAP	Average	7.6%	2,080	8.10
		Std. Dev.	0.9%		
		COV%	11.8%		
Cores after winter at 6 months	HMA+RAP	Average	6.3%	3,632	4.47
		Std. Dev.	0.4%		
		COV%	6.0%		
	Evotherm 3G+RAP	Average	8.2%	2,520	5.90
		Std. Dev.	0.2%		
		COV%	2.4%		
	Sasobit+RAP	Average	8.3%	2,340	7.00
		Std. Dev.	0.2%		
		COV%	2.8%		
Cores after summer at 12 months	HMA+RAP	Average	7.7%	4,515	2.63
		Std. Dev.	0.2%		
		COV%	2.2%		
	Evotherm 3G+RAP	Average	8.5%	4,748	2.58
		Std. Dev.	0.2%		
		COV%	2.0%		
	Sasobit+RAP	Average	8.1%	4,144	2.93
		Std. Dev.	0.2%		
		COV%	2.2%		
On-site PMLC	HMA+RAP	Average	6.9%	5,243	2.78
		Std. Dev.	0.0%		
		COV%	0.2%		
	Evotherm 3G+RAP	Average	6.3%	4,372	3.72
		Std. Dev.	0.1%		
		COV%	0.9%		
	Sasobit+RAP	Average	6.9%	3,370	3.89
		Std. Dev.	0.1%		

Specimen Type	Mixture Type	Air Voids %		SIP	Stripping Slope (μm/cycle)
		COV%	1.3%		
Off-site PMLC	HMA+RAP	Average			
		Std. Dev.			
		COV%			
	Evotherm 3G+RAP	Average	7.4%	4,382	2.89
		Std. Dev.	0.2%		
		COV%	2.5%		
	Sasobit +RAP	Average	7.1%	4,008	3.22
		Std. Dev.	0.4%		
		COV%	5.9%		
LMLC	HMA+RAP	Average	7.7%	2,732	5.41
		Std. Dev.	0.0%		
		COV%	0.1%		
	Evotherm 3G+RAP	Average	6.8%	1,677	10.13
		Std. Dev.	0.3%		
		COV%	4.4%		
	Sasobit +RAP	Average	5.9%	2,176	6.59
		Std. Dev.	0.8%		
		COV%	13.2%		

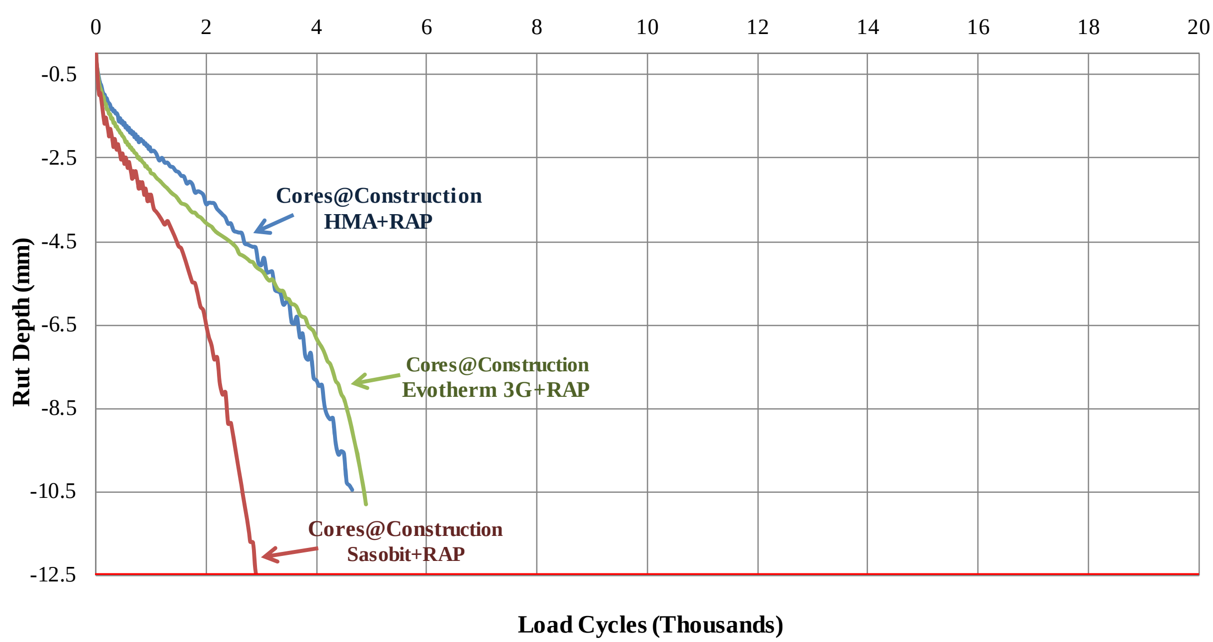


Figure B.12. HWTT Load Cycles versus Depth for the Iowa Field Project PMFC Cores at Construction

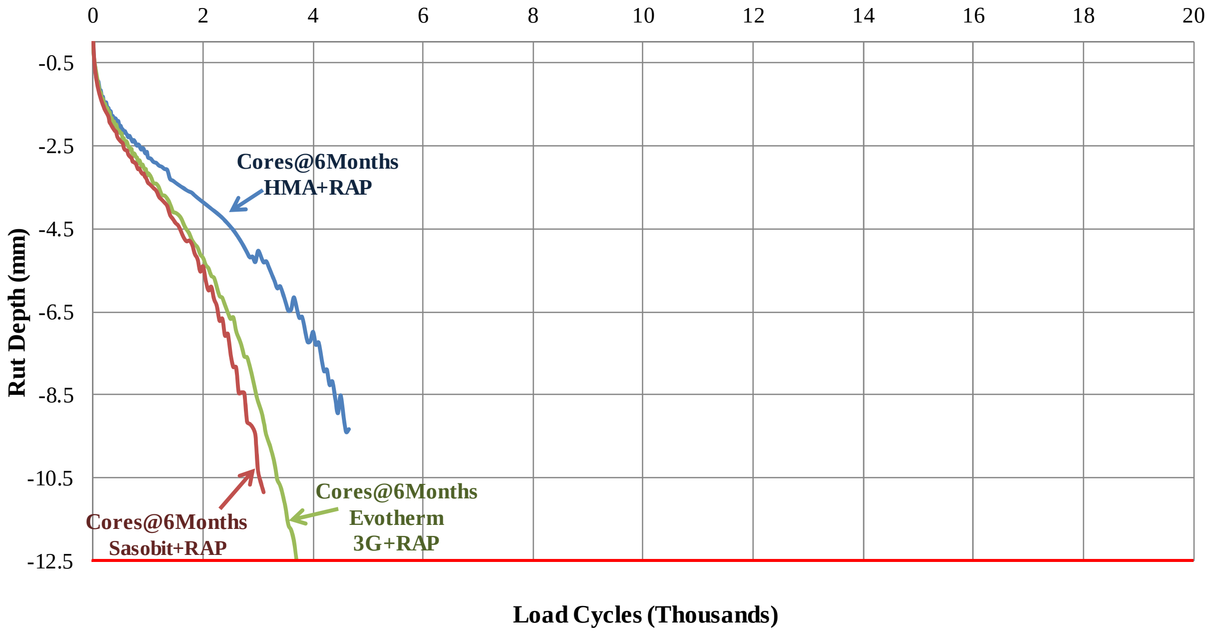


Figure B.13. HWTT Load Cycles versus Depth for the Iowa Field Project PMFC Cores after Winter at 6 Months In Service

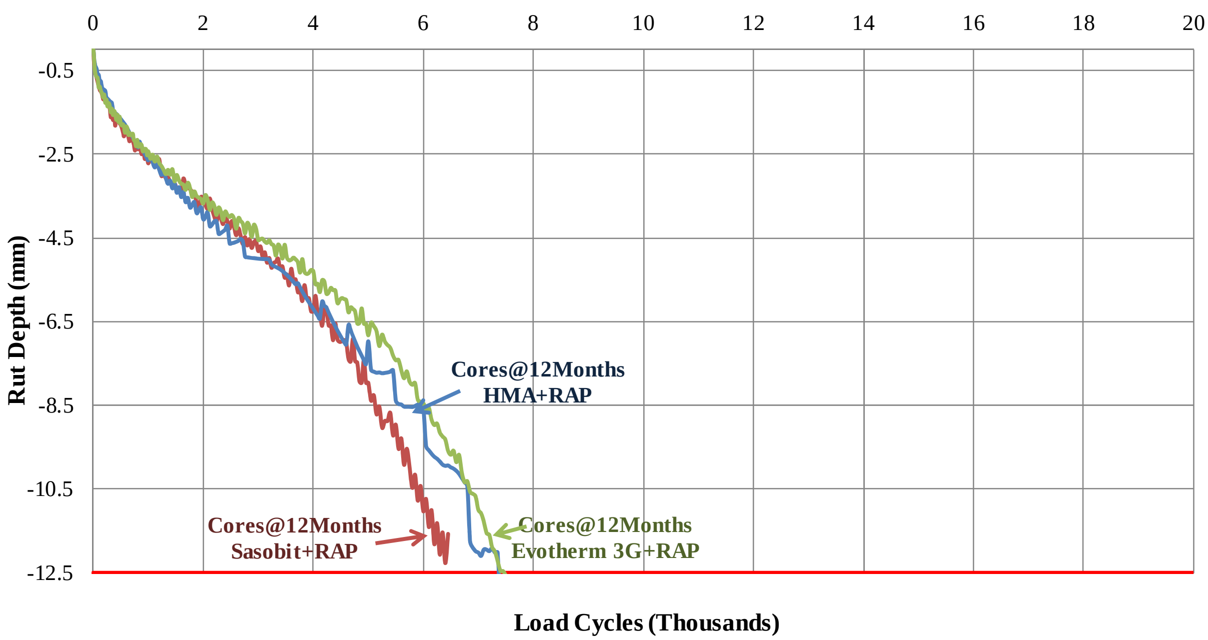


Figure B.14. HWTT Load Cycles versus Depth for the Iowa Field Project PMFC Cores after Summer at 12 Months In Service

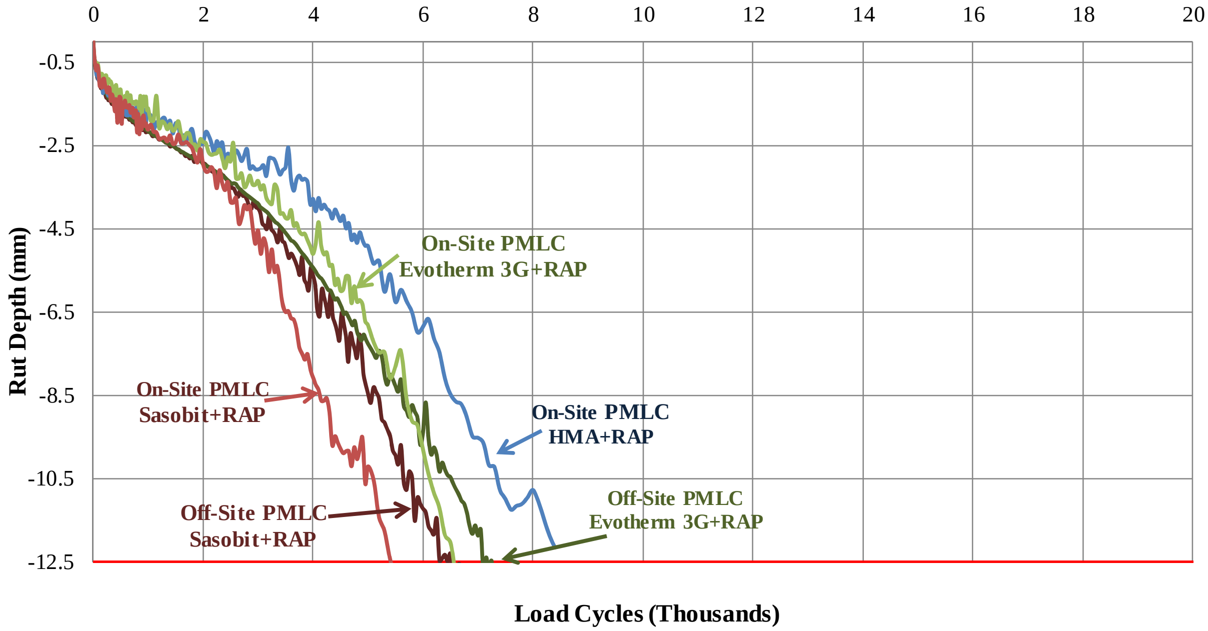


Figure B.15. HWTT Load Cycles versus Depth for the Iowa Field Project On-Site and Off-Site PMLC Specimens

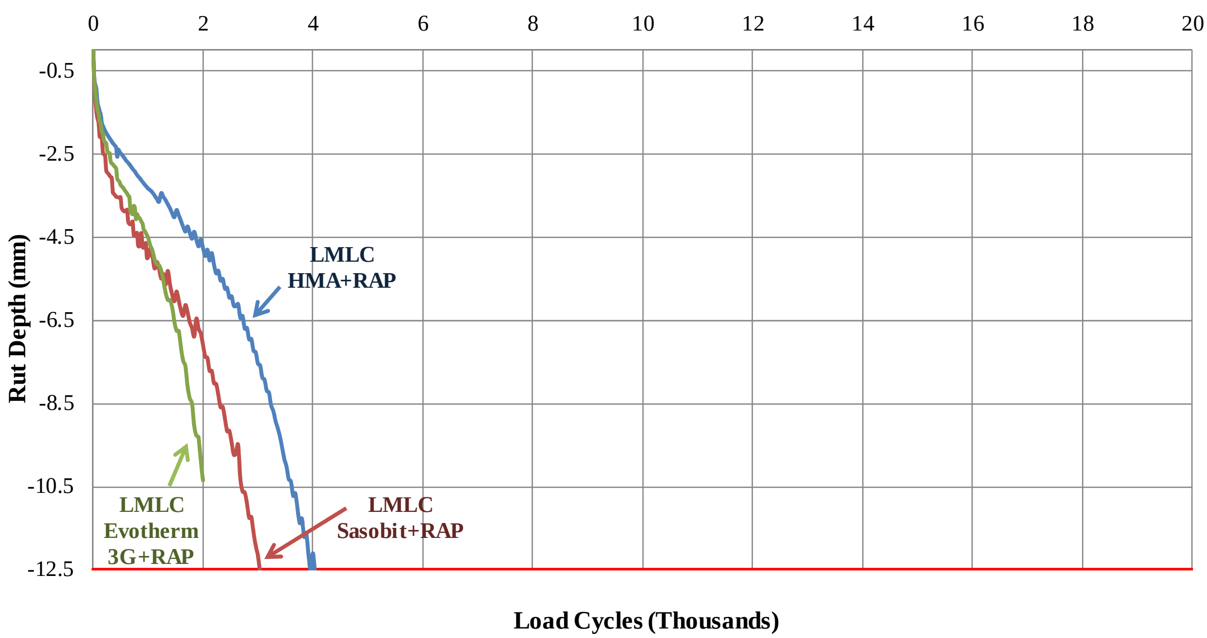
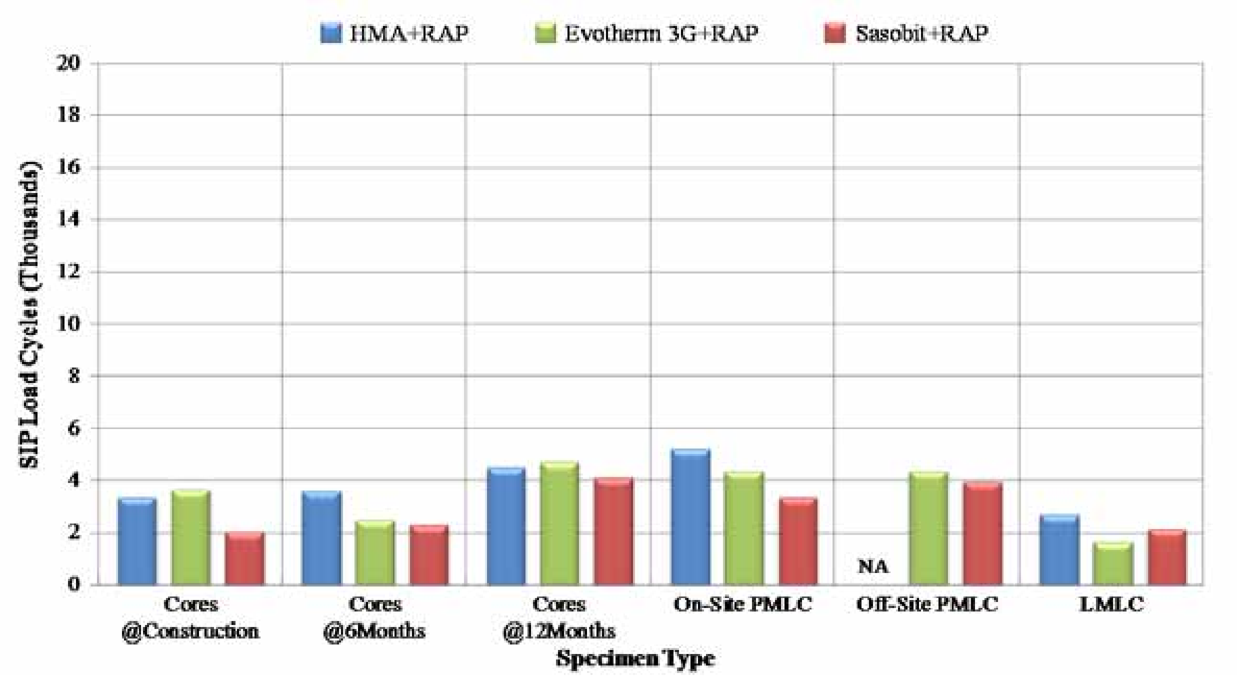
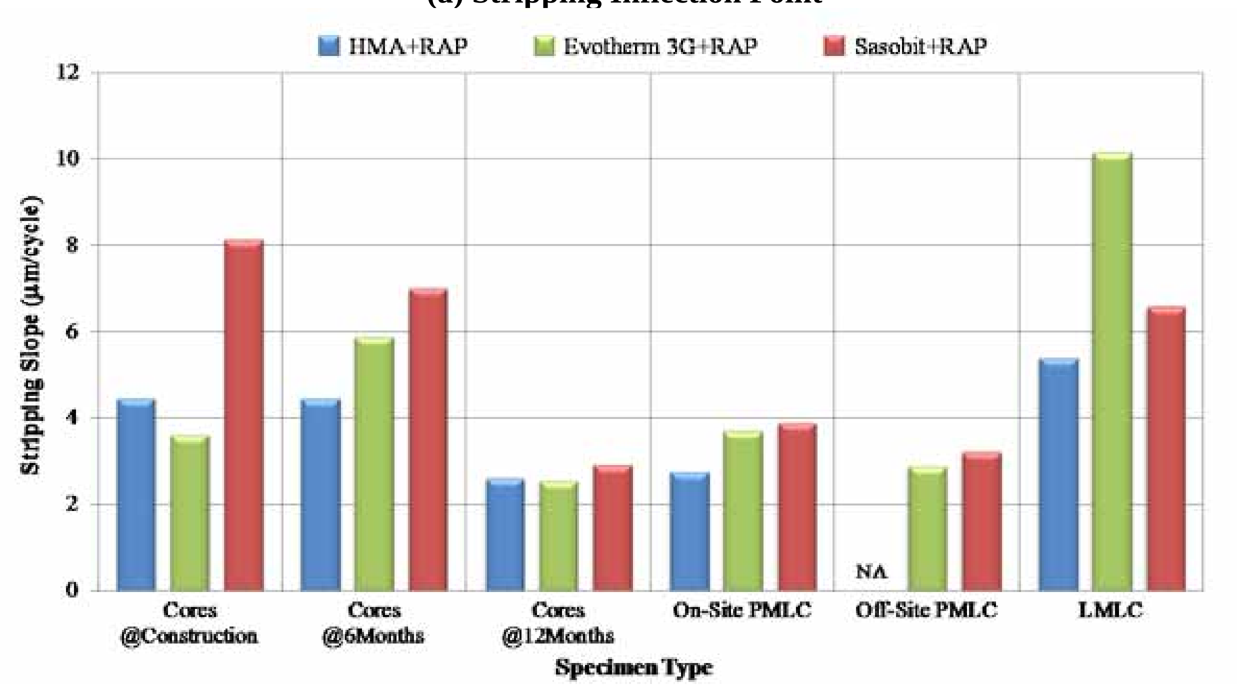


Figure B.16. HWTT Load Cycles versus Depth for the Iowa Field Project LMLC Specimens



(a) Stripping Inflection Point



(b) Stripping Slope

Figure B.17. HWTT Results by Specimen Type for the Iowa Field Project

Montana Field Project The output of the HWTT results for the Montana field project showed very good performance for all mixtures. The rut depth versus load cycle plots for all mixtures exhibited a fairly high or unnoticeable SIP and a very low or even null stripping slope (Table B.11 and Figure B.18 through Figure B.21).

Figure B.22 shows SIP and stripping slope exclusively to facilitate the comparison of the test results in terms of moisture susceptibility. The up-pointing arrows in Figure B.22(a) indicate that the SIP did not occur after 20,000 load cycles. It is clear from Figure B.22 that for all specimen types in this field project, the WMA technologies were equal or better than the HMA control mixture. The one exception was WMA foaming off-site PMLC specimens, which had a lower SIP and higher stripping slope. However, these values are considered acceptable when compared to the HWTT results and observed performance of the Texas and Iowa field projects.

Table B.11. HWTT Results for the Montana Field Project

Specimen Type	Mixture Type	Air Voids %		SIP	Stripping Slope (μm/cycle)
Cores at construction	HMA	Average	6.25%	11,754	0.62
		Std. Dev.	0.49%		
		COV%	7.83%		
	Evotherm 3G	Average	4.78%	19,111	0.43
		Std. Dev.	0.50%		
		COV%	10.40%		
	Sasobit	Average	4.89%	11,657	0.74
		Std. Dev.	0.30%		
		COV%	6.11%		
	Foaming	Average	4.25%	12,961	0.59
		Std. Dev.	0.17%		
		COV%	4.08%		
Cores after winter at 6 months	HMA	Average	4.05%	8,943	1.01
		Std. Dev.	0.16%		
		COV%	3.89%		
	Evotherm 3G	Average	3.50%	NA	0.45
		Std. Dev.	0.40%		
		COV%	11.34%		
	Sasobit	Average	4.12%	NA	0.34
		Std. Dev.	0.47%		
		COV%	11.49%		
	Foaming	Average	3.81%	9,840	0.63
		Std. Dev.	0.11%		
		COV%	3.00%		
On-site PMLC	HMA	Average	6.26%	NA	0
		Std. Dev.	0.12%		
		COV%	1.99%		
	Evotherm 3G	Average	5.84%	NA	0
		Std. Dev.	0.09%		
		COV%	1.60%		
	Sasobit	Average	6.63%	NA	0
		Std. Dev.	0.45%		
		COV%	6.72%		
	Foaming	Average	6.36%	NA	0
		Std. Dev.	0.11%		
		COV%	1.79%		

Specimen Type	Mixture Type	Air Voids %		SIP	Stripping Slope (μm/cycle)
Off-site PMLC	HMA	Average	5.92%	NA	0.17
		Std. Dev.	0.21%		
		COV%	3.61%		
	Evotherm 3G	Average	8.32%	NA	0
		Std. Dev.	0.13%		
		COV%	1.58%		
	Sasobit	Average	6.97%	NA	0
		Std. Dev.	0.39%		
		COV%	5.57%		
	Foaming	Average	6.75%	13,687	0.65
		Std. Dev.	0.33%		
		COV%	4.95%		

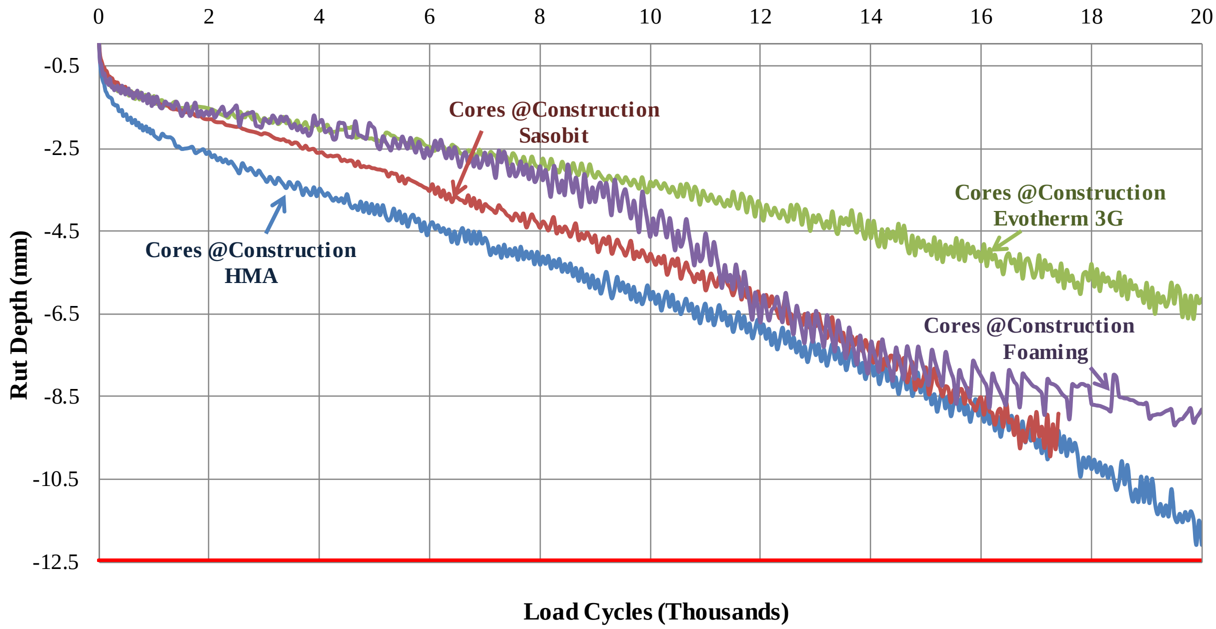


Figure B.18. HWTT Load Cycles versus Depth for the Montana Field Project PMFC Cores at Construction

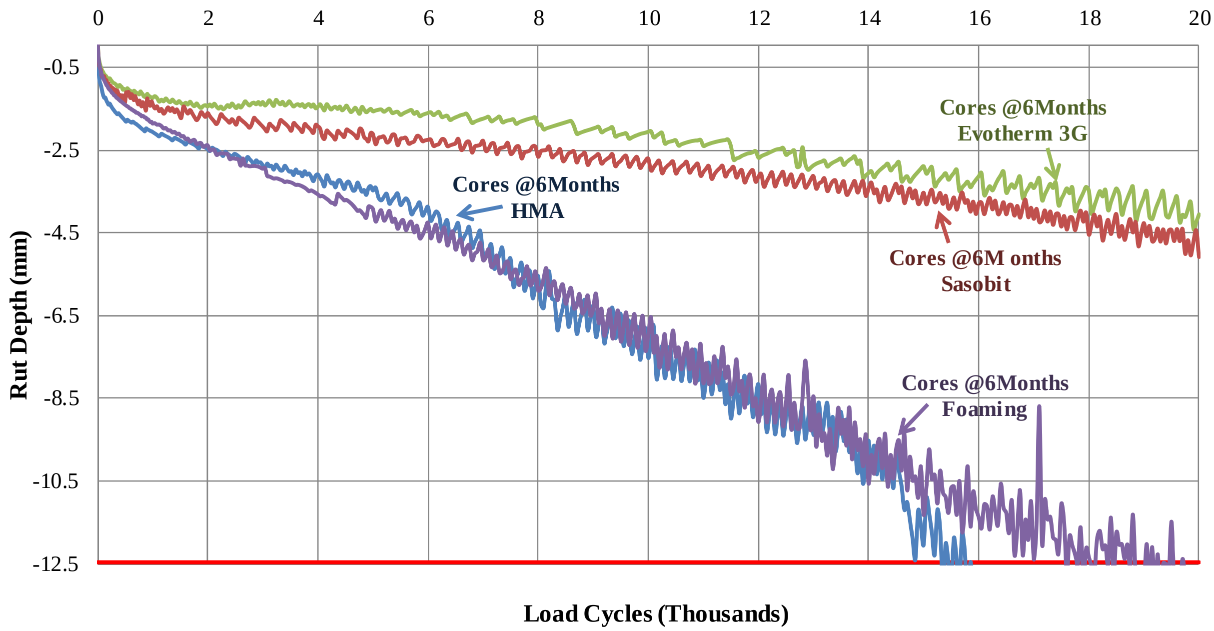


Figure B.19. HWTT Load Cycles versus Depth for the Montana Field Project PMFC Cores after Winter at 6 Months In Service

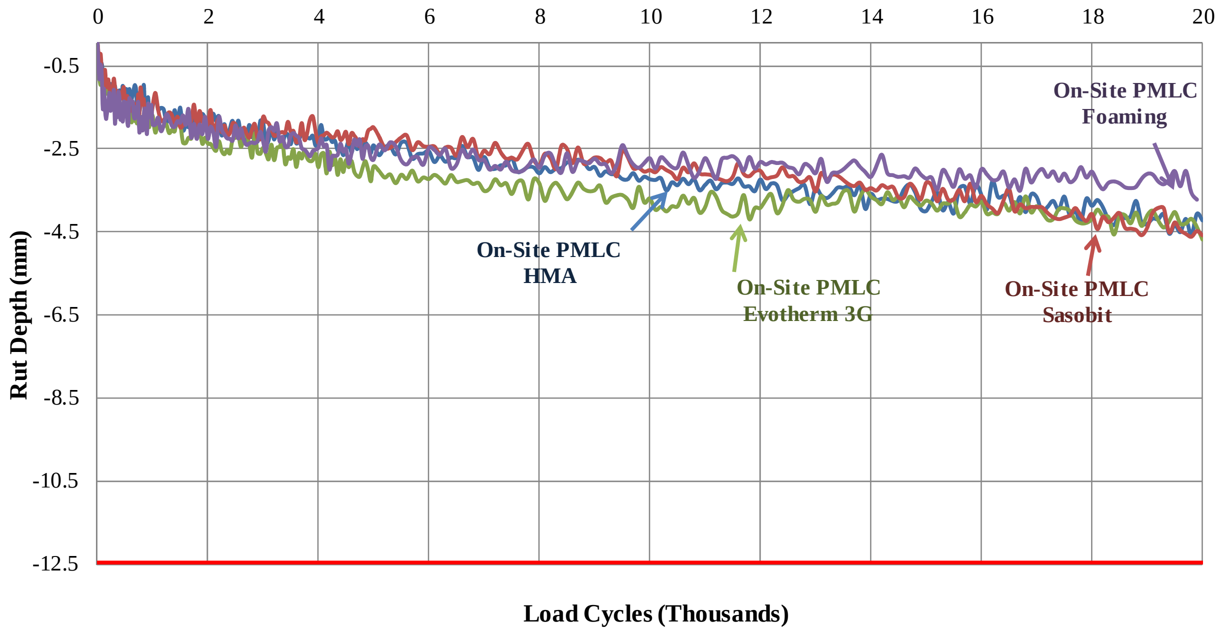


Figure B.20. HWTT Load Cycles versus Depth for the Montana Field Project On-Site PMLC Specimens

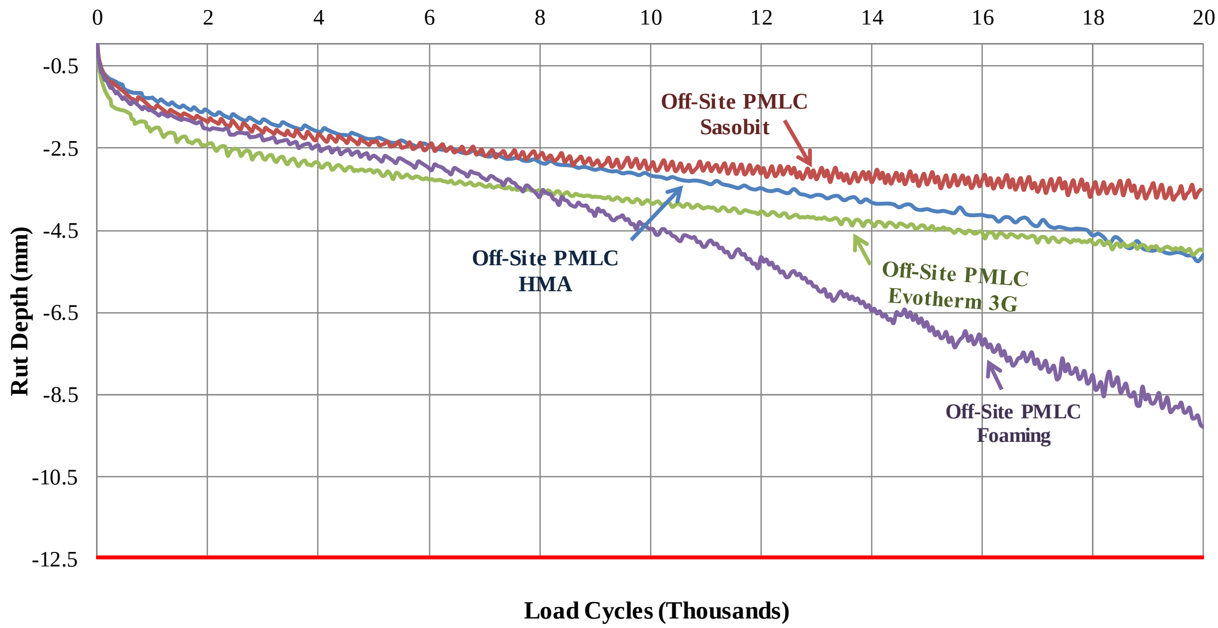
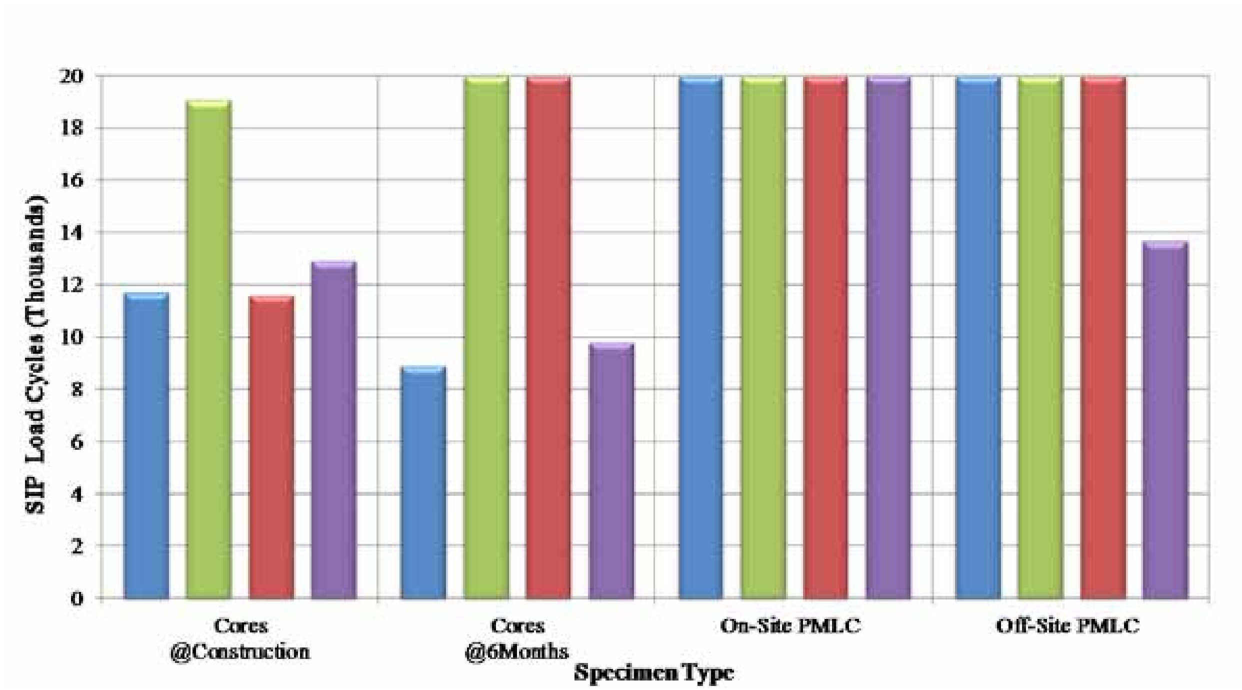
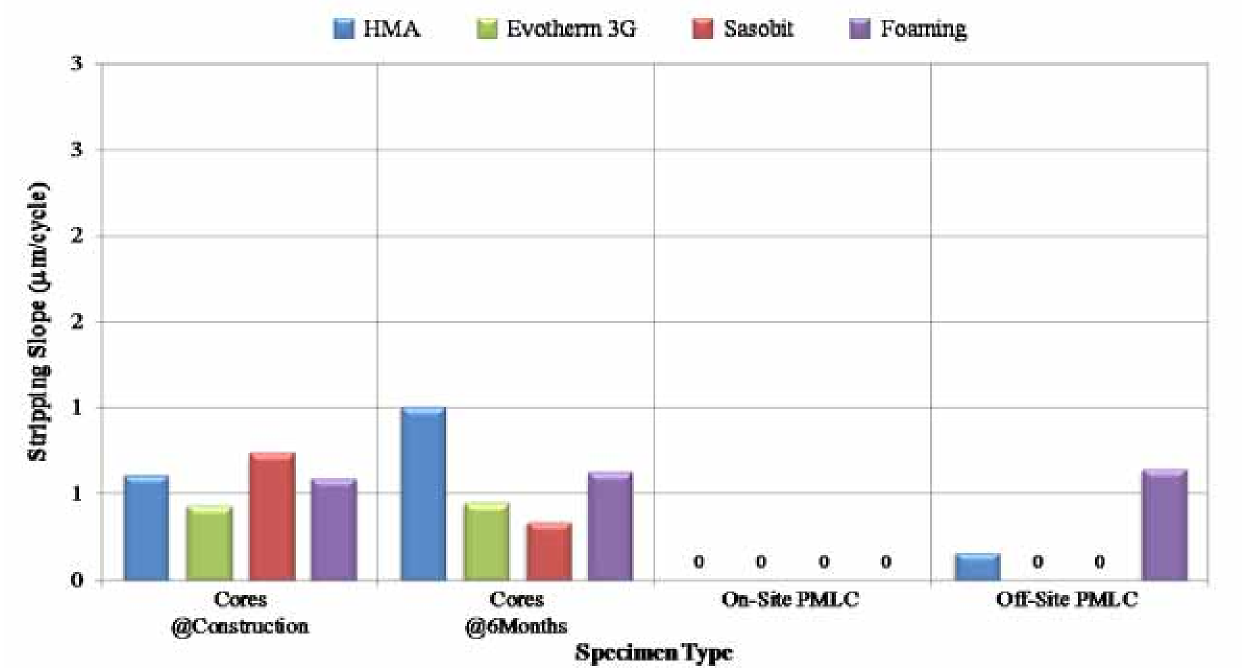


Figure B.21. HWTT Load Cycles versus Depth for the Montana Field Project Off-Site PMLC Specimens



(a) Stripping Inflection Point



(b) Stripping Slope

Figure B.22. HWTT Results by Specimen Type for the Montana Field Project

Texas Field Project The HWTT results for this field project showed high variability and dependency on specimen and mixture type (Table B.12 and Figure B.23 through Figure B.27). Figure B.28 shows the SIP and stripping slope results for comparison of the different mixture types in terms of moisture susceptibility. The up-pointing arrows in Figure B.28(a) indicate that the SIP did not occur after 20,000 passes or load cycles. HMA performed better that WMA in the case of off-site PMLC, LMLC specimens, and PMFC cores at construction. When comparing only the WMA mixtures, WMA Foaming performed worse than the Evotherm DAT™. In the case of the on-site PMLC specimens, WMA Foaming performed similar to HMA, while WMA Evotherm DAT™ showed inferior performance (i.e., lower SIP and higher stripping slope). Finally, for PMFC cores after summer at 8 months in service, both WMAs showed better performance than HMA.

Table B.12. HWTT Results for the Texas Field Project

Specimen Type	Mixture Type	Air Voids %		SIP	Stripping Slope (μm/cycle)
Cores at construction	HMA	Average	5.7%	10,210	1.15
		Std. Dev.	0.6%		
		COV%	11.1%		
	Evotherm DAT	Average	9.2%	7,703	1.76
		Std. Dev.	1.3%		
		COV%	14.2%		
	Foaming	Average	8.1%	5,690	1.42
		Std. Dev.	0.8%		
		COV%	9.4%		
Cores after summer at 8 months	HMA	Average	8.4%	11,630	0.32
		Std. Dev.	0.3%		
		COV%	4.1%		
	Evotherm DAT	Average	7.6%	NA	0
		Std. Dev.	0.5%		
		COV%	6.2%		
	Foaming	Average	8.2%	NA	0
		Std. Dev.	0.2%		
		COV%	2.4%		
On-site PMLC	HMA	Average	5.9%	6,720	1.69
		Std. Dev.	0.0%		
		COV%	0.0%		
	Evotherm DAT	Average	6.7%	4,206	2.67
		Std. Dev.	0.5%		
		COV%	7.4%		
	Foaming	Average	5.2%	7,181	1.32
		Std. Dev.	0.1%		
		COV%	1.2%		
Off-site PMLC	HMA	Average	8.4%	13,140	0.85
		Std. Dev.	0.2%		
		COV%	2.9%		
	Evotherm DAT	Average	7.1%	11,003	0.80
		Std. Dev.	0.1%		
		COV%	1.7%		
	Foaming	Average	7.3%	8,090	1.11
		Std. Dev.	0.1%		
		COV%	0.8%		

Specimen Type	Mixture Type	Air Voids %		SIP	Stripping Slope (μm/cycle)
LMLC	HMA	Average	6.4%	11,754	0.69
		Std. Dev.	0.5%		
		COV%	7.7%		
	Evotherm DAT	Average	6.5%	6,256	1.71
		Std. Dev.	0.2%		
		COV%	2.4%		
	Foaming	Average	7.4%	4,111	2.90
		Std. Dev.	0.1%		
		COV%	1.6%		

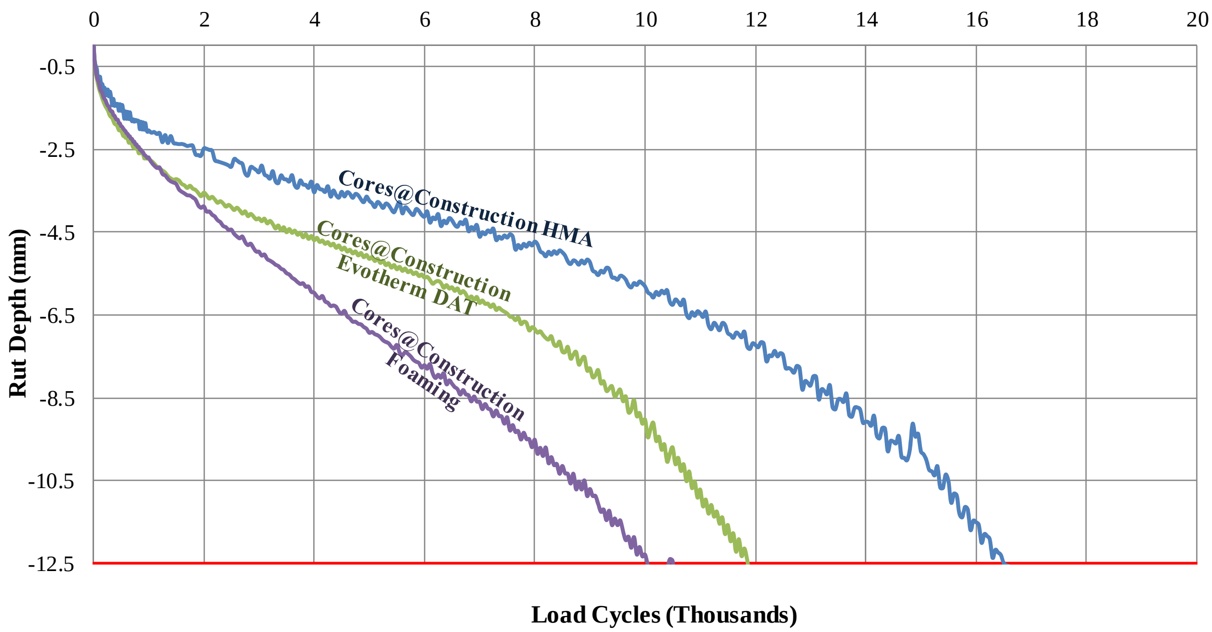


Figure B.23. HWTT Load Cycles versus Depth for the Texas Field Project PMFC Cores at Construction

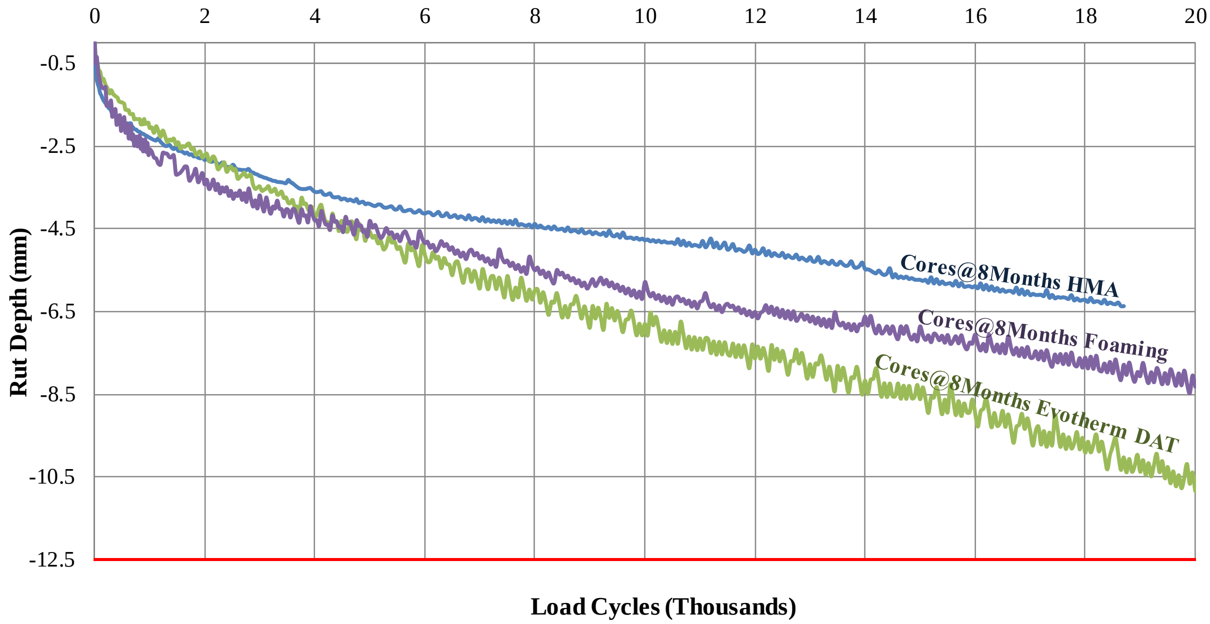


Figure B.24. HWTT Load Cycles versus Depth for the Texas Field Project PMFC Cores after Summer at 8 Months In Service

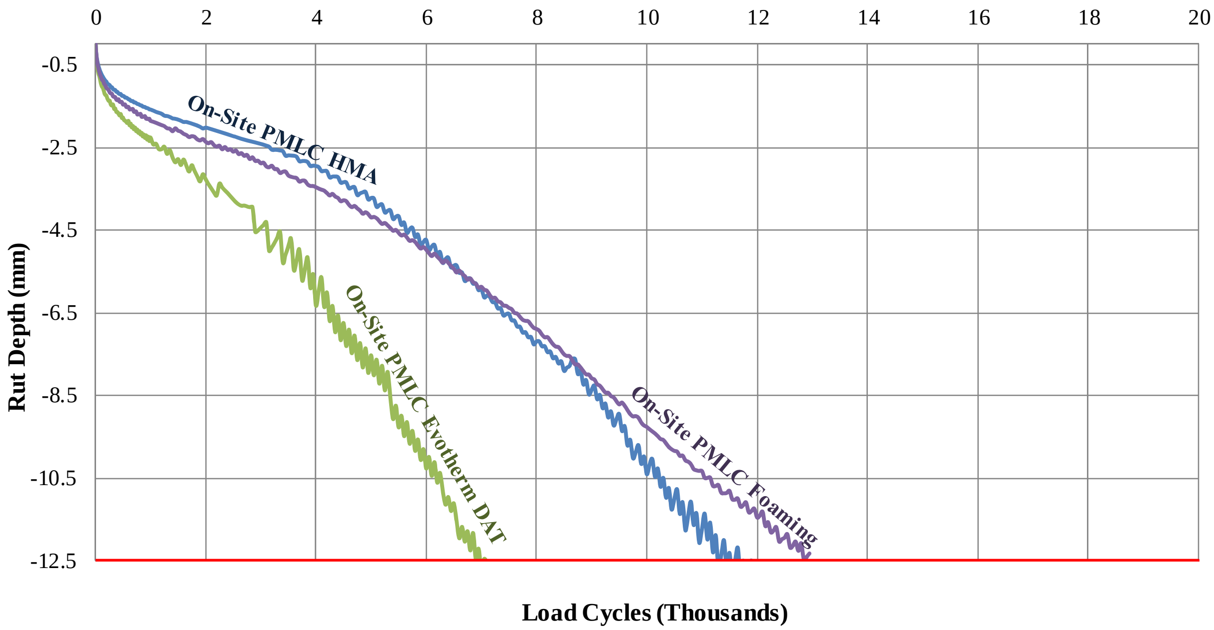


Figure B.25. HWTT Load Cycles versus Depth for the Texas Field Project On-Site PMLC Specimens

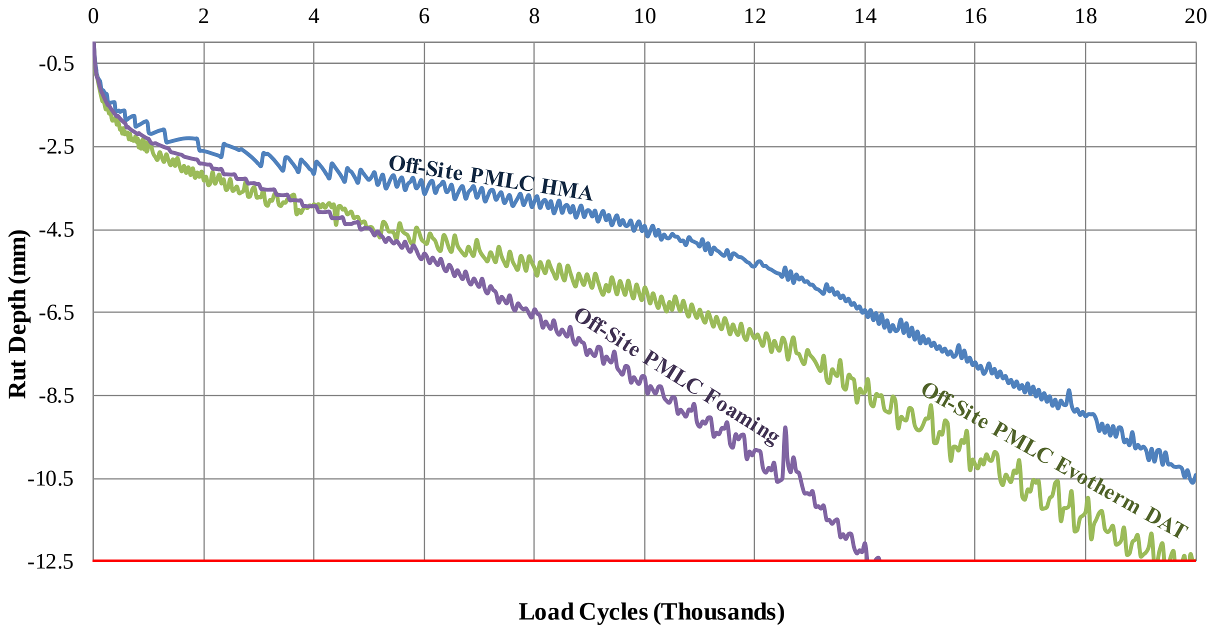


Figure B.26. HWTT Load Cycles versus Depth for the Texas Field Project Off-Site PMLC Specimens

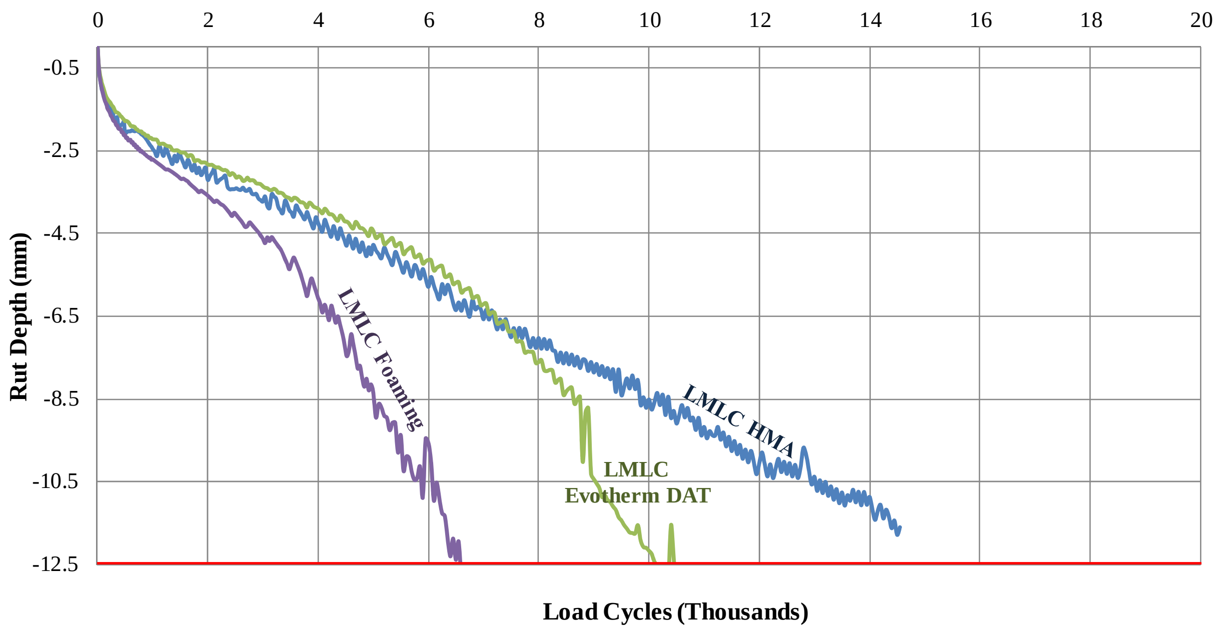
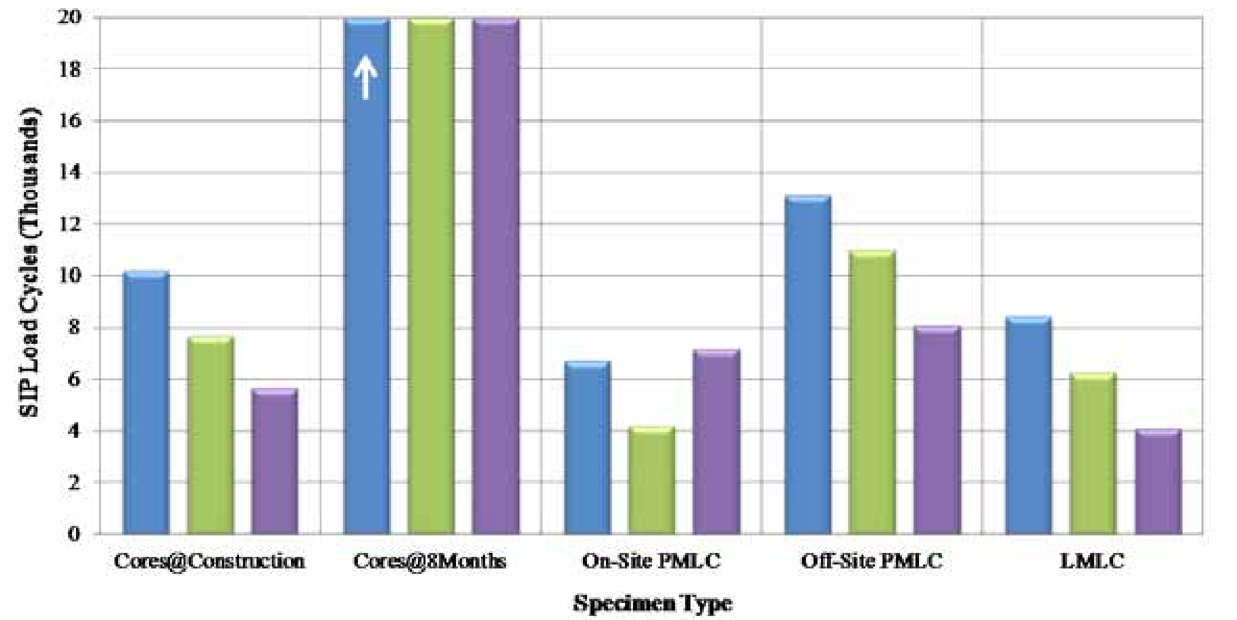
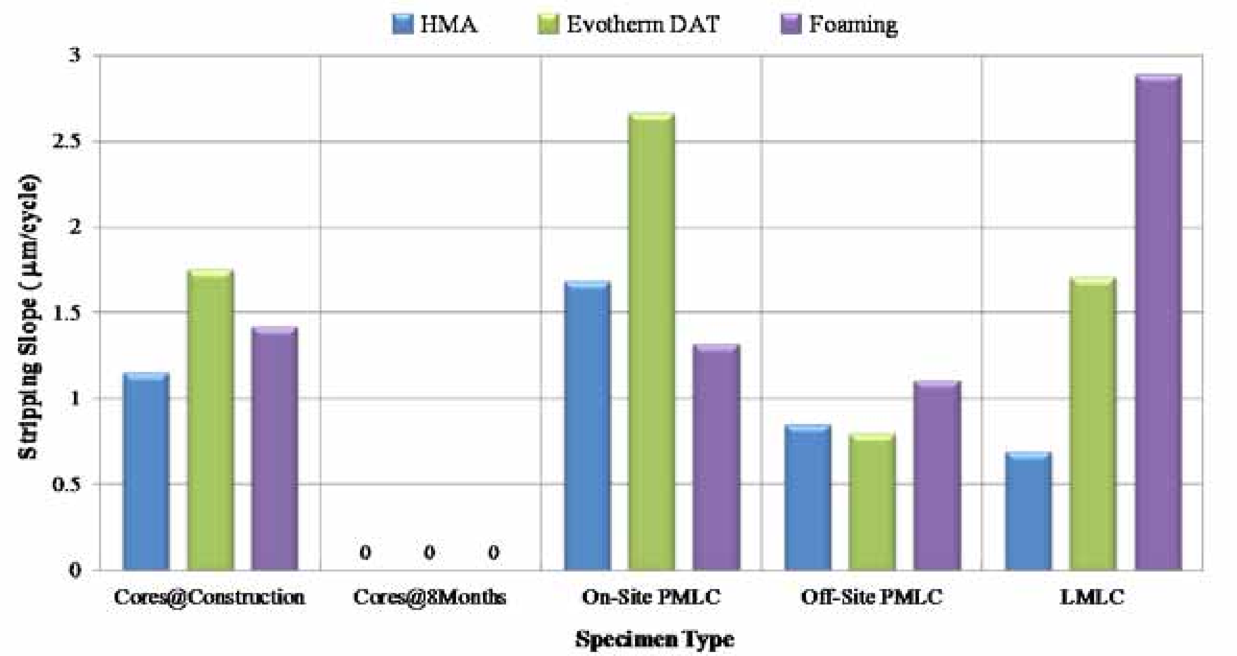


Figure B.27. HWTT Load Cycles versus Depth for the Texas Field Project LMLC Specimens



(a) Stripping Inflection Point



(b) Stripping Slope

Figure B.28. HWTT Results by Specimen Type for the Texas Field Project

New Mexico Field Project HWTT results for the New Mexico field project are described in Table B.13 and Figure B.29 through Figure B.34. None of the New Mexico mixtures had an observable SIP, and therefore the stripping slope was 0.0 μm/cycle in all cases. In addition, for every specimen type, all the WMA mixtures with RAP were equivalent to the HMA with RAP mixture.

Table B.13. HWTT Results for the New Mexico Field Project

Specimen Type	Mixture Type	Air Voids %		SIP	Stripping Slope (μm/cycle)
Cores at construction	HMA+RAP	Average	5.68%	NA	0
		Std. Dev.	0.15%		
		COV%	2.67%		
	Evotherm 3G+RAP	Average	7.94%	NA	0
		Std. Dev.	0.29%		
		COV%	3.70%		
	Foaming+RAP	Average	3.94%	NA	0
		Std. Dev.	0.13%		
		COV%	3.38%		
On-site PMLC	HMA+RAP	Average	6.13%	NA	0
		Std. Dev.	0.27%		
		COV%	4.34%		
	Evotherm 3G+RAP	Average	6.45%	NA	0
		Std. Dev.	0.21%		
		COV%	3.18%		
	Foaming+RAP	Average	6.76%	NA	0
		Std. Dev.	0.21%		
		COV%	3.14%		
Off-site PMLC	HMA+RAP	Average	7.41%	NA	0
		Std. Dev.	0.41%		
		COV%	5.50%		
	Evotherm 3G+RAP	Average	6.66%	NA	0
		Std. Dev.	0.12%		
		COV%	1.73%		
	Foaming+RAP	Average	6.74%	NA	0
		Std. Dev.	0.53%		
		COV%	7.89%		
LMLC	HMA+RAP	Average	2301.52%	NA	0
		Std. Dev.	1535.36%		
		COV%	66.71%		
	Evotherm 3G+RAP	Average	2852.00%	NA	0
		Std. Dev.	1897.77%		
		COV%	66.54%		
	Foaming+RAP	Average	5.86%	NA	0
		Std. Dev.	0.15%		
		COV%	2.57%		

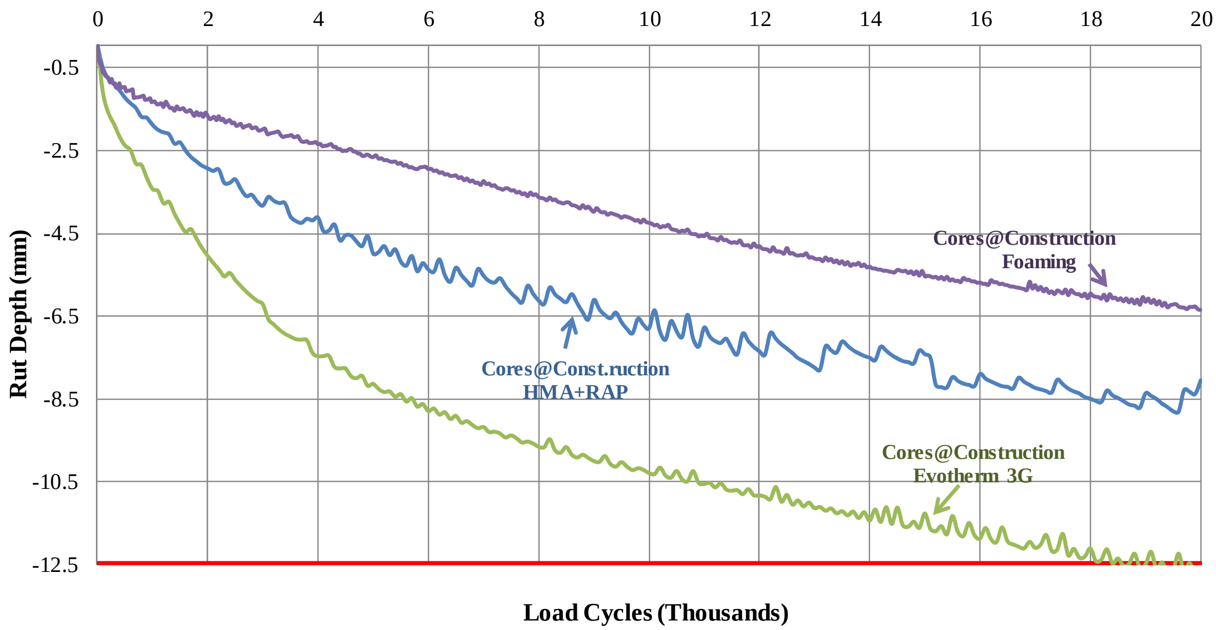


Figure B.29. HWTT Load Cycles versus Depth for the New Mexico Field Project PMFC Cores at Construction

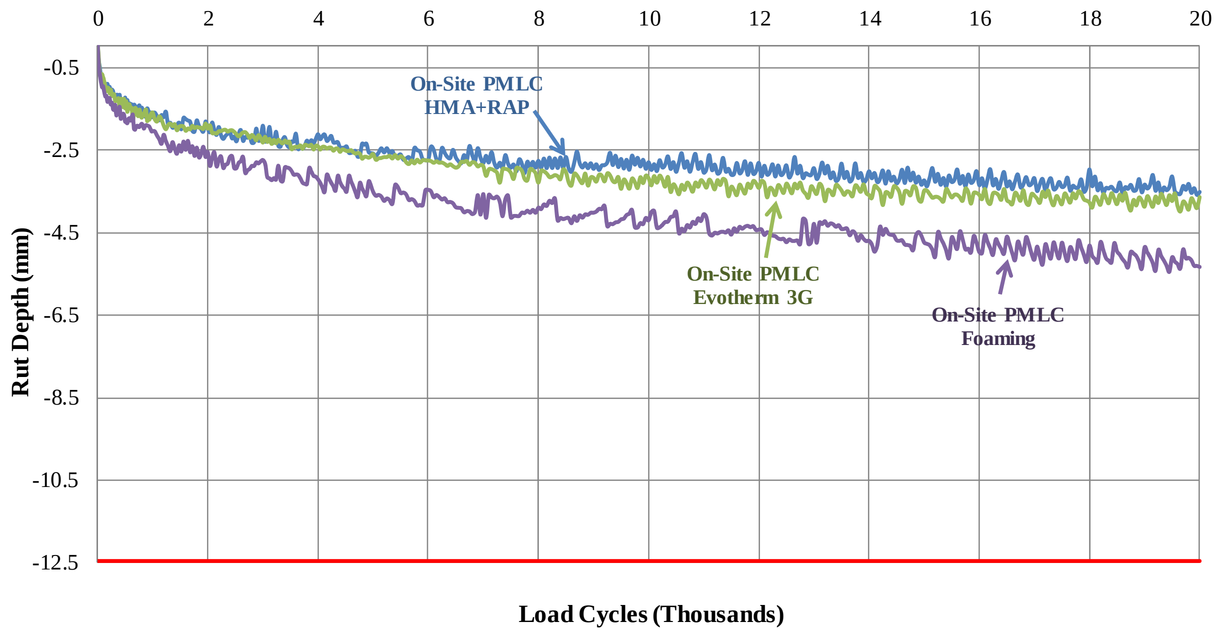


Figure B.30. HWTT Load Cycles versus Depth for the New Mexico Field Project On-Site PMLC Specimens

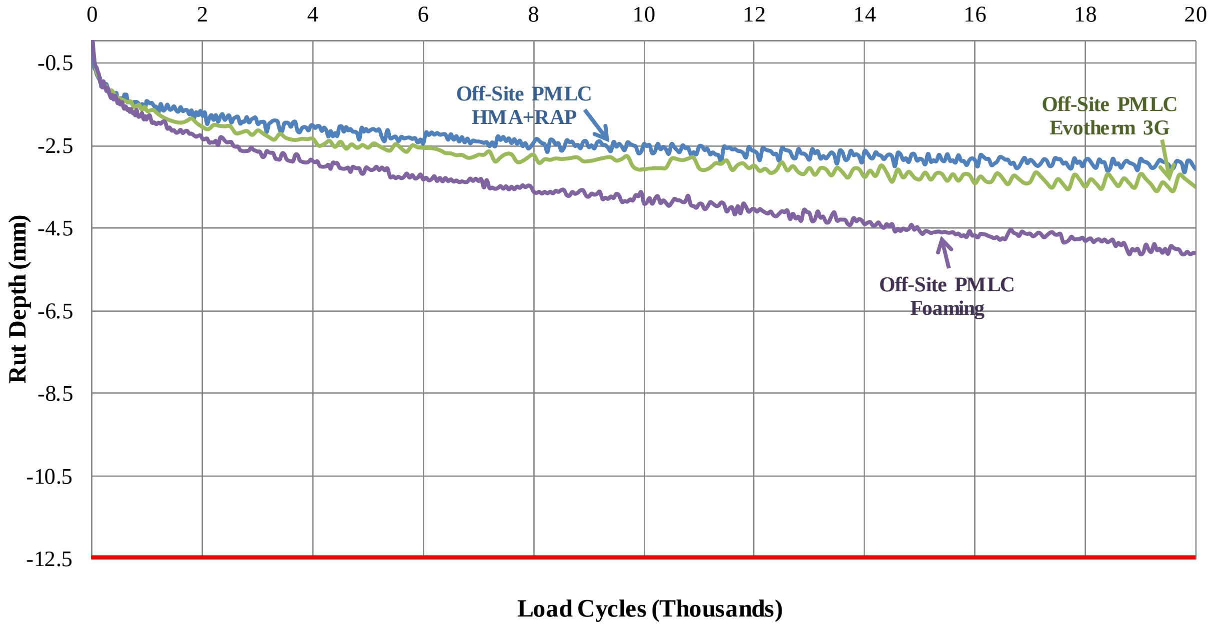


Figure B.31. HWTT Load Cycles versus Depth for the New Mexico Field Project Off-Site PMLC Specimens

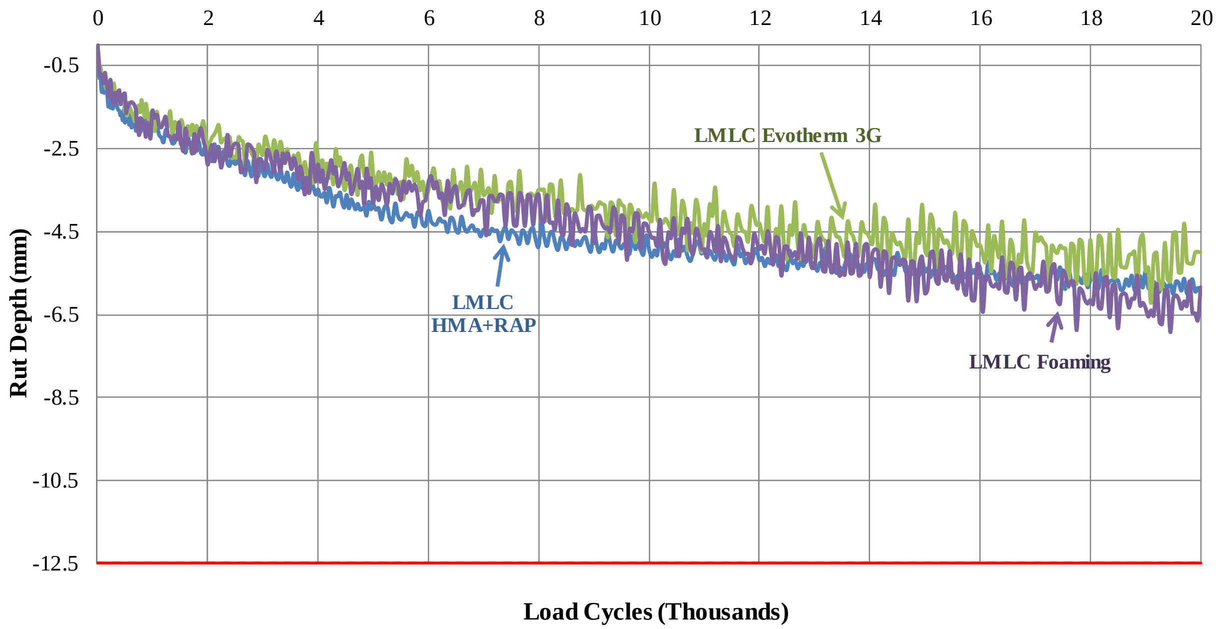


Figure B.32. HWTT Load Cycles versus Depth for the New Mexico Field Project LMLC Specimens

Summary For the Iowa and Texas field projects, the WMA mixtures commonly exhibited inferior performance as compared to HMA in the HWTT. The best performance achieved by the WMA mixtures as compared to HMA for each specimen type in both field projects corresponded to the PMFC cores after summer. For the Texas field project, the SIP showed the same trends as the stripping slope parameter when comparing the WMA to the HMA mixtures; however, this was not the case for the Iowa field project, where the WMA mixtures appeared to be equivalent to HMA yet both mixture types exhibited poor performance as indicated by their low SIP values.

For the Montana and New Mexico field projects, all WMA mixtures performed adequately for all specimen types. Given that all these field projects had differences in materials, such as modified/unmodified binders and inclusion of RAP, the common factor for the good performing mixtures (i.e., Montana and New Mexico) was the inclusion of anti-stripping agents, while the mixtures showing poor performance in their early life (i.e., Iowa and Texas) did not include an anti-stripping agent.

Effect of Anti-Stripping Agents

To evaluate and quantify the effect of hydrated lime and a liquid anti-stripping (LAS) agent on the moisture susceptibility of the WMA mixtures, several WMA and HMA specimens were prepared as designed and a companion set of specimens was prepared using 1 percent hydrated lime (by weight of mix) and 0.5 percent anti-stripping agent (by weight of binder). A common anti-stripping agent, AD-Here® LOF 6500 produced by ArrMaz, was selected for this study.

To assess the effectiveness of the hydrated lime and the LAS agent, dry and wet IDT strength, TSR, dry and wet M_R, and M_R-ratio were measured on LMLC specimens. Moisture conditioning for all wet specimens was done following AASHTO T 283 with one F/T cycle. The wet IDT strength and wet M_R of the specimens with hydrated lime and LAS agent were compared against the wet IDT and wet M_R of the specimens without any hydrated lime or LAS agent for each mixture type. ANOVA and Tukey's HSD were performed on these sets of values to assess moisture susceptibility of the specimens and quantify if the anti-stripping agents offered any improvement. As before, to identify differences in the TSR values, a d2s of 9.3 percent was used based on the precision and bias statement for AASHTO T 283 (Azari, 2010) and a d2s of 10 percent was assumed for M_R-ratio.

In the figures presented in this section, Tukey's HSD statistical groups are indicated by capital letters in the center of the bars corresponding to wet IDT strength or wet M_R values. In these same graphs, the solid part of the bar represents the average wet IDT strength or average wet M_R stiffness of three replicate specimens and the part of the bar with no fill extends up to the average dry IDT strength or average dry M_R stiffness of three replicate specimens. The error bars represent ± one standard deviation from the average value.

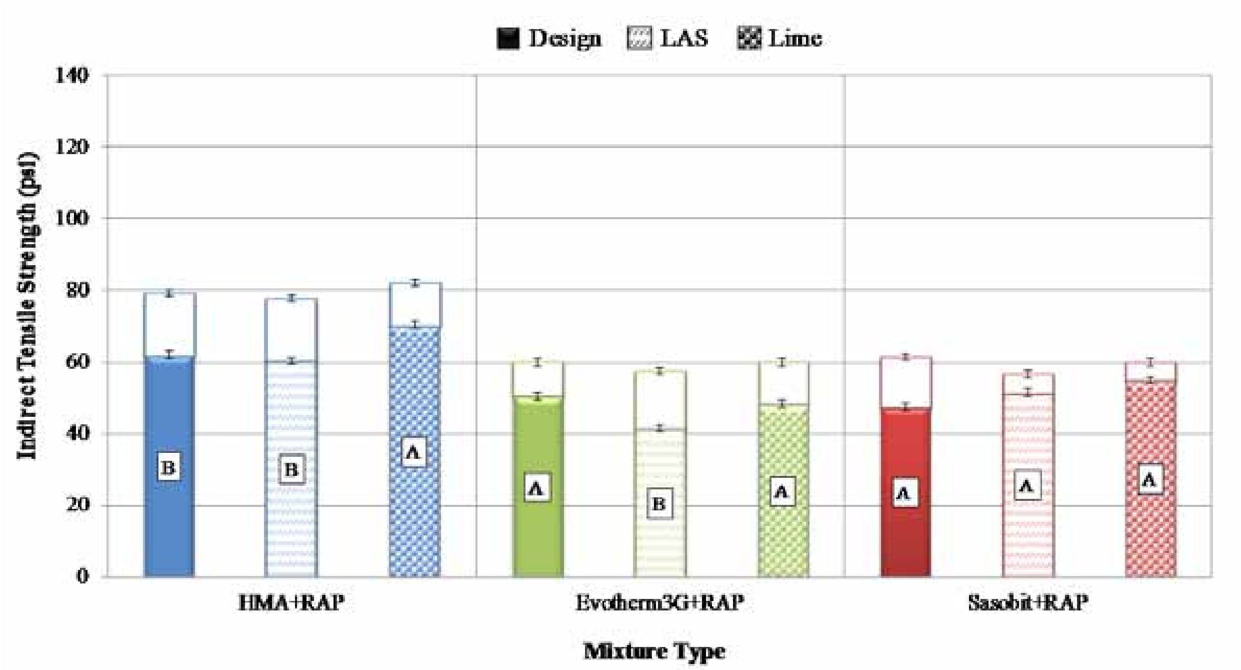
Dry and Wet IDT Strength and TSR

Iowa Field Project The IDT strength results are presented in Table B.14 and Figure B.33 for all Iowa specimens. From Figure B.33(a), it is apparent that the addition of hydrated lime to all mixture types yielded equivalent or improved performance in terms of wet IDT strength, as indicated by Tukey's HSD statistical groups. Only the incorporation of an LAS agent to the Evotherm® 3G with RAP yielded worse performance as compared to the mixture without any anti-stripping agents. All TSR values were above 70 percent, which is considered acceptable (Figure B.33[b]). Based on the d2s value of 9.3 percent, equivalent TSR values were shown across specimen types for each mixture type, except for the case of WMA Sasobit® with RAP, where the addition of either anti-stripping agent produced significantly improved TSR values. The highest TSR values were achieved by Sasobit® with RAP with added anti-stripping agents.

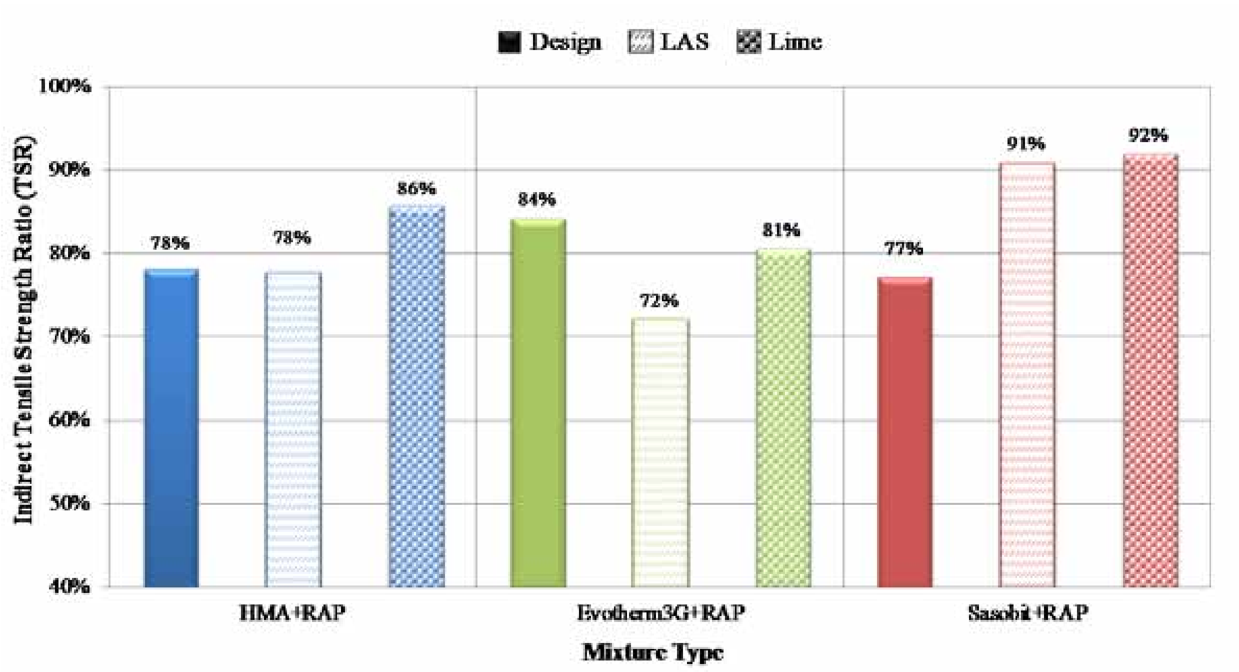
Table B.14. Indirect Tensile Strength Results for the Iowa Field Project Anti-Stripping Experiment

Specimen Type	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
HMA + RAP	As Design	Average	7.2%	7.3%	79.2	62.0	78.2%
		Std. Dev.	0.1%	0.1%	1.0	1.7	
		COV%	1.6%	2.1%	1.3%	2.8%	
	LAS	Average	7.5%	7.0%	77.7	60.5	77.8%
		Std. Dev.	0.2%	0.7%	2.4	5.2	
		COV%	2.2%	9.2%	3.0%	8.7%	
	Lime	Average	6.3%	6.2%	82.1	70.4	85.7%
		Std. Dev.	0.1%	0.1%	2.6	1.8	
		COV%	1.7%	1.2%	3.2%	2.5%	
Evotherm 3G + RAP	As Design	Average	6.8%	6.4%	59.9	50.5	84.3%
		Std. Dev.	0.6%	0.1%	1.3	2.5	
		COV%	9.0%	1.8%	2.2%	4.9%	
	LAS	Average	6.2%	6.4%	57.4	41.5	72.2%
		Std. Dev.	0.1%	0.1%	6.1	0.9	
		COV%	1.6%	0.9%	10.6%	2.1%	
	Lime	Average	5.9%	6.4%	59.9	48.3	80.6%
		Std. Dev.	0.2%	0.4%	7.8	2.9	
		COV%	4.1%	7.0%	13.1%	6.0%	
Sasobit + RAP	As Design	Average	5.9%	5.7%	61.5	47.5	77.2%
		Std. Dev.	0.2%	0.1%	1.5	2.5	
		COV%	2.7%	1.0%	2.5%	5.3%	

Specimen Type	Mixture Type		Air Voids %		IDT (psi)		TSR
			Dry	Wet	Dry	Wet	
	LAS	Average	5.9%	5.8%	56.6	51.4	90.9%
		Std. Dev.	0.3%	0.1%	2.2	2.0	
		COV%	4.5%	1.7%	4.0%	3.8%	
	Lime	Average	5.4%	5.4%	59.8	55.0	92.0%
		Std. Dev.	0.5%	0.4%	1.7	5.3	
		COV%	8.4%	6.5%	2.9%	9.7%	



(a) Wet and Dry Indirect Tensile Strength
(the Statistical Comparisons Are Only Valid within Each Mixture Type)



(b) Tensile Strength Ratio

Figure B.33. Indirect Tensile Strength Results for the Iowa Field Project Anti-Stripping Experiment

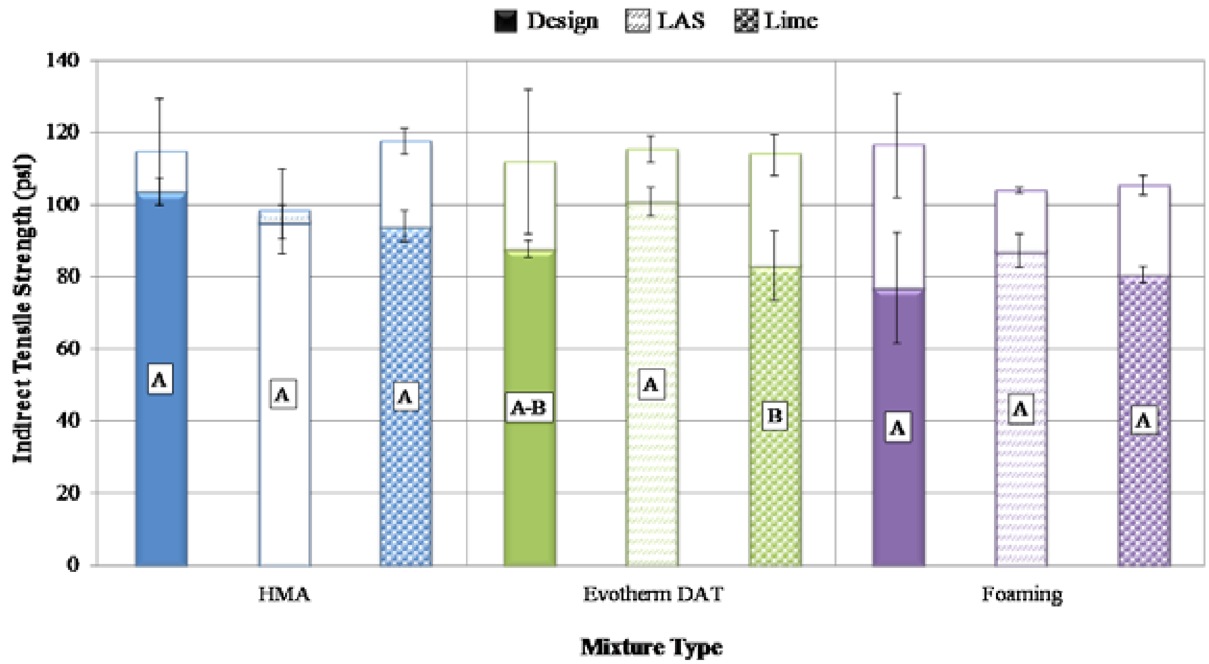
Texas Field Project Table B.15 and Figure B.34(a) show that for all mixture types, the addition of hydrated lime or LAS agent was not statistically different in terms of wet IDT strength as compared to the mixture without added anti-stripping agents. The TSR values were more variable than the ones from the Iowa field project, ranging from 66 percent in the case of foaming to 100 percent in the case of HMA plus LAS. From the specimens with added hydrated lime or LAS agent, the ones with the highest TSR value corresponded to the specimens with added LAS agent.

Based on the d2s value of 9.3 percent for TSR, WMA Evotherm DAT™ did not show improved performance in terms of TSR with the addition of either anti-stripping agent. However, WMA foaming did show improved performance with the addition of either anti-stripping agent. HMA exhibited mixed results, with the addition of hydrated lime causing a decrease in TSR and the addition of LAS agent causing an increase in TSR.

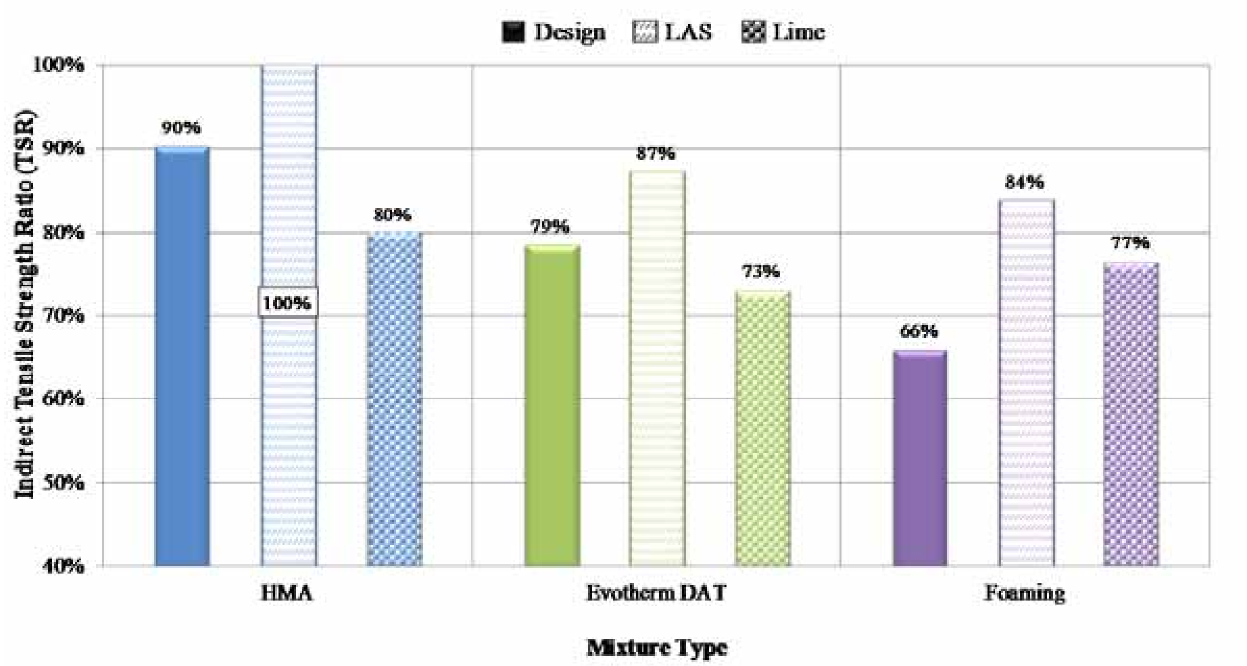
Table B.15. Indirect Tensile Strength Results for the Texas Field Project Anti-Stripping Experiment

Specimen Type	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
HMA	As Design	Average	5.7%	6.0%	114.7	103.7	90.4%
		Std. Dev.	0.4%	0.2%	14.8	3.9	
		COV%	7.3%	3.7%	12.9%	3.8%	
	LAS	Average	6.1%	6.1%	95.2	98.4	103.4%

Specimen Type	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
		Std. Dev.	0.2%	0.1%	4.7	11.7	
		COV%	3.8%	1.8%	4.9%	11.9%	
	Lime	Average	6.4%	6.2%	117.6	94.0	79.9%
		Std. Dev.	0.2%	0.1%	3.5	4.3	
		COV%	3.0%	2.2%	3.0%	4.6%	
Evotherm DAT	As Design	Average	7.8%	6.5%	111.8	87.8	78.5%
		Std. Dev.	1.8%	0.4%	20.0	2.3	
		COV%	23.4%	6.5%	17.9%	2.7%	
	LAS	Average	5.9%	6.2%	115.4	100.8	87.3%
		Std. Dev.	0.2%	0.3%	3.7	4.0	
		COV%	3.1%	4.4%	3.2%	4.0%	
	Lime	Average	6.2%	6.0%	113.9	83.2	73.1%
		Std. Dev.	0.2%	0.3%	5.6	9.6	
		COV%	4.0%	5.0%	4.9%	11.5%	
Foaming	As Design	Average	6.6%	6.5%	116.5	76.8	66.0%
		Std. Dev.	0.2%	0.3%	14.5	15.4	
		COV%	3.0%	4.6%	12.5%	20.0%	
	LAS	Average	6.7%	6.5%	104.0	87.2	83.9%
		Std. Dev.	0.3%	0.0%	1.0	4.7	
		COV%	3.8%	0.6%	1.0%	5.4%	
	Lime	Average	6.3%	6.6%	105.5	80.7	76.5%
		Std. Dev.	0.4%	0.2%	2.6	2.2	
		COV%	6.9%	3.5%	2.5%	2.8%	



(a) Wet and Dry Indirect Tensile Strength
(the Statistical Comparisons Are Only Valid within Each Mixture Type)



(b) Tensile Strength Ratio

Figure B.34. Indirect Tensile Strength Results for the Texas Field Project Anti-Stripping Experiment

Summary TSR values were generally equivalent or better with the addition of either anti-stripping agent as compared to the design value, but the addition of the LAS showed more instances of improvement. One exception was the IDT strength and TSR results obtained from the Iowa Evotherm® 3G with RAP with added LAS. In this case, the wet IDT strength and TSR values had a significant decrease when compared to the design value. Therefore, the addition of LAS to certain WMA additives that are also known for their anti-stripping qualities could have a negative effect on the moisture resistance of the mixture, possibly due to the interaction of the amines that are included in both types of products.

Dry and Wet M_R and M_R-ratio

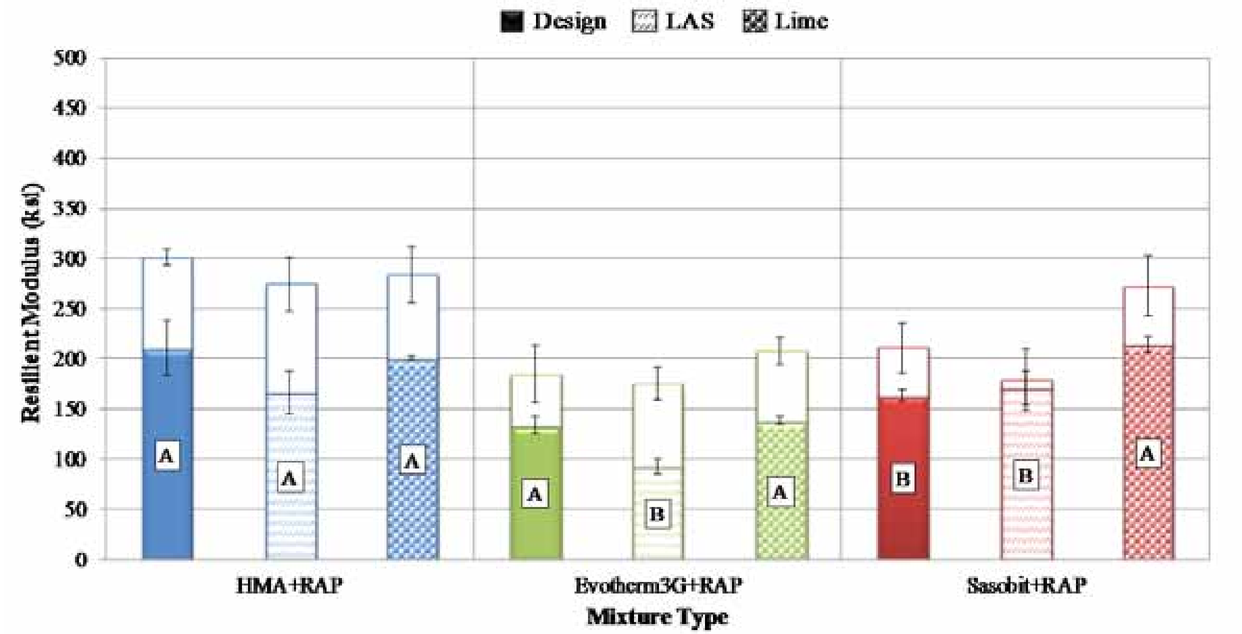
Iowa Field Project The M_R results are presented in Table B.16 and Figure B.35 for all Iowa specimens. In terms of wet M_R stiffness, Sasobit® with RAP showed improved moisture resistance with incorporation of hydrated lime (Figure B.35[a]). For M_R -ratio, the LAS agent showed greater benefits when added to WMA Sasobit® with RAP, as shown in Figure B.35(b).

Using the assumed d2s value of 10 percent to compare the M_R-ratio results, the addition of hydrated lime did not improve the performance for any of the mixture types. Adding an LAS agent showed a decrease in M_R-ratio for WMA Evotherm® 3G with RAP, an increase in M_R-ratio for WMA Sasobit® with RAP, and no change in M_R-ratio for HMA with RAP.

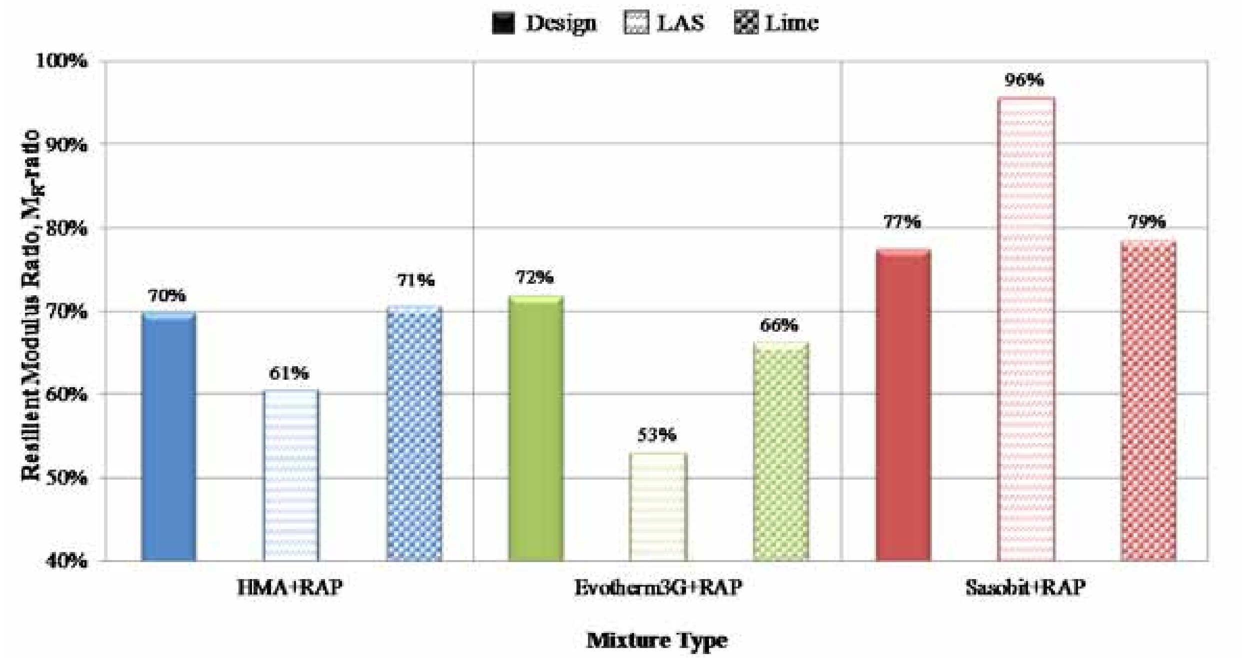
Table B.16. M_R Results for the Iowa Field Project Anti-Stripping Experiment

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
HMA + RAP	As Design	Average	7.2%	301.0	210.3	69.9%
		Std. Dev.	0.1%	7.7	27.4	
		COV%	0.7%	2.6%	13.0%	
	LAS	Average	7.3%	274.8	166.3	60.5%
		Std. Dev.	0.3%	27.2	21.0	
		COV%	4.5%	9.9%	12.7%	
	Lime	Average	7.0%	284.2	200.8	70.7%
		Std. Dev.	0.1%	27.5	2.2	
		COV%	2.1%	9.7%	1.1%	
Evotherm 3G + RAP	As Design	Average	6.8%	185.1	133.1	71.9%
		Std. Dev.	0.0%	28.8	8.3	
		COV%	0.6%	15.5%	6.2%	
	LAS	Average	6.9%	175.1	92.8	53.0%
		Std. Dev.	0.2%	16.4	7.7	
		COV%	2.7%	9.4%	8.3%	
	Lime	Average	6.7%	208.0	137.9	66.3%
		Std.	0.2%	13.6	4.0	

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
		Dev.				
		COV%	3.4%	6.5%	2.9%	
Sasobit + RAP	As Design	Average	7.6%	211.3	163.7	77.4%
		Std. Dev.	0.2%	24.6	5.4	
		COV%	2.1%	11.6%	3.3%	
	LAS	Average	7.5%	179.1	171.2	95.6%
		Std. Dev.	0.8%	30.7	16.8	
		COV%	10.7%	17.1%	9.8%	
	Lime	Average	7.1%	273.2	214.7	78.6%
		Std. Dev.	0.5%	29.8	7.6	
		COV%	7.6%	10.9%	3.6%	



(a) Wet and Dry Resilient Modulus (the Statistical Comparisons Are Only Valid within Each Mixture Type)



(b) Resilient Modulus Ratio

Figure B.35. Resilient Modulus Results for the Iowa Field Project Anti-Stripping Experiment

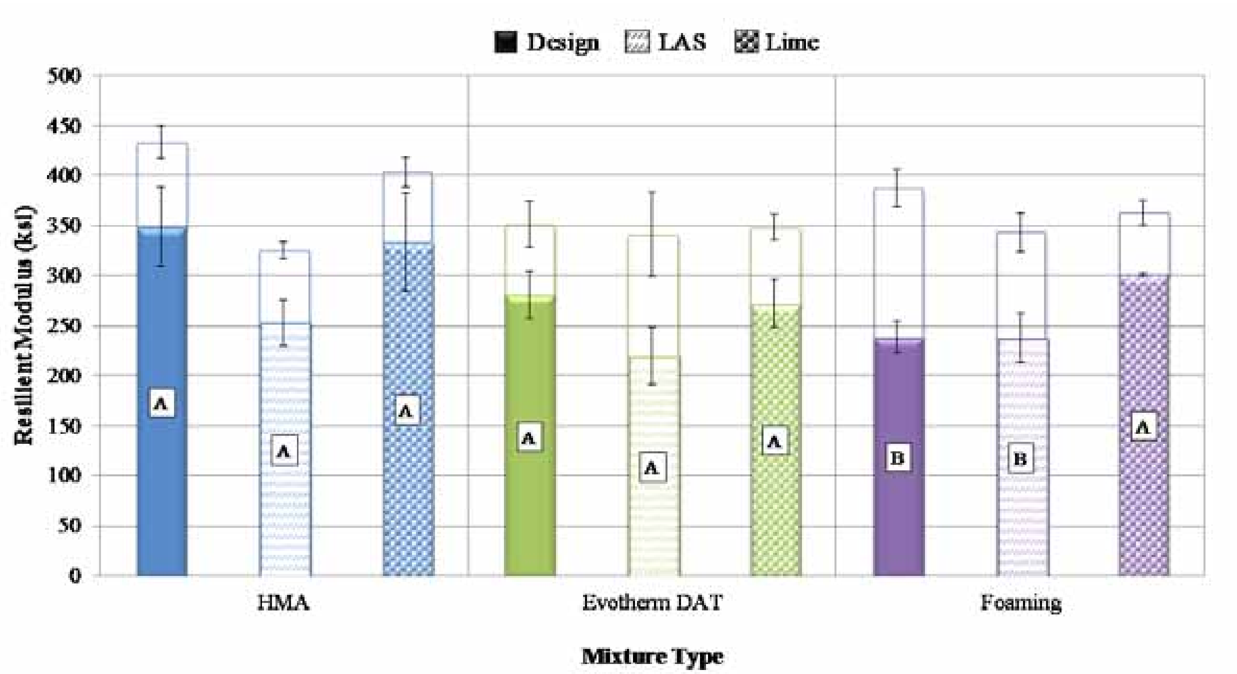
Texas Field Project The M_R results are presented in Table B.17 and Figure B.36 for all Texas specimens.The results from this field project showed that WMA Foaming improved its moisture resistance with the incorporation of hydrated lime (Figure B.36[a] and Figure B.36[b]).For the other mixtures, adding any of the anti-stripping agents yielded similar statistical groups (i.e., no improved performance).

Based on the assumed d2s value of 10 percent, the addition of either anti-stripping agent did not improve performance in terms of M_R-ratio for HMA. Adding an LAS agent showed a decrease in M_R-ratio for WMA Evotherm DAT™ and no change in performance for WMA Foaming. Adding lime showed an increase in M_R-ratio for WMA Foaming.

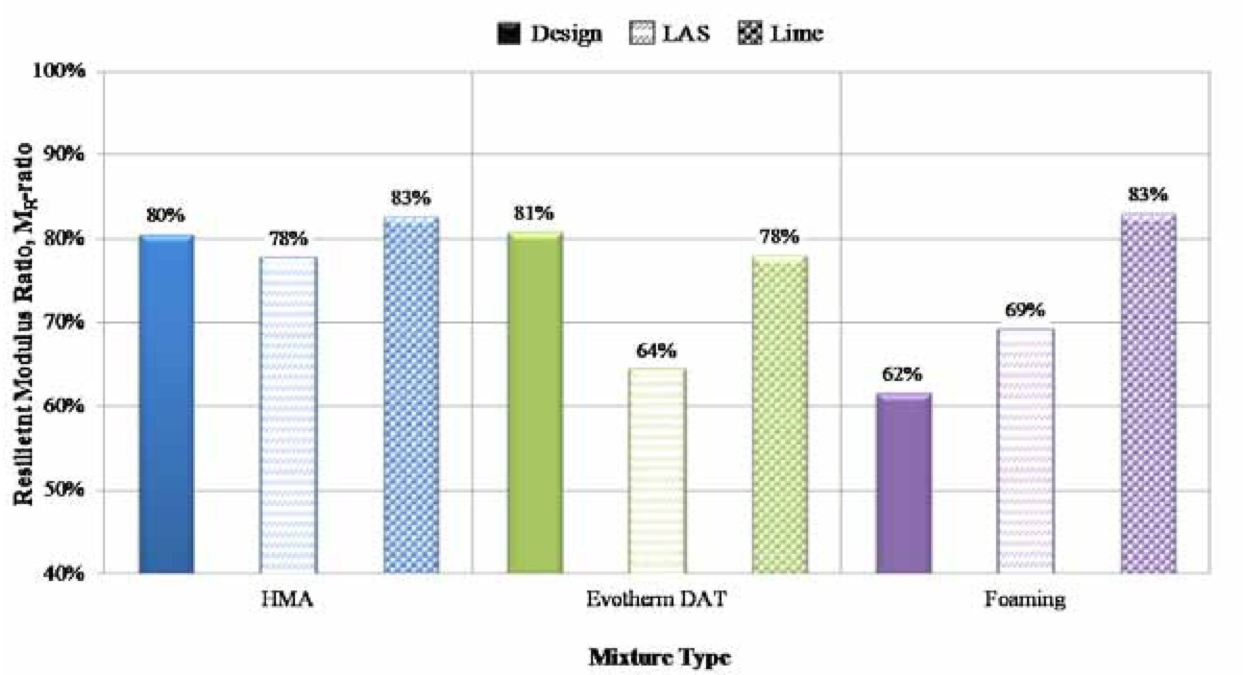
Table B.17. M_R Results for the Texas Field Project Anti-Stripping Experiment

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
HMA	As Design	Average	6.6%	433.0	348.5	80.5%
		Std. Dev.	0.4%	16.4	39.4	
		COV%	5.4%	3.8%	11.3%	
	LAS	Average	7.3%	325.4	253.0	77.8%
		Std. Dev.	0.0%	8.1	23.2	
		COV%	0.2%	2.5%	9.2%	
	Lime	Average	7.1%	403.4	333.4	82.7%
		Std. Dev.	0.3%	14.6	49.3	
		COV%	4.2%	3.6%	14.8%	
Evotherm DAT	As Design	Average	6.5%	351.5	280.7	79.9%
		Std. Dev.	0.2%	22.8	23.6	
		COV%	2.9%	6.5%	8.4%	
	LAS	Average	8.3%	341.1	219.6	64.4%
		Std. Dev.	0.1%	42.2	28.9	
		COV%	1.1%	12.4%	13.2%	
	Lime	Average	7.9%	348.5	271.9	78.0%
		Std. Dev.	0.1%	13.0	24.0	
		COV%	1.8%	3.7%	8.8%	
Foaming	As Design	Average	7.6%	387.6	238.6	61.6%
		Std. Dev.	0.2%	18.9	16.1	
		COV%	3.0%	4.9%	6.8%	
	LAS	Average	6.9%	343.4	237.7	69.2%
		Std. Dev.	0.2%	19.4	24.6	
		COV%	3.5%	5.6%	10.3%	

Specimen Type	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
	Lime	Average	6.8%	363.4	301.5	83.0%
		Std. Dev.	0.3%	12.6	2.0	
		COV%	4.5%	3.5%	0.7%	



(a) Wet and Dry Resilient Modulus
(the Statistical Comparisons Are Only Valid within Each Mixture Type)



(b) Resilient Modulus Ratio

Figure B.36. Resilient Modulus Results for the Texas Field Project Anti-Stripping Experiment

Summary The M_R -ratio for both field projects decreased when the LAS was combined with the Evotherm WMA technology. In addition, the wet M_R stiffness for the Iowa WMA Evotherm® 3G with RAP was significantly lower as compared to the design value. The addition of hydrated lime showed more instances of improvement in terms of wet M_R stiffness.

Effect of Specimen Type

This appendix explores the differences in test results between specimen types within the same mixture type. The data utilized for this comparison correspond to the results presented in Section B.2.1, regrouped for the purpose of the specimen type comparison. The same criterion was used for comparing TSR and M_R-ratio values (i.e., 9.3 percent and 10.0 percent, respectively). For wet IDT strength and wet M_R, the differences in specimen type were assessed with ANOVA and Tukey's HSD. Moisture conditioning for all wet specimens was done following AASHTO T 283 with one F/T cycle.

In the figures presented in this section, Tukey's HSD statistical groups for the wet IDT strength or M_R values are indicated by capital letters in the center of the bars. In these same graphs, the solid part of the bar represents the average wet IDT strength or average wet M_R stiffness of three replicate specimens. The part of the bar with no fill extends up to the average dry IDT strength or average dry M_R stiffness of three replicate specimens. The error bars represent ± one standard deviation from the average values.

Each mixture type is represented with a different color, and the specimen types are illustrated with different patterns. In all figures, the order of the specimen types from left to right is as follows: PMFC cores at construction, after winter at 6 months in service (Iowa and Montana) and after summer at 8 or 12 months in service (Texas and Iowa, respectively); on-site PMLC specimens; off-site PMLC specimens; and finally, LMLC specimens. In the case of the M_R-ratio, several spaces corresponding to the PMFC cores are left blank when the data were not available.

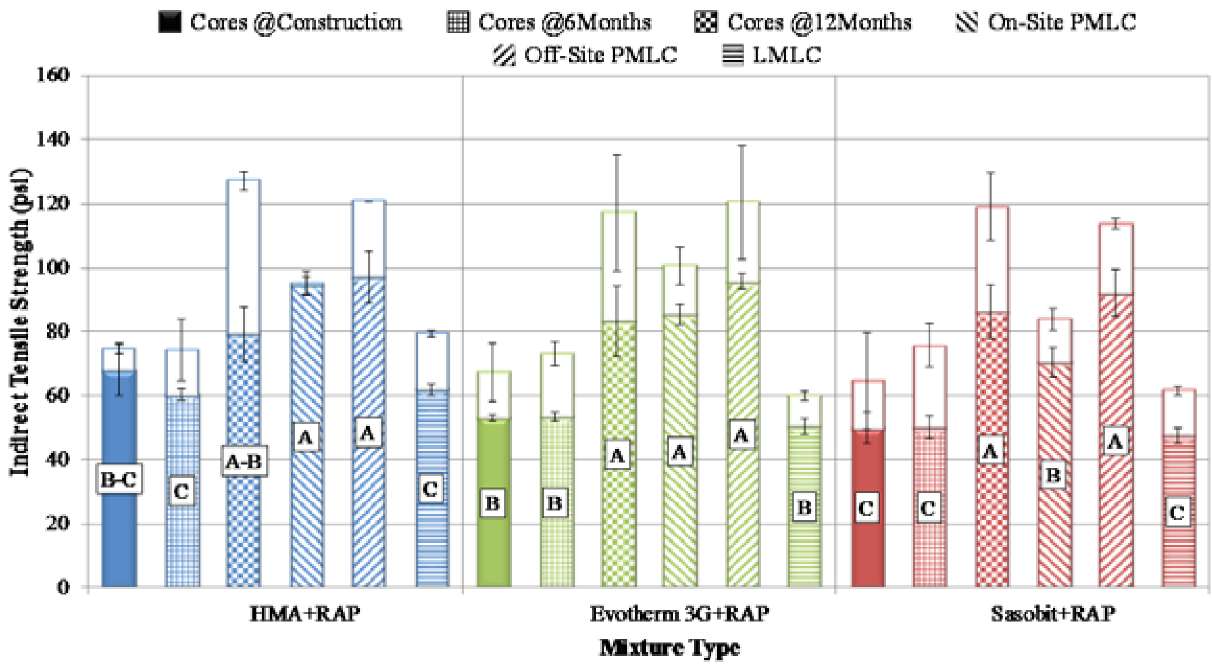
Dry and Wet IDT Strength and TSR

Iowa Field Project Figure B.37 shows the IDT test results for the three mixture types used in the Iowa field project along with Tukey's HSD statistical groups. For all mixture types, PMFC cores at construction, PMFC cores after winter at 6 months in service, and LMLC specimens provided similar wet strengths (Figure B.37). This verified that the selected conditioning protocol for preparing LMLC specimens (i.e., 2 h at 275°F [135°C] for HMA and 2 h at 240°F [115°C] for WMA) simulates not only dry M_R stiffness but also the performance after moisture conditioning of PMFC cores in early life. PMFC cores after summer at 12 months in service showed higher wet and dry IDT strengths for all mixture types, but TSR varied within mixture types.

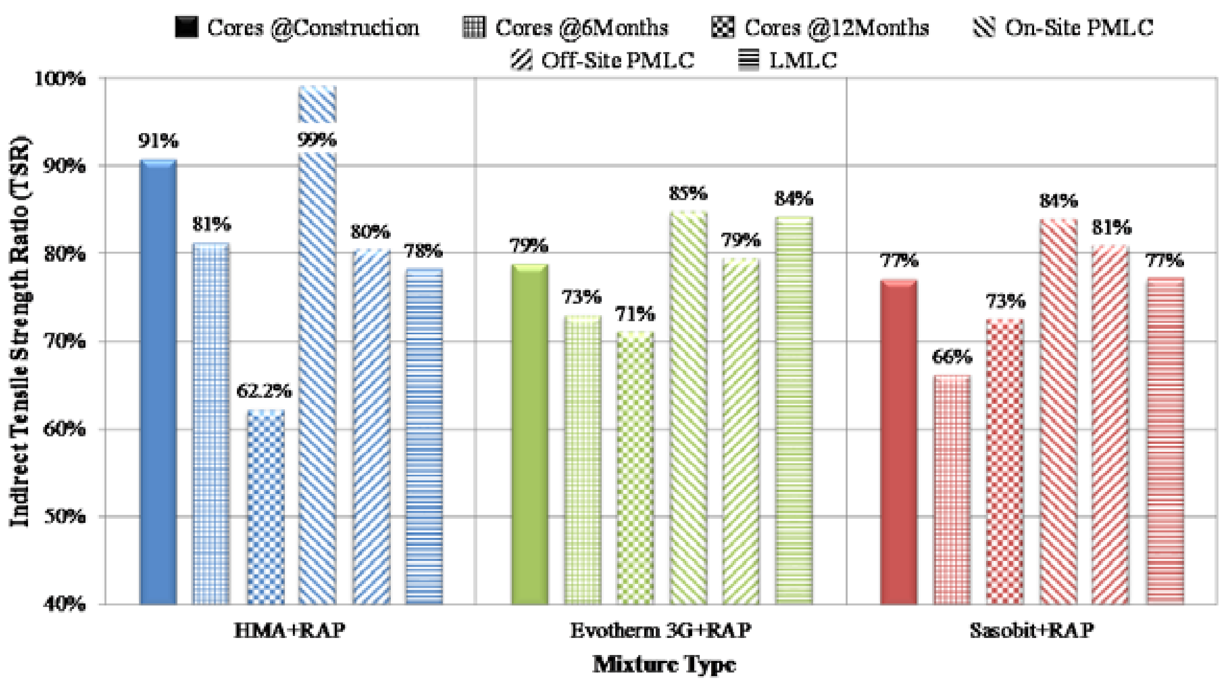
The wet IDT strengths for on-site PMLC versus off-site PMLC specimens were statistically equivalent for WMA Evotherm® 3G with RAP and HMA with RAP, but for the WMA Sasobit® with RAP, the off-site PMLC specimens had a higher wet IDT strength. The dry IDT strengths for off-site PMLC specimens were consistently higher, resulting in lower TSR values. The on-site PMLC specimens had the highest TSR for all mixture types. For WMA Evotherm® 3G with RAP and Sasobit® with RAP, the PMFC cores after summer at 12 months in service and after winter at 6 months in service, respectively, showed the lowest TSR, while the HMA PMFC cores after summer at 12 months in service showed the lowest TSR within that mixture type (Figure B.37[b]).

Based on the d2s value of 9.3 percent, there was a significant difference between on-site and off-site (reheated) PMLC specimens in terms of TSR for HMA with RAP but not for the WMAs with RAP. With field aging over a 12 month period, the PMFC cores showed a statistically significant decrease in TSR for HMA with RAP, but not for the WMAs with RAP.

The LMLC specimens for all mixture types represented the early life (i.e., equivalent performance to the PMFC cores at construction or PMFC cores after winter at 6 months in service) in terms of TSR.



(a) Wet and Dry Indirect Tensile Strength
(the Statistical Comparisons Are Only Valid within Each Mixture Type)



(b) Tensile Strength Ratio

Figure B.37. Indirect Tensile Strength Results by Mixture Type for the Iowa Field Project

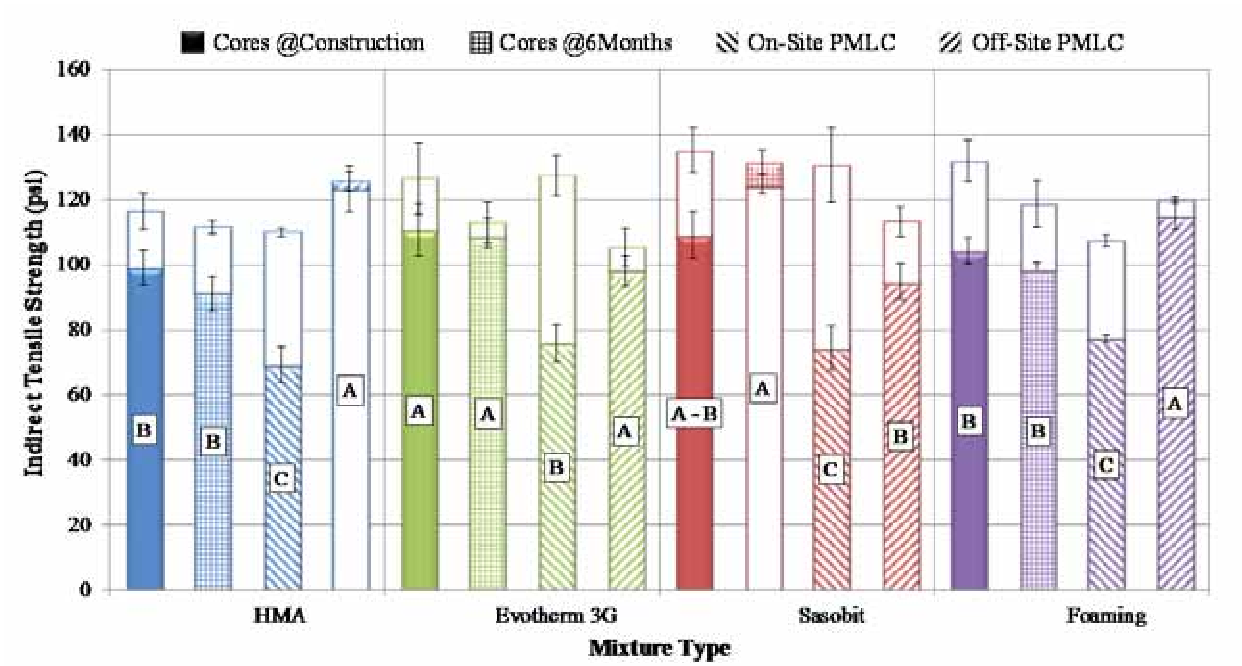
Montana Field Project Results for Montana IDT testing grouped by mixture type and compared by specimen type are provided in Figure B.38. The dry IDT strengths for both on-site PMLC specimens and PMFC cores (both at construction and after winter at 6 months in service) were comparable; however, the wet IDT strengths were statistically lower for the on-site PMLC specimens as compared to their PMFC core counterparts (Figure B.38[a]). This translated into much lower TSR values for on-site PMLC specimens, as shown in Figure B.38(b). The reason for this difference is likely the specimen AV, which ranged between 6.4 to 7.1 percent for on-site PMLC specimens, between 3.6 and 5.4 percent for PMFC cores at construction, and between 2.8 and 3.8 percent for PMFC cores after winter at 6 months in service.

All TSR values (Figure B.38[b]) except for the ones obtained for the on-site PMLC specimens were close to or exceeded 80 percent. This trend is opposite to the one observed for the Iowa field project, where the on-site PMLC specimens had the highest TSR for all specimen types. The highest TSR values for the WMA specimens corresponded to the off-site PMLC specimens and PMFC cores at 6 months. This again is contrary to the observation for the Iowa field project, where the PMFC cores at 6 and 12 months after construction showed the lowest TSR values.

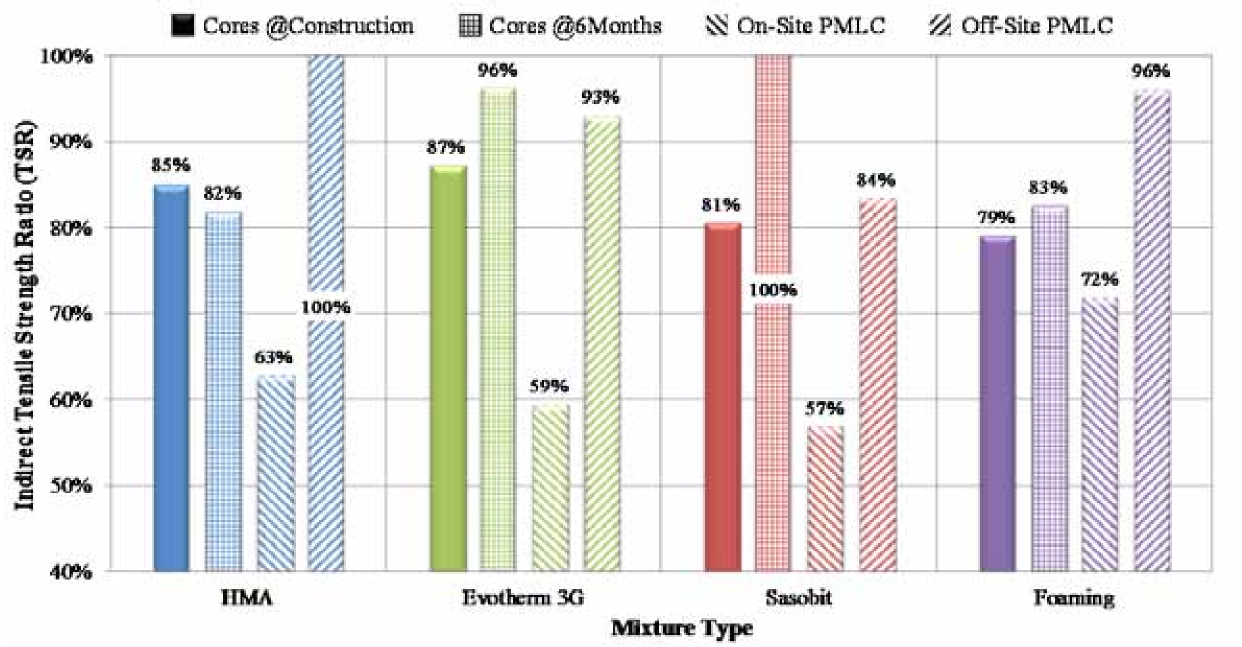
Using the d2s value of 9.3 percent to compare the TSR values, a significant difference was observed between on-site and off-site (reheated) PMLC specimens in terms of TSR for HMA and both WMAs.

Texas Field Project The IDT strength test results for the Texas field project showed that the PMFC cores after summer at 8 months in service had significantly higher values of dry and wet IDT strength for HMA and WMAs as indicated by the statistical groups in Figure B.39(a). TSR values for these PMFC cores after summer at 8 months in service (Figure B.39[b]) were also the highest for both WMAs and significantly higher with respect to the PMFC cores at construction for all mixtures. The LMLC specimens were closest to the PMFC cores at construction in terms of wet IDT strength for both WMAs. For all mixture types, the lowest wet IDT strength corresponded to the PMFC cores at construction.

When applying the d2s value of 9.3 percent to compare the TSR results, a significant difference between HMA on-site and off-site (reheated) PMLC specimens was observed. With aging over an 8 month period, the PMFC cores showed a significant increase in TSR for HMA and both WMAs. The TSR of the LMLC specimens for both WMAs was significantly different from both PMFC cores at construction and PMFC cores after summer at 8 months in service, with values in between these two instances. For the HMA mixtures, on the other hand, the LMLC specimens exhibited larger TSR values than both sets of PMFC cores.

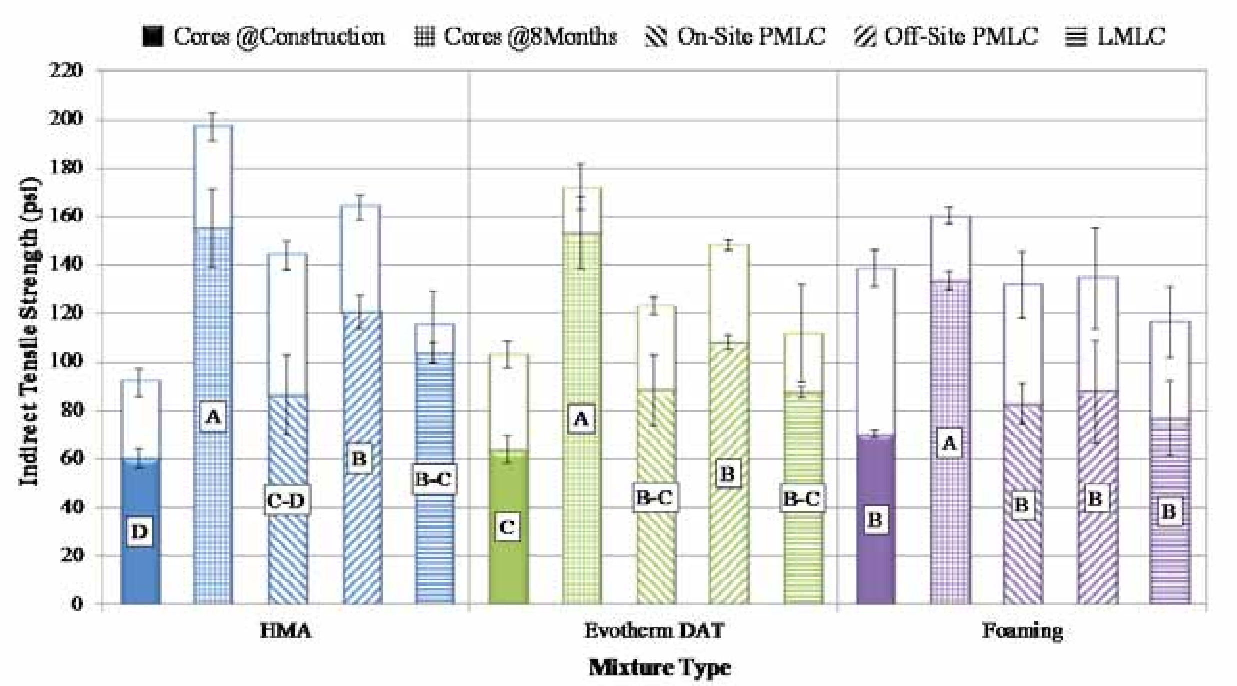


(a) Wet and Dry Indirect Tensile Strength
(the Statistical Comparisons Are Only Valid within Each Mixture Type)

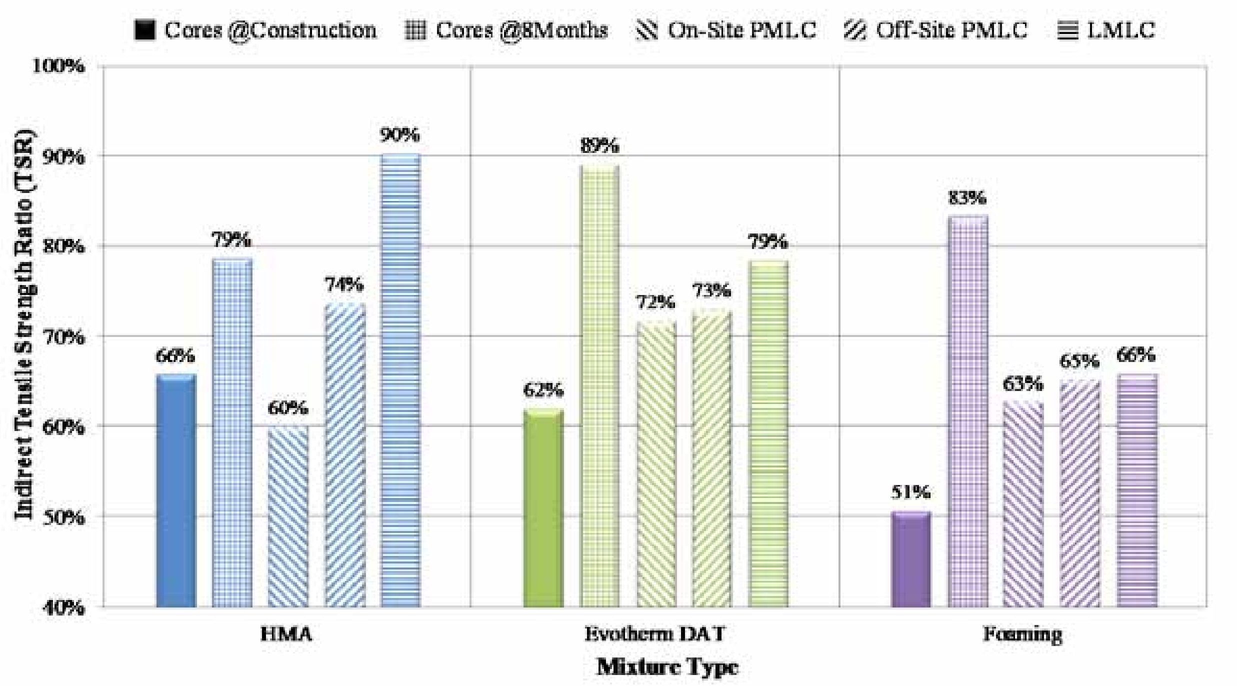


(b) Tensile Strength Ratio

Figure B.38. Indirect Tensile Strength Results by Mixture Type for the Montana Field Project



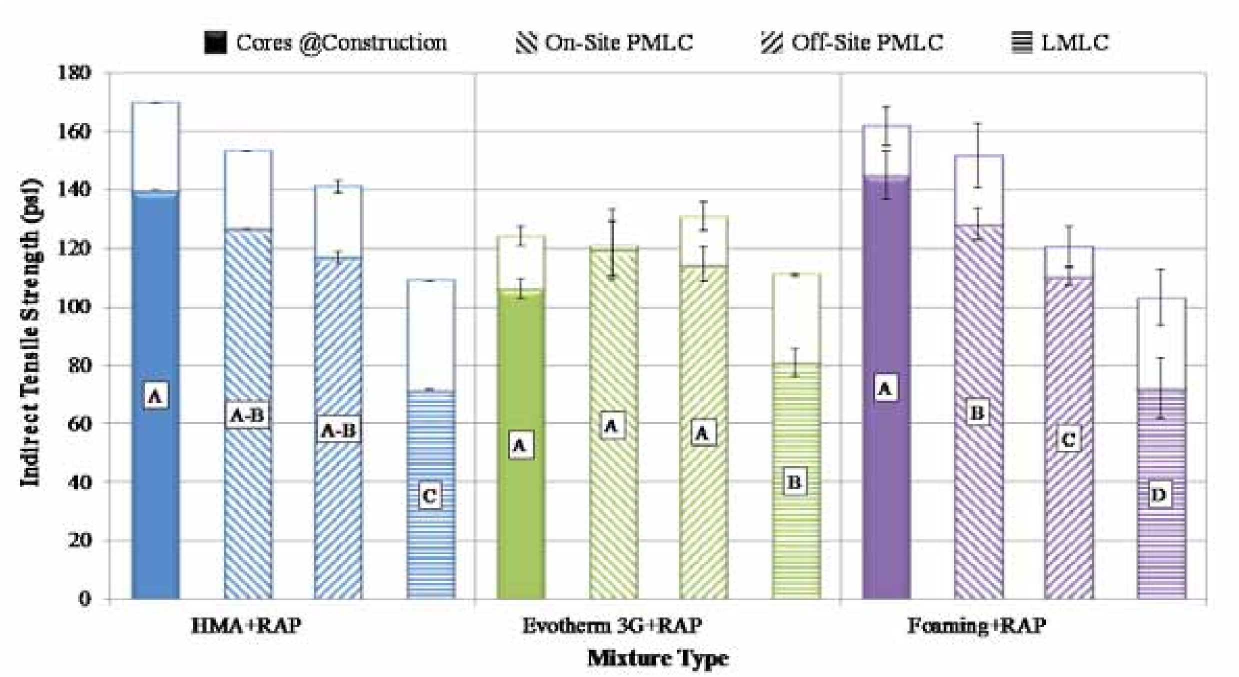
(a) Wet and Dry Indirect Tensile Strength
(the Statistical Comparisons Are Only Valid within Each Mixture Type)



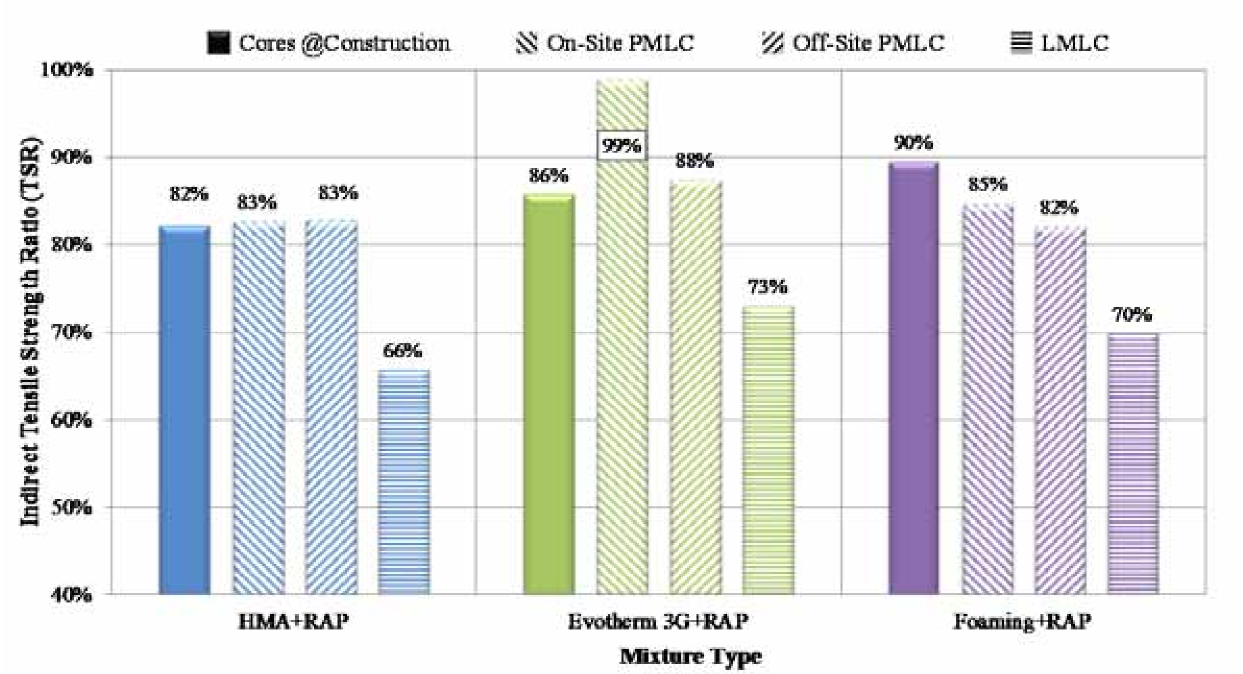
(b) Tensile Strength Ratio

Figure B.39. Indirect Tensile Strength Results by Mixture Type for the Texas Field Project

New Mexico Field Project The effect of specimen type on the IDT testing for the New Mexico field project is shown in Figure B.40. The LMLC specimens showed decreased performance in terms of dry and wet IDT strengths and TSR values in comparison to the PMLC specimens and PMFC cores at construction. In the case of wet IDT strength, HMA with RAP and WMA Evotherm® 3G with RAP PMFC cores at construction, on-site PMLC, and off-site PMLC were equivalent. For WMA Foaming with RAP, the wet IDT strengths were higher for the PMFC cores at construction followed by the on-site PMLC and then the off-site PMLC specimens.



(a) Wet and Dry Indirect Tensile Strength
(the Statistical Comparisons Are Only Valid within Each Mixture Type)



(b) Tensile Strength Ratio

Figure B.40. Indirect Tensile Strength Results by Mixture Type for the New Mexico Field Project

Summary For all field projects including LMLC specimens, this specimen type exhibited the lowest wet IDT strength values; in addition, all LMLC WMA mixtures in these same field projects (with the exception of New Mexico) had wet IDT strength values comparable to the ones obtained for PMFC cores at construction. In most cases, the best performing specimen types were the PMFC cores after summer, the off-site PMLC specimens, or both.

Dry and Wet M_R and M_R-ratio

Iowa Field Project The on-site PMLC specimens for this field project were received in October 2011, immediately tested for dry M_R, stored at 77°F (25°C) until the summer of 2012, and at that time retested for dry M_R and conditioned for wet M_R to obtain the M_R -ratio. The dry M_R values measured in October 2011 were lower than the M_R values measured during the summer of 2012, which indicated that these specimens aged when stored at 77°F (25°C). In addition, the difference in stiffness was more pronounced for the WMA mixtures (about 25 percent increase in M_R) versus the HMA mixtures (about 10 percent increase in M_R). Therefore, the conclusions obtained from the comparison of on-site PMLC specimens for this field project may have been affected by the higher storage temperatures these specimens experienced. For all other field projects, if there was a lag between specimen acquisition and testing, the specimens were stored in a temperature-controlled room set between 64°F and 68°F (18°C and 20°C).

In terms of dry M_R stiffness, PMFC cores after winter at 6 months in service for all the mixtures, especially in the case of HMA with RAP and Evotherm® 3G with RAP, demonstrated equivalent M_R stiffness to the PMFC cores at construction (Figure B.41[a]). Therefore, the change in dry M_R stiffness after one winter (i.e., at construction versus at 6 months) was not as pronounced. However, the PMFC cores showed a significant increase in dry M_R stiffness after

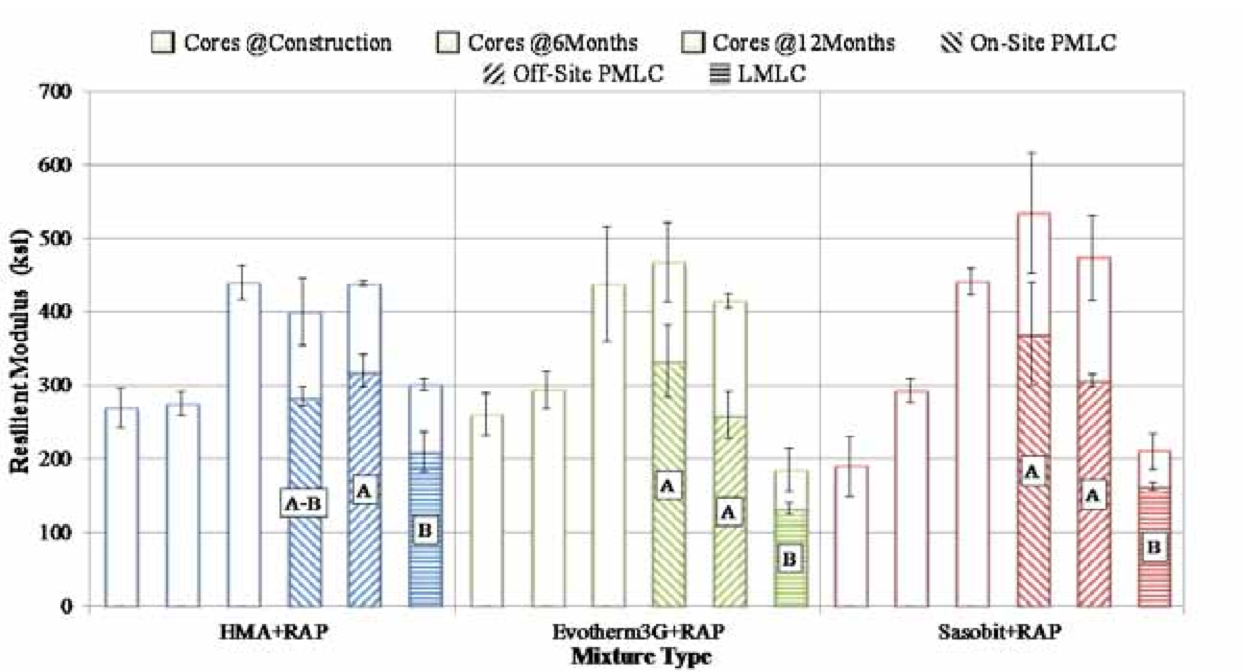
one summer at 12 months in service. For both WMA mixtures, the LMLC specimens resulted in statistically lower wet M_R values as compared to the on-site or off-site PMLC specimens.

Based on the assumed d2s value of 10 percent for M_R-ratio, there was no significant difference between on-site and off-site (reheated) PMLC specimens in terms of M_R-ratio for the HMA with RAP and both WMAs with RAP. The only significant difference based on the mentioned threshold was between the Sasobit® with RAP off-site PMLC versus LMLC specimens.

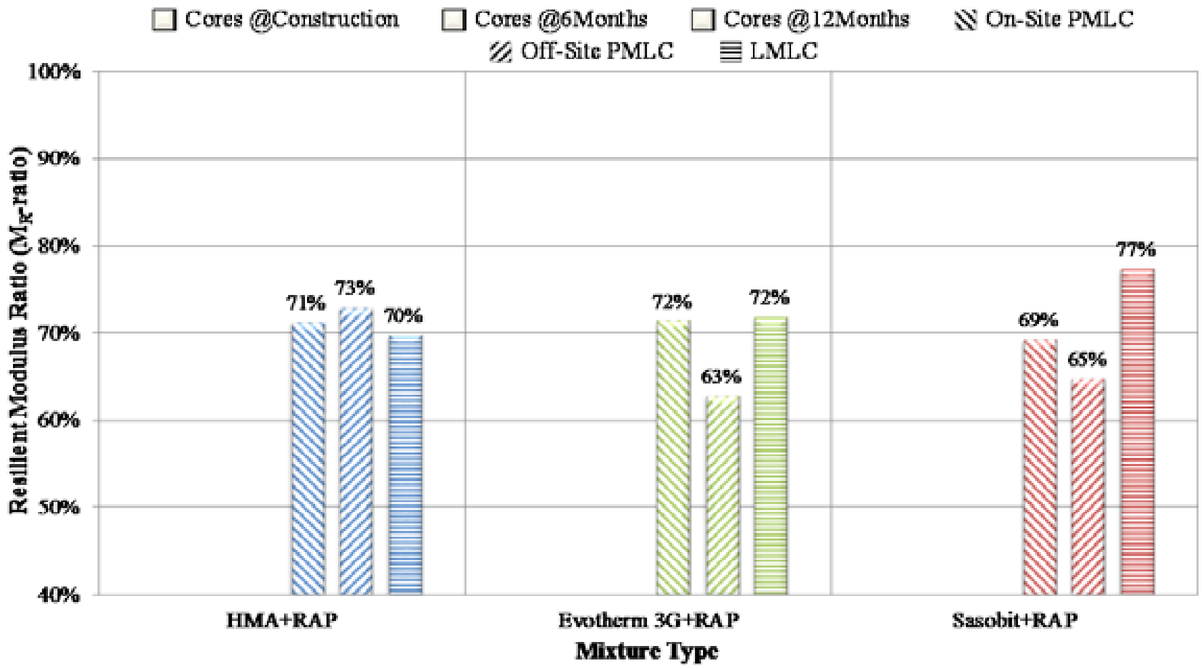
Montana Field Project The M_R results for the Montana project are shown in Figure B.42. The statistical comparison of the wet M_R results by specimen type indicated that on-site and off-site PMLC specimens had equivalent wet M_R stiffness in all instances except WMA Evotherm® 3G, where the wet M_R for the off-site PMLC specimens was lower (Figure B.42[a]). Similar to the results obtained for Iowa, the dry M_R values for the PMFC cores at construction and PMFC cores after winter at 6 months in service were practically equivalent, when considering the average value and the ± one standard deviation indicated by the error bars.

In terms of M_R-ratio, all values for on-site and off-site PMLC specimens were 80 percent or higher. Two of the WMA mixtures (i.e., WMA Evotherm® 3G and WMA Foaming) exhibited larger off-site PMLC M_R-ratios versus the on-site PMLC specimens, indicating that the difference in M_R stiffness before and after moisture conditioning was less. The other WMA Sasobit® and HMA resulted in a similar M_R-ratio for both on-site and off-site PMLC specimens.

Based on the assumed d2s value of 10 percent for M_R-ratio, the mixtures with a significant difference between on-site and off-site (reheated) PMLC specimens were WMA Evotherm® 3G and WMA Foaming.

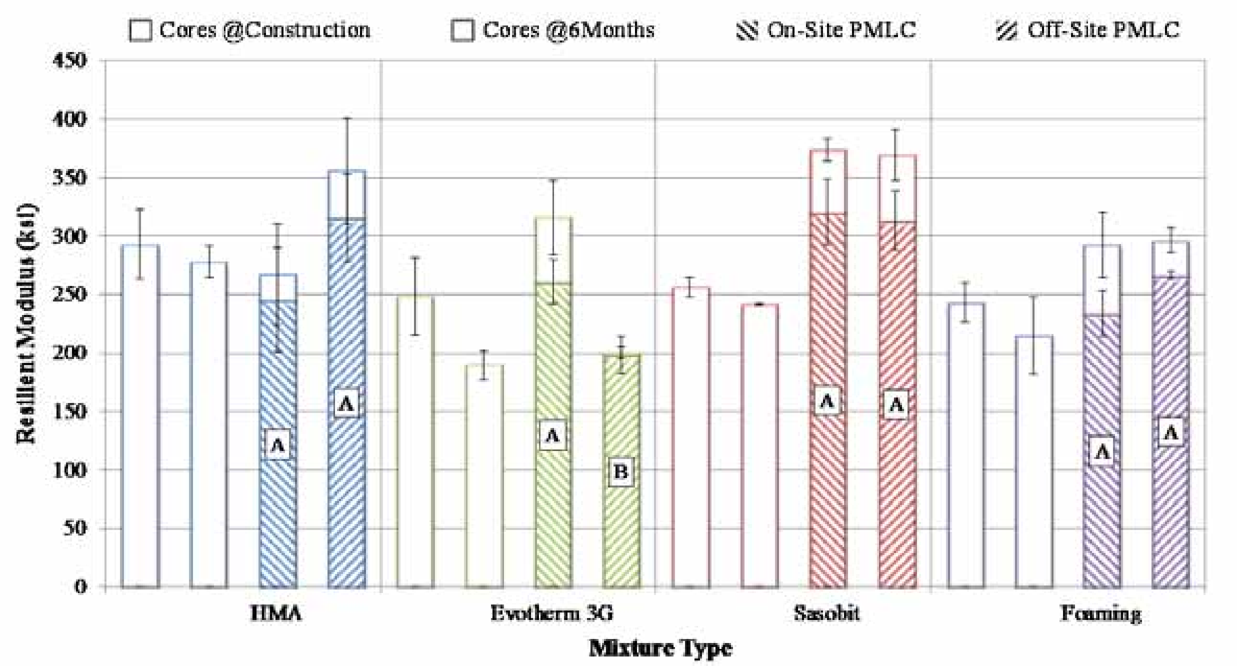


(a) Dry and Wet Resilient Modulus
(the Statistical Comparisons Are Only Valid within Each Mixture Type)



(b) Resilient Modulus Ratio

Figure B.41. Resilient Modulus Test Results by Mixture Type for the Iowa Field Project

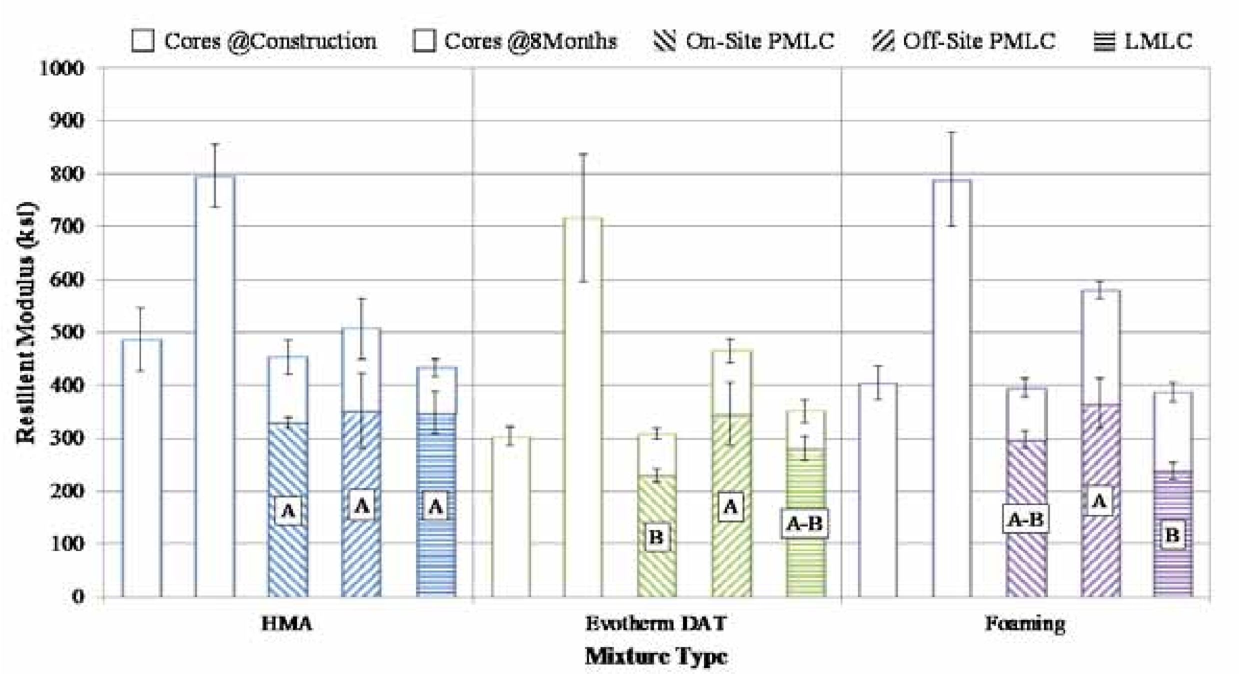


(a) Dry and Wet Resilient Modulus
(the Statistical Comparisons Are Only Valid within Each Mixture Type)

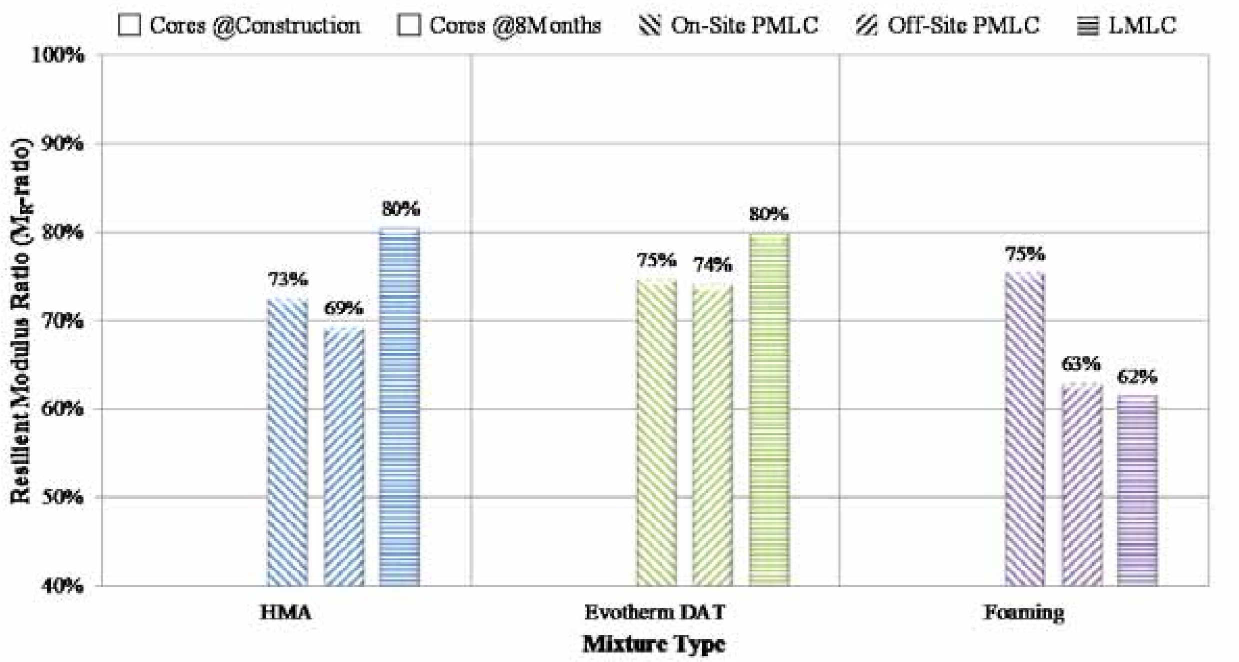
(b) Resilient Modulus Ratio

Figure B.42. Resilient Modulus Test Results by Mixture Type for the Montana Field Project

Texas Field Project Figure B.43 illustrates the M_R results for the Texas field project. The PMFC cores after summer at 8 months in service for all mixture types showed a significantly higher M_R value than the PMFC cores at construction (Figure B.43[a]). In addition, after a summer in the field, both WMAs exhibited equivalent dry stiffness as compared to HMA. On-site PMLC and LMLC specimens showed equivalency in both dry and wet M_R for all mixture types. The off-site WMA specimens showed a slightly higher or equivalent wet M_R stiffness as compared to the on-site or LMLC specimens. As shown in Figure B.43(b) and based on the assumed d2s value of 10 percent for M_R -ratio, there was no significant difference between on-site and off-site (reheated) PMLC specimens in terms of M_R -ratio for the HMA and WMA Evotherm DAT™. In addition, for these two mixtures, the TSR for the LMLC specimens was higher. The on-site PMLC specimens for WMA Foaming exhibited higher M_R -ratio as compared to the off-site PMLC or LMLC specimens.



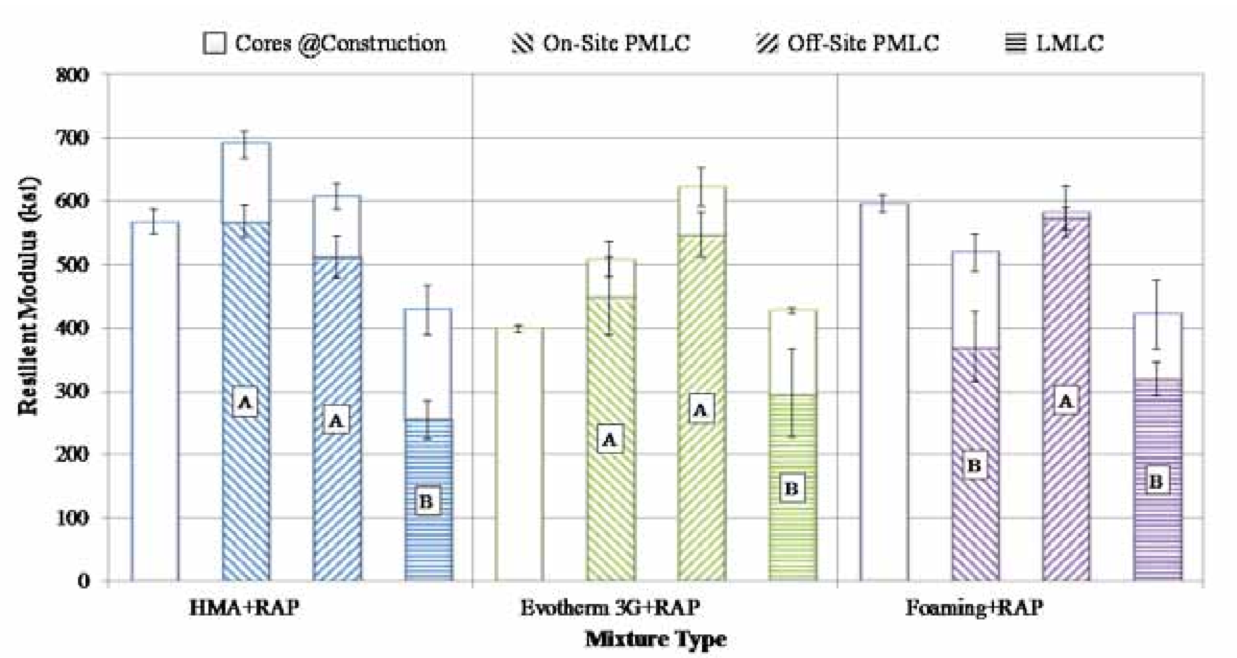
(a) Dry and Wet Resilient Modulus
(the Statistical Comparisons Are Only Valid within Each Mixture Type)



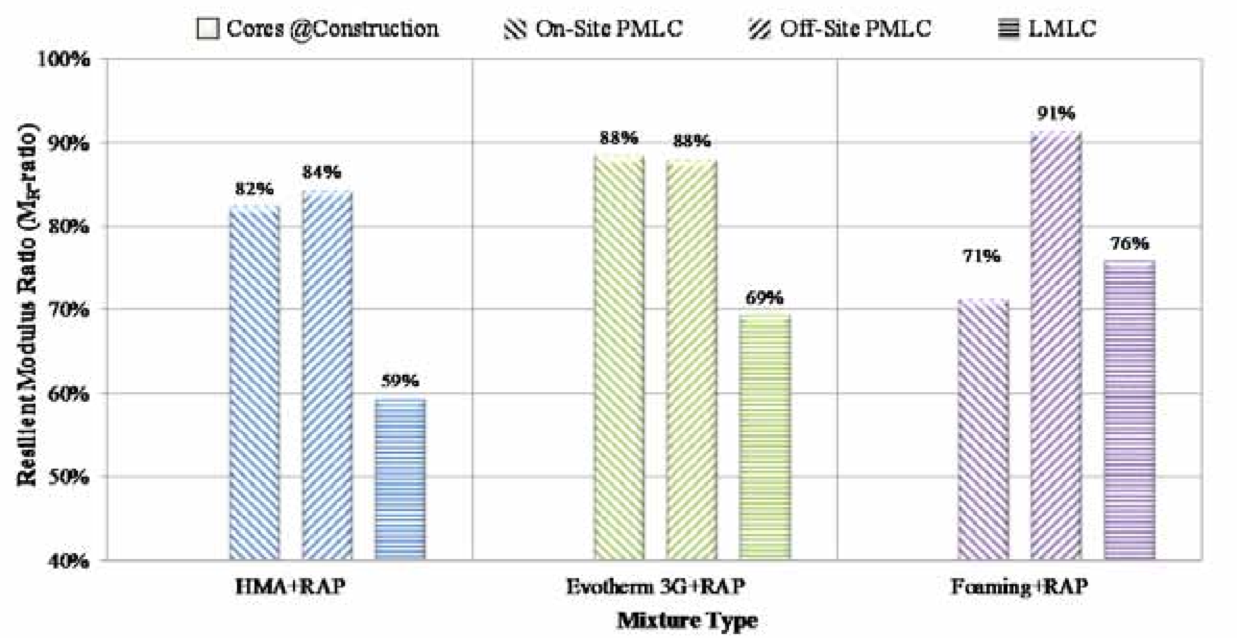
(b) Resilient Modulus Ratio

Figure B.43. Resilient Modulus Test Results by Mixture Type for the Texas Field Project

New Mexico Field Project M_R results from the New Mexico field project are shown in Figure B.44. In general, the on-site PMLC and off-site PMLC exhibited equivalent wet M_R stiffness. The one exception was WMA Foaming with RAP, which showed an increase in M_R stiffness for the off-site PMLC specimens, possibly as a result of reheating the mixture (Figure B.44[a]).



(a) Dry and Wet Resilient Modulus (the Statistical Comparisons Are Only Valid within Each Mixture Type)



(b) Resilient Modulus Ratio

Figure B.44. Resilient Modulus Test Results by Mixture Type for the New Mexico Field Project

The wet stiffness of the LMLC specimens was statistically equivalent to the wet stiffness of the on-site PMLC specimens for HMA and WMA Foaming with RAP; for the other two mixtures, the wet stiffness of the on-site PMLC specimens was statistically higher.

For HMA with RAP and WMA Evotherm® 3G with RAP LMLC specimens, the wet M_R values were significantly lower than the ones obtained for on-site or off-site PMLC specimens. The same trend was observed in the case of M_R-ratio (Figure B.44[b]), with much lower ratios for HMA with RAP and WMA Evotherm® 3G with RAP LMLC specimens. The highest M_R-ratio for WMA Foaming was obtained in the case of the off-site PMLC specimens.

Summary For all field projects, the wet M_R stiffness and M_R -ratio between on-site and off-site PMLC specimens were in most cases statistically equivalent.

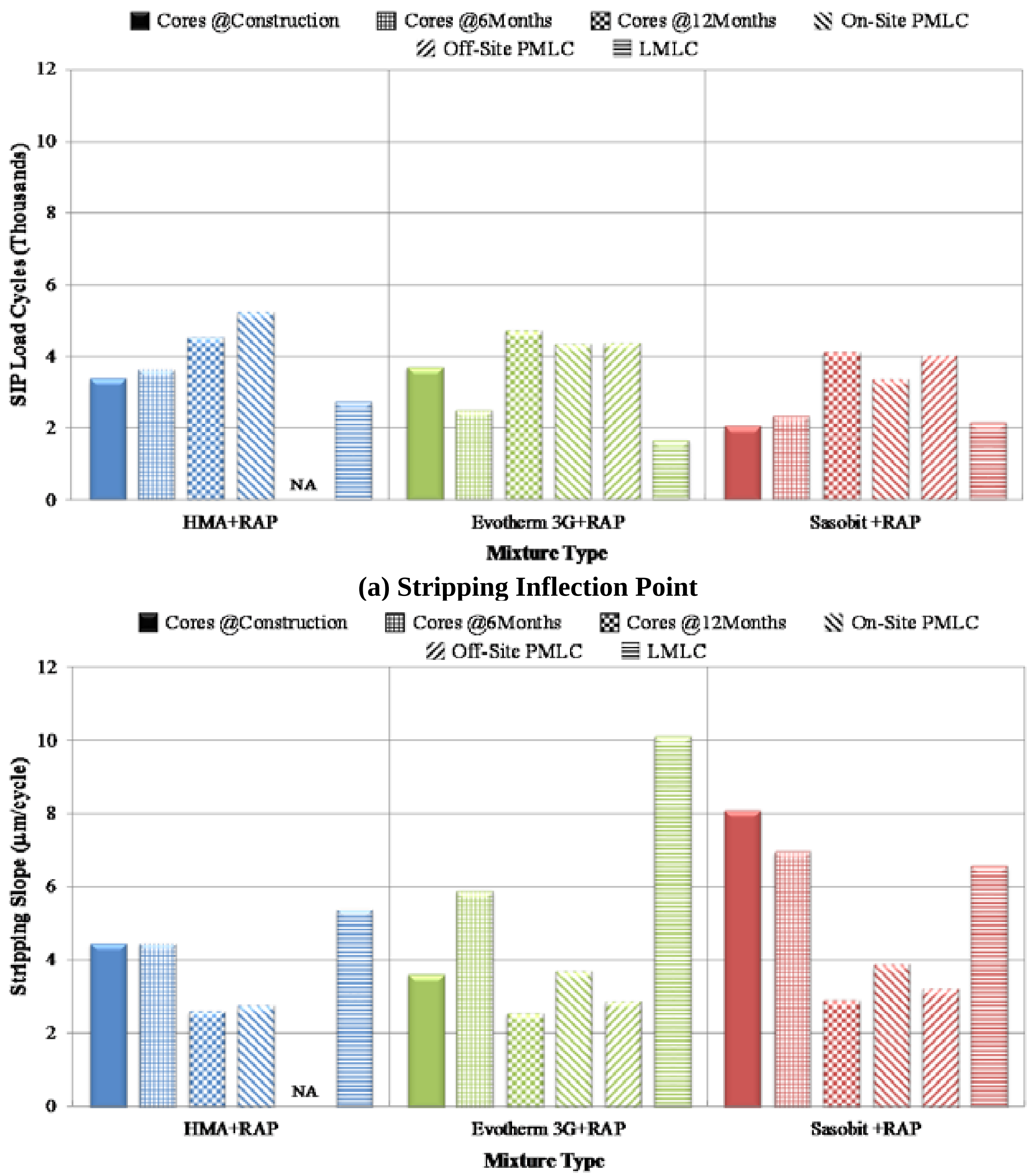
Hamburg Wheel-Tracking Test Results

The data presented in this section corresponds to the information previously detailed in Section B.2.1.3 with the difference being that in the figures, the groupings are made by mixture type in order to facilitate identifying the differences in specimen type.

Iowa Field Project HWTT results for the Iowa field project compared by specimen type within each mixture type are shown in Figure B.45 in terms of SIP and stripping slope. In general, all Iowa mixtures performed poorly regardless of the specimen type. All SIP values were below 6,000 cycles, which demonstrates these mixtures are moisture susceptible. From the stripping slope results, it is clear that the PMFC cores after a summer at 12 months in service performed better than any other specimen type. This confirms that with time, not only did the stiffness of the mixtures increase, but also their moisture resistance improved. This is true for both HMA and WMAs.

Montana Field Project Figure B.46 shows the HWTT results for the Montana field project comparing different specimen types; results are shown in terms of SIP and stripping slope. PMFC cores at construction and PMFC cores after winter at 6 months in service showed poorer performance as compared to the on-site and off-site PMLC specimens. Nevertheless, all mixtures from this field project exhibited adequate performance, with relatively high SIP values and a low rate of deterioration after stripping, as indicated by the low stripping slope values (i.e., 1.0 μm/cycle or below).

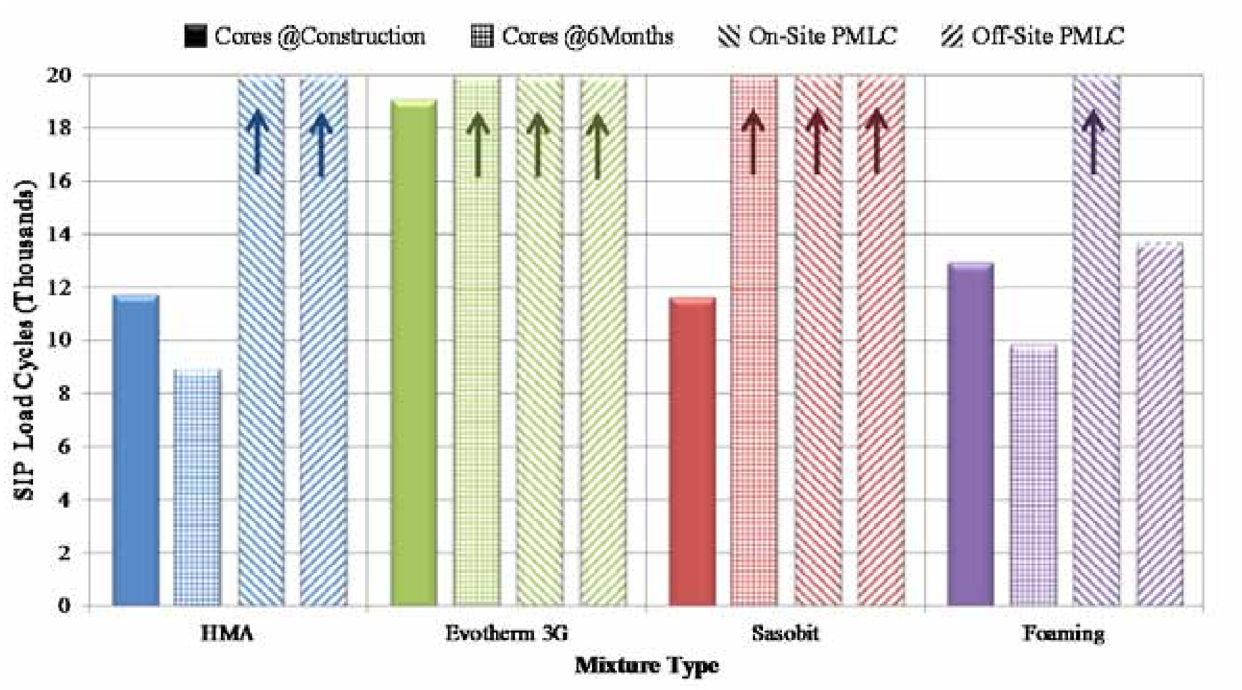
Texas Field Project Figure B.47 shows the HWTT SIP and stripping slope results for the Texas field project. In this case, there was no clear trend for most of the specimen types. PMFC cores after summer at 8 months in service were the only specimens that for all mixture types showed a high SIP (greater than 20,000 cycles in the case of WMA Evotherm DAT™ and WMA Foaming and low stripping slope in the case of HMA). The worst performers were Evotherm DAT™ on-site PMLC specimens and WMA Foaming LMLC specimens, demonstrating low SIP and high stripping slope values. In all other instances, the SIP was close to or above 6,000 cycles and the stripping slope was below 2.0 μm/cycle.



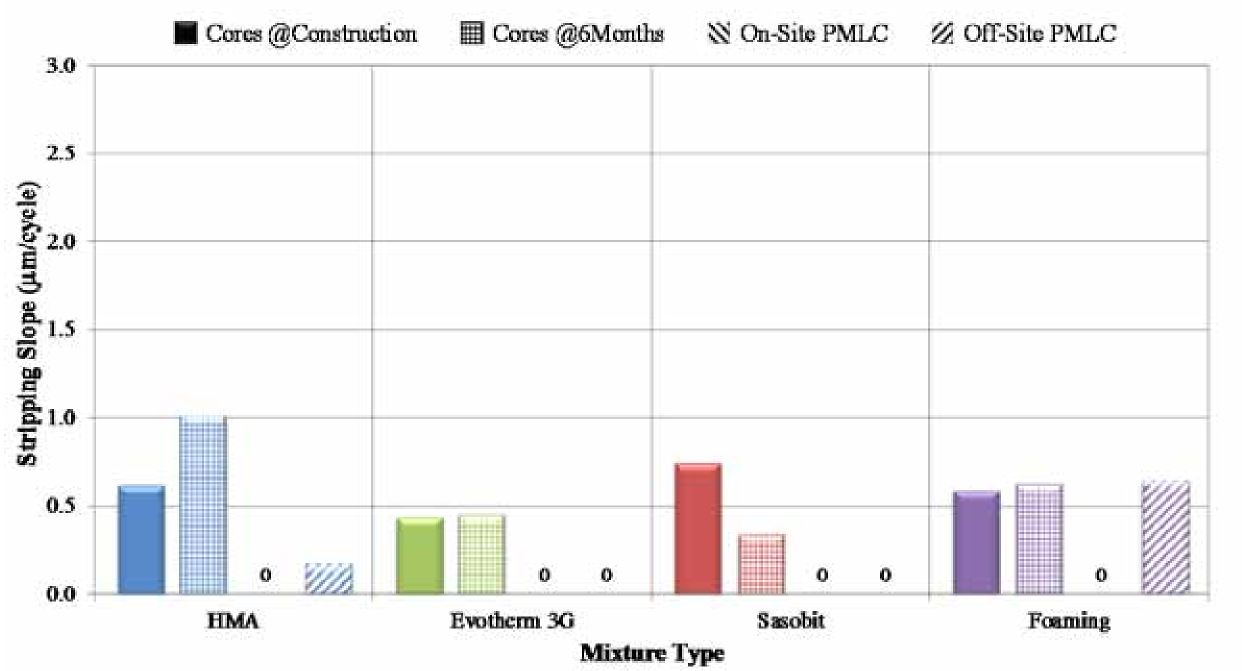
(a) Stripping Inflection Point

(b) Stripping Slope

Figure B.45. HWTT Results by Mixture Type for the Iowa Field Project

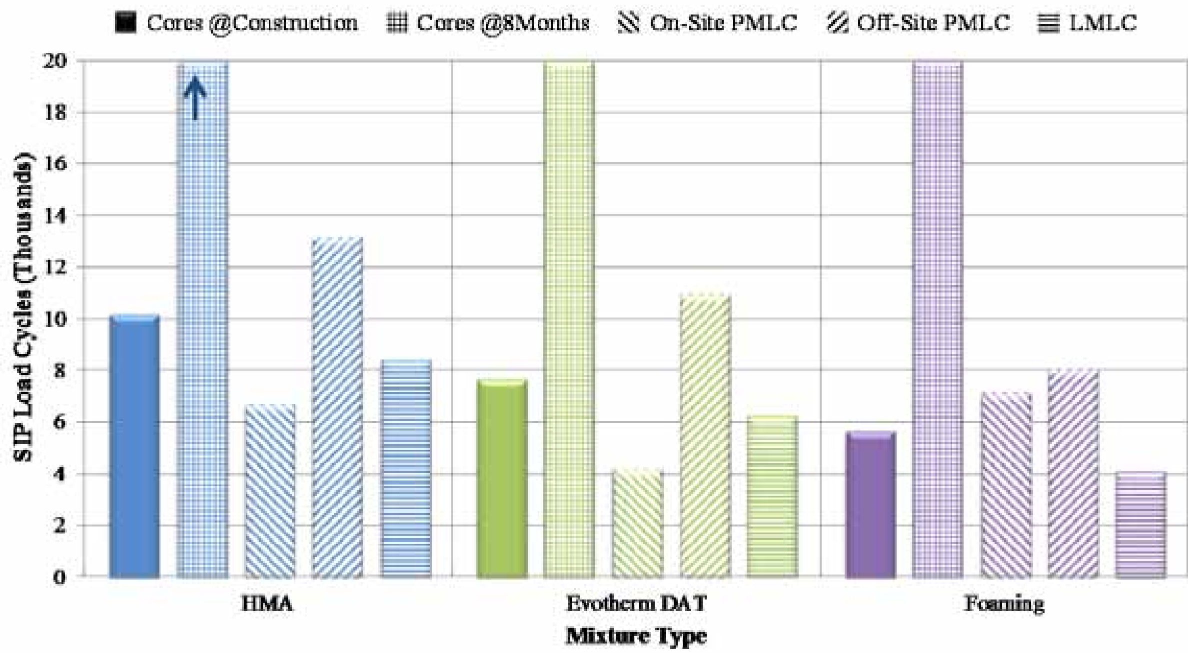


(a) Stripping Inflection Point

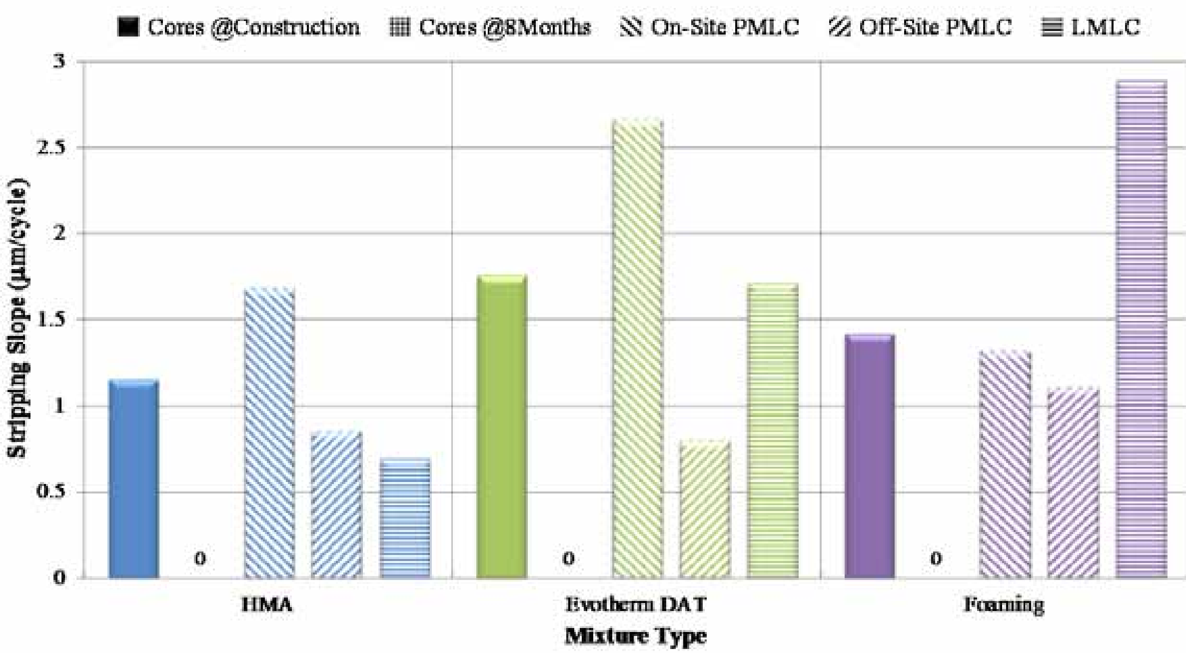


(b) Stripping Slope

Figure B.46. HWTT Results by Mixture Type for the Montana Field Project



(a) Stripping Inflection Point



(b) Stripping Slope

Figure B.47. HWTT Results by Mixture Type for the Texas Field Project

New Mexico Field Project For the New Mexico field project, all mixture types showed a SIP higher than 20,000 cycles and consequently a stripping slope of 0 μm/cycle. Regardless of the differences in rutting, as shown in Figure B.29 through Figure B.32, there was no evidence of stripping for any of these mixtures, and therefore all specimen types were considered equivalent in terms of HWTT performance.

Summary For the WMA mixtures belonging to the Iowa and Texas field projects, the PMFC cores after a summer in service exhibited the best performance among all specimen types. For the Montana and New Mexico field projects, all mixture types within the different specimen types performed well. These two field projects included an anti-stripping agent in their mixtures—hydrated lime in the case of Montana and Versabind in the case of New Mexico. The inclusion of these anti-strip agents not only improved the moisture resistance of the mixtures but also stiffened them, providing better HWTT results and minimizing the differences in results with additional aging.

APPENDIX C. PERFORMANCE EVOLUTION EXPERIMENT

PREVIOUS RESEARCH ON WMA PERFORMANCE EVOLUTION

The results from the laboratory conditioning experiment indicated that the initial stiffness of the warm mix asphalt (WMA) is less than the stiffness of conventional hot mix asphalt (HMA), and this gap can be reduced with increased elapsed time in the field. In the past few years, a number of studies were conducted to quantify WMA performance evolution for WMA in an effort to understand the difference between HMA and WMA and its impact on performance. More importantly, it is relevant to determine when (or if) the properties of the two types of mixtures converge. This is particularly significant when evaluating moisture susceptibility, which can occur early in the life of the pavement or after several years in service, depending on environmental and loading conditions.

In a recent research study aimed at identifying moisture-conditioning parameters that caused variability in the modified Lottman (i.e., AASHTO T 283) test results and lack of agreement between the laboratory test results and observed field performance, the evolution effect was recognized as a crucial factor in understanding and describing these discrepancies (Kringos et al., 2009). Moisture infiltration in the field is a concentration-driven process and, as such, the time necessary for the moisture to activate in the components of the mixture and the weakening mechanism (e.g., pumping action) is most likely different from the saturation used in the laboratory procedure, which is based on pressure (i.e., vacuum saturation) and static loading. In addition, the evolution was identified as the link between mixture physical properties (i.e., mastic film thickness) and environmental conditions (i.e., accessibility to moisture) that may indicate when moisture damage is more likely to occur in the field (Kringos et al., 2011).

For binders, the effect of aging time and temperature on performance was evaluated on short-term and long-term aged WMA binders at standard and low temperatures (Hanz et al., 2011). A performance-grade (PG) 64-22 binder combined with Advera®, Rediset™, and a viscosity-reducing additive was evaluated. For the short-term aging, the rolling thin film oven (RTFO) procedure at the standard temperature of 325°F (163°C) and reduced temperatures of 220°F (104°C) and 250°F (121°C) was used. The performance evaluation was based on the continuous PG and non-recoverable creep compliance. The long-term oven aging was done using the pressure aging vessel (PAV) at 220°F (104°C) and 325°F (163°C). The high temperature binder properties were significantly affected by the lower short-term aging temperature, causing a decrease equivalent to one PG (i.e., 6°C) for the binders aged at 220°F (104°C). In contrast, the intermediate and low temperature binder properties were not significantly affected by the PAV aging at lower temperatures. From these observations, the study concluded that reduced binder aging had an adverse effect on the high temperature performance of the binder, especially during the early life of the pavement.

For mixtures, several researchers have also measured the effect of long-term oven aging (LTOA) on WMA. Mogawer et al. (2010) used WMA mixtures prepared using Advera® and SonneWarmix™, conditioned/cured for 4 h at 235°F (113°C), allowed to cool at room temperature for 6 h, and then long-term aged for 14 h at 140°F (60°C). The results of the Hamburg Wheel-Tracking Test (HWTT; AASHTO T 324) were compared against WMA mixtures aged for 4 h at 235°F (113°C), 265°F (129°C), and 295°F (146°C). For SonneWarmix™, the number of load cycles needed to reach the stripping inflection point (SIP) was lower (i.e., 4,200 passes) than for those with 4 h conditioning/curing at 235°F (113°C; i.e.,

4,300 passes). For Advera®, the number of load cycles (i.e., 4,000 passes) needed was between the values obtained for those with conditioning/curing at 235°F (113°C; i.e., 3,400 passes) and 265°F (129°C; 5,500 passes).

In another study, the effect of LTOA on WMA mixtures was assessed by oven aging the specimens in a forced-draft oven for 5 days at 185°F (85°C). Mixtures were prepared with Aspha-min®, Sasobit®, and Evotherm DAT™ using two aggregate sources and various amounts of coal ash and shingles (Xiao et al., 2011). The indirect tensile (IDT) strength values of the aged and unaged specimens were very similar; however, the difference was significant for moisture-conditioned WMA specimens according to the South Carolina SC T70 procedure. The IDT strength for the moisture-conditioned and aged WMA specimens was higher versus their unconditioned counterparts (except for Aspha-min®). The study concluded that the long-term oven-aging process improved the moisture susceptibility of the WMA mixtures.

A study by Diefenderfer and Hearon (2008) also used the LTOA in a forced-draft oven at 185°F (85°C) for 4 and 8 days to evaluate the performance of WMA mixtures prepared with Sasobit® in the IDT strength test (AASHTO T 283). Test results indicated that the tensile strength ratio (TSR) of WMA mixtures produced at 266°F (130°C) and 230°F (110°C) increased after long-term oven aging in the oven for 4 days prior to testing, while there was no change in TSR for WMA mixtures produced at 302°F (150°C). Additionally, the increase in TSR values was shown only by WMA mixtures produced at 230°F (110°C) as the LTOA time was extended from 4 days to 8 days. In general, it was concluded by the authors that the moisture resistance of WMA mixtures with Sasobit® increased significantly with LTOA.

A study at University of Nottingham was performed by Brown and Scholz (2000) to evaluate the aging characteristics of asphalt mixtures. In the study, a set of specimens of different mixtures was fabricated and long-term aged at 185°F (85°C) for 120 h prior to being tested to determine the mixture stiffness. Laboratory results indicated that there was a significant increase in stiffness of mixtures with LTOA. Therefore, it was concluded that LTOA was effective in increasing mixture stiffness.

A study (Bueche and Dumont, 2011) aimed at evaluating the effect of aging time on mixture properties proposed that WMA properties in terms of rutting resistance and moisture susceptibility are not significantly affected by aging time. In the study, specimens were long-term aged at room temperature for a series of periods (0, 1, 2, 4, and 12 weeks) prior to being tested with the HWTT (AASHTO T 324) and IDT strength test (AASHTO T 283). From the test results, no significant difference in terms of moisture resistance was shown for those mixtures with different aging times.

In the field, the effect of the evolution has been evaluated using plant-mixed, field-compacted (PMFC) cores from WMA pavements after 1 month and 1 year in service (Estakhri et al., 2009). The HWTT rut depths were compared to those for plant-mixed, laboratory-compacted (PMLC) specimens that were prepared at a compaction temperature of 240°F (116°C) and 300°F (149°C; HMA was only compacted at 300°F [149°C]). All the laboratory-compacted WMA specimens failed the HWTT criteria of maximum rut depth of 0.5 inch (12.5 mm) at 20,000 passes. The 1 month old WMA PMFC cores showed no improvement in rut resistance, but the results of the 1 year old WMA PMFC cores improved significantly, with rutting values similar to the ones obtained for the control HMA specimens. The IDT strength results showed a significant improvement of the 1 month old cores (i.e., 160 psi [1,103 kPa]) versus the PMLC specimens (i.e., 60 psi [414 kPa]) with more than double the increase in strength. The IDT strength of the HMA control stayed constant after 1 year in service.

Another study by Estakhri (2012) evaluated the field performance of WMA with different in-service times as compared to HMA. Ten field projects in Texas were included in the study. Test results from the HWTT (AASHTO T 324), overlay test (OT), and IDT strength test (AASHTO T 283) were utilized to evaluate mixture performance in terms of resistance to rutting and cracking and dry and wet strengths. It was found in the study that in the majority of the field projects, WMA showed comparable performance as HMA in laboratory tests. In addition, WMA PMFC cores after 1 year in service indicated significant stiffening, as compared to those taken at construction.

A study aimed at correlating laboratory short-term oven aging (STOA) and LTOA with mixture aging in the field was performed by Bell et al. (1994). Several field projects were included in the study, and PMFC cores with a wide range of service life in the field were obtained and tested to determine the triaxial and diametral resilient modulus (M_R). Laboratory specimens were fabricated using materials from the field projects and conditioned with STOA and LTOA protocols prior to being tested. M_R results indicated that the STOA of 4 h at 275°F (135°C) was representative of the aging due to the construction process. Similar hardening of mixtures was achieved by LTOA at 185°F (85°C) and LTOA at a higher temperature of 212°F (100°C) for a shorter time. More specifically, the LTOA of 4 days at 212°F (100°C) or 8 days at 185°F (85°C) was approximately representative of 9 years in the field pavement.

TEST RESULTS AND DATA ANALYSES FOR WMA PERFORMANCE EVOLUTION

This chapter first provides the laboratory test results in Phase I of the WMA performance evolution experimental design, in terms of changes in mixture stiffness in the field and laboratory, followed by the correlation of mixture aging in these two conditions. Then, test results in Phase II of the WMA performance evolution experimental design are introduced, including WMA and HMA performance evaluation in terms of strength and stiffness and moisture susceptibility on the basis of IDT strength, M_R, and HWTT test results.

Phase I of the WMA Performance Evolution Experimental Design

PMFC cores at construction and after winter at 6 months or after summer at 8 months in service from the Iowa and Texas field projects, respectively, and those after summer at 12 months in service from the Iowa field project were tested to determine M_R stiffness to evaluate the change in mixture stiffness with aging in the field. Additionally, on-site PMLC specimens were also tested to represent the initial stiffness of HMA and WMA pavements in their early life. As mentioned in the WMA performance evolution experiment design in Chapter 2, Section 2.3.3, the same set of laboratory-mixed, laboratory-compacted (LMLC) specimens were aged at 140°F (60°C) over a series of periods (1, 2, 4, 8, and 16 weeks) prior to being tested with M_R. Test results in terms of stiffness change with aging in the field and laboratory are introduced in the following sections, and complete M_R results for the Iowa and Texas field projects are provided in Table C.1 and Table C.2, respectively.

Table C.1. Indirect Tensile Strength Performance Evolution Results for the Iowa Field Project

Specimen Type	Aging Stage /Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
PMFC Cores	At construction	HMA+RAP	Average	8.2%	269.3
			Standard Deviation	1.2%	27.1
			COV%	14.6%	10.1%
		Evotherm 3G+RAP	Average	8.5%	247.8
			Standard Deviation	1.1%	16.3
			COV%	12.9%	6.6%
		Sasobit+RAP	Average	8.5%	203.7
			Standard Deviation	1.5%	26.9
			COV%	17.6%	13.2%
PMFC Cores	After winter at 6 months	HMA+RAP	Average	7.5%	275.5
			Standard Deviation	0.0%	15.6
			COV%	0.1%	5.7%
		Evotherm 3G+RAP	Average	7.2%	293.4
			Standard Deviation	0.1%	16.0
			COV%	1.9%	5.5%
		Sasobit+RAP	Average	6.9%	293.8
			Standard Deviation	0.2%	25.6
			COV%	2.8%	8.7%
PMFC Cores	After summer at 12 months	HMA+RAP	Average	7.0%	440.6
			Standard Deviation	0.3%	22.5
			COV%	4.5%	5.1%
		Evotherm 3G+RAP	Average	7.7%	437.9
			Standard Deviation	0.7%	77.8
			COV%	9.7%	17.8%
		Sasobit+RAP	Average	7.1%	441.3
			Standard Deviation	0.7%	18.6
			COV%	10.0%	4.2%
LMLC	0 week at 140°F	HMA+RAP	Average	7.4%	334.8
			Standard Deviation	0.5%	10.1
			COV%	7.2%	3.0%
		Evotherm 3G+RAP	Average	6.4%	224.4
			Standard Deviation	0.1%	7.3
			COV%	2.1%	3.2%
		Sasobit+RAP	Average	7.6%	214.2
			Standard Deviation	0.5%	25.2
			COV%	6.5%	11.8%
LMLC	1 week at 140°F	HMA+RAP	Average	7.4%	396.8

Specimen Type	Aging Stage /Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
			Standard Deviation	0.5%	22.6
			COV%	7.2%	5.7%
		Evotherm 3G+RAP	Average	6.4%	270.3
			Standard Deviation	0.1%	24.7
			COV%	2.1%	9.2%
		Sasobit+RAP	Average	7.6%	331.6
			Standard Deviation	0.5%	15.4
			COV%	6.5%	4.7%
LMLC	2 weeks at 140°F	HMA+RAP	Average	7.4%	432.6
			Standard Deviation	0.5%	24.5
			COV%	7.2%	5.7%
		Evotherm 3G+RAP	Average	6.4%	346.0
			Standard Deviation	0.1%	17.1
			COV%	2.1%	4.9%
		Sasobit+RAP	Average	7.6%	351.8
			Standard Deviation	0.5%	13.6
			COV%	6.5%	3.9%
LMLC	4 weeks at 140°F	HMA+RAP	Average	7.4%	548.8
			Standard Deviation	0.5%	14.1
			COV%	7.2%	2.6%
		Evotherm 3G+RAP	Average	6.4%	408.1
			Standard Deviation	0.1%	53.2
			COV%	2.1%	13.0%
		Sasobit+RAP	Average	7.6%	422.8
			Standard Deviation	0.5%	34.2
			COV%	6.5%	8.1%
LMLC	8 weeks at 140°F	HMA+RAP	Average	7.4%	633.8
			Standard Deviation	0.5%	18.8
			COV%	7.2%	3.0%
		Evotherm 3G+RAP	Average	6.4%	566.2
			Standard Deviation	0.1%	32.0
			COV%	2.1%	5.7%
		Sasobit+RAP	Average	7.6%	484.7
			Standard Deviation	0.5%	9.1
			COV%	6.5%	1.9%
LMLC	16 weeks at 140°F	HMA+RAP	Average	7.4%	739.8
			Standard Deviation	0.5%	23.6

Specimen Type	Aging Stage /Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
			COV%	7.2%	3.2%
		Evotherm 3G+RAP	Average	6.4%	634.0
			Standard Deviation	0.1%	36.2
			COV%	2.1%	5.7%
		Sasobit+RAP	Average	7.6%	650.7
			Standard Deviation	0.5%	43.3
			COV%	6.5%	6.7%

Table C.2. Indirect Tensile Strength Performance Evolution Results for the Texas Field Project

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
PMFC Cores	At construction	HMA	Average	7.0%	494.3
			Standard Deviation	0.5%	62.1
			COV%	7.1%	12.6%
		Evotherm DAT	Average	9.9%	305.1
			Standard Deviation	0.3%	12.4
			COV%	3.0%	4.1%
		Foaming	Average	7.0%	403.9
			Standard Deviation	0.1%	32.8
			COV%	1.4%	8.1%
PMFC Cores	After summer at 8 months	HMA	Average	7.0%	796.2
			Standard Deviation	0.7%	50.1
			COV%	10.0%	6.3%
		Evotherm DAT	Average	7.1%	715.7
			Standard Deviation	0.3%	124.5
			COV%	4.2%	17.4%
		Foaming	Average	7.0%	789.3
			Standard Deviation	0.1%	85.6
			COV%	1.4%	10.8%
LMLC	0 week at 140°F	HMA	Average	6.7%	422.1
			Standard Deviation	0.2%	55.5
			COV%	3.0%	13.2%
		Evotherm DAT	Average	6.2%	351.5
			Standard Deviation	0.2%	22.8
			COV%	3.2%	6.5%

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
		Foaming	Average	7.2%	387.6
			Standard Deviation	0.2%	18.9
			COV%	2.8%	4.9%
LMLC	1 week at 140°F	HMA	Average	6.7%	538.9
			Standard Deviation	0.2%	19.2
			COV%	3.0%	3.6%
		Evotherm DAT	Average	6.2%	520.5
			Standard Deviation	0.2%	33.5
			COV%	3.2%	6.4%
		Foaming	Average	7.2%	542.6
			Standard Deviation	0.2%	32.3
			COV%	2.8%	5.9%
LMLC	2 weeks at 140°F	HMA	Average	6.7%	588.8
			Standard Deviation	0.2%	11.5
			COV%	3.0%	2.0%
		Evotherm DAT	Average	6.2%	552.6
			Standard Deviation	0.2%	29.0
			COV%	3.2%	5.2%
		Foaming	Average	7.2%	581.3
			Standard Deviation	0.2%	58.8
			COV%	2.8%	10.1%
LMLC	4 weeks at 140°F	HMA	Average	6.7%	635.7
			Standard Deviation	0.2%	79.0
			COV%	3.0%	12.4%
		Evotherm DAT	Average	6.2%	700.0
			Standard Deviation	0.2%	58.3
			COV%	3.2%	8.3%
	5 weeks at 140°F	Foaming	Average	7.2%	686.6
			Standard Deviation	0.2%	26.3
			COV%	2.8%	3.8%
LMLC	8 weeks at 140°F	HMA	Average	6.7%	681.5
			Standard Deviation	0.2%	101.8
			COV%	3.0%	14.9%
		Evotherm DAT	Average	6.2%	740.6
			Standard Deviation	0.2%	19.3
			COV%	3.2%	2.6%
		Foaming	Average	7.2%	794.7
			Standard Deviation	0.2%	140.1

Specimen Type	Aging Stage/ Conditioning Protocol	Mixture Type	Statistics	Air Voids	M_R (ksi)
			COV%	2.8%	17.6%
LMLC	16 weeks at 140°F	HMA	Average	6.7%	913.2
			Standard Deviation	0.2%	81.8
			COV%	3.0%	9.0%
		Evotherm DAT	Average	6.2%	874.7
			Standard Deviation	0.2%	7.0
			COV%	3.2%	0.8%
		Foaming	Average	7.2%	912.7
			Standard Deviation	0.2%	93.6
			COV%	2.8%	10.3%

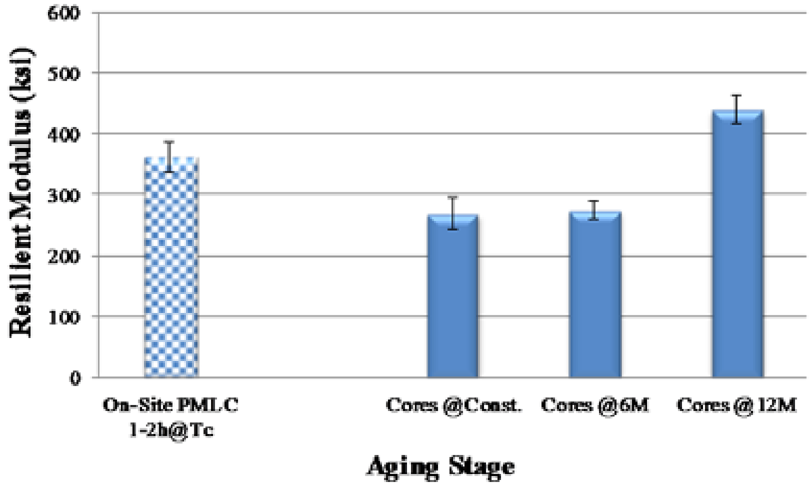
Mixture Aging in the Field

Figure C.1 and Figure C.2 present M_R stiffness of on-site PMLC specimens and PMFC cores for the Iowa and Texas field projects, respectively. In each graph, on-site PMLC specimens are presented on the left side, and PMFC cores with different in-service times in the field are shown on the right side. Each bar in Figure C.1 and Figure C.2 represents the average value of three replicate specimens, and the error bars represent ± one standard deviation from the average value.

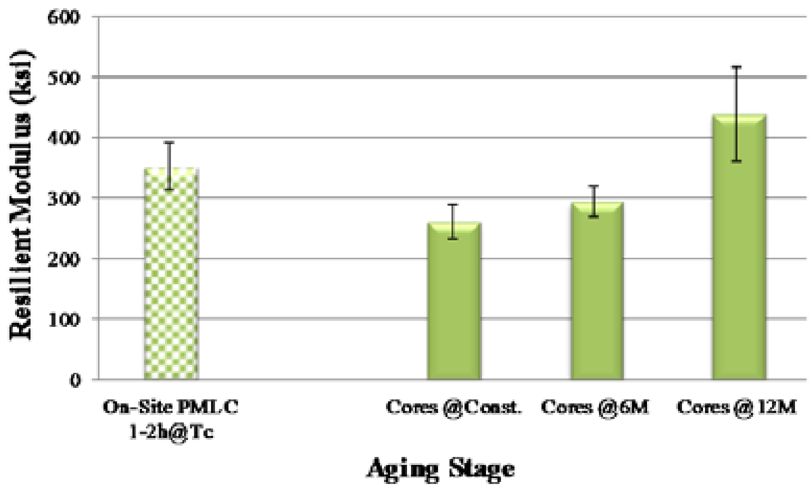
As illustrated in Figure C.1 for the Iowa field project, HMA with reclaimed asphalt pavement (RAP) and WMA with RAP on-site PMLC specimens had higher stiffness as compared to the PMFC cores at construction and after winter at 6 months in service. However, the stiffness of PMFC cores after summer at 12 months in service was higher than that of on-site PMLC specimens for all mixtures except WMA Sasobit® with RAP, which showed equivalent stiffness for both specimen types. The stiffness of HMA with RAP and WMA Evotherm® 3G with RAP PMFC cores increased slightly after winter at 6 months in service, while PMFC cores of WMA with Sasobit® increased significantly. In addition, a greater increase in stiffness of PMFC cores from 6 months to 12 months in service was noted for all mixtures. As described in Chapter 2, Section 2.1, Table 4, the placement of pavement sections for the Iowa field project was completed in September 2011. Thus, pavements were subjected to the winter climatic conditions for the first 6 months in service and summer climatic conditions from 6 months to 12 months in service. Therefore, it is assumed that the accelerated aging of pavements in the field from 6 months to 12 months in service was related to the high in-service temperature experienced by the pavement during the summer.

Comparison of M_R stiffness for the on-site PMLC specimens with two different conditioning times from the Texas field project showed that there was no increase in stiffness for on-site PMLC specimens conditioned with 0-1 h at T_c as compared to those conditioned with 1-2 h at the same temperature (Figure C.2). Equivalent stiffness was also shown for on-site PMLC specimens and PMFC cores at construction, indicating the same level of mixture aging. The difference in mixture stiffness between on-site PMLC specimens and PMFC cores depends on several factors, such as binder stiffness, aggregate anisotropy, and total air void (AV). The

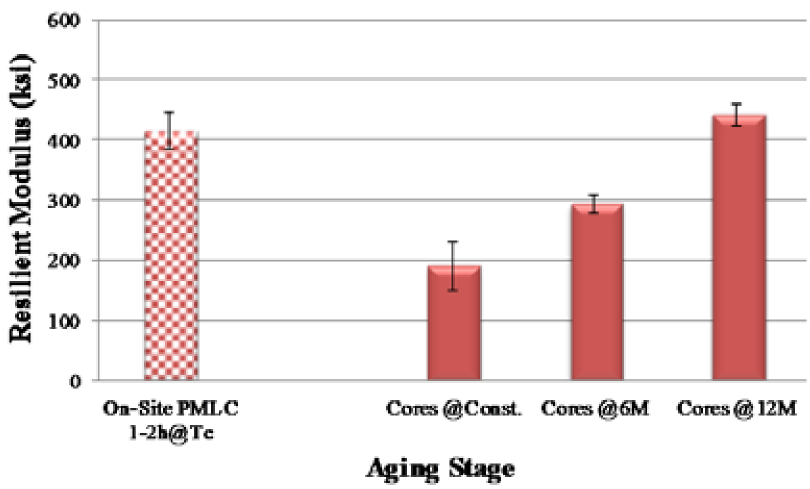
stiffness of PMFC cores for both HMA and WMA increased significantly from at construction to after summer at 8 months in service. The placement of pavement sections for the Texas field project was completed in January 2012, and thus the pavement was subjected to summer climatic conditions prior to the second set of cores being taken and tested with M_R. Therefore, the expectation that pavements may experience significant aging in the summer was verified by the increase in M_R stiffness after the summer for the Texas field project.



(a) HMA+RAP

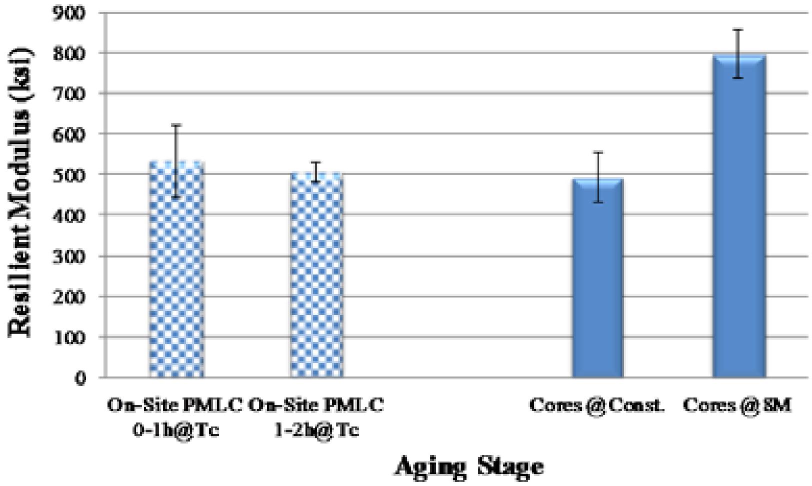


(b) Evotherm 3G+RAP

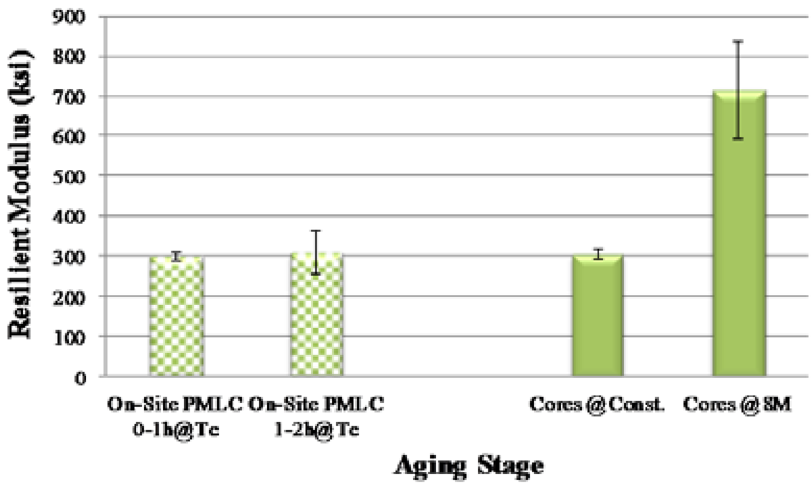


(c) Sasobit+RAP

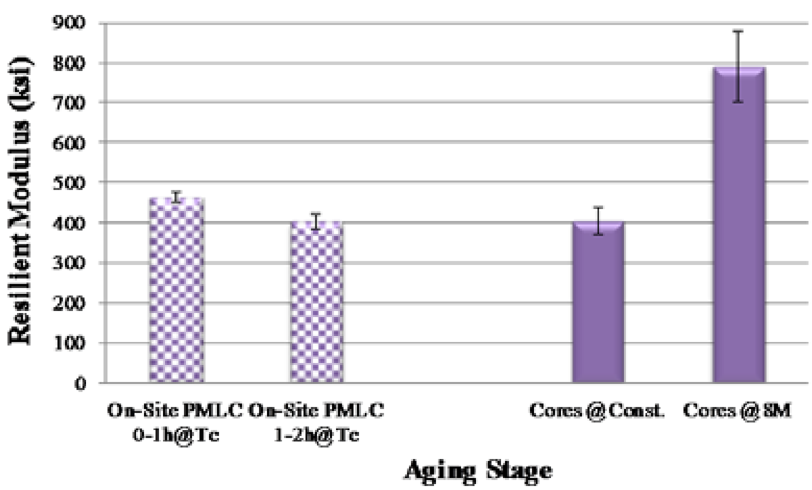
Figure C.1. On-Site PMLC Specimen and PMFC Core M_R Results for the Iowa Field Project



(a) HMA



(b) Evotherm DAT



(c) Foaming

Figure C.2. On-Site PMLC Specimen and PMFC Core M_R Results for the Texas Field Project

The period in the field needed to achieve equivalent stiffness between HMA and WMA for the Iowa and Texas field projects was determined as shown in Figure C.3 and Figure C.4. For the Iowa field project (Figure C.3), the initial stiffness of PMFC cores for HMA with RAP was higher than that for WMA Sasobit® with RAP and equivalent to that for WMA Evotherm® 3G with RAP. For PMFC cores after winter at 6 months in service, equivalent stiffness between HMA with RAP and WMA mixtures with RAP was achieved. The changes in mixture stiffness with aging time in the field for the Texas field project are shown in Figure C.4. As illustrated, the stiffness of PMFC cores at construction for HMA was higher than both WMA mixtures, with the stiffness of WMA Foaming being higher than that of WMA Evotherm DAT™. After summer at 8 months in service, the stiffness of PMFC cores for all mixtures increased significantly, and equivalent stiffness was achieved between HMA and WMA Foaming.

Thus, it can be inferred from the M_R stiffness that HMA and WMA PMFC cores from both field projects experienced significant increases in stiffness with aging in the field since construction. The increase in stiffness in the summer was more significant than that in the winter, which is likely due to the high in-service temperature experienced by the pavement in the summer. Equivalent stiffness between HMA with RAP and WMA mixtures with RAP was achieved for PMFC cores after winter at 6 months in service for Iowa, while for the Texas field project, WMA Evotherm DAT™ PMFC cores were less stiff than HMA or WMA Foaming PMFC cores were. Thus, in the case of Texas, PMFC cores with additional field aging would be needed to determine the period when the stiffness of HMA and WMA Evotherm DAT™ converge. Additionally, as indicated in Figure C.3 and Figure C.4, a higher rate of increase in mixture stiffness was shown for WMA pavements as compared to HMA pavements for both field projects.

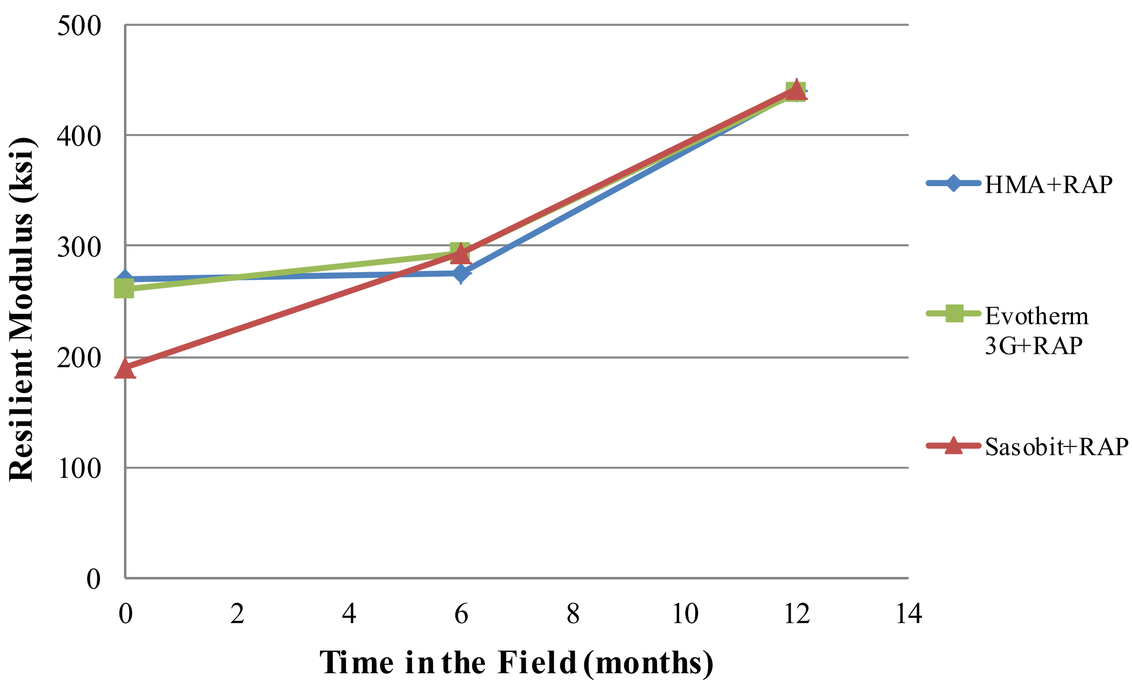


Figure C.3. Evolution of M_R Stiffness in the Field for the Iowa Field Project

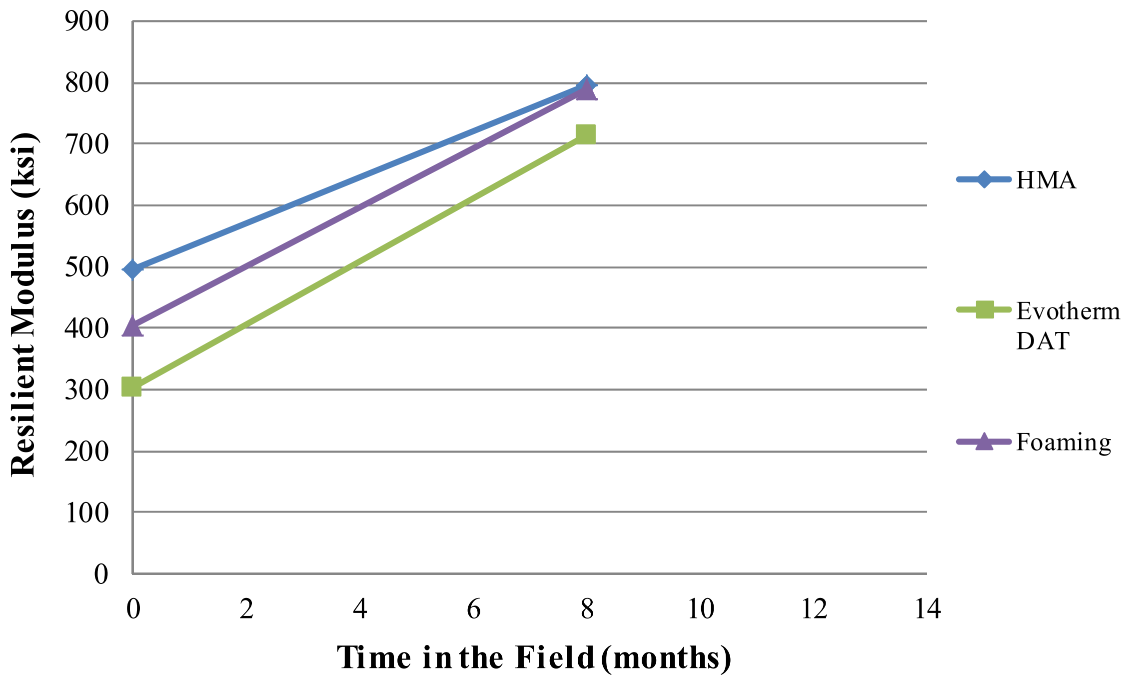


Figure C.4. Evolution of M_R Stiffness in the Field for the Texas Field Project

Mixture Aging in the Laboratory

Figure C.5 and Figure C.6 present the M_R stiffness for LMLC specimens aged at 140°F (60°C) over a series of periods for the Iowa and Texas field projects, respectively. Each bar represents the average value of three replicate specimens, and the error bars represent ± one standard deviation from the average value.

Figure C.5 and Figure C.6 indicate that the stiffness of HMA and WMA LMLC specimens increased significantly with aging in the laboratory at 140°F (60°C). As illustrated, the slopes of the curves, referring to the rate of change in mixture stiffness over the same period, were similar for HMA and WMA mixtures. In addition, for both HMA and WMA mixtures, the change in M_R stiffness during the first week of laboratory aging was higher than the change in stiffness recorded afterwards.

To explore further the different aging behavior in the laboratory of HMA and WMA mixtures, curve fitting was employed on the M_R stiffness acquired at different times. The exponential function shown in Equation C.1 and Figure C.7 was selected to fit the M_R stiffness of the different mixtures over the series of laboratory LTOA periods.

$$E_{(t)} = E_0 + (E_{max} - E_0) * e^{-(\frac{\rho}{t})^{\beta}} \qquad \text{(C.1)}$$

Where,

E(t): mixture stiffness with aging in the laboratory at time t.
E_{max}: maximum mixture stiffness with aging in the laboratory at time infinity.
E_0: initial mixture stiffness at time 0.
ρ: curve coefficient.
t: aging time in the laboratory.
β: curve coefficient.

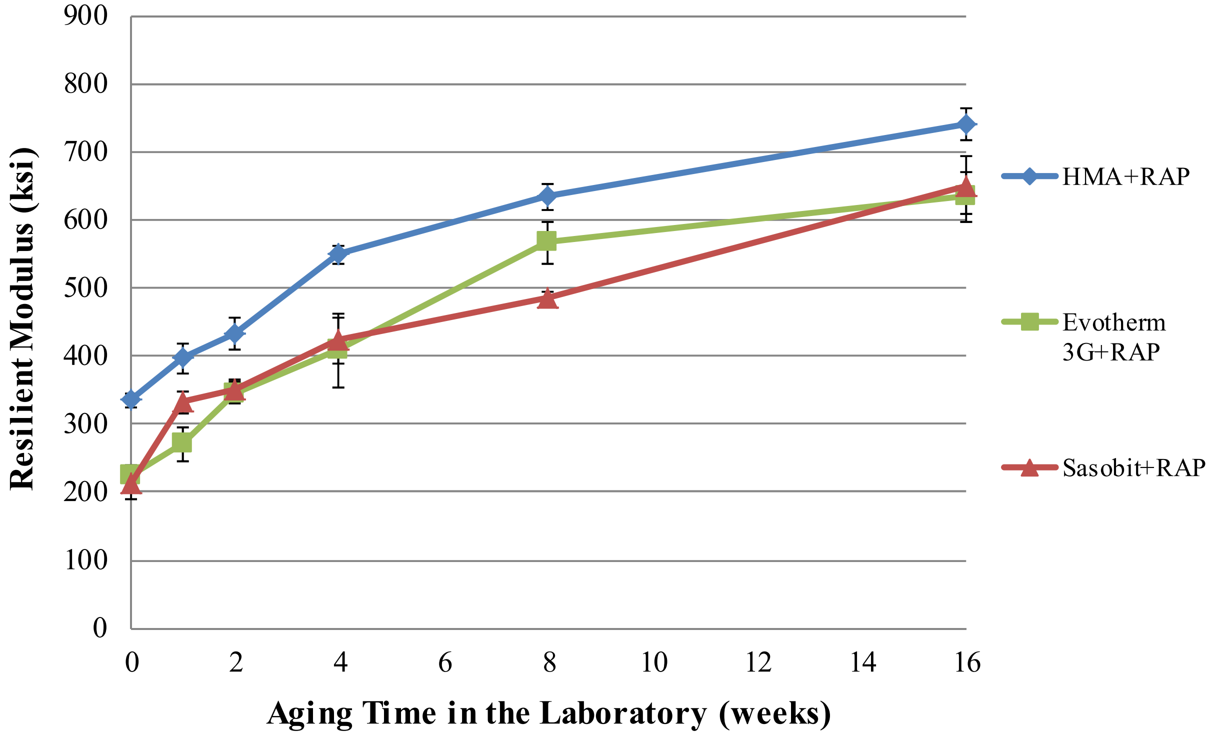


Figure C.5. Evolution of M_R Stiffness with Laboratory Aging for the Iowa Field Project

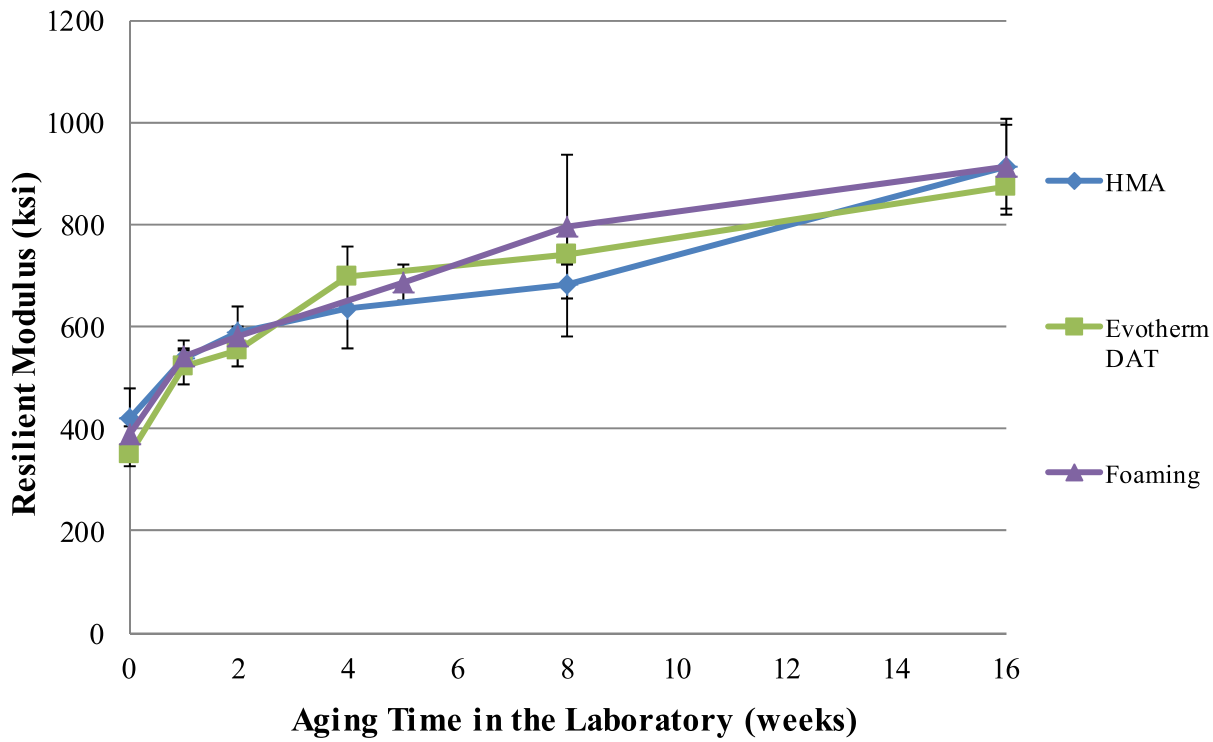


Figure C.6. Evolution of M_R Stiffness with Laboratory Aging for the Texas Field Project

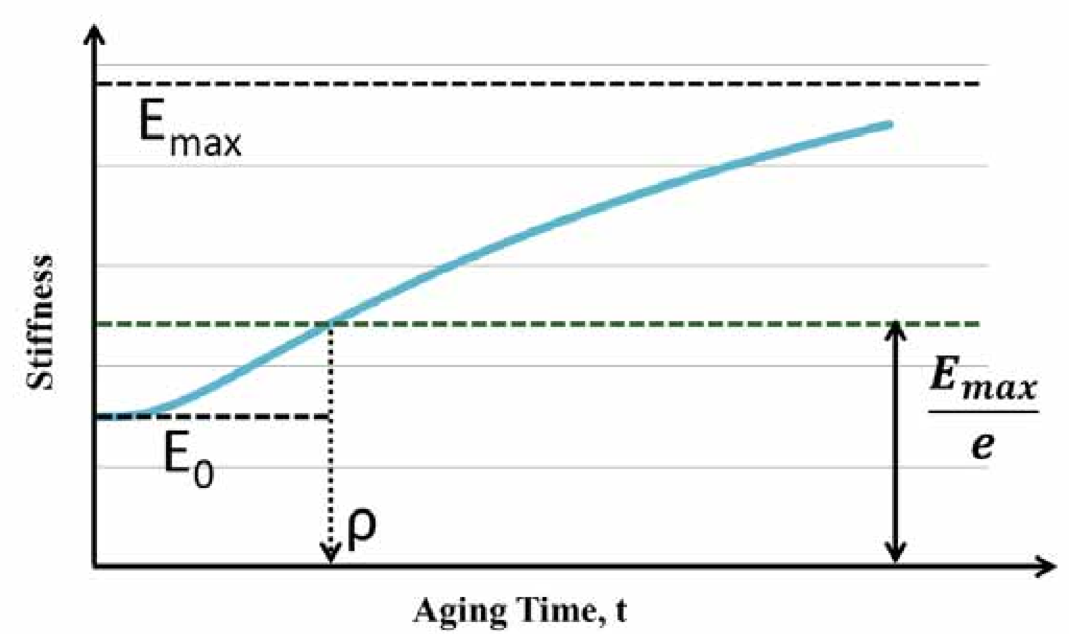
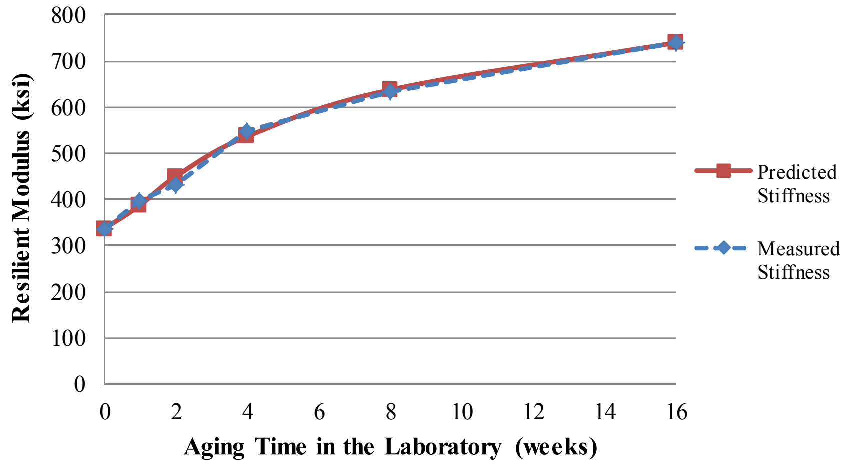


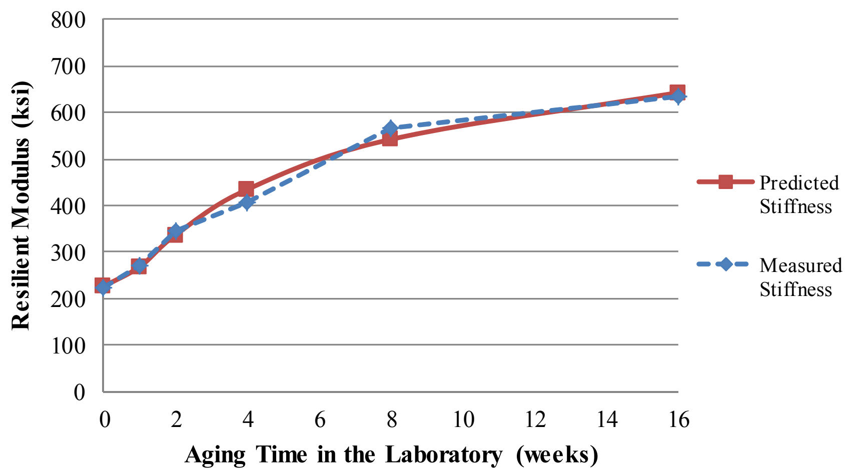
Figure C.7. The Exponential Function Fitting Curve

For each mixture from the Iowa and Texas field projects, four parameters of E_{max}, E_0, ρ, and β were determined based on the least squares fitting using the measured M_R stiffness. Predicted mixture stiffness in terms of M_R and measured M_R for the Iowa and Texas field projects are shown in Figure C.8 and Figure C.9, respectively. As indicated in these figures, there is a good correlation between predicted and measured mixture stiffness. The predicted mixture stiffness over a series of aging periods in the laboratory for the Iowa and Texas field projects is summarized in Figure C.10 and Figure C.11, respectively.

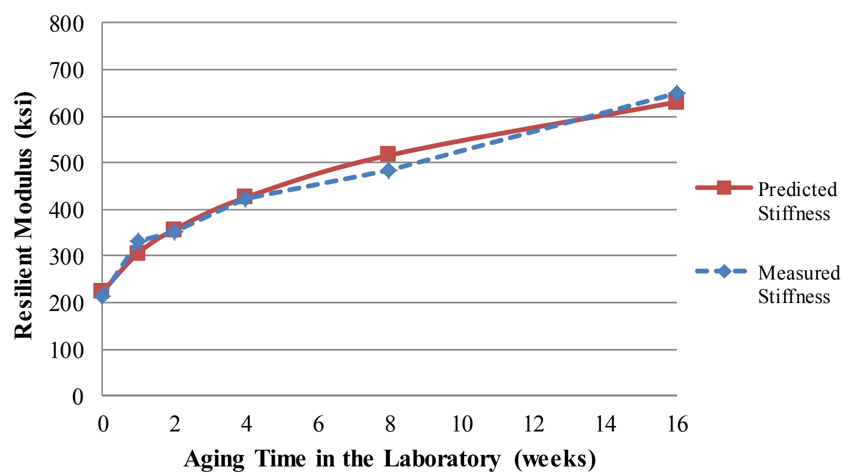
As illustrated in Figure C.10, the stiffness of the Iowa HMA with RAP was higher than the stiffness of WMA Evotherm® 3G with RAP and WMA Sasobit® with RAP for all laboratory aging times. Thus, the equivalent stiffness between HMA with RAP and WMA mixtures with RAP was achieved. The significant percentage of RAP used in the Iowa mixtures was likely a factor contributing to the discrepancy between the stiffness of HMA with RAP and WMA mixtures with RAP. The predicted stiffness of WMA mixtures with RAP after 2 weeks of laboratory aging was similar to the initial stiffness of HMA with RAP, as shown in Figure C.10; therefore, the laboratory aging protocol of 2 weeks at 140°F (60°C) was selected to simulate the stiffness of Iowa mixtures in their early life. Predicted stiffness of mixtures from the Texas field project, shown in Figure C.11, indicated that the initial stiffness of HMA after LTOA at 140°F (60°C) was equivalent to that of WMA Evotherm DAT™ and WMA Foaming.



(a) HMA+RAP

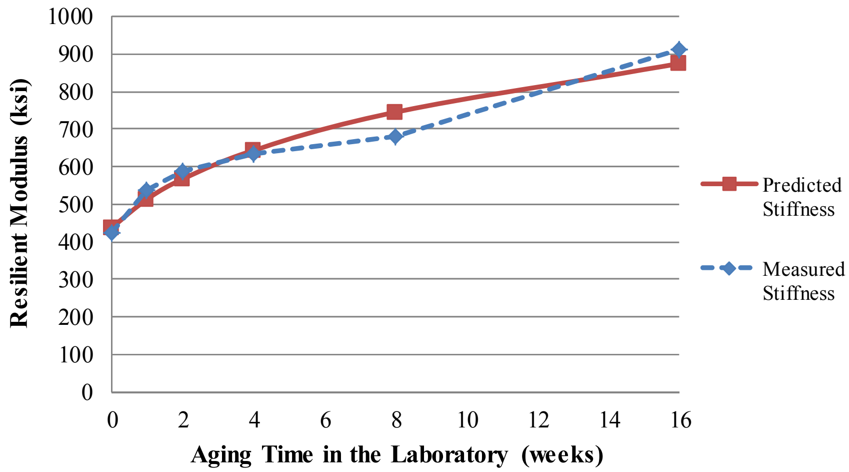


(b) Evotherm 3G+RAP

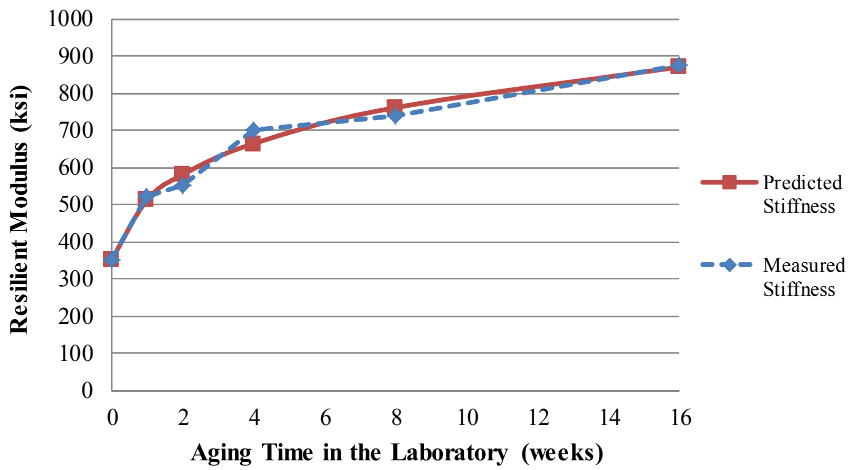


(c) Sasobit+RAP

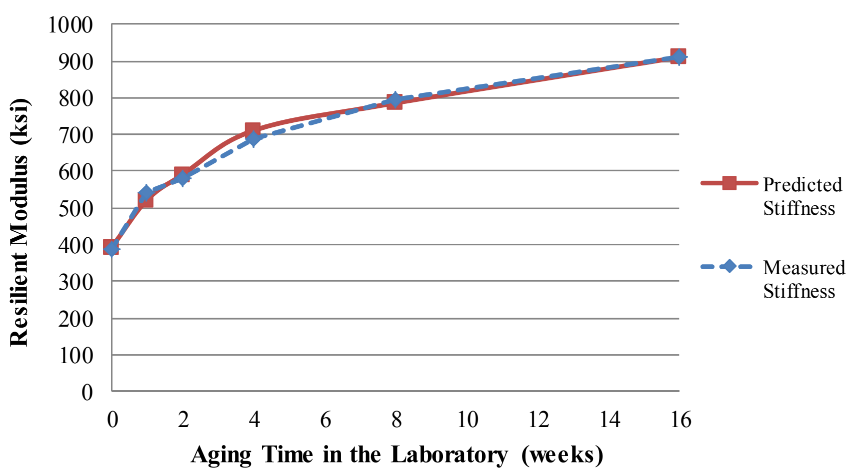
Figure C.8. Measured and Predicted M_R for the Iowa Field Project



(a) HMA



(b) Evotherm DAT



(c) Foaming

Figure C.9. Measured and Predicted M_R for the Texas Field Project

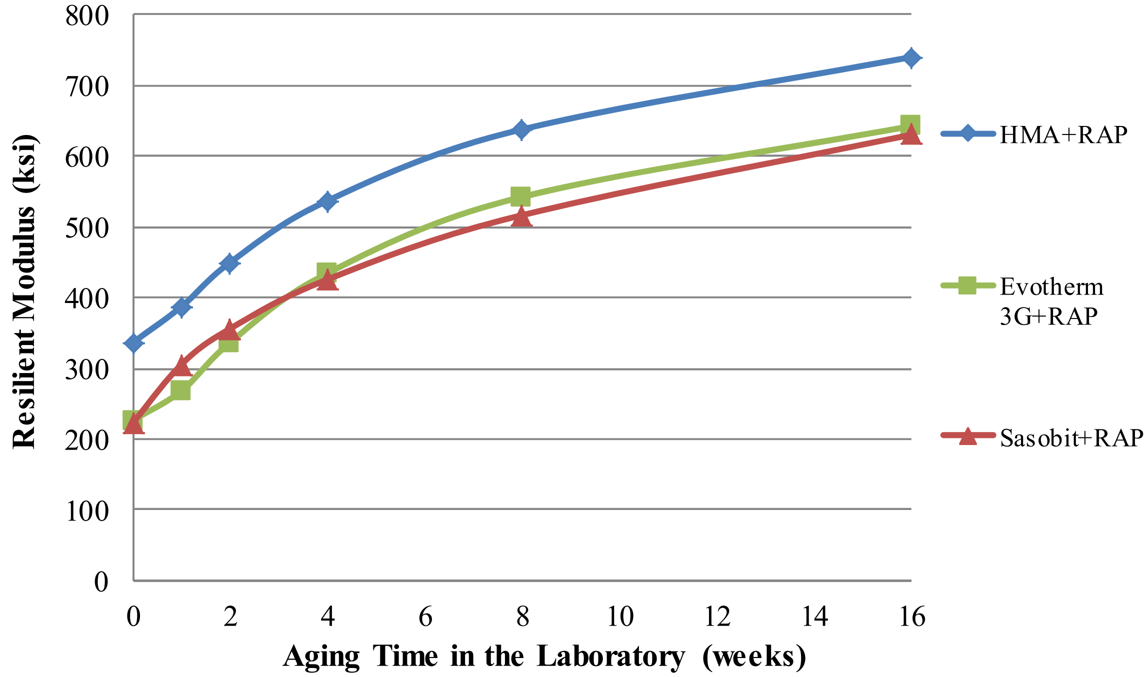


Figure C.10. Change in Predicted M_R with Laboratory Aging for the Iowa Field Project

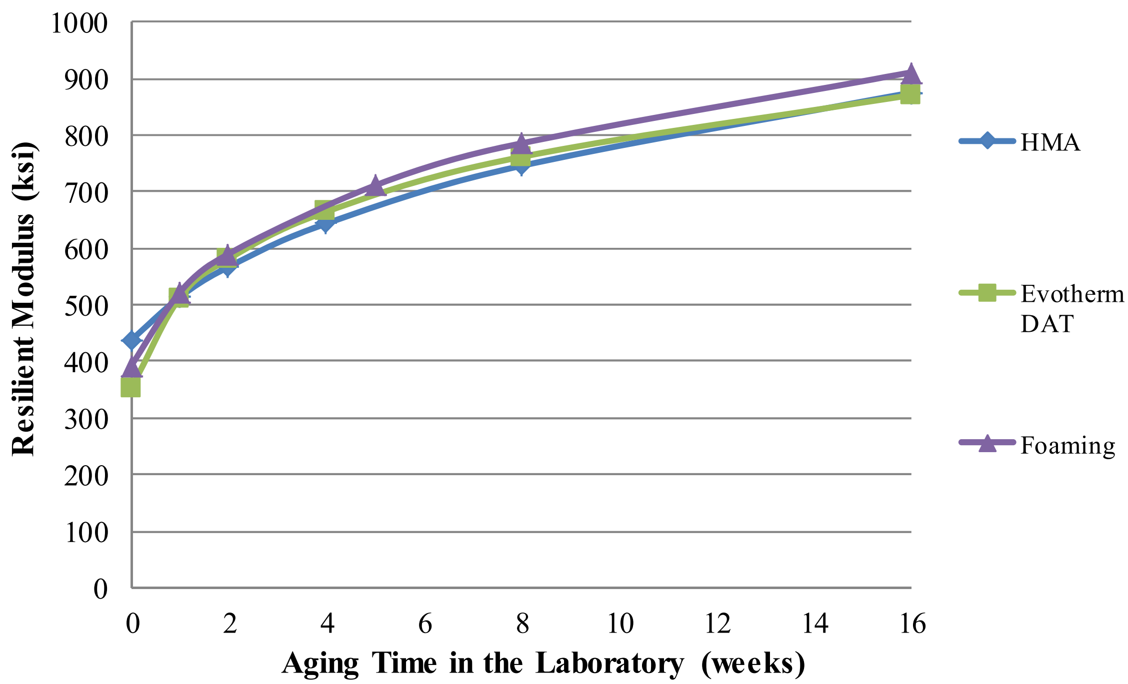


Figure C.11. Change in Predicted M_R with Laboratory Aging for the Texas Field Project

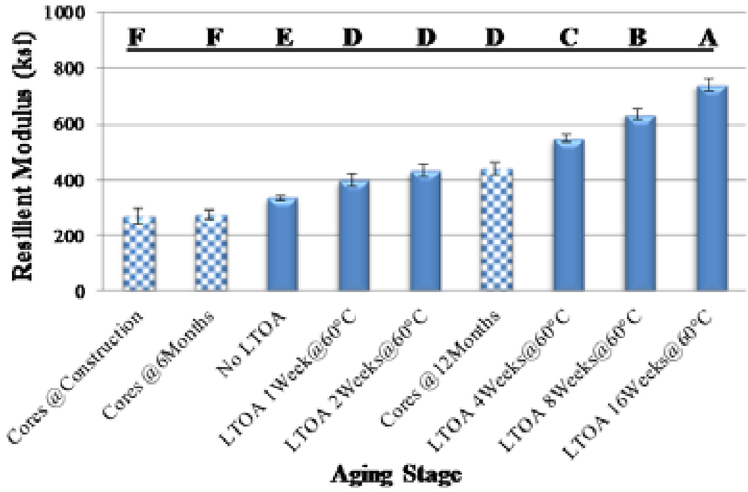
Based on the M_R stiffness presented in Figure C.10 and Figure C.11, the LTOA protocol of 2 weeks at 140°F (60°C) was selected. This aging period represented the time at which the stiffness of WMA was similar to the initial stiffness of HMA (Iowa field project) or the stiffness of HMA and WMA converged (Texas field project). Additionally, considering a previous study in Texas on the correlation between laboratory and field aging of asphalt mixtures (Glover et al.,

2005), the laboratory aging protocol of 16 weeks at 140°F (60°C) was expected to characterize the field aging of asphalt pavements approximately 1-2 years after construction. Therefore, LTOA of 2 weeks and 16 weeks at 140°F (60°C) was selected for Phase II of the WMA performance evolution experimental design that also included LTOA at 185°F (85°C) for 5 days according to AASHTO R 30. New sets of LMLC specimens were fabricated and subjected to these LTOA protocols prior to being tested with dry/wet IDT strength test, dry/wet M_R test, and HWTT tests in order to evaluate the difference in long-term (but still early life) properties between HMA and WMA in terms of mixture strength, stiffness, and moisture susceptibility.

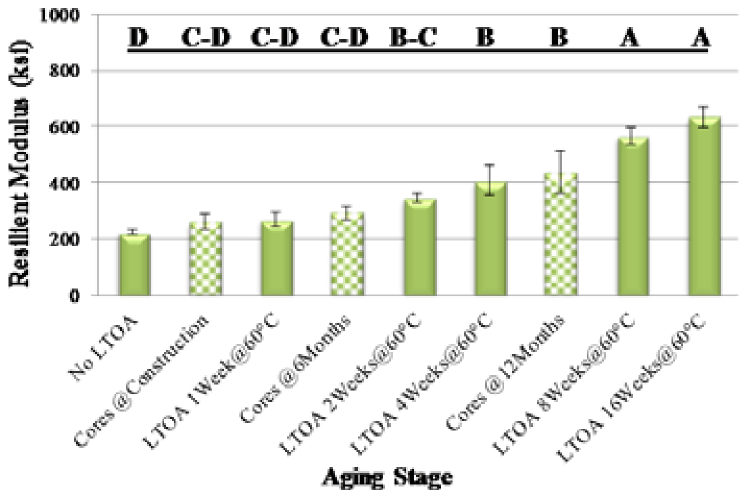
Correlation between Mixture Aging in the Field and in the Laboratory

Figure C.12 and Figure C.13 present the M_R stiffness of PMFC cores and LMLC specimens with different aging times in the field and laboratory for the Iowa and Texas field pavements, respectively. In each graph, the specimen types are arranged from lowest to highest stiffness from left to right. Each bar in Figure C.12 and Figure C.13 represents the average value of three replicate specimens, and the error bars represent ± one standard deviation from the average value.

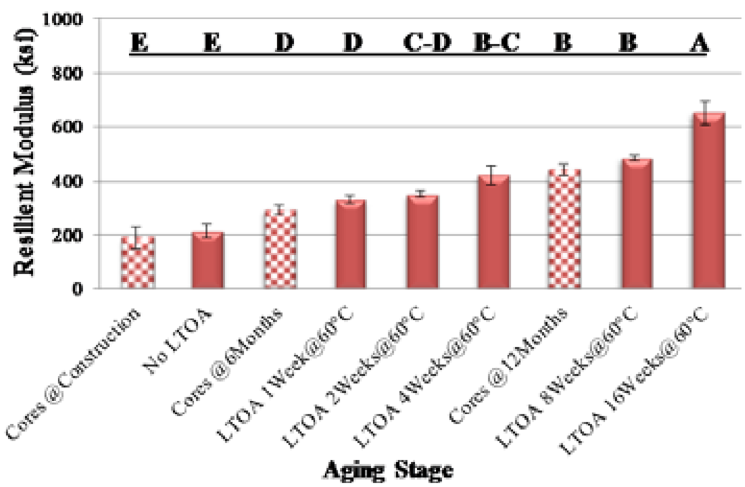
To explore the differences between mixture stiffness in the field and laboratory, a statistical analysis was completed to account for the variability in the M_R stiffness. Analysis of variance (ANOVA) and Tukey-Kramer Honestly Significant Difference (Tukey's HSD) tests were conducted with a 5 percent significance level (i.e., alpha = 0.05) to verify the difference in M_R stiffness between LMLC specimens with and without LTOA protocols versus PMFC cores with different in-service times. Detailed results from these statistical analyses are provided in Appendix H by corresponding figure or table number. The general results of Tukey's HSD test on different aging stages are shown in Figure C.12 and Figure C.13 with capital letters above the M_R stiffness bars. The M_R stiffness decreases as letters change from A to F. Different letters indicate M_R stiffnesses that are significantly different from each other.



(a) HMA+RAP

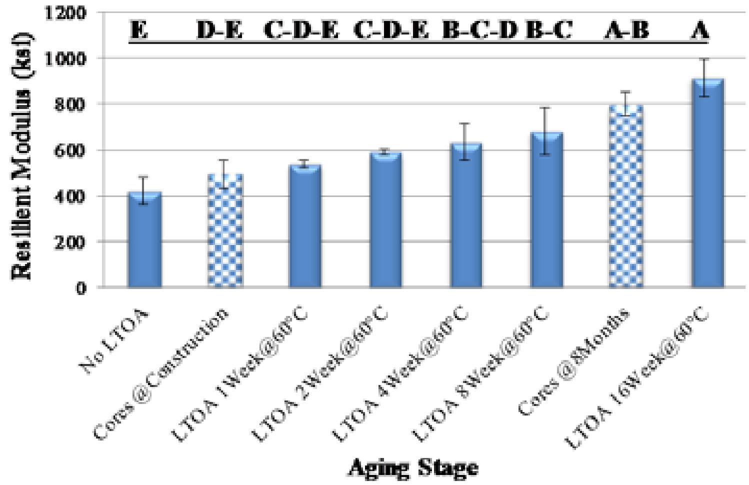


(b) Evotherm 3G+RAP

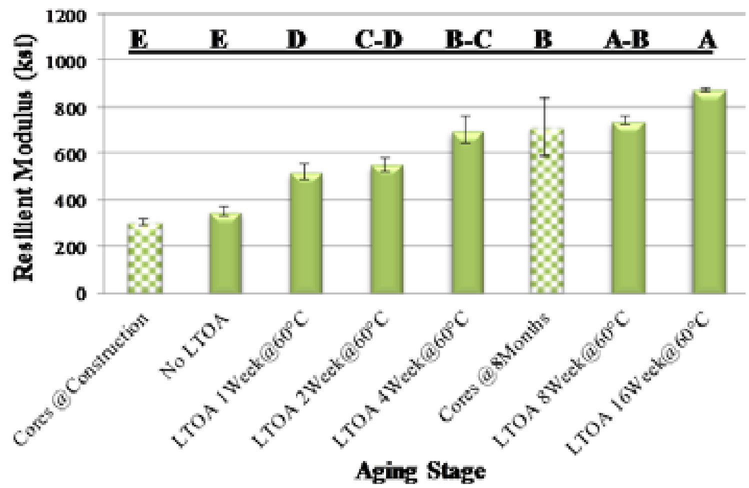


(c) Sasobit+RAP

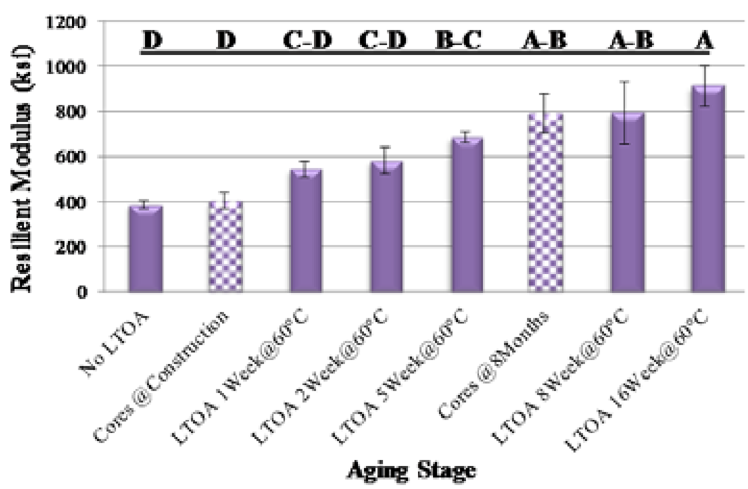
Figure C.12. M_R Results of PMFC Cores and LMLC Specimens with Different Aging for the Iowa Field Project



(a) HMA



(b) Evotherm DAT



(c) Foaming

Figure C.13. M_R Results of PMFC Cores and LMLC Specimens with Different Aging for the Texas Field Project

As illustrated in Figure C.12, the stiffness of Iowa PMFC cores at construction and after winter at 6 months in service in the field was less than the stiffness of the LMLC specimens. However, similar stiffness was achieved between PMFC cores after summer at 12 months in service and LMLC specimens with 1 week and 2 weeks at 140°F (60°C). The LTOA protocol of 4 weeks at 140°F (60°C) in the laboratory was statistically equivalent to 12 months of field aging for the two WMA mixtures with RAP.

Comparison of M_R stiffness for the PMFC cores and LMLC specimens from the Texas field project (Figure C.13) showed that for HMA, similar stiffness was exhibited between PMFC cores at construction and LMLC specimens with aging protocols of 0 (i.e., no LTOA) to 4 weeks at 140°F (60°C) in the laboratory. Laboratory aging for 8 weeks and 16 weeks was able to simulate the field aging after summer at 8 months in service in Texas. For M_R stiffness of Texas WMA Evotherm DAT™, the laboratory aging protocols of 0 weeks and 4 to 8 weeks at 140°F (60°C) were representative of the field aging at construction and after summer at 8 months in service, respectively. Similar results were shown by M_R stiffness of Texas WMA Foaming, with a slight difference in that a statistically equivalent stiffness was attained between PMFC cores at construction and LMLC specimens with up to 2 weeks of laboratory LTOA at 140°F (60°C).

Phase II of the WMA Performance Evolution Experimental Design

Effect of Field Aging and Laboratory Long-Term Oven Aging on HMA and WMA Performance

This section describes the comparison of the performance of Iowa and Texas PMFC cores with different in-service times in the field against the performance of LMLC specimens with and without laboratory LTOA protocols using dry/wet IDT strength test, dry/wet M_R stiffness, and HWTT test results. Specifically, dry IDT strength and dry M_R stiffness were selected to evaluate mixture strength and stiffness, and test parameters of wet IDT strength, TSR, wet M_R stiffness, M_R-ratio, SIP, and stripping slope in HWTT tests were utilized to evaluate moisture susceptibility. More importantly, the effects of field aging and laboratory LTOA protocols on the performance of HMA and WMA were evaluated based on those results.

Indirect Tensile Strength Test For the test results presented in this section, three specimens were tested in dry condition and three specimens were tested after moisture conditioning following the procedure outlined by AASHTO T 283. Dry IDT strength was selected to evaluate mixture strength, while wet IDT strength and TSR values were considered in this analysis as indicators of mixture moisture susceptibility. ANOVA and Tukey's HSD were performed on the dry and wet IDT strengths to discriminate strength and moisture susceptibility of HMA and WMA mixtures with different field and laboratory aging. Detailed results from these statistical analyses are provided in Appendix H by corresponding figure or table number. The analysis was done independently for each mixture type (i.e., HMA with RAP, WMA Evotherm® 3G with RAP, WMA Sasobit® with RAP, etc.). However, because only one TSR value was produced from each set of six specimens, the TSR results for different mixture types or different specimen types were compared to each other based on a recently developed precision estimate for AASHTO T 283 (Azari, 2010). Based on that report, an acceptable range of two TSR results not being different (d2s) for a single operator with a 95 percent confidence level is 9.3 percent.

In the figures included in this section, PMFC cores with different field in-service times are presented on the left side of the figure, and LMLC specimens with different laboratory LTOA protocols are shown on the right side of the figure. In addition, the solid part of the bar represents the average wet IDT strength of three replicate specimens, and the part of the bar with no fill extends up to the average dry IDT strength. The error bars represent ± one standard deviation from the average value.

Dry and wet IDT strengths for all Iowa mixture types are shown in Table C.3 and Figure C.14a, with mixtures with different field aging and laboratory LTOA protocols compared within each mixture type. In addition, statistical analysis similar to that used in Section C.2.1.3 was utilized to verify the difference in dry and wet IDT strengths among PMFC cores and LMLC specimens from the Iowa field project. The statistical results of Tukey's HSD test are summarized in Table C.4.

Table C.3. Indirect Tensile Strength Performance Evolution Results for the Iowa Field Project

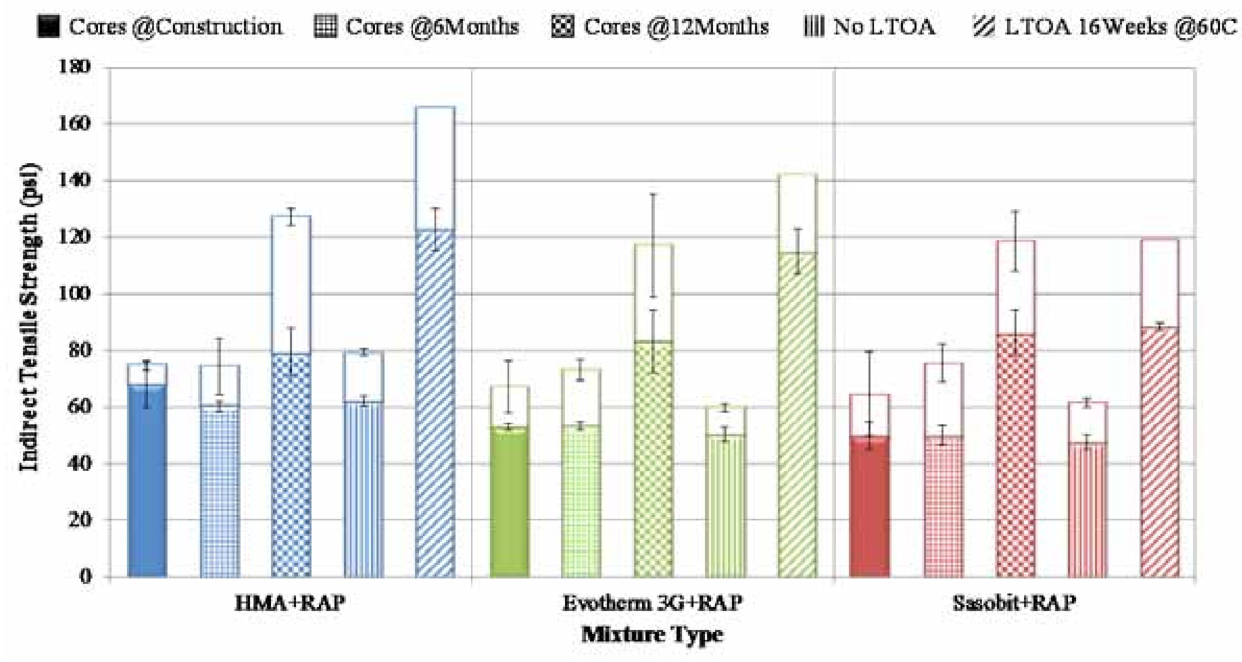
Aging Stage	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
Cores @Construction	HMA + RAP	Average	8.2%	7.6%	74.9	68.0	90.8%
		Std. Dev.	1.2%	0.5%	1.6	8.1	
		COV%	14.6%	6.2%	2.2%	11.9%	
	Evotherm 3G + RAP	Average	9.4%	7.9%	67.2	53.0	78.9%
		Std. Dev.	1.3%	1.2%	9.3	1.1	
		COV%	13.4%	15.8%	13.8%	2.2%	
	Sasobit + RAP	Average	8.7%	9.2%	64.6	49.8	77.2%
		Std. Dev.	2.3%	0.5%	15.1	4.9	
		COV%	26.5%	5.8%	23.4%	9.8%	
es @6 Month	HMA + RAP	Average	7.9%	7.5%	74.4	60.4	81.3%

Aging Stage	Mixture Type		Air Voids %		IDT (psi)		TSR
			Dry	Wet	Dry	Wet	
		Std. Dev.	0.3%	0.1%	9.8	1.8	
		COV%	4.4%	1.3%	13.2%	3.0%	
	Evotherm 3G + RAP	Average	8.1%	8.2%	73.1	53.4	73.0%
		Std. Dev.	0.7%	0.6%	3.6	1.5	
		COV%	8.5%	7.2%	4.9%	2.7%	
	Sasobit + RAP	Average	7.4%	7.7%	75.6	50.0	66.1%
		Std. Dev.	0.4%	0.4%	6.7	3.4	
		COV%	5.7%	5.6%	8.9%	6.8%	
Cores @12Months	HMA + RAP	Average	7.0%	7.0%	127.2	79.2	62.2%
		Std. Dev.	0.3%	0.3%	2.9	8.5	
		COV%	4.5%	4.5%	2.2%	10.7%	
	Evotherm 3G + RAP	Average	7.7%	7.4%	117.2	83.3	71.1%
		Std. Dev.	0.7%	0.9%	18.2	11.1	
		COV%	9.7%	11.5%	15.5%	13.3%	
	Sasobit + RAP	Average	7.1%	6.8%	118.8	86.2	72.6%
		Std. Dev.	0.7%	0.9%	10.6	8.3	
		COV%	10.0%	12.8%	8.9%	9.6%	
LMLC No LTOA	HMA + RAP	Average	7.2%	7.3%	79.2	62.0	78.2%
		Std. Dev.	0.1%	0.1%	1.0	1.7	
		COV%	1.6%	2.1%	1.3%	2.8%	
	Evotherm 3G + RAP	Average	6.8%	6.4%	59.9	50.5	84.3%
		Std. Dev.	0.6%	0.1%	1.3	2.5	
		COV%	9.0%	1.8%	2.2%	4.9%	
	Sasobit + RAP	Average	5.9%	5.7%	61.5	47.5	77.2%
		Std. Dev.	0.2%	0.1%	1.5	2.5	
		COV%	2.7%	1.0%	2.5%	5.3%	
LMLC LTOA 16Weeks @60C	HMA + RAP	Average	7.5%	7.3%	166.0	122.7	73.9%
		Std. Dev.	-	0.1%	-	7.3	
		COV%	-	1.8%	-	5.9%	
	Evotherm 3G + RAP	Average	6.4%	6.5%	142.2	115.0	80.8%
		Std. Dev.	-	0.2%	-	7.9	
		COV%	-	2.8%	-	6.9%	

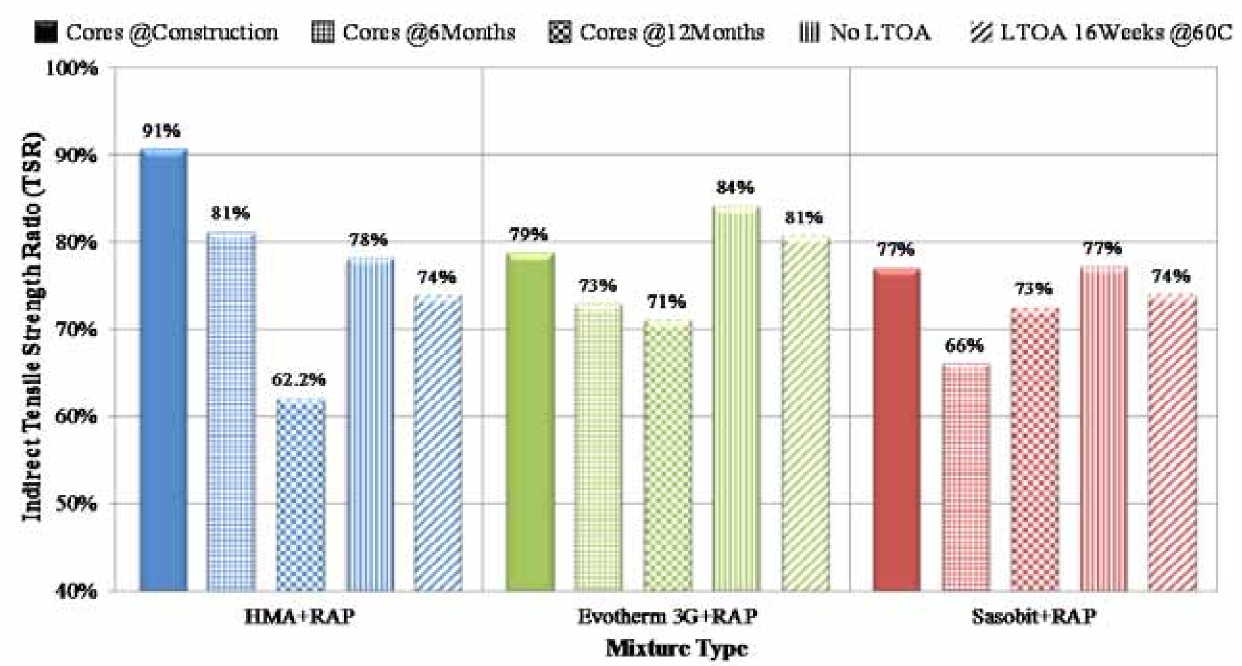
Aging Stage	Mixture Type		Air Voids %		IDT (psi)		TSR
			Dry	Wet	Dry	Wet	
	Sasobit + RAP	Average	7.4%	7.7%	119.3	88.3	74.0%
		Std. Dev.	-	0.7%	-	1.5	
		COV%	-	8.6%	-	1.8%	

For HMA with RAP and the two WMA mixtures with RAP in this field project, dry and wet IDT strengths of PMFC cores at construction and PMFC cores after winter at 6 months in service were statistically equivalent. However, there was a significant increase in dry and wet IDT strengths for PMFC cores after summer at 12 months in service. Considering the construction dates of the field project, the increase in IDT strengths of PMFC cores after summer at 12 months in service is likely due to the accelerated aging of the pavement in the field at high in-service temperature during the summer months. Equivalent dry and wet IDT strengths of PMFC cores at construction, PMFC cores after winter at 6 months in service, and LMLC specimens without LTOA were observed for all mixtures. The laboratory LTOA protocol of 16 weeks at 140°F (60°C) significantly increased the dry and wet IDT strengths of HMA with RAP and WMA mixtures with RAP. Based on these results, field aging after the first summer in the field and laboratory LTOA protocols have a remarkable effect on dry and wet IDT strengths.

Table C.3 and Figure C.14b show the TSR values for the Iowa mixtures with different field aging and laboratory LTOA protocols, for each mixture type. TSR values of HMA with RAP PMFC cores decreased from 91 percent to 62 percent as field aging time increased from at construction to after summer at 12 months in service. However, the decrease in TSR values for WMA Evotherm® 3G with RAP and WMA Sasobit® with RAP PMFC cores was insignificant, based on the d2s value of 9.3 percent (Azari, 2010). Additionally, for the HMA with RAP and the two WMA mixtures with RAP, the laboratory LTOA protocol of 16 weeks at 140°F (60°C) had no significant effect on increasing the TSR values of the LMLC specimens.



(a) Dry and Wet IDT Strengths



(b) Tensile Strength Ratio

Figure C.14. IDT Strength Test Results by Mixture Type for the Iowa Field Project

Table C.4. Tukey's HSD Groupings for the IDT Strength Test Results by Mixture Type for the Iowa Field Project

Mixture Type	Parameter	PMFC Cores			LMLC Specimens	
		At construction	After winter at 6 months	After summer at 12 months	No LTOA	16W@60C
HMA+RAP	Dry IDT Strength	C	C	B	C	A
Evotherm 3G+RAP	Dry IDT Strength	B	B	A	B	A
Sasobit+RAP	Dry IDT Strength	B	B	A	B	A
HMA+RAP	Wet IDT Strength	B-C	C	B	C	A
Evotherm 3G+RAP	Wet IDT Strength	C	C	B	C	A
Sasobit+RAP	Wet IDT Strength	B	B	A	B	A

Dry and wet IDT strengths for all Texas mixture types are shown in Table C.5 and Figure C.15a, with mixtures with different field aging and laboratory LTOA protocols compared within each mixture type. In addition, the statistical analysis results of Tukey's HSD test on Texas dry and wet IDT strengths are summarized in Table C.6.

Table C.5. Indirect Tensile Strength Performance Evolution Results for the Texas Field Project

Aging Stage	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
Cores @Construction	HMA	Average	9.6%	10.2%	91.6	60.3	65.8%
		Std. Dev.	0.1%	0.4%	5.7	4.2	
		COV%	1.3%	3.6%	6.2%	6.9%	
	Evotherm DAT	Average	7.6%	8.1%	103.0	63.9	62.1%
		Std. Dev.	0.1%	0.1%	5.3	5.6	
		COV%	2.0%	1.2%	5.2%	8.8%	
	Foaming	Average	6.1%	6.7%	138.5	70.3	50.8%
		Std. Dev.	0.4%	0.5%	7.5	1.5	
		COV%	5.7%	6.8%	5.4%	2.2%	
Cores @8Months	HMA	Average	6.6%	6.3%	196.9	155.2	78.8%
		Std. Dev.	0.8%	0.9%	5.7	16.3	
		COV%	12.6%	14.7%	2.9%	10.5%	
	Evotherm DAT	Average	6.3%	6.1%	172.0	153.4	89.1%
		Std. Dev.	0.5%	0.5%	9.6	14.6	
		COV%	8.4%	8.0%	5.6%	9.6%	
	Foaming	Average	7.2%	6.9%	160.1	133.6	83.4%

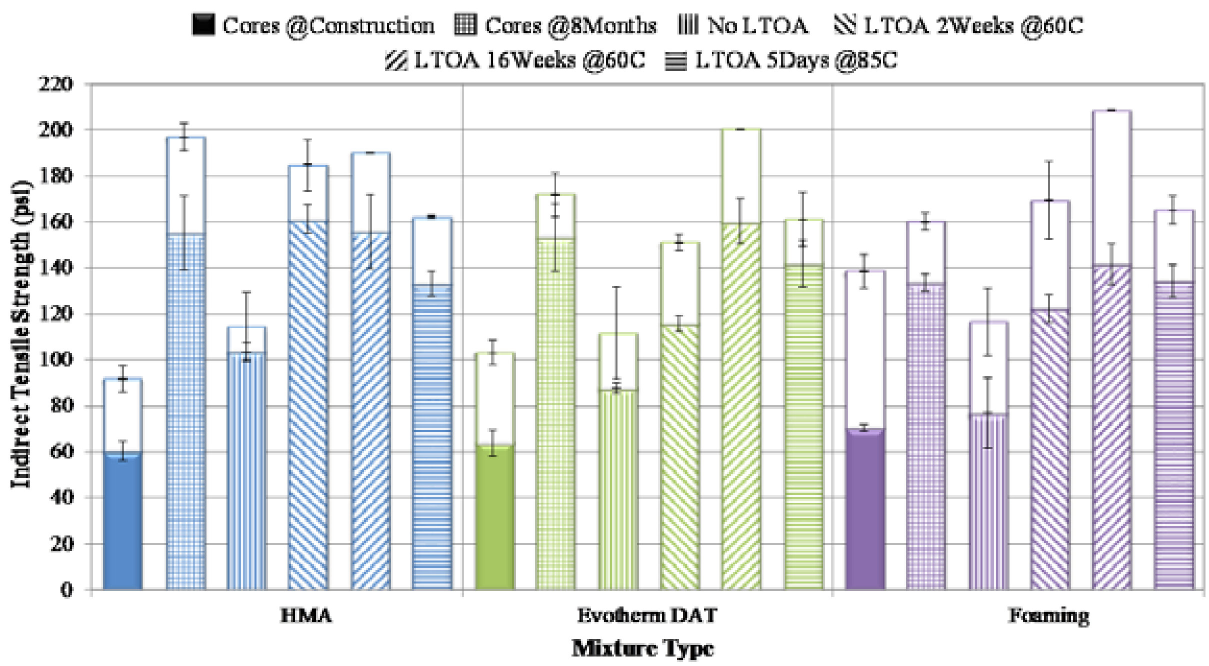
Aging Stage	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
		Std. Dev.	0.4%	0.4%	3.6	3.7	
		COV%	6.0%	5.9%	2.2%	2.8%	
LMLC No LTOA	HMA	Average	5.7%	6.0%	114.7	103.7	90.4%
		Std. Dev.	0.4%	0.2%	14.8	3.9	
		COV%	7.3%	3.7%	12.9%	3.8%	
	Evotherm DAT	Average	7.8%	6.5%	111.8	87.8	78.5%
		Std. Dev.	1.8%	0.4%	20.0	2.3	
		COV%	23.4%	6.5%	17.9%	2.7%	
	Foaming	Average	6.6%	6.5%	116.5	76.8	66.0%
		Std. Dev.	0.2%	0.3%	14.5	15.4	
		COV%	3.0%	4.6%	12.5%	20.0%	
LMLC LTOA 2Weeks @60C	HMA	Average	6.1%	6.0%	184.6	161.1	87.3%
		Std. Dev.	0.5%	0.3%	10.9	6.4	
		COV%	8.3%	5.2%	5.9%	4.0%	
	Evotherm DAT	Average	6.8%	7.0%	150.9	116.0	76.8%
		Std. Dev.	0.1%	0.3%	3.2	3.6	
		COV%	2.2%	4.5%	2.1%	3.1%	
	Foaming	Average	7.0%	7.0%	169.4	122.5	72.3%
		Std. Dev.	0.3%	0.6%	17.0	6.0	
		COV%	4.9%	8.8%	10.0%	4.9%	
LMLC LTOA 16Weeks @60C	HMA	Average	6.7%	6.7%	190.0	155.7	82.0%
		Std. Dev.	-	0.3%	-	16.3	
		COV%	-	4.9%	-	10.5%	
	Evotherm DAT	Average	6.4%	6.2%	200.1	160.1	80.0%
		Std. Dev.	-	0.3%	-	9.8	
		COV%	-	4.4%	-	6.1%	
	Foaming	Average	7.2%	7.3%	208.3	141.5	67.9%
		Std. Dev.	-	0.3%	-	8.9	
		COV%	-	3.9%	-	6.3%	
LMLC LTOA 5Days @85C	HMA	Average	6.3%	6.4%	162.1	133.2	82.2%
		Std. Dev.	0.3%	0.1%	0.5	5.3	
		COV%	4.5%	1.9%	0.3%	4.0%	

Aging Stage	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
	Evotherm DAT	Average	7.0%	7.0%	161.3	142.0	88.0%
		Std. Dev.	0.3%	0.4%	11.9	10.2	
		COV%	3.7%	6.1%	7.3%	7.2%	
	Foaming	Average	6.9%	7.0%	165.1	134.5	81.5%
		Std. Dev.	0.1%	0.1%	6.1	7.1	
		COV%	1.3%	1.0%	3.7%	5.2%	

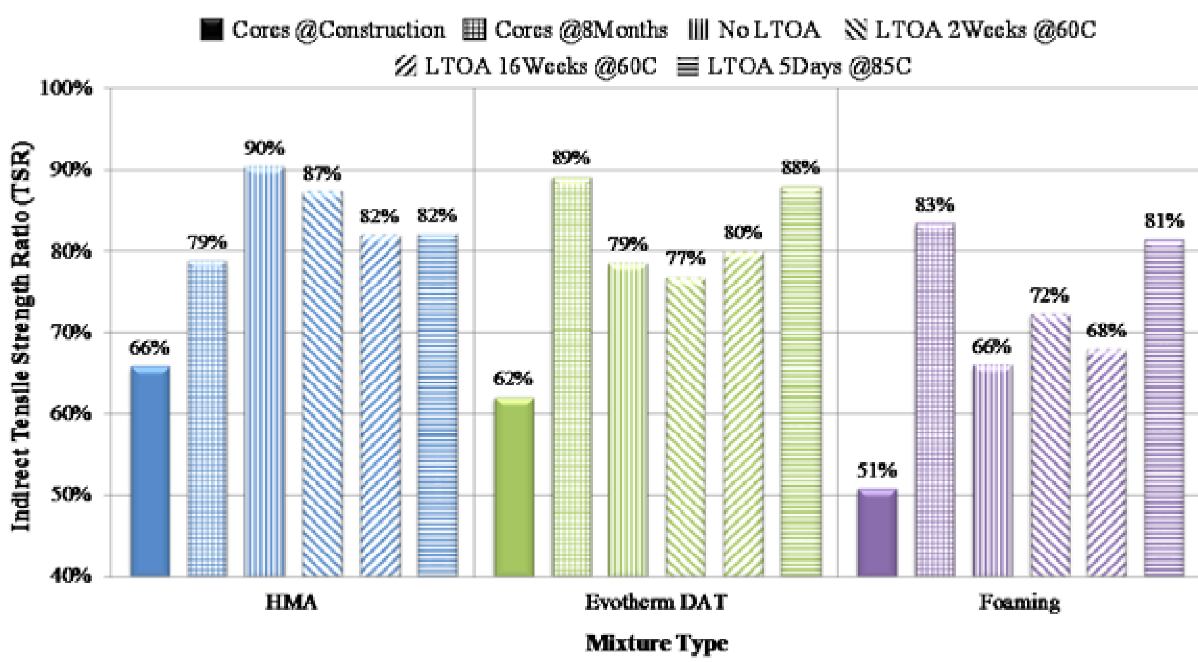
As illustrated, for HMA and two WMA mixtures, PMFC cores after summer at 8 months in service had significantly higher dry and wet IDT strengths as compared to those at construction. The comparison in dry and wet IDT strengths of LMLC mixtures with different laboratory LTOA protocols indicated that the laboratory LTOA protocols increased the IDT strength of the asphalt mixtures.

The HMA and WMA mixtures with LTOA protocol of 16 weeks at 140°F (60°C) had statistically higher or equivalent dry and wet IDT strength than those with LTOA protocol of 2 weeks at 140°F (60°C), indicating the effect of increased LTOA time on mixture strength. The increase in mixture strength after LTOA protocol of 5 days at 185°F (85°C) was greater than or equivalent to the stiffness after subjecting the HMA and the two WMA mixtures to an LTOA protocol of 2 weeks at 140°F (60°C). This indicated that the same level of mixture strengths could be achieved by an LTOA protocol with less time at higher temperature. In addition, equivalent dry and wet IDT strengths between PMFC cores after summer at 8 months in service and LMLC specimens with LTOA protocols were achieved by the majority of the mixtures from the Texas field project.

Table C.5 and Figure C.15b show the TSR for the Texas mixtures with different field aging and laboratory LTOA protocols, grouped by mixture type. For the HMA and the two WMA mixtures, TSR values of PMFC cores at construction were lower than 70 percent, while those of PMFC cores after summer at 8 months in service were closer to or above 80 percent. For HMA and WMA Evotherm DAT™, the effect of the laboratory LTOA protocols on the TSR of LMLC specimens was insignificant, considering the 9.3 percent d2s limit. Additionally, the TSR of those mixtures (except for WMA Evotherm DAT™ with 2 weeks at 140°F [60°C]) was higher than or equivalent to 80 percent. As for WMA Foaming, the laboratory LTOA protocol of 5 days at 185°F (85°C) had a significant increasing effect on the TSR value, while 2 weeks at 140°F (60°C) and 16 weeks at 140°F (60°C) did not. Therefore, the TSR value of WMA Foaming was more sensitive to LTOA temperature than LTOA time.



(a) Dry and Wet IDT Strengths



(b) Tensile Strength Ratio

Figure C.15. IDT Strength Test Results by Mixture Type for the Texas Field Project

Table C.6. Tukey's HSD Groupings for the IDT Strength Test Results by Mixture Type for the Texas Field Project

Mixture Type	Parameter	PMFC Cores: At construction	PMFC Cores: After summer at 8 months	LMLC Specimens: No LTOA	LMLC Specimens: 2W@60C	LMLC Specimens: 16W@60C	LMLC Specimens: 5D@85C
HMA	Dry IDT Strength	C	A	C	A	A	B
Evotherm DAT	Dry IDT Strength	C	A-B	C	B	A	A-B
Foaming	Dry IDT Strength	B-C	B	C	A-B	A	A-B
HMA	Wet IDT Strength	D	A-B	C	A-B	A-B	B
Evotherm DAT	Wet IDT Strength	C	A	C	B	A	A
Foaming	Wet IDT Strength	B-C	A	B	A	A	A

Dry and wet IDT strengths for all New Mexico mixture types are shown in Table C.7 and Figure C.16a, with PMFC cores at construction and mixtures with different laboratory LTOA protocols compared within each mixture type. In addition, the statistical analysis results of Tukey's HSD test on New Mexico dry and wet IDT strengths are summarized in Table C.8.

Table C.7. Indirect Tensile Strength Performance Evolution Results for the New Mexico Field Project

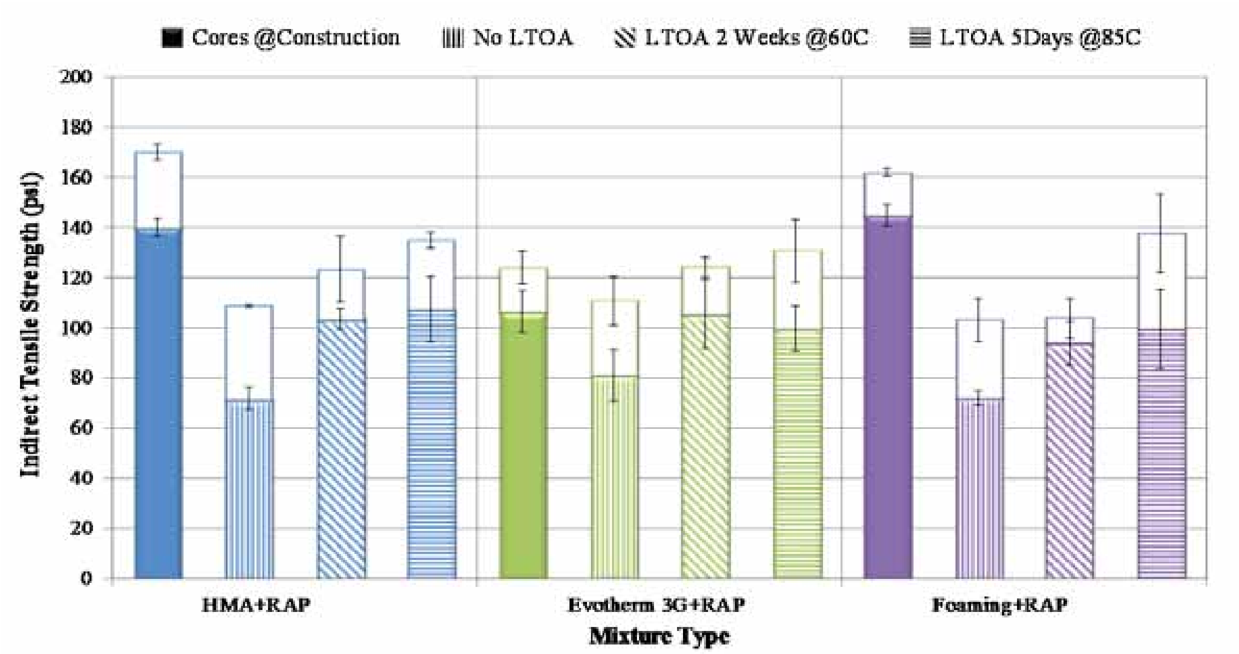
Aging Stage	Mixture Type		Air Voids % Dry	Air Voids % Wet	IDT (psi) Dry	IDT (psi) Wet	TSR
Cores @Construction	HMA + RAP	Average	6.3%	6.5%	169.8	139.9	82.4%
		Std. Dev.	0.5%	0.5%	3.3	3.5	
		COV%	7.5%	8.3%	2.0%	2.5%	
	Evotherm 3G + RAP	Average	7.4%	7.4%	124.0	106.3	85.8%
		Std. Dev.	0.2%	0.2%	6.7	8.3	
		COV%	2.2%	2.2%	5.4%	7.8%	
	Foaming + RAP	Average	4.6%	4.7%	161.9	145.0	89.6%
		Std. Dev.	0.2%	0.2%	1.4	4.3	
		COV%	4.5%	3.5%	0.9%	3.0%	
LMLC No LTOA	HMA + RAP	Average	6.9%	7.0%	108.9	71.6	65.8%
		Std. Dev.	0.4%	0.6%	0.5	4.7	
		COV%	5.1%	8.6%	0.4%	6.6%	
	Evotherm 3G + RAP	Average	7.5%	7.0%	110.9	81.1	73.1%
		Std. Dev.	0.4%	0.7%	9.8	10.3	
		COV%	5.5%	10.1%	8.8%	12.7%	
	Foaming + RAP	Average	6.1%	6.4%	103.2	72.2	70.0%

Aging Stage	Mixture Type		Air Voids %		IDT (psi)		TSR
			Dry	Wet	Dry	Wet	
		Std. Dev.	0.2%	0.4%	8.8	2.8	
		COV%	3.0%	6.2%	8.5%	3.9%	
LMLC LTOA 2Weeks @60C	HMA + RAP	Average	6.8%	6.9%	123.2	103.5	84.0%
		Std. Dev.	0.2%	0.6%	13.0	4.1	
		COV%	3.5%	8.4%	10.5%	4.0%	
	Evotherm 3G + RAP	Average	6.8%	6.8%	124.1	105.5	85.0%
		Std. Dev.	0.5%	0.2%	3.9	13.6	
		COV%	8.0%	3.5%	3.1%	12.9%	
	Foaming + RAP	Average	6.3%	6.5%	127.2	93.9	73.9%
		Std. Dev.	0.4%	0.2%	8.1	8.6	
		COV%	6.2%	3.0%	6.3%	9.2%	
LMLC LTOA 5Days @85C	HMA + RAP	Average	7.3%	7.4%	135.0	107.3	79.5%
		Std. Dev.	0.2%	0.9%	3.0	13.0	
		COV%	2.9%	11.8%	2.2%	12.1%	
	Evotherm 3G + RAP	Average	8.1%	8.1%	130.7	99.8	76.4%
		Std. Dev.	0.4%	0.3%	12.6	8.9	
		COV%	5.2%	3.7%	9.6%	8.9%	
	Foaming + RAP	Average	6.7%	6.7%	137.5	99.5	72.4%
		Std. Dev.	0.3%	0.2%	15.7	16.0	
		COV%	3.9%	2.9%	11.4%	16.1%	

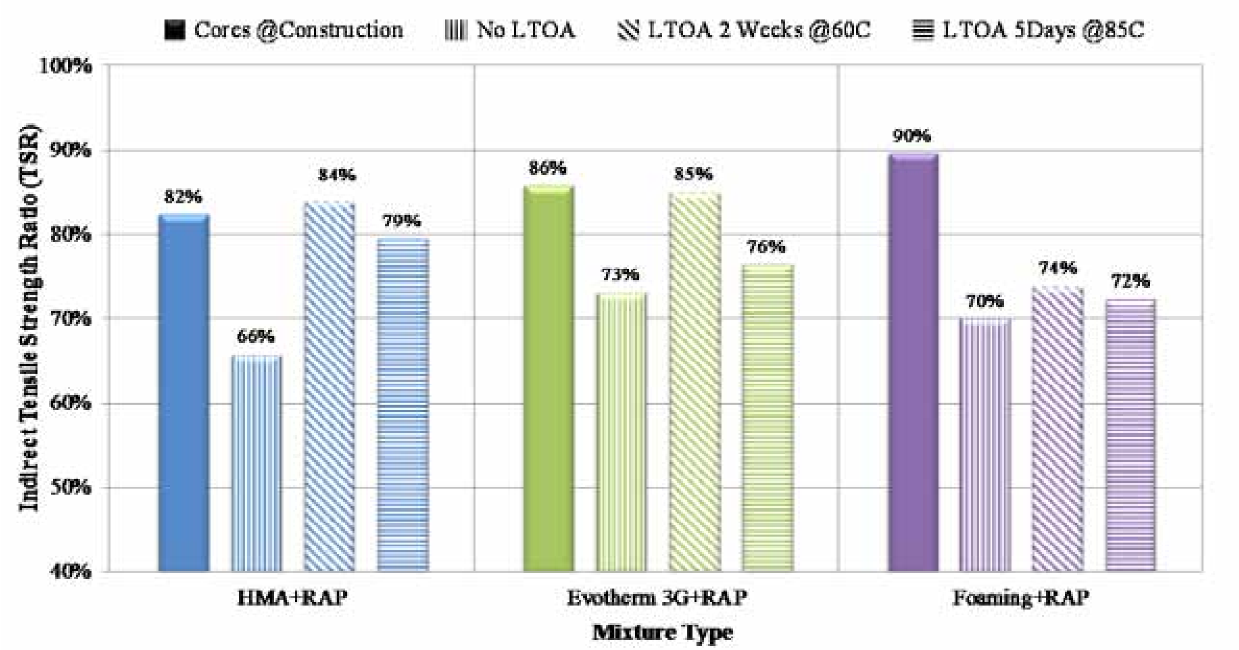
As illustrated, for all mixtures, the dry and wet IDT strengths of LMLC specimens with LTOA protocols were statistically higher than or equivalent to those of LMLC specimens without LTOA. Thus, the laboratory LTOA was able to improve the IDT strengths of asphalt mixtures. Additionally, statistically equivalent dry and wet IDT strengths were achieved between LMLC specimens with LTOA protocols of 2 weeks at 140°F (60°C) and 5 days at 185°F (85°C). The comparison in dry and wet IDT strengths of PMFC cores at construction and LMLC specimens without LTOA indicated that for all mixtures except WMA Evotherm® 3G with RAP, the PMFC cores at construction had statistically higher dry and wet IDT strengths.

Table C.7 and Figure C.16b show the TSR for the New Mexico PMFC cores at construction and mixtures with different laboratory LTOA protocols. For all the mixtures, LMLC specimens with LTOA protocols had higher or equivalent TSR values as compared to those without LTOA, considering the 9.3 percent d2s limit. Equivalent TSR values were achieved for LMLC specimens after LTOA protocols of 2 weeks at 140°F (60°C) and 5 days at 185°F (85°C). The comparison in TSR between PMFC cores at construction and LMLC specimens without LTOA showed that for all mixtures, PMFC cores at construction had TSR values higher than 80 percent, while LMLC specimens had TSR values lower than 80 percent. Therefore, as compared

to PMFC cores at construction, LMLC specimens are considered more susceptible to moisture damage.



(a) Dry and Wet IDT Strengths



(b) Tensile Strength Ratio

Figure C.16. IDT Strength Test Results by Mixture Type for the New Mexico Field Project

Table C.8. Tukey's HSD Groupings for the IDT Strength Test Results by Mixture Type for the New Mexico Field Project

Mixture Type	Parameter	PMFC Cores	LMLC Specimens		
		At construction	No LTOA	2W@60C	5D@85C
HMA+RAP	Dry IDT Strength	A	C	B-C	B
Evotherm 3G+RAP		A	A	A	A
Foaming+RAP		A	C	B-C	A-B
HMA+RAP	Wet IDT Strength	A	C	B	B
Evotherm 3G+RAP		A	A	A	A
Foaming+RAP		A	C	B-C	B

Dry/Wet Resilient Modulus In the figures included in this section, PMFC cores with different field in-service times are presented on the left side of the figure, and LMLC specimens with different LTOAs are shown on the right side of the figure. The solid part of the bar represents the average wet MR stiffness of three replicate specimens, and the part of the bar with no fill extends up to the average dry MR stiffness. For PMFC cores, no wet MR stiffness was measured, and thus only the dry results are shown (bars with no fill). In addition, the error bars represent ± one standard deviation from the average value.

ANOVA and Tukey's HSD were performed on the dry and wet M_R stiffness to evaluate dry stiffness and moisture susceptibility, respectively, in HMA and WMA specimens with different field and laboratory aging. Detailed results from these statistical analyses are provided in Appendix H by corresponding figure or table number. The analysis was performed independently for each mixture type (i.e., HMA with RAP, WMA Evotherm® 3G with RAP, WMA Sasobit® with RAP, etc.). A precision and bias statement was not available for the M_R-ratio, but since M_R is a non-destructive test and the wet and dry stiffness measurements were conducted on the same specimen, the d2s value is likely of the same magnitude as the one for TSR (i.e., 9.3 percent; Azari, 2010). When also considering the smaller sample size used in the M_R test versus the one used to develop the AASHTO T 283 precision and bias statement, an acceptable range of two M_R stiffnesses for a single operator of 10 percent was considered acceptable in this study as a limit for identifying significant differences within mixture types and specimen types.

Dry and wet M_R stiffnesses for all Iowa mixtures are shown in Table C.9 and Figure C.17a, with mixtures with different field aging and laboratory LTOA protocols compared for each mixture type. In addition, the statistical results of Tukey's HSD test are summarized in Table C.10.

Table C.9. M_R Performance Evolution Results for the Iowa Field Project

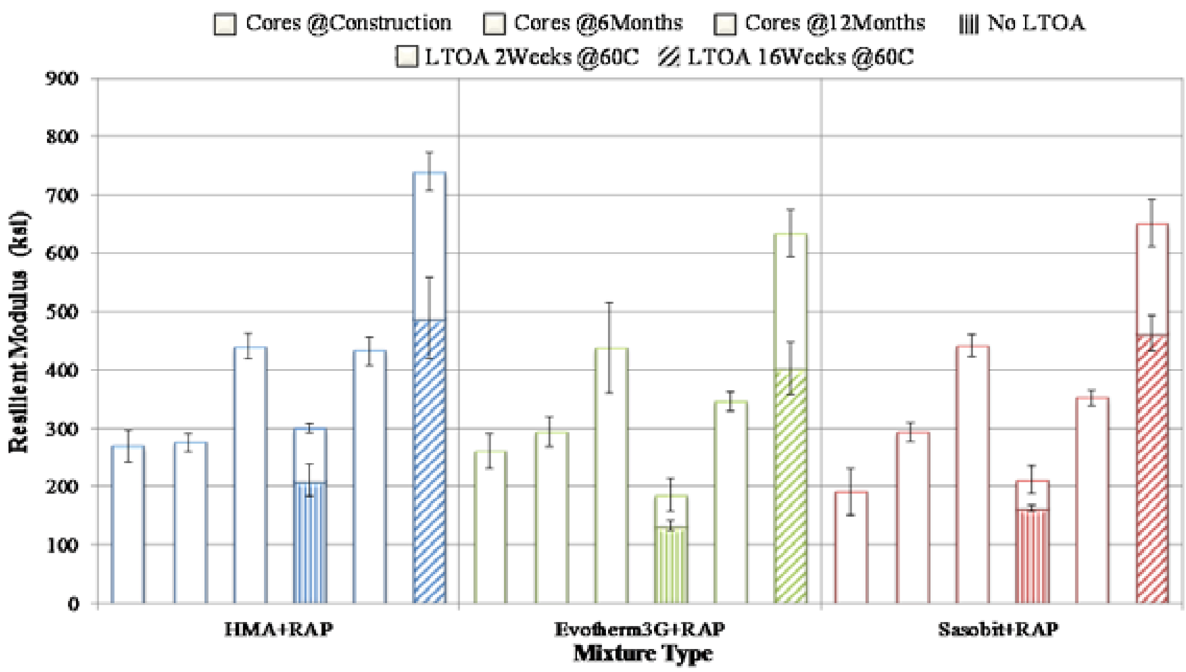
Aging Stage	Mixture Type		Air Voids %	M_R (ksi)		M_R-ratio
				Dry	Wet	
Cores @Construction	HMA + RAP	Average	8.2%	269.3	-	-
		Std. Dev.	1.2%	27.1	-	
		COV%	14.6%	10.1%	-	
	Evotherm 3G + RAP	Average	8.5%	260.6	-	-
		Std.	1.1%	28.8	-	

Aging Stage	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
		Dev.				
		COV%	12.9%	11.1%	-	
	Sasobit + RAP	Average	8.5%	190.4	-	-
		Std. Dev.	1.5%	40.0	-	
		COV%	17.6%	21.0%	-	
Cores @8Months	HMA + RAP	Average	7.5%	275.5	-	-
		Std. Dev.	0.0%	15.6	-	
		COV%	0.1%	5.7%	-	
	Evotherm 3G + RAP	Average	7.2%	293.8	-	-
		Std. Dev.	0.1%	25.6	-	
		COV%	1.9%	8.7%	-	
	Sasobit + RAP	Average	6.9%	293.4	-	-
		Std. Dev.	0.2%	16.0	-	
		COV%	2.8%	5.5%	-	
Cores @12Months	HMA + RAP	Average	7.0%	440.6	-	-
		Std. Dev.	0.3%	22.5	-	
		COV%	4.5%	5.1%	-	
	Evotherm 3G + RAP	Average	7.7%	437.9	-	-
		Std. Dev.	0.7%	77.8	-	
		COV%	9.7%	17.8%	-	
	Sasobit + RAP	Average	7.1%	441.3	-	-
		Std. Dev.	0.7%	18.6	-	
		COV%	10.0%	4.2%	-	
LMLC No LTOA	HMA + RAP	Average	7.2%	301.0	210.3	69.9%
		Std. Dev.	0.1%	7.7	27.4	
		COV%	0.7%	2.6%	13.0%	
	Evotherm 3G + RAP	Average	6.8%	185.1	133.1	71.9%
		Std. Dev.	0.0%	28.8	8.3	
		COV%	0.6%	15.5%	6.2%	
	Sasobit + RAP	Average	7.6%	211.3	163.7	77.4%
		Std. Dev.	0.2%	24.6	5.4	
		COV%	2.1%	11.6%	3.3%	
LT OA 2W eek	HMA + RAP	Average	7.4%	432.6	-	-

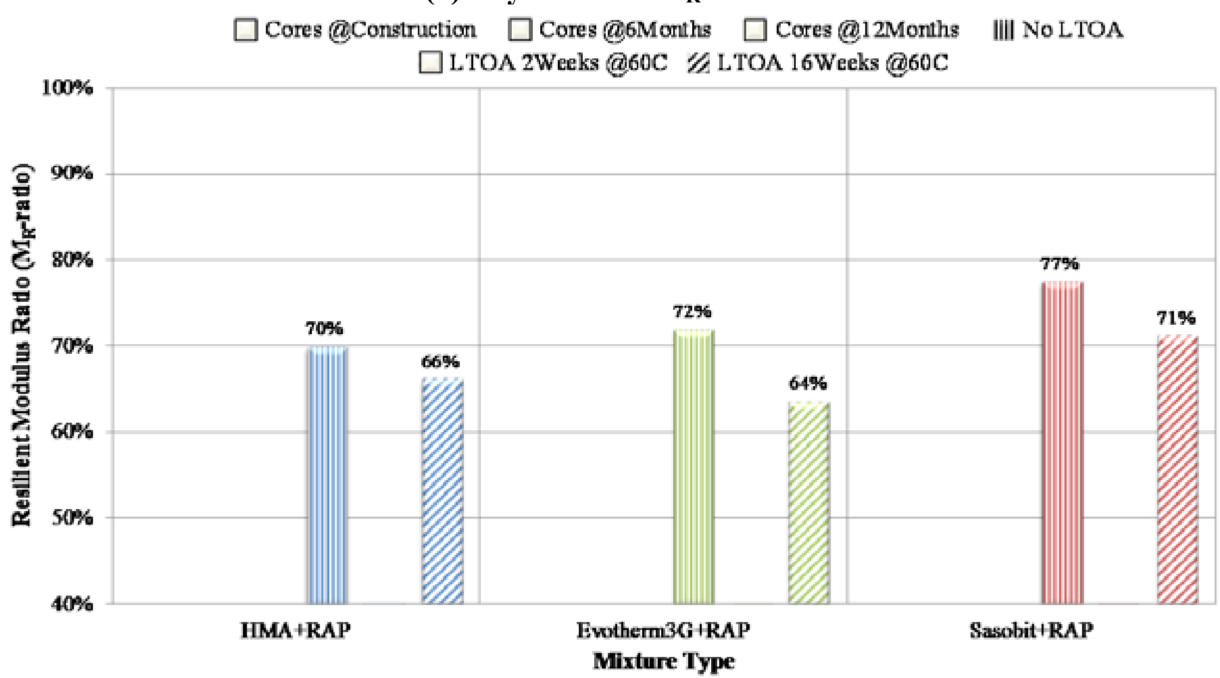
Aging Stage	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
		Std. Dev.	0.1%	24.5	-	
		COV%	1.9%	5.7%	-	
	Evotherm 3G + RAP	Average	6.4%	346.0	-	-
		Std. Dev.	0.1%	17.1	-	
		COV%	2.1%	4.9%	-	
	Sasobit + RAP	Average	7.6%	351.8	-	-
		Std. Dev.	0.5%	13.6	-	
		COV%	6.5%	3.9%	-	
LMLC LTOA 16Weeks @60C	HMA + RAP	Average	7.4%	739.8	489.2	66.1%
		Std. Dev.	0.1%	33.2	69.1	
		COV%	1.9%	4.5%	14.1%	
	Evotherm 3G + RAP	Average	6.4%	634.0	402.9	63.6%
		Std. Dev.	0.1%	39.4	45.2	
		COV%	2.1%	6.2%	11.2%	
	Sasobit + RAP	Average	7.6%	650.7	463.2	71.2%
		Std. Dev.	0.5%	40.5	30.8	
		COV%	6.5%	6.2%	6.6%	

The comparison of dry M_R stiffness for PMFC cores with different field aging times was discussed in detail in Section C.2.1.1. As previously mentioned, field aging after one summer had a significant effect on increasing the mixture dry stiffness. In addition, for all mixtures, LMLC specimens with laboratory LTOA protocols had statistically higher dry and wet M_R stiffnesses than those without LTOA. Also, the increase in mixture dry stiffness from the LTOA protocol of 16 weeks at 140°F (60°C) was more significant than that from the LTOA protocol of 2 weeks at 140°F (60°C).

Table C.9 and Figure C.17b show the wet-to-dry M_R-ratio for the Iowa LMLC mixtures with and without laboratory LTOA protocols, for each mixture type. As illustrated, for all mixtures, LMLC specimens with LTOA had equivalent M_R-ratios, versus those without LTOA, based on the assumed d2s value of 10 percent. Therefore, the effect of laboratory LTOA protocol on M_R-ratio is considered insignificant.



(a) Dry and Wet M_R Stiffness



(b) Resilient Modulus Ratio

Figure C.17. M_R Test Results by Mixture Type for the Iowa Field Project

Table C.10. Tukey's HSD Groupings for the M_R Test Results by Mixture Type for the Iowa Field Project

Mixture	Parameter	PMFC Cores			LMLC with LTOA Protocols		
		At construction	After winter at 6 months	After summer at 12 months	No LTOA	2W@60C	16W@60C
HMA+RAP	Dry M_R	C	C	B	C	B	A
Evotherm 3G+RAP	Dry M_R	C-D	C-D	B	D	B-C	A
Sasobit+RAP	Dry M_R	D	C	B	D	C	A
HMA+RAP	Wet M_R				B		A
Evotherm 3G+RAP	Wet M_R				B		A
Sasobit+RAP	Wet M_R				B		A

Dry and wet M_R stiffnesses for all Texas mixture types are shown in Table C.11 and Figure C.18a, with mixtures with different field aging and laboratory LTOA protocols compared within each mixture type. In addition, the statistical analysis results of Tukey's HSD test on Texas dry and wet M_R stiffness are summarized in Table C.12.

Table C.11. M_R Performance Evolution Results for the Texas Field Project

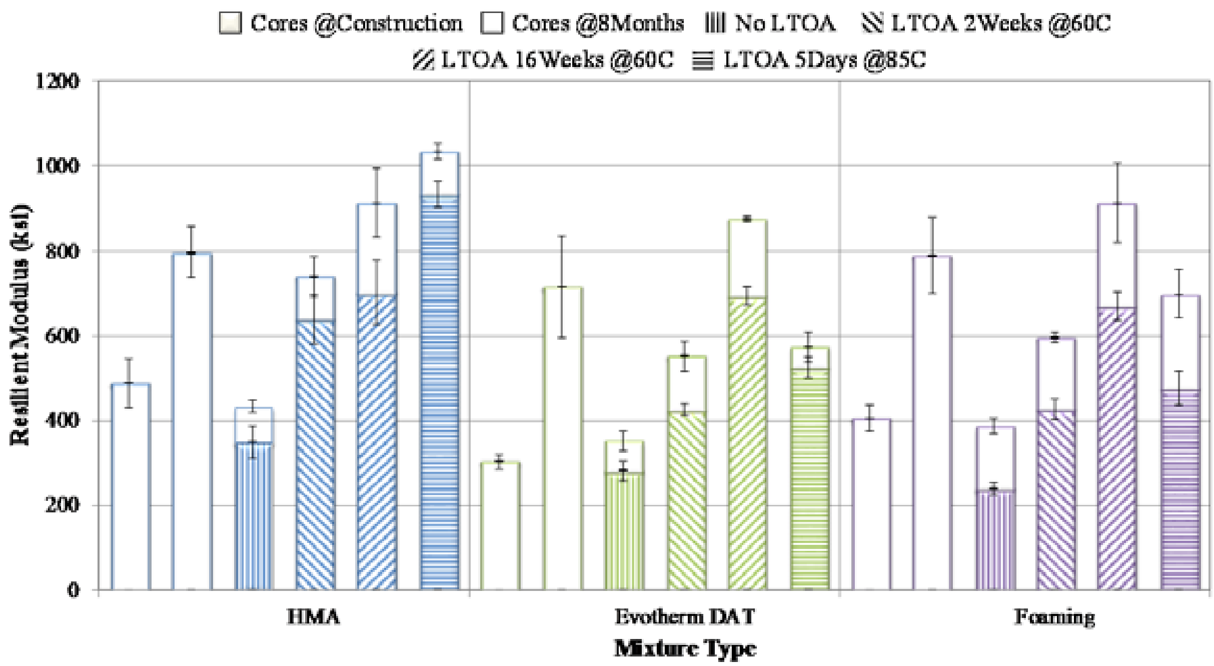
Aging Stage	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
Cores @Construction	HMA	Average	7.0%	487.1	-	-
		Std. Dev.	0.5%	59.0	-	
		COV%	7.1%	12.1%	-	
	Evotherm DAT	Average	9.9%	303.0	-	-
		Std. Dev.	0.3%	17.4	-	
		COV%	3.0%	5.7%	-	
	Foaming	Average	7.0%	403.9	-	-
		Std. Dev.	0.1%	31.0	-	
		COV%	1.4%	7.7%	-	
Cores @8Months	HMA	Average	7.0%	796.2	-	-
		Std. Dev.	0.7%	59.5	-	
		COV%	10.2%	7.5%	-	
	Evotherm DAT	Average	7.1%	715.7	-	-
		Std. Dev.	0.3%	120.4	-	
		COV%	3.6%	16.8%	-	
	Foaming	Average	7.0%	789.3	-	-

Aging Stage	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
		Std. Dev.	0.1%	88.9	-	
		COV%	1.5%	11.3%	-	
LMLC No LTOA	HMA	Average	6.6%	433.0	348.5	80.5%
		Std. Dev.	0.4%	16.4	39.4	
		COV%	5.4%	3.8%	11.3%	
	Evotherm DAT	Average	6.5%	351.5	280.7	79.9%
		Std. Dev.	0.2%	22.8	23.6	
		COV%	2.9%	6.5%	8.4%	
	Foaming	Average	7.6%	387.6	238.6	61.6%
		Std. Dev.	0.2%	18.9	16.1	
		COV%	3.0%	4.9%	6.8%	
LMLC LTOA 2Weeks @60C	HMA	Average	6.2%	738.9	638.2	86.4%
		Std. Dev.	0.0%	47.0	58.2	
		COV%	0.8%	6.4%	9.1%	
	Evotherm DAT	Average	6.9%	551.1	424.5	77.0%
		Std. Dev.	0.0%	35.7	14.2	
		COV%	0.6%	6.5%	3.3%	
	Foaming	Average	7.0%	594.3	426.0	71.7%
		Std. Dev.	0.6%	12.4	24.8	
		COV%	8.8%	2.1%	5.8%	
LMLC LTOA 16Weeks @60C	HMA	Average	6.7%	913.2	701.4	76.8%
		Std. Dev.	0.3%	81.8	74.4	
		COV%	4.9%	9.0%	10.6%	
	Evotherm DAT	Average	6.2%	874.7	694.1	79.4%
		Std. Dev.	0.3%	7.0	21.1	
		COV%	4.4%	0.8%	3.0%	
	Foaming	Average	7.3%	912.7	669.4	73.3%
		Std. Dev.	0.3%	93.6	33.9	
		COV%	3.9%	10.3%	5.1%	
LMLC LTOA 5Days @85C	HMA	Average	5.8%	1,034.9	933.6	90.2%
		Std. Dev.	0.0%	19.0	30.9	
		COV%	0.2%	1.8%	3.3%	

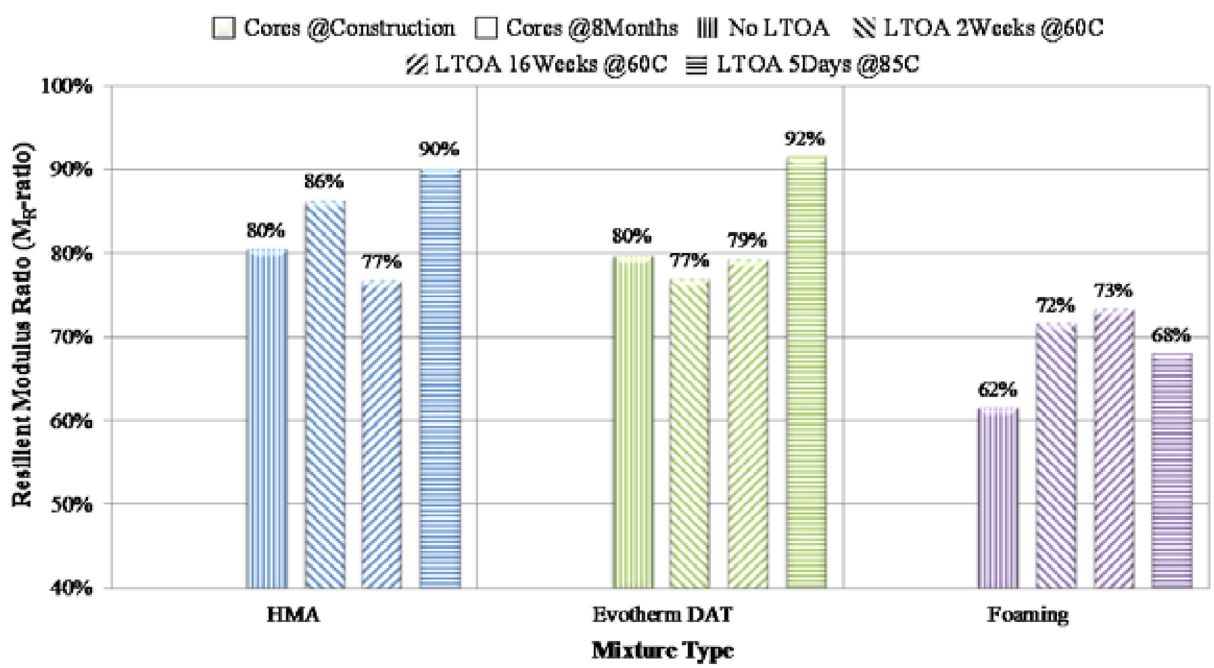
Aging Stage	Mixture Type		Air Voids %	M_R (ksi)		M_R-ratio
				Dry	Wet	
	Evotherm DAT	Average	6.9%	573.2	524.9	91.6%
		Std. Dev.	0.3%	35.5	25.5	
		COV%	4.7%	6.2%	4.9%	
	Foaming	Average	7.0%	697.9	474.9	68.1%
		Std. Dev.	0.1%	56.1	39.4	
		COV%	1.0%	8.0%	8.3%	

As illustrated, for all mixtures, PMFC cores after summer at 8 months in service had statistically significant higher dry M_R stiffness as compared to PMFC cores at construction. The comparison in dry and wet M_R stiffness of LMLC mixtures with laboratory LTOA protocols indicated that the laboratory LTOA protocols were able to improve significantly the dry and wet stiffness of the asphalt mixtures. HMA and WMA with LTOA protocol of 16 weeks at 140°F (60°C) had in most cases statistically higher dry and wet M_R stiffness than those with LTOA protocol of 2 weeks at 140°F (60°C), indicating the effect of increased LTOA time on mixture stiffness. The increase in dry and wet stiffness after LTOA protocol of 5 days at 185°F (85°C) was more significant than that after LTOA protocol of 2 weeks at 140°F (60°C) for HMA, while the difference in stiffness between mixtures with these two laboratory LTOA protocols was less pronounced for WMA Evotherm DAT™ and WMA Foaming.

Table C.11 and Figure C.18b show the wet-to-dry M_R-ratio for the Texas mixtures with different laboratory LTOA protocols, for each mixture type. For HMA, the effect of laboratory LTOA protocols on mixture M_R-ratio was insignificant, considering the assumed d2s value of 10 percent. M_R-ratios for WMA Evotherm DAT™ specimens showed that among those three laboratory LTOA protocols, only 5 days at 185°F (85°C) was able to increase the M_R-ratio of the mixture. However, different trends in M_R-ratio values were shown for WMA Foaming with different LTOA protocols. The effect of LTOA of 5 days at 185°F (85°C) on this mixture's M_R-ratio was insignificant, while that of LTOA of 16 weeks at 140°F (60°C) was significant.



(a) Dry and Wet M_R Stiffness



(b) Resilient Modulus Ratio

Figure C.18. M_R Test Results by Mixture Type for the Texas Field Project

Table C.12. Tukey's HSD Groupings for the M_R Test Results by Mixture Type for the Texas Field Project

Mixture	Parameter	PMFC Cores		LMLC with LTOA Protocols			
		At construction	After summer at 8 months	No LTOA	2W@60C	16W@60C	5D@85C
HMA	Dry M_R	D	B-C	D	C	A-B	A
Evotherm DAT	Dry M_R	D	B-C	D	C	A	B-C
Foaming	Dry M_R	D	A-B	D	C	A	B-C
HMA	Wet M_R			C	B	B	A
Evotherm DAT	Wet M_R			D	C	A	B
Foaming	Wet M_R			C	B	A	B

Dry and wet M_R stiffnesses for all New Mexico mixture types are shown in Table C.13 and Figure C.19a, with PMFC cores at construction and mixtures with different laboratory LTOA protocols compared within each mixture type. In addition, the statistical analysis results of Tukey's HSD test on New Mexico dry and wet M_R stiffness are summarized in Table C.14.

Table C.13. M_R Performance Evolution Results for the New Mexico Field Project

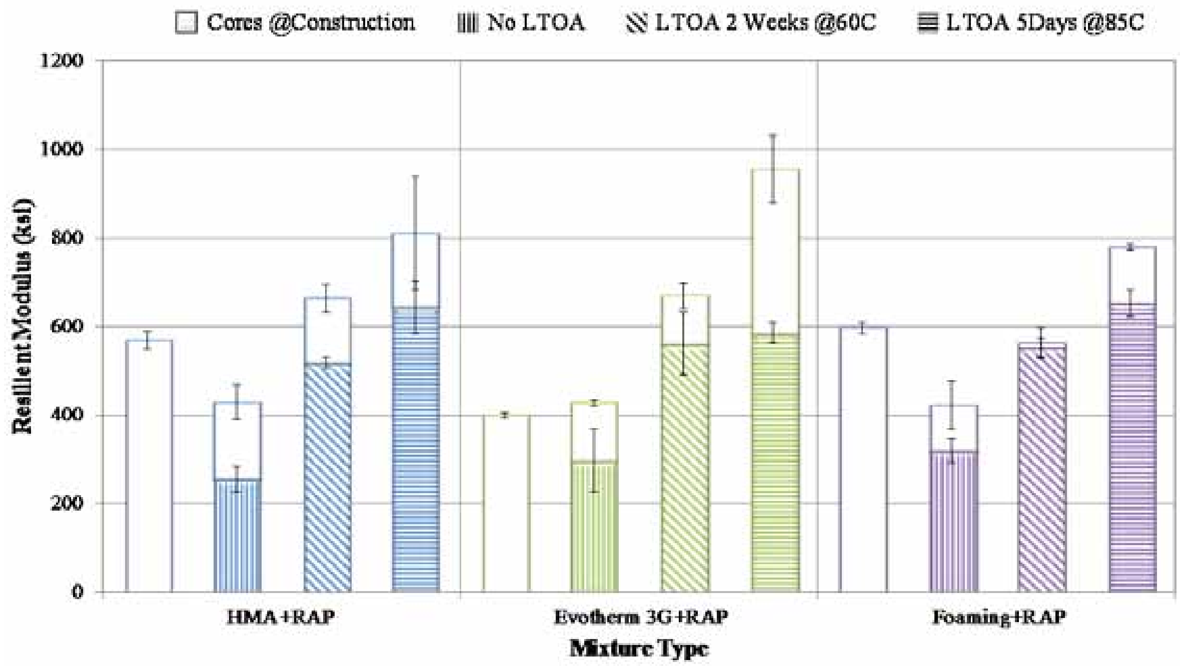
Aging Stage	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
Cores @Construction	HMA + RAP	Average	6.3%	568.1	-	-
		Std. Dev.	0.5%	20.1	-	
		COV%	7.5%	3.5%	-	
	Evotherm 3G + RAP	Average	7.4%	398.5	-	-
		Std. Dev.	0.2%	5.2	-	
		COV%	2.2%	1.3%	-	
	Foaming + RAP	Average	4.9%	596.4	-	-
		Std. Dev.	0.6%	12.9	-	
		COV%	13.0%	2.2%	-	
LMLC No LTOA	HMA + RAP	Average	7.2%	428.3	254.5	59.4%
		Std. Dev.	0.4%	38.7	29.5	
		COV%	5.5%	9.0%	11.6%	
	Evotherm 3G + RAP	Average	7.3%	427.3	296.5	69.4%
		Std. Dev.	0.2%	5.2	69.7	
		COV%	2.7%	1.2%	23.5%	
	Foaming + RAP	Average	5.8%	421.1	319.7	75.9%
		Std.	0.6%	54.4	26.4	

Aging Stage	Mixture Type		Air Voids %	M_R (ksi) Dry	M_R (ksi) Wet	M_R-ratio
		Dev.				
		COV%	9.7%	12.9%	8.3%	
LMLC LTOA 2Weeks @60C	HMA + RAP	Average	6.3%	663.3	517.7	78.1%
		Std. Dev.	0.4%	32.2	11.9	
		COV%	5.8%	4.9%	2.3%	
	Evotherm 3G + RAP	Average	7.2%	669.8	560.7	83.7%
		Std. Dev.	0.3%	28.6	70.9	
		COV%	4.2%	4.3%	12.6%	
	Foaming + RAP	Average	6.1%	598.7	553.0	92.4%
		Std. Dev.	0.4%	34.7	22.1	
		COV%	6.8%	5.8%	4.0%	
LMLC LTOA 5Days @85C	HMA + RAP	Average	7.1%	811.4	643.4	79.3%
		Std. Dev.	0.3%	127.2	60.8	
		COV%	4.1%	15.7%	9.5%	
	Evotherm 3G + RAP	Average	7.5%	954.9	585.3	61.3%
		Std. Dev.	0.0%	76.5	22.3	
		COV%	0.6%	8.0%	3.8%	
	Foaming + RAP	Average	5.9%	780.0	653.3	83.8%
		Std. Dev.	0.0%	7.6	30.3	
		COV%	0.8%	1.0%	4.6%	

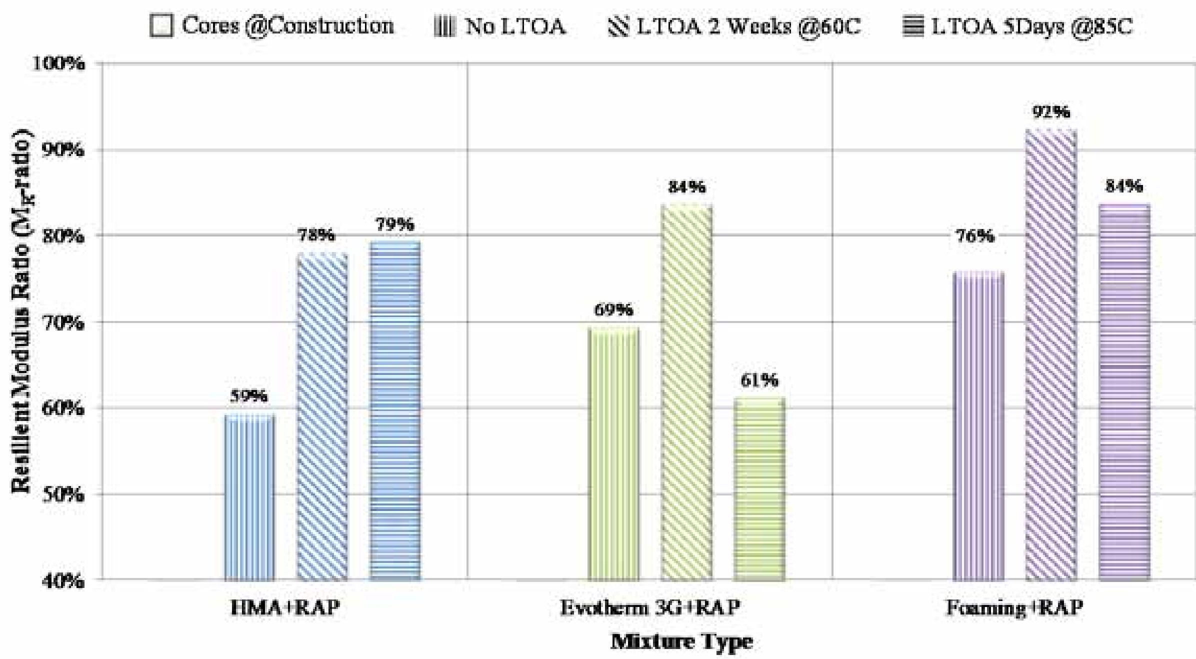
As illustrated, for all New Mexico mixtures, LMLC specimens with LTOA protocols had statistically higher dry and wet M_R stiffness than those without LTOA, indicating that laboratory LTOA was able to increase significantly the mixture stiffness. In addition, in the majority of cases, LMLC specimens with LTOA of 5 days at 185°F (85°C) had statistically higher dry and wet M_R stiffness than those with LTOA of 2 weeks at 140°F (60°C). Therefore, the increase in mixture stiffness was more sensitive to LTOA temperature as compared to LTOA time. The comparison in dry M_R stiffness between PMFC cores at construction and LMLC specimens without LTOA showed that for all mixtures except WMA Foaming with RAP, the LMLC specimens had statistically equivalent stiffness as compared to their corresponding PMFC cores at construction, which further validated the standard laboratory conditioning protocols proposed for preparing LMLC specimens.

Table C.13 and Figure C.19b show the wet-to-dry M_R-ratio for New Mexico mixtures with different laboratory LTOA protocols, for each mixture type. For all mixture types, the laboratory LTOA protocol of 2 weeks at 140°F (60°C) was able to increase significantly the M_R-ratios for the LMLC specimens, as compared to the LMLC specimens without LTOA. However,

the effect on M_R-ratio from the laboratory LTOA of 5 days at 185°F (85°C) was different for Evotherm® 3G with RAP, showing a decrease in M_R-ratio.



(a) Dry and Wet M_R Stiffness



(b) Resilient Modulus Ratio

Figure C.19. M_R Test Results by Mixture Type for the New Mexico Field Project

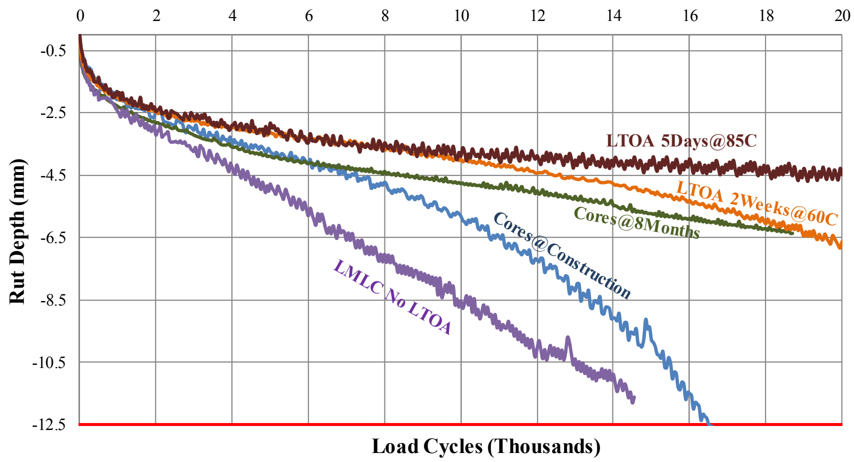
Table C.14. Tukey's HSD Groupings for the M_R Test Results by Mixture Type for the New Mexico Field Project

Mixture	Parameter	PMFC Cores	LMLC with LTOA Protocols		
		At construction	No LTOA	2W@60C	5D@85C
HMA+RAP	Dry M_R	B-C	C	A-B	A
Evotherm 3G+RAP		C	C	B	A
Foaming+RAP		B	C	B	A
HMA+RAP	Wet M_R		C	B	A
Evotherm 3G+RAP			B	A	A
Foaming+RAP			C	B	A

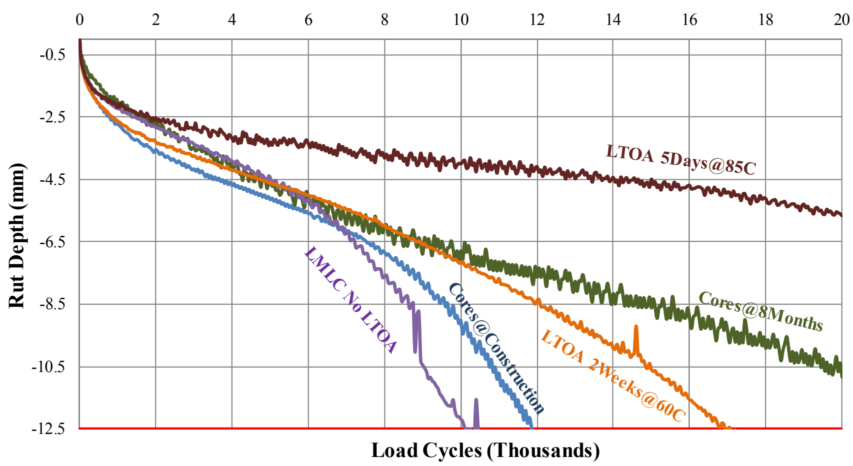
Hamburg Wheel-Tracking Test For the data analysis described in this section, the SIP and the stripping slope were used to assess moisture susceptibility. A precision and bias statement was not available for HWTT test results; therefore, the average differences in SIP and the stripping slope for all Texas mixtures that exhibited stripping were calculated, yielding approximately 2,000 load cycles and 0.2 μm/cycle, respectively. These two values were used as the d2s thresholds to compare results.

HWTT results for all Texas mixture types are shown in Figure C.20, with mixtures with different field aging and laboratory LTOA protocols compared for each mixture type. As illustrated in Figure C.20, for all mixtures, PMFC cores at construction and LMLC specimens without LTOA did not pass the failure criteria of 20,000 load cycles with less than 0.5 inch (12.5 mm) rut depth. However, PMFC cores after summer at 8 months in service and LMLC specimens with laboratory LTOA protocols had a significantly better performance in the HWTT test. The SIP and stripping slope values for all mixtures are summarized in Table C.15.

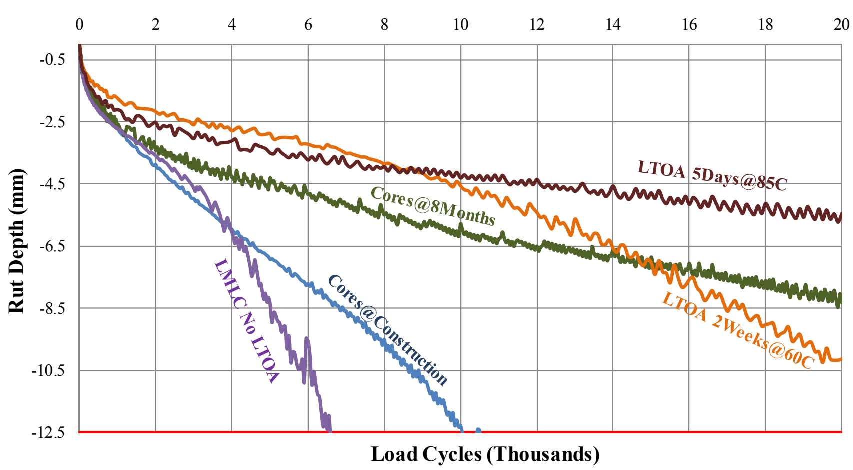
Figure C.21 shows the SIP and the stripping slope for the Texas field project to give a representative comparison in HWTT results of mixtures with different field aging and laboratory LTOA protocols. The upward arrows in Figure C.21a indicate that the SIP was larger than 20,000 load cycles. As illustrated, the WMA mixture PMFC cores after summer at 8 months in service had significantly higher SIP values (considering the d2s of 2,000 load cycles) and lower stripping slope than the PMFC cores at construction, indicating improved resistance to moisture susceptibility with field aging. The comparison of HWTT results between LMLC specimens with and without LTOA protocols indicated that the effect of laboratory LTOA on improving moisture susceptibility was also significant. For all mixtures, the LMLC specimens with laboratory LTOA protocols had higher SIP and lower stripping slope than those without LTOA. Therefore, field aging and laboratory LTOA were able to improve HMA and WMA performance in HWTT tests in terms of resistance to moisture susceptibility.



(a) HMA



(b) Evotherm DAT



(c) Foaming

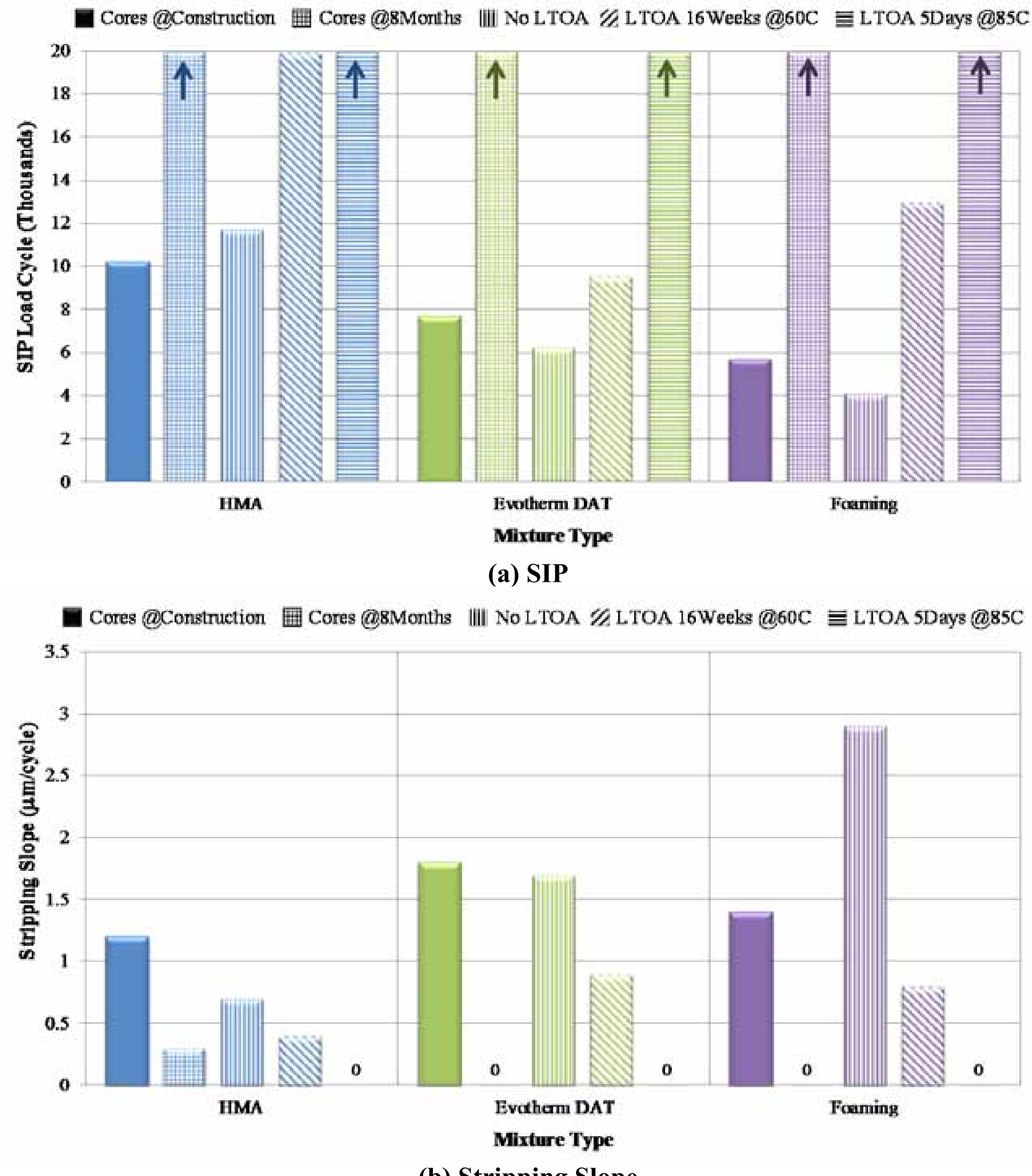
Figure C.20. HWTT Load Cycles versus Rut Depth by Mixture Type for the Texas Field Project

Table C.15. HWTT SIP and Stripping Slope Results for the Texas Field Project

Specimen Type	Mixture Type	Air Voids %		SIP (cycles)	Stripping Slope (µm/cycle)
Cores at construction	HMA	Average	5.7%	10,210	1.2
		Std. Dev.	0.6%		
		COV%	11.1%		
	Evotherm DAT	Average	9.2%	7,703	1.8
		Std. Dev.	1.3%		
		COV%	14.2%		
	Foaming	Average	8.1%	5,690	1.4
		Std. Dev.	0.8%		
		COV%	9.4%		
Cores after summer at 8 months	HMA	Average	8.4%	11,630	0.3
		Std. Dev.	0.3%		
		COV%	4.1%		
	Evotherm DAT	Average	7.6%	>20,000	0
		Std. Dev.	0.5%		
		COV%	6.2%		
	Foaming	Average	8.2%	>20,000	0
		Std. Dev.	0.2%		
		COV%	2.4%		
No LTOA	HMA	Average	6.4%	11,754	0.7
		Std. Dev.	0.5%		
		COV%	7.7%		
	Evotherm DAT	Average	6.5%	6,256	1.7
		Std. Dev.	0.2%		
		COV%	2.4%		
	Foaming	Average	7.4%	4,111	2.9
		Std. Dev.	0.1%		
		COV%	1.6%		
LTOA 2W@60C	HMA	Average	6.3%	19,949	0.4
		Std. Dev.	0.3%		
		COV%	4.7%		
	Evotherm DAT	Average	7.3%	9,547	0.9
		Std. Dev.	0.2%		
		COV%	3.3%		
	Foaming	Average	7.0%	12,941	0.8
		Std. Dev.	0.2%		
		COV%	3.0%		

Specimen Type	Mixture Type	Air Voids %		SIP (cycles)	Stripping Slope (µm/cycle)
LTOA 5D@85C	HMA	Average	5.7%	10,210	0
		Std. Dev.	0.6%		
		COV%	11.1%		
	Evotherm DAT	Average	9.2%	7,703	0
		Std. Dev.	1.3%		
		COV%	14.2%		
	Foaming	Average	8.1%	5,690	0
		Std. Dev.	0.8%		
		COV%	9.4%		

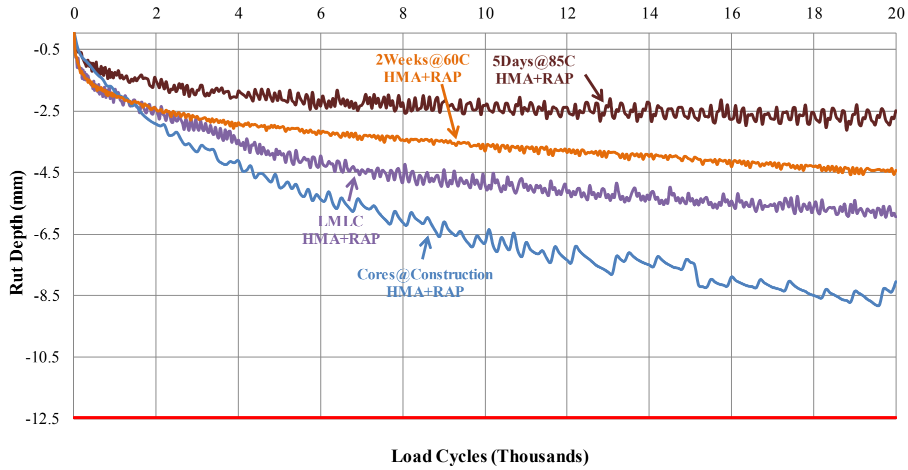
HWTT results for all New Mexico mixture types are shown in Figure C.22, with PMFC cores at construction and mixtures with different laboratory LTOA protocols compared for each mixture type. As illustrated in Figure C.22, for all New Mexico mixtures, PMFC cores at construction and LMLC specimens passed the failure criteria of 20,000 load cycles with less than 0.5 inch (12.5 mm) rut depth. More specifically, stripping did not occur in the HWTT tests for all New Mexico mixtures, and therefore for all those mixtures, the SIP values were higher than 20,000 load cycles and the stripping slopes were zero, as summarized in Table C.16.



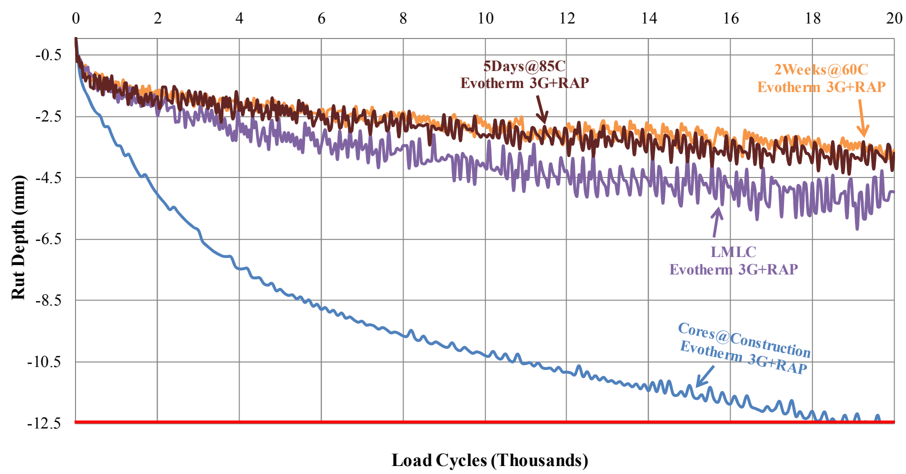
(a) SIP

(b) Stripping Slope

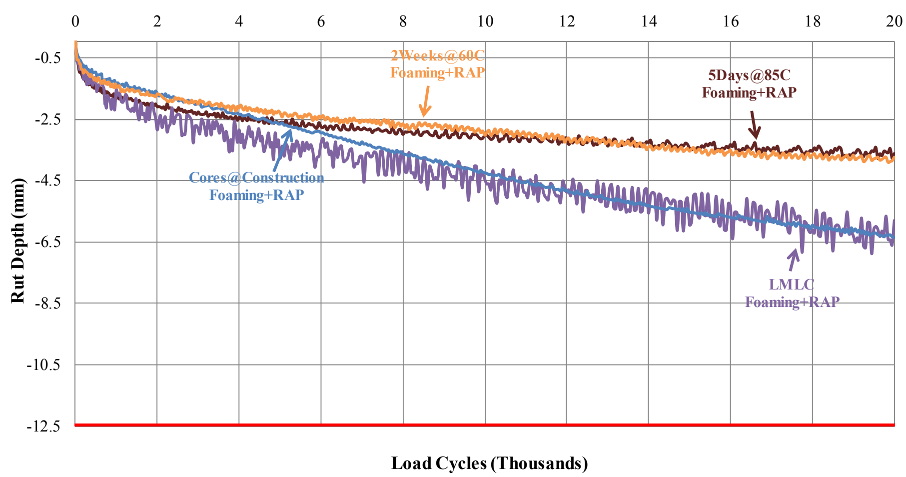
Figure C.21. HWTT Results by Mixture Type for the Texas Field Project



(a) HMA+RAP



(b) Evotherm 3G+RAP



(c) Foaming+RAP

Figure C.22. HWTT Load Cycles versus Rut Depth by Mixture Type for the New Mexico Field Project

Table C.16. HWTT SIP and Stripping Slope Results for the New Mexico Field Project

Specimen Type	Mixture Type	Air Voids %		SIP (cycles)	Stripping Slope (µm/cycle)
Cores at construction	HMA+RAP	Average	6.5%	>20,000	0
		Std. Dev.	0.9%		
		COV%	13.9%		
	Evotherm 3G+RAP	Average	8.6%	>20,000	0
		Std. Dev.	0.6%		
		COV%	6.8%		
	Foaming+RAP	Average	4.7%	>20,000	0
		Std. Dev.	0.4%		
		COV%	8.7%		
No LTOA	HMA+RAP	Average	6.4%	>20,000	0
		Std. Dev.	0.2%		
		COV%	3.2%		
	Evotherm 3G+RAP	Average	7.4%	>20,000	0
		Std. Dev.	0.9%		
		COV%	11.8%		
	Foaming+RAP	Average	5.9%	>20,000	0
		Std. Dev.	0.2%		
		COV%	2.6%		
LTOA 2W@60C	HMA+RAP	Average	5.7%	>20,000	0
		Std. Dev.	0.2%		
		COV%	4.0%		
	Evotherm 3G+RAP	Average	6.2%	>20,000	0
		Std. Dev.	0.3%		
		COV%	4.8%		
	Foaming+RAP	Average	6.0%	>20,000	0
		Std. Dev.	0.1%		
		COV%	2.3%		
LTOA 5D@85C	HMA+RAP	Average	6.9%	>20,000	0
		Std. Dev.	1.1%		
		COV%	16.7%		
	Evotherm 3G+RAP	Average	7.0%	>20,000	0
		Std. Dev.	0.7%		
		COV%	9.4%		
	Foaming+RAP	Average	6.2%	>20,000	0
		Std. Dev.	0.7%		
		COV%	10.9%		

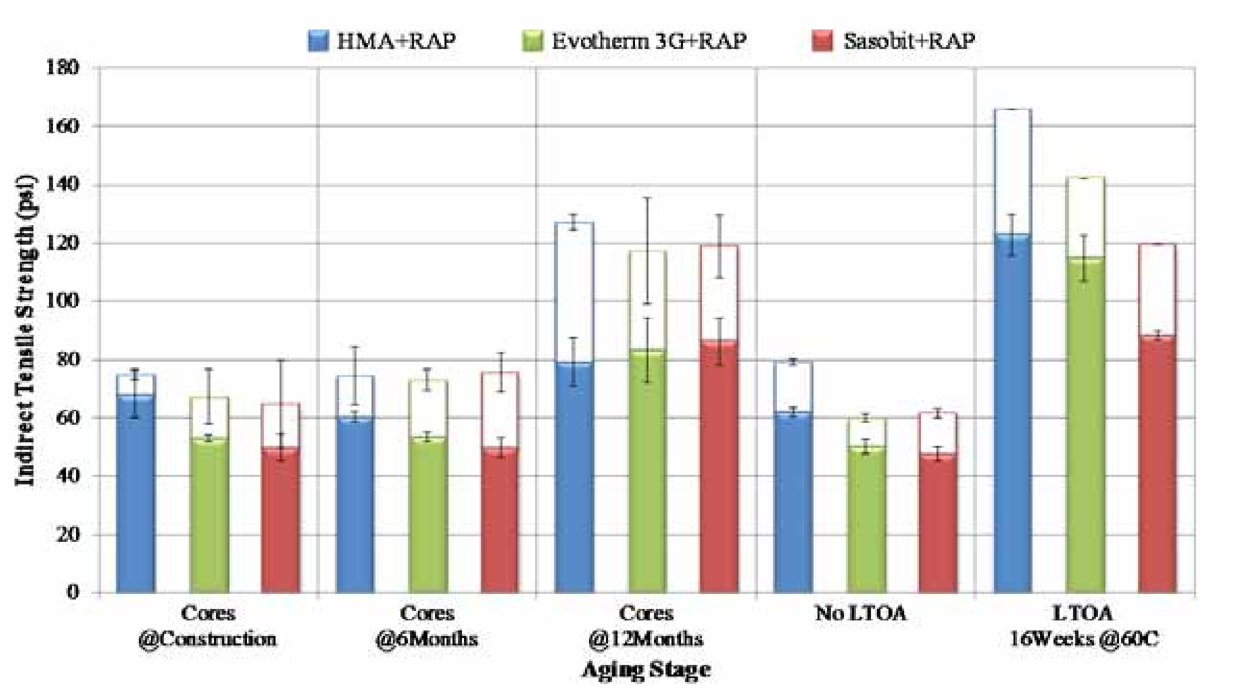
Comparison of HMA vs. WMA Performance after Field and Laboratory Long-Term Oven Aging

As described in this section, HMA and WMA with different field aging times and laboratory LTOA protocols in the Iowa, Texas, and New Mexico field projects were compared. Dry IDT strength and dry M_R stiffness were utilized to evaluate mixture strength and stiffness, and wet IDT strength, TSR, wet M_R stiffness, M_R-ratio, SIP, and stripping slope were used to evaluate mixture resistance to moisture susceptibility. More importantly, based on the test results, the difference in mixture performance between HMA and WMA at different field and laboratory aging stages was evaluated.

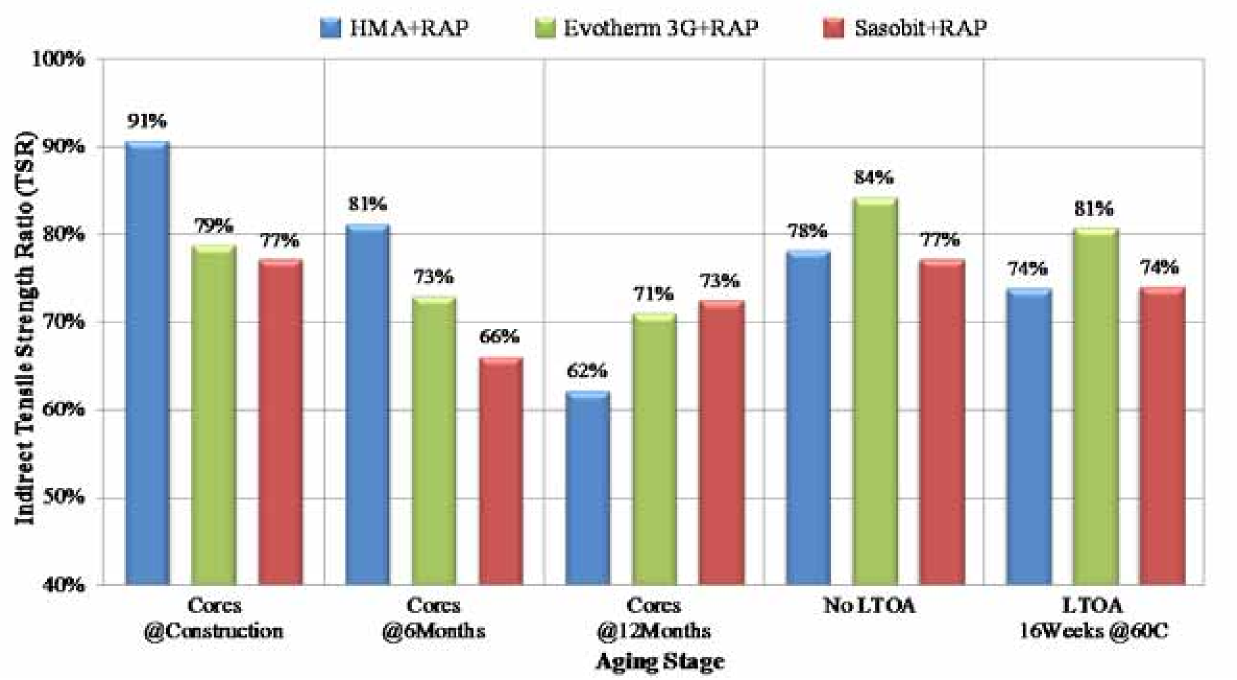
Indirect Tensile Strength Test Dry and wet IDT strengths for all Iowa mixtures are shown in Figure C.23a, with HMA with RAP compared to WMA mixtures with RAP for each field and laboratory aging stage. In addition, the statistical analysis results of Tukey's HSD on the dry and wet IDT strengths are summarized in Table C.9.

As illustrated, PMFC cores at construction and after winter at 6 months in service of HMA with RAP had statistically higher or equivalent dry and wet IDT strengths as compared to those of WMA Evotherm® 3G with RAP and WMA Sasobit® with RAP. In addition, equivalent dry and wet IDT strengths were also achieved between HMA with RAP and the WMA mixtures with RAP by PMFC cores after summer at 12 months in service. For all field and laboratory aging stages except laboratory LTOA of 16 weeks at 140°F (60°C), WMA Evotherm® 3G with RAP and WMA Sasobit® with RAP had equivalent dry and wet IDT strengths. In the case of LMLC specimens with LTOA of 16 weeks at 140°F (60°C), dry and wet IDT strengths of WMA Evotherm® 3G with RAP were significantly higher than those of WMA Sasobit® with RAP.

Figure C.23b presents the wet-to-dry TSR values for all the Iowa mixtures for each field and laboratory aging stage. All TSR values of PMFC cores except WMA Sasobit® with RAP PMFC cores after winter at 6 months in service and HMA with RAP PMFC cores after summer at 12 months in service were higher than 70 percent. In the case of PMFC cores at construction and after winter at 6 months in service, the TSR values of HMA with RAP were higher when compared to the WMA with RAP mixtures. The opposite trend was shown for PMFC cores after summer at 12 months in service. Based on the d2s value of 9.3 percent for TSR (Azari, 2010), equivalent TSR values were obtained between LMLC HMA with RAP and LMLC WMA with RAP specimens.



(a) Dry and Wet IDT Strengths



(b) Tensile Strength Ratio

Figure C.23. IDT Strength Test Results by Specimen Type for the Iowa Field Project

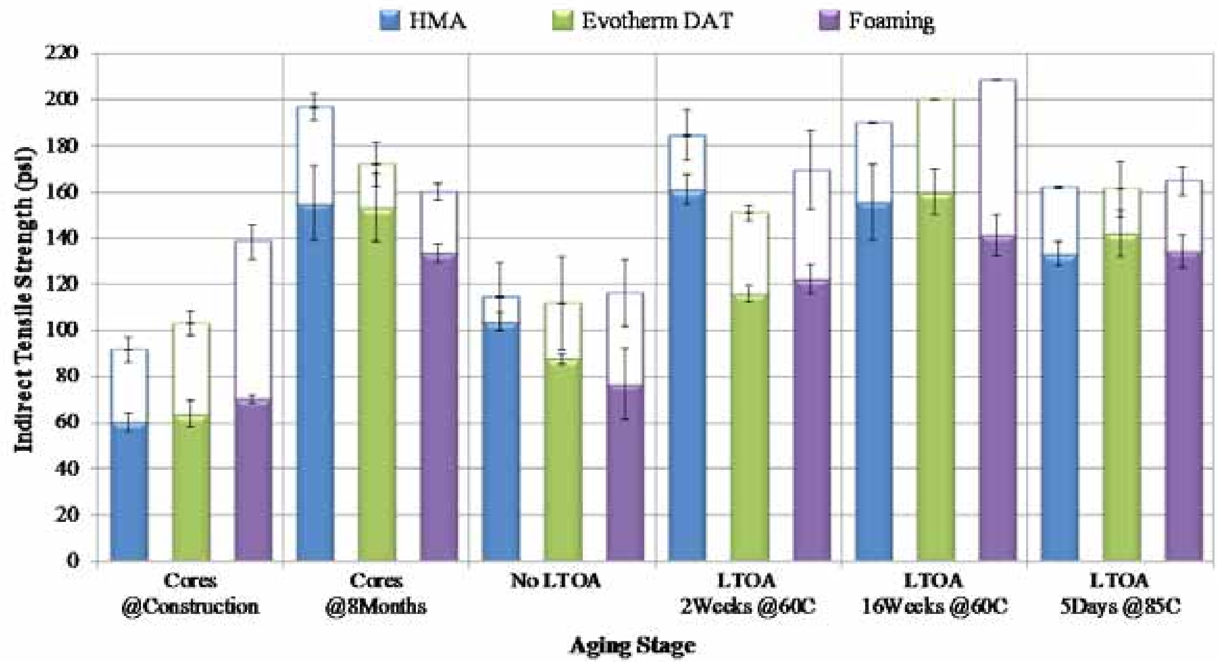
Table C.17. Tukey's HSD Groupings for the IDT Strength Test Results by Specimen Type for the Iowa Field Project

Specimen Type		Parameter	HMA+RAP	Evotherm 3G+RAP	Sasobit+RAP
PMFC Cores	At construction	Dry IDT Strength	A	A	A
	After winter at 6 months		A	A	A
	After summer at 8 months		A	A	A
LMLC with LTOA Protocols	No LTOA		A	B	B
	16W@60C				
PMFC Cores	At construction	Wet IDT Strength	A	A-B	B
	After winter at 6 months		A	B	B
	After summer at 8 months		A	A	A
LMLC with LTOA Protocols	No LTOA		A	B	B
	16W@60C		A	A	B

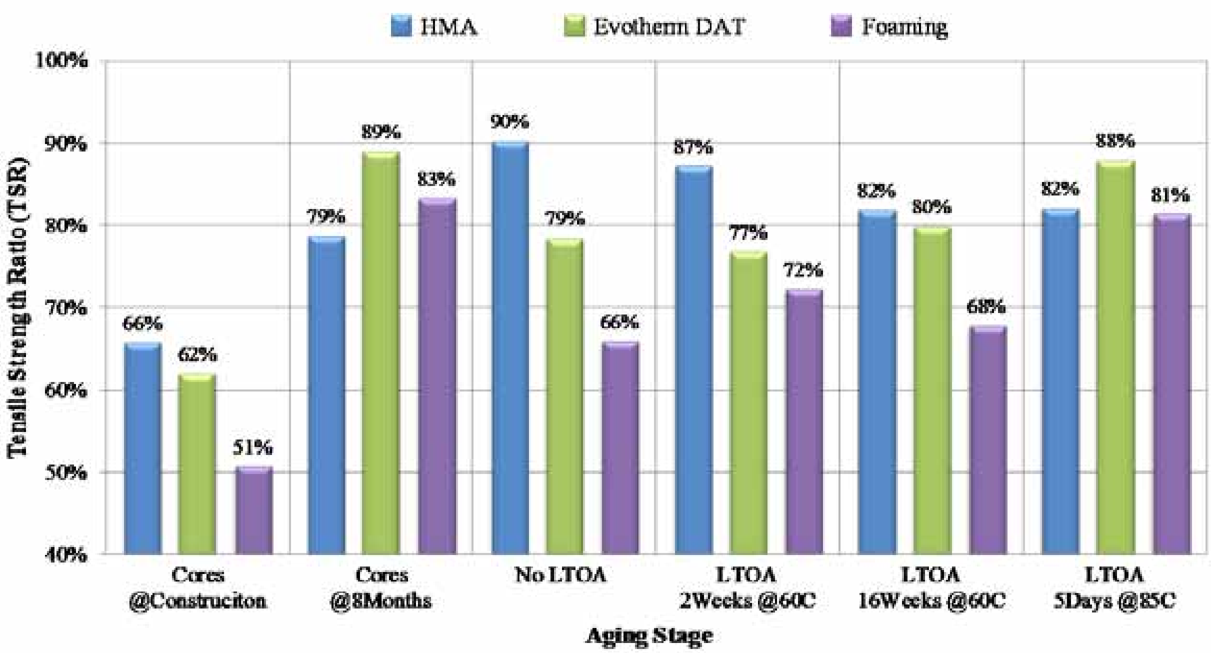
Dry and wet IDT strengths for all Texas mixtures are shown in Figure C.24a, with HMA compared against the WMA mixtures for each field and laboratory aging stage. Additionally, the statistical analysis results of Tukey's HSD for the dry and wet IDT strengths are summarized in Table C.18.

In all cases (except PMFC cores at construction), the dry and wet IDT strengths of HMA were statistically higher or equivalent to the WMA mixtures. For the LMLC specimens, the ones with no LTOA showed equal dry IDT strength for the HMA and WMA mixtures, but in the case of wet IDT strength, WMA Foaming showed a significantly lower value. WMA Evotherm DAT™ LMLC specimens with 2 weeks aging at 140°F (60°C) showed significantly lower dry and wet IDT strengths. In the case of 5 days at 185°F (85°C), HMA and WMA mixtures had equivalent dry and wet IDT strengths.

Figure C.24b presents the wet-to-dry TSR values for all Texas mixtures, with HMA compared with WMA mixtures for each field and laboratory aging stage. In the case of PMFC cores at construction, HMA and WMA Evotherm DAT™ had equivalent TSR values (based on the d2s value of 9.3 percent) that were both higher than that for WMA Foaming. However, statistically higher and equivalent TSR values of PMFC cores after summer at 8 months in service were shown for WMA Evotherm DAT™ and WMA Foaming, respectively, as compared to HMA. All WMA Foaming LMLC specimens except those subjected to the LTOA protocol of 5 days at 185°F (85°C) had the lowest TSR values of all mixture types, even lower than the minimum threshold of 80 percent suggested by AASHTO T 283. Statistically higher TSR values for HMA were shown for LMLC specimens without LTOA and those with LTOA protocol of 2 weeks at 140°F (60°C). However, in the cases of LMLC specimens with longer LTOA time or higher LTOA temperature, equivalent TSR values were obtained for HMA and WMA Evotherm DAT™.



(a) Dry and Wet IDT Strengths



(b) Tensile Strength Ratio

Figure C.24. IDT Strength Test Results by Specimen Type for the Texas Field Project

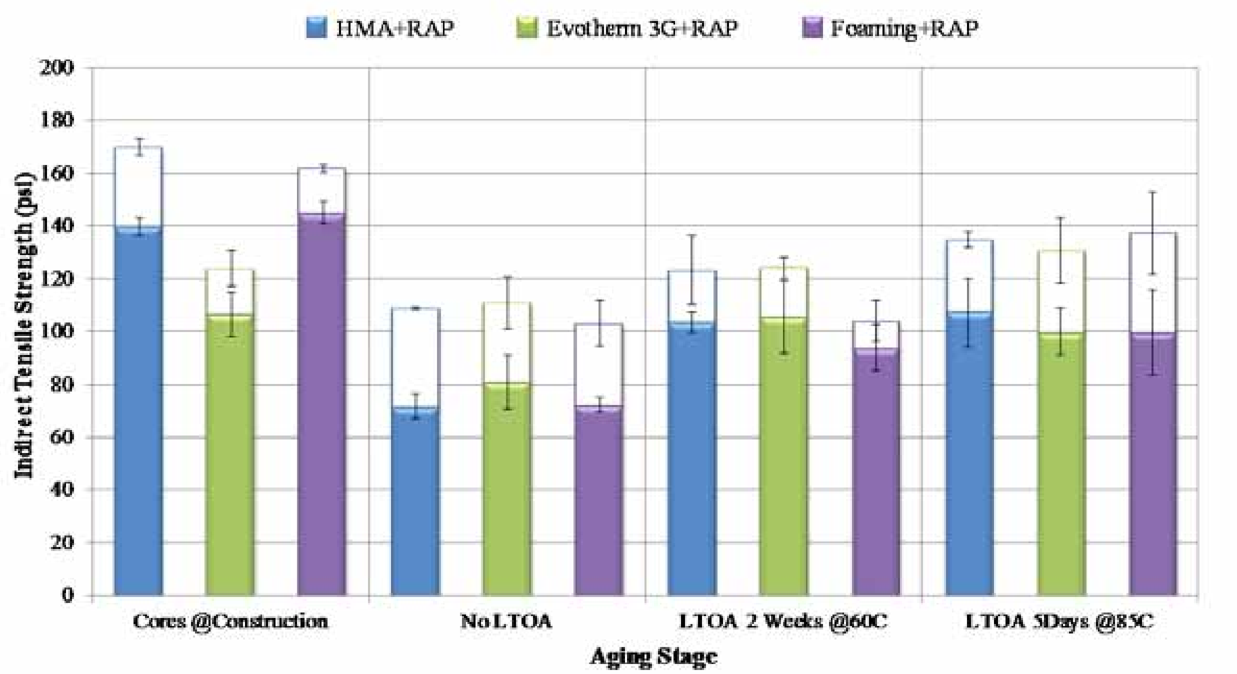
Table C.18. Tukey's HSD Groupings for the IDT Strength Test Results by Specimen Type for the Texas Field Project

Specimen Type		Parameter	HMA	Evotherm DAT	Foaming
PMFC Cores	At construction	Dry IDT Strength	B	B	A
PMFC Cores	After summer at 8 months	Dry IDT Strength	A	B	B
LMLC	No LTOA	Dry IDT Strength	A	A	A
LMLC	2W@60C	Dry IDT Strength	A	B	A-B
LMLC	16W@60C	Dry IDT Strength			
LMLC	5D@85C	Dry IDT Strength	A	A	A
PMFC Cores	At construction	Wet IDT Strength	A	A	A
PMFC Cores	After summer at 8 months	Wet IDT Strength	A	A	A
LMLC	No LTOA	Wet IDT Strength	A	A-B	B
LMLC	2W@60C	Wet IDT Strength	A	B	B
LMLC	16W@60C	Wet IDT Strength	A	A	A
LMLC	5D@85C	Wet IDT Strength	A	A	A

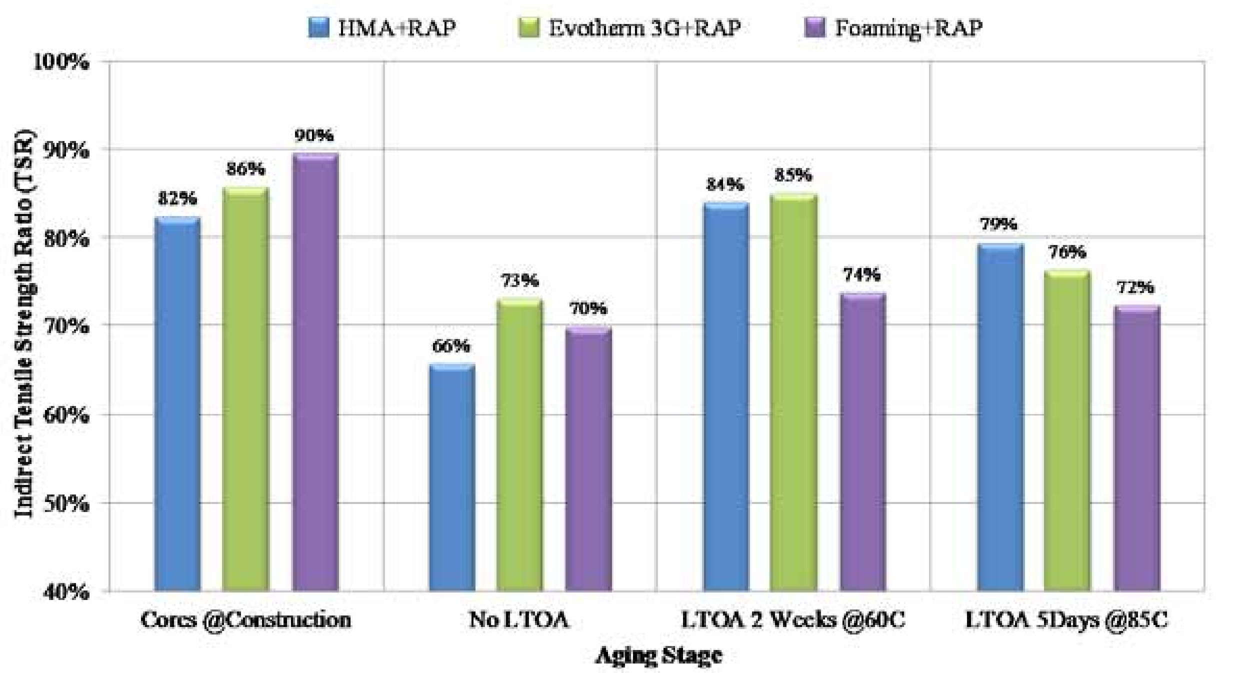
Dry and wet IDT strengths for all New Mexico mixtures are shown in Figure C.25a, with HMA with RAP compared against the WMA with RAP mixtures for each field and laboratory aging stage. Additionally, the statistical analysis results of Tukey's HSD on the dry and wet IDT strengths are summarized in Table C.19.

WMA Evotherm® 3G with RAP PMFC cores at construction had lower dry and wet IDT strengths than the HMA with RAP and WMA Foaming with RAP, indicating more susceptibility to moisture damage. However, the comparison in dry and wet strengths among LMLC specimens of mixtures with RAP indicated that statistically equivalent strengths were obtained between HMA with RAP and WMA mixtures with RAP.

Figure C.25b presents the wet-to-dry TSR values for all New Mexico mixtures, comparing the HMA with RAP against the WMA mixtures with RAP for each field and laboratory aging stage. In the case of PMFC cores at construction, LMLC specimens without LTOA, and those with LTOA of 5 days at 185°F (85°C), equivalent TSR values were shown by HMA with RAP and the two WMA mixtures with RAP when considering the d2s value of 9.3 percent. For the LMLC specimens with LTOA of 2 weeks at 140°F (60°C), HMA with RAP and WMA Evotherm® 3G with RAP had equivalent TSR values, and these were significantly higher than the TSR value of the WMA Foaming with RAP mixture.



(a) Dry and Wet IDT Strengths



(b) Tensile Strength Ratio

Figure C.25. IDT Strength Test Results by Specimen Type for the New Mexico Field Project

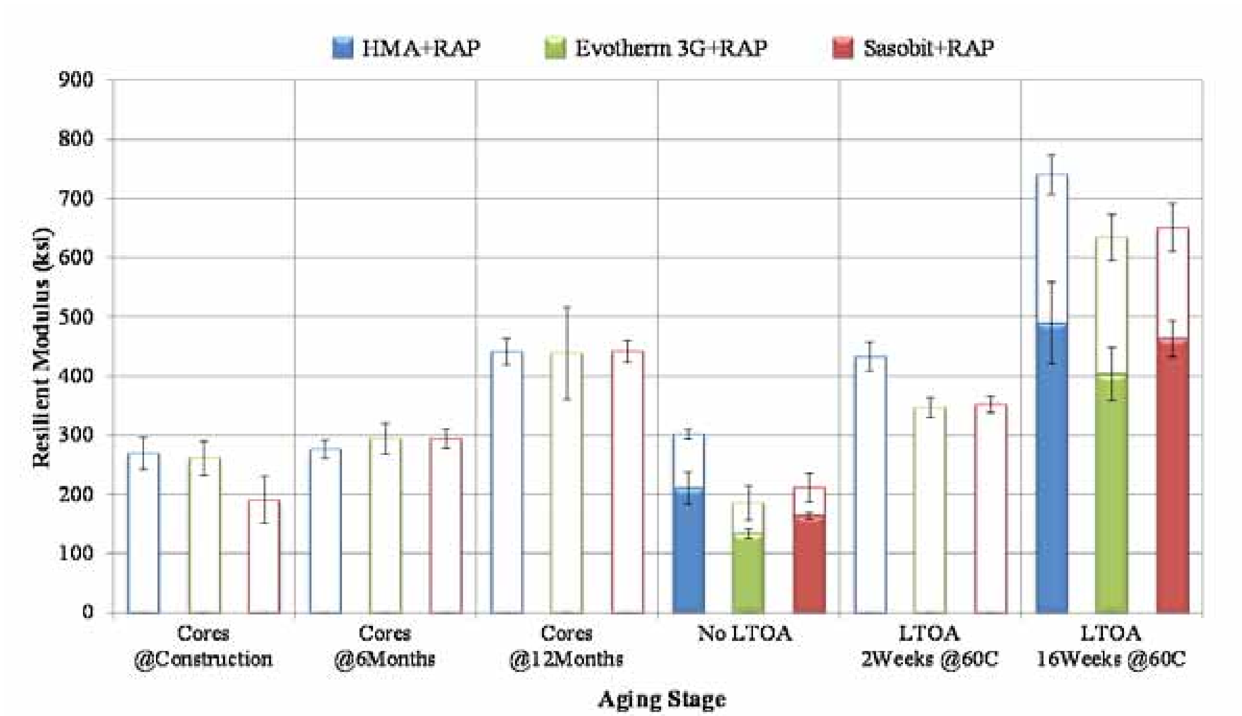
Table C.19. Tukey's HSD Groupings for the IDT Strength Test Results by Specimen Type for the New Mexico Field Project

Specimen Type		Parameter	HMA+RAP	Evotherm 3G+RAP	Foaming+RAP
PMFC Cores	At construction	Dry IDT Strength	A	B	A
LMLC with LTOA Protocols	No LTOA		A	A	A
	2W@60C		A	A	A
	5D@85C		A	A	A
PMFC Cores	At construction	Wet IDT Strength	A	B	A
LMLC with LTOA Protocols	No LTOA		A	A	A
	2W@60C		A	A	A
	5D@85C		A	A	A

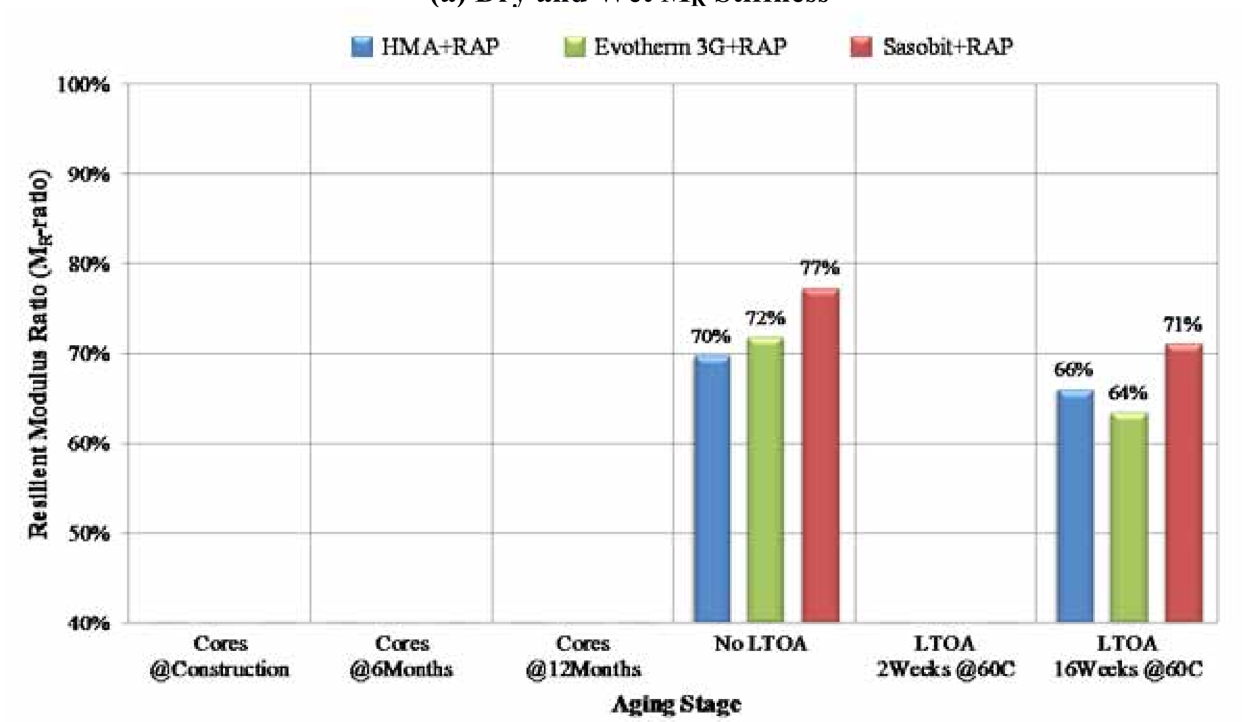
Resilient Modulus Test Dry and wet MR stiffnesses for all Iowa mixtures are shown in Figure C.26a, with HMA with RAP compared against WMA mixtures with RAP for each field and laboratory aging stage. Additionally, the statistical analysis results of Tukey's HSD on the dry and wet MR stiffness are summarized in Table C.20.

As shown, equivalent dry M_R stiffness was obtained between the HMA with RAP and the WMA with RAP mixtures in the case of PMFC cores at construction. As for the LMLC specimens, HMA with RAP had higher initial dry and wet stiffness as compared to the two WMA mixtures with RAP, while equivalent wet stiffness was achieved with laboratory LTOA of 16 weeks at 140°F (60°C).

Figure C.26b shows the wet-to-dry M_R-ratio for the Iowa HMA with RAP and WMA with RAP LMLC specimens with and without laboratory LTOA protocols. Based on the assumed d2s value of 10 percent, an equivalent M_R-ratio was observed between the HMA with RAP and WMA with RAP LMLC specimens with and without LTOA protocols. Therefore, based on M_R-ratio, there is no evidence that WMA with RAP LMLC specimens were more susceptible to moisture damage as compared to the HMA with RAP mixtures.



(a) Dry and Wet M_R Stiffness



(b) Resilient Modulus Ratio

Figure C.26. M_R Test Results by Specimen Type for the Iowa Field Project

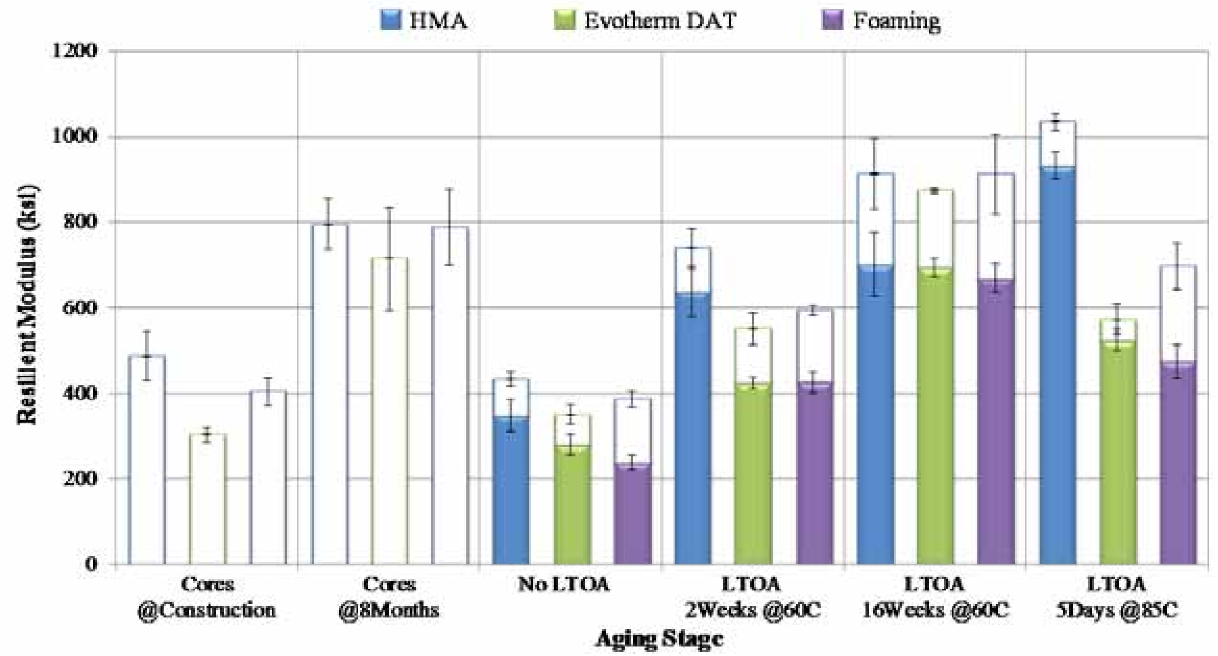
Table C.20. Tukey's HSD Groupings for the M_R Test Results by Specimen Type for the Iowa Field Project

Specimen Type		Parameter	HMA	Evotherm 3G+RAP	Sasobit+RAP
PMFC Cores	At construction	Dry M_R	A	A	A
	After winter at 6 months		A	A	A
	After summer at 12 months		A	A	A
LMLC	No LTOA		A	B	B
	16W@60C		A	B	B
PMFC Cores	At construction	Wet M_R			
	After winter at 6 months				
	After summer at 12 months				
LMLC	No LTOA		A	B	B
	16W@60C		A	A	A

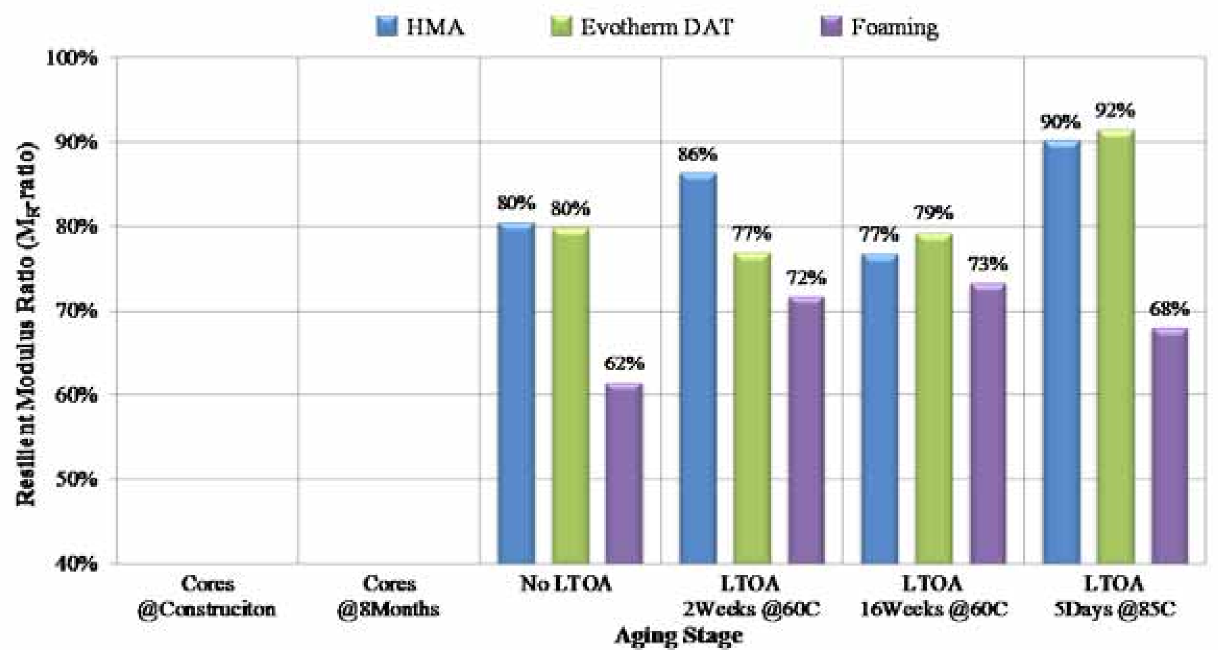
Dry and wet M_R stiffnesses for all Texas mixtures are shown in Figure C.27a, with HMA compared against WMA mixtures for each field and laboratory aging stage. In addition, the statistical analysis results of Tukey's HSD on the dry and wet M_R stiffness are summarized in Table C.21.

The dry stiffness of HMA PMFC cores at construction was statistically higher than the stiffness of WMA Evotherm DAT™ and equivalent to the stiffness of WMA Foaming. However, equivalent dry stiffness was achieved between HMA and the two WMA mixtures after summer at 8 months in service. The comparison in dry and wet M_R stiffness of LMLC specimens indicated that HMA had higher or equivalent initial (i.e., no LTOA) dry and wet stiffness as compared to the two WMA mixtures; however, this difference was reduced after aging for 16 weeks at 140°F (60°C). In the case of LMLC specimens with LTOA for 5 days at 185°F (85°C), the dry and wet M_R stiffness of HMA was still higher than the stiffness of the two WMA mixtures.

Figure C.27b shows the wet-to-dry M_R-ratio for Texas HMA and WMA LMLC specimens with and without laboratory LTOA protocols. WMA Foaming showed the lowest M_R-ratio values for all LMLC specimens with and without LTOA protocols. Equivalent M_R-ratio values in all LMLC specimens were shown between HMA and WMA Evotherm DAT™.



(a) Dry and Wet M_R Stiffness



(b) Resilient Modulus Ratio

Figure C.27. M_R Test Results by Specimen Type for the Texas Field Project

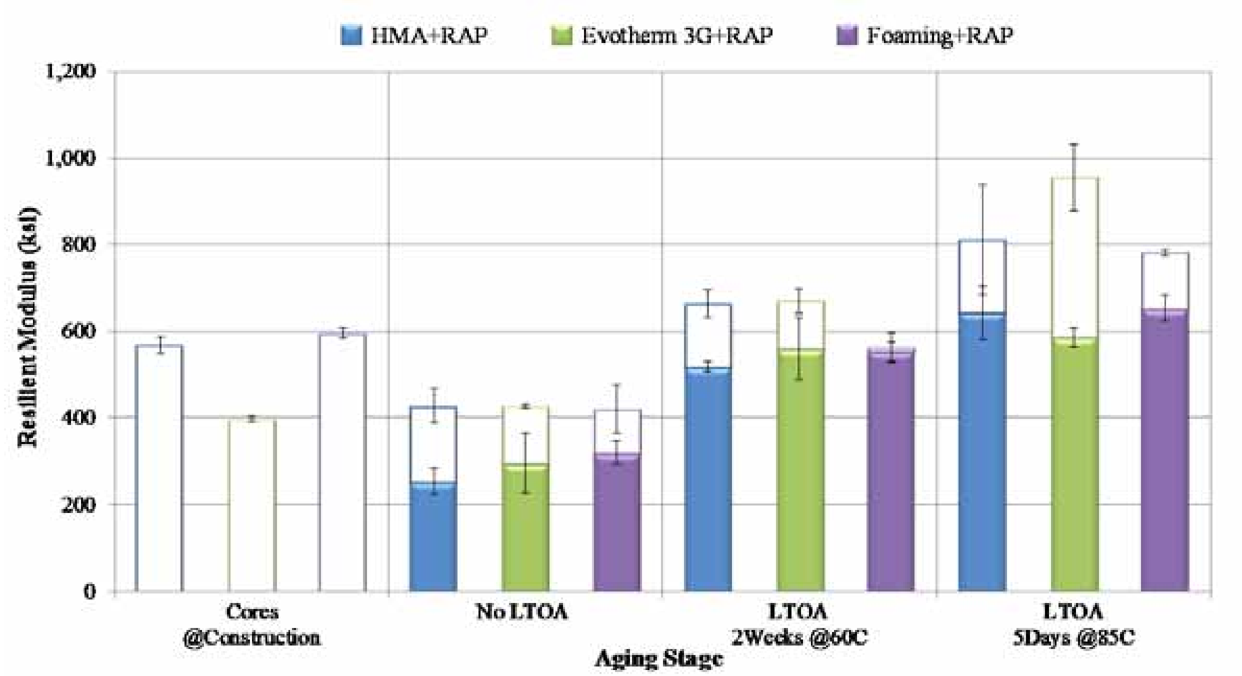
Table C.21. Tukey's HSD Groupings for the M_R Test Results by Specimen Type for the Texas Field Project

Aging Stages		Parameter	HMA	Evotherm DAT	Foaming
PMFC Cores	At construction	Dry M_R	A	B	A-B
	After summer at 8 months		A	A	A
LMLC	No LTOA		A	B	A-B
	2W@60C		A	B	B
	16W@60C		A	A	A
	5D@85C		A	C	B
PMFC Cores	At construction	Wet M_R			
	After summer at 8 months				
LMLC	No LTOA		A	A-B	B
	2W@60C		A	B	B
	16W@60C		A	A	A
	5D@85C		A	B	B

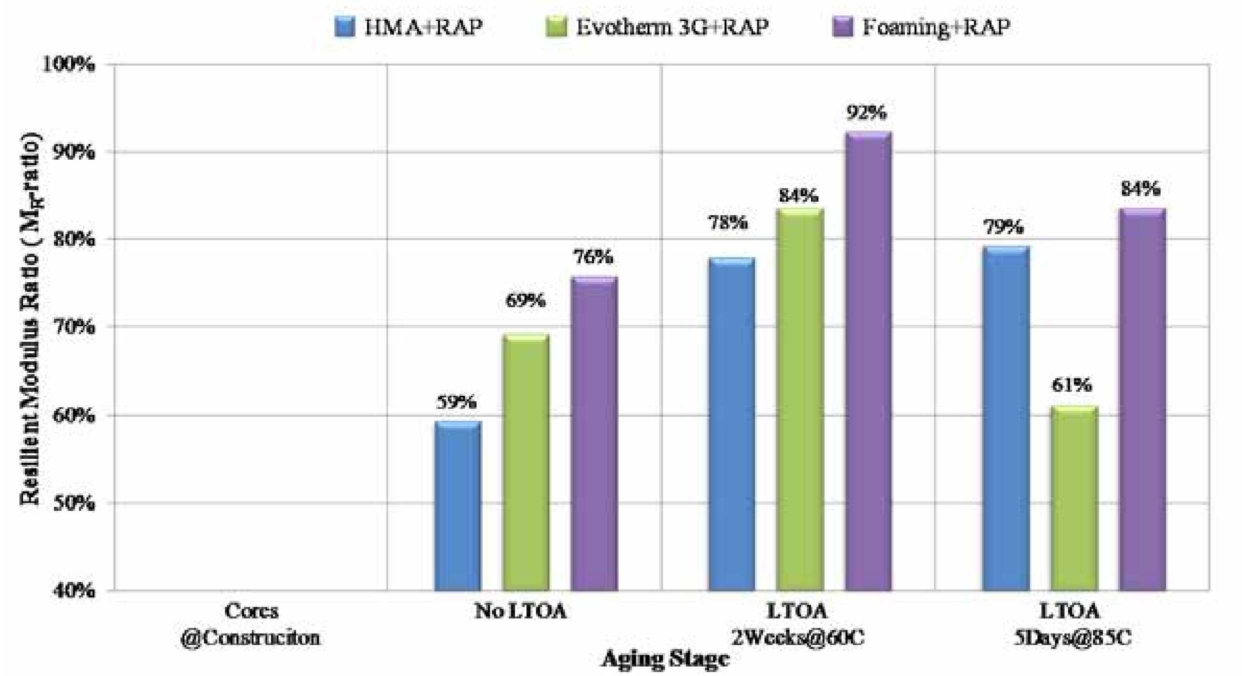
Dry and wet M_R stiffnesses for all New Mexico mixtures are shown in Figure C.28a, with HMA with RAP compared against the WMA mixtures with RAP for each field and laboratory aging stage. In addition, the statistical analysis results of Tukey's HSD test on the dry and wet M_R stiffness are summarized in Table C.22.

As shown in the figures, the comparison in M_R stiffness between the HMA with RAP and the two WMA mixtures with RAP indicated that statistically equivalent dry and wet M_R stiffness was obtained by LMLC specimens with and without laboratory LTOA protocols. However, in the case of PMFC cores at construction, WMA Evotherm® 3G with RAP had lower dry M_R stiffness than HMA with RAP and WMA Foaming with RAP.

Figure C.28b shows the wet-to-dry M_R-ratio for New Mexico HMA with RAP and WMA with RAP LMLC specimens with and without laboratory LTOA protocols. In the case of WMA with RAP LMLC specimens without LTOA, the TSR values of the two WMA mixtures with RAP were higher than the TSR obtained for the HMA with RAP mixture. For LMLC specimens with an LTOA protocol of 2 weeks at 140°F (60°C), equivalent TSR values were shown by HMA with RAP and WMA Evotherm® 3G with RAP, and a significantly higher TSR value was achieved by WMA Foaming with RAP. A different trend in terms of TSR values was shown by LMLC specimens with the LTOA protocol of 5 days at 185°F (85°C); WMA Evotherm® 3G with RAP had a lower TSR value as compared to HMA with RAP and WMA Foaming with RAP.



(a) Dry and Wet M_R Stiffness



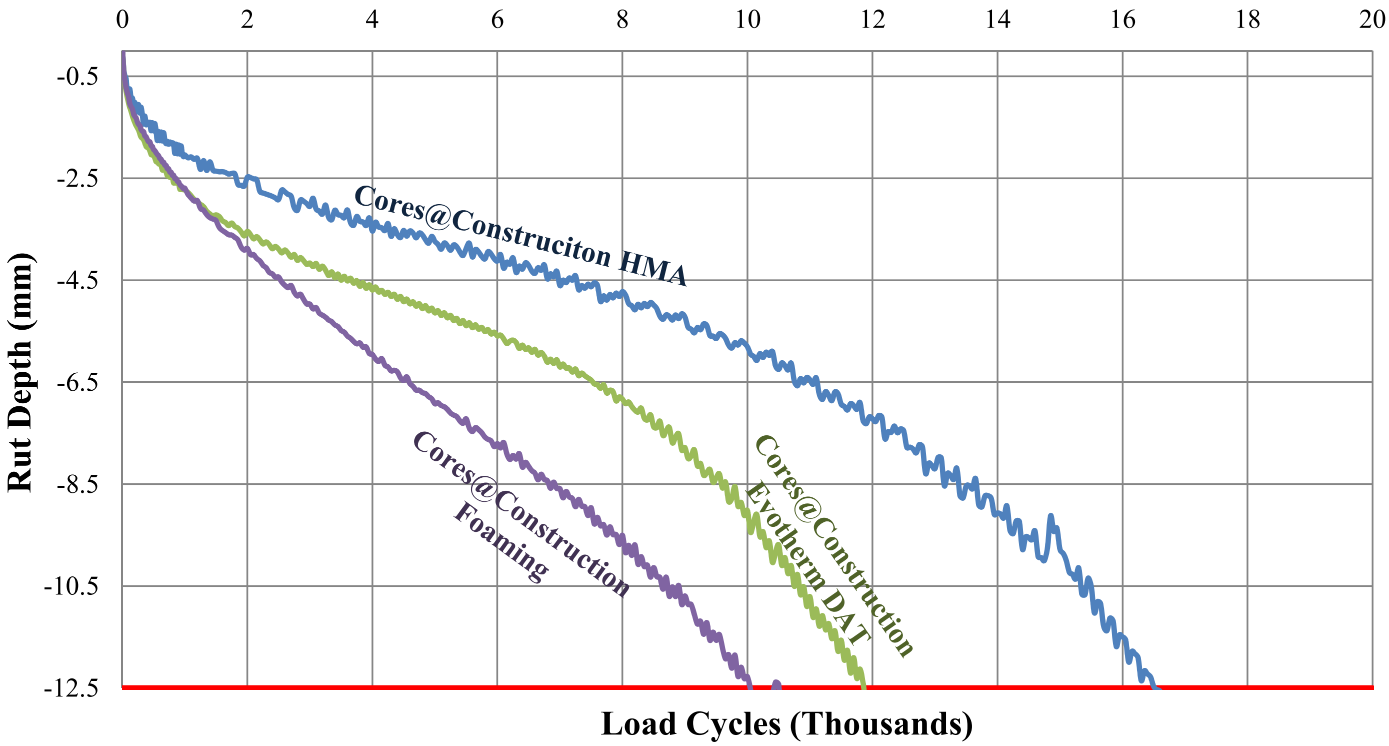
(b) Resilient Modulus Ratio

Figure C.28. M_R Test Results by Specimen Type for the New Mexico Field Project

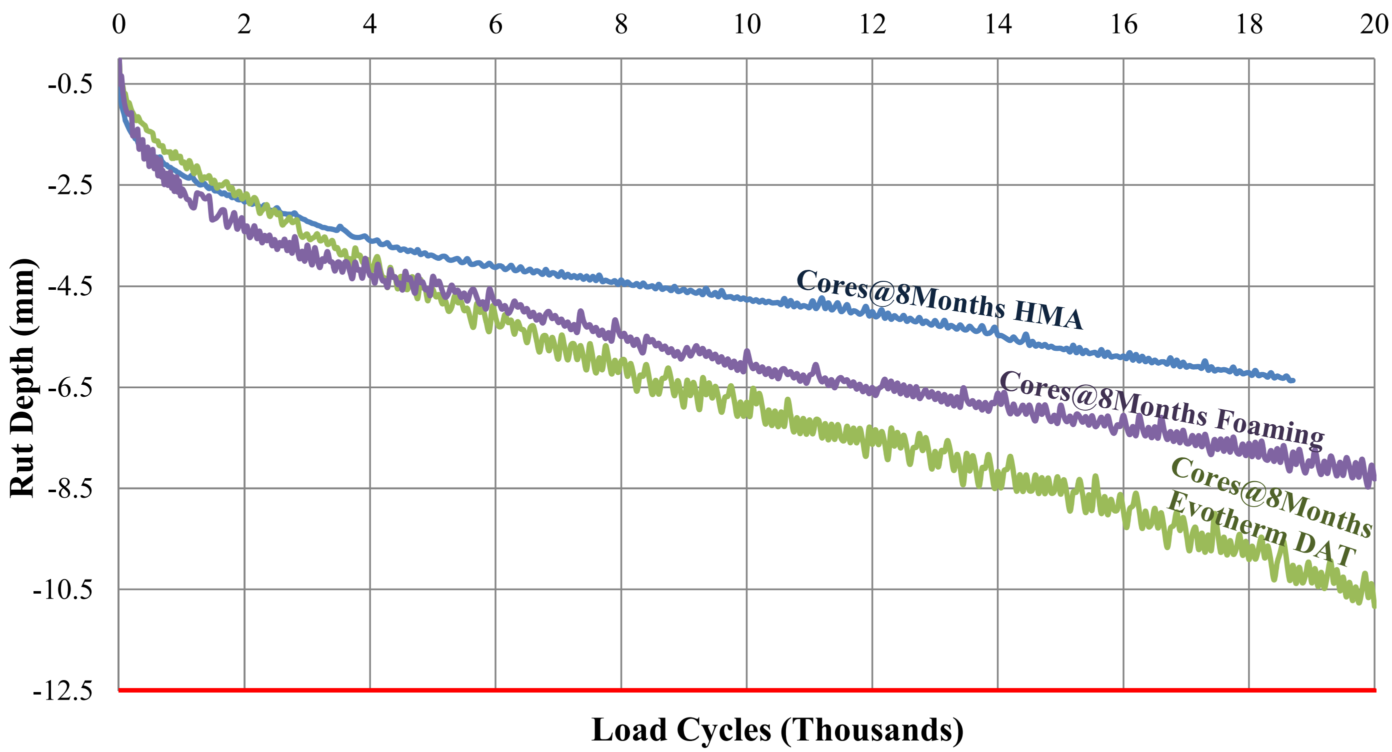
Table C.22. Tukey's HSD Groupings for the M_R Test Results by Specimen Type for the New Mexico Field Project

Specimen Type		Parameter	HMA+RAP	Evotherm 3G+RAP	Foaming+RAP
PMFC Cores	At construction	Dry M_R	A	B	A
LMLC with LTOA Protocols	No LTOA		A	A	A
	2W@60C		A	A	A
	5D@85C		A	A	A
PMFC Cores	At construction	Wet M_R			
LMLC with LTOA Protocols	No LTOA		A	A	A
	2W@60C		A	A	A
	5D@85C		A	A	A

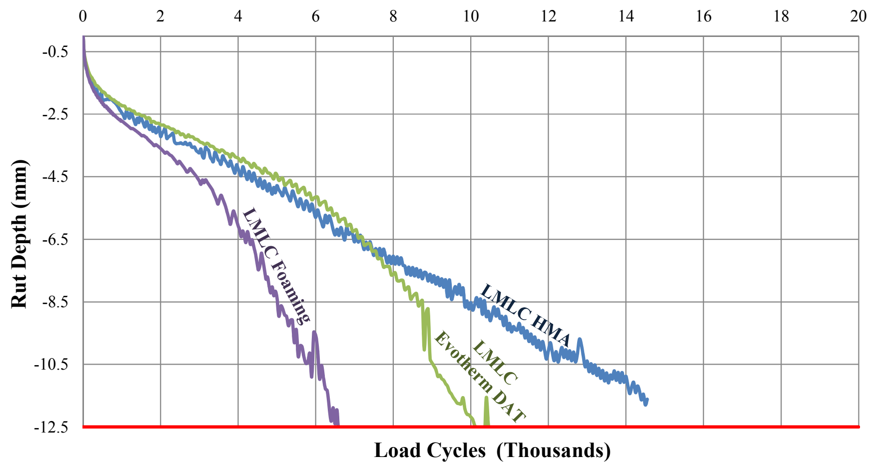
Hamburg Wheel-Tracking Test HWTT results for all Texas mixtures are shown in Figure C.29, with HMA compared against the WMA mixtures for each field and laboratory aging stage. As shown, in the majority of cases (PMFC cores after summer at 8 months in service being the exception), HMA had better performance in terms of rutting and moisture susceptibility than the WMA mixtures did.



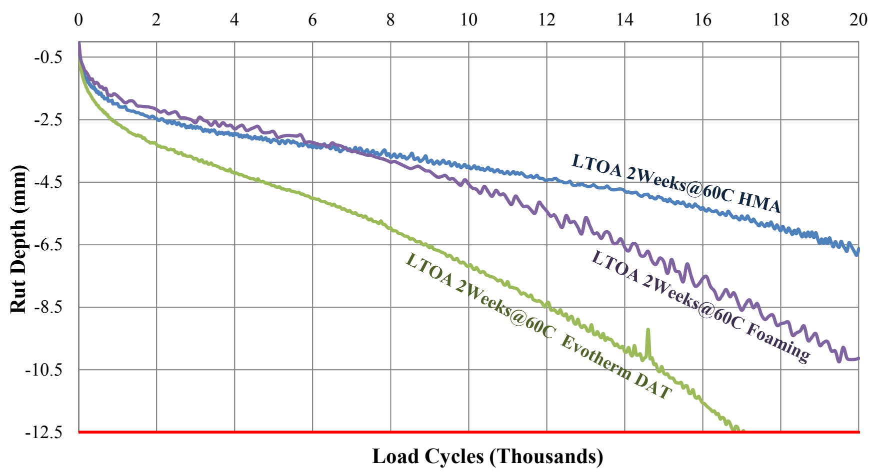
(a) PMFC Cores at Construction



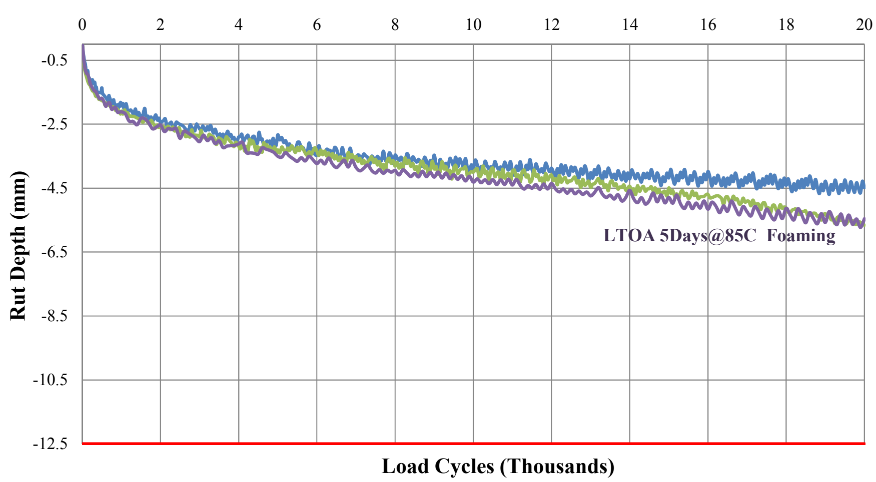
(b) PMFC Cores after Summer at 8 Months In Service



(c) LMLC Specimens without LTOA



(d) LMLC Specimens with LTOA of 2 Weeks at 140°F (60°C)



(e) LMLC Specimens with LTOA of 5 Days at 185°F (85°C)

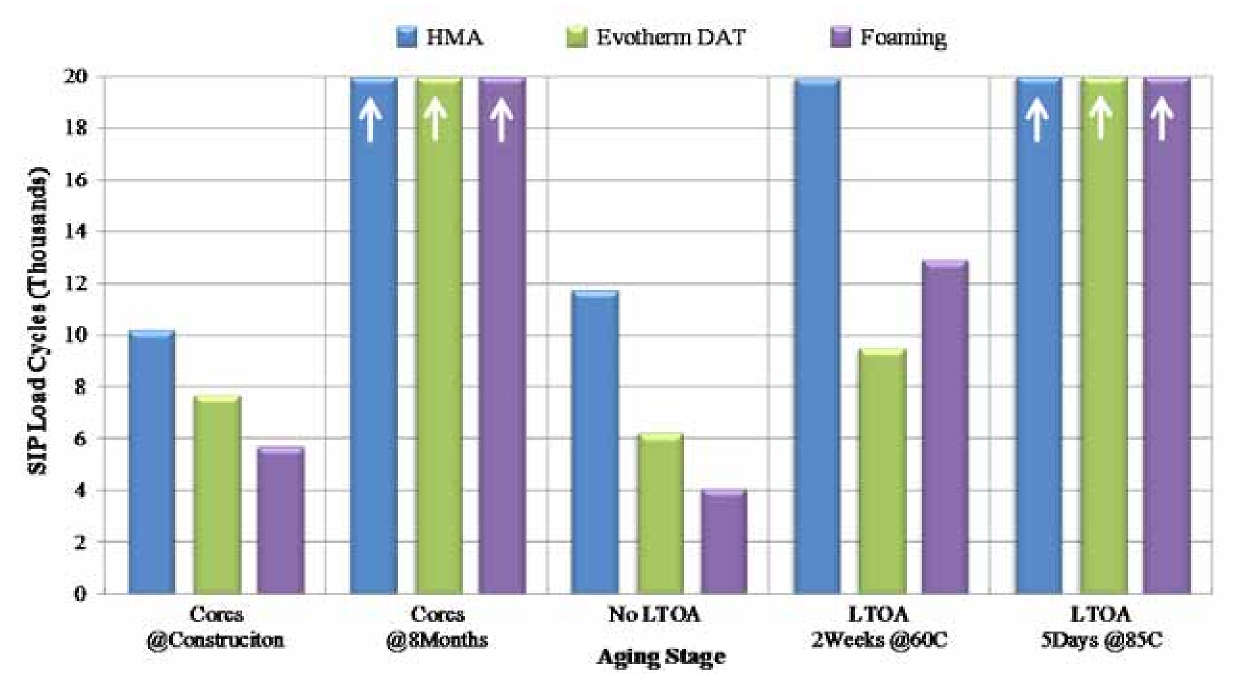
Figure C.29. HWTT Load Cycles versus Rut Depth by Specimen Type for the Texas Field Project

Figure C.30 shows the SIP and the stripping slope from the HWTT results obtained after testing the Texas mixtures. These parameters were used to compare the moisture susceptibility of HMA and WMA mixtures for each field and laboratory aging stage. The upward arrows located at the end of the bars in Figure C.30a indicate that the SIP was higher than 20,000 load cycles; in other words, no SIP was detected from the results.

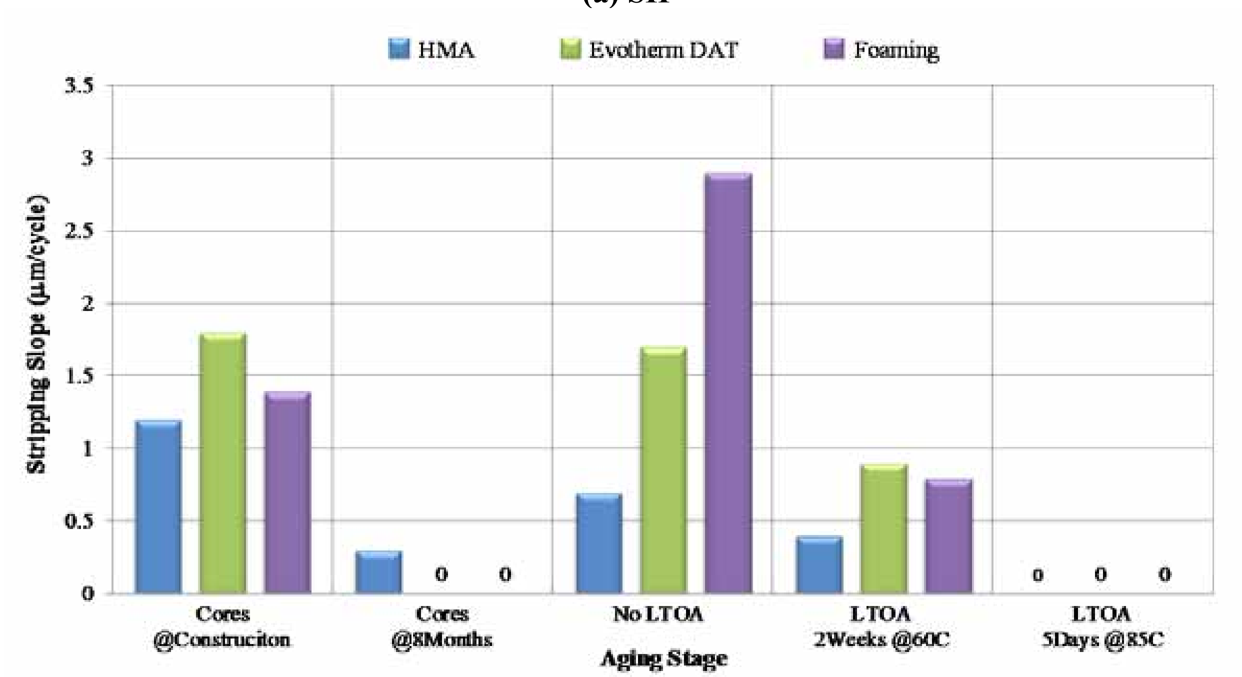
In all cases, HMA had higher or equivalent SIP values than its WMA counterparts, except for PMFC cores after summer at 8 months in service, where an opposite trend in SIP values was obtained. WMA Evotherm DAT™ had higher SIP values than WMA Foaming in PMFC cores at construction and LMLC specimens without LTOA. However, equivalent SIP values were obtained by the two WMA mixtures in PMFC cores after summer at 8 months in service and LMLC specimens with LTOA protocol of 5 days at 185°F (85°C).

Test results shown in Figure C.30 indicated better moisture resistance for HMA specimens as compared to WMA except for PMFC cores after summer at 8 months in service, as indicated by higher or equivalent SIP and lower or equivalent stripping slopes. Results of PMFC cores after summer at 8 months in service indicated that HMA had a higher stripping slope than the two WMA mixtures, although the stripping slope for the HMA mixture was very small.

HWTT results for all New Mexico mixtures are shown in Figure C.31, with HMA with RAP compared against the WMA mixtures with RAP for each field and laboratory aging stage. As discussed before, no stripping occurred in any of the New Mexico field and laboratory mixtures in the HWTT tests. Therefore, HMA with RAP and WMA mixtures with RAP are expected to have an equivalent performance in terms of moisture damage resistance.

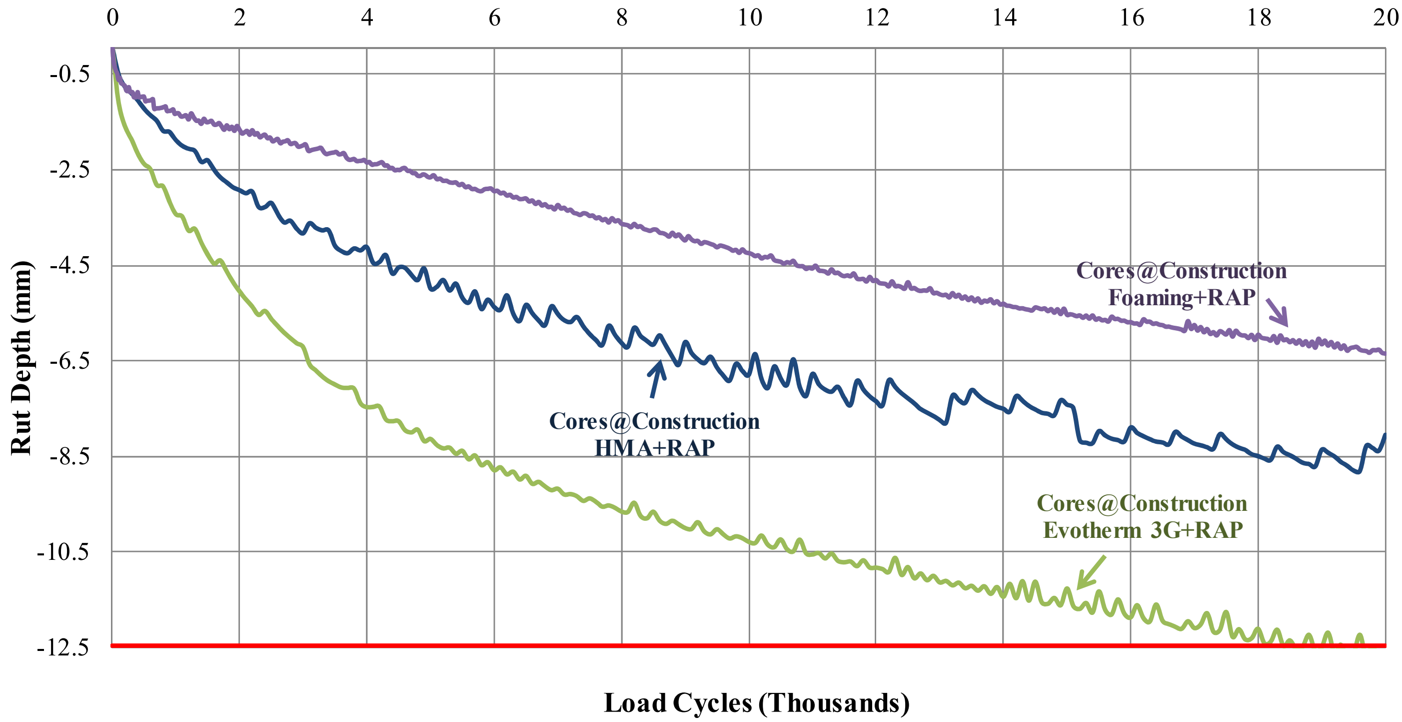


(a) SIP

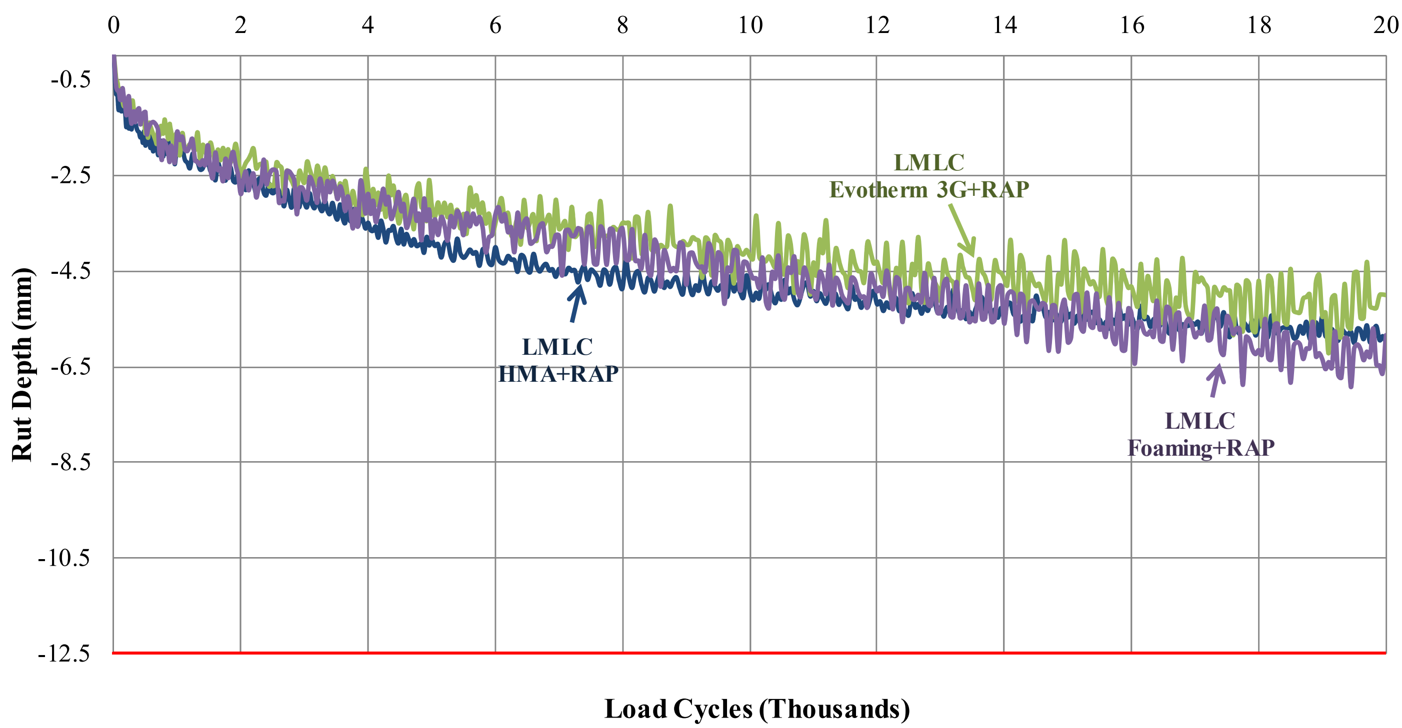


(b) Stripping Slope

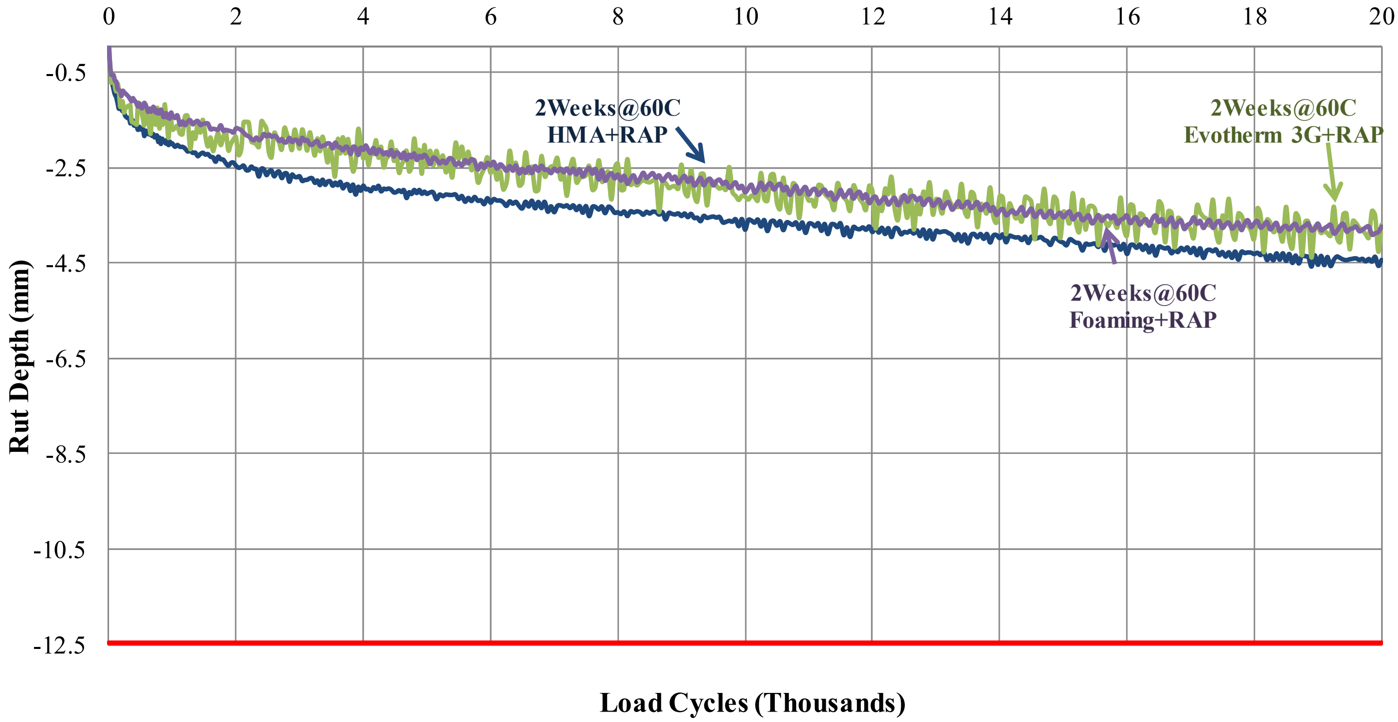
Figure C.30. HWTT Results by Specimen Type for the Texas Field Project



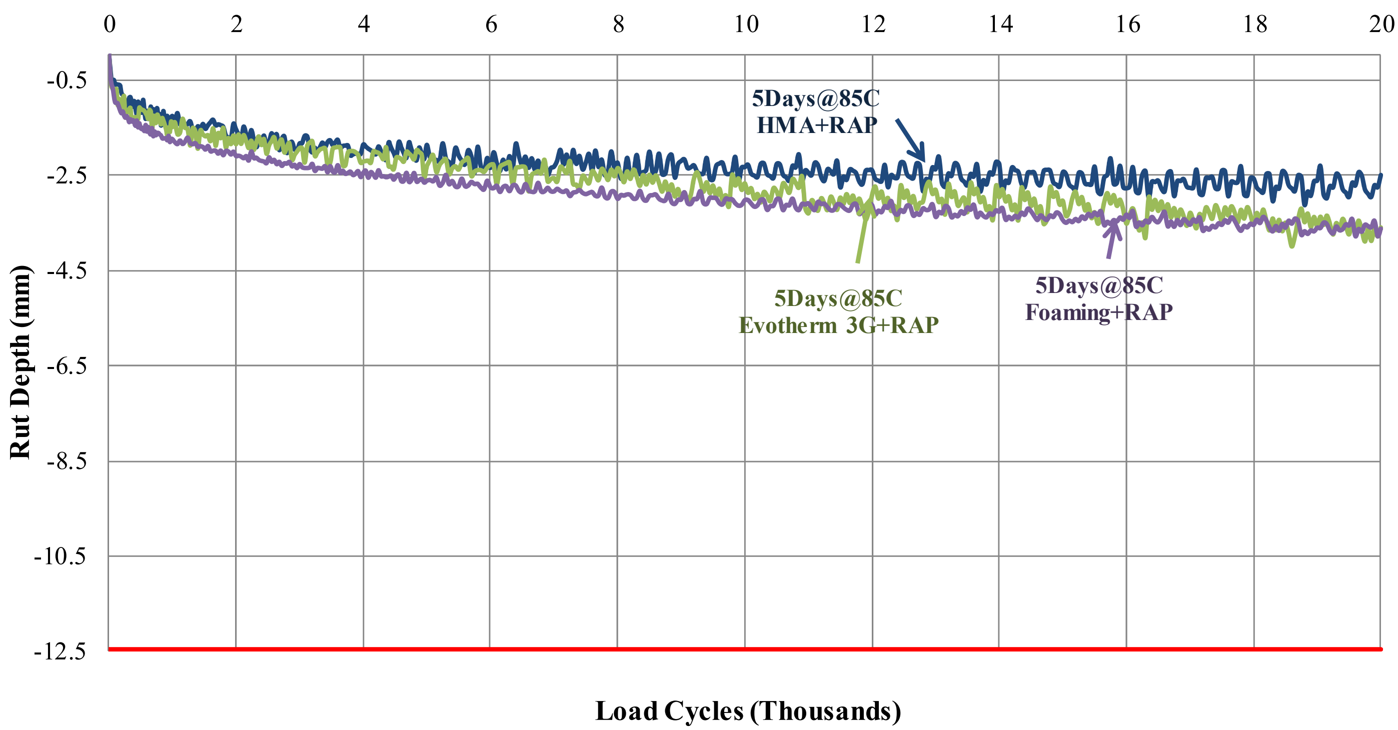
(a) PMFC Cores at Construction



(b) LMLC Specimens without LTOA



(c) LMLC Specimens with LTOA of 2 Weeks at 140°F (60°C)



(d) LMLC Specimens with LTOA of 5 Days at 185°F (85°C)

Figure C.31. HWTT Load Cycles versus Rut Depth by Specimen Type for the New Mexico Field Project

APPENDIX D. CONSTRUCTION REPORTS FOR FIELD PROJECTS

IOWA US HIGHWAY 34

General Description of the Project

The field project in Iowa was located on US Highway 34 in the southwest part of the state, between the city of Creston and the city of Corning and spanning two counties: Union and Adams. The widening and resurfacing job, Project ID NHSX-34-3(35)-3H-02, was constructed between late August and early September of 2011. The test sections were especially set up for two National Cooperative Highway Research Program (NCHRP) research projects: 9-49 and 9-49A. Although all the test sections for this research project were located in Adams County, the job was executed under the supervision of the Iowa Department of Transportation (IADOT)—Creston Construction Office. The contractor for this job was Norris Asphalt Paving Company from Ottumwa, Iowa.

US Highway 34 is a two-lane two-way highway located in a rural area with light to moderate traffic. The project site was mostly flat with some rolling terrain. The total length of the project was approximately 17 mi with 32 ft average roadbed width. The average overlay thickness was 1.5 inches (38 mm). The top layer of the existing pavement was milled off and an intermediate level-off course was paved before placing the surface layer. Figure D.1 shows a general view of the project site. Figure D.2 shows the various asphalt layers constructed at different times including the recent surface overlay.

Figure D.1. Iowa US 34 Project Site

Figure D.2. Typical Iowa Pavement Structure Including the Recent Overlay

The field project consisted of three test sections employing hot mix asphalt (HMA) with reclaimed asphalt pavement (RAP), warm mix asphalt (WMA) Sasobit® with RAP, and WMA Evotherm® 3G with RAP. Each WMA section included approximately 6,000 tons of mixture, while the HMA section included approximately 19,000 tons of mixture. The contractor paved 3,500 to 4,000 tons each day. During paving, the research team monitored and recorded construction data, compacted specimens on site using plant mixture without reheating or with minimum reheating to reach the compaction temperature, and obtained field cores and raw materials.

Mixtures and Materials

This field project used a 0.5 inch (12.5 mm) nominal maximum aggregate size (NMAS) dense-graded mixture (i.e., IADOT HMA 3M) for the surface layer with 17 percent RAP from the project site. The binder content of the RAP was approximately 5.25 percent. The virgin aggregates were obtained from four different sources: two limestone aggregates, a quartzite aggregate, and field sand. The moisture content of the aggregate was approximately 4.4 to 4.5 percent. All three mixtures used the same aggregate gradation, were designed at 86 design gyrations (N_{des}), and had 4.6 percent and 5.4 percent virgin binder and total binder content, respectively. The contractor did not incorporate any anti-stripping agent in the mixture. Bituminous Materials Company supplied the performance-graded (PG) 58-28 binder from its Des Moines, Iowa, terminal. The asphalt binder was unmodified.

Both Evotherm® 3G and Sasobit® additives were blended with the asphalt binder at the terminal. Evotherm® 3G was added at 0.5 percent by weight of total binder content. During production of the WMA Sasobit® and WMA Evotherm® mixtures, the contractor used 0.2 percent less asphalt binder as compared to the HMA mixture. The detailed HMA mix design is presented in Figure D.3.

Form 956 ver. 8.13

Iowa Department of Transportation

Highway Division - Office of Materials

HMA Gyratory Mix Design

Mix Data

County :	Adams		Project : NHSX-034-3(35)--3H-02	Mix No. :	4BD11-28
Mix Size (in.) :	1/2	Type A	Contractor : Norris Asphalt Paving Co.	Contract No. :	28859
Mix Type:	HMA 3M	L - 3 Option	Design Life ESAL's :	Date:	08/03/11
Intended Use :	Surface		Location : MP 62.38 - 82.92	ON US 34 from Jct. 148 to W Creston Corp. Limits	

Aggregate	% in Mix	Source ID	Source Location	Beds	Gsb	%Abs	FAA
Man sand	27.0%	AMO046	Bethany, Harrison Co/Norris Aggreg	20A-20C	2.570	2.25	45.0
3/8 Chips	10.0%	A63002	Durham Mine/Martin Marietta	101	2.431	3.81	45.0
3/4 Clean	15.0%	A63002	Durham Mine/Martin Marietta	88-95	2.526	2.91	45.0
Sand	21.0%	A25518	Raccoon River Sand/Martin Marietta		2.614	0.68	43.0
3/4 Quartzite	10.0%	ASD002	Dell Rapids E. Minnehaha Co/Lg Ev		2.648	0.20	45.0
1/2 RAP	17.0%	ABC11-95	17% Project (5.25 % AC)		2.591	1.72	41.2

Job Mix Formula - Combined Gradation (Sieve Size in.)

	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
Upper Tolerance	100	100	99	90	70	48		22			5
	100	100	92	83	63	43	28	18	9.4	4.4	3.0
Lower Tolerance	100	100	85	76	56	38		14			1.0

Home

Asphalt Binder Source and Grade: Bit. Mtls. PG 58-28

Gyratory Data

% Asphalt Binder	5.00	**5.44**	5.50	6.00	Number of Gyrations
Corrected Gmb @ N-Des.	2.315	**2.333**	2.336	2.343	N-Initial
Max. Sp.Gr. (Gmm)	2.442	**2.431**	2.429	2.412	7
% Gmm @ N- Initial	87.4	**88.3**	88.4	89.5	N-Design
%Gmm @ N-Max	95.8	**97.1**	97.3	98.3	86
% Air Voids	5.2	**4.0**	3.8	2.9	N-Max
% VMA	14.4	**14.1**	14.1	14.3	134
% VFA	63.9	**71.7**	72.8	80.0	Gsb for Angularity
Film Thickness	9.97	**10.90**	11.03	12.23	Method A
Filler Bit. Ratio	0.73	**0.67**	0.66	0.59	2.593
Gsb	2.569	**2.569**	2.569	2.569	Pba / %Abs Ratio
Gse	2.632	**2.636**	2.637	2.638	0.54
Pbe	4.09	**4.47**	4.52	5.01	Slope of Compaction
Pba	0.96	**1.02**	1.03	1.05	Curve
% New Asphalt Binder	82.9	**84.3**	84.5	85.9	14.6
Asphalt Binder Sp.Gr. @ 25c	1.031	**1.031**	1.031	1.031	Mix Gmm Linearity
% Water Abs	1.88	**1.88**	1.88	1.88	Excellent
S.A. m^2 / Kg.	4.10	**4.10**	4.10	4.10	Pb Range Check
% + 4 Type 4 Agg. Or Better	87.4	**87.4**	87.4	87.4	1.00
% + 4 Type 2 or 3 Agg.	27.1	**27.1**	27.1	27.1	RAM Check
% -4 Type 2	0.5	**0.5**	0.5	0.5	OK
Fineness Modulus of Type 2	0.6	**0.6**	0.6	0.6	
Angularity-method A	41	**41**	41	41	Specification Check
% Flat & Elongated	5.6	**5.6**	5.6	5.6	Comply
Sand Equivalent	78	**78**	78	78	TSR Check
Aggregate Type	A	**A**	A	A	
% Crushed	75	**75**	75	75	91.6

Disposition : An asphalt content of 5.4% is recommended to start this project.

Data shown in 5.44% column is interpolated from test data.

The % ADD AC to start project is 4.6%

Comments : Verification complied, final approval based on plant produced HMA.

Copies to : Norris Asphalt Paving Co. Ames Creston RCE D. Redmond - DME

Buhmann Lab Dist 1 Matls/ District 4 Matls File

Mix Designer & Cert.# : Vicki Williams SE-126 Signed : Marcia Buhmann Dist. 4 Materials

Figure D.3. Iowa US 34 HMA Mix Design

Plant and Mixture Production

The counter-flow drum asphalt mix plant, a portable Gencor Ultra 400 (see Figure D.4), was approximately 14 years old and rated at 400 tons/h production. It had two Gencor Hy-way brand horizontal binder tanks. The plant also had a Gencor 100-ton capacity storage silo. The plant used five cold feed bins for virgin aggregates and one separate bin for RAP. The plant had a conventional baghouse fines collection system, and part of the baghouse fines was reintroduced into the drum. A drag slat conveyor carried the mixture from the drum to the storage silo.

Typically, the plant operator started production at a higher temperature and lowered it to the target mixing temperature after dispensing five or six truckloads. In this project, regardless of the mixture type, the asphalt binder temperature was always maintained between 310°F and 320°F (154°C and 160°C) at the tank. Table D.1 presents the data for the particular production day and time when the loose mixtures employed in this project were collected.

Table D.1. Production, Paving, and Ambient Temperatures for the Iowa Field Site

Mixture	Date of Production	Plant Mixture Temp (°F)	Paving Temp (°F)	Ambient Temp (°F)
WMA Sasobit®	09-08-2011	270-277	240-248	60 to 74
WMA Evotherm® 3G	09-10-2011	260-265	235-240	64 to 77
Hot Mix Asphalt	09-12-2011	315-320	295-300	70 to 80

Figure D.4. Asphalt Mix Plant at the Iowa Field Site

Construction

The asphalt mix plant was located approximately 3 mi north from the north end of the project site. The distance of the asphalt mix plant from the Sasobit®, Evotherm® 3G, and HMA test sections was approximately 14, 18, and 21 mi, respectively. The hauling time to those three sections was approximately 22, 27, and 30 min, respectively. The mixtures were hauled using end dump trucks. The end dump trucks released the loose mixtures into the material transfer

vehicle (MTV) chute. Later, the MTV transferred the mixtures into the paver hopper after remixing (see Figure D.5).

This job used two dual steel-drum vibratory rollers (breakdown and finish) and one pneumatic-tire roller (intermediate). One dual steel-drum vibratory roller compacted the loose mat in four to five passes. The pneumatic-tire roller made approximately nine passes followed by three passes of the finish roller. The finish roller operated at low-amplitude, low-frequency vibration mode. The tire pressure of the intermediate roller was set at 90 psi, and the roller had a skirt to retain the temperature. The breakdown and intermediate roller followed the paver closely. Before paving, the contractor applied SS-1 tack coat at a rate of 0.05 gal/yd^2. The application of the tack coat was not uniform across the mat. Table D.2 lists the equipment used for laydown and compaction. Typical paving width was approximately 16 ft.

Figure D.5. Laydown of Loose Mixture at the Iowa Field Site

Table D.2. Paving Equipment Used at the Iowa Field Site

Equipment Type	Manufacturer	Model
Material Transfer Device	Roadtec	SB 2500C
Paver	Roadtec	2115-04
Breakdown Roller	Bomag	BW 284 AD
Intermediate Roller	Ingersoll Rand	PT-240R
Finish Roller (steel-wheeled)	Bomag	BW 284 AD

Sample Collection

Plant mixture was collected from the truck right after discharge from the silo (see Figure D.6). Large quantities of mixture were collected for later use in the laboratory as well as for on-site specimen compaction. The materials sampling scheme is listed in Table D.3. In addition to loose mixture, the research team collected straight PG 58-28 asphalt binder, asphalt binder blended with additives, virgin aggregate, and RAP materials form the asphalt mix plant. With the help of IADOT personnel, the research team also collected 36 road cores from the three

test sections right after construction (i.e., September 2011). Basically, these specimens were initially obtained from random locations for quality control. Later, in March 2012 (see Figure D.7) and September 2012, IADOT once again helped the research team by obtaining 36 road cores on each occasion.

Figure D.6. Loose Plant Mixture Collection from the Truck at the Iowa Asphalt Mix Plant

Table D.3. Material Sampling Scheme at the Iowa Field Site

Sample Type	Material	Point of Sampling
Lab Mixed, Lab Compacted	Fine Aggregate	Stockpile
	Coarse Aggregate	Stockpile
	RAP	Stockpile
	PG 58-28 Asphalt	Transport Truck at Asphalt Mix Plant
	PG 58-34 Asphalt with Evotherm® 3G	Transport Truck at Asphalt Mix Plant
	Sasobit®	Manufacturer
Plant Mixed, Lab Compacted	Loose Mixture	Truck at Asphalt Mix Plant
Plant Mixed, Field Compacted First Set Right after Construction—September 2011	Road Cores	Random
Plant Mixed, Field Compacted Second Set—March 2012	Road Cores	Travel Lane (between wheelpath)
Plant Mixed, Field Compacted Third Set—September 2012	Road Cores	Travel Lane (between wheelpath)

Figure D.7. Field Core Collection 6 Months after Construction

On-Site Plant-Mixed, Laboratory-Compacted (PMLC) Specimen Compaction

Fifty-six 6 inch (150 mm) diameter specimens were compacted on site using plant mixture at a temporary IADOT laboratory located within a 5 min driving distance from the asphalt mix plant. Thirty-two of them were 2.4 inches (61 mm) tall, and 24 of them were 3.75 inches (95 mm) tall. Loose plant mixture collected from the truck at the plant was quickly brought to the lab and placed in the oven between 1 to 2 h to achieve compaction temperature. Specimens were compacted using a Pine portable Superpave gyratory compactor (SGC; Model AGFB) to 7±1 percent air voids (see Figure D.8).

Figure D.8. Pine Compactor Used to Prepare the On-Site PMLC Specimens

Field Performance

In March of 2013, after about 18 months in service, the IADOT was contacted to obtain an overall assessment of the condition of the pavement. A crew was dispatched to observe the performance of all test sections. The crew reported no issues with the HMA with RAP section; however, the Evotherm® 3G with RAP and Sasobit® with RAP showed some signs of distress (see Figure D.9). The issues were localized on the center of the lane, and thus it was hypothesized that construction issues (i.e., paver segregation at the crown) and subsequent deterioration caused by a snow plow blade caused the observed distress.

(a) Sasobit Eastbound **(b) Evotherm 3G Eastbound**

Figure D.9. Condition of the Iowa WMA Pavement Sections after 18 Months In Service

MONTANA INTERSTATE HIGHWAY 15

General Description of the Project

The Montana field project was located on IH 15 in the southwest part of the state, just north of the Idaho-Montana state border, between the cities of Monida and Lima, in the Butte District (see Figure D.10). IH 15 is a four-lane divided highway located in a rural area with light to moderate traffic. The project site had rolling to mountainous terrain.

Construction took place during the months of September and early part of October 2011. The contractor of this job, Project ID IM 15-1(109)0 & IM 15-1(107)0, was Jim Gillman Construction of Butte, Montana. The total length of the project was approximately 18 mi with about 40 ft average roadbed width. The average overlay thickness was 2.5 inches (63 mm). The top layer of the existing pavement was milled off before placing the overlay. Figure D.11 shows

the typical pavement structure including the recent overlay. In July 2012, the Montana Department of Transportation (MTDOT) placed a sealcoat friction course on top of the overlay.

Figure D.10. Montana IH 15 Project Site

Figure D.11. Typical IH 15 Pavement Structure Including Recent Overlay

Mixtures and Materials

In this project, a 0.75 inch (19 mm) NMAS dense-graded (Montana Grade “S”) mixture employing virgin aggregate (siliceous) from a quarry adjacent to the asphalt mix plant was used for the surface layer. The mixture contained aggregate from three stockpiles belonging to the same source. Additionally, 1.4 percent hydrated lime was used. No RAP was incorporated in the mixture.

This project site had four test sections including three WMA technologies: HMA, WMA Foaming, WMA Evotherm® 3G, and WMA Sasobit®. All test sections were located on the southbound lanes of IH 15. Approximately 4,000 tons or more were produced from each one of the WMA technologies.

Idaho Asphalt provided the styrene-butadiene-styrene (SBS) modified PG 70-28 asphalt binder from its Blackfoot, Idaho terminal. Sasobit® was blended with the asphalt binder at the terminal, while Evotherm® 3G was injected into the binder spray line at the asphalt mix plant.

All four Superpave mixtures used the same aggregate gradation and incorporated the hydrated lime into the virgin aggregates using a pug mill before entering into the drum through the conveyor belt. The moisture content of the aggregate was approximately 2.5 to 3.0 percent. In addition, all mixtures were designed at 75 gyrations (N_{des}) and had 4.6 percent binder content. The HMA mix design and mixture properties are shown in Figures D.12 and D.13, respectively.

MIX SUMMARY SHEET

Monida-Lima

Sample Information			
Project No.:	IM 15-1(109)0	Mix Design No:	
Contractor:	Gilman Construction	Mix (mm):	19.0
Sample Date:	NR	Traffic Level:	b
Test Date:	6/17/2011	Lot , Sublot:	1,2
Sampled by:	Gilman Construction	Gyrations @ Ni	7
Tested by:	RA-HKM	Gyrations @ Nd	75
Mix/Compact Temp:	325 292	Gyrations @ Nm	115

Sample Data					
Volumetrics			Aggregate		
Property	Value	Targets	Property	Stockpile	Limits
Rice MSG (Gmm):	2.458		25.0mm (1")	100%	100%
Avg. Bulk (Gmb):	2.373		19.0mm (3/4")	100%	90-100%
Agg. Sp. Gr. (Gsb):	2.603		12.5mm (1/2")	86%	90%
Film Thickness, um	8.1		9.5mm (3/8")	66%	
Tensile Strength, TSR	91	70% Min	4.75mm (#4)	43%	
% Hydrated Lime	1.4	1.4 Min	2.36mm (#8)	28%	23%-49%
%Gmm @ Ni	86.4	≤ 90.5	1.18mm (#16)	21%	
% Gmm @ Nd	96.5	96.5	600um (#30)	16%	
% Gmm @ Nm	97.9	≤ 98.0	300um (#50)	12%	
% Air Voids @ Nd	3.46	3.4-4.0	150um (#100)	9%	
% VMA @ Nd	13.0	13.0% MIN	75um (#200)	5.8%	2%-8%
% VFA @ Nd	73.8	65%-78%	Design AC %:	4.60	
Dust/Asphalt	1.38	0.6%-1.6%	Sand Equivalent	48	45 Min
Gmb @ Nd	2.373		FAA	48	45 Min
Gse	2.632		Volume Swell		10 Max
Pba	0.43		FF, 2 or more	98	80 Min
Pbe	4.19		F & E, 3:1 Ratio	11.1	20 Max

Comments:

CA= 0.438

FAc= 0.604

FAf= 0.464

Date Printed: 06/17/11

Figure D.12. Montana IH 15 HMA Summary Mix Design

DOWL HKM SUPERPAVE MIX DESIGN			
PAVING CONTRACTOR:	Gilman Construction	MIX METHOD:	MDT-332
PROJECT NO:	IM 15-1(109)0	COMPACTION METHOD:	75 Gyrations
PROJECT:	Monida-Lima	SPECIFICATIONS:	Grade S - 19 mm
GRADE OF MIX:	S	DATE:	6/17/2011
AGGREGATE:	19 mm	HAMBURG:	20,000 Pass 13 mm
Lime:	Pete Lien	ASPHALT CEMENT:	Idaho Asphalt PG 70-28
CA:	Snowline Interchange	Specific Gravity:	1.034
3/8:	Snowline Interchange	ANTISTRIP AGENT:	Hyd. Lime
CF:	Snowline Interchange	Quantity:	1.40%
		HKM Project NO:	4041.20199

AGGREGATE GRADATION							
Description	CA	3/8	CF		Lime	Stockpile Avg.	Mix Sample
	46.35%	7.89%	44.38%		1.38%	100%	
Sieve					Percent Passing		
1"	100%	100%	100%		100%	100%	100%
3/4"	100%	100%	100%		100%	100%	100%
1/2"	69%	100%	100%		100%	86%	86%
3/8"	26%	100%	100%		100%	66%	66%
#4	2%	6%	90%		100%	43%	43%
#8	2%	3%	56%		100%	28%	27%
#16	2%	3%	41%		100%	21%	20%
#30	2%	3%	30%		100%	16%	16%
#50	2%	2%	23%		100%	12%	13%
#100	1%	2%	15%		96%	9%	9%
#200	0.80%	1.30%	9.30%		86%	5.8%	6.4%
AGGREGATE PROPERTIES					Min		Max
Fractured Faces, 2 or more					80	98	
Fine Aggregate Angularity					45	48.4	
Bulk Specific Gravity						2.603	
Absorption %						1.05	
Flat and Elongated 3:1 ratio						11.1	20
LA Abrasion							40
Sand Equivalent					45	48	
Volume Swell							10
MIX PROPERTIES					Min	Optimum	Max
Asphalt Content (% of Total Mix)	4.50	5.00	5.50	6.00	4.00	4.60	
Effective Asphalt Content	4.09	4.59	5.09	5.59		4.20	
Compacted Bulk Specific Gravity	2.368	2.397	2.401	2.401		2.373	
Effective Aggragte Specific Gravity	2.633	2.631	2.631	2.632		2.632	
AASHTO T209 Specific Gravity	2.462	2.442	2.425	2.409		2.458	
Air Voids, %	3.8	1.9	1.0	0.3	3.4	3.5	4.0
Voids in Mineral Aggregate, %	13.1	12.5	12.9	13.3	13.0	13.0	
Voids Filled, %	70.8	85.2	92.2	97.4	65	73.8	78
Density @ N(ini), %	86.1	87.7	88.7	89.6		86.4	89
Density @ N(max), %						97.9	98
Unit Weight, pcf	147.7	149.5	149.8	149.8		148.1	
Asphalt Absorption	0.43	0.43	0.43	0.43		0.43	
Dust (effective) Asphalt Ratio	1.42	1.26	1.14	1.03	0.6	1.38	1.6
Film Thickness, µm	7.9	9	10	11	6	8.1	12.0
OTHER MIX PROPERTIES							
Hydrated Lime (% of Total Mix)					1.4	1.4	
Tensile Strength Ratio					70	91	
Mixing Temperature, F					315	325	335
Compaction Temperature, F						292	

Figure D.13. Montana IH 15 HMA Mixture Properties

Plant and Mixture Production

The asphalt mix plant, a portable Gencor Ultra 400 (see Figures D.14 and D.15) counter-flow drum, was approximately 15 years old. The plant was rated at 500 tons/h production. It had two CEI brand horizontal binder tanks. The plant also had a 100 ton capacity surge bin. In addition, the plant used three out of four available cold bins to store virgin aggregates. A conventional baghouse (Gencor 85000 CFM) fines collection system was used during production, and part of the baghouse fines was reintroduced into the drum. A drag slat conveyor carried the asphalt mixture from the drum to the storage silo. The asphalt mix plant used a separate lime silo, and lime was added near the mixing area along with the baghouse fines. The plant was equipped with an Aesco-Madsen's Eco-Foam II static inline vortex mixing foaming system (see Figure D.15).

Production commenced using the mix design bin split values of 46.4 percent coarse fines, 7.9 percent intermediate fines, 44.4 percent crushed fines, and 1.4 percent hydrated lime. The startup asphalt binder plant setting was adjusted from the mix design target of 4.6 percent to a plant setting of 4.55 percent. Spot checks averaged 4.58 percent through the 38 days of production. The mixture moisture content averaged 0.05 percent with 3.0 percent aggregate stockpile moisture content.

The average discharge temperature for the control HMA was 320°F (160°C), and 285°F (140°C) for WMA Sasobit® and WMA Foaming. WMA Evotherm® 3G average discharge temperature was 274°F (134°C).

Figure D.14. Asphalt Mix Plant at the Montana Field Site

Figure D.15. Counter-Flow Drum and Foaming System at the Montana Field Site

Typically, the plant operator started the production at a higher temperature and lowered it to the target mixing temperature after four or five truckloads. In this project, the majority of the asphalt mixture produced was HMA. Regardless of mixture type, the temperature in the asphalt binder tank was maintained at 320°F (160°C). Table D.4 presents the data for the particular production day and time when samples of loose asphalt mixture for each mixture type were collected.

Table D.4. Production and Paving Temperatures for the Montana Field Site

Mixture	Date of Production	Plant Mixture Temp (°F)	Paving Temp (°F)
Hot Mix Asphalt	08-26-2011	315-320	
WMA Sasobit®	09-15-2011	275-280	240-250
WMA Evotherm® 3G	09-22-2011	270-275	
WMA Foaming	09/27/2011	270-275	275-280

Construction

The asphalt mix plant was located approximately midway between the project's limit and the highway. The longest distance between the asphalt mix plant and the construction site was approximately 11 mi. The average hauling time was approximately 15 min or less. The mixtures were hauled using belly dump trucks. Once the belly dump trucks released the mixtures on the road, the windrow picked up the mixtures and dropped them into the paver chute. A view of the typical paving operation is shown in Figure D.16.

Four dual steel-drum vibratory rollers were used during compaction. Two steel-drum rollers worked in tandem for breaking down the mixture. Each breakdown roller compacted the loose mixture in seven to eight passes in vibratory mode. The intermediate roller compacted the mat in seven to eight passes at low vibration. The finish roller operated at static mode and made three to four passes. The complete paving process, from the laydown by the paver to the compaction by the finish roller, was completed within 20 to 25 min. Before paving, the contractor applied a CSS-1H tack coat with a mixture ratio of 2:1 at a rate of 0.07 gal/yd^2. Table D.5 lists the equipment used for laydown and compaction.

In July 2012, MTDOT placed a chip seal layer on top of the HMA and WMA sections as a friction course.

Figure D.16. Laydown of Loose Mixture at the Montana Field Site

Table D.5. Paving Equipment Used at Montana Field Site

Equipment Type	Manufacturer	Model
Windrow	Cedarapids	MS-2
Paver	Caterpillar Inc.	CAT AP1055D
Breakdown Roller-1	Caterpillar Inc.	CAT CB 634D
Breakdown Roller-2	Ingersoll Rand	DD-158
Intermediate Roller	Ingersoll Rand	DD-130HF
Finish Roller (steel-wheeled)	Hamm	HD 140

Sample Collection

Plant mixture was collected from the truck right after the mixture discharge from the silo (see Figure D.17). Large quantities of mixture were collected for later use in the laboratory as well as for on-site specimen preparation. The materials sampling scheme is listed in Table D.6. In addition to loose mixture, the research team collected small amounts of straight PG 70-28, PG 70-28 binder blended with Evotherm® 3G, virgin aggregate, and hydrated lime from the asphalt mix plant. With the help of MTDOT personnel, the research team also collected 40 road cores from each of the four test sections right after construction (i.e., September 2011) and again 7 to 8 months after construction (i.e., May 2012).

Figure D.17. Loose Mixture Collection from the Truck at the Montana Asphalt Mix Plant

Table D.6. Material Sampling Scheme at the Montana Field Site

Sample Type	**Material**	**Point of Sampling**
Lab Mixed, Lab Compacted	Fine Aggregate	Stockpile
	Coarse Aggregate	Stockpile
	RAP	Stockpile
	Lime	Manufacturer's Plant
	PG 70-28 Asphalt	Asphalt Mix Plant
	PG 58-34 Asphalt with Evotherm® 3G	
Plant Mixed, Lab Compacted	Loose Mixture	Truck at Asphalt Mix Plant
Plant Mixed, Field Compacted First Coring—October 2011	Road Cores	Main Lane (between wheelpath)
Plant Mixed, Field Compacted Second Coring—May 2012	Road Cores	Main Lane (between wheelpath)

On-Site PMLC Specimen Compaction

Fifty-six 6 inch (150 mm) diameter specimens were compacted on site using plant mixture at the Federal Highway Administration (FHWA) mobile lab trailer, which was located within the asphalt mix plant premises. Thirty-two of them were 2.4 inches (61 mm) tall, and 24 of them were 3.75 inches (95 mm) tall. Loose plant mixture collected from the truck at the plant was quickly brought to the FHWA mobile lab trailer and placed in the oven between 1 to 2 h to achieve compaction temperature. Specimens were compacted using an industrial process control (IPC) SGC to 7±1 percent air voids.

TEXAS FARM-TO-MARKET HIGHWAY 973

General Description of the Project

The Texas Department of Transportation (TxDOT) set up an experimental overlay on FM 973 in Travis County, in the Austin District, in order to conduct testing and long-term performance monitoring for several research projects. This experimental construction project (Project ID STP 1102 [371]) was planned to explore the different aspects of WMA, as well as the effect of RAP and recycled asphalt shingles (RAS) on the performance of HMA and WMA mixes. Researchers involved in various state and federal studies actively participated in testing and monitoring of these test sections. The overlay construction started on December 1, 2011, and took 1.5 months to complete due to inclement weather and holidays. J. D. Ramming Paving Company was the general contractor for this project.

The project site was located just north of the Austin Bergstrom International Airport (see Figure D.18). The length of the project was approximately 2.9 mi. Within the project limits, there was an aggregate quarry and a concrete plant that generated very high-volume truck traffic.

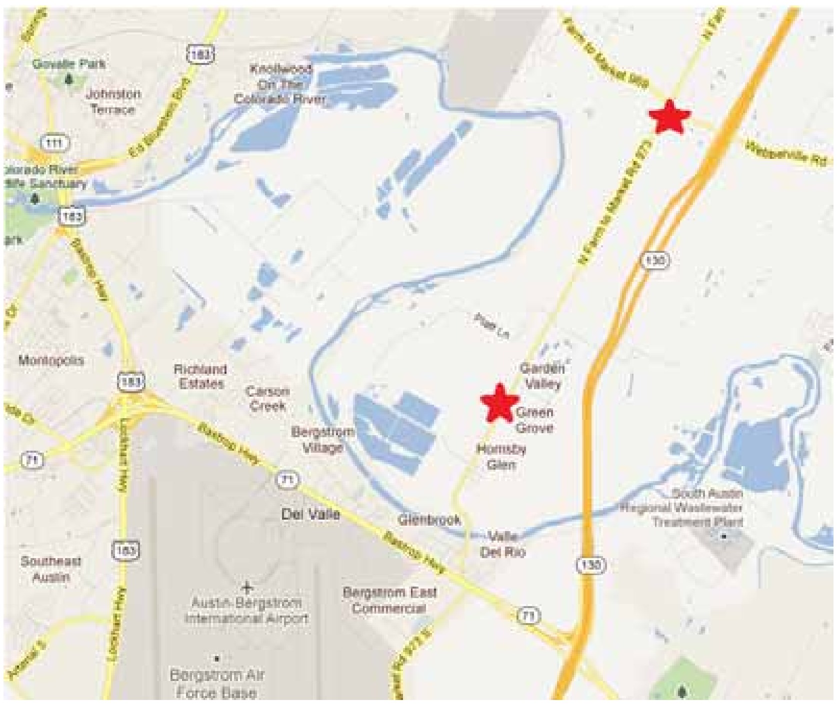


Figure D.18. Project Limits for the Texas Field Site

Nine test sections were laid out as shown in Figure D.19. This portion of FM 973 experiences moderate to high-volume traffic. Current (2011) traffic data were reported as 11,000 and 11,300 annual average daily traffic (AADT) for the north and south end, respectively. Percent truck traffic was reported from 4.2 to 4.3 percent.

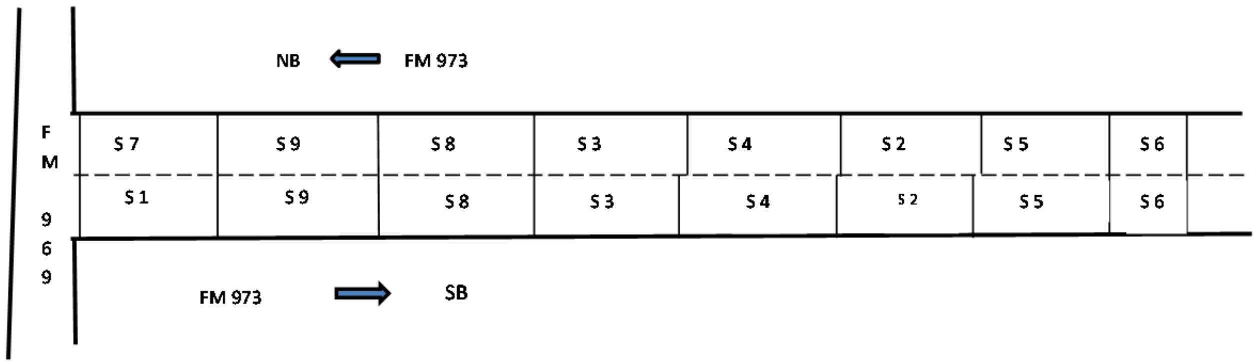


Figure D.19. Schematic Layout Diagram of the Texas Field Site Test Sections (not to scale)

Mixture and Materials

A TxDOT Type C (0.5 inch [12.5 mm] NMAS) surface mix was used in the project. The aggregate structure was the same for all mixtures used in the various test sections. Figure D.20 presents the mix design used in Section 1.

The differences between test sections are listed in Table D.7, namely the type of mixture (i.e., HMA vs. WMA), the type of asphalt binder (i.e., PG 70-22, PG 64-22, and PG 58-28), and the amount of RAP/RAS added to the mixture (i.e., 0/15/30 percent RAP and 0/3/5 percent RAS).

The asphalt binders, classified as PG 70-22 (SBS modified binder) and PG 58-28, were supplied by Valero Asphalt Company from its Corpus Christi, Texas, refinery. Pelican Refining Company supplied the PG 64-22 (unmodified) asphalt binder from its Channelview, Texas, facility. All mixtures used virgin limestone from Cemex Aggregate located just across from the asphalt mix plant. RAP and RAS came from various sources.

Table D.7. List of Test Sections with Construction Date for the Texas Field Project

Section No.	Lot No.	Mixture Description				Date of Paving
		Type	Binder	RAP %	RAS %	
1	1	HMA	PG 70-22	0	0	12/01/11
7	2	WMA Foaming	PG 70-22	0	0	12/01/11
9	3	WMA Evotherm DAT™	PG 64-22	15	3	12/13/11
8	4	WMA Evotherm DAT™	PG 70-22	0	0	01/04/12
3	5	HMA	PG 64-22	15	3	01/05/12
4	6	HMA	PG 64-22	0	5	01/06/12
2	7	HMA	PG 64-22	30	0	01/16/12
5	8	HMA	PG 58-28	30	0	01/17/12
6	9	HMA	PG 58-28	15	3	01/18/12

TEXAS DEPARTMENT OF TRANSPORTATION

HMACP MIXTURE DESIGN : COMBINED GRADATION

Refresh Workbook

File Version: 04/28/11 08:29:35

SAMPLE ID:		SAMPLE DATE:	
LOT NUMBER:		LETTING DATE:	
SAMPLE STATUS:		CONTROLLING CSJ:	
COUNTY:	Jimmy Whited #652	SPEC YEAR:	2004
SAMPLED BY:		SPEC ITEM:	
SAMPLE LOCATION:		SPECIAL PROVISION:	
MATERIAL CODE:	Type C	MIX TYPE:	SS3224_C_Coarse_Surface
MATERIAL NAME:	70SC1000 #1	WMA Included in Design?	No
PRODUCER:	RTI Hot Mix, Ltd.	WMA TECHNOLOGY:	
AREA ENGINEER:		PROJECT MANAGER:	
		WMA RATE:	UNITS:
COURSE\LIFT:	Surface	STATION:	
DIST. FROM CL:		CONTRACTOR DESIGN #:	70SC1000 #1

Recycled Binder, %	
Bin No.8 :	0.0
Bin No.9 :	0.0
Bin No.10 :	0.0
Total	***0.0***

Use this value in the QC/QA template>>

Ratio of Recycled to Total Binder, % *(based on binder percent (%) entered below in this worksheet)*
0.0

	AGGREGATE BIN FRACTIONS							"RECYCLED MATERIALS"			
	Bin No.1	Bin No.2	Bin No.3	Bin No.4	Bin No.5	Bin No.6	Bin No.7	Bin No.8	Bin No.9	Bin No.10	
Aggregate Source:	Limestone_Dolom	Limestone_Dolom	Limestone_Dolom	Limestone_Dolom	Gravel			Fractionated RAP	RAS		Material Type
Aggregate Pit:	Ruby	Ruby	Ruby	Ruby					Ramming LTD-Buda		Material Source
Aggregate Number:											RAS Type
Sample ID:	Type C	Type D	Type F	Mfg. Sand	Field Sand						Sample ID
Recycled Material?								Recycled Asphalt Binder (%)			
Asphalt%:								5.0	20.0		
Hydrated Lime?:								0.0 %of Tot. Mix	0.0 %of Tot. Mix	%of Tot. Mix	
Individual Bin (%):	25.0 Percent	20.0 Percent	22.0 Percent	24.0 Percent	9.0 Percent	Percent	Percent	%of Aggr.	%of Aggr.	%of Aggr.	

Sieve Size:	Bin 1 Cum % Passing	Bin 1 Wtd Cum %	Bin 2 Cum % Passing	Bin 2 Wtd Cum %	Bin 3 Cum % Passing	Bin 3 Wtd Cum %	Bin 4 Cum % Passing	Bin 4 Wtd Cum %	Bin 5 Cum % Passing	Bin 5 Wtd Cum %	Bin 6 Cum % Passing	Bin 6 Wtd Cum %	Bin 7 Cum % Passing	Bin 7 Wtd Cum %
1"	100.0	25.0	100.0	20.0	100.0	22.0	100.0	24.0	100.0	9.0				
3/4"	100.0	25.0	100.0	20.0	100.0	22.0	100.0	24.0	100.0	9.0				
3/8"	56.4	14.1	70.7	14.1	100.0	22.0	100.0	24.0	100.0	9.0				
No. 4	10.9	2.7	14.3	2.9	76.4	16.8	99.9	24.0	99.8	9.0				
No. 8	4.7	1.2	6.3	1.3	20.6	4.5	89.8	21.6	98.1	8.8				
No. 30	3.3	0.8	3.7	0.7	6.2	1.4	40.3	9.7	90.5	8.1				
No. 50	2.6	0.7	3.3	0.7	4.8	1.1	24.2	5.8	66.9	6.0				
No. 200	2.2	0.6	2.7	0.5	3.9	0.9	7.6	1.8	3.7	0.3				

Sieve Size:	Bin 8 Cum % Passing	Bin 8 Wtd Cum %	Bin 9 Cum % Passing	Bin 9 Wtd Cum %	Bin 10 Cum % Passing	Bin 10 Wtd Cum %	Combined Gradation: Total Bin 100.0% Cum % Passing	Lower & Upper Specification Limits: Lower	Upper	Within Spec's	Restricted Zone: Lower	Upper	Within Spec's	Individual % Retained	Cumulative % Retained	Sieve Size
1"	100.0	0.0	100.0	0.0			100.0	100.0	100.0	Yes				0.0	0.0	1"
3/4"	100.0	0.0	100.0	0.0			100.0	95.0	100.0	Yes				0.0	0.0	3/4"
3/8"	92.4	0.0	100.0	0.0			83.2	70.0	85.0	Yes				16.8	16.8	3/8"
No. 4	71.1	0.0	99.7	0.0			55.4	43.0	63.0	Yes				27.9	44.6	No. 4
No. 8	53.0	0.0	98.9	0.0			37.3	32.0	44.0	Yes				18.0	62.7	No. 8
No. 30	33.2	0.0	62.8	0.0			20.7	14.0	28.0	Yes				16.6	79.3	No. 30
No. 50	21.9	0.0	53.7	0.0			14.2	7.0	21.0	Yes				6.6	85.8	No. 50
No. 200	6.4	0.0	23.4	0.0			4.1	2.0	7.0	Yes				10.1	95.9	No. 200

(Bold Italic) Not within specifications ***(Bold Italic)*** Not within specifications- Restricted Zone *(Italic)* Not cumulative

Lift Thickness, in:	2.00	Binder Substitution?	No	Binder Originally Specified	PG 70-22	Substitute Binder:	PG 64-22
Asphalt Source & Grade:	Valero	Binder Percent, (%):	5.2	Asphalt Spec. Grav.:	1.033		
Antistripping Agent:		Percent, (%):					

Dry Rodded Unit Weight of Coarse Agg. (pcf):

Figure D.20. Mix Design Used in Test Section 1 (HMA without RAP or RAS, PG 70-22)

Plant and Mixture Production

The RTI hot mix plant located in Buda, Texas, supplied the asphalt mixture. This plant, owned by Ramming Paving Co, was approximately 30 mi away from the jobsite. The driving time between the asphalt plant and job site was between 30 to 40 min. RTI had an approximately 10 year old Astec double barrel unitized drum mixer (counter-flow) plant with a capacity of 350 tons/h production rate (see Figure D.21). The dimension of the drum was 35 ft in length and 8 ft in diameter. The plant also had seven cold feed bins in addition to one RAP bin and one RAS bin. There were three storage silos, with each having a capacity of 200 tons. The plant had a conventional baghouse fines collection system, and part of the baghouse fines was reintroduced into the drum. A drag slat conveyor carried the mix from the drum to the storage silo. The plant was equipped with one lime silo and two vertical Heatec binder storage tanks.

An Astec green foaming system was added to the plant approximately 2 years prior to this construction job. The Evotherm DAT™ WMA additive was added to the asphalt line during production.

Typically, the plant was initially operated at higher-than-normal production temperatures and brought down to the target temperature after a few truckloads. The moisture content of the aggregate was somewhere between 4 to 5 percent. The average silo storage time was between 10 to 12 min. RTI employed 12 belly dump trucks to haul the loose mixtures to the construction site. The trucks had tarps on them to reduce heat loss.

Figure D.21. RTI Hot Mix Plant Located in Buda, Texas

Construction

The contractor repaired and patched some areas of existing surface distress (especially at the north end of the project) in November before the start of the overlay construction. Two mixtures (i.e., Test Section 1—HMA control, and Test Section 7—WMA Foaming) were produced and placed on the first day of production on December 1, 2011. The rest of the mixtures were produced and placed one per day. Section 1 and 7, both approximately 2,000 ft

long, were placed side-by-side on the southbound and northbound lanes, respectively. All other test sections were placed on both directions of the roadway.

Just before placing the overlay, a layer of underseal (or seal coat) was placed on top of the existing pavement surface (see Figure D.22). The seal coat used was a CHFRS-2P emulsion sprayed at a rate of 0.25 gal/yd^2 and covered by a Grade 4 Type B uncoated limestone aggregate at a rate of 260 yd^2/yd^3. Then, the belly dump trucks released the loose mix on the fresh seal coat and an MTV, alternately known as a shuttle buggy, picked up the mixture and transferred it to the paver hoper (see Figure D.23). Typically, each day the chip seal placement started at 9:00 a.m. and the paving was completed by 3:30 p.m.

Figure D.22. Application of Underseal before Overlay Laydown

Figure D.23. Windrow Operation Using Shuttle Buggy

Table D.8 shows the list of the equipment used during construction. The paver was equipped with a MOBA brand Pave-IR bar to record the surface temperature of the mat right behind the paver (see Figure D.24). The loose mat was compacted with one dual-wheel steel roller as a breakdown roller, one pneumatic-tire roller as an intermediate roller, and one small steel-wheel roller as a finisher. On one occasion, two pneumatic rollers were used. Paving was done from north to south regardless of the direction of travel. In general, the paving width was 16 ft in each direction with an average of 2 inches of compacted mat thickness.

Table D.8. Paving Equipment Used at the Texas Field Site

Equipment Type	Manufacturer	Model
Material Transfer Vehicle	Roadtec	SB 25000
Paver	Barber-Green	BG 2000
Breakdown Roller (steel-wheeled)	Volvo	
Pneumatic Roller	Bomag	24RH
Finish Roller (steel-wheeled)	Ingersoll Rand	
Finish Roller	Dynapac	CC 142

Figure D.24. Paver Equipped with Pave-IR Bar

Sample Collection

Plant mix was collected from the truck right after discharge from the silo (see Figure D.25). Large quantities of mixtures were collected for later use in the laboratory as well as for on-site specimen preparation. In addition, the research team collected samples of the three asphalt binder PG grades, virgin aggregates, RAPs, and RAS materials. The materials sampling scheme is summarized in Table D.9.

Figure D.25. Loose Mixture Collection from the Truck at RTI Hot Mix Plant

Table D.9. Material Sampling Scheme at the Texas Field Site

Sample Type	Material	Point of Sampling
Lab Mixed, Lab Compacted	Fine Aggregate	Stockpile
	Coarse Aggregate	Stockpile
	RAP	Stockpile
	RAS	Stockpile
	Binder (all grades)	Transport Truck at Asphalt Mix Plant
	Evotherm DAT™ Additive	Asphalt Mix Plant
Plant Mixed, Lab Compacted	Loose Mixture	Truck at Asphalt Mix Plant
Plant Mixed, Field Compacted First Set after Construction—January 2012	Road Cores	Travel Lane (between wheelpath)
Plant Mixed, Field Compacted Second Set—September 2012	Road Cores	Travel Lane (between wheelpath)
Plant Mixed, Field Compacted Third Set—March 2013	Road Cores	Travel Lane (between wheelpath)

On-Site PMLC Specimen Compaction

The loose plant mix collected from the truck at the plant was quickly brought to the on-site mobile lab and placed in the oven between 1 to 2 h to achieve the required compaction temperature. This on-site lab was owned by RTI. All on-site specimens were compacted using a

Troxler Superpave gyratory compactor to 7±1 percent air voids (see Figure D.26). As part of NCHRP 9-49, approximately thirteen 6 inch diameter specimens were compacted on-site using loose plant mix from five test sections.

Figure D.26. Troxler Compactor Used to Prepare the On-Site PMLC Specimens

Field Specimens

Because of several interruptions during construction due to weather conditions and holidays, all road cores were collected after the completion of the entire project and labeled as having the same field age, although the control section (HMA with PG 70-22) was constructed during the first week of December 2011 and the final test section was paved on January 18, 2012.

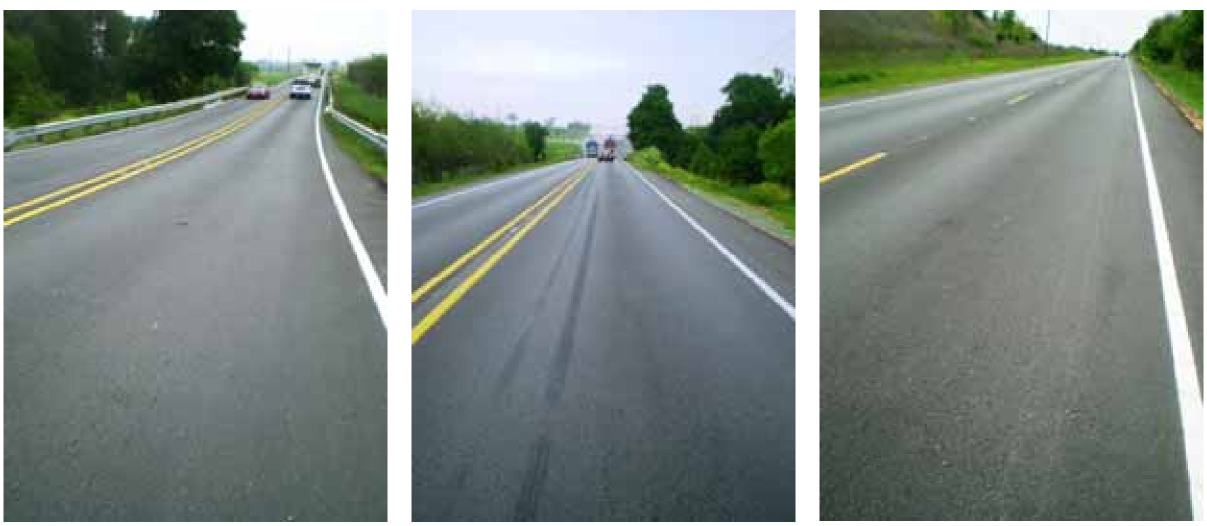
The first set of road cores was collected during the last week of January 2012. Thus, the first sets of cores collected from the different test sections were subjected to environmental and traffic conditions in the field between 2 weeks and 8 weeks. The road cores were drilled at the center of the travel lane (between wheelpath), spread approximately equal distance on both directions. Figure D.27 shows a typical core obtained from Section 9.

The next round of road cores was obtained during the second week of September 2012—approximately 8 to 9 months after overlay construction. In addition, the research team also collected a third set of cores from the test sections during March 2013, which will be tested under NCHRP Project 9-52.

Figure D.27. Typical Texas Pavement Structure Including the Recent Overlay

Field Performance

An overall assessment of the condition of the pavement was performed on three occasions: 2-3 months, 6-7 months, and 14-15 months after construction. The conditions of Sections 1, 7, and 8 (which were the sections of interest in this project) were satisfactory, as shown in Figures D.28, D.29, and D.30.



(a) HMA **(b) WMA Foaming** **(c) WMA Evotherm**

Figure D.28. Performance of the Texas Field Sections after 2-3 Months In Service

(a) HMA

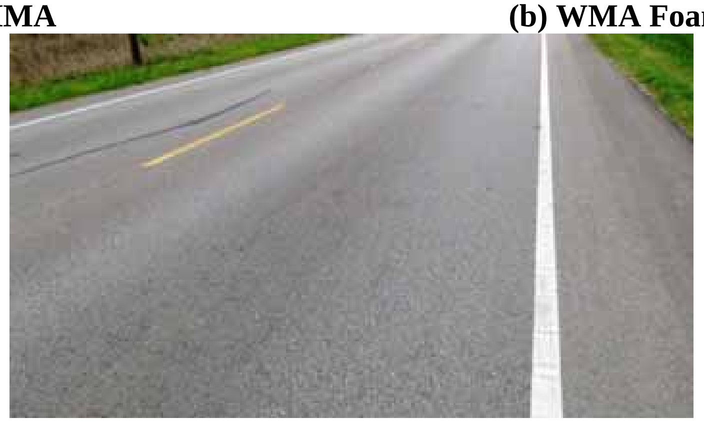
(b) WMA Foaming

(c) WMA Evotherm

Figure D.29. Performance of the Texas Field Sections after 6-7 Months In Service

(a) HMA

(b) WMA Foaming



(c) WMA Evotherm

Figure D.30. Performance of the Texas Field Sections after 14-15 Months In Service

NEW MEXICO INTERSTATE HIGHWAY 25

General Description of the Project

The New Mexico test sections were located on IH 25 between Williamsburg and Elephant Butte, Sierra County, in the southeast part of the state. An overall view of the

construction site is shown in Figure D.31. IH 25 is a four-lane (two-lane in each direction) rural highway with moderate traffic. The stretch of highway where the test sections were placed is characterized by rolling terrain. This field project was constructed during the third week of October 2012. James Hamilton Construction Company from Silver City, New Mexico, was the contractor for this project.

The total length of the overlay project was approximately 18 mi (28.8 km). Near the location of the test sections, the total roadway width was 26 ft. The main-lane paving width was approximately 13 ft. The average overlay thickness was 2.5 inches (63 mm). The existing pavement surface had moderate to severe alligator cracking on the wheelpath. Therefore, before placing the overlay, the top of the existing pavement was milled off 2.5 inches (63 mm).

Figure D.31. New Mexico IH 25 Project Site

Mixtures and Materials

The New Mexico Department of Transportation (NMDOT) used a 0.75 inch (19 mm) NMAS dense-graded mixture (i.e., NMDOT SPIII) for the surface layer. The aggregate, a siliceous rock, was obtained from a nearby pit located very close to the Rio Grande River. This type of aggregate is highly absorptive; the combined aggregate water absorption at saturated surface dry condition was reported as 2.9 percent. The moisture content of the aggregate was between 3.5 to 4.0 percent. Thirty-five percent RAP was also added to the mixture, which was screened over a 2 inch (50 mm) sieve.

Besides the control HMA with RAP mixture, this project included a control HMA without RAP, WMA Foaming with RAP, and Evotherm® 3G with RAP. Only 500 tons of HMA without RAP and approximately 2,000 tons of WMA with Evotherm® 3G were placed. The HMA without RAP mixture used 5.4 percent PG 76-22 asphalt binder. The other three mixtures, which included 35 percent RAP, were designed with a PG 64-28 modified asphalt binder. The percent virgin binder and total binder content for these mixtures was 3.0 percent and 5.4 percent, respectively. NuStar Energy Company from Santa Fe, New Mexico, supplied both asphalt binder types. Evotherm® 3G was blended with the asphalt binder at 0.5 percent by weight of total binder content at the asphalt mix plant.

The plant was equipped with an Astec Green System asphalt foaming system. During mixture production, the water added to produce the WMA foaming mixture was reported as 2.0 percent by weight of virgin asphalt binder content. Except for the HMA with RAP mixture, all other mixtures used the same aggregate gradation and binder content. All four mixtures incorporated 1 percent Versabind mineral filler mixed with the virgin aggregates at 4.4 percent moisture content using a pug mill before entering into the drum through the conveyor belt. The moisture content of the aggregate was approximately 3.5 to 4.0 percent. All four Superpave mixtures were designed at 100 gyrations (N_{des}). The mix designs with and without RAP are detailed in Figures D.32 and D.33.

Plant and Mixture Production

The asphalt mix plant, a portable Astec double barrel (see Figure D.34), was a counter-flow drum design with an external mixing drum. The plant was about 10 years old at the time of construction. The capacity of the plant was 450 tons/h, and it had two horizontal binder tanks. The plant did not have a silo; rather, it had a 50 ton capacity Astec surge bin. The plant used three (out of five) cold bins for virgin aggregates. RAP materials were screened over a 2 inch screen before entering into the mixing drum. The plant had a conventional baghouse fines collection system, and part of the baghouse fines was reintroduced into the drum. A drag slat conveyor carried the mixture from the drum to the surge bin.

Typically, the plant operator started production at a higher temperature and then lowered it to the target mixing temperature after four or five truck loads. In this project, the majority of the asphalt mixture that was produced consisted of WMA foaming with 35 percent RAP. Although the project was almost 18 mi long, the test sections were located within 3 mi. Table D.10 shows the temperature data for the particular production day and time when the loose mixture for each mixture type was collected.

State Materials Bureau
ASPHALT DESIGN UNIT
P.O. Box 1149, Santa Fe, NM 87504-1149

New Mexico DEPARTMENT OF TRANSPORTATION

Superpave Volumetric Mix Design for HMA - Version PA 12.8

SUMMARY OF MIX DESIGN

SP-III w/35% RAP Experimental HMA Test Section for James Hamilton Construction Co.

Project No.:	1C00003 - HMA Test Section		
Control No.:	1C00003	QLA?	Yes
Location:	I-25		
County:	Sierra	District:	1
Project Mgr:	Brian Torres	D1-Phone: 575-544-6591	
Dist Lab Spvr.	Gilberto Garcia	D1-Phone: 575-544-6591	
Contractor:	James Hamilton Construction Co.		
Designed by:	CA2 Testing		
HMA Supplier:	James Hamilton Construction Co.		

Aggregates[1]	Source #1	Source #2
Aggr. Source	T or C pit	N/A
Location:	T or C	N/A
County:	Sierra	N/A
Filler Source:	N/A	N/A
RAP Source:	Project	N/A
Versabind	GCC Cemento	

Design ESALs(mil)	Compaction Parameters $N_{initial}$	N_{design}	$N_{maximum}$
19.70	8	100	160
Estimated Plug Wt. @ N_{des}	4600	grams	

Combination Used		Bulk Sp. Gravities	Abs. %
CA	33.0%	2.457	2.3
Int	7.0%	2.431	2.7
Dirty Fines	24.0%	2.356	3.7
RAP	35.0%	2.580	
Versabind	1.0%	3.000	

SML Mix Design No:	12-D1-17-134 HMA-
NMDOT Lab No:	2012-01534
ITL Mix Design No:	MD125-12
Mix Des Submittal Date:	10/30/2012
Date of Final Revision:	11/5/2012
Issue Date:	11/5/2012

Test Method used to Determine CA & FA Sp. Gr. & Absorps.: AASHTO T-84 / T-85

NOTE: Field Verification SG Tests shall use the same method.

Method of Calibration for Gyratory Compactors: Internal Angle

NOTE: Same Calibration Method should be used for all GCs.

Asphalt

Grade Specified:	PG 76-22
Gr. Used:	PG 64-28
Sp. Gravity of Used Asphalt (Gb):	1.02
Asphalt Source:	Nustar
Plant Location:	Rosario, NM.
Mixing Temperature:	310 ° F
Molding Temperature:	295 ° F
Laydown Temperature:	295 +/- 22 F
Lab Compaction Temp:	295 +/- 4 F

Type of Mat'l:	Sand & gravel	
Type of Mix:	SP-III	
Est. HMA Qty.	109,270	Tons

Combined Aggregate Specific Gravity (G_{sb}):	2.486
Combined Specific Gravity of Fine Aggregates:	2.356
Combined Aggregate Water Absorption @ SSD:	2.9%

GRADATIONS USED:		2.0 in.	1.5 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200
Percentage Passing		100	100	100	95	80	66	43	29	20	15	11	8.4	5.6
SPECIFICATION:		100	100	100	90 - 100	Max 90			23-49					2.0-8.0
Acceptance Tolerances:	Max			100	100		74	50						7.0
	Min				90		58	36						4.2

SUMMARY OF DESIGN INFORMATION

Specimens compacted to N_{Design} 100 Gyrations

Design Parameters	Design[2] Values	Design Criteria Lower	Design Criteria Upper	Acceptance Limits Lower	Acceptance Limits Upper
Asphalt	5.4	-		4.9	5.9
Virgin A.C.	3.0	-		-	-
Air Voids	4.0	4.0		2.6	5.4
VMA	13.5	13.5	15.0	11.9	15.1
VFA	70.4	68.0	75.0	-	-
Gse	2.561	-		-	-
Eff. % AC	4.3	-		-	-
Versabind	1.0	1.0 Min		1.0	1.4

Design Parameters			Design[2] Values	Design Criteria Lower	Design Criteria Upper	Acceptance Limits Lower	Acceptance Limits Upper
Unit Weight, lb/ft3			141.8	-		-	-
Gmb (T-166) @ Ndes			2.272	-		-	-
Gmm (T-209) @ Design A.C.			2.367	-		-	-
Density @$N_{initial}$	8	Gyrations	86.9	89 Max		-	-
Density @$N_{maximum}$	160	Gyrations	97.5	98 Max		-	-
Dust Proportion			1.3	0.6	1.4	1.0	1.6
Binder Absorption			1.20	-		-	-
Water@ Mixing of		+ Aggregates	4.4%	-		-	-

PROPERTIES @ DESIGN GYRATIONS

AC (%)	Gmm (T-209)	Gmb (T-166)	Unit Wt. (lb/ft3)	Air Voids (%)	VMA (%)	VFA (%)	Dust to Binder Ratio
5.00	2.371	2.215	138.2	6.6	15.3	57.0	1.39
5.50	2.355	2.243	140.0	4.8	14.7	67.6	1.24
6.00	2.339	2.268	141.5	3.0	14.2	78.8	1.11
6.50	2.321	2.287	142.7	1.5	14.0	89.5	1.00

Tensile Strength Ratio (T 283-07)

Average Dry Tensile Strength	Average Wet Tensile Strength	Tensile Strength Ratio	Specification
175.5 psi	156.8 psi	89	>= 85

	Pit Mat'l.	RAP 1	RAP 2	Specs.	Limit
Flat & Elongated Pieces @ 3:1 (ASTM D4791)	6%	12%		20%	Max
Fine Aggregate Angularity (T-304, Method A)	46.6%			45%	Min
CA 1 Fractured Face (NMDOT)	100%	100%		95%	Min
CA 2 Fractured Faces (NMDOT)	100%	94%		90%	Min
Combined Sand Equivalent (T-176)	53%			45%	Min
Soundness Loss (T-104)	2%			15%	Max
LA Wear (T-96)	18%	35%		40%	Max - RAP
Aggregate Index Pit #1:	5			25	Max
Aggregate Index Pit #2:				25	Max

Tested by:	David Salas
	Mary
Reported by:	Danny Marquez
Reviewed & Submitted by:	Lea Ann Marquez
NM P.E. License No.	16029
Contact Phone:	505-718-3050

Special Notes & Instructions

1. The design data was obtained from material submitted by the Contractor.
2. Minor field adjustments may be necessary to achieve and maintain specified limits.
3. The specification limits are in accordance with Section 423 of the NMDOT Std Specifications for Road & Bridge Construction - 2007 Edition & Supp. Spec.
4. We removed 0.6% of the -#200 fraction during the verification of this design

Reviewed by:	Parviz Aziz P.E.
NM P.E. License No.	10834
	State Asphalt Engineer
Contact Phone:	(505) 827-5568
E-mail:	[illegible]

Figure D.32. Mix Design for HMA and WMA Mixtures with 35 Percent RAP

State Materials Bureau
ASPHALT DESIGN UNIT
P.O. Box 1149, Santa Fe, NM 87504-1149

New Mexico DEPARTMENT OF TRANSPORTATION
MOBILITY FOR EVERYONE

Superpave Volumetric Mix Design for HMA - Version PA 12.8

SUMMARY OF MIX DESIGN

SP-III w/PG 76-28 Experimental Virgin HMA Test Section for James Hamilton Construction Co.

Project No.:	1C00003 Virgin HMA Test Section		
Control No.:	1C00003	QLA?	Yes
Location:	I-25		
County:	Sierra	District:	1
Project Mgr:	Brian Torres	D1-Phone: 575-544-6561	
Dist Lab Spvr.	Gilberto Garcia	D1-Phone: 575-544-6381	
Contractor:	James Hamilton Construction Co.		
Designed by:	CA2 Testing		
HMA Supplier:	James Hamilton Construction Co.		

Aggregates[1]	Source #1	Source #2
Aggr. Source	T or C pit	N/A
Location:	T or C	N/A
County:	Sierra	N/A
Filler Source:	N/A	N/A
RAP Source:	N/A	N/A
Versabind	GCC Cemento	

Design ESALs(mil)	Compaction Parameters $N_{initial}$	N_{design}	$N_{maximum}$
19.70	8	100	160
Estimated Plug Wt. @ N_{des}	4500	grams	

Combination Used		Bulk Sp. Gravities	Abs. %
3/4"	38.0%	2.522	1.0
3/8"	17.0%	2.521	0.9
CF	44.0%	2.484	0.7
Versabind	1.0%	3.000	

SML Mix Design No:	2012-01-19-136 VHMA-TS
NMDOT Lab No:	2012-01536
ITL Mix Design No:	MD126-12
Mix Des Submittal Date:	11/5/2012
Date of Final Revision:	11/7/2012
Issue Date:	11/7/2012
Test Method used to Determine CA & FA Sp. Gr. & Absorps.	AASHTO TP 77 (NMDOT 001)

NOTE: Field Verification SG Tests shall use the same method.

Method of Calibration for Gyratory Compactors: Internal Angle

NOTE: Same Calibration Method should be used for all GCs.

Asphalt			
Grade Specified:	PG 76-22	Gr. Used:	PG 76-28
Sp. Gravity of Used Asphalt (Gb):	1.004		
Asphalt Source:	Nustar		
Plant Location:	Rosario, NM.		
Mixing Temperature:	340 ° F		
Molding Temperature:	320 ° F		
Laydown Temperature:	320 +/- 22 F		
Lab Compaction Temp:	320 +/- 4 F		

Type of Mat'l:	Sand & Gravel	
Type of Mix:	SP-III	
Est. HMA Qty.	109,270	Tons

Combined Aggregate Specific Gravity (G_{sb}):	2.509
Combined Specific Gravity of Fine Aggregates:	2.484
Combined Aggregate Water Absorption @ SSD:	0.9%

GRADATIONS USED:		2.0 in.	1.5 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200
Percentage Passing:		100	100	100	95	80	68	47	33	23	17	12	9.3	4.5
SPECIFICATION:		100	100	100	90 - 100	Max 90			23-49					2.0-8.0
Acceptance Tolerences:	Max			100	100		76	54						5.9
	Min				90		60	40						3.1

SUMMARY OF DESIGN INFORMATION

Specimens compacted to N_{Design} 100 Gyrations

Design Parameters	Design[2] Values	Design Criteria Lower	Design Criteria Upper	Acceptance Limits Lower	Acceptance Limits Upper
Asphalt	5.4	-		4.9	5.9
Virgin A.C.	5.4	-		-	-
Air Voids	4.0	4.0		2.6	5.4
VMA	15.0	13.5	15.0	13.4	16.6
VFA	73.3	68.0	75.0	-	-
Gse	2.545	-		-	-
Eff.% AC	4.9	-		-	-
Versabind	1.0	1.0 Min		1.0	1.4

Design Parameters	Design[2] Values	Design Criteria Lower	Design Criteria Upper	Acceptance Limits Lower	Acceptance Limits Upper
Unit Weight, lb/ft3	140.7	-		-	-
Gmb (T-166) @ Ndes	2.255	-		-	-
Gmm (T-209) @ Design A.C.	2.350	-		-	-
Density @$N_{initial}$ 8 Gyrations	86.9	89 Max		-	-
Density @$N_{maximum}$ 160 Gyrations	97.0	98 Max		-	-
Dust Proportion	0.9	0.6	1.4	0.6	1.2
Binder Absorption	0.57	-		-	-
Water@ Mixing of + Aggregates	2.4%	-		-	-

PROPERTIES @ DESIGN GYRATIONS

AC (%)	Gmm (T-209)	Gmb (T-166)	Unit Wt. (lb/ft3)	Air Voids (%)	VMA (%)	VFA (%)	Dust to Binder Ratio
4.90	2.360	2.233	139.4	5.4	15.3	65.1	1.00
5.40	2.349	2.263	141.2	3.7	14.7	75.0	0.92
5.90	2.333	2.282	142.4	2.2	14.4	85.0	0.84
6.40	2.309	2.296	143.3	0.5	14.3	96.3	0.75

Tensile Strength Ratio (T 283-07)	Average Dry Tensile Strength	Average Wet Tensile Strength	Tensile Strength Ratio	Specification
	188.2 psi	170.0 psi	90	> or = 85

	Pit Mat'l.	RAP 1	RAP 2	Specs.	Limit
Flat & Elongated Pieces @ 3:1 (ASTM D4791)	6%			20%	Max
Fine Aggregate Angularity (T-304, Method A)	48.5%			45%	Min
CA 1 Fractured Face (NMDOT)	100%			95%	Min
CA 2 Fractured Faces (NMDOT)	100%			90%	Min
Combined Sand Equivalent (T-176)	53%			45%	Min
Soundness Loss (T-104)	2%			15%	Max
LA Wear (T-96)	18%				
Aggregate Index Pit #1:	9			25	Max
Aggregate Index Pit #2:				25	Max

Tested by:	David Salas
	Navor Trujillo
Reported by:	Danny Marquez
Reviewed & Submitted by:	Lea Ann Marquez
NM P.E. License No.	16029
Contact Phone:	505-718-3030

Special Notes & Instructions	
	1. The design data was obtained from material submitted by the Contractor.
	2. Minor field adjustments may be necessary to achieve and maintain specified limits.
	3.The specification limits are in accordance with Section 423 of the NMDOT Std Specifications for Road & Bridge Construction - 2007 Edition & Supp. Specs
	4. We removed 2.5% of the -#200 fraction during the design phase of this mix

Reviewed by:	Parveez Anwar P.E.
NM P.E. License No.	10834
	State Asphalt Engineer
Contact Phone:	(505) 827-5656
E-mail:	[illegible]

Figure D.33. Mix Design for HMA Mixture without RAP

Figure D.34. Asphalt Mix Plant at the New Mexico Field Site

Table D.10. Production, Paving and Ambient Temperatures for the New Mexico Field Site

Mixture Type	Date of Production	Plant Mixture Temp (°F)	Paving Temp (°F)	Ambient Temp (°F)
WMA Foaming with RAP	10.16.12	285	265-270	60 to 80
HMA with RAP	10.17.12	315	285-290	60 to 80
HMA without RAP	10.18.12	345	330-335	60 to 80
WMA Evotherm® 3G with RAP	10.19.12	275	255-260	60 to 80

Construction

The asphalt mix plant was located at the north end of the project, while the test sections were located toward the south end. The average hauling distance and time from the plant to the test sections were approximately 15 mi and 20 min, respectively. The mixtures were hauled using belly dump trucks with a tarp on top. Once the belly dump trucks released the mixtures on the road, a windrow pick-up machine transferred the mixtures and dropped them into the paver chute (see Figure D.35).

This job used three steel-wheeled rollers (see list of paving equipment in Table D.11). The breakdown roller was used to compact the loose mixture using seven passes in vibratory mode. The intermediate roller immediately followed, compacting with approximately seven passes. Surprisingly, the finish roller also operated in vibratory mode, although at very low frequency and low amplitude. The finish roller also used seven passes.

Before paving, the contractor applied CSS-1H tack coat with a mixture ratio of 2:1 at a rate of 0.05 gal/yd^2 over the milled surface.

Figure D.35. Windrow Equipment Used at the New Mexico Field Site

Table D.11. Paving Equipment Used at New Mexico Field Site

Equipment Type	Manufacturer	Model
Windrow	Weiler	E 650A
Paver	Caterpillar Inc.	CAT 10-20B
Breakdown Roller (steel-wheeled)	Bomag	HYPAC C784A
Intermediate Roller (steel-wheeled)	Bomag	HYPAC C784A
Finish Roller (steel-wheeled)	Bomag	HYPAC C784A

Sample Collection

Plant mixture was collected right after the trucks released the mixtures in front of the windrow (see Figure D.36). The time that elapsed between the truck leaving the plant and the loose mixture sample collection was approximately 20 min. A large quantity of mixtures was collected for later use in the laboratory using the scheme listed in Table D.12. A smaller quantity of mixture collected from the road was immediately brought back to the FHWA mobile lab trailer located next to the project site for on-site specimen compaction.

The research team also collected PG 76-22 and PG 64-28 asphalt binder, virgin aggregate, Versabind (mineral filler), Evotherm® 3G, and RAP from the asphalt mix plant. With the help of the contractor's personnel, 48 road cores from four test sections were collected right after construction.

Figure D.36. Loose Mixture Sampling at the New Mexico Field Site

Table D.12. Material Sampling Scheme at the New Mexico Field Site

Sample Type	Material	Point of Sampling
Lab Mixed, Lab Compacted	Fine Aggregate	Stockpile
	Coarse Aggregate	Stockpile
	RAP	Stockpile
	Versabind	Silo
	PG 76-22 Asphalt	Transport Truck
	PG 64-28 Asphalt	Transport Truck
	Evotherm® 3G	Plant
Plant Mixed, Lab Compacted	Loose Mixture	Windrow
Plant Mixed, Field Compacted First Coring—October 2012	Road Cores	Main Lane (between wheelpath)

On-Site PMLC Specimen Compaction

Fifty-six 6 inch (150 mm) diameter specimens were compacted on site using plant mixture at the FHWA mobile lab trailer located next to the project site in Williamsburg. Thirty-two of them were 2.4 inches (61 mm) tall, and 24 of them were 3.75 inches (95 mm) tall. Loose plant mixture collected by the windrow was quickly brought to the mobile lab trailer and placed in the oven between 1 to 2 h to achieve the desired compaction temperature. Specimens were compacted using an IPC SGC to 7±1 percent air voids. In addition, six specimens with each of these four mixtures were compacted for Asphalt Mixture Performance Tester (AMPT) testing. The AMPT specimens were cored and sawed from larger specimens to a final dimension of 4 inches (100 mm) in diameter by 6 inches (150 mm) in height.

APPENDIX E. MIXTURE VOLUMETRICS

Table E.1. Volumetrics by Field Project—WMA vs. HMA

Field Project	Specimen Type	Mixture Type	AV (%)		G_{mm}	P_{ba} (%)	Effective FT (µm)	WMA vs. HMA G_{mm} d2s = 0.014 (AASHTO T 209)
			Average	Range				
Iowa	PMFC Cores	HMA+RAP	8.2%	6.3%-9.9%	2.443	1.33	11.68	
Iowa	PMFC Cores	Evotherm 3G+RAP	8.5%	6.5%-10.4%	2.434	1.17	12.14	equivalent
Iowa	PMFC Cores	Sasobit+RAP	8.5%	6.5%-11.1%	2.438	1.24	11.94	equivalent
Iowa	On-Site PMLC	HMA+RAP	6.7%	6.0%-7.6%	2.443	1.33	11.68	
Iowa	On-Site PMLC	Evotherm 3G+RAP	6.2%	5.8%-6.6%	2.434	1.17	12.14	equivalent
Iowa	On-Site PMLC	Sasobit+RAP	6.4%	5.5%-7.2%	2.438	1.24	11.94	equivalent
Iowa	LMLC	HMA+RAP	7.4%	6.9%-8.2%	2.415	0.82	13.12	
Iowa	LMLC	Evotherm 3G+RAP	6.5%	6.3%-6.9%	2.400	0.54	13.90	lower
Iowa	LMLC	Sasobit+RAP	6.7%	5.7%-8.1%	2.374	0.04	15.28	lower
Iowa	Off-Site PMLC	HMA+RAP	7.0%	6.8%-7.1%	2.443	1.33	11.68	
Iowa	Off-Site PMLC	Evotherm 3G+RAP	7.3%	7.1%-7.6%	2.434	1.17	12.14	equivalent
Iowa	Off-Site PMLC	Sasobit+RAP	7.1%	6.8%-7.3%	2.438	1.24	11.94	equivalent
Texas	PMFC Cores	HMA	8.0%	5.0%-10.4%	2.420	0.53	11.46	
Texas	PMFC Cores	Evotherm DAT	8.5%	7.3%-10.2%	2.408	0.30	12.01	equivalent
Texas	PMFC Cores	Foaming	7.1%	5.8%-8.7%	2.400	0.15	12.38	lower
Texas	On-Site PMLC	HMA	6.0%	5.6%-6.9%	2.420	0.53	11.46	
Texas	On-Site PMLC	Evotherm DAT	6.6%	6.4%-7.4%	2.408	0.30	12.01	equivalent
Texas	On-Site PMLC	Foaming	5.2%	4.7%-5.5%	2.400	0.15	12.38	lower
Texas	LMLC	HMA	6.5%	6.0%-7.0%	2.397	0.10	12.52	
Texas	LMLC	Evotherm DAT	6.5%	6.1%-7.0%	2.399	0.13	12.42	equivalent
Texas	LMLC	Foaming	7.1%	6.2%-7.7%	2.407	0.28	12.05	equivalent
Texas	Off-Site PMLC	HMA	7.6%	6.6%-8.8%	2.420	0.53	11.46	
Texas	Off-Site PMLC	Evotherm DAT	7.0%	6.7%-7.4%	2.408	0.30	12.01	equivalent
Texas	Off-Site PMLC	Foaming	7.1%	6.2%-7.4%	2.400	0.15	12.38	lower

Field Project	Specimen Type	Mixture Type	AV (%)		G_{mm}	P_{ba} (%)	Effective FT (µm)	WMA vs. HMA G_{mm} d2s = 0.014 (AASHTO T 209)
			Average	Range				
Montana	PMFC Cores	HMA	5.7%	5.0%-7.0%	2.454	0.37	8.14	
Montana	PMFC Cores	Evotherm 3G	4.3%	3.8%-5.2%	2.456	0.41	8.08	equivalent
Montana	PMFC Cores	Sasobit	4.5%	3.8%-5.3%	2.463	0.53	7.85	equivalent
Montana	PMFC Cores	Foaming	3.9%	3.4%-4.5%	2.456	0.41	8.08	equivalent
Montana	On-Site PMLC	HMA	6.7%	6.0%-7.7%	2.454	0.37	8.14	
Montana	On-Site PMLC	Evotherm 3G	6.3%	5.7%-6.8%	2.456	0.41	8.08	equivalent
Montana	On-Site PMLC	Sasobit	6.8%	6.3%-7.3%	2.463	0.53	7.85	equivalent
Montana	On-Site PMLC	Foaming	6.5%	6.1%-7.1%	2.456	0.41	8.08	equivalent
Montana	Off-Site PMLC	HMA	6.1%	5.6%-7.2%	2.444	0.19	8.47	
Montana	Off-Site PMLC	Evotherm 3G	7.8%	7.4%-8.2%	2.466	0.59	7.75	higher
Montana	Off-Site PMLC	Sasobit	7.2%	6.6%-7.6%	2.459	0.46	7.98	higher
Montana	Off-Site PMLC	Foaming	6.6%	6.0%-7.1%	2.457	0.42	8.04	equivalent
New Mexico	PMFC Cores	HMA+RAP	6.1%	5.5%-7.0%	2.340	0.37	10.28	
New Mexico	PMFC Cores	Evotherm 3G+RAP	7.8%	7.2%-8.3%	2.343	0.43	10.17	equivalent
New Mexico	PMFC Cores	Foaming+RAP	4.4%	3.8%-4.9%	2.335	0.27	10.47	equivalent
New Mexico	On-Site PMLC	HMA+RAP	6.6%	5.8%-7.3%	2.340	0.37	10.28	
New Mexico	On-Site PMLC	Evotherm 3G+RAP	6.6%	6.2%-7.1%	2.343	0.43	10.17	equivalent
New Mexico	On-Site PMLC	Foaming+RAP	6.6%	5.5%-7.2%	2.335	0.27	10.47	equivalent
New Mexico	LMLC	HMA+RAP	6.8%	6.1%-7.6%	2.339	0.35	10.32	
New Mexico	LMLC	Evotherm 3G+RAP	7.3%	6.1%-8.0%	2.351	0.58	9.88	equivalent
New Mexico	LMLC	Foaming+RAP	6.0%	5.1%-6.7%	2.339	0.35	10.32	equivalent
New Mexico	Off-Site PMLC	HMA+RAP	7.5%	6.7%-8.1%	2.339	0.35	10.32	
New Mexico	Off-Site PMLC	Evotherm 3G+RAP	6.5%	5.8%-7.3%	2.333	0.23	10.55	equivalent
New Mexico	Off-Site PMLC	Foaming+RAP	7.1%	6.2%-8.0%	2.349	0.54	9.95	equivalent

Table E.2. Volumetrics by Field Project—PMFC Cores vs. LMLC and Off-Site PMLC Specimens

Field Project	Mixture Type	Specimen Type	AV (%)		G_{mm}	P_{ba} (%)	Effective FT (μm)	PMFC vs. LMLC G_{mm} d2s = 0.014 (AASHTO T 209)	PMFC vs. Off-Site PMLC G_{mm} d2s = 0.014 (AASHTO T 209)
			Average	Range					
Iowa	HMA+RAP	PMFC Cores	8.2%	6.3%-9.9%	2.443	1.33	11.68		
Iowa	HMA+RAP	LMLC	7.4%	6.9%-8.2%	2.415	0.82	13.12	higher	
Iowa	HMA+RAP	Off-Site PMLC	7.0%	6.8%-7.1%	2.443	1.33	11.68		equivalent
Iowa	Evotherm 3G+RAP	PMFC Cores	8.5%	6.5%-10.4%	2.434	1.17	12.14		
Iowa	Evotherm 3G+RAP	LMLC	6.5%	6.3%-6.9%	2.400	0.54	13.90	higher	
Iowa	Evotherm 3G+RAP	Off-Site PMLC	7.3%	7.1%-7.6%	2.434	1.17	12.14		equivalent
Iowa	Sasobit+RAP	PMFC Cores	8.5%	6.5%-11.1%	2.438	1.24	11.94		
Iowa	Sasobit+RAP	LMLC	6.7%	5.7%-8.1%	2.374	0.04	15.28	higher	
Iowa	Sasobit+RAP	Off-Site PMLC	7.1%	6.8%-7.3%	2.438	1.24	11.94		equivalent
Texas	HMA	PMFC Cores	8.0%	5.0%-10.4%	2.420	0.53	11.46		
Texas	HMA	LMLC	6.5%	6.0%-7.0%	2.397	0.10	12.52	higher	
Texas	HMA	Off-Site PMLC	7.6%	6.6%-8.8%	2.420	0.53	11.46		equivalent
Texas	Evotherm DAT	PMFC Cores	8.5%	7.3%-10.2%	2.408	0.30	12.01		
Texas	Evotherm DAT	LMLC	6.5%	6.1%-7.0%	2.399	0.13	12.42	equivalent	
Texas	Evotherm DAT	Off-Site PMLC	7.0%	6.7%-7.4%	2.408	0.30	12.01		equivalent
Texas	Foaming	PMFC Cores	7.1%	5.8%-8.7%	2.400	0.15	12.38		
Texas	Foaming	LMLC	7.1%	6.2%-7.7%	2.407	0.28	12.05	equivalent	
Texas	Foaming	Off-Site PMLC	7.1%	6.2%-7.4%	2.400	0.15	12.38		equivalent
Montana	HMA	PMFC Cores	5.7%	5.0%-7.0%	2.454	0.37	8.14		
Montana	HMA	Off-Site PMLC	6.1%	5.6%-7.2%	2.444	0.19	8.47		equivalent
Montana	Evotherm 3G	PMFC Cores	4.3%	3.8%-5.2%	2.456	0.41	8.08		
Montana	Evotherm 3G	Off-Site PMLC	7.8%	7.4%-8.2%	2.466	0.59	7.75		equivalent
Montana	Sasobit	PMFC Cores	4.5%	3.8%-5.3%	2.463	0.53	7.85		
Montana	Sasobit	Off-Site PMLC	7.2%	6.6%-7.6%	2.459	0.46	7.98		equivalent
Montana	Foaming	PMFC Cores	3.9%	3.4%-4.5%	2.456	0.41	8.08		
Montana	Foaming	Off-Site PMLC	6.6%	6.0%-7.1%	2.457	0.42	8.04		equivalent

Field Project	Mixture Type	Specimen Type	AV (%)		G_{mm}	P_{ba} (%)	Effective FT (μm)	PMFC vs. LMLC G_{mm} d2s = 0.014 (AASHTO T 209)	PMFC vs. Off-Site PMLC G_{mm} d2s = 0.014 (AASHTO T 209)
			Average	Range					
New Mexico	HMA+RAP	PMFC Cores	6.1%	5.5%-7.0%	2.340	0.37	10.28		
New Mexico	HMA+RAP	LMLC	6.8%	6.1%-7.6%	2.339	0.35	10.32	equivalent	
New Mexico	HMA+RAP	Off-Site PMLC	7.5%	6.7%-8.1%	2.339	0.35	10.32		equivalent
New Mexico	Evotherm 3G+RAP	PMFC Cores	7.8%	7.2%-8.3%	2.343	0.43	10.17		
New Mexico	Evotherm 3G+RAP	LMLC	7.3%	6.1%-8.0%	2.351	0.58	9.88	equivalent	
New Mexico	Evotherm 3G+RAP	Off-Site PMLC	6.5%	5.8%-7.3%	2.333	0.23	10.55		equivalent
New Mexico	Foaming+RAP	PMFC Cores	4.4%	3.8%-4.9%	2.335	0.27	10.47		
New Mexico	Foaming+RAP	LMLC	6.0%	5.1%-6.7%	2.339	0.35	10.32	equivalent	
New Mexico	Foaming+RAP	Off-Site PMLC	7.1%	6.2%-8.0%	2.349	0.54	9.95		lower

Note: Volumetric calculation is performed in accordance with STP 204-19; d2s value for G_{mm} (single operator, single laboratory) is 0.014, according to AASHTO Standard T 209; volumetric parameters of P_{ba} and effective FT are further calculated from G_{mm}—higher G_{mm} values correspond to higher P_{ba} and lower effective FT; PMFC cores refer to PMFC cores at construction; PMFC cores and on-site PMLC specimens are assumed to have the same G_{mm} values.

APPENDIX G. FUTURE WORK PLAN TO EVALUATE MOISTURE SUSCEPTIBILITY OF HMA AND WMA

INTRODUCTION

Comparisons between hot mix asphalt (HMA) and warm mix asphalt (WMA) moisture performance were done in this project in terms of indirect tensile (IDT) strength, resilient modulus (M_R) stiffness, and Hamburg Wheel-Tracking Test (HWTT) stripping potential. The conclusions derived from the results of these tests were sometimes different, likely due to the type of test (i.e., destructive, like IDT strength, versus nondestructive, like M_R stiffness), and the type of load applied (i.e., monotonic versus repeated). For example, Texas WMA Evotherm DAT™ laboratory-mixed, laboratory-compacted (LMLC) specimens exhibited an improved wet IDT strength when a liquid anti-stripping (LAS) agent was added to the mixture but worse performance when comparing the wet M_R and M_R-ratio to the mixture without the LAS agent. In addition, this same mixture type showed equivalent performance to HMA when comparing wet IDT strength and the tensile strength ratio (TSR) but exhibited inferior performance in HWTT.

Strength and stiffness are both important parameters for characterizing asphalt mixtures. In this project, both tests were performed on specimens with different moisture and aging conditions. The change in properties between the unconditioned or dry state versus the conditioned or wet state was considered an indicator of the susceptibility of a mixture to moisture damage. However, the behavior of a mixture in the laboratory and the field is related to many other materials and mixture properties, such as the physical and chemical properties of the aggregates and the asphalt binder, the total air voids (AVs) in the mixture, the thickness of the asphalt layer in the pavement, etc.

Therefore, there is a need for a parameter (or parameters) with physical significance that combines several relevant mixture characteristics and provides a reasonably objective means of comparing mixture performance at the plant, in the laboratory, and in the field as placed and with age and exposure. This parameter should be applicable to both monotonic loading tests (e.g., IDT and M_R) and repeated loading under extreme moisture exposure conditions (e.g., HWTT). With such a parameter, it will be possible to determine which laboratory tests provide equivalent conditioning to core samples taken from the field after being exposed to many months of aging, moisture exposure, and repeated traffic loading.

It is with this practical objective in mind—to propose an objective measure of mixture performance under monotonic loading and repeated loading—that this appendix reviews the data that have been compiled in this project. In developing the mentioned parameter (or parameters), maximum use of applications of micromechanics, fracture mechanics, repeated loading plasticity, and pseudo strain energy concepts was made. Once the parameter is developed, it will then be possible to recommend material property measurements that are not currently made, which will give the performance parameter (or parameters) a greater physical significance.

MONOTONIC LOADING CRITERIA

In the IDT test, a monotonic load is applied at a constant rate of 2 inch/min (50 mm/min) until a vertical crack appears. Because of this, a performance parameter that has physical significance will be one that is borrowed, at least in concept, from the discipline of fracture mechanics. The Griffith crack growth criterion (Griffith, 1920) proposes a crack initiation model

based on the balance of energy in which an external stress applied to the material is stored as energy and this energy is released by the initiation and growth of a crack. The amount of energy needed to start a crack is related to material properties such as tensile strength and modulus. The Griffith crack growth criterion was developed for a brittle, elastic material with a flaw in it. The criterion is expressed in Equation G.1.

$$\boldsymbol{\sigma_t^2 \bar{c}} = \frac{\boldsymbol{2E\Gamma}}{\boldsymbol{\pi}} \qquad \text{(G.1)}$$

Where,

σ_t → tensile strength.
E → modulus.
$\bar{c}$ → mean radius of the cracked area.
Γ → surface energy.

Also, the term 2 Γ corresponds to the adhesive bond energy (ΔG); therefore, Equation G.1 can be expressed as:

$$\sigma_t^2 \bar{c} = \frac{E\Delta G}{\pi} \qquad \text{(G.2)}$$

For application to the initial crack growth in asphalt mixtures, the mean radius of the cracked area will be a function of the AV density, the cross-sectional area of the specimen, and the percent AV in the sample (Equation G.3).

$$\frac{\boldsymbol{\pi m \bar{c}^2}}{\boldsymbol{A}} = \%\boldsymbol{air} \qquad \text{(G.3)}$$

Solving for $\boldsymbol{\bar{c}}$ in Equation G.3 results in the following equation:

$$\boldsymbol{\bar{c}} = \sqrt{\frac{\%\boldsymbol{air}}{\boldsymbol{\pi(m/A)}}} \qquad \text{(G.4)}$$

Integrating Equation G.4 into Equation G.2 results in the following:

$$\frac{\boldsymbol{\sigma^2}}{\boldsymbol{E}} \sqrt{\frac{\%\boldsymbol{air}}{\boldsymbol{\pi(m/A)}}} = \frac{\boldsymbol{\Delta G}}{\boldsymbol{\pi}} \qquad \text{(G.5)}$$

$$\boldsymbol{\sigma^2} = \frac{\boldsymbol{E\Delta G}}{\boldsymbol{\pi}} \sqrt{\frac{\boldsymbol{\pi(m/A)}}{\%\boldsymbol{air}}} \qquad \text{(G.6)}$$

$$\sigma_t = \frac{(E\Delta G)^{1/2}}{\pi^{1/2}} \sqrt[4]{\frac{\pi(m/A)}{\%air}} \qquad \text{(G.7)}$$

$$\sigma_t = (E\Delta G)^{1/2} \left(\frac{m/A}{\pi\%air}\right)^{1/4} \qquad \text{(G.8)}$$

$$\frac{{\sigma_t}^2}{E} = \Delta\mathrm{G}\,\left(\frac{m/A}{\pi\%air}\right)^{1/2} \tag{G.9}$$

Finally, solving for the bond energy yields the following equation:

$$\Delta G = \frac{{\sigma_t}^2}{E}\left(\frac{\pi\,\%air}{m/A}\right)^{1/2} \tag{G.10}$$

From Equation G.10, the bond energy (ΔG), following the Griffith crack growth theory, can be calculated with the tensile strength (σ_t), modulus (*E*), air void content (*%air*), and crack density (*m/A*) for an asphalt mixture. The term $\frac{{\sigma_t}^2}{E}$ in Equation G.10 corresponds to the strain energy (U) of a ductile material; therefore, the bond energy can be calculated using Equation G.11.

$$\Delta\mathbf{G} = \mathrm{U}\left(\frac{\boldsymbol{\pi\%air}}{\boldsymbol{m/A}}\right)^{\mathbf{1/2}} \tag{G.11}$$

As mentioned before, the Griffith crack growth theory was developed for a brittle material, and asphalt mixtures are between brittle and ductile behavior. Further explanation on how to consider this factor is provided in the following section.

Ductile and Brittle Behavior

Materials will exhibit a different behavior under the application of a constant load rate depending on how ductile or brittle they are. This behavior is illustrated in the dimensionless stress-strain curve described in Figure G.1. The X axis corresponds to the strain at time (t) divided by the total strain at the time of maximum stress; the Y axis corresponds to the stress at time (t) divided by the maximum stress.

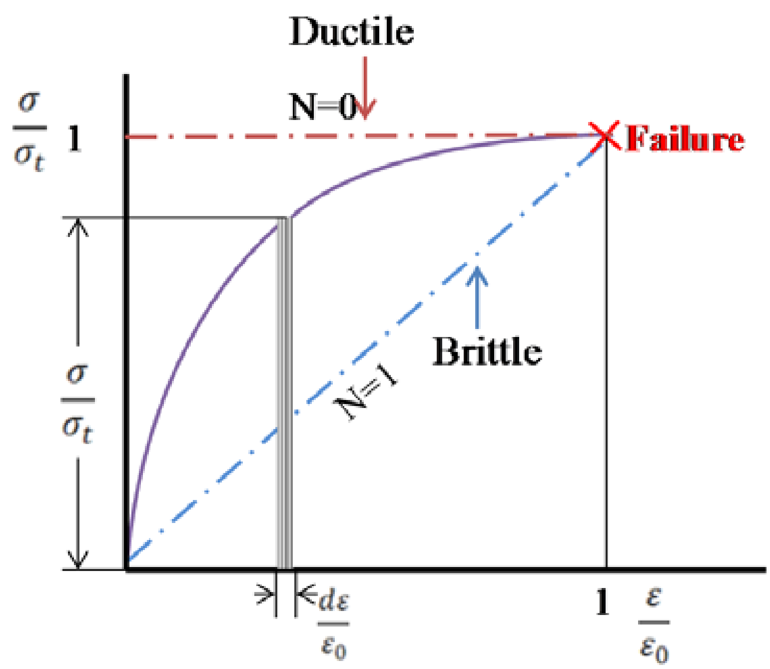


Figure G.1. Dimensionless Stress-Strain Curve

From Figure G.1, the following equation is derived:

$$\frac{\boldsymbol{\sigma}}{\boldsymbol{\sigma_t}} = \left(\frac{\boldsymbol{\varepsilon}}{\boldsymbol{\varepsilon_0}}\right)^{\boldsymbol{N}} \quad \text{or} \quad \boldsymbol{\sigma} = \boldsymbol{\sigma_t}\left(\frac{\boldsymbol{\varepsilon}}{\boldsymbol{\varepsilon_0}}\right)^{\boldsymbol{N}} \tag{G.12}$$

Therefore, the area (I_1) under the dimensionless stress-strain curve can be obtained by the following integral:

$$I_1 = \int_{\frac{\varepsilon}{\varepsilon_0}=0}^{\frac{\varepsilon}{\varepsilon_0}=1} \left(\frac{\sigma}{\sigma_t}\right) d\left(\frac{\varepsilon}{\varepsilon_0}\right) = \int_{\frac{\varepsilon}{\varepsilon_0}=0}^{\frac{\varepsilon}{\varepsilon_0}=1} \left(\frac{\varepsilon}{\varepsilon_0}\right)^N d\left(\frac{\varepsilon}{\varepsilon_0}\right) \tag{G.13}$$

$$I_1 = \frac{1}{N+1}\left[\left(\frac{\varepsilon}{\varepsilon_0}\right)^{N+1}\right]_0^1 \tag{G.14}$$

$$\boldsymbol{I_1} = \frac{\mathbf{1}}{\boldsymbol{N+1}} \tag{G.15}$$

By calculating the area under the dimensionless stress-strain curve, the curve form index N can be obtained. Figure G.1 showed that:

- Brittle material, N = 1 → $U = \frac{\sigma_t^2}{2E}$.
- Ductile material, N = 0 → $U = \frac{\sigma_t^2}{E}$.

Thus, instead of using Equation G.11, the strain energy for a ductile material can be calculated as described in Equation G.16:

$$U = \frac{\sigma_t^2}{E} \quad (G.16)$$

Then, for all mixtures, Equation G.17 can be used to account for how ductile or brittle the mixture is. It is important to account for the ductility of the mixture since a more ductile mixture will require more energy to initiate and propagate the crack.

$$U = \frac{\sigma_t^2}{(N+1)E} \quad (G.17)$$

Where,

σ_t → tensile strength.

E → modulus.

N → curve form index, $0 < N < 1$.

Adhesive Bond Energy

Applying the Griffith crack growth theory for asphalt mixtures (Equation G.11) and considering the mixture is not completely brittle nor ductile (Equation G.17), the bond energy can be calculated with Equation G.18 using the modulus, strength, and AV content of the mixture in question. Bond energy is an indicator of the adhesive strength between the mixture component materials (i.e., aggregates and asphalt binder).

$$\Delta G = \frac{{\sigma_t}^2}{(1+N)E}\left(\frac{\pi \% air}{m/A}\right)^{1/2} \quad (G.18)$$

Where,

σ_t → IDT strength.

N → curve form index calculated from IDT data.

E → resilient modulus.

m/A → assumed AV density (AV/mm^2).

$\%air$ → average AV content (typically around 7 percent).

Currently, the AV density (i.e., *m/A*) is unknown, and was assumed in this project to be about the same for all mixes tested. However, this assumption is probably incorrect when comparing mixes with distinctively different aggregate gradations. This parameter does not need to be measured in each sample. Instead, experience with mixtures with distinctively different gradations will permit the use of typical AV densities for each type of gradation.

For the purpose of this project, which focused on moisture susceptibility, it was assumed that if the adhesive bonding between aggregate and binder in the mixture was disrupted, then the energy required to start a crack growing would be lowered from the initial dry state of the specimens to the wet condition. Moisture conditioning of the tested specimen consisted of vacuum saturation and one freeze/thaw (F/T) cycle per AASHTO T 283.

RESULTS FROM MONOTONIC LOADING: TEXAS FIELD PROJECT

This section discusses an example of calculating the adhesive bond energy utilizing the laboratory data corresponding to the Texas field project with the proposed monotonic loading

criteria methodology. One control HMA plus two WMA technologies were included as part of this analysis.

Stress-Strain Curve Form Index

The stress-strain curve form index, *N*, was calculated as explained previously for each specimen tested, and the average of three replicates values was reported as *N* for each mixture type in dry and wet condition. Results are shown in Figure G.2. The solid bars correspond to the *N* index value wet condition, and the bars with no fill extend to the dry *N* index value; different colors indicate the type of mixture as detailed in the figure's legend. The error bars represent ± one standard deviation from the average value.

From Figure G.2, it is clear that in most cases, the wet and dry conditions had no significant difference in how ductile or brittle the mixture was. Greater differences between the *N* index values were observed in the LMLC specimens, which also seemed to be the more ductile in all cases except for Evotherm DAT™ (Table G.1). The dry LMLC HMA specimens appeared to be the most ductile. In addition, the LMLC HMA specimens experienced the most noticeable difference in *N* from dry to wet condition.

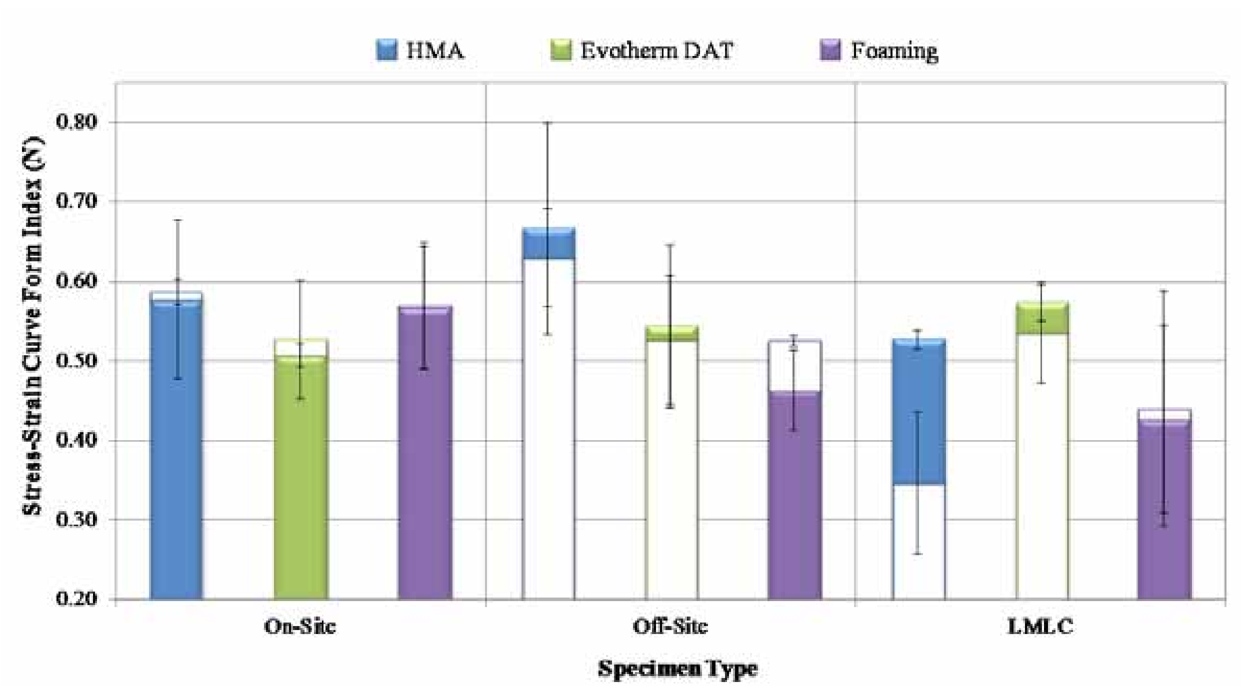


Figure G.2. Stress-Strain Curve Form Index, *N*, for the Texas Field Project

Table G.1. Average Dry and Wet *N* by Specimen Type for the Texas Field Project

Specimen Type	HMA		Evotherm DAT		Foaming	
	Dry	Wet	Dry	Wet	Dry	Wet
On-Site PMLC	0.59	0.58	0.53	0.51	0.57	0.57
Off-Site PMLC	0.63	0.67	0.53	0.54	0.53	0.46
LMLC	0.35	0.53	0.54	0.57	0.44	0.43

The Texas field project was also included as part of the anti-stripping experiment and the effect of the anti-stripping agents evaluated with respect to the stress-strain curve form index. From Figure G.3, it is apparent that HMA, which was the only LMLC mixture exhibiting a significant change in *N* from dry to wet condition (see Figure G.2), became more brittle with the addition of anti-stripping agents, and once the anti-stripping agents were added, moisture conditioning did not significantly affect the ductility of the mixture. The WMA Evotherm DAT™ LMLC mixtures were not affected by either the addition of anti-stripping agents or the moisture-conditioning process. Contrary to the results observed in the case of HMA, the design WMA Foaming LMLC mixtures showed no differences in dry vs. wet *N* index values. However, the dry vs. wet *N* index became significantly different with the addition of the anti-stripping agents.

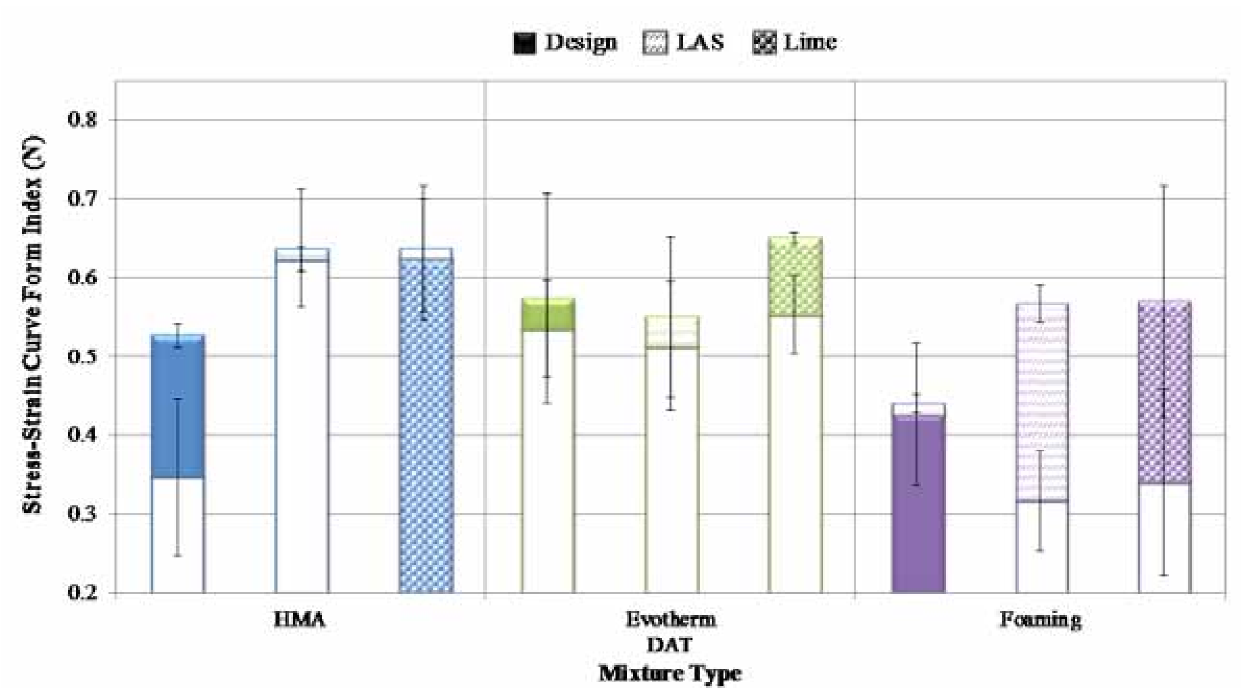


Figure G.3. Stress-Strain Curve Form Index, *N*, for the Texas Anti-Stripping Experiment

In general, HMA and WMA Evotherm DAT™ exhibited similar N index values. WMA Foaming appeared to have, in general, a more ductile behavior. When the anti-stripping agents were added to this mixture, the moisture-conditioning process had a significant impact on ductility. A summary of the *N* index values for the mixtures used in the Texas anti-stripping experiment is provided in Table G.2.

Table G.2. Average Dry and Wet *N* for the Texas Anti-Stripping Experiment

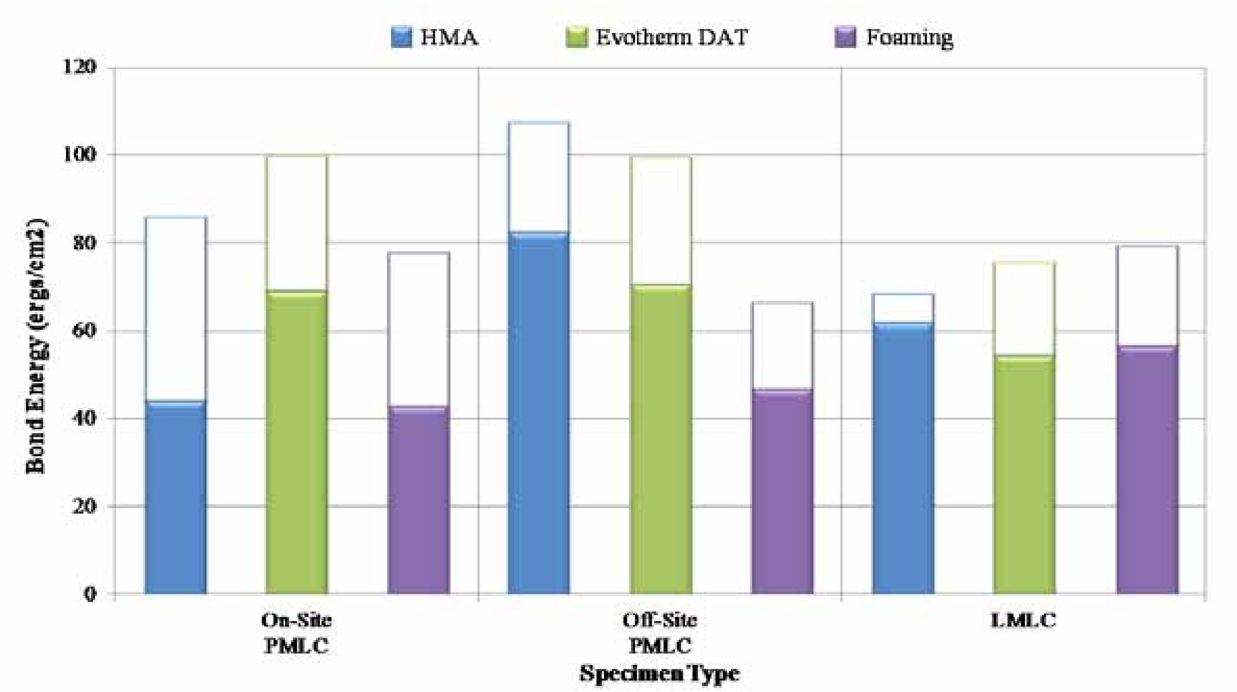
Mixture Type	Design		LAS		Lime	
	Dry	Wet	Dry	Wet	Dry	Wet
HMA	0.35	0.53	0.62	0.64	0.64	0.62
Evotherm DAT	0.54	0.57	0.51	0.55	0.55	0.65
Foaming	0.44	0.43	0.32	0.57	0.34	0.57

Adhesive Bond Energy

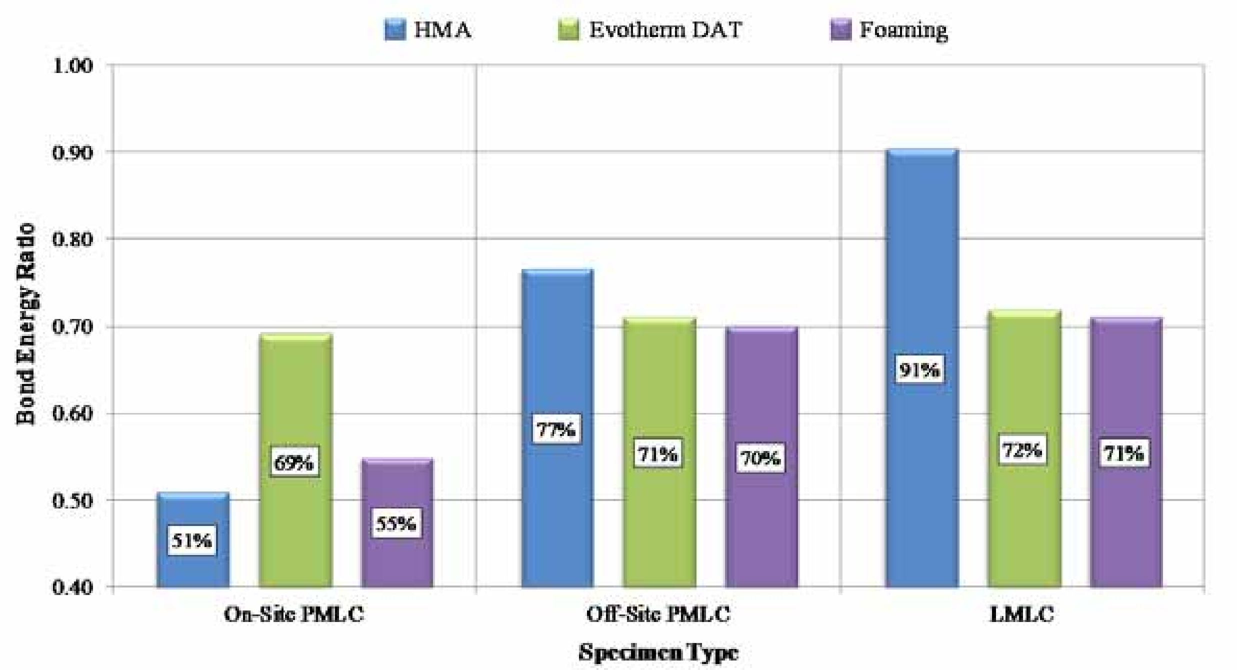
The adhesive bond energy calculations were completed in accordance with the equations presented in Section G.2.2 and using the *N* index values listed in the previous section. The bond energy and the wet/dry bond energy ratio results are shown in Figure G.4 and summarized in Table G.3. The solid part of the bars in Figure G.4(a) represent the bond energy calculations for specimens in wet condition, and the part of the bar with no fill extends up to the bond energy corresponding to dry specimens.

Figure G.4(a) shows that HMA exhibited the most change in bond energy with different specimen types. WMA Foaming mixtures exhibited the lowest dry bond energy for both on-site and off-site PMLC specimens as compared to HMA and Evotherm DAT™. For LMLC specimens, the wet and dry bond energy of all mixtures was about the same for all mixture types.

Figure G.4(b) shows the wet/dry bond energy ratio. The results presented in this figure indicate that the on-site PMLC had the lowest values ratios (i.e., the greatest difference between dry and wet bond energy values). WMA Evotherm DAT™ was the only mixture type that regardless of the specimen type had relatively constant bond energy ratios.



(a) Dry and Wet Bond Energy



(b) Bond Energy Ratio

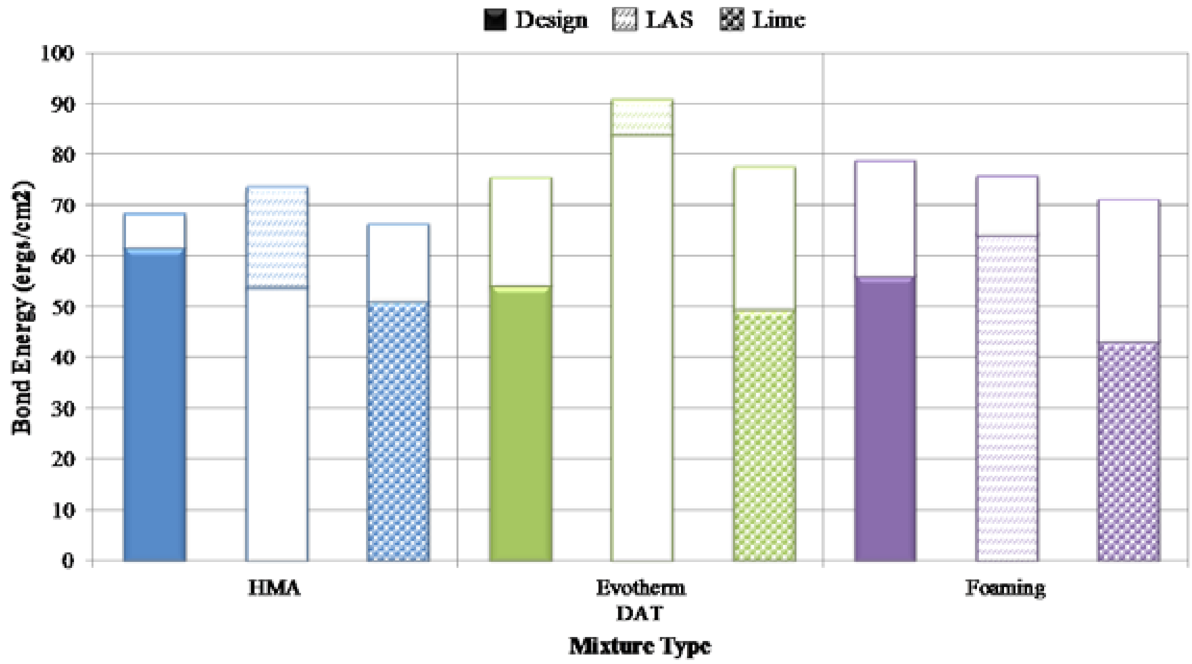
Figure G.4. Bond Energy Results for the Texas Field Project

Table G.3. Dry and Wet Bond Energy by Specimen Type for the Texas Field Project (ergs/cm^2)

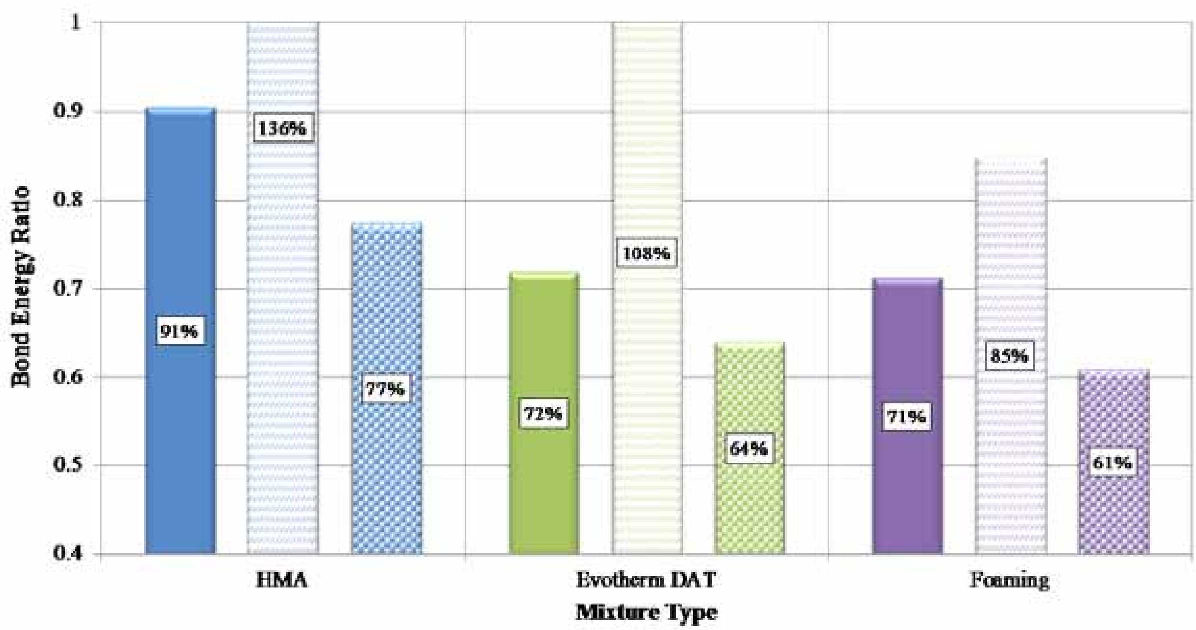
Specimen Type	HMA		Evotherm DAT		Foaming	
	Dry	Wet	Dry	Wet	Dry	Wet
On-Site PMLC	86.0	43.9	99.7	68.9	77.7	42.7
Off-Site PMLC	107.3	82.4	99.3	70.6	66.5	46.6
LMLC	68.4	61.9	75.7	54.4	79.1	56.4

For the bond energy analysis of the Texas mixtures used in the anti-stripping experiment, the calculated *N* index for each mixture type and condition was also considered. As described in the previous section, these mixtures had greater differences in *N* than those from the overall test plan. Figure G.5 shows the results for the bond energy calculations.

Table G.4 and Figure G.5(a) present the dry and wet bond energies for all mixtures as designed and with added anti-stripping agents. When the LAS agent was used, the wet bond strength was the highest for all mixture types, even larger than the dry bond strength in the case of HMA and Evotherm DAT™. The results presented in Figure G.5(b) show that the best bond energy ratios were achieved by the inclusion of an LAS agent, while the worst bond energy ratios corresponded to the mixtures with added lime.



(a) Dry and Wet Bond Energy



(b) Bond Energy Ratio

Figure G.5. Bond Energy Results for the Texas Anti-Stripping Experiment

Table G.4. Bond Energy for the Texas Anti-Stripping Experiment (ergs/cm^2)

Mixture Type	Design		LAS		Lime	
	Dry	Wet	Dry	Wet	Dry	Wet
HMA	68.4	61.9	54.1	73.8	66.4	51.4
Evotherm DAT	75.7	54.4	84.2	91.0	77.8	49.8
Foaming	79.1	56.4	76.0	64.6	71.4	43.5

Summary

Commonly used methods for evaluating moisture susceptibility rely on individual performance tests such as the ones used in this project (e.g., IDT, M_R, etc.). When the results of these tests are considered independently, different conclusions are obtained. For example, a mixture may have higher wet M_R stiffness but equivalent or lower wet IDT strength when compared to other mixtures, as seen in the case of the Montana WMA Sasobit® off-site PMLC specimens. The opposite was true for the Texas WMA Evotherm DAT™ mixture, which exhibited equivalent wet IDT strength but significantly reduced wet M_R stiffness as compared to HMA and WMA Foaming. More importantly, neither tensile strength nor stiffness alone govern the mixture performance in the field, and a combination of other important material and mixture characteristics also need to be considered.

To overcome these shortcomings, a parameter based on bond energy was proposed to combine the strength, stiffness, and AV characteristics of the mixtures. The dataset used to validate this parameter (i.e., mixtures from the Texas field project) showed that the mixtures with added LAS agent had better bond energy results after moisture conditioning. In some cases, the addition of LAS agents, besides enhancing the chemical bonding between asphalt and aggregates on the mixture, also rendered a softer mixture, which was not necessarily a negative side effect from the use of these products.

It is often assumed that higher stiffness and strength are absolute indicators of enhanced performance, but when asphalt ages, it leads to the same behavior. Indeed, rutting potential is improved with increased stiffness, but stiffer mixtures are, in most cases, more prone to cracking (depending of the thickness of the pavement). Assessing mixture performance with the proposed parameter was intended to consider several performance and mixture factors simultaneously. The limited application of the parameter to a monotonic loading performance criterion showed that it does permit comparisons of different mixtures and specimen types with remarkable consistency, as was hoped when this approach was proposed.

The monotonic loading stripping performance parameter based on surface energy proposed here should be used in the future in the same way to gain experience and to propose further useful modifications. Some of the more obvious modifications will be recommended at the conclusion of this chapter. With such further refinement, more experience will be needed to establish thresholds and even mixture design and conditioning criteria and specifications.

REPEATED LOADING CRITERIA

HWTT is a laboratory test that utilizes repetitive loading in the presence of water and measures combined mixture resistance to stripping and rutting. As shown in Figure G.6, two sets of Superpave gyratory compacted (SGC) specimens are placed together as a single specimen, submerged in water at 122°F (50°C), and subjected to 50-52 passes of a steel wheel per minute.

Each set of the specimens is loaded for a maximum of 20,000 load cycles or until the center of the specimen deforms by 0.5 inch (12.5 mm).

Figure G.6. HWTT Equipment with Loaded SGC Specimens

During testing, rut depths at different positions along the specimens are recorded with every load cycle. This information is then plotted and presented as the output of the test. The resulting HWTT curves (i.e., rut depth in the center of the specimen vs. load cycles) are divided into three main phases—post-compaction, creep phase, and stripping phase—as shown in Figure G.7 (Solaimanian et al., 2003). Post-compaction is the consolidation of the specimen that occurs as the wheel load densifies the mixture and the AVs decrease significantly. This first phase is usually considered to occur within the first 1,000 load cycles. The second, or creep, phase is the deformation that occurs due to the viscous flow of the asphalt mixture and is represented by a constant rut depth increase rate with load cycles. The stripping phase (third phase) starts once the bond between the asphalt binder and the aggregate starts degrading, causing visible damage such as stripping or raveling with added load cycles.

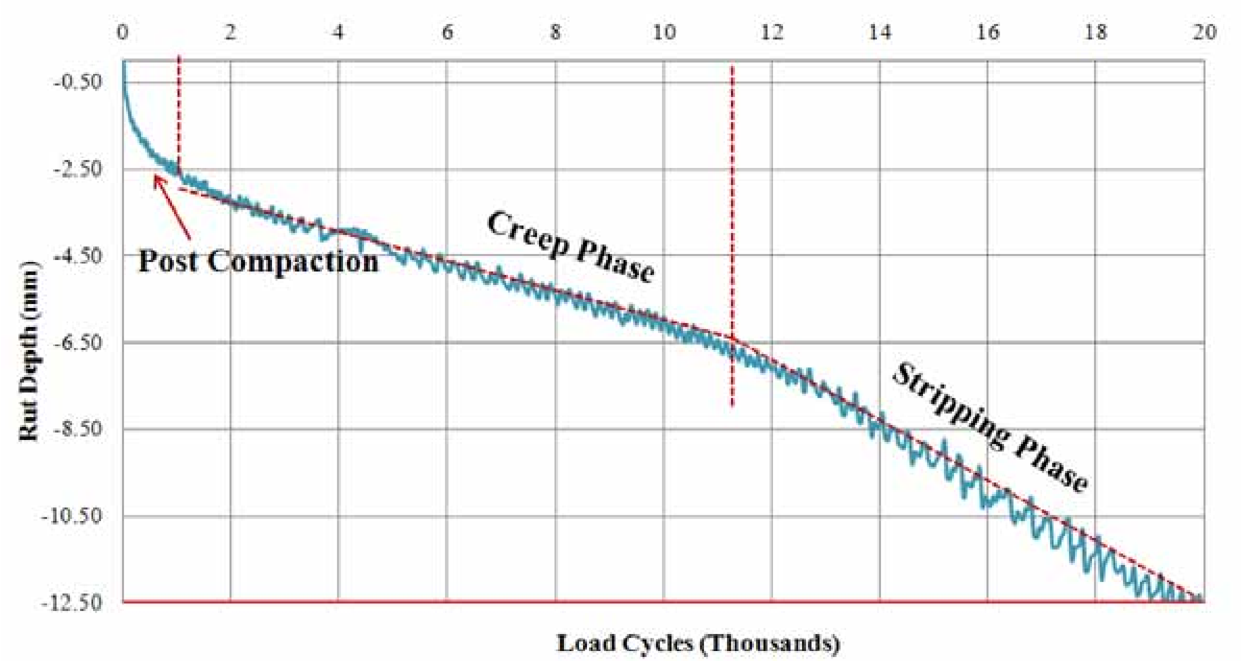


Figure G.7. Typical HWTT Rut Depth versus Load Cycle Output

Field experience indicates that rut depth due to mixture stripping contributes to a significant portion of the total rut depth of the pavement. The stripping inflection point (SIP) represents the number of load cycles in the HWTT curve where a sudden increase in rut depth occurs, mainly due to stripping of the binder from the aggregates. The SIP is graphically represented at the intersection of the fitted line that characterizes the creep phase (i.e., creep slope) and the fitted line that describes the stripping phase (i.e., stripping slope). Currently, the SIP and rut depth at a certain number of load cycles are widely used as test parameters to evaluate any given mixture's resistance to moisture susceptibility and rutting. However, previous experience with the HWTT test has indicated that measuring rut depth at a specific number of load cycles is not always able to evaluate accurately the mixture resistance to rutting, due to the contribution of stripping to rut depth. Additionally, the evaluation of mixture resistance to stripping solely on the basis of SIP has also been questioned, due to its sensitivity to the ending point of the test, which is involved in the calculation of the stripping slope.

A novel methodology to analyze HWTT test results is provided in this report, and three test parameters that are able to evaluate with much better accuracy the mixture's resistance to rutting and stripping are proposed. As with the monotonic loading parameter discussed in the previous section, it is desirable to develop a single number that is derived from the test data without subjective interpretation, and that allows a direct comparison between different mixture and specimen types. It is also desirable to propose a single parameter that combines the results of more than one test.

When analyzing the HWTT curves, a critical point is where the curvature of the rut depth versus load cycle line changes from positive to negative (i.e., inflection point), as shown in Figure G.8. This point was labeled stripping number (SN) in this project. Several measurements are proposed to compare the performance of a given mixture prior to the SN and the subsequent resistance to stripping after the SN.

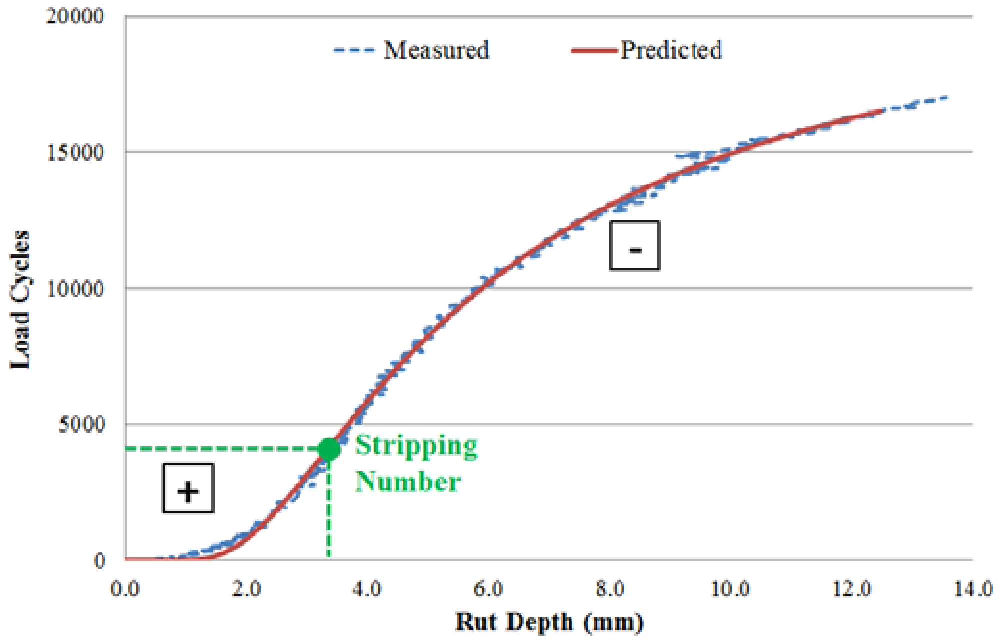


Figure G.8. HWTT Stripping Number Definition

Two different fitting curves were used to describe the data. One is a power law that fits the rut depth versus load cycle curve prior to the SN, and the second is the three-parameter model used in the Mechanistic Empirical Pavement Design Guide (MEPDG) to describe the three phases of rutting, including the third phase in which the rutting accelerates beyond the flow point (NCHRP 1-37A, 2002). The inflection point determined with the three-parameter model is equivalent to the flow point used in rut depth predictions. One of the advantages of using the three-parameter model is that it determines a maximum number of load cycles that the mixture will not be able to exceed. The difference between this asymptote value and the number of load cycles to the SN (i.e., LC_{SN}) is the remaining life of the mixture, which is a measure of the ability of the mixture to resist stripping after its onset.

Several performance measurements that make use of the data from these two fitting curves and from the IDT test under wet conditions are proposed. All of these parameters have physical significance, obtained without subjective interpretation from the output data.

Data Analysis Methodology

The load cycle versus rut depth output data were plotted to obtain a typical curve for the HWTT test, as shown in Figure G.8. Then, Equation G.19 was used to fit the results.

$$LC_{RD} = LC_{ult} * e^{-\left(\frac{\rho}{RD}\right)^{\beta}} \quad \text{(G.19)}$$

Where,

LC_{RD} → load cycles at a specified rut depth.
LC_{ult} → maximum load cycle.
RD → rut depth of the HWTT specimen.
ρ → curve fitting coefficient.
β → curve fitting coefficient.

The fitted line was composed of one part with positive curvature, followed by another part with negative curvature. In the part of the fitted line with positive curvature, the mixture was expected to be stiffening by the action of the repeated load applications and the rut depth was expected to be increasing due to specimen consolidation. On the other hand, in the part of the fitted line with negative curvature, the mixture was expected to be softening also due to the action of the repeated wheel-load applications and the stripping of the asphalt binder from the aggregate. Thus, the rutting that occurred in the part of the fitted line with negative curvature was only attributed to stripping.

To determine the LC_{SN}, the second derivative of Equation G.19 is set to zero. The derivation is as follows:

$$\frac{\partial LC_{RD}}{\partial RD} = LC_{ult} * e^{-(\frac{\rho}{RD})^{\beta}} * \frac{\beta\rho^{\beta}}{RD^{(\beta+1)}} \quad \text{(G.20)}$$

$$\frac{\partial^2 LC_{RD}}{\partial RD^2} = LC_{ult} * e^{-(\frac{\rho}{RD})^{\beta}} * \frac{\beta^2\rho^2\beta}{RD^{2(\beta+1)}} - LC_{ult} * e^{-(\frac{\rho}{RD})^{\beta}} * \frac{\beta(\beta+1)\rho^{\beta}}{RD^{(\beta+2)}} \quad \text{(G.21)}$$

Setting Equation G.21 equal to zero, the rut depth at the SN (RD_{SN}) is found as follows:

$$RD_{SN} = (\frac{\beta}{\beta+1})^{1/\beta} * \rho \quad \text{(G.22)}$$

The LC_{SN} is then calculated using the following equation:

$$LC_{SN} = LC_{ult} * e^{-(\frac{\beta+1}{\beta})} \quad \text{(G.23)}$$

LC_{SN} represents the maximum number of load cycles that the asphalt mixture can resist in the HWTT test before the adhesive fracture between the asphalt binder and the aggregate occurs. Mixtures with higher LC_{SN} values are expected to have better resistance to stripping as compared to those with lower LC_{SN} values. The curve fitting coefficient β in Equation G.19 represents the growth rate of rut depth after LC_{SN}. Mixtures with higher β values are likely to have faster stripping rates as compared to those with lower β values.

Mixtures that did not show a stripping phase in the HWTT were considered to have a robust resistance to stripping, with LC_{SN} values larger than the number of load cycles applied during the test (i.e., 20,000). In these instances, for comparison purposes to other mixture and specimen types, the LC_{SN} and β values were set to 20,000 cycles and 0, respectively.

As previously mentioned, it was assumed that the rut depth recorded in the creep phase of the HWTT test was solely due to the accumulation of permanent strain in the specimen under wheel loading in the presence of water. The Federal Highway Administration (FHWA) Viscoelastic System (VESYS; Kenis, 1977) permanent strain characterization employs a power law model to describe the relationship between permanent strain (ε_p) and number of load cycles:

$$\varepsilon_p = I(LC)^S \quad \text{(G.24)}$$

Where I and S are regression constants and LC represents the number of load cycles. The intercept I represents the permanent strain at $LC = 1$. The slope S represents the rate of change in $log(\varepsilon_p)$ as a function of the change in $log(LC)$.

For the HWTT test results, the permanent strain of the specimen was calculated as the ratio of the rut depth to the specimen thickness at any given number of load cycles up to LC_{SN}. A typical load cycle versus permanent strain HWTT curve including the post-compaction and creep stages is presented in Figure G.9.

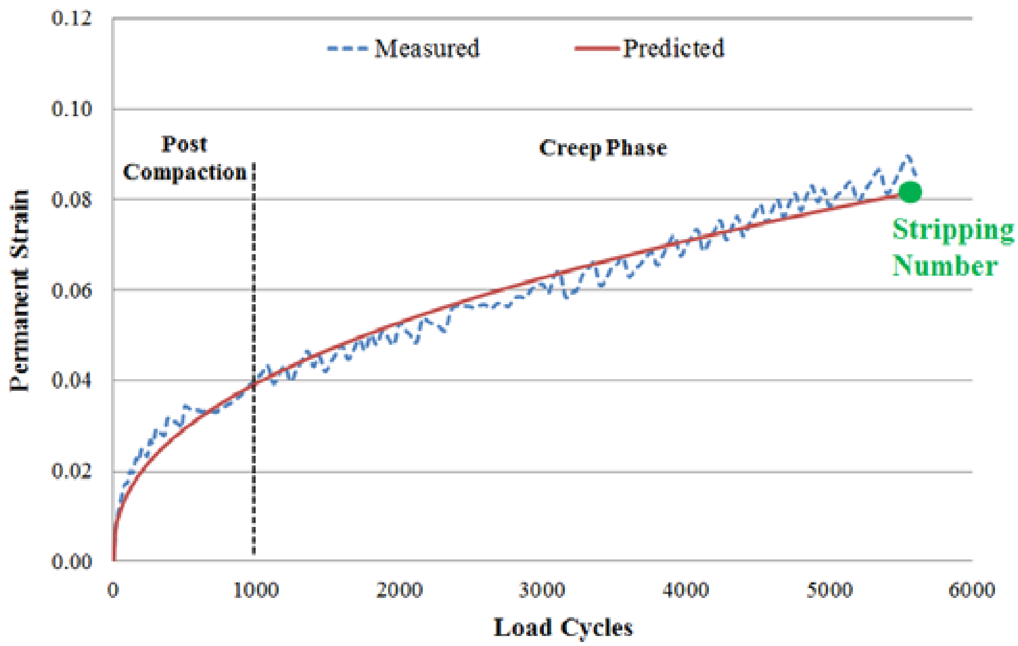


Figure G.9. Typical Permanent Strain versus Load Cycles in the HWTT Post-Compaction and Creep Phases

The permanent strain relationship can be expressed as:

$$\varepsilon_p = I(LC)^S \qquad \text{(G.25)}$$

As illustrated, the relationship between load cycles and permanent strain is not linear, due to the nonlinear viscoplastic property of the asphalt mixture. Mixtures that have higher I and lower S values are expected to have higher permanent strain and therefore higher rut depths than those with lower I and higher S values, given the same number of load cycles in the HWTT test. The permanent strain increment for each load cycle can be defined as:

$$\frac{\partial \varepsilon_p}{\partial (LC)} = IS(LC)^{S-1} \qquad \text{(G.26)}$$

As shown in Equation G.26, the permanent strain increment of the specimen for each load cycle is dependent on load cycles. This is different from the permanent strain behavior of linear viscoplastic materials, which is independent of load cycles.

To quantify the mixture resistance to rut depth under load cycles in the HWTT test, a parameter-labeled average permanent strain ($\overline{\Delta\varepsilon_p}$), was proposed. In the calculation of this parameter, it was assumed that the asphalt mixture behaved like a linear viscoplastic material, with a constant rut depth increment rate with each load cycle. Therefore, $\overline{\Delta\varepsilon_p}$ was defined as the

slope of the permanent strain versus load cycle graph of an equivalent linear viscoplastic material during the creep phase in the HWTT test, as illustrated in Figure G.10.

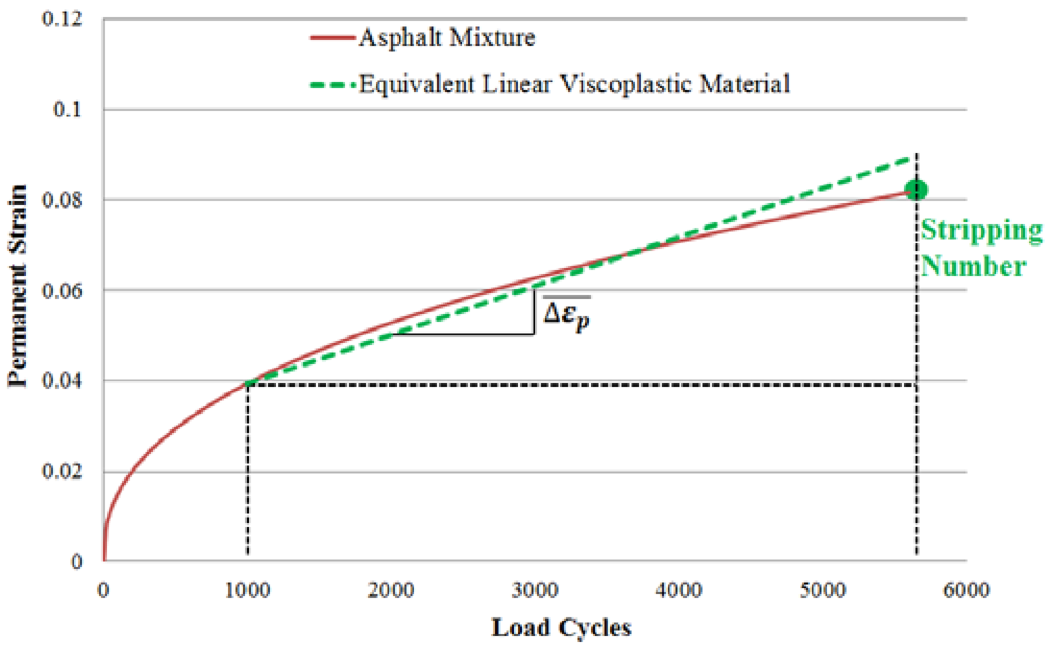


Figure G.10. Average Permanent Strain for an Equivalent Linear Viscoplastic Material

$\overline{\Delta\varepsilon_p}$ is calculated with the assumption that the shaded areas under the permanent strain versus load cycle curves for the nonlinear viscoplastic asphalt mixture and the equivalent linear viscoplastic material shown in Figure G.11 are the same.

For the asphalt mixture:

$$Permanent\ Strain_{Asphalt\ Mixture} = \int \left(\varepsilon_{p(LC)} - \varepsilon_{p(1000)}\right) d(LC)$$

$$= \int_{1000}^{LC_{SN}} [I(LC)^S - I(1000)^S] d(LC)$$

$$= \frac{I}{S+1}[(LC_{SN})^{S+1} - (1000)^{S+1}] - I(1000)^S(LC_{SN} - 1000) \qquad \text{(G.27)}$$

For the equivalent linear viscoplastic material:

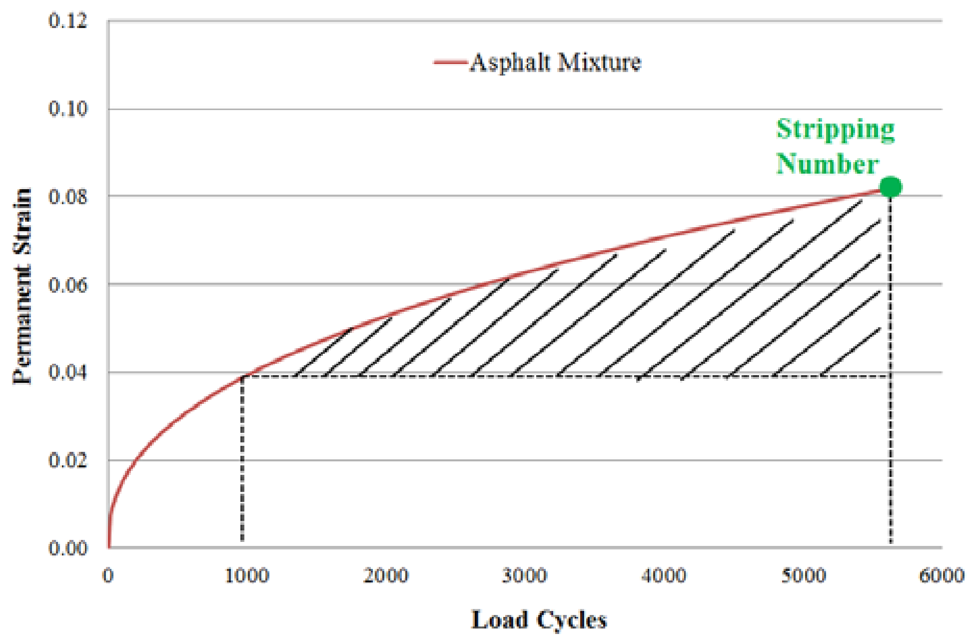
$$Permanent\ Strain_{Linear\ Viscoplastic} \int \varepsilon_p(LC) d(LC) = \int_{1000}^{LC_{SN}} \overline{\Delta\varepsilon_p} LC d(LC)$$

$$= \frac{\overline{\Delta\varepsilon_p}}{2}(LC_{SN} - 1000)^2 \qquad \text{(G.28)}$$

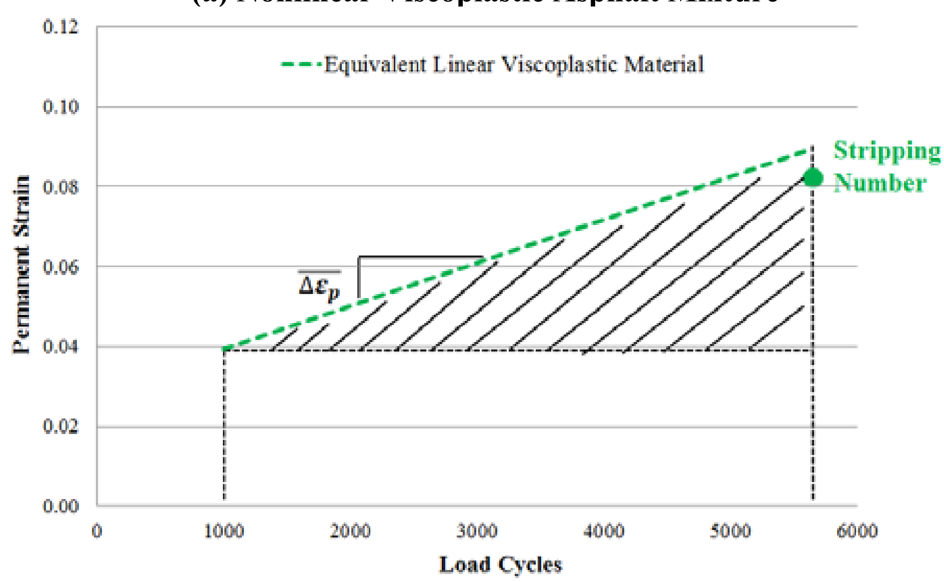
Making Equations G.27 and G.28 equal gives the following:

$$Permanent\ Strain_{Asphalt\ Mixture} = Permanent\ Strain_{Linear\ Viscoplastic}$$

$$\overline{\Delta\varepsilon_p} = \frac{2I[(LC_{SN})^{S+1} - (1000)^{S+1}]}{(S+1)(LC_{SN} - 1000)^2} - \frac{2I(1000)^S}{LC_{SN} - 1000} \qquad \text{(G.29)}$$



(a) Nonlinear Viscoplastic Asphalt Mixture



(b) Equivalent Linear Viscoplastic Material

Figure G.11. Area Under the Permanent Strain versus Load Cycles Curve

The parameter $\overline{\Delta\varepsilon_p}$ represents the average permanent strain increment experienced by the asphalt mixture with each load cycle in the HWTT test. Asphalt mixtures with higher $\overline{\Delta\varepsilon_p}$ values are expected to be more susceptible to rutting than those with lower $\overline{\Delta\varepsilon_p}$ values before the start of the stripping phase.

Besides $\overline{\Delta\varepsilon_p}$, there is a need to have an additional measure, derived directly from the data, that represents the resistance of the mixture to stripping beyond the SN. This is accomplished by defining remaining life (LC_R) as follows:

$$Remaining\ Life = LC_{ult} - LC_{SN} \tag{G.30}$$

LC_R is the number of load cycles between the SN and the end of the test, as illustrated in Figure G.12.

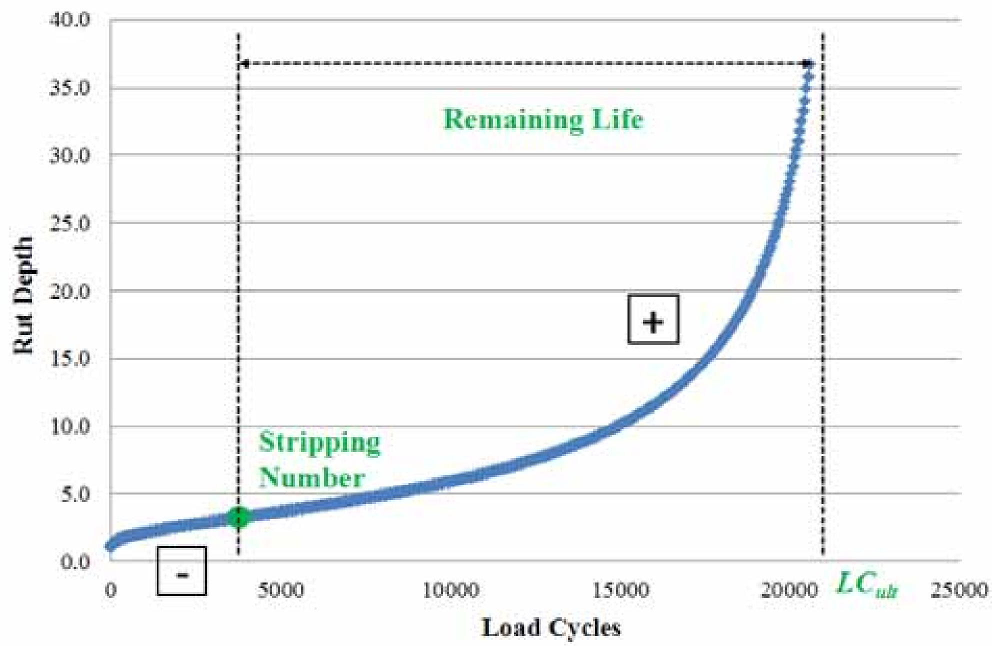


Figure G.12. HWTT Remaining Life Definition

Both test parameters, LC_{SN} and LC_R, are proposed to evaluate the mixture resistance to rutting prior to stripping and the resistance to stripping beyond the SN, respectively. LC_{SN} is meant to complement $\overline{\Delta\varepsilon_p}$ and an additional parameter to evaluate the mixture resistance to rutting in the presence of warm water before stripping. Compared to the SIP, which is one of the most commonly used HWTT output test parameters to assess stripping, LC_{SN}, LC_R, and $\overline{\Delta\varepsilon_p}$ are calculated from the HWTT test results using nonlinear regression and avoiding subjective data interpretation when fitting the curves to the creep and stripping phases (as opposed to what is done when estimating the SIP). Moreover, as will be shown in Section G.5, these three measures are able to discriminate between mixtures with different resistance to stripping and rutting in the HWTT test.

One downside of the proposed parameters is that the SN is calculated using an exponential fitting curve, while $\overline{\Delta\varepsilon_p}$ is obtained using a power law fitting curve. To contrast the results of the power law fitting curve used in the rutting phase versus the exponential fitting curve used to represent the entire rut depth vs. load cycles curve, the slope of both fitted curves at the SN was compared. The comparison was based on the magnitude of the slope as well as the resulting ranking of the mixtures. The equation slope of the power law fitting curve at the SN is given in Equation G.26. The slope of the exponential fitting curve at the SN is given in Equations G.31 and G.32.

$$RD = \rho * \left[\ln\left(\frac{LC_{ult}}{LC}\right)\right]^{-\frac{1}{\beta}} \tag{G.31}$$

$$\frac{\partial RD}{\partial LC}_{SN} = \frac{\rho}{\beta * LC_{SN}} * \left[\ln(\frac{LC_{ult}}{LC_{SN}})\right]^{-(\frac{1}{\beta}+1)} \quad \text{(G.32)}$$

Finally, an additional parameter was developed to combine several test results into a single value and achieve a more comprehensive comparison of the performance of the different mixture and specimen types. This parameter is based on the theory of crack growth in viscoelastic media by R. A. Schapery (1975, 1978, and 1984). In the development of the theory, Schapery showed that the coefficients in the Paris' fracture law (Paris et al., 1963, 1965) could be determined with the results of simpler and more fundamental tests. Paris' law is described by the following equation:

$$\frac{\partial c}{\partial N} = A(\Delta K)^n \quad \text{(G.33)}$$

Where,

A → fracture coefficient.
n → fracture exponent.
ΔK → change of stress intensity factor during loading and unloading.
c → crack size.
N → number of load repetitions.

Schapery demonstrated that the A coefficient could be computed using the following expression:

$$A \propto \left(\frac{\pi^{2m+1}}{\Delta G * E_r}\right)^{\frac{1}{m}} * \frac{1}{{\sigma_t}^2 * I} \quad \text{(G.34)}$$

$$\Delta G = \frac{{\sigma_t}^2 * (\%air)^{\frac{1}{2}}}{(N+1) * E_r} \quad \text{(G.35)}$$

$$I = \frac{2}{N+1} \quad \text{(G.36)}$$

Where,

ΔG → bond energy.
E_r → relaxation modulus coefficient.
σ_t → tensile strength of the material being fractured.
m → slope of the log (creep) versus log (time) curve, comparable to the slope, S, in the power form curve shown above in Equation G.25.
N → brittle-ductile number used above in formulating the monotonic loading performance number.

Taking the logarithm of the A coefficient expression provides a repeated loading performance number that combines the results of the HWTT and the IDT tests. The logarithm of A has been used in previous studies and has been reported in the technical literature (e.g., Cleveland et al., 2003) as a crack speed index. The number is always negative; the more negative it is, the slower the crack will grow. The best mixture as indicated by this crack speed index (CSI) is the one with the larger negative number. The equation for the CSI is as follows:

$$\log A \propto -\frac{1}{2S}\log(\%air) + \left(\frac{1}{S}+1\right)\log(N+1) + \left(\frac{1}{S}+2\right)\log(\pi) - (\frac{2}{S}+2)\log(\sigma_t) \tag{G.37}$$

In Equation G.37, the wet IDT test results provide the tensile strength (σ_t) and the brittle-ductile (*N*) values, while the HWTT test results provide the air void content ($\%air$) and the slope value (*S*). It is reasonable to expect that slower crack speeds correspond to longer remaining lives. However, in this repeated loading performance parameter, the magnitude of the CSI is dominated by the magnitude of the IDT strength. Therefore, although it is generally true that lower CSI values correspond to a larger LC_R, the two performance parameters do not rank the mixtures with the same conditioning in the same way. This observation will be illustrated in Section G.5, where all of these performance parameters are presented graphically.

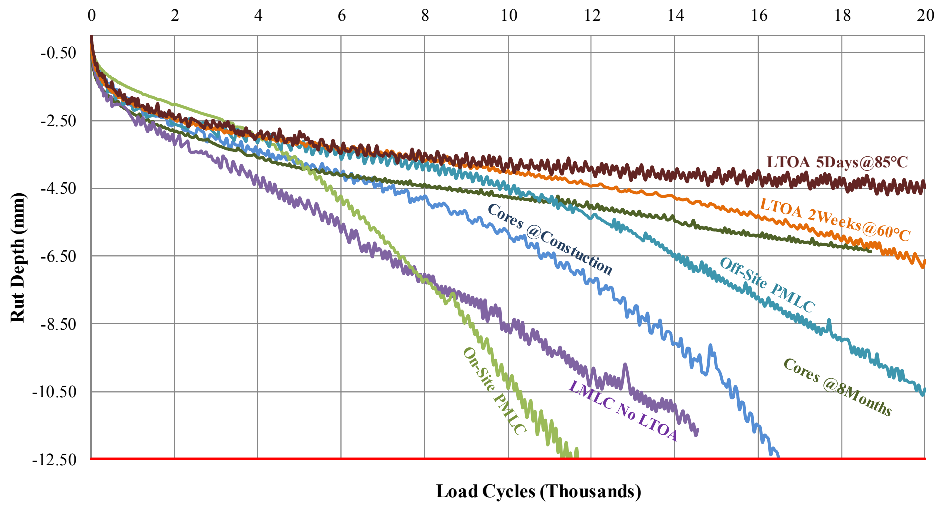
RESULTS FROM REPEATED LOADING: TEXAS FIELD PROJECT

HWTT test results of several Texas mixtures were analyzed in this project with the proposed repeated loading criteria. The protocols for short-term oven aging (STOA) of the loose mix prior to compaction and long-term oven aging (LTOA) of the compacted specimens prior to testing are summarized in Table G.5. The plots of rut depth versus load cycles are illustrated in Figure G.13 for each mixture type included in the analysis.

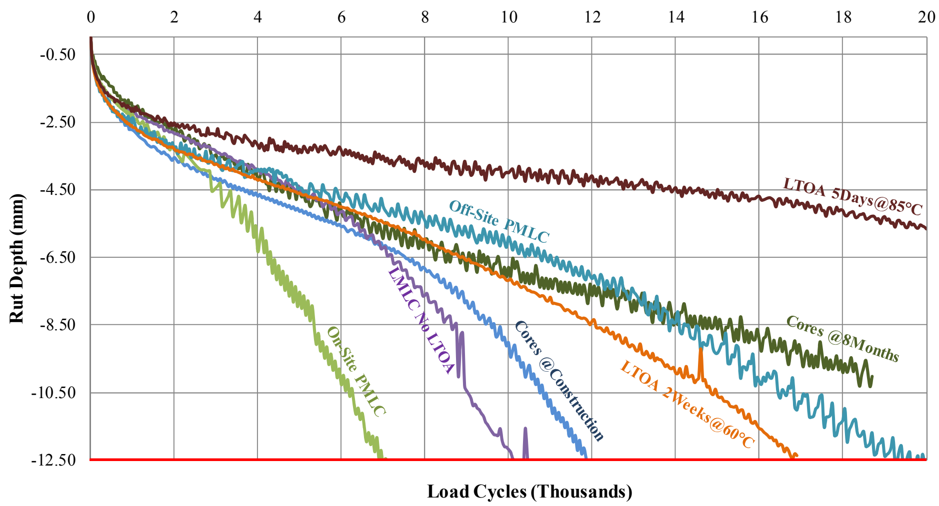
Table G.5. STOA and LTOA Protocols by Specimen Type for the Texas Field Project

Specimen Type	STOA Protocol	LTOA Protocol
Cores at Construction	No Field Aging	
Cores after Summer at 8 Months	Summer Field Aging	
On-Site PMLC	1-2 h at T_c	
Off-Site PMLC	Reheat to T_c	
LMLC	2 h at 275°F (HMA) 2 h at 240°F (WMA)	2 Weeks at 140°F 5 Days at 185°F

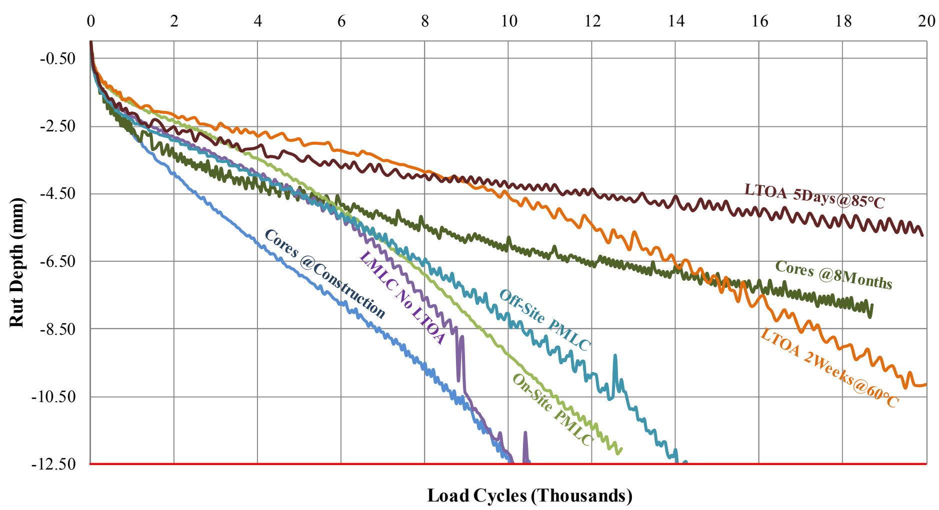
The resulting performance parameters of LC_{SN} and LC_R for Texas mixtures are summarized in Figure G.14 and Figure G.15, respectively. As illustrated in Figure G.14, plant-mixed, field-compacted (PMFC) cores after summer at 8 months in service had significantly higher LC_{SN} values than those at construction, which indicated that PMFC cores after summer at 8 months in service had better resistance to stripping. Similar and relatively low LC_{SN} values were obtained for WMA PMFC cores at construction and LMLC specimens without LTOA. Therefore, the WMA mixtures could be considered susceptible to stripping in their early life. WMA off-site PMLC specimens had larger LC_{SN} values than their corresponding on-site PMLC specimens did, which is likely due to the additional reheating of the loose mixture prior to compaction. The comparison between LMLC specimens without LTOA to those with LTOA protocols indicated the significant effect of aging on improved resistance to stripping, as revealed by the higher LC_{SN} values obtained by the latter. Additionally, WMA PMFC cores after summer at 8 months in service had significantly higher LC_{SN} values, and thus better resistance to stripping, than LMLC specimens with LTOA protocol of 5 days at 185°F (85°C), while the opposite trend was for shown for HMA.



(a) HMA



(b) Evotherm DAT™



(c) Foaming

Figure G.13. HWTT Test Results by Mixture Type for the Texas Field Project

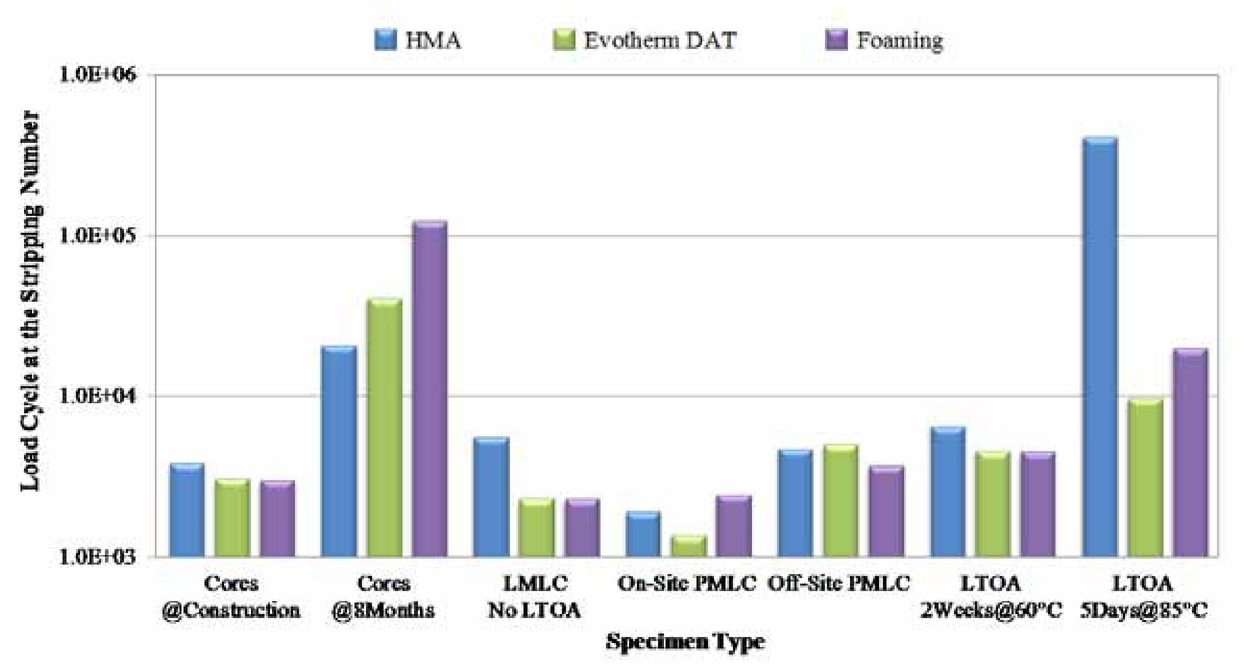


Figure G.14. Load Cycles at the SN Parameter (LC_{SN}) for the Texas Field Project (log scale)

As illustrated in Figure G.15, PMFC cores after summer at 8 months in service had a significantly higher LC_R than those at construction, which indicated that PMFC cores after summer at 8 months in service had better performance after stripping in the HWTT test. Similar LC_R values were shown for WMA PMFC cores at construction, LMLC specimens without LTOA, on-site PMLC specimens, and off-site PMLC specimens. Specifically, these values were relatively low, and therefore the performance of WMA pavements in their early life may deteriorate at a significant higher rate after stripping occurs in the mixture. The comparison between LMLC specimens without LTOA and those with LTOA protocols indicated that the mixture performance after stripping improved with an LTOA of 5 days at 185°F (85°C; no improved performance was observed with an LTOA of 2 weeks at 140°F [60°C]). Additionally, WMA PMFC cores after summer at 8 months in service had significantly higher LC_R values, and thus better performance after stripping occurred than with LMLC specimens with an LTOA of 5 days at 185°F (85°C), while the opposite trend was observed in the case of HMA.

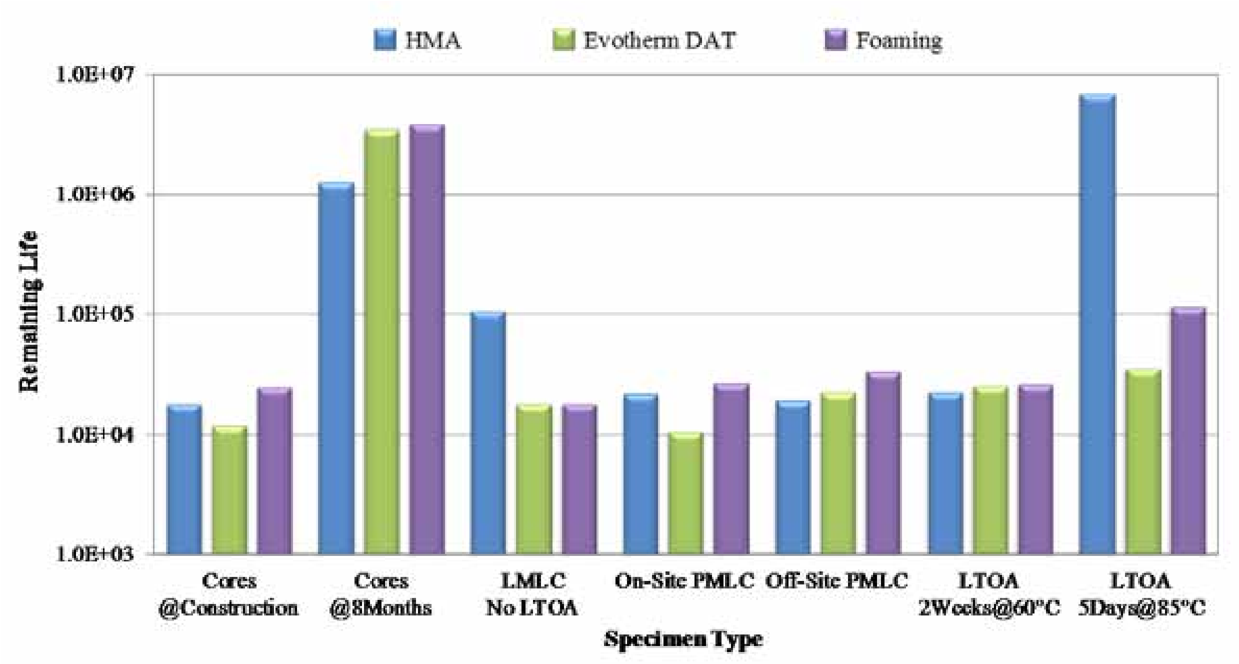


Figure G.15. Remaining Life Parameter (LC_R) for the Texas Field Project (log scale)

Figure G.16 summarizes the rutting susceptibility parameter, $\overline{\Delta\varepsilon_p}$, for the Texas mixtures. As illustrated, WMA PMFC cores after summer at 8 months in service had lower $\overline{\Delta\varepsilon_p}$ values than those at construction, indicating better resistance to rutting in the HWTT test. The comparison between LMLC specimens with and without LTOA showed that the mixtures with LTOA had lower $\overline{\Delta\varepsilon_p}$ values, and thus better resistance to rutting in the presence of warm water, than those with no LTOA. The correlation between field and laboratory LTOA revealed that the increase in mixture rutting resistance from LTOA protocols was more significant than or equivalent to that from field aging after a summer, except for WMA Evotherm DAT™ with an LTOA of 2 weeks at 140°F (60°C).

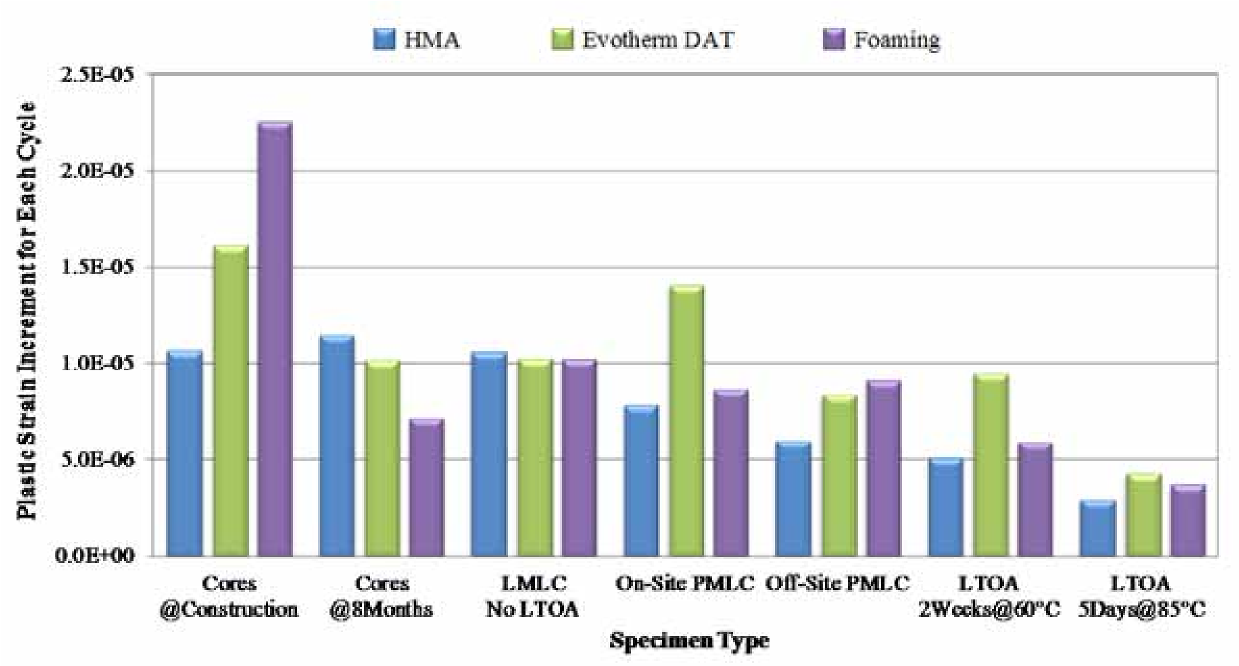


Figure G.16. Average Permanent Strain Parameter ($\overline{\Delta\varepsilon_p}$) for the Texas Field Project

Figure G.17 illustrates the slope of the rut depth versus load cycle curve at the SN calculated using the three-parameter MEPDG model given in Equations G.31 and G.32. The raking of the slopes (not the magnitudes) in this figure should be compared with the ranking of the slopes in Figure G.18, which correspond to the slope of the load cycles versus permanent strain curve at the SN using the VESYS power form shown in Equations G.25 and G.26. The ranking of the slopes and not the magnitudes are compared because the results in Figure G.17 correspond to rut depths, while the results presented in Figure G.18 correspond to permanent strains. The rut depths in Figure G.17 could be converted into permanent strain by dividing each HWTT displacement by the thickness of the sample being tested. However, the thickness of the specimens was not recorded, and therefore no direct comparison was available for this set of data. In the future, each HWTT sample thickness should be measured to be able to compare magnitudes directly.

The HWTT samples are usually around 50 mm. If this approximate value is used to multiply the vertical scale of Figure G.17 by $2 \times 10E^{-2}$, it is possible to make an approximate comparison between the scales of the two graphs. When contrasting the relative magnitude of the slopes and the ranking of the mixtures, it is clear that the two graphs yield the same conclusions. A lower slope generally means less permanent strain prior to stripping and a longer LC_R beyond the SN. The ranking of each of the mixtures within each compaction and conditioning group are consistent between both of the figures. In fact, the same ranking is also observed when compared to the $\Delta\varepsilon_p$ parameter presented in Figure G.16.

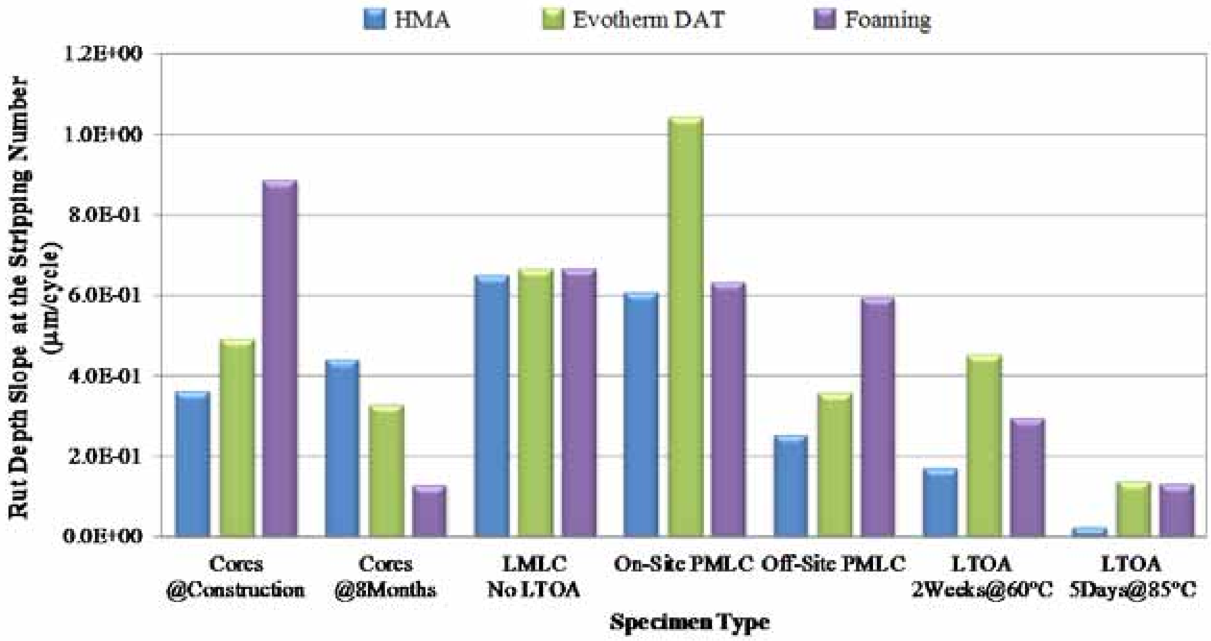


Figure G.17. Rut Depth Slope at the SN Based on the Three-Parameter MEPDG Model

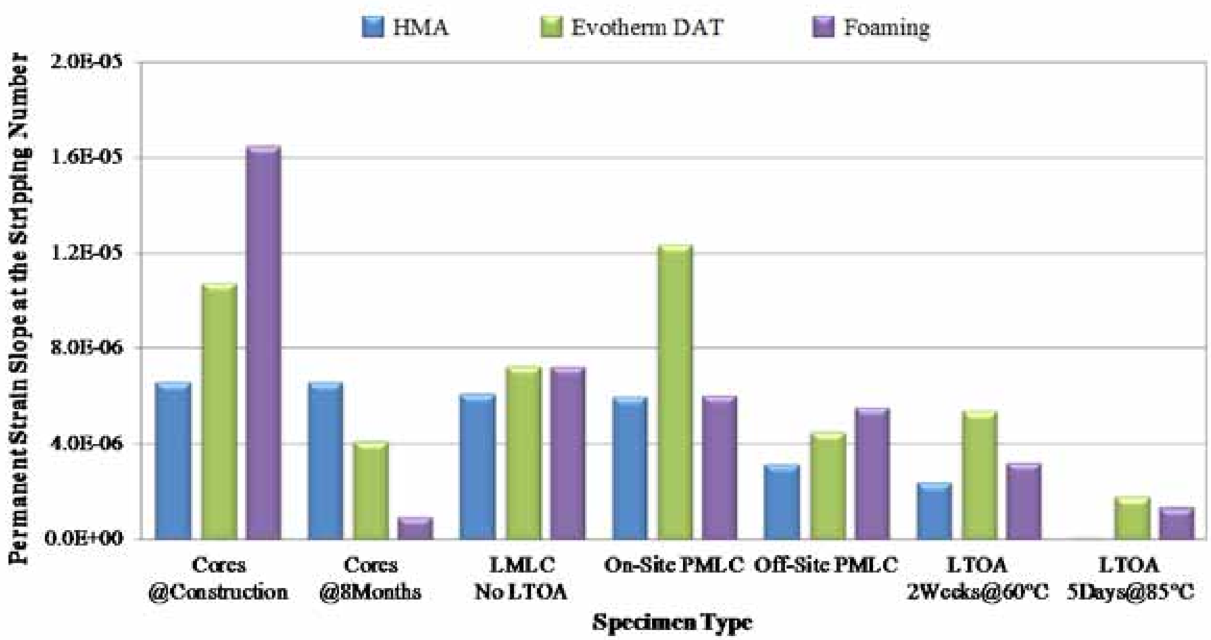


Figure G.18. Permanent Strain Slope at the SN Based on the FHWA-VESYS Power Model

The CSI results are illustrated in Figure G.19. As calculated using Equation G.37, the value is negative, but in Figure G.19, the absolute value of CSI is presented. Therefore, the larger the value of CSI, the slower the crack speed, and thus the better the expected performance. In all of the previous graphs, the on-site PMLC and the LTOA samples that were held for 5 days at 185˚F (85˚C) were generally comparable. However, the CSI results show closer values for the LMLC and the on-site PMLC specimens. In addition, the two LTOA protocols indicate

comparability. Neither of these two observations seems reasonable in view of the rankings of the other performance parameters shown before. The discrepancy is likely due to the dominant effect of the wet IDT strength on the CSI calculation.

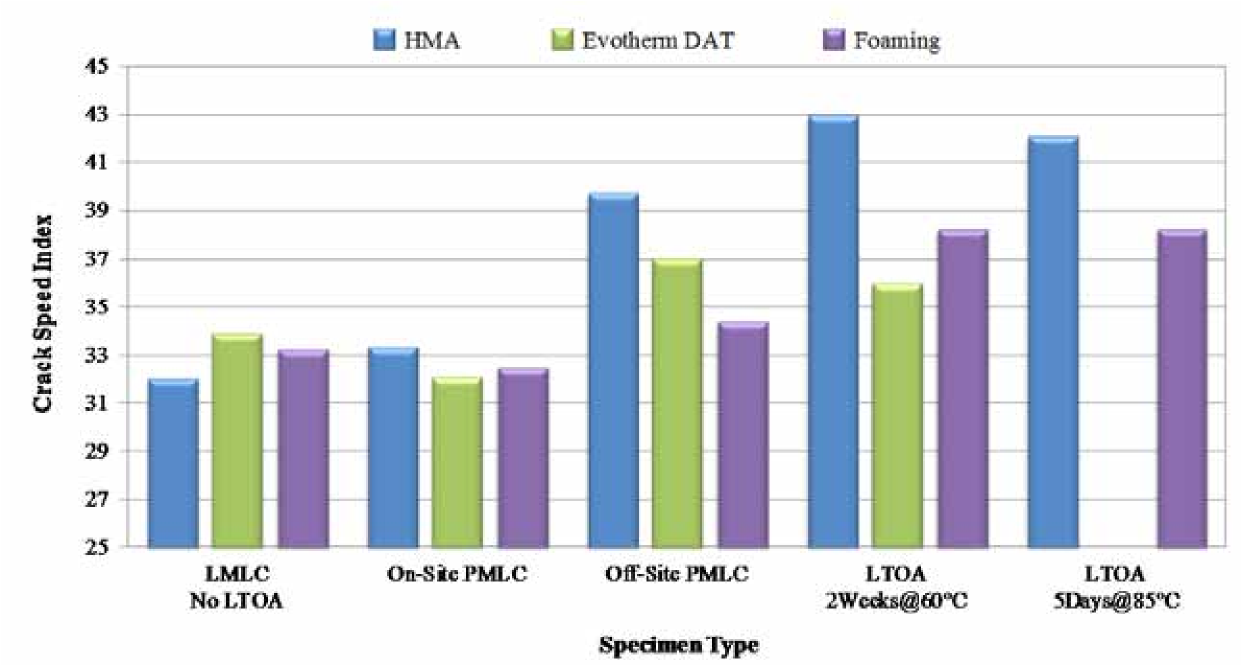


Figure G.19. Crack Speed Index (CSI) Parameter for the Texas Field Project

The measured bond strength (instead of the inferred bond strength from the IDT strength and M_R tests) could be the missing key piece that restores comparability between the mixture rankings resulting from the CSI and the other performance parameters. An improved CSI would include a measured bond energy, M_R, and IDT strength all under wet conditions or perhaps a direct measurement of the Paris' law *A* coefficient under wet conditions and repeated loading by a simple and rapid process that is now available. Two different and simple methods for getting an independent measure of the bond energy are recommended in the next section on recommended future investigations.

RECOMMENDED FUTURE INVESTIGATIONS

In reviewing the results of the proposed performance parameters for both the monotonic and repeated loading test results, several observations have become clear. The first of these is that when stripping initiates in a mixture, it is a fracture phenomenon: water fracturing the bond between the asphalt and the aggregate. This is what has made the single performance parameters provide such consistent comparisons among the mixtures with different compaction, exposure, and conditioning. The implications of this are that measuring the missing material properties will provide even more reliable means of comparing mixtures and even of setting target criteria and specifications for the mixtures to meet regardless of the type of WMA additives and modifiers, the addition of reclaimed asphalt pavement (RAP) or recycled asphalt shingles (RAS), and even the provision of anti-stripping additives that are used in the mixtures.

The improvement of these parameters will be particularly useful and practical in providing criteria for radically different types of mixtures that have various aggregate sizes and

gradations, geologic origins, mineralogical compositions, and dissimilar surface energies than those that have been studied in this project. The principal purpose of improving the criteria that have been proposed here is to be better able to anticipate the eventual performance of these mixtures as they are affected by conditions of exposure to traffic, aging, and moisture.

Observations from the Tests Made in This Project

The AV density and true bond energy are two important measurements used in the calculations that can improve the ability of the proposed monotonic loading and repeated loading performance parameters to provide objective comparisons between mixtures.

As has been discussed above, the AV density (m/A) does not need to be measured for each sample, although there is a simple test method that will permit this to be done without the use of X-Ray computed tomography (CT). The method uses the material test system (MTS) machine or any similar loading apparatus in which a controlled cyclic axial strain test is run. This repeated load direct tension (RDT) test can be completed in a matter of 10 min, and the AV density can be subsequently determined with existing data reduction software (Luo and Lytton, 2011). As an alternative, a characteristic AV density should be determined only for different types of mixtures that use dissimilar gradations and aggregate sizes. Including the characteristic AV density of a mixture will improve the consistency of comparisons between mixtures of both the bond energy (ΔG) monotonic loading criterion and the CSI repeated loading criterion.

The consistency of ranking of the mixtures under different compaction, exposure, and conditioning states shows that the SN, the LC_R, and the monotonic loading ΔG can be used to determine the laboratory aging conditions that are comparable with months of aging in the field. In its present form, the repeated loading CSI needs to be modified in order to be as good an indicator. It is important to have such a repeated loading performance parameter that is a combination of the results of several different but relevant tests because it includes in a single number an overall summary evaluation of the results of all of the testing that is performed on a given mixture. In its present form, it reflects a dominating influence of the IDT wet strength and hardly any of the repeated loading test results. Suggestions for useful modifications to the CSI are made subsequently in this section of this appendix.

The modulus that was used in calculating the monotonic loading ΔG was the M_R that was measured in both wet and dry indirect tension. In order to have a bond energy parameter that is more consistent with the actual moisture condition of the mixture in the field, it is better to measure the modulus in tension after moisture conditioning. Thus, the modulus that is measured in the IDT test in the wet condition is a better value to use in calculating the monotonic loading ΔG. This wet M_R test could also be performed on field cores prior to their being tested in the HWTT.

In reviewing the results of the HWTT, it became apparent that all of the data that were used in evaluating the performance of the HWTT were obtained from the first portions of the curves, both the FHWA-VESYS and the MEPDG forms, prior to reaching the SN. This means that the HWTT does not need to be run to 20,000 load cycles but instead can be terminated when reaching the load cycles at the SN. Most mixtures used in this project required less than 5,000 load cycles to reach SN. Even those tests where the LC_{SN} never reached 20,000 load cycles were fitted with the coefficients that were needed to infer the SN. Therefore, by using the analysis methods that have been demonstrated here, the length of time that is required for the HWTT can be greatly reduced without loss of the information that it is presently capable of providing.

In addition to improvements in the proposed performance parameters and additional measurements, there is a need to find a comparable moisture aging condition when testing. The data that were available in this project were either dry or vacuum saturated moisture conditioned in the laboratory and uncontrolled in the cores taken in the field. Recent investigation into the moisture state in the asphalt surface layers in a variety of climates has demonstrated that the relative humidity in the asphalt layer reaches levels above 95 percent within 6 months of the laydown operation (Tong et al., 2011). This means that in order to simulate the actual moisture conditions in the field, both field and laboratory-compacted samples should be exposed to a high level of relative humidity as near to 100 percent as possible prior to testing. There is no need to have an elaborate relative humidity chamber in which to moisture condition the samples. Instead, a 55 gallon drum or a plastic equivalent that can be closed and has distilled water in the bottom will serve the purpose very well. The conditioning drum needs to be kept in steady temperature conditions in order to reach the desired level of relative humidity in the shortest possible time. Samples can be weighed periodically to find when they have reached a stable weight to start testing. As an alternative, the samples can be moisture conditioned with steam, which will introduce water vapor into the mixture at a higher temperature and will accelerate the rate at which the sample reaches a stable wet moisture condition. Using water vapor either at room temperature or as steam has the added advantage of not building up liquid pore water pressure in the AV in the mix as do all methods that use liquid water.

Suggested Investigations from Current Research

Testing methods and material properties that could have contributed to a more in-depth scrutiny of the different HMA and WMA treatments are suggested in this section. The present evaluations would have been improved if the AV density, m/A; the actual bond energy, ΔG; the actual Paris' law fracture coefficient, A, and exponent, n; and the healing properties of both HMA and WMA had been measured and compared with those same properties of cores taken from the field after different periods of time, exposure, and conditioning. The ability to measure the fracture and healing characteristics of an asphalt mixture provides more information on the response of the material to repeated loading, an area that is currently represented only by the HWTT. In addition, the tests that were conducted in this project were aimed at measuring resistance to damage (rutting and cracking) and did not evaluate the ability of the material to heal between load applications. Healing is an important factor in estimating the life of a pavement, as is the resistance to fracture, neither of which was evaluated in the accelerated loading test methods used in this project. Finally, in view of the importance being attached to the design and construction of perpetual pavements, it is desirable to determine the endurance limit of each of these mixes but in a way that is both accurate and rapid.

In making suggestions of tests and material properties that would improve the ability to devise performance parameters that are consistent and reliable indexes of mixture performance, it is desirable to use those tests that can be performed on equipment that is readily available and tests that can be completed in an amount of time that is no longer than that which is required by the HWTT. If more complicated or time-consuming tests are needed, they should be performed to determine the overall characteristics for a broad type of mixture, such as the characteristic AV density, m/A. However, there is an alternative to the X-Ray CT test to get the initial AV density, and that is the RDT test, which is described below. There are other reasons for suggesting the same RDT test as well.

Bond Energy Measurements

There are two methods for measuring the bond energy. One of these is by measuring the surface energies of the aggregate and binder separately and then calculating the bond energy. The second method is to measure it directly using the RDT test. The second method has the advantage of determining the bond energy of a mixture after it has been conditioned by heat or moisture. Having a separate measurement of the bond energy will allow the monotonic loading performance parameter, ΔG, to be a dimensionless number similar to the dimensionless numbers that revolutionized the discipline of pipe flow. This dimensionless number will include the results of three tests: IDT, RDT, and M_R, all of which have been conditioned in the same way. The graph in Figure G.20 shows calculated dry bond energies using the surface energies of two aggregates and one asphalt binder with a variety of WMA additives. The asphalt binder has two performance grades (PGs), 64-22 and 76-22. The two aggregates are limestone and river gravel.

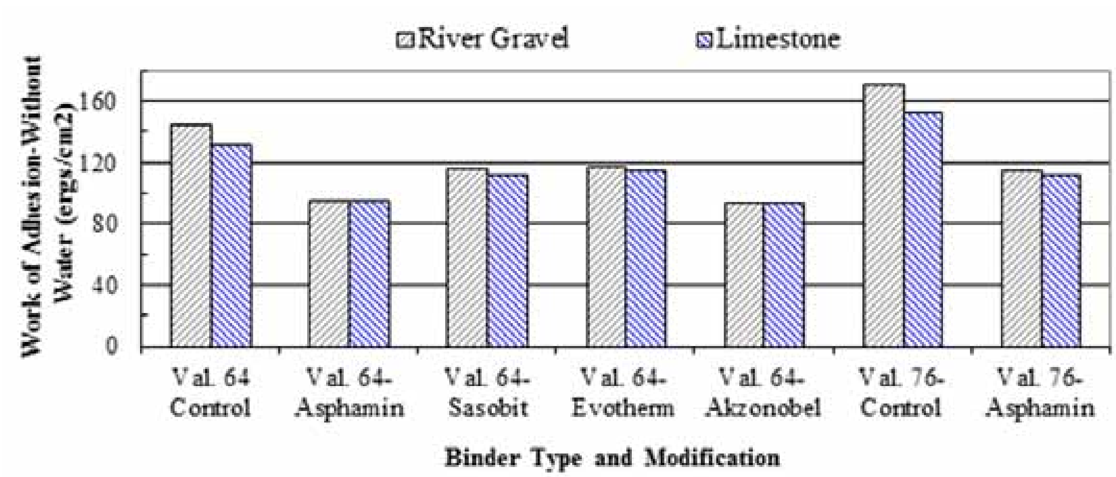


Figure G.20. Calculated Dry Bond Energies for Mixtures with Different Types of Asphalt Binder, Aggregates, and WMA Additives (Tong et al., 2011)

Figure G.20 demonstrates that the PG grade of the binder and choice of aggregate will have an effect on the bond energy, which is shown in this figure as the work of adhesion. Not shown here are the calculated bond energies for specific levels of relative humidity. The general rule is that as the relative humidity increases, the bond energy decreases. The rate of decrease differs from one aggregate-binder combination to another. Bond energy also decreases with aging, and the rate of decrease depends upon the aggregate-binder combination as well.

The direct measurement of the bond energy can be made with the RDT test and using the stress-strain state at the endurance limit. The reason for this is explained in a subsequent section that is focused on the RDT test. For the present purposes, it is sufficient to note that the bond energy can be measured in this test in approximately 10 min, regardless of the conditioning that has been applied to the sample.

Table G.6 gives the results of the RDT test performed on mixtures with two different binders, two different AVs, and two different levels of laboratory aging as part of an ongoing research study sponsored by the Asphalt Research Consortium (ARC). The data presented in the table shows for each mixture the strain level at the endurance limit and the corresponding dissipated pseudo strain energy, plus the measured bond energy and the recoverable pseudo

strain energy, both at the endurance limit. The bond energy measured from the RDT test and the bond energy calculated from surface free energies measured separately on the binder in unaged and aged conditions with the Wilhelmy Plate (WP) apparatus are listed.

Table G.6. Validation of Crack Growth Criterion for Different Asphalt Mixtures

Mixture Condition	Endurance Limit (με)	Measured WP Bond Energy (ergs/cm^2)	Average of Measured RDT Bond Energy (ergs/cm^2)	Measured RDT Bond Energy (ergs/cm^2)	Left Side of Crack Growth Criterion	Right Side of Crack Growth Criterion
NuStar, 0, 4%[a]	53	87.0	81.1	70.4	6.95 x 10^{-2}	8.61 x 10^{-2}
NuStar, 0, 7%	49			91.8	9.22 x 10^{-2}	8.72 x 10^{-2}
NuStar, 6, 4%	45	75.8	76.1	66.6	7.20 x 10^{-2}	8.11 x 10^{-2}
NuStar, 6, 7%	51			85.6	8.80 x 10^{-2}	7.81 x 10^{-2}
Valero, 0, 4%	50	107.0	107.2	110.8	1.13 x 10^{-1}	1.09 x 10^{-1}
Valero, 0, 7%	53			103.6	1.08 x 10^{-1}	1.12 x 10^{-1}
Valero, 6, 4%	44	93.2	91.9	88.8	9.25 x 10^{-2}	9.69 x 10^{-2}
Valero, 6, 7%	40			95.0	1.02 x 10^{-1}	1.00E x 10^{-1}

[a] NuStar represents the type of asphalt binder, 0 represents the time of aging, 4% represents the AV content.

The first thing to notice about the numbers presented in the table is that they are in the same range of magnitude as the work of adhesion previously shown in Figure G.20. The second thing to notice is that the bond energies in Table G.6 are in the same range as the dry bond energies that are illustrated in Figure G.4(a) and Figure G.5(a) as the monotonic loading performance parameter. These bond energy values were calculated from entirely different tests, including the IDT test and the M_R test. The third thing to notice is that the bond energies that were measured in the RDT test appear to be more variable than the others. There is a good reason for this: the RDT test was performed in the MTS machine, which is normally used in tests requiring much higher load levels and is difficult to control at the low levels of strain that are characteristic of the endurance limit. In fact, the strain increments that had to be used in the MTS machine to locate the endurance limit were 10 με. This suggests that a smaller and less expensive loading apparatus that is capable of more precision at lower levels of strain and displacement will be capable of more repeatable results. The fourth thing to notice is that the bond energy measured in the RDT test is lower in the aged mixture than in the unaged mixture. This expected pattern is also seen in the bond energies from the WP measurements. The possibility of making direct measurements of bond energies in mixtures suggests that the bond energies after moisture conditioning can also be measured in this way.

Repeated Direct Tension Test

In view of the potential usefulness of the RDT test to future investigations of the properties of mixtures, the following is a summary of the information that can be gained from this test.

The RDT test is a constant strain test that is made at two different strain levels: undamaged and damaged. The tests that are made in the undamaged strain level provide the

benchmark undamaged properties of the mixture. The tests that are made in the damaged strain levels determine the amount of damage, that is, the departure from the undamaged condition that has been done with repeated loads.

The stress-strain curve at the lower strain levels is shown in Figure G.21.

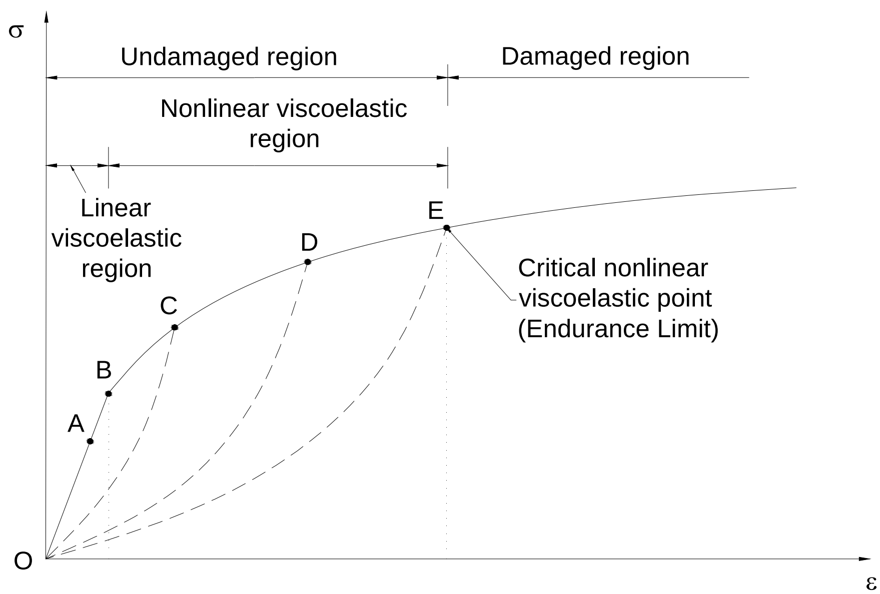


Figure G.21. Typical Stress-Strain Curve for Asphalt Mixtures

As the strain level increases, the material passes through the linear viscoelastic phase, then the nonlinear viscoelastic phase, and then into the damaged phase. The difference between the linear and nonlinear phases is that in the linear phase, all energy that is put into the mixture is recovered, whereas in the nonlinear phase, there is a loss or dissipation of energy. Beyond the endurance limit, the material properties of the mixture begin to change: the apparent modulus decreases and the apparent phase angle increases. If the state of the stress and strain in the mixture is exactly at the endurance limit, cracks are not growing but energy is being dissipated and most of the energy is recovered. The energy balance at the endurance limit allows the bond energy to be measured directly; at this unique point, the following principle applies:

Recoverable Dissipated Pseudo Strain Energy = Bond Energy + Plastic Dissipated Pseudo Strain Energy

Both pseudo strain energy components can be measured directly, and the difference is the measured bond energy. Pseudo strain energy is the total energy input to the mixture minus the energy that is used in overcoming viscous resistance. Viscous resistance is measured in the linear viscoelastic phase. Once the mixture enters into the damaged phase, cracks begin to grow and the dissipated pseudo strain energy has two components, both of which grow with repeated load cycles: the plastic component and that due to crack growth. When the cracks begin to grow, a careful accounting of the dissipated pseudo strain energy within each load cycle permits the determination of the number of cracks and their mean size. A typical result of this is illustrated in Figure G.22. As the damaging number of load cycles increases, there is initially an increase of the number of cracks followed by a monotonic decrease. As the number of load cycles increases,

the larger cracks become larger by coalescing with the smaller cracks and their number decreases.

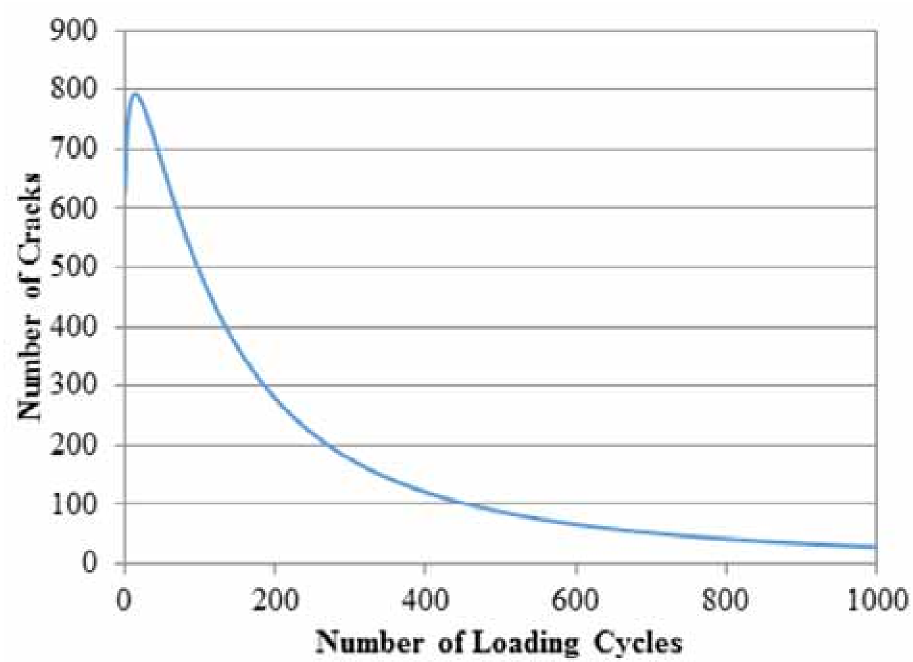


Figure G.22. Typical Number of Cracks versus Number of Loading Cycles Behavior

The initial number of cracks is the initial number of AVs in the specimen cross section. Thus, the RDT test can provide the initial AV density that was missing from both the monotonic and repeated loading performance parameters. This initial number of AVs has been compared with the number of detectable AVs that can be determined with X-Ray CT and found to be greater (Luo and Lytton, 2011). The mean air void size determined by this method is smaller than the resolution limit of the X-Ray CT equipment.

As the cracks continue to grow and to coalesce, a unique relationship develops between the total area of the cracks and the number of load cycles. A power law equation is fitted to this set of data, and the coefficients have been shown to be mathematically related to the Paris' law coefficient, A, and the exponent, n. Recalling that the logarithm of A is the CSI, it is possible by using the RDT test to measure this index directly. It is found that there is a linear relation between the log A and the exponent, n, the slope of which changes with the age of the mixture. A typical graph of the relationship that is generated with the RDT test is shown in Figure G.23.

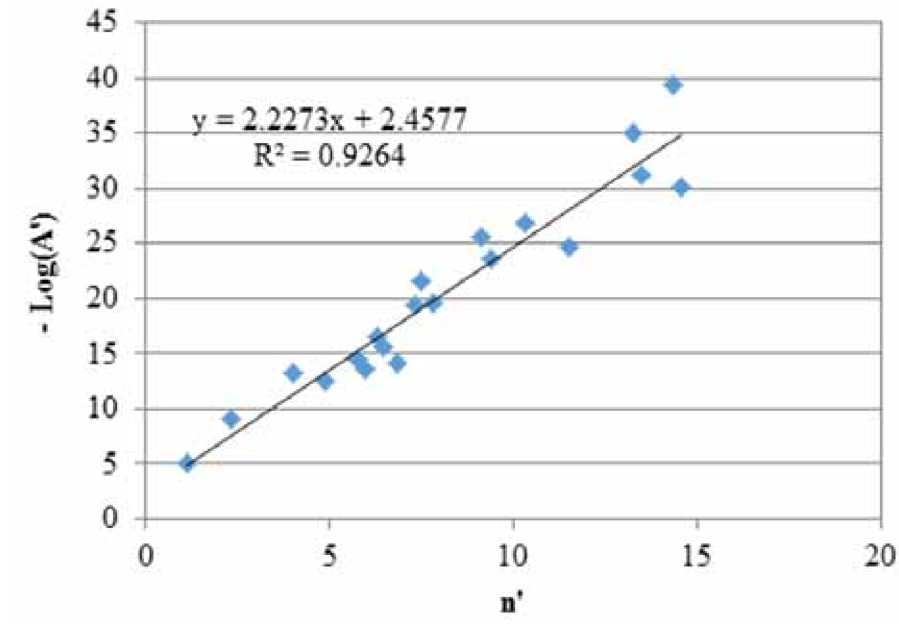


Figure G.23. Typical Relationship between *A′* and *n′*

The scatter around the fitted line is due to the fact that mixtures with several ages are plotted on the same graph. The CSI (i.e., log *A*) of these mixtures varies between -5 and -40. This range is greater than the range between -31 and -43 that was determined with the proposed hybrid CSI (see Figure G.19). Although the tests were not on the same mixtures or binders, the proposed narrower and slower (more negative) range of the hybrid CSI suggests that the hybrid index is not as sensitive to actual crack growth rates as in an actual measurement of crack growth, as in the RDT test.

The performance of a mixture depends not only on its resistance to the principal forms of distress but also, in the instance of fatigue cracking, in its ability to heal. There are two phases in the healing process: crack closure and the interdiffusion of binder molecules across the former crack surface (Wool and O'Connor, 1981; Schapery, 1989). The second part will not occur until the two faces of a crack come back in contact. It is possible to measure the crack closure with a variant of the RDT test. The test is the creep and step recovery (CSR) test, in which this essential healing process is measured directly. Figure G.24 shows several of these measured crack closure curves for different AV and aging conditions. The vertical scale of the healing graph is the percentage of the crack cross-sectional area that has closed.

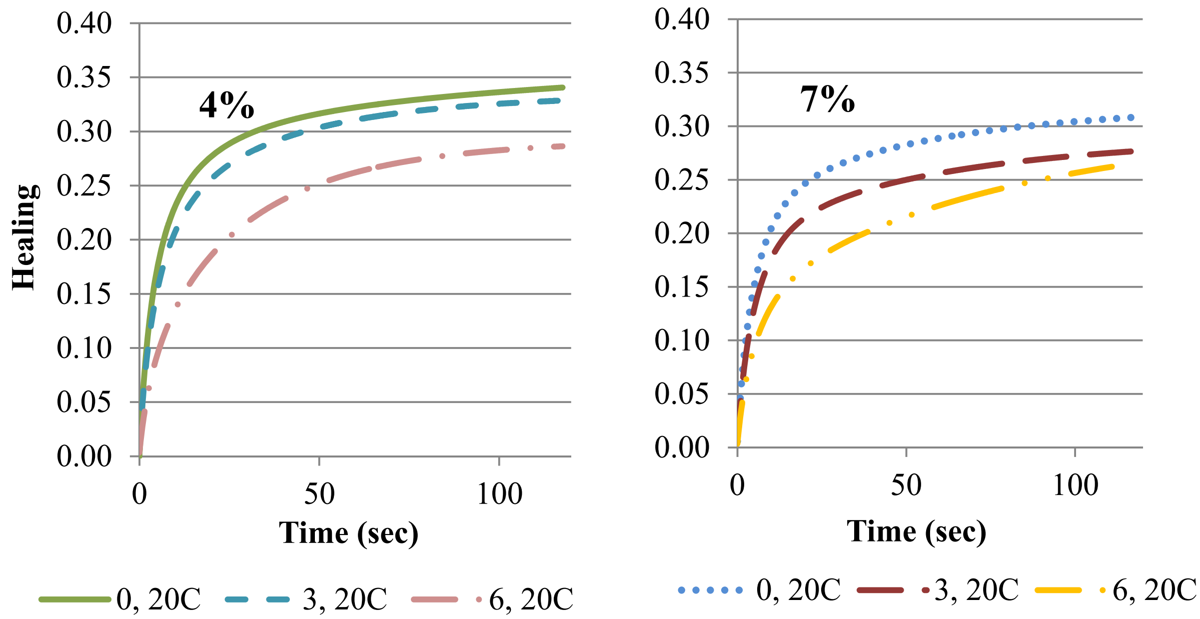


Figure G.24. Healing Curves for Asphalt Mixtures with Different AV Content (4 percent, 7 percent) and Different Aging Periods (0, 3, 6 months) at 20°C

The healing or crack closure curves are bounded by the initial healing rate and the final long-term healing rate. It has been empirically found that the initial healing rate is related to the nonpolar part of the bond energy, and the long-term healing rate is related to the polar part of the bond energy. Both the rates and the total amount of healing are clearly diminished by the amount of aging that the mixture has experienced. Being able to measure these rates and magnitudes of healing provides a needed addition to the mixture properties that must be evaluated in selecting a binder and a WMA additive for a given mixture and project.

The RDT test is a simple, accurate, and rapid test that requires standard testing equipment. The data reduction has been developed into macro and spreadsheet form so that the conversion of the raw data into the final material properties that are shown here is also straightforward. Table G.7 gives the times that are required to complete different aspects of the RDT test.

The test times for this very useful test are short, and the software for the reduction of the data make the determination of the relevant mixture properties simple and straightforward. Samples to be tested can be conditioned in the standard ways or even the nonstandard ways suggested above, such as using water vapor and conditioning at high levels of relative humidity or even using steam to accelerate the entry of moisture into the mixture. In order to obtain the master curves of these mixtures the tests must be run at three different temperatures, and the time required for the sample to stabilize at a new temperature is about 3 h. When all of these times are added, a complete characterization of a given mixture, including both damaged and undamaged properties, can be completed in the course of 1 day.

Table G.7. Test Times for Repeated Direct Tension Test

Test	Equipment	Required Time for Test	Properties
Undamaged-Damaged Boundary Strain		3 or 4 times (4 min testing + 15 min recovery)	Endurance limit & bond energy
RDT_Undamaged		4 min	Tensile modulus & phase angle Quasi-compressive modulus & phase angle
RDT_Damaged	MTS	16 min	Modified Paris' law A, n
CSR_Undamaged		4 min	Undamaged recovery modulus
CSR_Damaged		4 min	Damaged recovery modulus, healing rates
Sample Temperature Change		3 h	Constant temperature

SUMMARY

As indicated by test results of Texas mixtures shown in Figure G.2, Figure G.4(a), and Figure G.5(a) for the monotonic loading criteria and Figure G.14, Figure G.15, and Figure G.16 for the repeated loading criteria, these test parameters provide useful and consistent mixture performance parameters under a wide variety of conditions. The form index, N, and the calculated wet and dry bond energies, ΔG, provided consistent measures of performance in the monotonic loading tests. The HWTT test parameters of the number of load cycles at the stripping number, LC_{SN}, the remaining life, LC_R, and the average permanent strain increment, $\overline{\Delta\varepsilon_p}$, were able to evaluate the mixture resistance to stripping and rutting in the presence of warm water under repeated loading.

The repeated loading crack speed index (CSI) made use of the IDT strength and its form index from the monotonic loading as well as the AV and the slope of the average permanent strain increment from the repeated loading to provide a hybrid performance parameter for repeated loading. The dominance of the monotonic loading IDT strength in this formula made this index less useful as a performance indicator. Furthermore, its inconsistency with the other performance indicators suggests future modifications that may prove to be both useful and consistent.

The use of the RDT test measures the Paris' law coefficient and exponent directly, and the CSI is the logarithm of the Paris' law coefficient. In addition, the RDT test provides a direct measurement of the endurance limit, the bond energy in tension, and the crack closure function in healing. All of these latter measures are important in the actual performance of a mixture and should be included in the evaluation of the expected performance of the mixture.

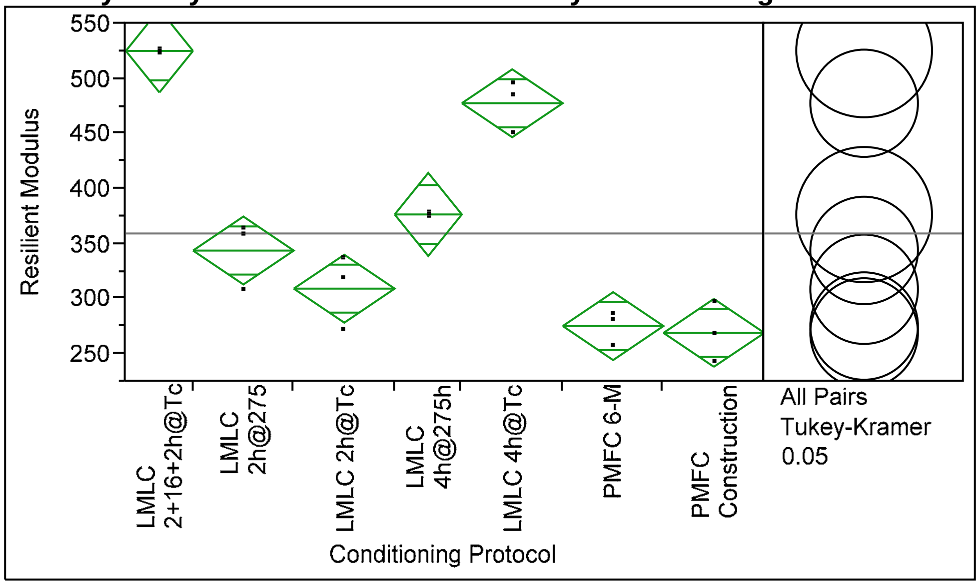
Finally, the conditioning of the sample to simulate both aging and exposure to moisture needs to be adjusted to represent better the effects of the environmental conditions for the in-service mixture. Having reliable performance parameters such as presented here will make it possible to discover and validate those laboratory conditions that will most closely match the environmental effects of field exposure. Once these conditions can be established, minimum and maximum thresholds for acceptable mixture performance can be determined, and these can be applied regardless of whether the mixture is HMA or WMA, or whether it has additives or

modifiers or has RAP or RAS added to it. To have consistent performance parameters that reliably define those mixtures that will perform well in the field should be the ultimate objective of these tests on asphalt mixtures.

APPENDIX H. STATISTICAL RESULTS

Figure A.1 (a)

Oneway Analysis of Resilient Modulus By Conditioning Protocol



Missing Rows
2Excluded Rows
81

Oneway Anova
Summary of Fit

Rsquare	0.954523
Adj Rsquare	0.931784
Root Mean Square Error	24.5163
Mean of Response	359.6168
Observations (or Sum Wgts)	19

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocol	6	151385.53	25230.9	41.9781	<.0001*
Error	12	7212.59	601.0		
C. Total	18	158598.12			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC 2+16+2h@Tc	2	525.365	17.336	487.59	563.14
LMLC 2h@275	3	344.070	14.154	313.23	374.91
LMLC 2h@Tc	3	309.477	14.154	278.64	340.32
LMLC 4h@275h	2	376.800	17.336	339.03	414.57
LMLC 4h@Tc	3	477.780	14.154	446.94	508.62
PMFC 6-M	3	275.467	14.154	244.63	306.31
PMFC Construction	3	269.337	14.154	238.50	300.18

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.49985	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LMLC 2+16+2h@Tc	LMLC 4h@Tc	LMLC 4h@275h	LMLC 2h@275	LMLC 2h@Tc	PMFC 6-M	PMFC Construction
LMLC 2+16+2h@Tc	-85.80	-30.74	62.76	102.97	137.56	171.57	177.70
LMLC 4h@Tc	-30.74	-70.06	22.65	63.65	98.25	132.26	138.39
LMLC 4h@275h	62.76	22.65	-85.80	-45.60	-11.00	23.01	29.14
LMLC 2h@275	102.97	63.65	-45.60	-70.06	-35.46	-1.45	4.68
LMLC 2h@Tc	137.56	98.25	-11.00	-35.46	-70.06	-36.05	-29.92
PMFC 6-M	171.57	132.26	23.01	-1.45	-36.05	-70.06	-63.93
PMFC Construction	177.70	138.39	29.14	4.68	-29.92	-63.93	-70.06

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
LMLC 2+16+2h@Tc	A	525.36500
LMLC 4h@Tc	A	477.78000

Level				Mean
LMLC 4h@275h	B			376.80000
LMLC 2h@275	B	C		344.07000
LMLC 2h@Tc	B	C	D	309.47667
PMFC 6-M		C	D	275.46667
PMFC Construction			D	269.33667

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LMLC 2+16+2h@Tc	PMFC Construction	256.0283	22.38022	177.701	334.3558	<.0001*
LMLC 2+16+2h@Tc	PMFC 6-M	249.8983	22.38022	171.571	328.2258	<.0001*
LMLC 2+16+2h@Tc	LMLC 2h@Tc	215.8883	22.38022	137.561	294.2158	<.0001*
LMLC 4h@Tc	PMFC Construction	208.4433	20.01748	138.385	278.5015	<.0001*
LMLC 4h@Tc	PMFC 6-M	202.3133	20.01748	132.255	272.3715	<.0001*
LMLC 2+16+2h@Tc	LMLC 2h@275	181.2950	22.38022	102.968	259.6224	<.0001*
LMLC 4h@Tc	LMLC 2h@Tc	168.3033	20.01748	98.245	238.3615	<.0001*
LMLC 2+16+2h@Tc	LMLC 4h@275h	148.5650	24.51630	62.762	234.3684	0.0008*
LMLC 4h@Tc	LMLC 2h@275	133.7100	20.01748	63.652	203.7682	0.0003*
LMLC 4h@275h	PMFC Construction	107.4633	22.38022	29.136	185.7908	0.0058*
LMLC 4h@275h	PMFC 6-M	101.3333	22.38022	23.006	179.6608	0.0091*
LMLC 4h@Tc	LMLC 4h@275h	100.9800	22.38022	22.653	179.3074	0.0093*
LMLC 2h@275	PMFC Construction	74.7333	20.01748	4.675	144.7915	0.0339*
LMLC 2h@275	PMFC 6-M	68.6033	20.01748	-1.455	138.6615	0.0564
LMLC 4h@275h	LMLC 2h@Tc	67.3233	22.38022	-11.004	145.6508	0.1112
LMLC 2+16+2h@Tc	LMLC 4h@Tc	47.5850	22.38022	-30.742	125.9124	0.3965
LMLC 2h@Tc	PMFC Construction	40.1400	20.01748	-29.918	110.1982	0.4580
LMLC 2h@275	LMLC 2h@Tc	34.5933	20.01748	-35.465	104.6515	0.6123
LMLC 2h@Tc	PMFC 6-M	34.0100	20.01748	-36.048	104.0682	0.6290
LMLC 4h@275h	LMLC 2h@275	32.7300	22.38022	-45.597	111.0574	0.7603
PMFC 6-M	PMFC Construction	6.1300	20.01748	-63.928	76.1882	0.9999

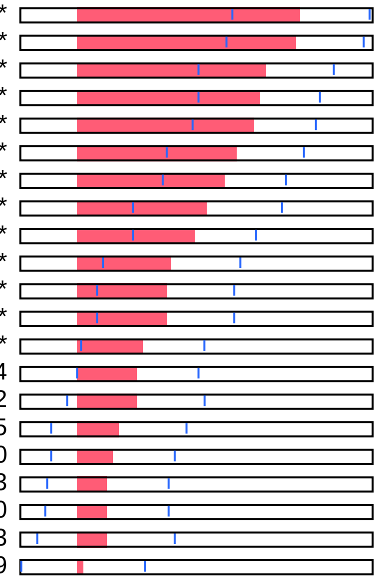
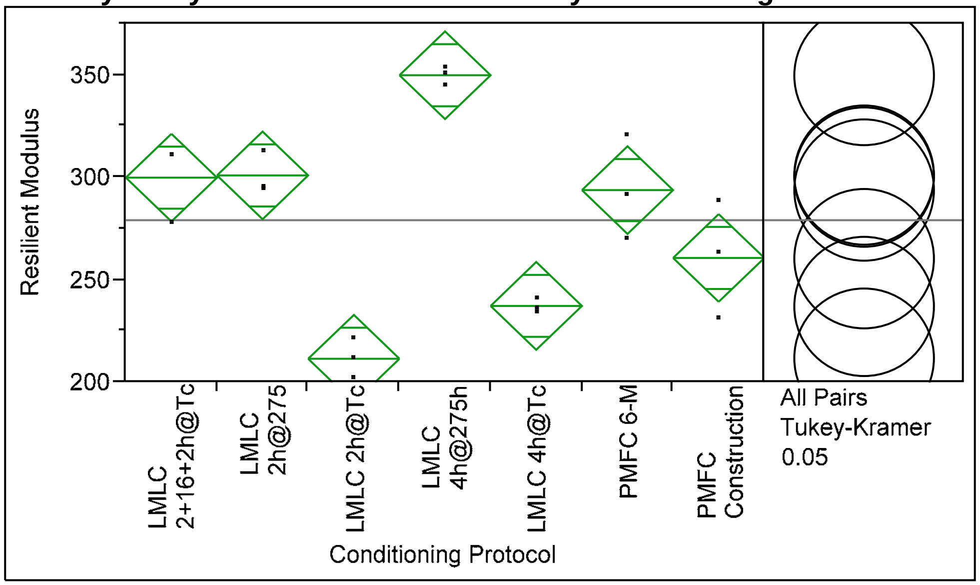


Figure A.1 (b)

Oneway Analysis of Resilient Modulus By Conditioning Protocol



Excluded Rows
81

Oneway Anova
Summary of Fit

Rsquare	0.901585
Adj Rsquare	0.859407
Root Mean Square Error	17.31308
Mean of Response	279.101
Observations (or Sum Wgts)	21

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocol	6	38443.512	6407.25	21.3758	<.0001*
Error	14	4196.400	299.74		
C. Total	20	42639.912			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC 2+16+2h@Tc	3	299.860	9.9957	278.42	321.30
LMLC 2h@275	3	300.970	9.9957	279.53	322.41
LMLC 2h@Tc	3	211.390	9.9957	189.95	232.83
LMLC 4h@275h	3	349.880	9.9957	328.44	371.32
LMLC 4h@Tc	3	237.220	9.9957	215.78	258.66
PMFC 6-M	3	293.770	9.9957	272.33	315.21
PMFC Construction	3	260.617	9.9957	239.18	282.06

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.41459	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LMLC 4h@275h	LMLC 2h@275	LMLC 2+16+2h@Tc	PMFC 6-M	PMFC Construction	LMLC 4h@Tc	LMLC 2h@Tc
LMLC 4h@275h	-48.269	0.641	1.751	7.841	40.994	64.391	90.221
LMLC 2h@275	0.641	-48.269	-47.159	-41.069	-7.916	15.481	41.311
LMLC 2+16+2h@Tc	1.751	-47.159	-48.269	-42.179	-9.026	14.371	40.201
PMFC 6-M	7.841	-41.069	-42.179	-48.269	-15.116	8.281	34.111
PMFC Construction	40.994	-7.916	-9.026	-15.116	-48.269	-24.872	0.958
LMLC 4h@Tc	64.391	15.481	14.371	8.281	-24.872	-48.269	-22.439
LMLC 2h@Tc	90.221	41.311	40.201	34.111	0.958	-22.439	-48.269

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
LMLC 4h@275h	A				349.88000
LMLC 2h@275		B			300.97000
LMLC 2+16+2h@Tc		B			299.86000
PMFC 6-M		B			293.77000
PMFC Construction		B	C		260.61667
LMLC 4h@Tc			C	D	237.22000
LMLC 2h@Tc				D	211.39000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LMLC 4h@275h	LMLC 2h@Tc	138.4900	14.13607	90.2212	186.7588	<.0001*
LMLC 4h@275h	LMLC 4h@Tc	112.6600	14.13607	64.3912	160.9288	<.0001*
LMLC 2h@275	LMLC 2h@Tc	89.5800	14.13607	41.3112	137.8488	0.0003*
LMLC 4h@275h	PMFC Construction	89.2633	14.13607	40.9945	137.5322	0.0003*
LMLC 2+16+2h@Tc	LMLC 2h@Tc	88.4700	14.13607	40.2012	136.7388	0.0003*
PMFC 6-M	LMLC 2h@Tc	82.3800	14.13607	34.1112	130.6488	0.0007*
LMLC 2h@275	LMLC 4h@Tc	63.7500	14.13607	15.4812	112.0188	0.0069*
LMLC 2+16+2h@Tc	LMLC 4h@Tc	62.6400	14.13607	14.3712	110.9088	0.0079*
PMFC 6-M	LMLC 4h@Tc	56.5500	14.13607	8.2812	104.8188	0.0173*
LMLC 4h@275h	PMFC 6-M	56.1100	14.13607	7.8412	104.3788	0.0184*
LMLC 4h@275h	LMLC 2+16+2h@Tc	50.0200	14.13607	1.7512	98.2888	0.0401*
PMFC Construction	LMLC 2h@Tc	49.2267	14.13607	0.9578	97.4955	0.0443*
LMLC 4h@275h	LMLC 2h@275	48.9100	14.13607	0.6412	97.1788	0.0461*
LMLC 2h@275	PMFC Construction	40.3533	14.13607	-7.9155	88.6222	0.1314
LMLC 2+16+2h@Tc	PMFC Construction	39.2433	14.13607	-9.0255	87.5122	0.1494
PMFC 6-M	PMFC Construction	33.1533	14.13607	-15.1155	81.4222	0.2892
LMLC 4h@Tc	LMLC 2h@Tc	25.8300	14.13607	-22.4388	74.0988	0.5525
PMFC Construction	LMLC 4h@Tc	23.3967	14.13607	-24.8722	71.6655	0.6529
LMLC 2h@275	PMFC 6-M	7.2000	14.13607	-41.0688	55.4688	0.9983
LMLC 2+16+2h@Tc	PMFC 6-M	6.0900	14.13607	-42.1788	54.3588	0.9993
LMLC 2h@275	LMLC 2+16+2h@Tc	1.1100	14.13607	-47.1588	49.3788	1.0000

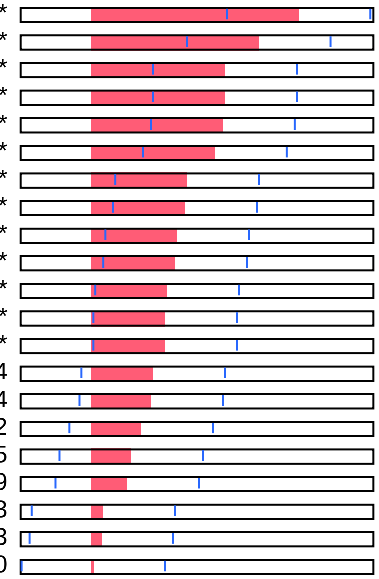
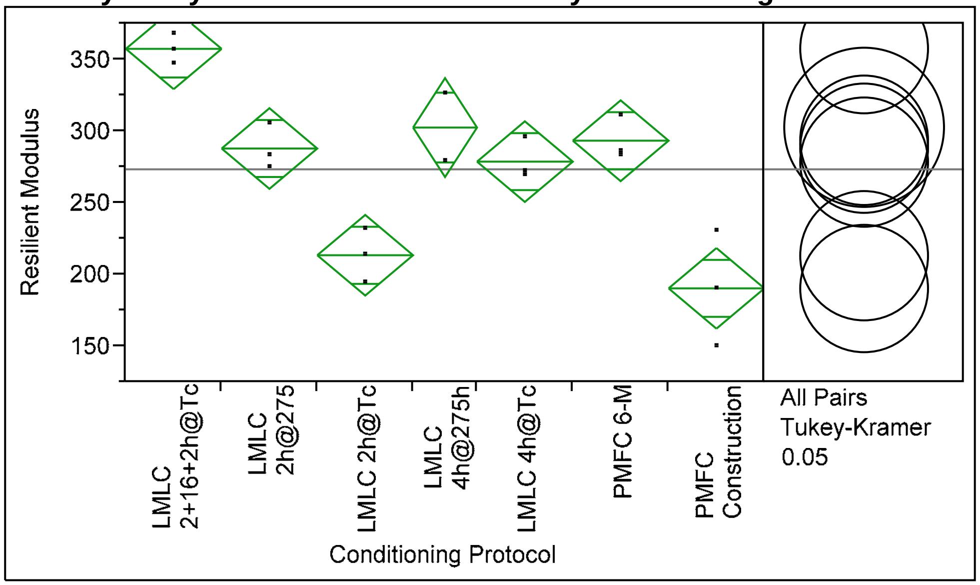


Figure A.1 (c)

Oneway Analysis of Resilient Modulus By Conditioning Protocol



Missing Rows
1Excluded Rows
81

Oneway Anova
Summary of Fit

Rsquare	0.894755
Adj Rsquare	0.84618
Root Mean Square Error	22.56785
Mean of Response	273.4995
Observations (or Sum Wgts)	20

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocol	6	56289.140	9381.52	18.4201	<.0001*
Error	13	6621.000	509.31		
C. Total	19	62910.140			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC 2+16+2h@Tc	3	357.503	13.030	329.35	385.65
LMLC 2h@275	3	287.980	13.030	259.83	316.13
LMLC 2h@Tc	3	213.470	13.030	185.32	241.62
LMLC 4h@275h	2	302.590	15.958	268.12	337.06
LMLC 4h@Tc	3	278.843	13.030	250.69	306.99
PMFC 6-M	3	293.400	13.030	265.25	321.55
PMFC Construction	3	190.407	13.030	162.26	218.56

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.45358	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LMLC 2+16+2h@Tc	LMLC 4h@275h	PMFC 6-M	LMLC 2h@275	LMLC 4h@Tc	LMLC 2h@Tc	PMFC Construction
LMLC 2+16+2h@Tc	-63.64	-16.24	0.47	5.89	15.02	80.40	103.46
LMLC 4h@275h	-16.24	-77.94	-61.96	-56.54	-47.40	17.97	41.03
PMFC 6-M	0.47	-61.96	-63.64	-58.22	-49.08	16.29	39.36
LMLC 2h@275	5.89	-56.54	-58.22	-63.64	-54.50	10.87	33.94
LMLC 4h@Tc	15.02	-47.40	-49.08	-54.50	-63.64	1.74	24.80
LMLC 2h@Tc	80.40	17.97	16.29	10.87	1.74	-63.64	-40.57
PMFC Construction	103.46	41.03	39.36	33.94	24.80	-40.57	-63.64

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LMLC 2+16+2h@Tc	A			357.50333
LMLC 4h@275h	A	B		302.59000
PMFC 6-M		B		293.40000
LMLC 2h@275		B		287.98000
LMLC 4h@Tc		B		278.84333
LMLC 2h@Tc			C	213.47000
PMFC Construction			C	190.40667

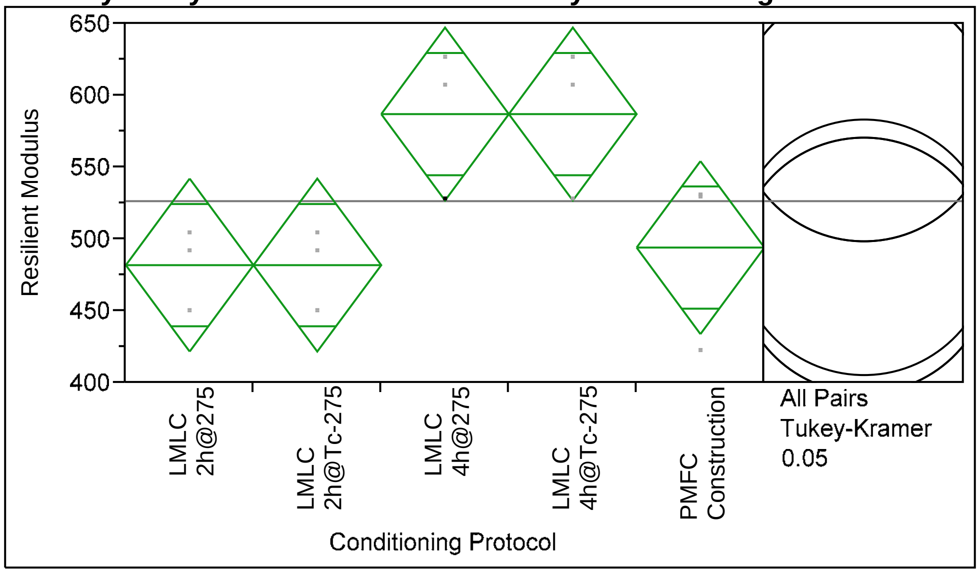
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LMLC 2+16+2h@Tc	PMFC Construction	167.0967	18.42657	103.459	230.7343	<.0001*
LMLC 2+16+2h@Tc	LMLC 2h@Tc	144.0333	18.42657	80.396	207.6709	<.0001*
LMLC 4h@275h	PMFC Construction	112.1833	20.60153	41.034	183.3323	0.0016*
PMFC 6-M	PMFC Construction	102.9933	18.42657	39.356	166.6309	0.0013*
LMLC 2h@275	PMFC Construction	97.5733	18.42657	33.936	161.2109	0.0021*
LMLC 4h@275h	LMLC 2h@Tc	89.1200	20.60153	17.971	160.2690	0.0110*
LMLC 4h@Tc	PMFC Construction	88.4367	18.42657	24.799	152.0743	0.0048*
PMFC 6-M	LMLC 2h@Tc	79.9300	18.42657	16.292	143.5676	0.0107*
LMLC 2+16+2h@Tc	LMLC 4h@Tc	78.6600	18.42657	15.022	142.2976	0.0121*
LMLC 2h@275	LMLC 2h@Tc	74.5100	18.42657	10.872	138.1476	0.0179*
LMLC 2+16+2h@Tc	LMLC 2h@275	69.5233	18.42657	5.886	133.1609	0.0287*
LMLC 4h@Tc	LMLC 2h@Tc	65.3733	18.42657	1.736	129.0109	0.0425*
LMLC 2+16+2h@Tc	PMFC 6-M	64.1033	18.42657	0.466	127.7409	0.0479*
LMLC 2+16+2h@Tc	LMLC 4h@275h	54.9133	20.60153	-16.236	126.0623	0.1833
LMLC 4h@275h	LMLC 4h@Tc	23.7467	20.60153	-47.402	94.8956	0.8997
LMLC 2h@Tc	PMFC Construction	23.0633	18.42657	-40.574	86.7009	0.8615
LMLC 4h@275h	LMLC 2h@275	14.6100	20.60153	-56.539	85.7590	0.9896
PMFC 6-M	LMLC 4h@Tc	14.5567	18.42657	-49.081	78.1943	0.9820
LMLC 4h@275h	PMFC 6-M	9.1900	20.60153	-61.959	80.3390	0.9992
LMLC 2h@275	LMLC 4h@Tc	9.1367	18.42657	-54.501	72.7743	0.9985
PMFC 6-M	LMLC 2h@275	5.4200	18.42657	-58.218	69.0576	0.9999

Figure A.2 (a)

Oneway Analysis of Resilient Modulus By Conditioning Protocol



Excluded Rows
93

Oneway Anova

Summary of Fit

Rsquare	0.628637
Adj Rsquare	0.480091
Root Mean Square Error	46.79407
Mean of Response	526.5367
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocol	4	37066.547	9266.64	4.2319	0.0293*
Error	10	21896.849	2189.68		
C. Total	14	58963.396			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC 2h@275	3	482.040	27.017	421.84	542.24
LMLC 2h@Tc-275	3	482.040	27.017	421.84	542.24
LMLC 4h@275	3	587.173	27.017	526.98	647.37
LMLC 4h@Tc-275	3	587.173	27.017	526.98	647.37
PMFC Construction	3	494.257	27.017	434.06	554.45

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.29108	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LMLC 4h@275	LMLC 4h@Tc-275	PMFC Construction	LMLC 2h@275	LMLC 2h@Tc-275
LMLC 4h@275	-125.74	-125.74	-32.83	-20.61	-20.61
LMLC 4h@Tc-275	-125.74	-125.74	-32.83	-20.61	-20.61
PMFC Construction	-32.83	-32.83	-125.74	-113.53	-113.53
LMLC 2h@275	-20.61	-20.61	-113.53	-125.74	-125.74
LMLC 2h@Tc-275	-20.61	-20.61	-113.53	-125.74	-125.74

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
LMLC 4h@275	A	587.17333
LMLC 4h@Tc-275	A	587.17333
PMFC Construction	A	494.25667
LMLC 2h@275	A	482.04000
LMLC 2h@Tc-275	A	482.04000

Levels not connected by same letter are significantly different.

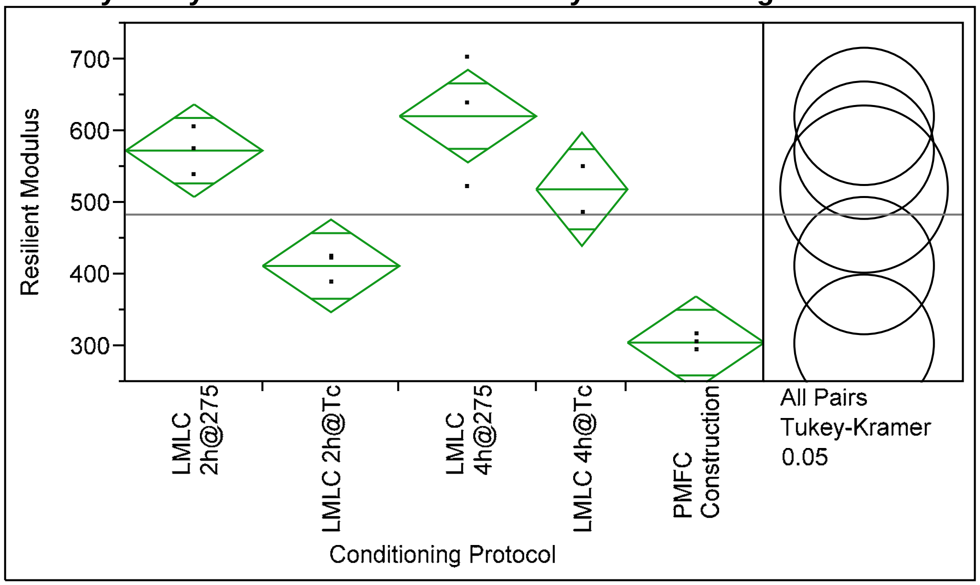
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LMLC 4h@275	LMLC 2h@275	105.1333	38.20720	-20.610	230.8764	0.1145
LMLC 4h@Tc-275	LMLC 2h@275	105.1333	38.20720	-20.610	230.8764	0.1145
LMLC 4h@275	LMLC 2h@Tc-275	105.1333	38.20720	-20.610	230.8764	0.1145
LMLC 4h@Tc-275	LMLC 2h@Tc-275	105.1333	38.20720	-20.610	230.8764	0.1145
LMLC 4h@275	PMFC Construction	92.9167	38.20720	-32.826	218.6597	0.1837
LMLC 4h@Tc-275	PMFC Construction	92.9167	38.20720	-32.826	218.6597	0.1837
PMFC Construction	LMLC 2h@275	12.2167	38.20720	-113.526	137.9597	0.9973
PMFC Construction	LMLC 2h@Tc-275	12.2167	38.20720	-113.526	137.9597	0.9973
LMLC 4h@Tc-275	LMLC 4h@275	0.0000	38.20720	-125.743	125.7430	1.0000
LMLC 2h@Tc-275	LMLC 2h@275	0.0000	38.20720	-125.743	125.7430	1.0000

Figure A.2 (b)

Oneway Analysis of Resilient Modulus By Conditioning Protocol



Missing Rows
1Excluded Rows
93

Oneway Anova
Summary of Fit

Rsquare	0.898082
Adj Rsquare	0.852785
Root Mean Square Error	49.47888
Mean of Response	483.7186
Observations (or Sum Wgts)	14

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocol	4	194154.30	48538.6	19.8266	0.0002*
Error	9	22033.43	2448.2		
C. Total	13	216187.73			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC 2h@275	3	573.003	28.567	508.38	637.63
LMLC 2h@Tc	3	412.083	28.567	347.46	476.71
LMLC 4h@275	3	621.123	28.567	556.50	685.75
LMLC 4h@Tc	2	519.055	34.987	439.91	598.20
PMFC Construction	3	305.107	28.567	240.48	369.73

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.36258	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LMLC 4h@275	LMLC 2h@275	LMLC 4h@Tc	LMLC 2h@Tc	PMFC Construction
LMLC 4h@275	-135.85	-87.73	-49.81	73.19	180.17
LMLC 2h@275	-87.73	-135.85	-97.93	25.07	132.05
LMLC 4h@Tc	-49.81	-97.93	-166.38	-44.91	62.07
LMLC 2h@Tc	73.19	25.07	-44.91	-135.85	-28.87
PMFC Construction	180.17	132.05	62.07	-28.87	-135.85

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LMLC 4h@275	A			621.12333
LMLC 2h@275	A			573.00333
LMLC 4h@Tc	A	B		519.05500
LMLC 2h@Tc		B	C	412.08333
PMFC Construction			C	305.10667

Levels not connected by same letter are significantly different.

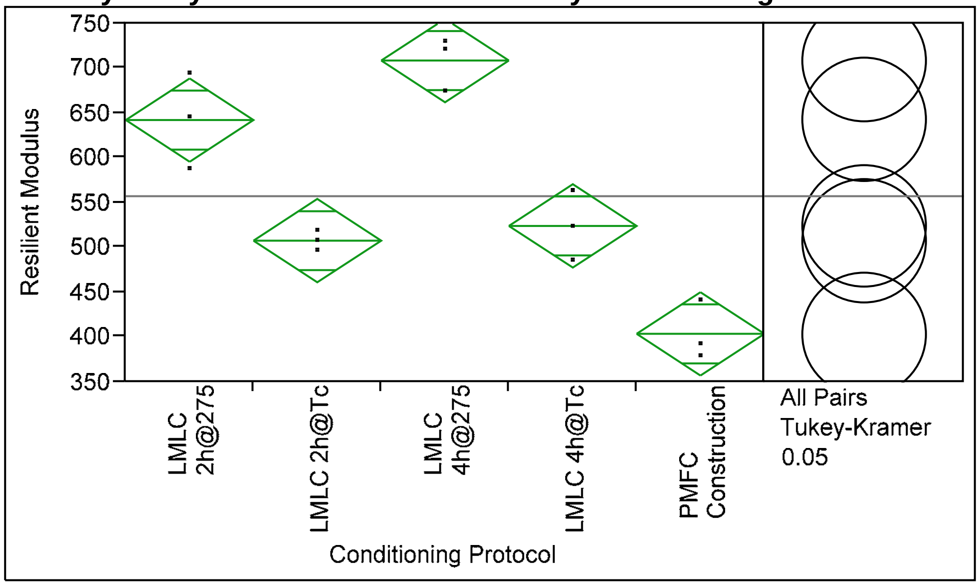
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LMLC 4h@275	PMFC Construction	316.0167	40.39933	180.171	451.8628	0.0002*
LMLC 2h@275	PMFC Construction	267.8967	40.39933	132.051	403.7428	0.0007*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LMLC 4h@Tc	PMFC Construction	213.9483	45.16783	62.068	365.8289	0.0071*
LMLC 4h@275	LMLC 2h@Tc	209.0400	40.39933	73.194	344.8861	0.0040*
LMLC 2h@275	LMLC 2h@Tc	160.9200	40.39933	25.074	296.7661	0.0203*
LMLC 2h@Tc	PMFC Construction	106.9767	40.39933	-28.869	242.8228	0.1412
LMLC 4h@Tc	LMLC 2h@Tc	106.9717	45.16783	-44.909	258.8523	0.2086
LMLC 4h@275	LMLC 4h@Tc	102.0683	45.16783	-49.812	253.9489	0.2416
LMLC 2h@275	LMLC 4h@Tc	53.9483	45.16783	-97.932	205.8289	0.7548
LMLC 4h@275	LMLC 2h@275	48.1200	40.39933	-87.726	183.9661	0.7565

Figure A.2 (c)

Oneway Analysis of Resilient Modulus By Conditioning Protocol



Excluded Rows
93

Oneway Anova

Summary of Fit

Rsquare	0.929253
Adj Rsquare	0.900954
Root Mean Square Error	36.18368
Mean of Response	557.5207
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocol	4	171969.78	42992.4	32.8372	<.0001*
Error	10	13092.59	1309.3		
C. Total	14	185062.37			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC 2h@275	3	642.507	20.891	595.96	689.05
LMLC 2h@Tc	3	507.907	20.891	461.36	554.45
LMLC 4h@275	3	708.943	20.891	662.40	755.49
LMLC 4h@Tc	3	524.390	20.891	477.84	570.94
PMFC Construction	3	403.857	20.891	357.31	450.40

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.29108	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LMLC 4h@275	LMLC 2h@275	LMLC 4h@Tc	LMLC 2h@Tc	PMFC Construction
LMLC 4h@275	-97.23	-30.79	87.32	103.81	207.86
LMLC 2h@275	-30.79	-97.23	20.89	37.37	141.42
LMLC 4h@Tc	87.32	20.89	-97.23	-80.75	23.30
LMLC 2h@Tc	103.81	37.37	-80.75	-97.23	6.82
PMFC Construction	207.86	141.42	23.30	6.82	-97.23

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LMLC 4h@275	A			708.94333
LMLC 2h@275	A			642.50667
LMLC 4h@Tc		B		524.39000
LMLC 2h@Tc		B		507.90667
PMFC Construction			C	403.85667

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LMLC 4h@275	PMFC Construction	305.0867	29.54385	207.855	402.3179	<.0001*
LMLC 2h@275	PMFC Construction	238.6500	29.54385	141.419	335.8812	<.0001*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LMLC 4h@275	LMLC 2h@Tc	201.0367	29.54385	103.805	298.2679	0.0004*
LMLC 4h@275	LMLC 4h@Tc	184.5533	29.54385	87.322	281.7846	0.0007*
LMLC 2h@275	LMLC 2h@Tc	134.6000	29.54385	37.369	231.8312	0.0072*
LMLC 4h@Tc	PMFC Construction	120.5333	29.54385	23.302	217.7646	0.0148*
LMLC 2h@275	LMLC 4h@Tc	118.1167	29.54385	20.885	215.3479	0.0168*
LMLC 2h@Tc	PMFC Construction	104.0500	29.54385	6.819	201.2812	0.0349*
LMLC 4h@275	LMLC 2h@275	66.4367	29.54385	-30.795	163.6679	0.2380
LMLC 4h@Tc	LMLC 2h@Tc	16.4833	29.54385	-80.748	113.7146	0.9784

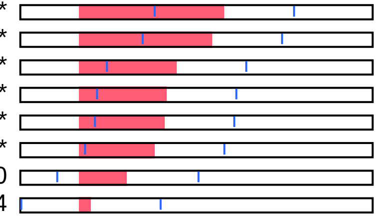
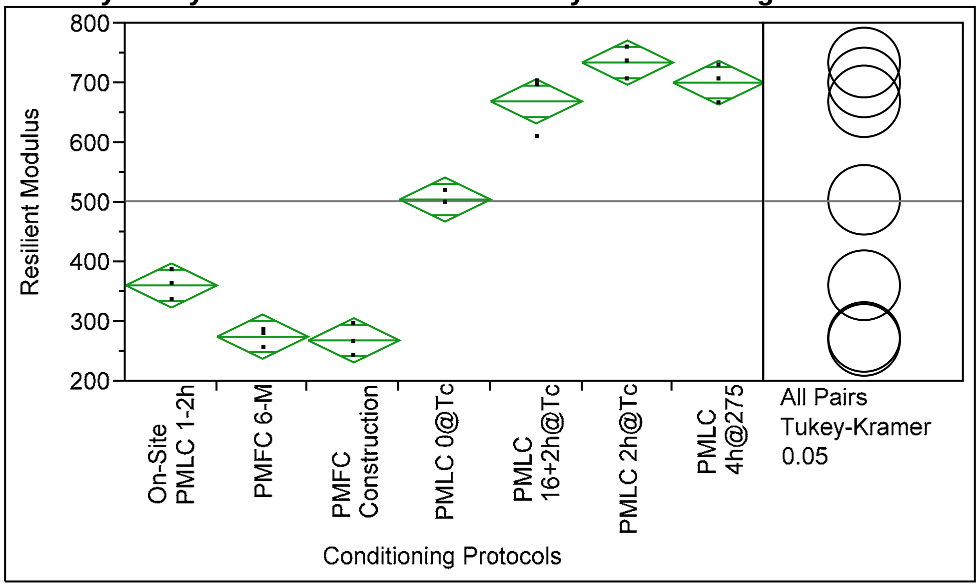


Figure A.3 (a)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Excluded Rows
105

Oneway Anova

Summary of Fit

Rsquare	0.983374
Adj Rsquare	0.976248
Root Mean Square Error	29.94034
Mean of Response	502.5138
Observations (or Sum Wgts)	21

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocols	6	742280.70	123713	138.0077	<.0001*
Error	14	12549.94	896		
C. Total	20	754830.64			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
On-Site PMLC 1-2h	3	361.327	17.286	324.25	398.40
PMFC 6-M	3	275.467	17.286	238.39	312.54
PMFC Construction	3	269.337	17.286	232.26	306.41
PMLC 0@Tc	3	505.307	17.286	468.23	542.38
PMLC 16+2h@Tc	3	669.950	17.286	632.88	707.02
PMLC 2h@Tc	3	734.977	17.286	697.90	772.05
PMLC 4h@275	3	701.233	17.286	664.16	738.31

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.41459	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMLC 2h@Tc	PMLC 4h@275	PMLC 16+2h@Tc	PMLC 0@Tc	On-Site PMLC 1-2h	PMFC 6-M	PMFC Construction
PMLC 2h@Tc	-83.47	-49.73	-18.45	146.20	290.18	376.04	382.17
PMLC 4h@275	-49.73	-83.47	-52.19	112.45	256.43	342.29	348.42
PMLC 16+2h@Tc	-18.45	-52.19	-83.47	81.17	225.15	311.01	317.14
PMLC 0@Tc	146.20	112.45	81.17	-83.47	60.51	146.37	152.50
On-Site PMLC 1-2h	290.18	256.43	225.15	60.51	-83.47	2.39	8.52
PMFC 6-M	376.04	342.29	311.01	146.37	2.39	-83.47	-77.34
PMFC Construction	382.17	348.42	317.14	152.50	8.52	-77.34	-83.47

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
PMLC 2h@Tc	A				734.97667
PMLC 4h@275	A				701.23333
PMLC 16+2h@Tc	A				669.95000
PMLC 0@Tc		B			505.30667
On-Site PMLC 1-2h			C		361.32667
PMFC 6-M				D	275.46667
PMFC Construction				D	269.33667

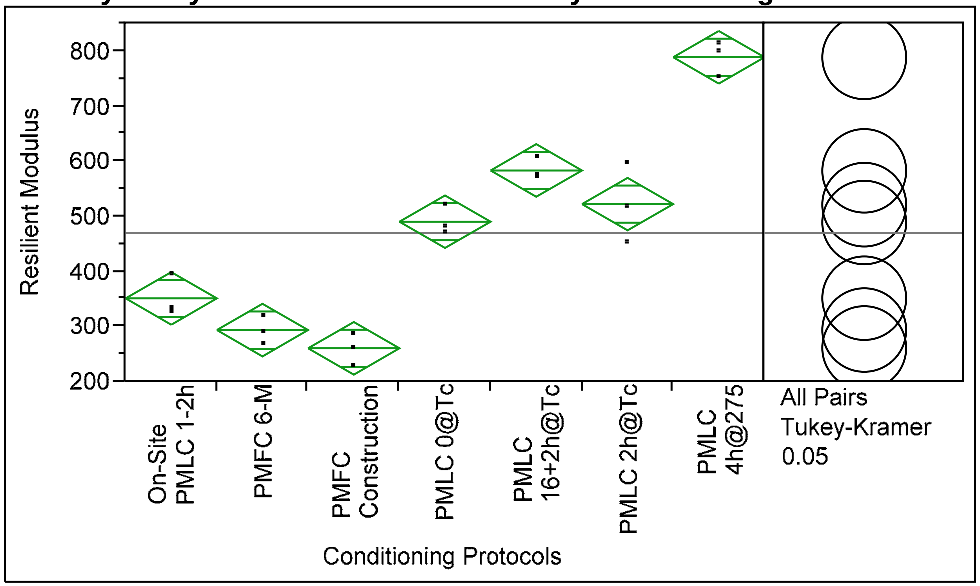
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMLC 2h@Tc	PMFC Construction	465.6400	24.44619	382.166	549.1136	<.0001*
PMLC 2h@Tc	PMFC 6-M	459.5100	24.44619	376.036	542.9836	<.0001*
PMLC 4h@275	PMFC Construction	431.8967	24.44619	348.423	515.3703	<.0001*
PMLC 4h@275	PMFC 6-M	425.7667	24.44619	342.293	509.2403	<.0001*
PMLC 16+2h@Tc	PMFC Construction	400.6133	24.44619	317.140	484.0870	<.0001*
PMLC 16+2h@Tc	PMFC 6-M	394.4833	24.44619	311.010	477.9570	<.0001*
PMLC 2h@Tc	On-Site PMLC 1-2h	373.6500	24.44619	290.176	457.1236	<.0001*
PMLC 4h@275	On-Site PMLC 1-2h	339.9067	24.44619	256.433	423.3803	<.0001*
PMLC 16+2h@Tc	On-Site PMLC 1-2h	308.6233	24.44619	225.150	392.0970	<.0001*
PMLC 0@Tc	PMFC Construction	235.9700	24.44619	152.496	319.4436	<.0001*
PMLC 0@Tc	PMFC 6-M	229.8400	24.44619	146.366	313.3136	<.0001*
PMLC 2h@Tc	PMLC 0@Tc	229.6700	24.44619	146.196	313.1436	<.0001*
PMLC 4h@275	PMLC 0@Tc	195.9267	24.44619	112.453	279.4003	<.0001*
PMLC 16+2h@Tc	PMLC 0@Tc	164.6433	24.44619	81.170	248.1170	0.0002*
PMLC 0@Tc	On-Site PMLC 1-2h	143.9800	24.44619	60.506	227.4536	0.0006*
On-Site PMLC 1-2h	PMFC Construction	91.9900	24.44619	8.516	175.4636	0.0267*
On-Site PMLC 1-2h	PMFC 6-M	85.8600	24.44619	2.386	169.3336	0.0420*
PMLC 2h@Tc	PMLC 16+2h@Tc	65.0267	24.44619	-18.447	148.5003	0.1800
PMLC 2h@Tc	PMLC 4h@275	33.7433	24.44619	-49.730	117.2170	0.8032
PMLC 4h@275	PMLC 16+2h@Tc	31.2833	24.44619	-52.190	114.7570	0.8502
PMFC 6-M	PMFC Construction	6.1300	24.44619	-77.344	89.6036	1.0000

Figure A.3 (b)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Excluded Rows
105

Oneway Anova

Summary of Fit

Rsquare	0.967547
Adj Rsquare	0.953638
Root Mean Square Error	38.54258
Mean of Response	470.1027
Observations (or Sum Wgts)	21

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**	**Prob > F**
Conditioning Protocols	6	620043.85	103341	69.5648	<.0001*
Error	14	20797.43	1486		
C. Total	20	640841.28			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
On-Site PMLC 1-2h	3	351.237	22.253	303.51	398.96
PMFC 6-M	3	293.770	22.253	246.04	341.50
PMFC Construction	3	260.617	22.253	212.89	308.34
PMLC 0@Tc	3	490.446	22.253	442.72	538.17
PMLC 16+2h@Tc	3	583.460	22.253	535.73	631.19
PMLC 2h@Tc	3	522.373	22.253	474.65	570.10
PMLC 4h@275	3	788.817	22.253	741.09	836.54

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.41459	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMLC 4h@275	PMLC 16+2h@Tc	PMLC 2h@Tc	PMLC 0@Tc	On-Site PMLC 1-2h	PMFC 6-M	PMFC Construction
PMLC 4h@275	-107.46	97.90	158.99	190.91	330.12	387.59	420.74
PMLC 16+2h@Tc	97.90	-107.46	-46.37	-14.44	124.77	182.23	215.39
PMLC 2h@Tc	158.99	-46.37	-107.46	-75.53	63.68	121.15	154.30
PMLC 0@Tc	190.91	-14.44	-75.53	-107.46	31.75	89.22	122.37
On-Site PMLC 1-2h	330.12	124.77	63.68	31.75	-107.46	-49.99	-16.84
PMFC 6-M	387.59	182.23	121.15	89.22	-49.99	-107.46	-74.30
PMFC Construction	420.74	215.39	154.30	122.37	-16.84	-74.30	-107.46

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
PMLC 4h@275	A			788.81667
PMLC 16+2h@Tc		B		583.46000
PMLC 2h@Tc		B		522.37333
PMLC 0@Tc		B		490.44580
On-Site PMLC 1-2h			C	351.23667
PMFC 6-M			C	293.77000
PMFC Construction			C	260.61667

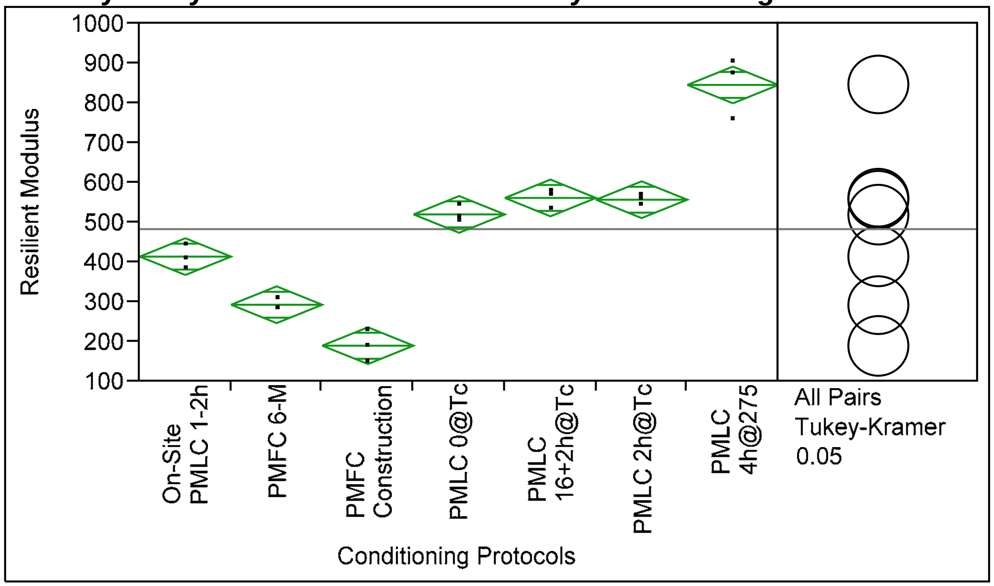
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMLC 4h@275	PMFC Construction	528.2000	31.46989	420.743	635.6567	<.0001*
PMLC 4h@275	PMFC 6-M	495.0467	31.46989	387.590	602.5033	<.0001*
PMLC 4h@275	On-Site PMLC 1-2h	437.5800	31.46989	330.123	545.0367	<.0001*
PMLC 16+2h@Tc	PMFC Construction	322.8433	31.46989	215.387	430.3000	<.0001*
PMLC 4h@275	PMLC 0@Tc	298.3709	31.46989	190.914	405.8275	<.0001*
PMLC 16+2h@Tc	PMFC 6-M	289.6900	31.46989	182.233	397.1467	<.0001*
PMLC 4h@275	PMLC 2h@Tc	266.4433	31.46989	158.987	373.9000	<.0001*
PMLC 2h@Tc	PMFC Construction	261.7567	31.46989	154.300	369.2133	<.0001*
PMLC 16+2h@Tc	On-Site PMLC 1-2h	232.2233	31.46989	124.767	339.6800	<.0001*
PMLC 0@Tc	PMFC Construction	229.8291	31.46989	122.372	337.2858	<.0001*
PMLC 2h@Tc	PMFC 6-M	228.6033	31.46989	121.147	336.0600	<.0001*
PMLC 4h@275	PMLC 16+2h@Tc	205.3567	31.46989	97.900	312.8133	0.0002*
PMLC 0@Tc	PMFC 6-M	196.6758	31.46989	89.219	304.1325	0.0003*
PMLC 2h@Tc	On-Site PMLC 1-2h	171.1367	31.46989	63.680	278.5933	0.0013*
PMLC 0@Tc	On-Site PMLC 1-2h	139.2091	31.46989	31.752	246.6658	0.0080*
PMLC 16+2h@Tc	PMLC 0@Tc	93.0142	31.46989	-14.442	200.4709	0.1110
On-Site PMLC 1-2h	PMFC Construction	90.6200	31.46989	-16.837	198.0767	0.1261
PMLC 16+2h@Tc	PMLC 2h@Tc	61.0867	31.46989	-46.370	168.5433	0.4877
On-Site PMLC 1-2h	PMFC 6-M	57.4667	31.46989	-49.990	164.9233	0.5532
PMFC 6-M	PMFC Construction	33.1533	31.46989	-74.303	140.6100	0.9318
PMLC 2h@Tc	PMLC 0@Tc	31.9275	31.46989	-75.529	139.3842	0.9422

Figure A.3 (c)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Excluded Rows
105

Oneway Anova

Summary of Fit

Rsquare	0.9766
Adj Rsquare	0.966572
Root Mean Square Error	37.32818
Mean of Response	483.5652
Observations (or Sum Wgts)	21

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**	**Prob > F**
Conditioning Protocols	6	814162.10	135694	97.3836	<.0001*
Error	14	19507.50	1393		
C. Total	20	833669.60			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
On-Site PMLC 1-2h	3	414.543	21.551	368.32	460.77
PMFC 6-M	3	293.400	21.551	247.18	339.62
PMFC Construction	3	190.407	21.551	144.18	236.63
PMLC 0@Tc	3	520.707	21.551	474.48	566.93
PMLC 16+2h@Tc	3	562.070	21.551	515.85	608.29
PMLC 2h@Tc	3	557.653	21.551	511.43	603.88
PMLC 4h@275	3	846.177	21.551	799.95	892.40

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.41459	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMLC 4h@275	PMLC 16+2h@Tc	PMLC 2h@Tc	PMLC 0@Tc	On-Site PMLC 1-2h	PMFC 6-M	PMFC Construction
PMLC 4h@275	-104.07	180.04	184.45	221.40	327.56	448.71	551.70
PMLC 16+2h@Tc	180.04	-104.07	-99.65	-62.71	43.46	164.60	267.59
PMLC 2h@Tc	184.45	-99.65	-104.07	-67.12	39.04	160.18	263.18
PMLC 0@Tc	221.40	-62.71	-67.12	-104.07	2.09	123.24	226.23
On-Site PMLC 1-2h	327.56	43.46	39.04	2.09	-104.07	17.07	120.07
PMFC 6-M	448.71	164.60	160.18	123.24	17.07	-104.07	-1.08
PMFC Construction	551.70	267.59	263.18	226.23	120.07	-1.08	-104.07

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
PMLC 4h@275	A				846.17667
PMLC 16+2h@Tc		B			562.07000
PMLC 2h@Tc		B			557.65333
PMLC 0@Tc		B			520.70667
On-Site PMLC 1-2h			C		414.54333
PMFC 6-M				D	293.40000
PMFC Construction				D	190.40667

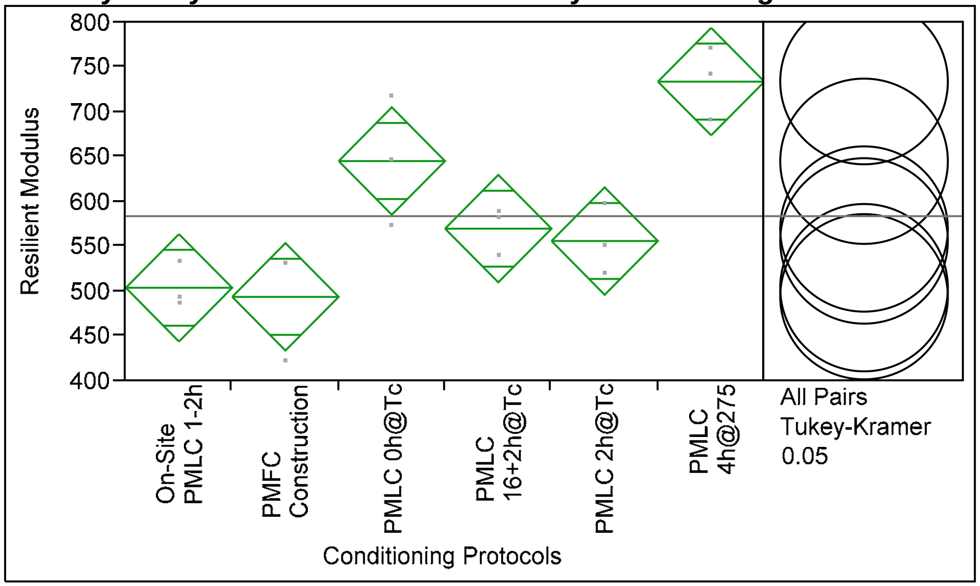
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMLC 4h@275	PMFC Construction	655.7700	30.47833	551.699	759.8409	<.0001*
PMLC 4h@275	PMFC 6-M	552.7767	30.47833	448.706	656.8476	<.0001*
PMLC 4h@275	On-Site PMLC 1-2h	431.6333	30.47833	327.562	535.7042	<.0001*
PMLC 16+2h@Tc	PMFC Construction	371.6633	30.47833	267.592	475.7342	<.0001*
PMLC 2h@Tc	PMFC Construction	367.2467	30.47833	263.176	471.3176	<.0001*
PMLC 0@Tc	PMFC Construction	330.3000	30.47833	226.229	434.3709	<.0001*
PMLC 4h@275	PMLC 0@Tc	325.4700	30.47833	221.399	429.5409	<.0001*
PMLC 4h@275	PMLC 2h@Tc	288.5233	30.47833	184.452	392.5942	<.0001*
PMLC 4h@275	PMLC 16+2h@Tc	284.1067	30.47833	180.036	388.1776	<.0001*
PMLC 16+2h@Tc	PMFC 6-M	268.6700	30.47833	164.599	372.7409	<.0001*
PMLC 2h@Tc	PMFC 6-M	264.2533	30.47833	160.182	368.3242	<.0001*
PMLC 0@Tc	PMFC 6-M	227.3067	30.47833	123.236	331.3776	<.0001*
On-Site PMLC 1-2h	PMFC Construction	224.1367	30.47833	120.066	328.2076	<.0001*
PMLC 16+2h@Tc	On-Site PMLC 1-2h	147.5267	30.47833	43.456	251.5976	0.0038*
PMLC 2h@Tc	On-Site PMLC 1-2h	143.1100	30.47833	39.039	247.1809	0.0049*
On-Site PMLC 1-2h	PMFC 6-M	121.1433	30.47833	17.072	225.2142	0.0182*
PMLC 0@Tc	On-Site PMLC 1-2h	106.1633	30.47833	2.092	210.2342	0.0442*
PMFC 6-M	PMFC Construction	102.9933	30.47833	-1.078	207.0642	0.0532
PMLC 16+2h@Tc	PMLC 0@Tc	41.3633	30.47833	-62.708	145.4342	0.8146
PMLC 2h@Tc	PMLC 0@Tc	36.9467	30.47833	-67.124	141.0176	0.8782
PMLC 16+2h@Tc	PMLC 2h@Tc	4.4167	30.47833	-99.654	108.4876	1.0000

Figure A.4 (a)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Excluded Rows
108

Oneway Anova

Summary of Fit

Rsquare	0.821368
Adj Rsquare	0.746938
Root Mean Square Error	47.6601
Mean of Response	584.285
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocols	5	125334.30	25066.9	11.0355	0.0004*
Error	12	27257.82	2271.5		
C. Total	17	152592.12			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
On-Site PMLC 1-2h	3	504.363	27.517	444.41	564.32
PMFC Construction	3	494.257	27.517	434.30	554.21
PMLC 0h@Tc	3	645.777	27.517	585.82	705.73
PMLC 16+2h@Tc	3	570.350	27.517	510.40	630.30
PMLC 2h@Tc	3	556.543	27.517	496.59	616.50
PMLC 4h@275	3	734.420	27.517	674.47	794.37

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMLC 4h@275	PMLC 0h@Tc	PMLC 16+2h@Tc	PMLC 2h@Tc	On-Site PMLC 1-2h	PMFC Construction
PMLC 4h@275	-130.71	-42.06	33.36	47.17	99.35	109.46
PMLC 0h@Tc	-42.06	-130.71	-55.28	-41.47	10.71	20.81
PMLC 16+2h@Tc	33.36	-55.28	-130.71	-116.90	-64.72	-54.61
PMLC 2h@Tc	47.17	-41.47	-116.90	-130.71	-78.53	-68.42
On-Site PMLC 1-2h	99.35	10.71	-64.72	-78.53	-130.71	-120.60
PMFC Construction	109.46	20.81	-54.61	-68.42	-120.60	-130.71

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
PMLC 4h@275	A			734.42000
PMLC 0h@Tc	A	B		645.77667
PMLC 16+2h@Tc		B	C	570.35000
PMLC 2h@Tc		B	C	556.54333
On-Site PMLC 1-2h			C	504.36333
PMFC Construction			C	494.25667

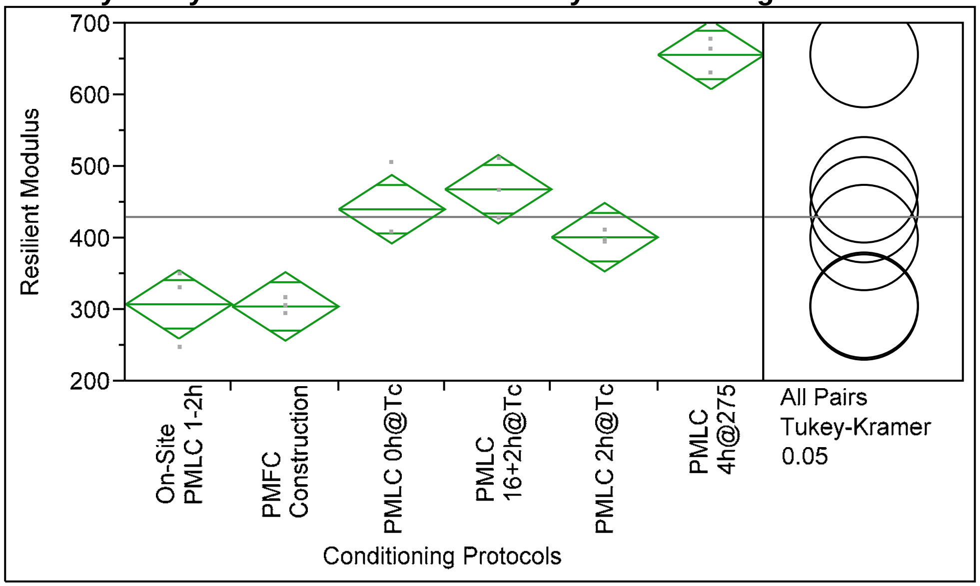
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMLC 4h@275	PMFC Construction	240.1633	38.91431	109.455	370.8712	0.0005*
PMLC 4h@275	On-Site PMLC 1-2h	230.0567	38.91431	99.349	360.7645	0.0008*
PMLC 4h@275	PMLC 2h@Tc	177.8767	38.91431	47.169	308.5845	0.0065*
PMLC 4h@275	PMLC 16+2h@Tc	164.0700	38.91431	33.362	294.7779	0.0118*
PMLC 0h@Tc	PMFC Construction	151.5200	38.91431	20.812	282.2279	0.0203*
PMLC 0h@Tc	On-Site PMLC 1-2h	141.4133	38.91431	10.705	272.1212	0.0315*
PMLC 0h@Tc	PMLC 2h@Tc	89.2333	38.91431	-41.475	219.9412	0.2680
PMLC 4h@275	PMLC 0h@Tc	88.6433	38.91431	-42.065	219.3512	0.2738
PMLC 16+2h@Tc	PMFC Construction	76.0933	38.91431	-54.615	206.8012	0.4177
PMLC 0h@Tc	PMLC 16+2h@Tc	75.4267	38.91431	-55.281	206.1345	0.4265
PMLC 16+2h@Tc	On-Site PMLC 1-2h	65.9867	38.91431	-64.721	196.6945	0.5586
PMLC 2h@Tc	PMFC Construction	62.2867	38.91431	-68.421	192.9945	0.6131
PMLC 2h@Tc	On-Site PMLC 1-2h	52.1800	38.91431	-78.528	182.8879	0.7586
PMLC 16+2h@Tc	PMLC 2h@Tc	13.8067	38.91431	-116.901	144.5145	0.9991
On-Site PMLC 1-2h	PMFC Construction	10.1067	38.91431	-120.601	140.8145	0.9998

Figure A.4 (b)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Excluded Rows
108

Oneway Anova

Summary of Fit

Rsquare	0.935503
Adj Rsquare	0.908629
Root Mean Square Error	38.09459
Mean of Response	430.1983
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocols	5	252587.17	50517.4	34.8108	<.0001*
Error	12	17414.38	1451.2		
C. Total	17	270001.55			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
On-Site PMLC 1-2h	3	308.060	21.994	260.14	355.98
PMFC Construction	3	305.107	21.994	257.19	353.03
PMLC 0h@Tc	3	440.877	21.994	392.96	488.80
PMLC 16+2h@Tc	3	468.847	21.994	420.93	516.77
PMLC 2h@Tc	3	401.793	21.994	353.87	449.71
PMLC 4h@275	3	656.507	21.994	608.59	704.43

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMLC 4h@275	PMLC 16+2h@Tc	PMLC 0h@Tc	PMLC 2h@Tc	On-Site PMLC 1-2h	PMFC Construction
PMLC 4h@275	-104.47	83.19	111.16	150.24	243.97	246.93
PMLC 16+2h@Tc	83.19	-104.47	-76.50	-37.42	56.31	59.27
PMLC 0h@Tc	111.16	-76.50	-104.47	-65.39	28.34	31.30
PMLC 2h@Tc	150.24	-37.42	-65.39	-104.47	-10.74	-7.79
On-Site PMLC 1-2h	243.97	56.31	28.34	-10.74	-104.47	-101.52
PMFC Construction	246.93	59.27	31.30	-7.79	-101.52	-104.47

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
PMLC 4h@275	A			656.50667
PMLC 16+2h@Tc		B		468.84667
PMLC 0h@Tc		B		440.87667
PMLC 2h@Tc		B	C	401.79333
On-Site PMLC 1-2h			C	308.06000
PMFC Construction			C	305.10667

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMLC 4h@275	PMFC Construction	351.4000	31.10411	246.926	455.8745	<.0001*
PMLC 4h@275	On-Site PMLC 1-2h	348.4467	31.10411	243.972	452.9211	<.0001*
PMLC 4h@275	PMLC 2h@Tc	254.7133	31.10411	150.239	359.1878	<.0001*
PMLC 4h@275	PMLC 0h@Tc	215.6300	31.10411	111.156	320.1045	0.0002*
PMLC 4h@275	PMLC 16+2h@Tc	187.6600	31.10411	83.186	292.1345	0.0006*
PMLC 16+2h@Tc	PMFC Construction	163.7400	31.10411	59.266	268.2145	0.0021*
PMLC 16+2h@Tc	On-Site PMLC 1-2h	160.7867	31.10411	56.312	265.2611	0.0025*
PMLC 0h@Tc	PMFC Construction	135.7700	31.10411	31.296	240.2445	0.0092*
PMLC 0h@Tc	On-Site PMLC 1-2h	132.8167	31.10411	28.342	237.2911	0.0108*
PMLC 2h@Tc	PMFC Construction	96.6867	31.10411	-7.788	201.1611	0.0758
PMLC 2h@Tc	On-Site PMLC 1-2h	93.7333	31.10411	-10.741	198.2078	0.0886
PMLC 16+2h@Tc	PMLC 2h@Tc	67.0533	31.10411	-37.421	171.5278	0.3235
PMLC 0h@Tc	PMLC 2h@Tc	39.0833	31.10411	-65.391	143.5578	0.8018
PMLC 16+2h@Tc	PMLC 0h@Tc	27.9700	31.10411	-76.504	132.4445	0.9394
On-Site PMLC 1-2h	PMFC Construction	2.9533	31.10411	-101.521	107.4278	1.0000

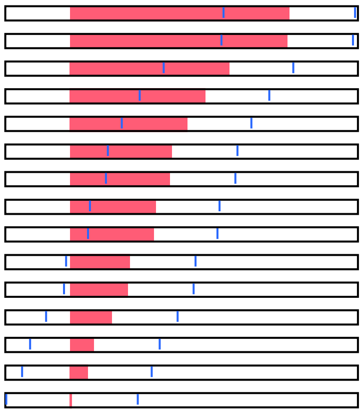
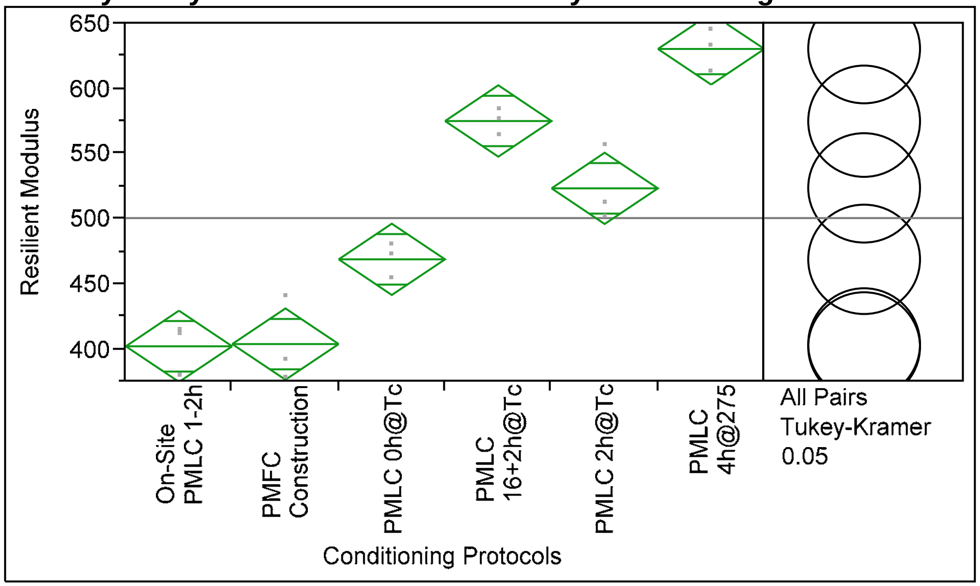


Figure A.4 (c)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Excluded Rows
108

Oneway Anova

Summary of Fit

Rsquare	0.957795
Adj Rsquare	0.94021
Root Mean Square Error	21.78047
Mean of Response	500.7489
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocols	5	129189.17	25837.8	54.4655	<.0001*
Error	12	5692.66	474.4		
C. Total	17	134881.84			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
On-Site PMLC 1-2h	3	402.167	12.575	374.77	429.57
PMFC Construction	3	403.857	12.575	376.46	431.26
PMLC 0h@Tc	3	468.990	12.575	441.59	496.39
PMLC 16+2h@Tc	3	575.317	12.575	547.92	602.72
PMLC 2h@Tc	3	523.537	12.575	496.14	550.94
PMLC 4h@275	3	630.627	12.575	603.23	658.03

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMLC 4h@275	PMLC 16+2h@Tc	PMLC 2h@Tc	PMLC 0h@Tc	PMFC Construction	On-Site PMLC 1-2h
PMLC 4h@275	-59.73	-4.42	47.36	101.90	167.04	168.73
PMLC 16+2h@Tc	-4.42	-59.73	-7.95	46.59	111.73	113.42
PMLC 2h@Tc	47.36	-7.95	-59.73	-5.19	59.95	61.64
PMLC 0h@Tc	101.90	46.59	-5.19	-59.73	5.40	7.09
PMFC Construction	167.04	111.73	59.95	5.40	-59.73	-58.04
On-Site PMLC 1-2h	168.73	113.42	61.64	7.09	-58.04	-59.73

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
PMLC 4h@275	A				630.62667
PMLC 16+2h@Tc	A	B			575.31667
PMLC 2h@Tc		B	C		523.53667
PMLC 0h@Tc			C		468.99000
PMFC Construction				D	403.85667
On-Site PMLC 1-2h				D	402.16667

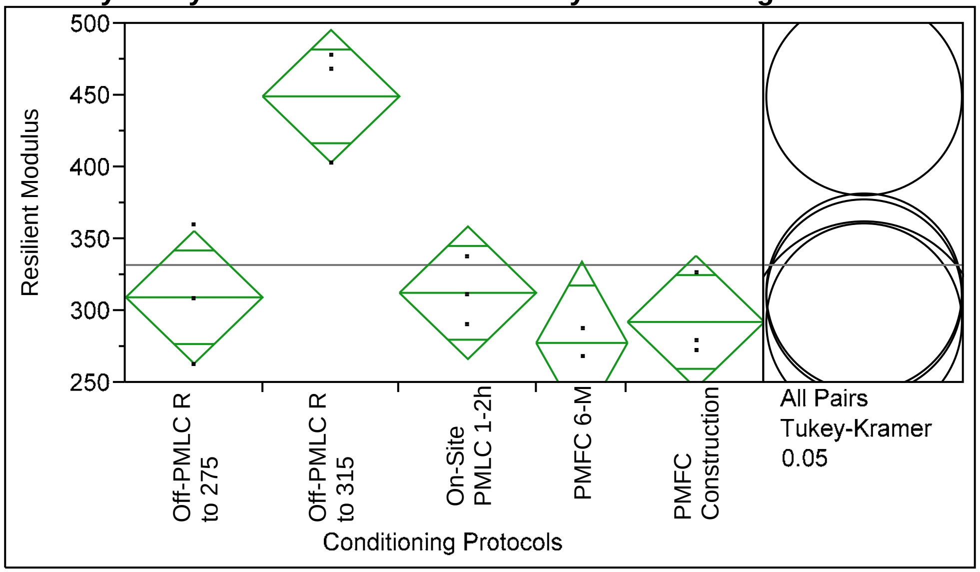
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMLC 4h@275	On-Site PMLC 1-2h	228.4600	17.78368	168.727	288.1929	<.0001*
PMLC 4h@275	PMFC Construction	226.7700	17.78368	167.037	286.5029	<.0001*
PMLC 16+2h@Tc	On-Site PMLC 1-2h	173.1500	17.78368	113.417	232.8829	<.0001*
PMLC 16+2h@Tc	PMFC Construction	171.4600	17.78368	111.727	231.1929	<.0001*
PMLC 4h@275	PMLC 0h@Tc	161.6367	17.78368	101.904	221.3696	<.0001*
PMLC 2h@Tc	On-Site PMLC 1-2h	121.3700	17.78368	61.637	181.1029	0.0002*
PMLC 2h@Tc	PMFC Construction	119.6800	17.78368	59.947	179.4129	0.0002*
PMLC 4h@275	PMLC 2h@Tc	107.0900	17.78368	47.357	166.8229	0.0007*
PMLC 16+2h@Tc	PMLC 0h@Tc	106.3267	17.78368	46.594	166.0596	0.0007*
PMLC 0h@Tc	On-Site PMLC 1-2h	66.8233	17.78368	7.090	126.5563	0.0255*
PMLC 0h@Tc	PMFC Construction	65.1333	17.78368	5.400	124.8663	0.0300*
PMLC 4h@275	PMLC 16+2h@Tc	55.3100	17.78368	-4.423	115.0429	0.0756
PMLC 2h@Tc	PMLC 0h@Tc	54.5467	17.78368	-5.186	114.2796	0.0811
PMLC 16+2h@Tc	PMLC 2h@Tc	51.7800	17.78368	-7.953	111.5129	0.1045
PMFC Construction	On-Site PMLC 1-2h	1.6900	17.78368	-58.043	61.4229	1.0000

Figure A.5 (a)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Missing Rows
1Excluded Rows
42

Oneway Anova

Summary of Fit

Rsquare	0.829322
Adj Rsquare	0.753464
Root Mean Square Error	35.33342
Mean of Response	332.1086
Observations (or Sum Wgts)	14

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**	**Prob > F**
Conditioning Protocols	4	54595.664	13648.9	10.9327	0.0017*
Error	9	11236.054	1248.5		
C. Total	13	65831.718			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-PMLC R to 275	3	309.693	20.400	263.55	355.84
Off-PMLC R to 315	3	449.570	20.400	403.42	495.72
On-Site PMLC 1-2h	3	312.790	20.400	266.64	358.94
PMFC 6-M	2	277.930	24.984	221.41	334.45
PMFC Construction	3	292.500	20.400	246.35	338.65

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.36258	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-PMLC R to 315	On-Site PMLC 1-2h	Off-PMLC R to 275	PMFC Construction	PMFC 6-M
Off-PMLC R to 315	-97.01	39.77	42.87	60.06	63.18
On-Site PMLC 1-2h	39.77	-97.01	-93.91	-76.72	-73.60
Off-PMLC R to 275	42.87	-93.91	-97.01	-79.82	-76.70
PMFC Construction	60.06	-76.72	-79.82	-97.01	-93.89
PMFC 6-M	63.18	-73.60	-76.70	-93.89	-118.81

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Off-PMLC R to 315	A		449.57000
On-Site PMLC 1-2h		B	312.79000
Off-PMLC R to 275		B	309.69333
PMFC Construction		B	292.50000
PMFC 6-M		B	277.93000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-PMLC R to 315	PMFC 6-M	171.6400	32.25485	63.1804	280.0996	0.0033*
Off-PMLC R to 315	PMFC Construction	157.0700	28.84962	60.0608	254.0792	0.0028*
Off-PMLC R to 315	Off-PMLC R to 275	139.8767	28.84962	42.8674	236.8859	0.0061*
Off-PMLC R to 315	On-Site PMLC 1-2h	136.7800	28.84962	39.7708	233.7892	0.0071*
On-Site PMLC 1-2h	PMFC 6-M	34.8600	32.25485	-73.5996	143.3196	0.8120
Off-PMLC R to 275	PMFC 6-M	31.7633	32.25485	-76.6963	140.2230	0.8557
On-Site PMLC 1-2h	PMFC Construction	20.2900	28.84962	-76.7192	117.2992	0.9506
Off-PMLC R to 275	PMFC Construction	17.1933	28.84962	-79.8159	114.2026	0.9723
PMFC Construction	PMFC 6-M	14.5700	32.25485	-93.8896	123.0296	0.9899
On-Site PMLC 1-2h	Off-PMLC R to 275	3.0967	28.84962	-93.9126	100.1059	1.0000

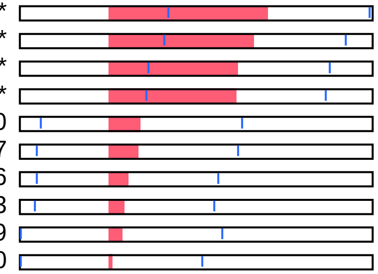
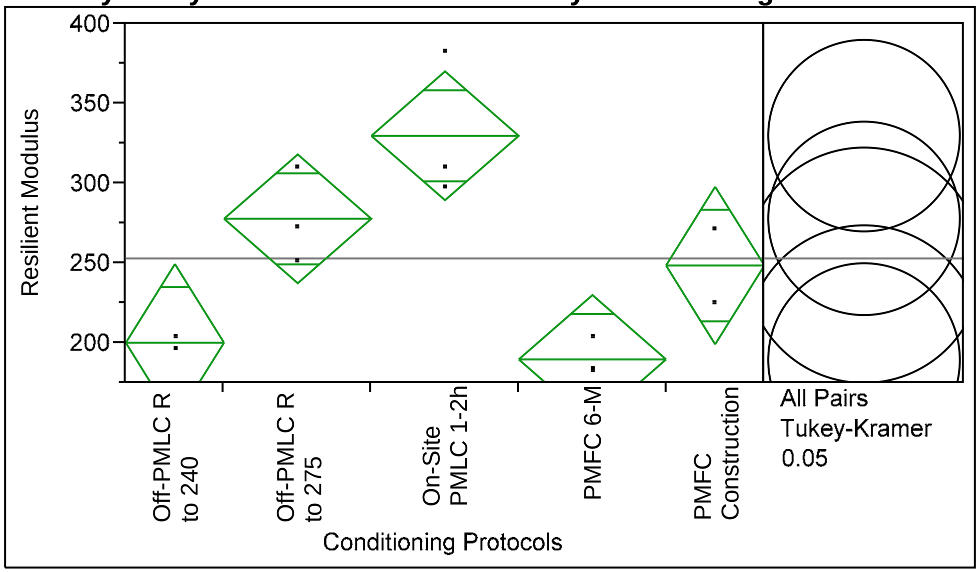


Figure A.5 (b)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Missing Rows
2Excluded Rows
42

Oneway Anova

Summary of Fit

Rsquare	0.83526
Adj Rsquare	0.752891
Root Mean Square Error	30.28369
Mean of Response	253.0692
Observations (or Sum Wgts)	13

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocols	4	37199.043	9299.76	10.1404	0.0032*
Error	8	7336.816	917.10		
C. Total	12	44535.858			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-PMLC R to 240	2	200.190	21.414	150.81	249.57
Off-PMLC R to 275	3	277.857	17.484	237.54	318.18
On-Site PMLC 1-2h	3	329.857	17.484	289.54	370.18
PMFC 6-M	3	189.733	17.484	149.41	230.05
PMFC Construction	2	248.590	21.414	199.21	297.97

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.45475	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	On-Site PMLC 1-2h	Off-PMLC R to 275	PMFC Construction	Off-PMLC R to 240	PMFC 6-M
On-Site PMLC 1-2h	-85.42	-33.42	-14.24	34.16	54.70
Off-PMLC R to 275	-33.42	-85.42	-66.24	-17.84	2.70
PMFC Construction	-14.24	-66.24	-104.62	-56.22	-36.65
Off-PMLC R to 240	34.16	-17.84	-56.22	-104.62	-85.05
PMFC 6-M	54.70	2.70	-36.65	-85.05	-85.42

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
On-Site PMLC 1-2h	A			329.85667
Off-PMLC R to 275	A	B		277.85667
PMFC Construction	A	B	C	248.59000
Off-PMLC R to 240		B	C	200.19000
PMFC 6-M			C	189.73333

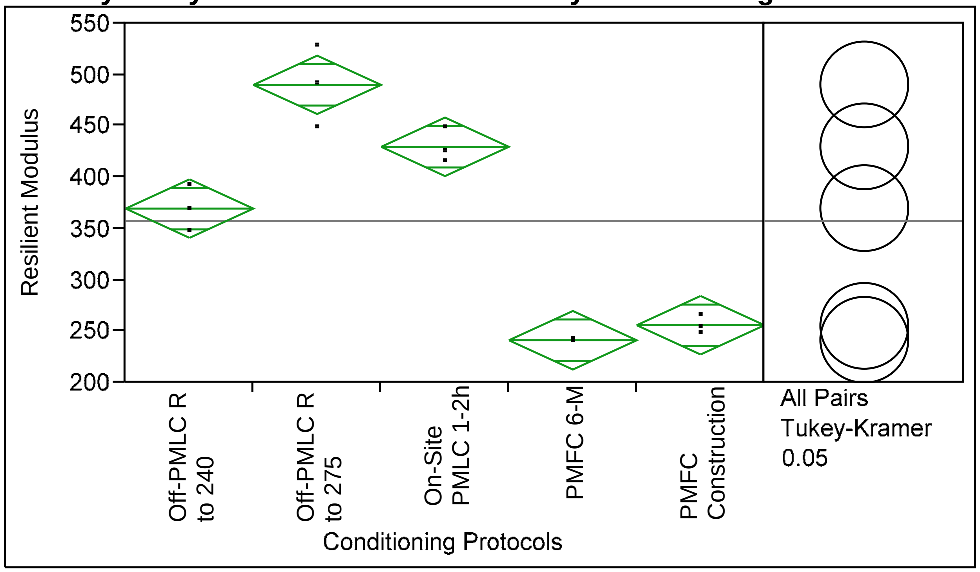
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
On-Site PMLC 1-2h	PMFC 6-M	140.1233	24.72653	54.6994	225.5473	0.0031*
On-Site PMLC 1-2h	Off-PMLC R to 240	129.6667	27.64510	34.1598	225.1735	0.0099*
Off-PMLC R to 275	PMFC 6-M	88.1233	24.72653	2.6994	173.5473	0.0431*
On-Site PMLC 1-2h	PMFC Construction	81.2667	27.64510	-14.2402	176.7735	0.1011
Off-PMLC R to 275	Off-PMLC R to 240	77.6667	27.64510	-17.8402	173.1735	0.1207
PMFC Construction	PMFC 6-M	58.8567	27.64510	-36.6502	154.3635	0.2949
On-Site PMLC 1-2h	Off-PMLC R to 275	52.0000	24.72653	-33.4239	137.4239	0.3045
PMFC Construction	Off-PMLC R to 240	48.4000	30.28369	-56.2225	153.0225	0.5365
Off-PMLC R to 275	PMFC Construction	29.2667	27.64510	-66.2402	124.7735	0.8220
Off-PMLC R to 240	PMFC 6-M	10.4567	27.64510	-85.0502	105.9635	0.9947

Figure A.5 (c)

Oneway Analysis of Resilient Modulus By Conditioning Protocols



Excluded Rows
42

Oneway Anova

Summary of Fit

Rsquare	0.966178
Adj Rsquare	0.952649
Root Mean Square Error	22.16782
Mean of Response	357.4733
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Conditioning Protocols	4	140377.87	35094.5	71.4155	<.0001*
Error	10	4914.12	491.4		
C. Total	14	145292.00			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-PMLC R to 240	3	369.663	12.799	341.15	398.18
Off-PMLC R to 275	3	490.327	12.799	461.81	518.84
On-Site PMLC 1-2h	3	429.887	12.799	401.37	458.40
PMFC 6-M	3	241.443	12.799	212.93	269.96
PMFC Construction	3	256.047	12.799	227.53	284.56

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.29108	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-PMLC R to 275	On-Site PMLC 1-2h	Off-PMLC R to 240	PMFC Construction	PMFC 6-M
Off-PMLC R to 275	-59.57	0.87	61.09	174.71	189.31
On-Site PMLC 1-2h	0.87	-59.57	0.65	114.27	128.87
Off-PMLC R to 240	61.09	0.65	-59.57	54.05	68.65
PMFC Construction	174.71	114.27	54.05	-59.57	-44.97
PMFC 6-M	189.31	128.87	68.65	-44.97	-59.57

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
Off-PMLC R to 275	A				490.32667
On-Site PMLC 1-2h		B			429.88667
Off-PMLC R to 240			C		369.66333
PMFC Construction				D	256.04667
PMFC 6-M				D	241.44333

Levels not connected by same letter are significantly different.

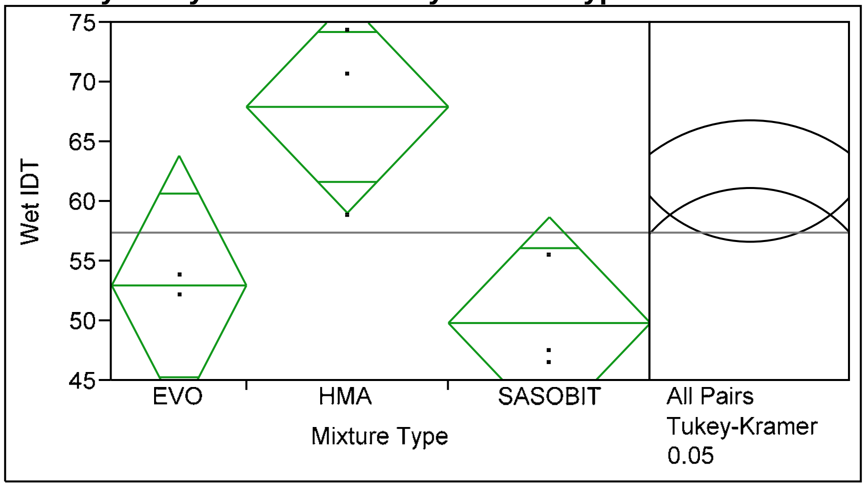
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-PMLC R to 275	PMFC 6-M	248.8833	18.09995	189.315	308.4518	<.0001*
Off-PMLC R to 275	PMFC Construction	234.2800	18.09995	174.712	293.8484	<.0001*
On-Site PMLC 1-2h	PMFC 6-M	188.4433	18.09995	128.875	248.0118	<.0001*
On-Site PMLC 1-2h	PMFC Construction	173.8400	18.09995	114.272	233.4084	<.0001*
Off-PMLC R to 240	PMFC 6-M	128.2200	18.09995	68.652	187.7884	0.0003*
Off-PMLC R to 275	Off-PMLC R to 240	120.6633	18.09995	61.095	180.2318	0.0004*
Off-PMLC R to 240	PMFC Construction	113.6167	18.09995	54.048	173.1851	0.0007*
Off-PMLC R to 275	On-Site PMLC 1-2h	60.4400	18.09995	0.872	120.0084	0.0464*
On-Site PMLC 1-2h	Off-PMLC R to 240	60.2233	18.09995	0.655	119.7918	0.0473*
PMFC Construction	PMFC 6-M	14.6033	18.09995	-44.965	74.1718	0.9227

Figure B.4 (a)

Cores@Const.

Oneway Analysis of Wet IDT By Mixture Type



Missing Rows
1

Oneway Anova
Summary of Fit

Rsquare	0.752513
Adj Rsquare	0.653518
Root Mean Square Error	5.982994
Mean of Response	57.42525
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	544.21254	272.106	7.6015	0.0305*
Error	5	178.98108	35.796		
C. Total	7	723.19362			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	2	52.9984	4.2306	42.123	63.874
HMA	3	67.9558	3.4543	59.076	76.835
SASOBIT	3	49.8459	3.4543	40.966	58.725

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	EVO	SASOBIT
HMA	-15.895	-2.814	2.214
EVO	-2.814	-19.468	-14.619
SASOBIT	2.214	-14.619	-15.895

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		67.955827
EVO	A	B	52.998405
SASOBIT		B	49.845904

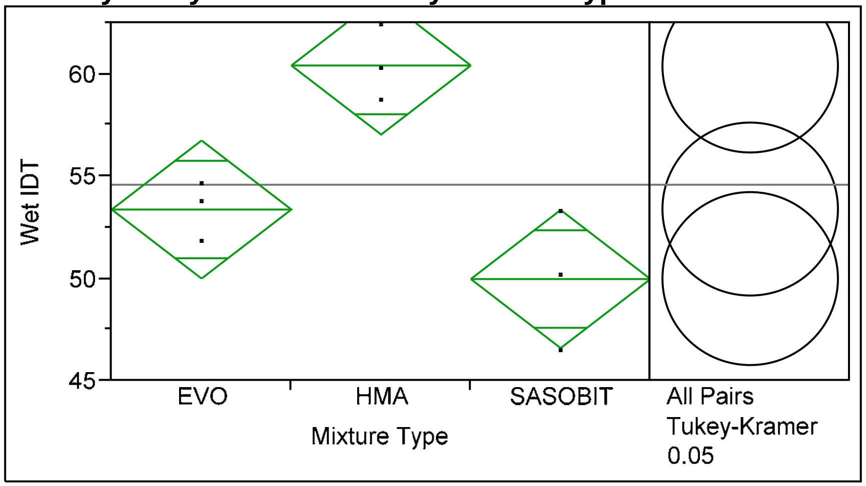
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	SASOBIT	18.10992	4.885094	2.2145	34.00535	0.0312*
HMA	EVO	14.95742	5.461701	-2.8142	32.72905	0.0882
EVO	SASOBIT	3.15250	5.461701	-14.6191	20.92413	0.8377

Cores@6M

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova

Summary of Fit

Rsquare	0.832556
Adj Rsquare	0.776741
Root Mean Square Error	2.389411
Mean of Response	54.60163
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	170.32420	85.1621	14.9164	0.0047*
Error	6	34.25572	5.7093		
C. Total	8	204.57992			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	53.3882	1.3795	50.013	56.764
HMA	3	60.4317	1.3795	57.056	63.807
SASOBIT	3	49.9850	1.3795	46.609	53.361

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	EVO	SASOBIT
HMA	-5.9858	1.0577	4.4608
EVO	1.0577	-5.9858	-2.5826
SASOBIT	4.4608	-2.5826	-5.9858

Positive values show pairs of means that are significantly different.

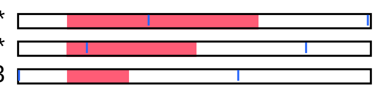
Connecting Letters Report

Level			Mean
HMA	A		60.431668
EVO		B	53.388197
SASOBIT		B	49.985033

Levels not connected by same letter are significantly different.

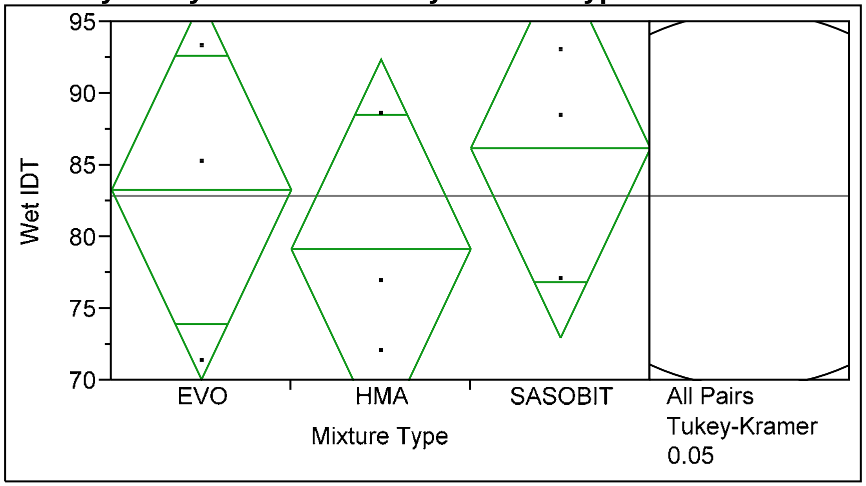
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	SASOBIT	10.44664	1.950946	4.46084	16.43243	0.0042*
HMA	EVO	7.04347	1.950946	1.05768	13.02927	0.0261*
EVO	SASOBIT	3.40316	1.950946	-2.58263	9.38896	0.2653



Cores@12M

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.124745
Adj Rsquare	-0.16701
Root Mean Square Error	9.360268
Mean of Response	82.90131
Observations (or Sum Wgts)	9

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**	**Prob > F**
Mixture Type	2	74.92316	37.4616	0.4276	0.6705
Error	6	525.68766	87.6146		
C. Total	8	600.61082			

Means for Oneway Anova

Level	**Number**	**Mean**	**Std Error**	**Lower 95%**	**Upper 95%**
EVO	3	83.3072	5.4042	70.084	96.531
HMA	3	79.1822	5.4042	65.959	92.406
SASOBIT	3	86.2146	5.4042	72.991	99.438

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	SASOBIT	EVO	HMA
SASOBIT	-23.449	-20.541	-16.416
EVO	-20.541	-23.449	-19.324
HMA	-16.416	-19.324	-23.449

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
SASOBIT	A	86.214570
EVO	A	83.307172
HMA	A	79.182174

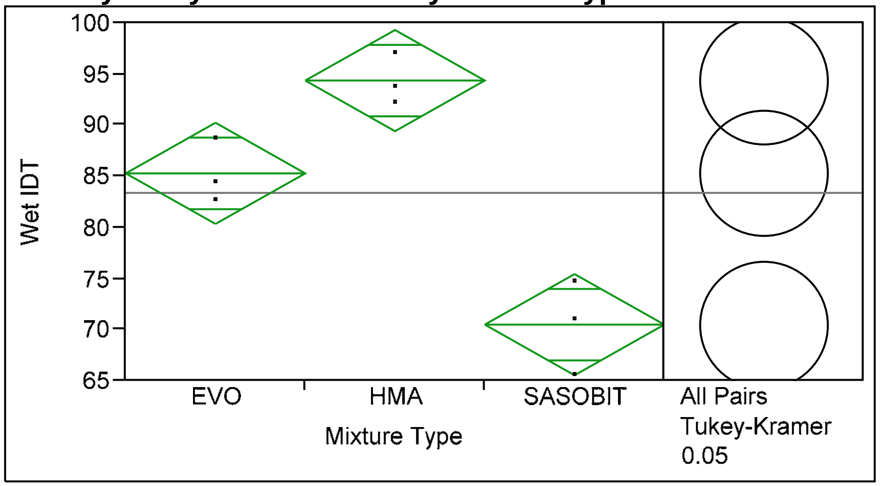
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
SASOBIT	HMA	7.032396	7.642626	-16.4163	30.48111	0.6485
EVO	HMA	4.124998	7.642626	-19.3237	27.57372	0.8553
SASOBIT	EVO	2.907398	7.642626	-20.5413	26.35612	0.9243

On-Site PMLC

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova

Summary of Fit

Rsquare	0.922102
Adj Rsquare	0.896136
Root Mean Square Error	3.503232
Mean of Response	83.40168
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	871.64761	435.824	35.5118	0.0005*
Error	6	73.63581	12.273		
C. Total	8	945.28342			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	85.3100	2.0226	80.361	90.259
HMA	3	94.3867	2.0226	89.438	99.336
SASOBIT	3	70.5084	2.0226	65.559	75.457

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	EVO	SASOBIT
HMA	-8.776	0.301	15.102
EVO	0.301	-8.776	6.026
SASOBIT	15.102	6.026	-8.776

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
HMA	A			94.386667
EVO		B		85.310000
SASOBIT			C	70.508364

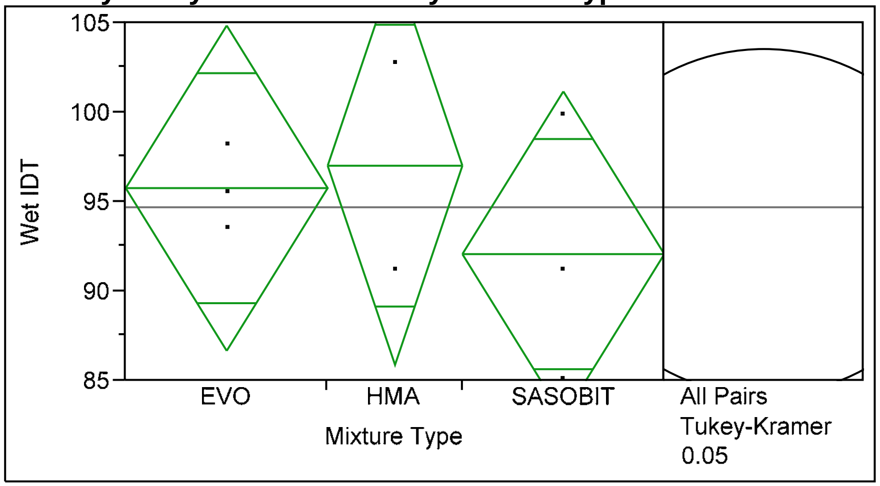
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	SASOBIT	23.87830	2.860377	15.10224	32.65437	0.0004*
EVO	SASOBIT	14.80164	2.860377	6.02557	23.57770	0.0050*
HMA	EVO	9.07667	2.860377	0.30060	17.85273	0.0440*

Off-Site PMLC

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.156496
Adj Rsquare	-0.18091
Root Mean Square Error	6.128127
Mean of Response	94.71002
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	34.83700	17.4185	0.4638	0.6535
Error	5	187.76973	37.5539		
C. Total	7	222.60673			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	95.7778	3.5381	86.683	104.87
HMA	2	97.0373	4.3332	85.898	108.18
SASOBIT	3	92.0906	3.5381	82.996	101.19

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	EVO	SASOBIT
HMA	-19.940	-16.943	-13.256
EVO	-16.943	-16.281	-12.594
SASOBIT	-13.256	-12.594	-16.281

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	97.037349
EVO	A	95.777834
SASOBIT	A	92.090644

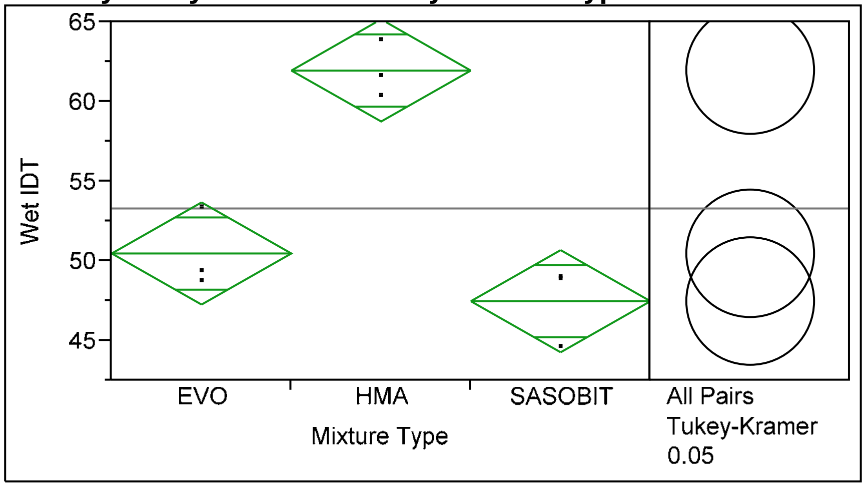
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	SASOBIT	4.946705	5.594189	-13.2560	23.14943	0.6723
EVO	SASOBIT	3.687190	5.003595	-12.5938	19.96820	0.7540
HMA	EVO	1.259515	5.594189	-16.9432	19.46224	0.9726

LMLC

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.919066
Adj Rsquare	0.892088
Root Mean Square Error	2.268325
Mean of Response	53.31778
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	350.57396	175.287	34.0674	0.0005*
Error	6	30.87180	5.145		
C. Total	8	381.44576			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	50.4867	1.3096	47.282	53.691
HMA	3	61.9733	1.3096	58.769	65.178
SASOBIT	3	47.4933	1.3096	44.289	50.698

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	EVO	SASOBIT
HMA	-5.6825	5.8042	8.7975
EVO	5.8042	-5.6825	-2.6891
SASOBIT	8.7975	-2.6891	-5.6825

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		61.973333
EVO		B	50.486667
SASOBIT		B	47.493333

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	SASOBIT	14.48000	1.852080	8.79754	20.16246	0.0006*
HMA	EVO	11.48667	1.852080	5.80421	17.16912	0.0020*
EVO	SASOBIT	2.99333	1.852080	-2.68912	8.67579	0.3099

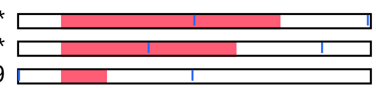
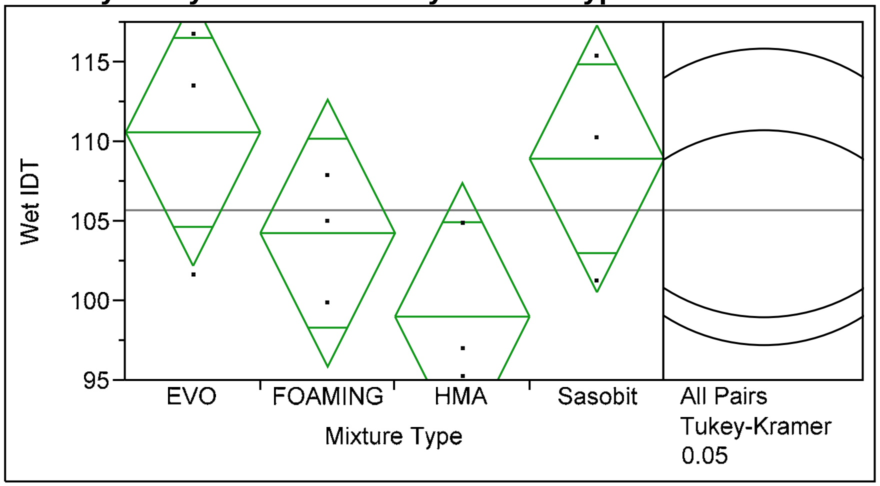


Figure B.5 (a)

Cores@Const.

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.433808
Adj Rsquare	0.221486
Root Mean Square Error	6.300915
Mean of Response	105.7258
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	3	243.35009	81.1167	2.0432	0.1864
Error	8	317.61220	39.7015		
C. Total	11	560.96229			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	110.617	3.6378	102.23	119.01
FOAMING	3	104.283	3.6378	95.89	112.67
HMA	3	99.043	3.6378	90.65	107.43
Sasobit	3	108.960	3.6378	100.57	117.35

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	EVO	Sasobit	FOAMING	HMA
EVO	-16.475	-14.818	-10.142	-4.902
Sasobit	-14.818	-16.475	-11.798	-6.558
FOAMING	-10.142	-11.798	-16.475	-11.235
HMA	-4.902	-6.558	-11.235	-16.475

Positive values show pairs of means that are significantly different.

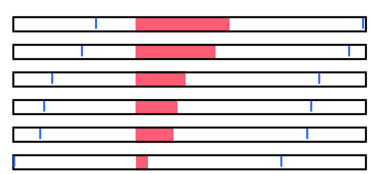
Connecting Letters Report

Level		Mean
EVO	A	110.61667
Sasobit	A	108.96000
FOAMING	A	104.28333
HMA	A	99.04333

Levels not connected by same letter are significantly different.

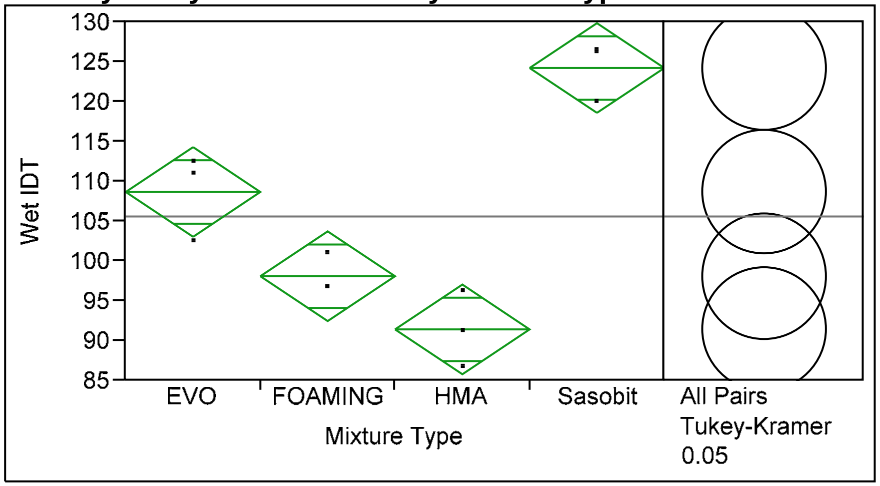
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
EVO	HMA	11.57333	5.144675	-4.9017	28.04835	0.1897
Sasobit	HMA	9.91667	5.144675	-6.5584	26.39169	0.2897
EVO	FOAMING	6.33333	5.144675	-10.1417	22.80835	0.6262
FOAMING	HMA	5.24000	5.144675	-11.2350	21.71502	0.7439
Sasobit	FOAMING	4.67667	5.144675	-11.7984	21.15169	0.8009
EVO	Sasobit	1.65667	5.144675	-14.8184	18.13169	0.9876



Cores@6M

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova

Summary of Fit

Rsquare	0.928097
Adj Rsquare	0.901133
Root Mean Square Error	4.224104
Mean of Response	105.6308
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	3	1842.4902	614.163	34.4203	<.0001*
Error	8	142.7445	17.843		
C. Total	11	1985.2347			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	108.700	2.4388	103.08	114.32
FOAMING	3	98.120	2.4388	92.50	103.74
HMA	3	91.443	2.4388	85.82	97.07

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	124.260	2.4388	118.64	129.88

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Sasobit	EVO	FOAMING	HMA
Sasobit	-11.045	4.515	15.095	21.772
EVO	4.515	-11.045	-0.465	6.212
FOAMING	15.095	-0.465	-11.045	-4.368
HMA	21.772	6.212	-4.368	-11.045

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Sasobit	A		124.26000
EVO	B		108.70000
FOAMING	B	C	98.12000
HMA		C	91.44333

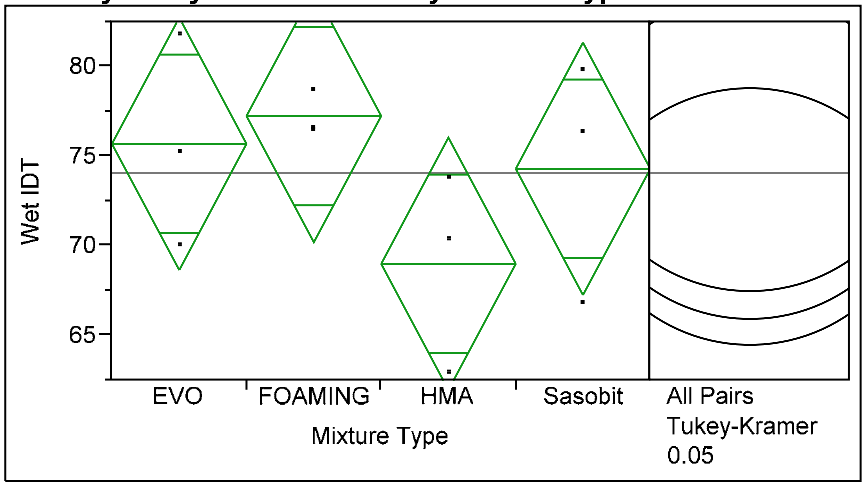
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Sasobit	HMA	32.81667	3.448967	21.7719	43.86145	<.0001*
Sasobit	FOAMING	26.14000	3.448967	15.0952	37.18478	0.0003*
EVO	HMA	17.25667	3.448967	6.2119	28.30145	0.0046*
Sasobit	EVO	15.56000	3.448967	4.5152	26.60478	0.0085*
EVO	FOAMING	10.58000	3.448967	-0.4648	21.62478	0.0605
FOAMING	HMA	6.67667	3.448967	-4.3681	17.72145	0.2867

On-Site PMLC

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.34014
Adj Rsquare	0.092693
Root Mean Square Error	5.294344
Mean of Response	74.0875
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	3	115.59022	38.5301	1.3746	0.3186
Error	8	224.24060	28.0301		
C. Total	11	339.83083			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	75.7233	3.0567	68.675	82.772
FOAMING	3	77.2733	3.0567	70.225	84.322
HMA	3	69.0233	3.0567	61.975	76.072

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	74.3300	3.0567	67.281	81.379

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	FOAMING	EVO	Sasobit	HMA
FOAMING	-13.843	-12.293	-10.900	-5.593
EVO	-12.293	-13.843	-12.450	-7.143
Sasobit	-10.900	-12.450	-13.843	-8.536
HMA	-5.593	-7.143	-8.536	-13.843

Positive values show pairs of means that are significantly different.

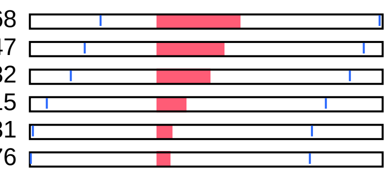
Connecting Letters Report

Level		Mean
FOAMING	A	77.273333
EVO	A	75.723333
Sasobit	A	74.330000
HMA	A	69.023333

Levels not connected by same letter are significantly different.

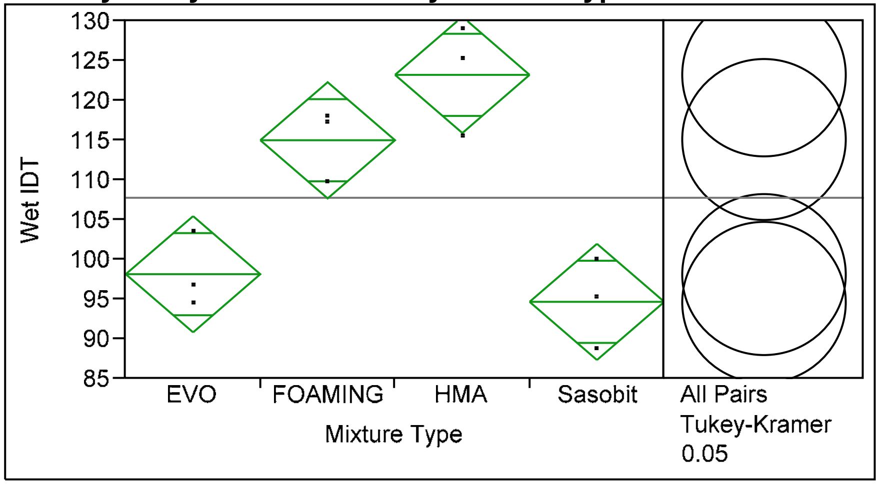
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
FOAMING	HMA	8.250000	4.322814	-5.5931	22.09314	0.2968
EVO	HMA	6.700000	4.322814	-7.1431	20.54314	0.4547
Sasobit	HMA	5.306667	4.322814	-8.5365	19.14980	0.6282
FOAMING	Sasobit	2.943333	4.322814	-10.8998	16.78647	0.9015
FOAMING	EVO	1.550000	4.322814	-12.2931	15.39314	0.9831
EVO	Sasobit	1.393333	4.322814	-12.4498	15.23647	0.9876



Off-Site PMLC

Oneway Analysis of Wet IDT By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.873558
Adj Rsquare	0.826142
Root Mean Square Error	5.488492
Mean of Response	107.7883
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	3	1664.9342	554.978	18.4234	0.0006*
Error	8	240.9883	30.124		
C. Total	11	1905.9226			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	98.180	3.1688	90.87	105.49
FOAMING	3	115.027	3.1688	107.72	122.33
HMA	3	123.247	3.1688	115.94	130.55

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	94.700	3.1688	87.39	102.01

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	FOAMING	EVO	Sasobit
HMA	-14.351	-6.131	10.716	14.196
FOAMING	-6.131	-14.351	2.496	5.976
EVO	10.716	2.496	-14.351	-10.871
Sasobit	14.196	5.976	-10.871	-14.351

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		123.24667
FOAMING	A		115.02667
EVO		B	98.18000
Sasobit		B	94.70000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Sasobit	28.54667	4.481335	14.1959	42.89744	0.0010*
HMA	EVO	25.06667	4.481335	10.7159	39.41744	0.0023*
FOAMING	Sasobit	20.32667	4.481335	5.9759	34.67744	0.0083*
FOAMING	EVO	16.84667	4.481335	2.4959	31.19744	0.0231*
HMA	FOAMING	8.22000	4.481335	-6.1308	22.57078	0.3257
EVO	Sasobit	3.48000	4.481335	-10.8708	17.83078	0.8630

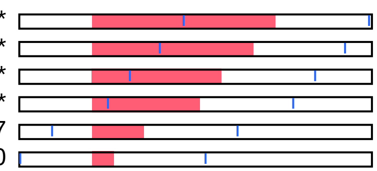
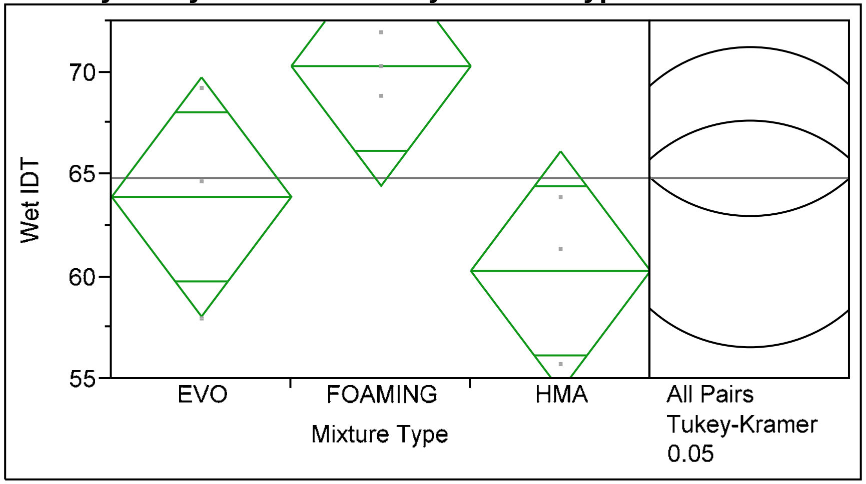


Figure B.6 (a)

Cores@Const.

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
6

Oneway Anova
Summary of Fit

Rsquare	0.599662
Adj Rsquare	0.466216
Root Mean Square Error	4.142988
Mean of Response	64.83694
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	154.26189	77.1309	4.4937	0.0642
Error	6	102.98609	17.1643		
C. Total	8	257.24798			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	63.9124	2.3920	58.059	69.765
FOAMING	3	70.3062	2.3920	64.453	76.159
HMA	3	60.2923	2.3920	54.439	66.145

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	FOAMING	EVO	HMA
FOAMING	-10.379	-3.985	-0.365
EVO	-3.985	-10.379	-6.759
HMA	-0.365	-6.759	-10.379

Positive values show pairs of means that are significantly different.

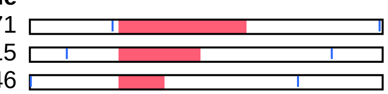
Connecting Letters Report

Level		Mean
FOAMING	A	70.306150
EVO	A	63.912360
HMA	A	60.292325

Levels not connected by same letter are significantly different.

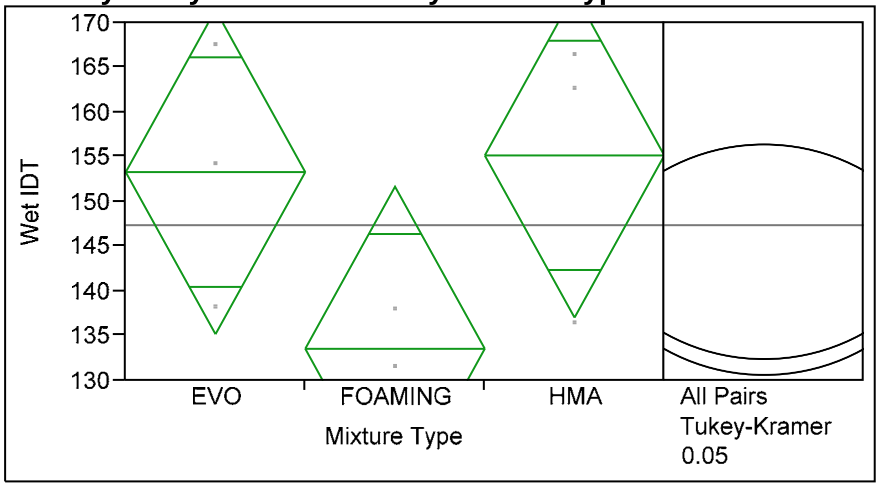
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
FOAMING	HMA	10.01382	3.382735	-0.36491	20.39256	0.0571
FOAMING	EVO	6.39379	3.382735	-3.98495	16.77253	0.2215
EVO	HMA	3.62003	3.382735	-6.75870	13.99877	0.5646



Cores@8M

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
6

Oneway Anova

Summary of Fit

Rsquare	0.465589
Adj Rsquare	0.287452
Root Mean Square Error	12.83445
Mean of Response	147.3936
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	861.0602	430.530	2.6137	0.1526
Error	6	988.3394	164.723		
C. Total	8	1849.3996			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	153.360	7.4100	135.23	171.49
FOAMING	3	133.602	7.4100	115.47	151.73

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	155.218	7.4100	137.09	173.35

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	EVO	FOAMING
HMA	-32.152	-30.294	-10.536
EVO	-30.294	-32.152	-12.394
FOAMING	-10.536	-12.394	-32.152

Positive values show pairs of means that are significantly different.

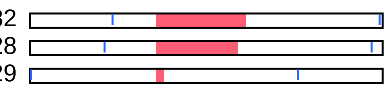
Connecting Letters Report

Level		Mean
HMA	A	155.21802
EVO	A	153.36043
FOAMING	A	133.60246

Levels not connected by same letter are significantly different.

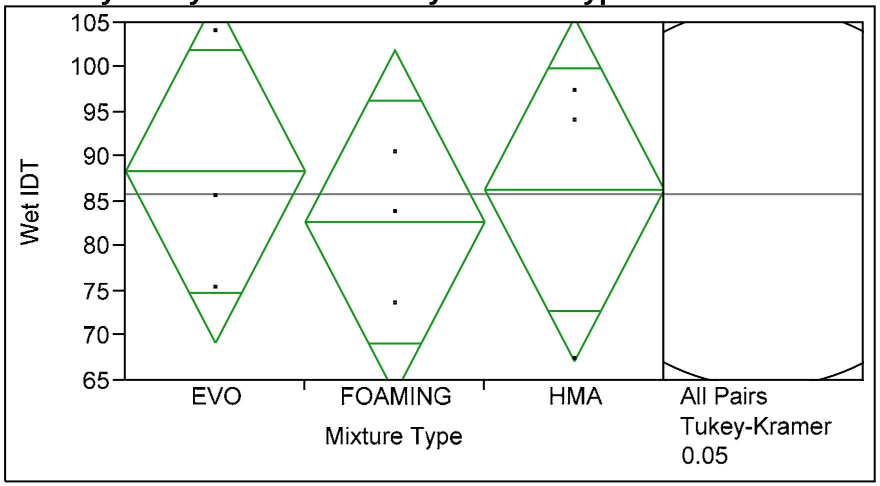
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	FOAMING	21.61556	10.47929	-10.5365	53.76758	0.1782
EVO	FOAMING	19.75797	10.47929	-12.3941	51.90999	0.2228
HMA	EVO	1.85759	10.47929	-30.2944	34.00961	0.9829



On-Site PMLC

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
6

Oneway Anova

Summary of Fit

Rsquare	0.042651
Adj Rsquare	-0.27647
Root Mean Square Error	13.58406
Mean of Response	85.86209
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	49.3251	24.663	0.1337	0.8774
Error	6	1107.1599	184.527		
C. Total	8	1156.4850			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	88.4340	7.8428	69.244	107.62
FOAMING	3	82.7707	7.8428	63.580	101.96

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	86.3815	7.8428	67.191	105.57

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	EVO	HMA	FOAMING
EVO	-34.030	-31.977	-28.366
HMA	-31.977	-34.030	-30.419
FOAMING	-28.366	-30.419	-34.030

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
EVO	A	88.434049
HMA	A	86.381541
FOAMING	A	82.770665

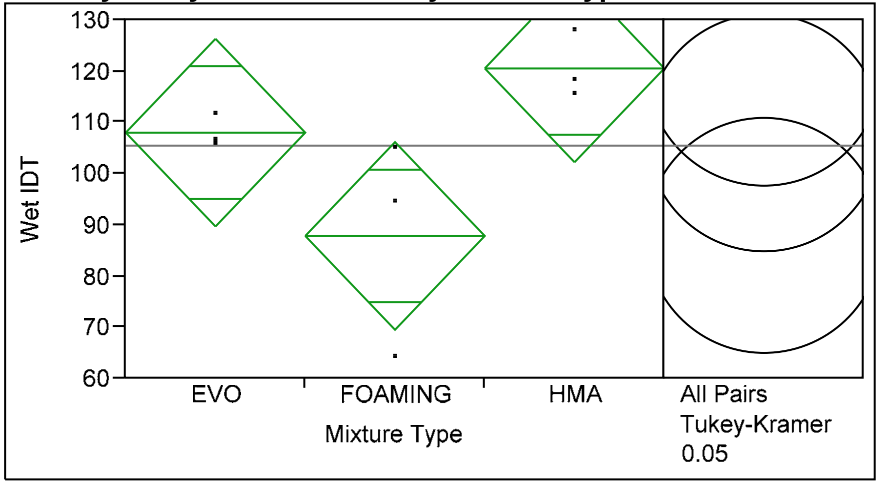
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
EVO	FOAMING	5.663384	11.09134	-28.3665	39.69326	0.8691
HMA	FOAMING	3.610875	11.09134	-30.4190	37.64075	0.9438
EVO	HMA	2.052509	11.09134	-31.9774	36.08239	0.9814

Off-Site PMLC

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
6

Oneway Anova

Summary of Fit

Rsquare	0.618157
Adj Rsquare	0.490875
Root Mean Square Error	12.97453
Mean of Response	105.5195
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	1635.1122	817.556	4.8566	0.0557
Error	6	1010.0301	168.338		
C. Total	8	2645.1423			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	108.065	7.4908	89.74	126.39
FOAMING	3	87.886	7.4908	69.56	106.22

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	120.607	7.4908	102.28	138.94

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	EVO	FOAMING
HMA	-32.503	-19.961	0.218
EVO	-19.961	-32.503	-12.325
FOAMING	0.218	-12.325	-32.503

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		120.60709
EVO	A	B	108.06488
FOAMING		B	87.88649

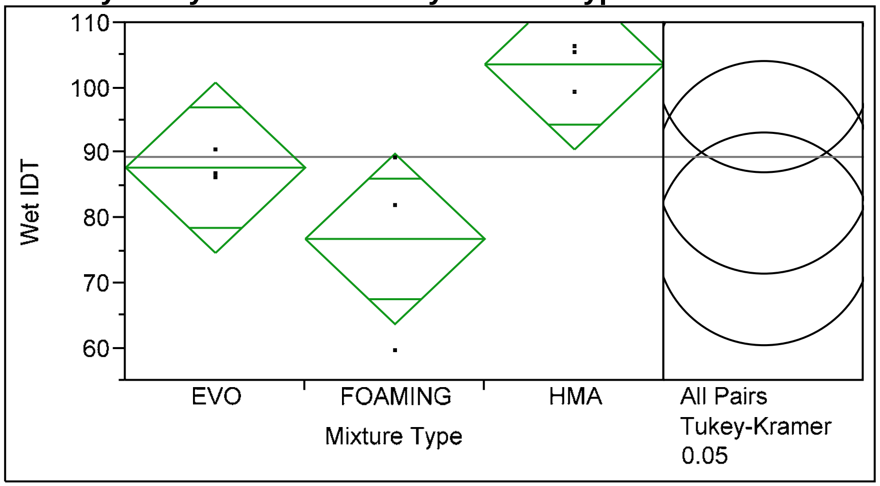
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	FOAMING	32.72060	10.59366	0.2177	65.22352	0.0488*
EVO	FOAMING	20.17839	10.59366	-12.3245	52.68131	0.2175
HMA	EVO	12.54221	10.59366	-19.9607	45.04514	0.5037

LMLC

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
6

Oneway Anova

Summary of Fit

Rsquare	0.678907
Adj Rsquare	0.571877
Root Mean Square Error	9.274147
Mean of Response	89.43111
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	1091.1375	545.569	6.3431	0.0331*
Error	6	516.0588	86.010		
C. Total	8	1607.1963			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	87.787	5.3544	74.685	100.89
FOAMING	3	76.843	5.3544	63.742	89.95

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	103.663	5.3544	90.562	116.77

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	EVO	FOAMING
HMA	-23.233	-7.356	3.587
EVO	-7.356	-23.233	-12.290
FOAMING	3.587	-12.290	-23.233

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		103.66333
EVO	A	B	87.78667
FOAMING		B	76.84333

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	FOAMING	26.82000	7.572309	3.5870	50.05298	0.0283*
HMA	EVO	15.87667	7.572309	-7.3563	39.10964	0.1707
EVO	FOAMING	10.94333	7.572309	-12.2896	34.17631	0.3787

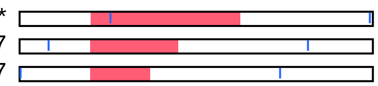
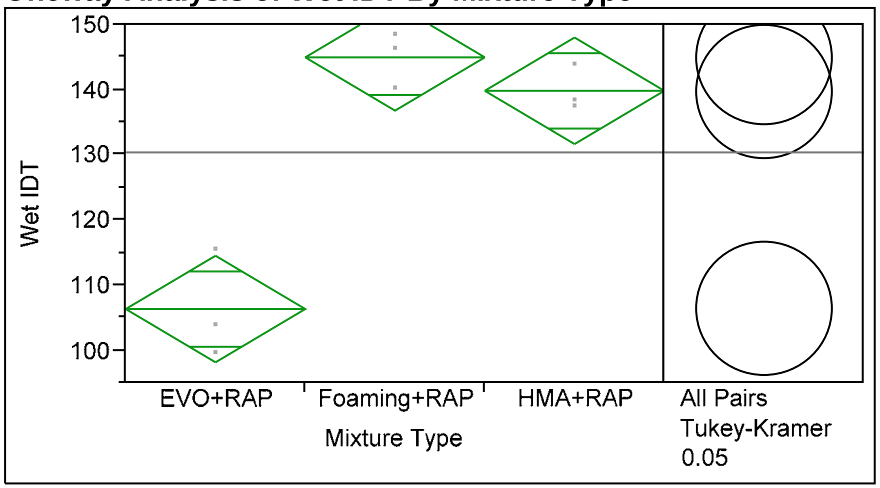


Figure B.7 (a)

Cores@Const.

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.929291
Adj Rsquare	0.905721
Root Mean Square Error	5.792662
Mean of Response	130.4089
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	2645.9631	1322.98	39.4273	0.0004*
Error	6	201.3296	33.55		
C. Total	8	2847.2927			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO+RAP	3	106.343	3.3444	98.16	114.53
Foaming+RAP	3	145.017	3.3444	136.83	153.20
HMA+RAP	3	139.867	3.3444	131.68	148.05

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	HMA+RAP	EVO+RAP
Foaming+RAP	-14.511	-9.361	24.162
HMA+RAP	-9.361	-14.511	19.012
EVO+RAP	24.162	19.012	-14.511

Positive values show pairs of means that are significantly different.

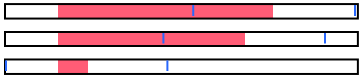
Connecting Letters Report

Level			Mean
Foaming+RAP	A		145.01667
HMA+RAP	A		139.86667
EVO+RAP		B	106.34333

Levels not connected by same letter are significantly different.

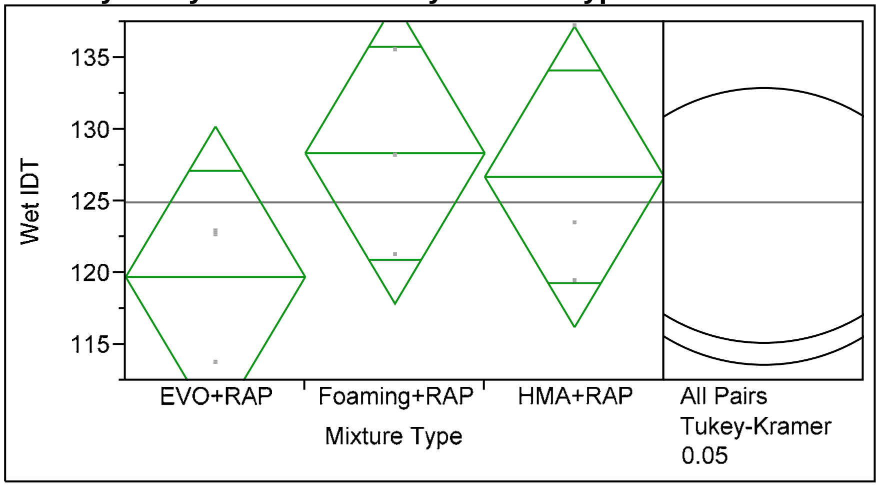
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	EVO+RAP	38.67333	4.729689	24.1619	53.18472	0.0004*
HMA+RAP	EVO+RAP	33.52333	4.729689	19.0119	48.03472	0.0010*
Foaming+RAP	HMA+RAP	5.15000	4.729689	-9.3614	19.66139	0.5544



On-Site PMLC

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.275713
Adj Rsquare	0.034284
Root Mean Square Error	7.429145
Mean of Response	124.94
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	126.05947	63.0297	1.1420	0.3800
Error	6	331.15313	55.1922		
C. Total	8	457.21260			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO+RAP	3	119.733	4.2892	109.24	130.23
Foaming+RAP	3	128.367	4.2892	117.87	138.86

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	126.720	4.2892	116.22	137.22

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	HMA+RAP	EVO+RAP
Foaming+RAP	-18.611	-16.964	-9.978
HMA+RAP	-16.964	-18.611	-11.624
EVO+RAP	-9.978	-11.624	-18.611

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming+RAP	A	128.36667
HMA+RAP	A	126.72000
EVO+RAP	A	119.73333

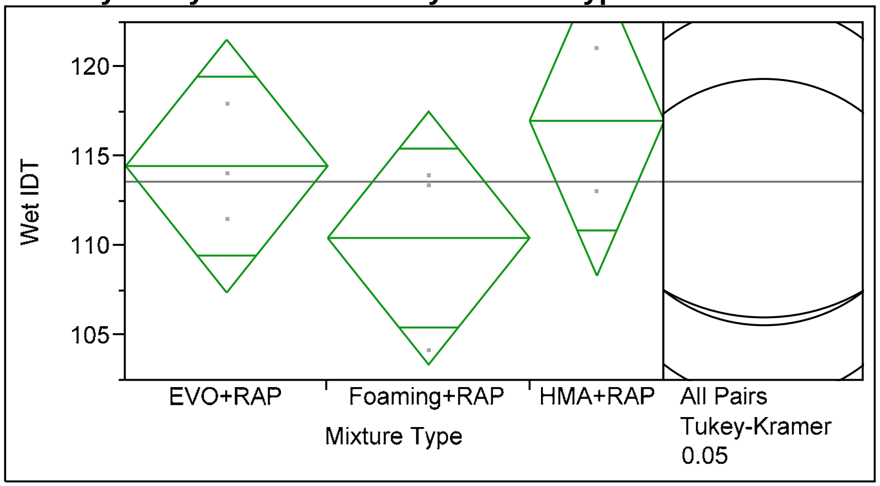
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	EVO+RAP	8.633333	6.065871	-9.9777	27.24433	0.3882
HMA+RAP	EVO+RAP	6.986667	6.065871	-11.6243	25.59767	0.5206
Foaming+RAP	HMA+RAP	1.646667	6.065871	-16.9643	20.25767	0.9605

Off-Site PMLC

Oneway Analysis of Wet IDT By Mixture Type



Missing Rows
1Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.327129
Adj Rsquare	0.057981
Root Mean Square Error	4.764247
Mean of Response	113.6363
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	55.17552	27.5878	1.2154	0.3714
Error	5	113.49027	22.6981		
C. Total	7	168.66579			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO+RAP	3	114.513	2.7506	107.44	121.58

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Foaming+RAP	3	110.490	2.7506	103.42	117.56
HMA+RAP	2	117.040	3.3688	108.38	125.70

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA+RAP	EVO+RAP	Foaming+RAP
HMA+RAP	-15.502	-11.625	-7.602
EVO+RAP	-11.625	-12.658	-8.634
Foaming+RAP	-7.602	-8.634	-12.658

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA+RAP	A	117.04000
EVO+RAP	A	114.51333
Foaming+RAP	A	110.49000

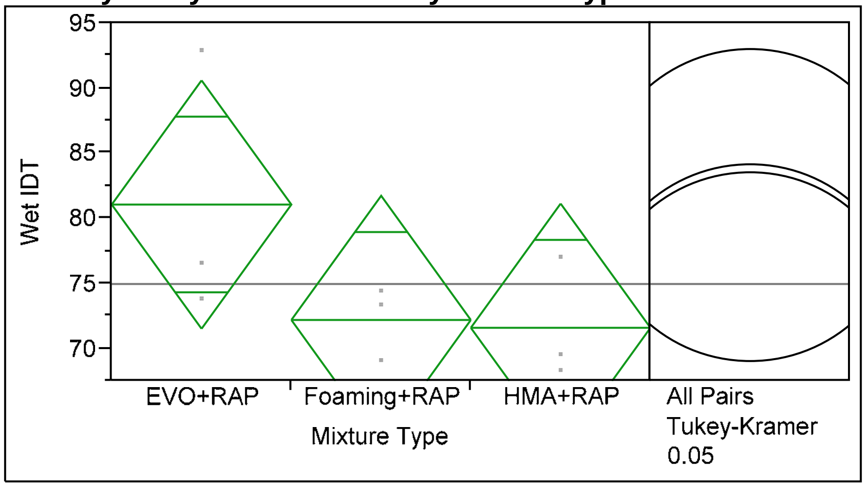
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA+RAP	Foaming+RAP	6.550000	4.349143	-7.6015	20.70152	0.3641
EVO+RAP	Foaming+RAP	4.023333	3.889992	-8.6342	16.68083	0.5896
HMA+RAP	EVO+RAP	2.526667	4.349143	-11.6248	16.67818	0.8358

LMLC

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.381188
Adj Rsquare	0.174917
Root Mean Square Error	6.757733
Mean of Response	74.94889
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	168.78496	84.3925	1.8480	0.2370
Error	6	274.00173	45.6670		
C. Total	8	442.78669			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO+RAP	3	81.0633	3.9016	71.517	90.610
Foaming+RAP	3	72.1933	3.9016	62.647	81.740

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	71.5900	3.9016	62.043	81.137

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	EVO+RAP	Foaming+RAP	HMA+RAP
EVO+RAP	-16.929	-8.059	-7.456
Foaming+RAP	-8.059	-16.929	-16.326
HMA+RAP	-7.456	-16.326	-16.929

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
EVO+RAP	A	81.063333
Foaming+RAP	A	72.193333
HMA+RAP	A	71.590000

Levels not connected by same letter are significantly different.

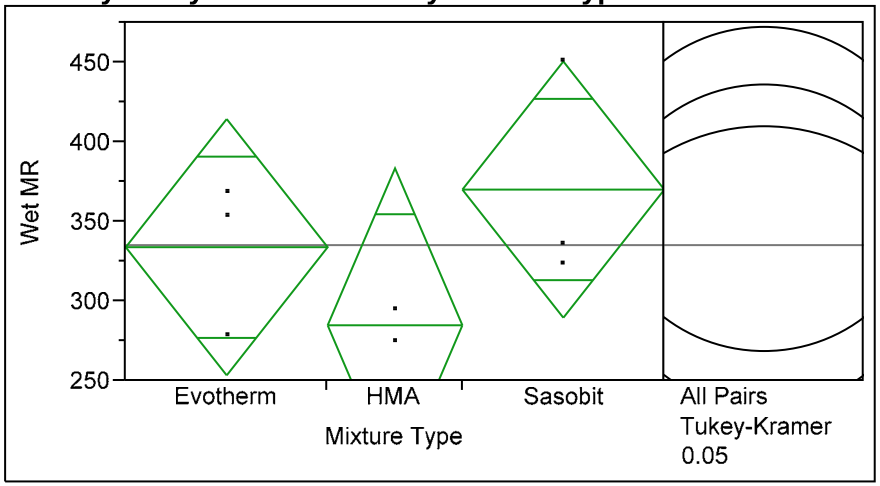
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
EVO+RAP	HMA+RAP	9.473333	5.517666	-7.4557	26.40236	0.2744
EVO+RAP	Foaming+RAP	8.870000	5.517666	-8.0590	25.79902	0.3131
Foaming+RAP	HMA+RAP	0.603333	5.517666	-16.3257	17.53236	0.9934

Figure B.8 (a)

On-Site PMLC

Oneway Analysis of Wet MR By Mixture Type



Missing Rows
1

Oneway Anova

Summary of Fit

Rsquare	0.372502
Adj Rsquare	0.121503
Root Mean Square Error	54.2586
Mean of Response	335.3413
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	8738.237	4369.12	1.4841	0.3119
Error	5	14719.977	2944.00		
C. Total	7	23458.214			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	334.013	31.326	253.49	414.54
HMA	2	284.963	38.367	186.34	383.59
Sasobit	3	370.255	31.326	289.73	450.78

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Sasobit	Evotherm	HMA
Sasobit	-144.15	-107.91	-75.87
Evotherm	-107.91	-144.15	-112.12
HMA	-75.87	-112.12	-176.55

Positive values show pairs of means that are significantly different.

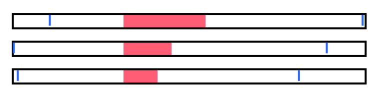
Connecting Letters Report

Level		Mean
Sasobit	A	370.25500
Evotherm	A	334.01333
HMA	A	284.96250

Levels not connected by same letter are significantly different.

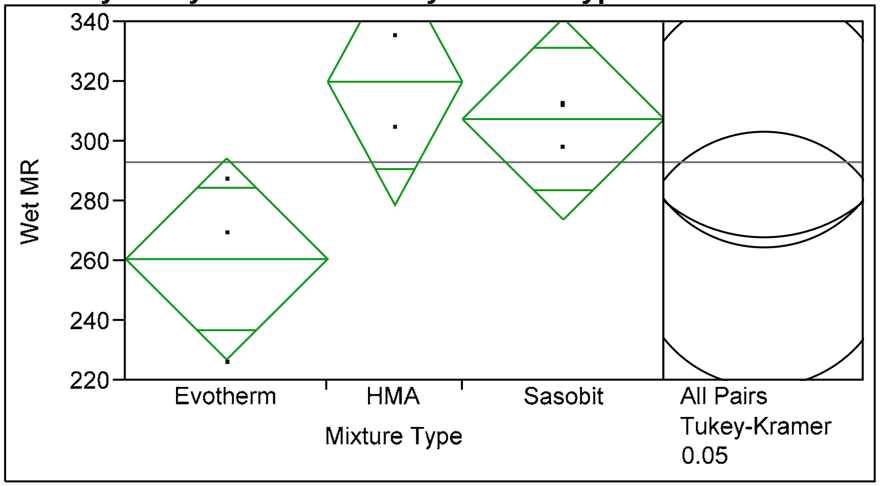
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Sasobit	HMA	85.29250	49.53110	-75.875	246.4599	0.2857
Evotherm	HMA	49.05083	49.53110	-112.117	210.2182	0.6136
Sasobit	Evotherm	36.24167	44.30196	-107.911	180.3942	0.7092



Off-Site PMLC

Oneway Analysis of Wet MR By Mixture Type



Oneway Anova

Summary of Fit

Rsquare	0.669552
Adj Rsquare	0.537372
Root Mean Square Error	22.71076
Mean of Response	293.1494
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	5225.3295	2612.66	5.0655	0.0628
Error	5	2578.8932	515.78		
C. Total	7	7804.2227			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	260.750	13.112	227.04	294.46
HMA	2	320.073	16.059	278.79	361.35
Sasobit	3	307.600	13.112	273.89	341.31

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-73.898	-54.987	-8.137
Sasobit	-54.987	-60.337	-13.487
Evotherm	-8.137	-13.487	-60.337

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	320.07250
Sasobit	A	307.60000
Evotherm	A	260.75000

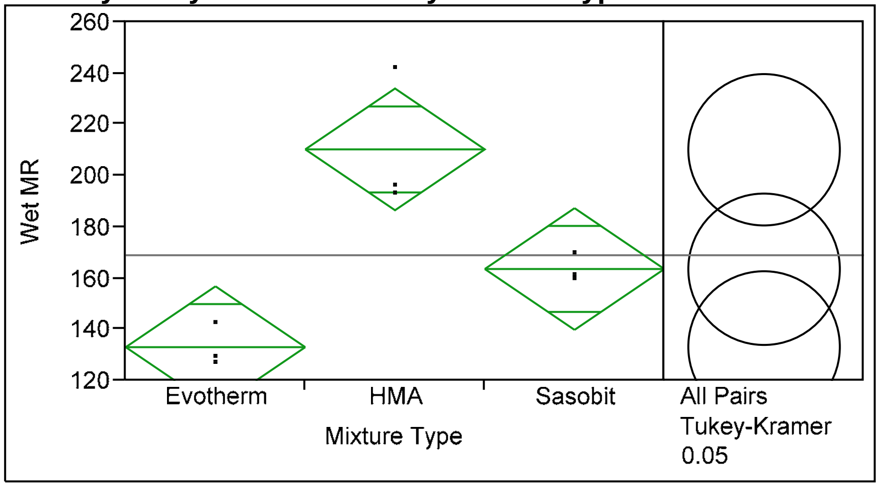
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	59.32250	20.73199	-8.1366	126.7816	0.0768
Sasobit	Evotherm	46.85000	18.54326	-13.4872	107.1872	0.1124
HMA	Sasobit	12.47250	20.73199	-54.9866	79.9316	0.8255

LMLC

Oneway Analysis of Wet MR By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.842304
Adj Rsquare	0.789739
Root Mean Square Error	16.82512
Mean of Response	169.0372
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	9072.290	4536.14	16.0240	0.0039*
Error	6	1698.509	283.08		
C. Total	8	10770.799			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	133.127	9.7140	109.36	156.90
HMA	3	210.335	9.7140	186.57	234.10
Sasobit	3	163.650	9.7140	139.88	187.42

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-42.149	4.536	35.059
Sasobit	4.536	-42.149	-11.626
Evotherm	35.059	-11.626	-42.149

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		210.33500
Sasobit		B	163.65000
Evotherm		B	133.12667

Levels not connected by same letter are significantly different.

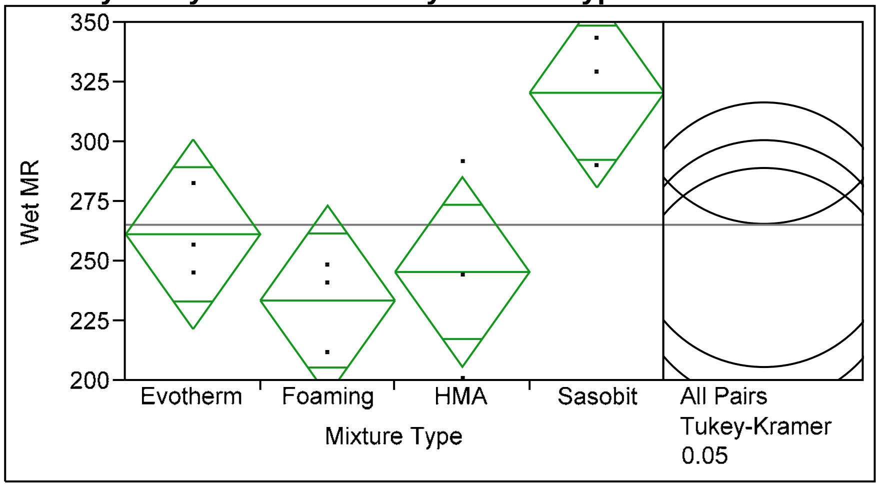
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	77.20833	13.73766	35.0592	119.3575	0.0033*
HMA	Sasobit	46.68500	13.73766	4.5358	88.8342	0.0335*
Sasobit	Evotherm	30.52333	13.73766	-11.6258	72.6725	0.1456

Figure B.9 (a)

On-Site PMLC

Oneway Analysis of Wet MR By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.652998
Adj Rsquare	0.522872
Root Mean Square Error	29.8496
Mean of Response	265.38
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	3	13413.633	4471.21	5.0182	0.0303*
Error	8	7127.989	891.00		
C. Total	11	20541.622			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	261.427	17.234	221.69	301.17
Foaming	3	233.707	17.234	193.97	273.45
HMA	3	245.658	17.234	205.92	285.40
Sasobit	3	320.728	17.234	280.99	360.47

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Sasobit	Evotherm	HMA	Foaming
Sasobit	-78.048	-18.746	-2.978	8.974
Evotherm	-18.746	-78.048	-62.280	-50.328
HMA	-2.978	-62.280	-78.048	-66.096
Foaming	8.974	-50.328	-66.096	-78.048

Positive values show pairs of means that are significantly different.

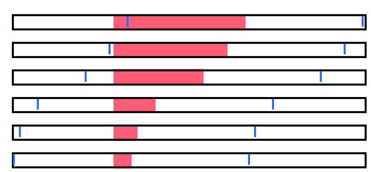
Connecting Letters Report

Level			Mean
Sasobit	A		320.72833
Evotherm	A	B	261.42667
HMA	A	B	245.65833
Foaming		B	233.70667

Levels not connected by same letter are significantly different.

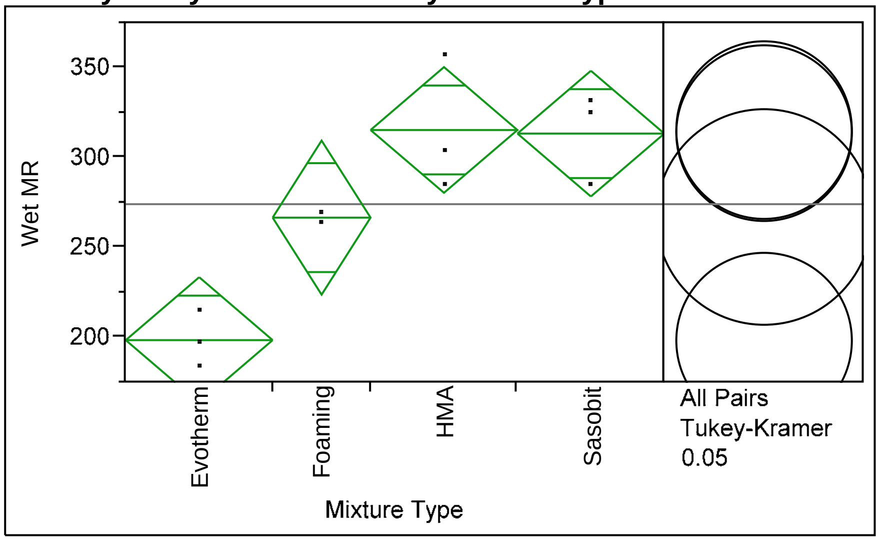
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Sasobit	Foaming	87.02167	24.37210	8.9738	165.0695	0.0299*
Sasobit	HMA	75.07000	24.37210	-2.9778	153.1178	0.0594
Sasobit	Evotherm	59.30167	24.37210	-18.7462	137.3495	0.1475
Evotherm	Foaming	27.72000	24.37210	-50.3278	105.7678	0.6787
Evotherm	HMA	15.76833	24.37210	-62.2795	93.8162	0.9137
HMA	Foaming	11.95167	24.37210	-66.0962	89.9995	0.9591



Off-Site PMLC

Oneway Analysis of Wet MR By Mixture Type



Missing Rows
1

Oneway Anova

Summary of Fit

Rsquare	0.854423
Adj Rsquare	0.792032
Root Mean Square Error	25.65169
Mean of Response	274.3059
Observations (or Sum Wgts)	11

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	3	27033.893	9011.30	13.6948	0.0026*
Error	7	4606.065	658.01		
C. Total	10	31639.958			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	198.667	14.810	163.65	233.69
Foaming	2	266.820	18.138	223.93	309.71
HMA	3	315.635	14.810	280.61	350.66
Sasobit	3	313.607	14.810	278.59	348.63

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.31014	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Foaming	Evotherm
HMA	-69.329	-67.301	-28.697	47.639
Sasobit	-67.301	-69.329	-30.726	45.611
Foaming	-28.697	-30.726	-84.911	-9.359
Evotherm	47.639	45.611	-9.359	-69.329

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		315.63500
Sasobit	A		313.60667
Foaming	A	B	266.82000
Evotherm		B	198.66667

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	116.9683	20.94452	47.6391	186.2976	0.0035*
Sasobit	Evotherm	114.9400	20.94452	45.6107	184.2693	0.0039*
Foaming	Evotherm	68.1533	23.41668	-9.3591	145.6658	0.0842
HMA	Foaming	48.8150	23.41668	-28.6975	126.3275	0.2460
Sasobit	Foaming	46.7867	23.41668	-30.7258	124.2991	0.2739
HMA	Sasobit	2.0283	20.94452	-67.3009	71.3576	0.9996

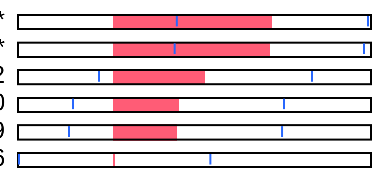
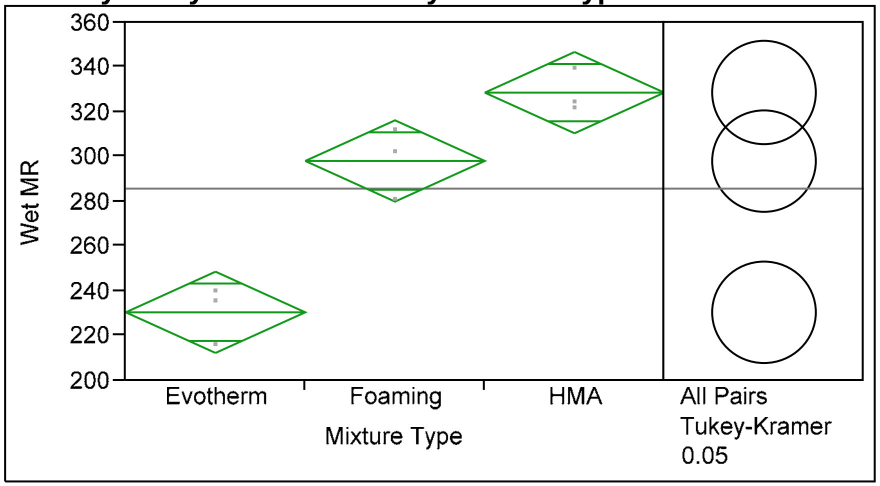


Figure B.10 (a)

On-Site PMLC

Oneway Analysis of Wet MR By Mixture Type



Excluded Rows
6

Oneway Anova

Summary of Fit

Rsquare	0.93861
Adj Rsquare	0.918146
Root Mean Square Error	12.8438
Mean of Response	285.9206
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	15132.988	7566.49	45.8678	0.0002*
Error	6	989.779	164.96		
C. Total	8	16122.767			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	230.677	7.4154	212.53	248.82
Foaming	3	298.270	7.4154	280.13	316.41
HMA	3	328.815	7.4154	310.67	346.96

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-32.175	-1.630	65.963
Foaming	-1.630	-32.175	35.418
Evotherm	65.963	35.418	-32.175

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		328.81500
Foaming	A		298.27000
Evotherm		B	230.67667

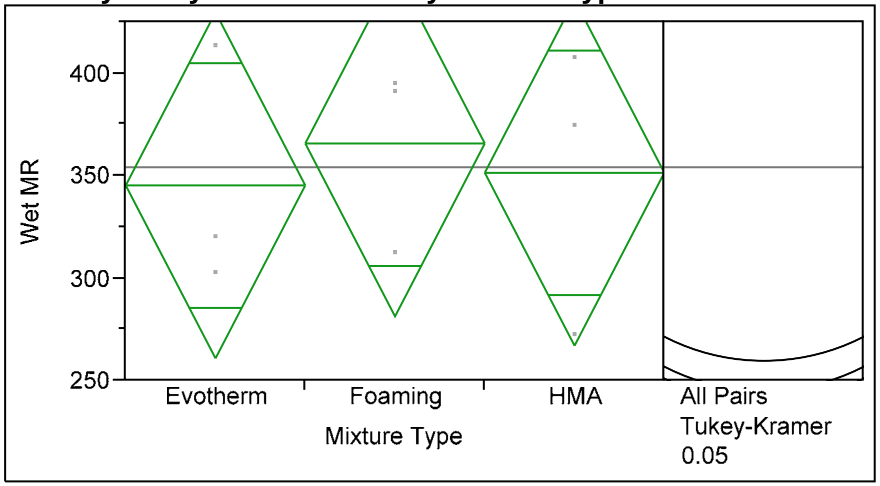
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	98.13833	10.48692	65.9629	130.3138	0.0002*
Foaming	Evotherm	67.59333	10.48692	35.4179	99.7688	0.0016*
HMA	Foaming	30.54500	10.48692	-1.6304	62.7204	0.0606

Off-Site PMLC

Oneway Analysis of Wet MR By Mixture Type



Excluded Rows
6

Oneway Anova

Summary of Fit

Rsquare	0.03001
Adj Rsquare	-0.29332
Root Mean Square Error	59.77561
Mean of Response	354.2239
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	663.292	331.65	0.0928	0.9126
Error	6	21438.742	3573.12		
C. Total	8	22102.034			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	345.335	34.511	260.89	429.78
Foaming	3	365.830	34.511	281.38	450.28

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	351.507	34.511	267.06	435.95

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming	HMA	Evotherm
Foaming	-149.75	-135.42	-129.25
HMA	-135.42	-149.75	-143.57
Evotherm	-129.25	-143.57	-149.75

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming	A	365.83000
HMA	A	351.50667
Evotherm	A	345.33500

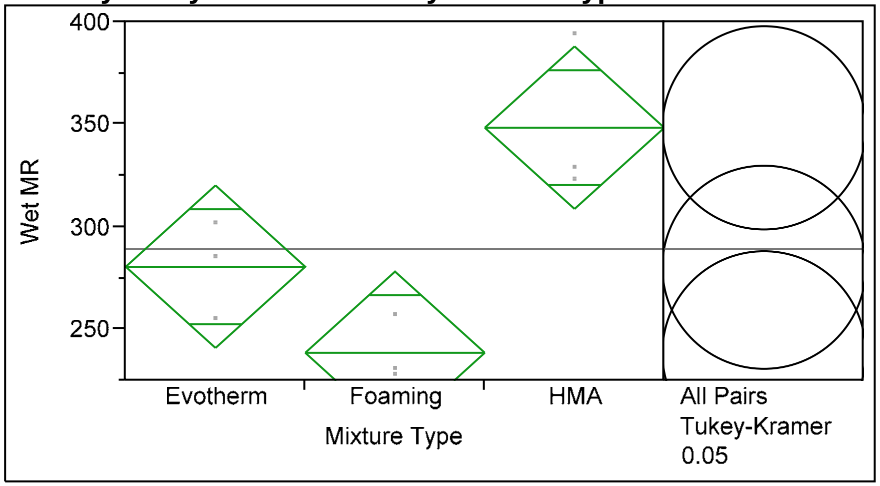
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming	Evotherm	20.49500	48.80658	-129.251	170.2409	0.9088
Foaming	HMA	14.32333	48.80658	-135.423	164.0692	0.9540
HMA	Evotherm	6.17167	48.80658	-143.574	155.9175	0.9912

LMLC

Oneway Analysis of Wet MR By Mixture Type



Excluded Rows
6

Oneway Anova

Summary of Fit

Rsquare	0.795795
Adj Rsquare	0.727727
Root Mean Square Error	28.09312
Mean of Response	289.2817
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	18453.842	9226.92	11.6911	0.0085*
Error	6	4735.342	789.22		
C. Total	8	23189.183			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	280.658	16.220	240.97	320.35
Foaming	3	238.640	16.220	198.95	278.33

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	348.547	16.220	308.86	388.23

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Foaming
HMA	-70.377	-2.489	39.530
Evotherm	-2.489	-70.377	-28.359
Foaming	39.530	-28.359	-70.377

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		348.54667
Evotherm	A	B	280.65833
Foaming		B	238.64000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Foaming	109.9067	22.93794	39.5296	180.2837	0.0072*
HMA	Evotherm	67.8883	22.93794	-2.4887	138.2654	0.0572
Evotherm	Foaming	42.0183	22.93794	-28.3587	112.3954	0.2382

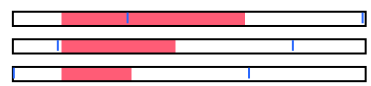
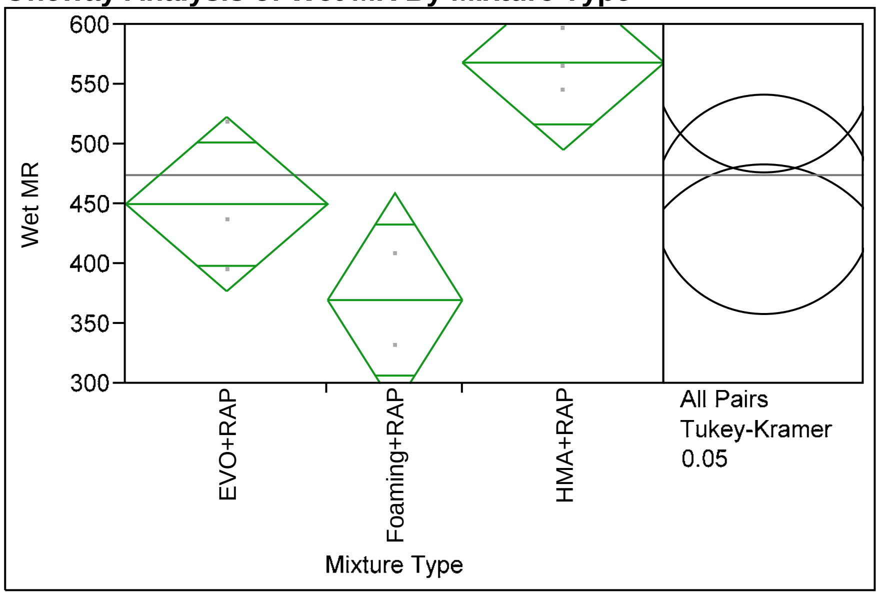


Figure B.11 (a)

On-Site PMLC

Oneway Analysis of Wet MR By Mixture Type



Missing Rows
1Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.805791
Adj Rsquare	0.728107
Root Mean Square Error	49.12304
Mean of Response	474.4713
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	50060.324	25030.2	10.3727	0.0166*

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Error	5	12065.365	2413.1		
C. Total	7	62125.688			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO+RAP	3	450.197	28.361	377.29	523.10
Foaming+RAP	2	370.000	34.735	280.71	459.29
HMA+RAP	3	568.393	28.361	495.49	641.30

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA+RAP	EVO+RAP	Foaming+RAP
HMA+RAP	-130.51	-12.31	52.48
EVO+RAP	-12.31	-130.51	-65.72
Foaming+RAP	52.48	-65.72	-159.84

Positive values show pairs of means that are significantly different.

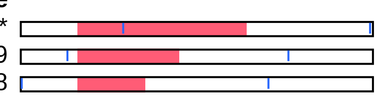
Connecting Letters Report

Level			Mean
HMA+RAP	A		568.39333
EVO+RAP	A	B	450.19667
Foaming+RAP		B	370.00000

Levels not connected by same letter are significantly different.

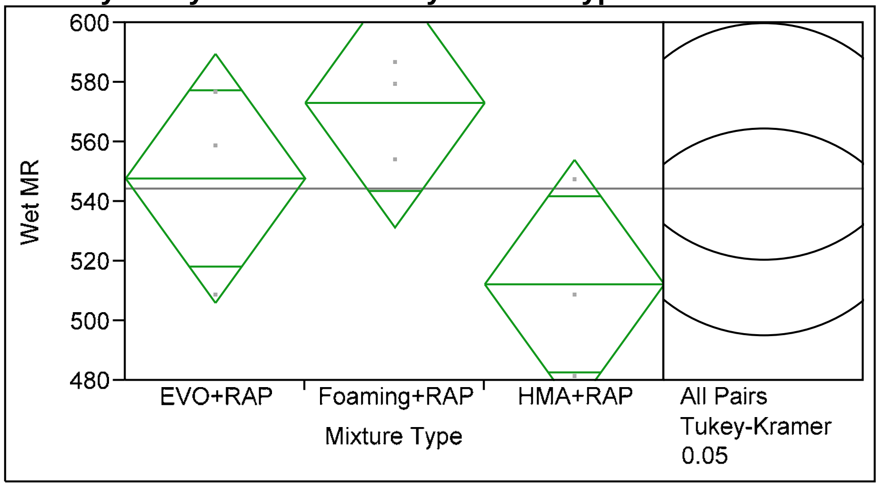
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA+RAP	Foaming+RAP	198.3933	44.84299	52.4804	344.3063	0.0157*
HMA+RAP	EVO+RAP	118.1967	40.10879	-12.3119	248.7052	0.0699
EVO+RAP	Foaming+RAP	80.1967	44.84299	-65.7163	226.1096	0.2648



Off-Site PMLC

Oneway Analysis of Wet MR By Mixture Type



Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.516562
Adj Rsquare	0.355416
Root Mean Square Error	29.57604
Mean of Response	544.5322
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	5608.065	2804.03	3.2056	0.1130
Error	6	5248.454	874.74		
C. Total	8	10856.519			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO+RAP	3	547.937	17.076	506.15	589.72
Foaming+RAP	3	573.260	17.076	531.48	615.04

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	512.400	17.076	470.62	554.18

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	EVO+RAP	HMA+RAP
Foaming+RAP	-74.092	-48.769	-13.232
EVO+RAP	-48.769	-74.092	-38.555
HMA+RAP	-13.232	-38.555	-74.092

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming+RAP	A	573.26000
EVO+RAP	A	547.93667
HMA+RAP	A	512.40000

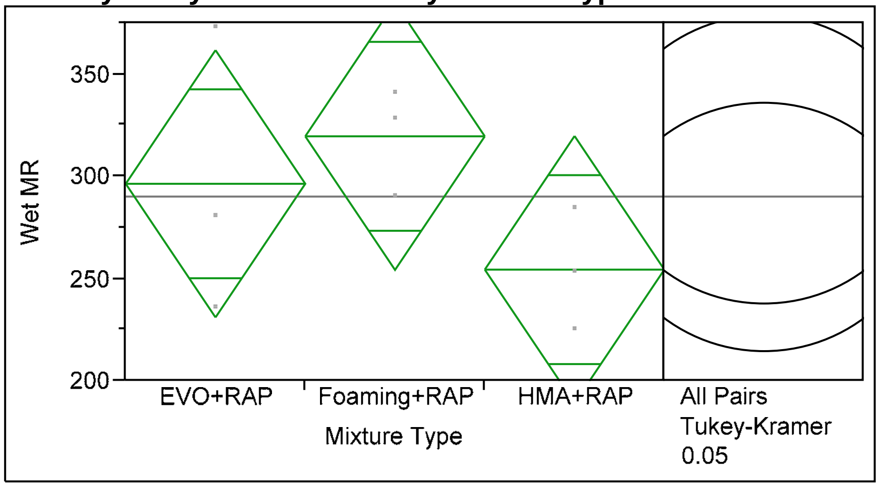
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	HMA+RAP	60.86000	24.14874	-13.2319	134.9519	0.0995
EVO+RAP	HMA+RAP	35.53667	24.14874	-38.5553	109.6286	0.3673
Foaming+RAP	EVO+RAP	25.32333	24.14874	-48.7686	99.4153	0.5764

LMLC

Oneway Analysis of Wet MR By Mixture Type



Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.337873
Adj Rsquare	0.117164
Root Mean Square Error	46.2572
Mean of Response	290.2167
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	6551.225	3275.61	1.5309	0.2903
Error	6	12838.373	2139.73		
C. Total	8	19389.598			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO+RAP	3	296.470	26.707	231.12	361.82
Foaming+RAP	3	319.687	26.707	254.34	385.04

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	254.493	26.707	189.14	319.84

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	EVO+RAP	HMA+RAP
Foaming+RAP	-115.88	-92.66	-50.69
EVO+RAP	-92.66	-115.88	-73.90
HMA+RAP	-50.69	-73.90	-115.88

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming+RAP	A	319.68667
EVO+RAP	A	296.47000
HMA+RAP	A	254.49333

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	HMA+RAP	65.19333	37.76885	-50.6871	181.0738	0.2713
EVO+RAP	HMA+RAP	41.97667	37.76885	-73.9038	157.8571	0.5422
Foaming+RAP	EVO+RAP	23.21667	37.76885	-92.6638	139.0971	0.8177

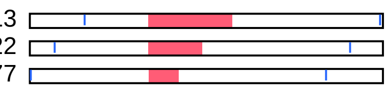
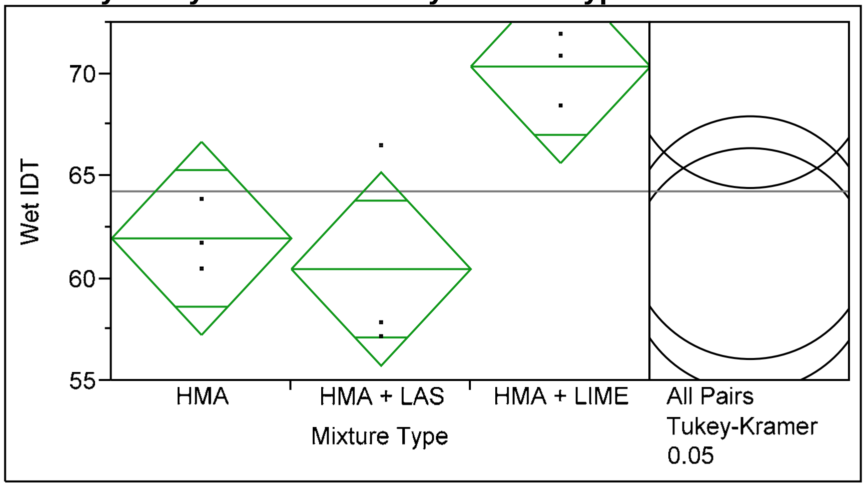


Figure B.33 (a)

HMA+RAP

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.717852
Adj Rsquare	0.623802
Root Mean Square Error	3.345146
Mean of Response	64.26667
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	170.82000	85.4100	7.6327	0.0225*
Error	6	67.14000	11.1900		
C. Total	8	237.96000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	61.9667	1.9313	57.241	66.692
HMA + LAS	3	60.4667	1.9313	55.741	65.192
HMA + LIME	3	70.3667	1.9313	65.641	75.092

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA + LIME	HMA	HMA + LAS
HMA + LIME	-8.3800	0.0200	1.5200
HMA	0.0200	-8.3800	-6.8800
HMA + LAS	1.5200	-6.8800	-8.3800

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA + LIME	A		70.366667
HMA		B	61.966667
HMA + LAS		B	60.466667

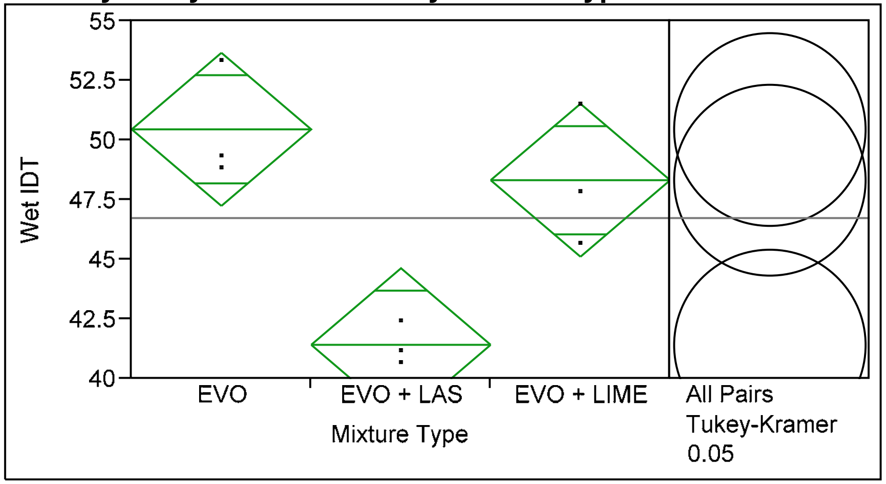
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA + LIME	HMA + LAS	9.900000	2.731300	1.51996	18.28004	0.0257*
HMA + LIME	HMA	8.400000	2.731300	0.01996	16.78004	0.0496*
HMA	HMA + LAS	1.500000	2.731300	-6.88004	9.88004	0.8507

Evotherm3G+RAP

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.812146
Adj Rsquare	0.749528
Root Mean Square Error	2.27083
Mean of Response	46.74444
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	133.76222	66.8811	12.9698	0.0066*
Error	6	30.94000	5.1567		
C. Total	8	164.70222			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	50.4667	1.3111	47.259	53.675
EVO + LAS	3	41.4333	1.3111	38.225	44.641

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO + LIME	3	48.3333	1.3111	45.125	51.541

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	EVO	EVO + LIME	EVO + LAS
EVO	-5.6887	-3.5554	3.3446
EVO + LIME	-3.5554	-5.6887	1.2113
EVO + LAS	3.3446	1.2113	-5.6887

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
EVO	A		50.466667
EVO + LIME	A		48.333333
EVO + LAS		B	41.433333

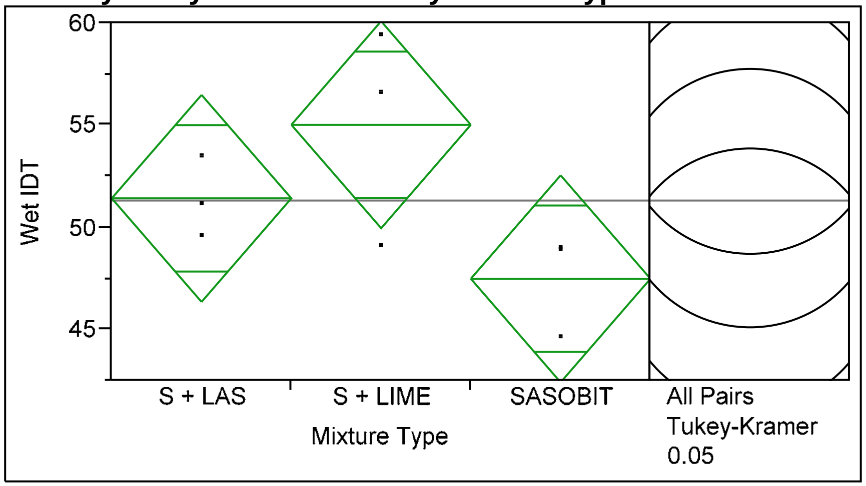
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
EVO	EVO + LAS	9.033333	1.854125	3.34460	14.72206	0.0067*
EVO + LIME	EVO + LAS	6.900000	1.854125	1.21127	12.58873	0.0229*
EVO	EVO + LIME	2.133333	1.854125	-3.55540	7.82206	0.5212

Sasobit+RAP

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.525117
Adj Rsquare	0.366823
Root Mean Square Error	3.58314
Mean of Response	51.32222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	85.18222	42.5911	3.3174	0.1071
Error	6	77.03333	12.8389		
C. Total	8	162.21556			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
S + LAS	3	51.4333	2.0687	46.371	56.495
S + LIME	3	55.0333	2.0687	49.971	60.095

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
SASOBIT	3	47.5000	2.0687	42.438	52.562

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	S + LIME	S + LAS	SASOBIT
S + LIME	-8.9762	-5.3762	-1.4429
S + LAS	-5.3762	-8.9762	-5.0429
SASOBIT	-1.4429	-5.0429	-8.9762

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
S + LIME	A	55.033333
S + LAS	A	51.433333
SASOBIT	A	47.500000

Levels not connected by same letter are significantly different.

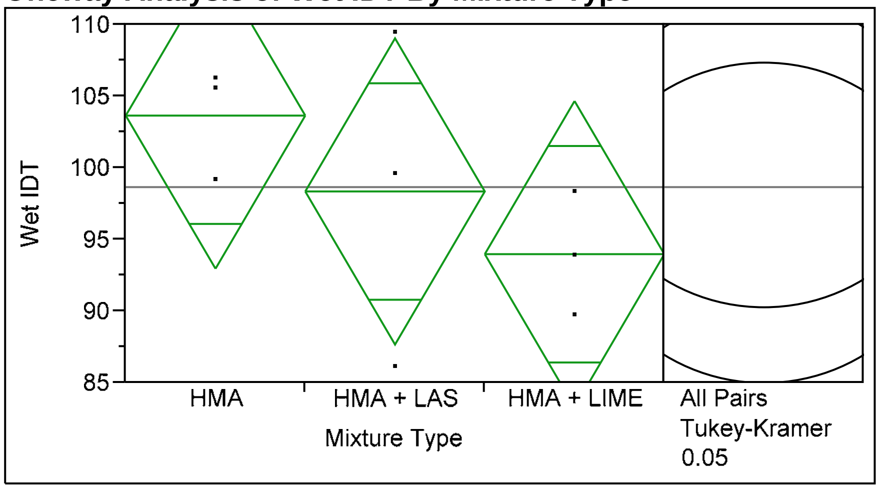
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
S + LIME	SASOBIT	7.533333	2.925621	-1.44291	16.50958	0.0928
S + LAS	SASOBIT	3.933333	2.925621	-5.04291	12.90958	0.4241
S + LIME	S + LAS	3.600000	2.925621	-5.37624	12.57624	0.4798

Figure B.34 (a)

HMA

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.290783
Adj Rsquare	0.054377
Root Mean Square Error	7.564932
Mean of Response	98.67333
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	140.78327	70.3916	1.2300	0.3567
Error	6	343.36913	57.2282		
C. Total	8	484.15240			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	103.663	4.3676	92.976	114.35
HMA + LAS	3	98.367	4.3676	87.679	109.05
HMA + LIME	3	93.990	4.3676	83.303	104.68

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	HMA + LAS	HMA + LIME
HMA	-18.951	-13.654	-9.278
HMA + LAS	-13.654	-18.951	-14.574
HMA + LIME	-9.278	-14.574	-18.951

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	103.66333
HMA + LAS	A	98.36667
HMA + LIME	A	93.99000

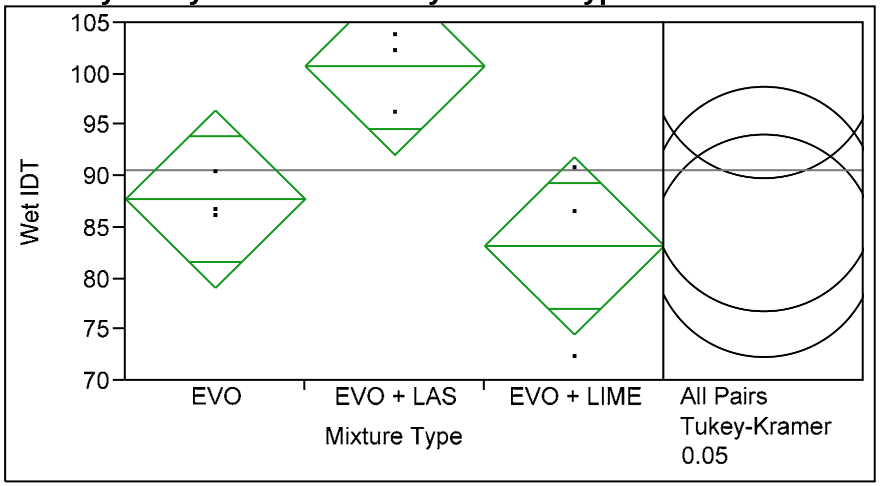
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	HMA + LIME	9.673333	6.176741	-9.2778	28.62450	0.3289
HMA	HMA + LAS	5.296667	6.176741	-13.6545	24.24783	0.6841
HMA + LAS	HMA + LIME	4.376667	6.176741	-14.5745	23.32783	0.7676

EvothermDAT

Oneway Analysis of Wet IDT By Mixture Type



H-114

Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.687602
Adj Rsquare	0.583469
Root Mean Square Error	6.150023
Mean of Response	90.59778
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	499.49682	249.748	6.6031	0.0305*
Error	6	226.93673	37.823		
C. Total	8	726.43356			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO	3	87.787	3.5507	79.098	96.47
EVO + LAS	3	100.797	3.5507	92.108	109.48

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
EVO + LIME	3	83.210	3.5507	74.522	91.90

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	EVO + LAS	EVO	EVO + LIME
EVO + LAS	-15.407	-2.397	2.180
EVO	-2.397	-15.407	-10.830
EVO + LIME	2.180	-10.830	-15.407

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
EVO + LAS	A		100.79667
EVO	A	B	87.78667
EVO + LIME		B	83.21000

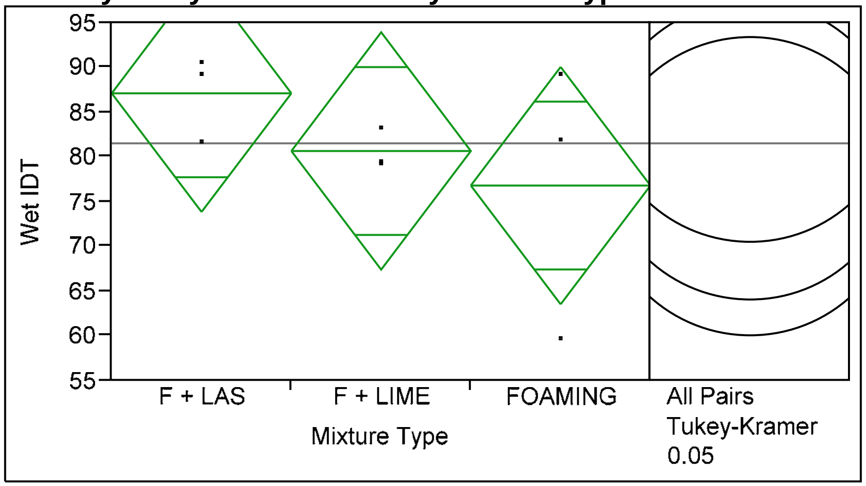
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
EVO + LAS	EVO + LIME	17.58667	5.021473	2.1800	32.99330	0.0296*
EVO + LAS	EVO	13.01000	5.021473	-2.3966	28.41663	0.0909
EVO	EVO + LIME	4.57667	5.021473	-10.8300	19.98330	0.6535

Foaming

Oneway Analysis of Wet IDT By Mixture Type



Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.23562
Adj Rsquare	-0.01917
Root Mean Square Error	9.393957
Mean of Response	81.5762
Observations (or Sum Wgts)	9

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**	**Prob > F**
Mixture Type	2	163.21146	81.6057	0.9247	0.4466
Error	6	529.47860	88.2464		
C. Total	8	692.69006			

Means for Oneway Anova

Level	**Number**	**Mean**	**Std Error**	**Lower 95%**	**Upper 95%**
F + LAS	3	87.1678	5.4236	73.897	100.44
F + LIME	3	80.7174	5.4236	67.446	93.99

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
FOAMING	3	76.8433	5.4236	63.572	90.11

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	F + LAS	F + LIME	FOAMING
F + LAS	-23.533	-17.083	-13.209
F + LIME	-17.083	-23.533	-19.659
FOAMING	-13.209	-19.659	-23.533

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
F + LAS	A	87.167829
F + LIME	A	80.717436
FOAMING	A	76.843333

Levels not connected by same letter are significantly different.

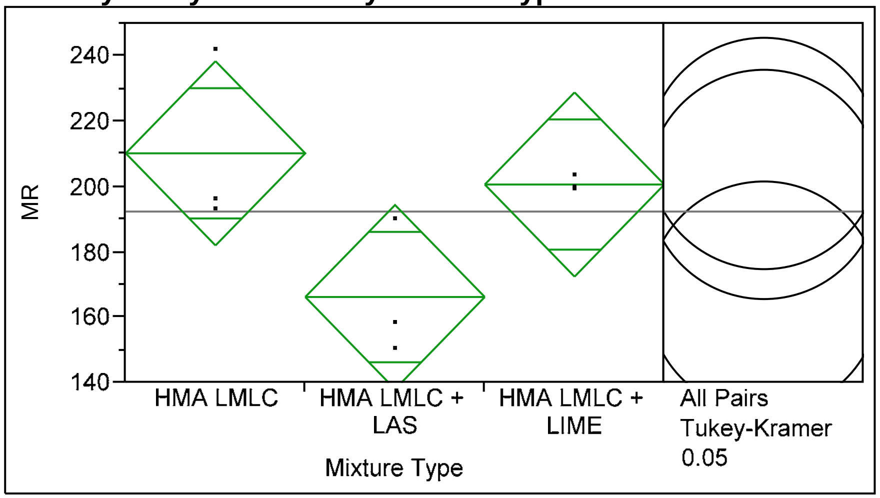
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
F + LAS	FOAMING	10.32450	7.670134	-13.2086	33.85761	0.4234
F + LAS	F + LIME	6.45039	7.670134	-17.0827	29.98351	0.6935
F + LIME	FOAMING	3.87410	7.670134	-19.6590	27.40722	0.8717

Figure B.35 (a)

HMA+RAP

Oneway Analysis of MR By Mixture Type



Oneway Anova
Summary of Fit

Rsquare	0.573407
Adj Rsquare	0.431209
Root Mean Square Error	19.98924
Mean of Response	192.4611
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	3222.4991	1611.25	4.0325	0.0776
Error	6	2397.4190	399.57		
C. Total	8	5619.9181			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA LMLC	3	210.335	11.541	182.10	238.57
HMA LMLC + LAS	3	166.277	11.541	138.04	194.52
HMA LMLC + LIME	3	200.772	11.541	172.53	229.01

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA LMLC	HMA LMLC + LIME	HMA LMLC + LAS
HMA LMLC	-50.076	-40.512	-6.017
HMA LMLC + LIME	-40.512	-50.076	-15.581
HMA LMLC + LAS	-6.017	-15.581	-50.076

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA LMLC	A	210.33500
HMA LMLC + LIME	A	200.77167
HMA LMLC + LAS	A	166.27667

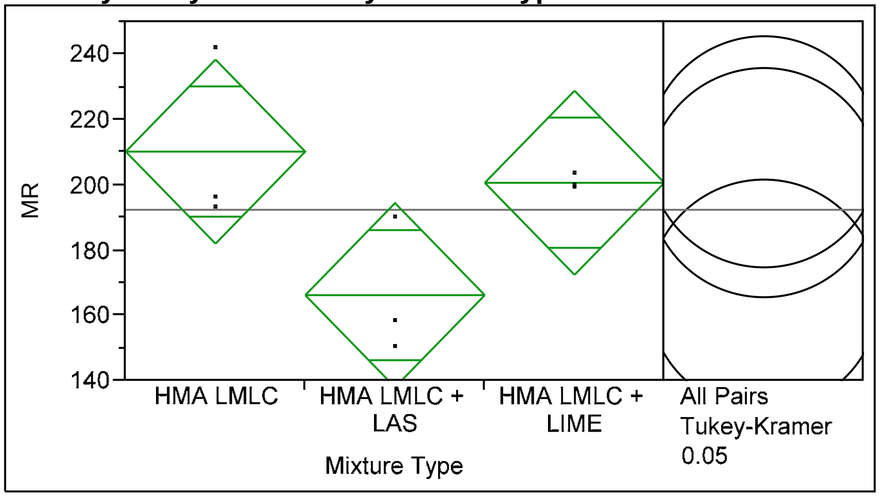
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA LMLC	HMA LMLC + LAS	44.05833	16.32115	-6.0174	94.13405	0.0792
HMA LMLC + LIME	HMA LMLC + LAS	34.49500	16.32115	-15.5807	84.57072	0.1671
HMA LMLC	HMA LMLC + LIME	9.56333	16.32115	-40.5124	59.63905	0.8324

Evotherm3G+RAP

Oneway Analysis of MR By Mixture Type



Oneway Anova

Summary of Fit

Rsquare	0.573407
Adj Rsquare	0.431209
Root Mean Square Error	19.98924
Mean of Response	192.4611
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	3222.4991	1611.25	4.0325	0.0776
Error	6	2397.4190	399.57		
C. Total	8	5619.9181			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA LMLC	3	210.335	11.541	182.10	238.57
HMA LMLC + LAS	3	166.277	11.541	138.04	194.52
HMA LMLC + LIME	3	200.772	11.541	172.53	229.01

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA LMLC	HMA LMLC + LIME	HMA LMLC + LAS
HMA LMLC	-50.076	-40.512	-6.017
HMA LMLC + LIME	-40.512	-50.076	-15.581
HMA LMLC + LAS	-6.017	-15.581	-50.076

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA LMLC	A	210.33500
HMA LMLC + LIME	A	200.77167
HMA LMLC + LAS	A	166.27667

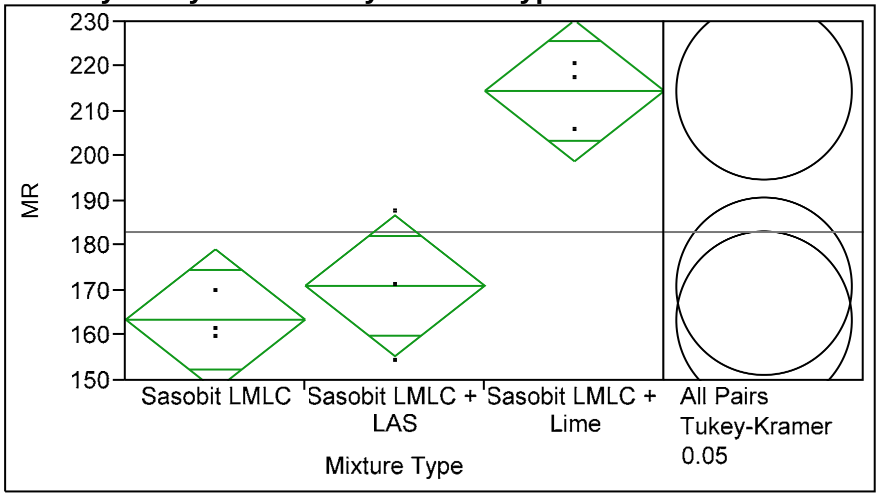
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA LMLC	HMA LMLC + LAS	44.05833	16.32115	-6.0174	94.13405	0.0792
HMA LMLC + LIME	HMA LMLC + LAS	34.49500	16.32115	-15.5807	84.57072	0.1671
HMA LMLC	HMA LMLC + LIME	9.56333	16.32115	-40.5124	59.63905	0.8324

Sasobit+RAP

Oneway Analysis of MR By Mixture Type



Oneway Anova

Summary of Fit

Rsquare	0.859821
Adj Rsquare	0.813094
Root Mean Square Error	11.12333
Mean of Response	183.1839
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture Type	2	4553.4955	2276.75	18.4012	0.0028*
Error	6	742.3708	123.73		
C. Total	8	5295.8663			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit LMLC	3	163.650	6.4221	147.94	179.36
Sasobit LMLC + LAS	3	171.208	6.4221	155.49	186.92
Sasobit LMLC + Lime	3	214.693	6.4221	198.98	230.41

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Sasobit LMLC + Lime	Sasobit LMLC + LAS	Sasobit LMLC
Sasobit LMLC + Lime	-27.865	15.620	23.178
Sasobit LMLC + LAS	15.620	-27.865	-20.307
Sasobit LMLC	23.178	-20.307	-27.865

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Sasobit LMLC + Lime	A		214.69333
Sasobit LMLC + LAS		B	171.20833
Sasobit LMLC		B	163.65000

Levels not connected by same letter are significantly different.

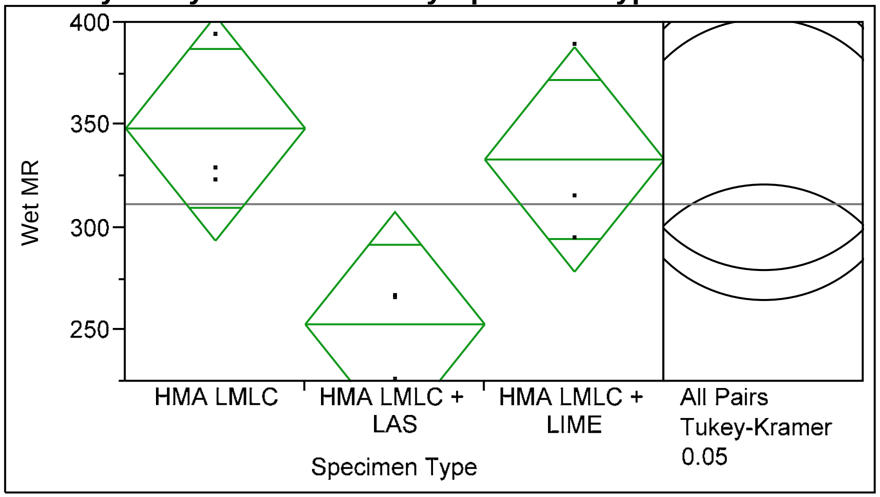
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Sasobit LMLC + Lime	Sasobit LMLC	51.04333	9.082161	23.1779	78.90876	0.0033*
Sasobit LMLC + Lime	Sasobit LMLC + LAS	43.48500	9.082161	15.6196	71.35043	0.0073*
Sasobit LMLC + LAS	Sasobit LMLC	7.55833	9.082161	-20.3071	35.42376	0.6985

Figure B.36 (a)

HMA

Oneway Analysis of Wet MR By Specimen Type



Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.636582
Adj Rsquare	0.515443
Root Mean Square Error	38.79158
Mean of Response	311.6522
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	15815.209	7907.60	5.2550	0.0480*
Error	6	9028.721	1504.79		
C. Total	8	24843.930			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA LMLC	3	348.547	22.396	293.74	403.35
HMA LMLC + LAS	3	253.018	22.396	198.22	307.82
HMA LMLC + LIME	3	333.392	22.396	278.59	388.19

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA LMLC	HMA LMLC + LIME	HMA LMLC + LAS
HMA LMLC	-97.178	-82.023	-1.650
HMA LMLC + LIME	-82.023	-97.178	-16.805
HMA LMLC + LAS	-1.650	-16.805	-97.178

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA LMLC	A	348.54667
HMA LMLC + LIME	A	333.39167
HMA LMLC + LAS	A	253.01833

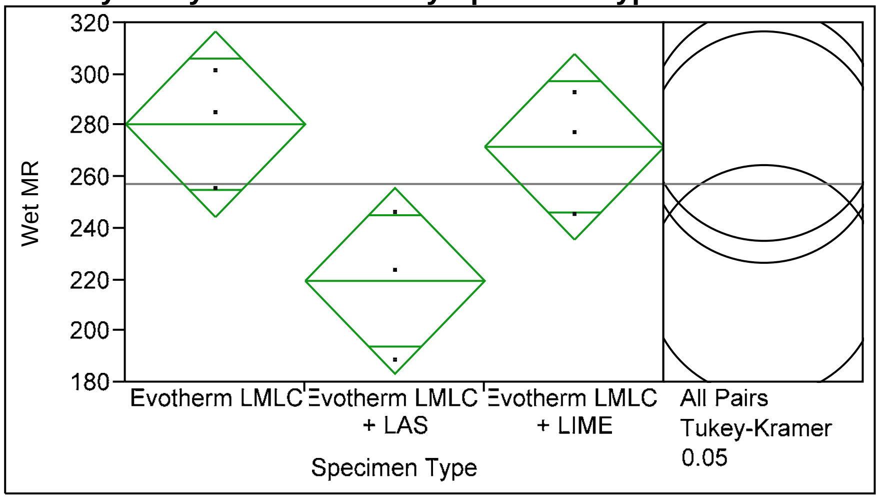
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA LMLC	HMA LMLC + LAS	95.52833	31.67319	-1.6498	192.7064	0.0533
HMA LMLC + LIME	HMA LMLC + LAS	80.37333	31.67319	-16.8048	177.5514	0.0973
HMA LMLC	HMA LMLC + LIME	15.15500	31.67319	-82.0231	112.3331	0.8838

EvothermDAT

Oneway Analysis of Wet MR By Specimen Type



Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.623569
Adj Rsquare	0.498093
Root Mean Square Error	25.62647
Mean of Response	257.3828
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	6527.230	3263.61	4.9696	0.0533
Error	6	3940.297	656.72		
C. Total	8	10467.527			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm LMLC	3	280.658	14.795	244.46	316.86
Evotherm LMLC + LAS	3	219.638	14.795	183.44	255.84

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm LMLC + LIME	3	271.852	14.795	235.65	308.05

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm LMLC	Evotherm LMLC + LIME	Evotherm LMLC + LAS
Evotherm LMLC	-64.198	-55.391	-3.178
Evotherm LMLC + LIME	-55.391	-64.198	-11.984
Evotherm LMLC + LAS	-3.178	-11.984	-64.198

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm LMLC	A	280.65833
Evotherm LMLC + LIME	A	271.85167
Evotherm LMLC + LAS	A	219.63833

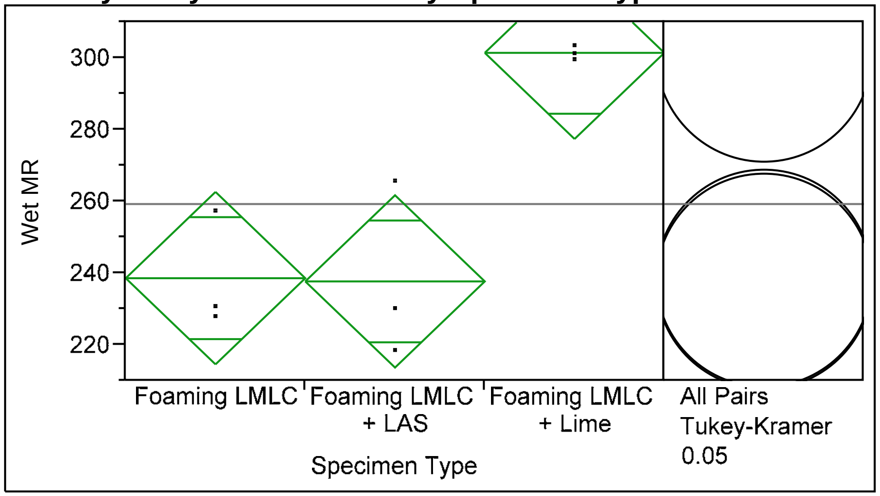
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm LMLC	Evotherm LMLC + LAS	61.02000	20.92393	-3.1777	125.2177	0.0604
Evotherm LMLC + LIME	Evotherm LMLC + LAS	52.21333	20.92393	-11.9844	116.4111	0.1027
Evotherm LMLC	Evotherm LMLC + LIME	8.80667	20.92393	-55.3911	73.0044	0.9084

Foaming

Oneway Analysis of Wet MR By Specimen Type



Excluded Rows
18

Oneway Anova

Summary of Fit

Rsquare	0.821814
Adj Rsquare	0.762418
Root Mean Square Error	17.01491
Mean of Response	259.2828
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	8011.4219	4005.71	13.8363	0.0057*
Error	6	1737.0430	289.51		
C. Total	8	9748.4649			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Foaming LMLC	3	238.640	9.8236	214.60	262.68
Foaming LMLC + LAS	3	237.735	9.8236	213.70	261.77

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Foaming LMLC + Lime	3	301.473	9.8236	277.44	325.51

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming LMLC + Lime	Foaming LMLC	Foaming LMLC + LAS
Foaming LMLC + Lime	-42.625	20.209	21.114
Foaming LMLC	20.209	-42.625	-41.720
Foaming LMLC + LAS	21.114	-41.720	-42.625

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Foaming LMLC + Lime	A		301.47333
Foaming LMLC		B	238.64000
Foaming LMLC + LAS		B	237.73500

Levels not connected by same letter are significantly different.

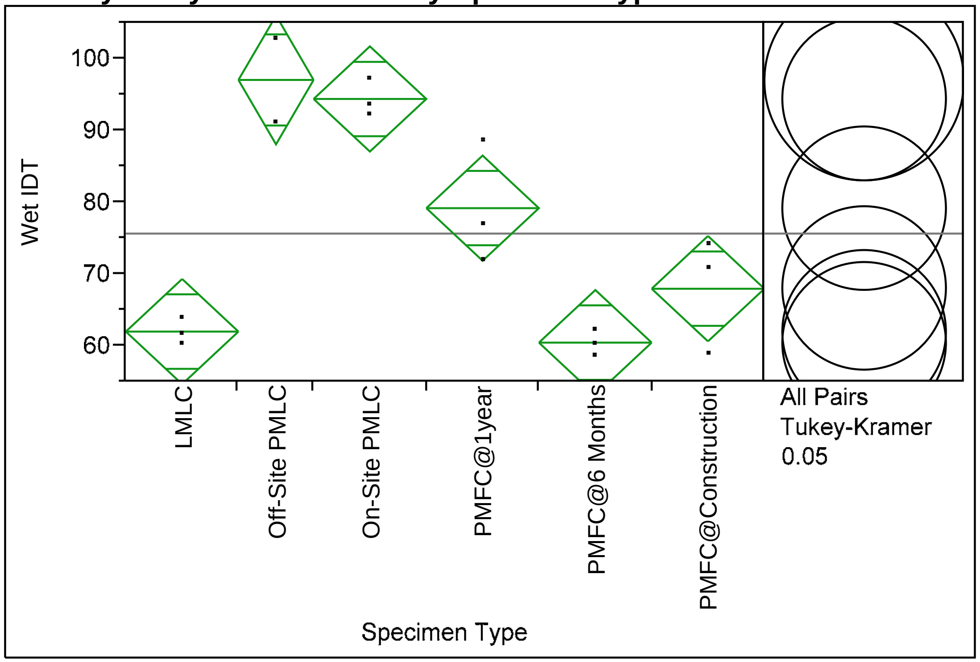
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming LMLC + Lime	Foaming LMLC + LAS	63.73833	13.89262	21.1137	106.3630	0.0089*
Foaming LMLC + Lime	Foaming LMLC	62.83333	13.89262	20.2087	105.4580	0.0095*
Foaming LMLC	Foaming LMLC + LAS	0.90500	13.89262	-41.7196	43.5296	0.9977

Figure B.37 (a)

HMA+RAP

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova

Summary of Fit

Rsquare	0.903745
Adj Rsquare	0.859993
Root Mean Square Error	5.770432
Mean of Response	75.63904
Observations (or Sum Wgts)	17

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	5	3438.9996	687.800	20.6560	<.0001*
Error	11	366.2767	33.298		
C. Total	16	3805.2763			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	61.9733	3.3316	54.641	69.31
Off-Site PMLC	2	97.0373	4.0803	88.057	106.02
On-Site PMLC	3	94.3867	3.3316	87.054	101.72
PMFC@1year	3	79.1822	3.3316	71.849	86.51
PMFC@6 Months	3	60.4317	3.3316	53.099	67.76
PMFC@Construction	3	67.9558	3.3316	60.623	75.29

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.41034	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	On-Site PMLC	PMFC@1year	PMFC@Construction	LMLC	PMFC@6 Months
Off-Site PMLC	-19.679	-15.314	-0.109	11.117	17.100	18.641
On-Site PMLC	-15.314	-16.068	-0.863	10.363	16.345	17.887
PMFC@1year	-0.109	-0.863	-16.068	-4.842	1.141	2.683
PMFC@Construction	11.117	10.363	-4.842	-16.068	-10.085	-8.544
LMLC	17.100	16.345	1.141	-10.085	-16.068	-14.526
PMFC@6 Months	18.641	17.887	2.683	-8.544	-14.526	-16.068

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
Off-Site PMLC	A			97.037349
On-Site PMLC	A			94.386667
PMFC@1year	A	B		79.182174
PMFC@Construction		B	C	67.955827
LMLC			C	61.973333

Level		Mean
PMFC@6 Months	C	60.431668

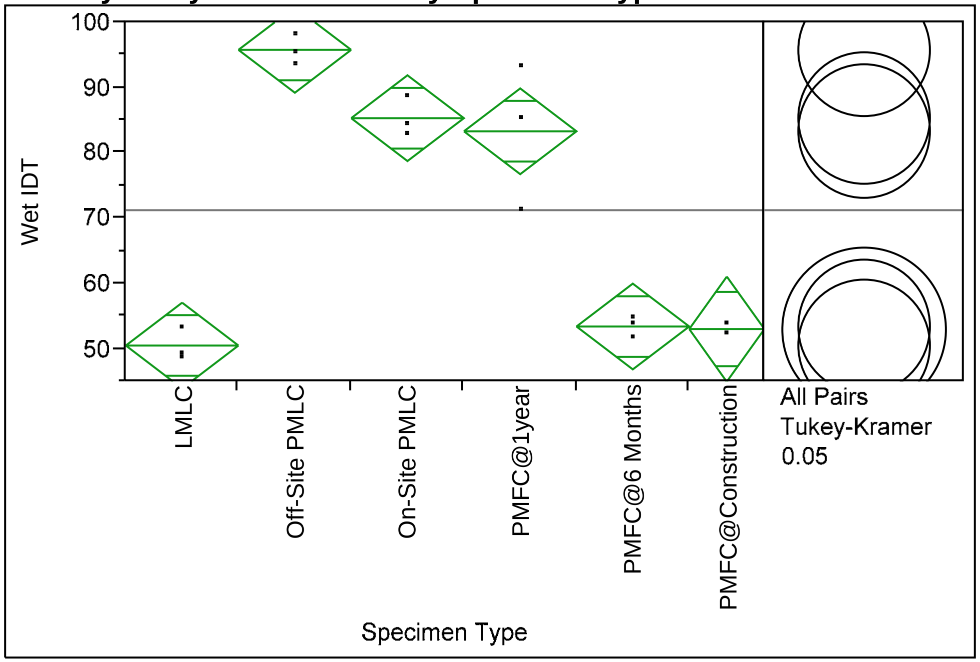
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	PMFC@6 Months	36.60568	5.267659	18.6412	54.57018	0.0003*
Off-Site PMLC	LMLC	35.06402	5.267659	17.0995	53.02852	0.0004*
On-Site PMLC	PMFC@6 Months	33.95500	4.711538	17.8871	50.02294	0.0002*
On-Site PMLC	LMLC	32.41333	4.711538	16.3454	48.48127	0.0003*
Off-Site PMLC	PMFC@Construction	29.08152	5.267659	11.1170	47.04602	0.0019*
On-Site PMLC	PMFC@Construction	26.43084	4.711538	10.3629	42.49878	0.0016*
PMFC@1year	PMFC@6 Months	18.75051	4.711538	2.6826	34.81845	0.0200*
Off-Site PMLC	PMFC@1year	17.85517	5.267659	-0.1093	35.81968	0.0517
PMFC@1year	LMLC	17.20884	4.711538	1.1409	33.27678	0.0339*
On-Site PMLC	PMFC@1year	15.20449	4.711538	-0.8634	31.27243	0.0670
PMFC@1year	PMFC@Construction	11.22635	4.711538	-4.8416	27.29429	0.2415
PMFC@Construction	PMFC@6 Months	7.52416	4.711538	-8.5438	23.59210	0.6164
PMFC@Construction	LMLC	5.98249	4.711538	-10.0854	22.05043	0.7948
Off-Site PMLC	On-Site PMLC	2.65068	5.267659	-15.3138	20.61519	0.9950
LMLC	PMFC@6 Months	1.54167	4.711538	-14.5263	17.60961	0.9993

Evotherm 3G+RAP

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.951373
Adj Rsquare	0.929269
Root Mean Square Error	5.169279
Mean of Response	71.22391
Observations (or Sum Wgts)	17

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	5	5750.7309	1150.15	43.0421	<.0001*
Error	11	293.9359	26.72		
C. Total	16	6044.6668			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	50.4867	2.9845	43.918	57.06
Off-Site PMLC	3	95.7778	2.9845	89.209	102.35
On-Site PMLC	3	85.3100	2.9845	78.741	91.88
PMFC@1year	3	83.3072	2.9845	76.738	89.88
PMFC@6 Months	3	53.3882	2.9845	46.819	59.96
PMFC@Construction	2	52.9984	3.6552	44.953	61.04

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.41034	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	On-Site PMLC	PMFC@1year	PMFC@6 Months	PMFC@Construction	LMLC
Off-Site PMLC	-14.394	-3.926	-1.923	27.996	26.686	30.897
On-Site PMLC	-3.926	-14.394	-12.391	17.528	16.219	20.429
PMFC@1year	-1.923	-12.391	-14.394	15.525	14.216	18.426
PMFC@6 Months	27.996	17.528	15.525	-14.394	-15.703	-11.492
PMFC@Construction	26.686	16.219	14.216	-15.703	-17.629	-13.581
LMLC	30.897	20.429	18.426	-11.492	-13.581	-14.394

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Off-Site PMLC	A		95.777834
On-Site PMLC	A		85.310000
PMFC@1year	A		83.307172
PMFC@6 Months		B	53.388197
PMFC@Construction		B	52.998405
LMLC		B	50.486667

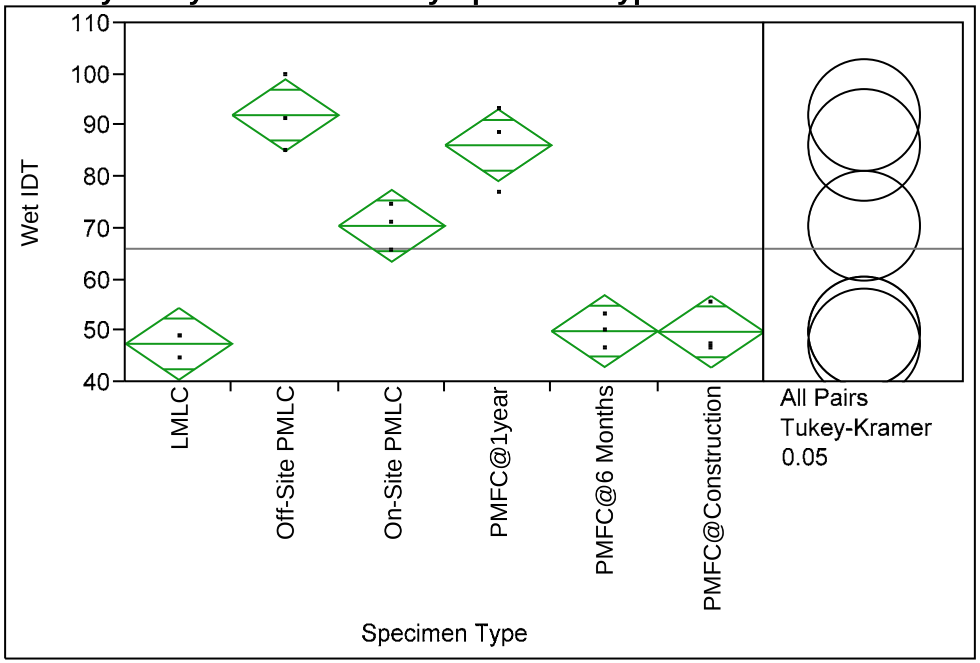
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	LMLC	45.29117	4.220698	30.8972	59.68518	<.0001*
Off-Site PMLC	PMFC@Construction	42.77943	4.718884	26.6864	58.87242	<.0001*
Off-Site PMLC	PMFC@6 Months	42.38964	4.220698	27.9956	56.78365	<.0001*
On-Site PMLC	LMLC	34.82333	4.220698	20.4293	49.21734	<.0001*
PMFC@1year	LMLC	32.82051	4.220698	18.4265	47.21452	<.0001*
On-Site PMLC	PMFC@Construction	32.31159	4.718884	16.2186	48.40459	0.0003*
On-Site PMLC	PMFC@6 Months	31.92180	4.220698	17.5278	46.31581	0.0001*
PMFC@1year	PMFC@Construction	30.30877	4.718884	14.2158	46.40176	0.0005*
PMFC@1year	PMFC@6 Months	29.91898	4.220698	15.5250	44.31299	0.0002*
Off-Site PMLC	PMFC@1year	12.47066	4.220698	-1.9233	26.86467	0.1029
Off-Site PMLC	On-Site PMLC	10.46783	4.220698	-3.9262	24.86185	0.2103
PMFC@6 Months	LMLC	2.90153	4.220698	-11.4925	17.29554	0.9797
PMFC@Construction	LMLC	2.51174	4.718884	-13.5813	18.60473	0.9935
On-Site PMLC	PMFC@1year	2.00283	4.220698	-12.3912	16.39684	0.9962
PMFC@6 Months	PMFC@Construction	0.38979	4.718884	-15.7032	16.48279	1.0000

Sasobit+RAP

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova

Summary of Fit

Rsquare	0.940923
Adj Rsquare	0.916308
Root Mean Square Error	5.560195
Mean of Response	66.02297
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	5	5908.8103	1181.76	38.2252	<.0001*
Error	12	370.9892	30.92		
C. Total	17	6279.7995			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	47.4933	3.2102	40.499	54.488
Off-Site PMLC	3	92.0906	3.2102	85.096	99.085
On-Site PMLC	3	70.5084	3.2102	63.514	77.503
PMFC@1year	3	86.2146	3.2102	79.220	93.209
PMFC@6 Months	3	49.9850	3.2102	42.991	56.979
PMFC@Construction	3	49.8459	3.2102	42.852	56.840

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	PMFC@1year	On-Site PMLC	PMFC@6 Months	PMFC@Construction	LMLC
Off-Site PMLC	-15.249	-9.373	6.333	26.857	26.996	29.348
PMFC@1year	-9.373	-15.249	0.457	20.981	21.120	23.472
On-Site PMLC	6.333	0.457	-15.249	5.274	5.414	7.766
PMFC@6 Months	26.857	20.981	5.274	-15.249	-15.110	-12.757
PMFC@Construction	26.996	21.120	5.414	-15.110	-15.249	-12.896
LMLC	29.348	23.472	7.766	-12.757	-12.896	-15.249

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
Off-Site PMLC	A			92.090644
PMFC@1year	A			86.214570
On-Site PMLC		B		70.508364
PMFC@6 Months			C	49.985033
PMFC@Construction			C	49.845904
LMLC			C	47.493333

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	LMLC	44.59731	4.539880	29.3485	59.84615	<.0001*
Off-Site PMLC	PMFC@Construction	42.24474	4.539880	26.9959	57.49358	<.0001*
Off-Site PMLC	PMFC@6 Months	42.10561	4.539880	26.8568	57.35445	<.0001*
PMFC@1year	LMLC	38.72124	4.539880	23.4724	53.97008	<.0001*
PMFC@1year	PMFC@Construction	36.36867	4.539880	21.1198	51.61751	<.0001*
PMFC@1year	PMFC@6 Months	36.22954	4.539880	20.9807	51.47838	<.0001*
On-Site PMLC	LMLC	23.01503	4.539880	7.7662	38.26387	0.0029*
Off-Site PMLC	On-Site PMLC	21.58228	4.539880	6.3334	36.83112	0.0048*
On-Site PMLC	PMFC@Construction	20.66246	4.539880	5.4136	35.91130	0.0067*
On-Site PMLC	PMFC@6 Months	20.52333	4.539880	5.2745	35.77217	0.0071*
PMFC@1year	On-Site PMLC	15.70621	4.539880	0.4574	30.95505	0.0422*
Off-Site PMLC	PMFC@1year	5.87607	4.539880	-9.3728	21.12491	0.7828
PMFC@6 Months	LMLC	2.49170	4.539880	-12.7571	17.74054	0.9927
PMFC@Construction	LMLC	2.35257	4.539880	-12.8963	17.60141	0.9944
PMFC@6 Months	PMFC@Construction	0.13913	4.539880	-15.1097	15.38797	1.0000

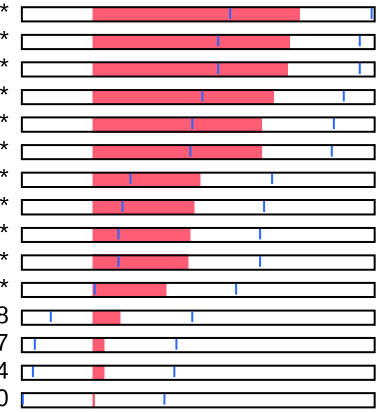
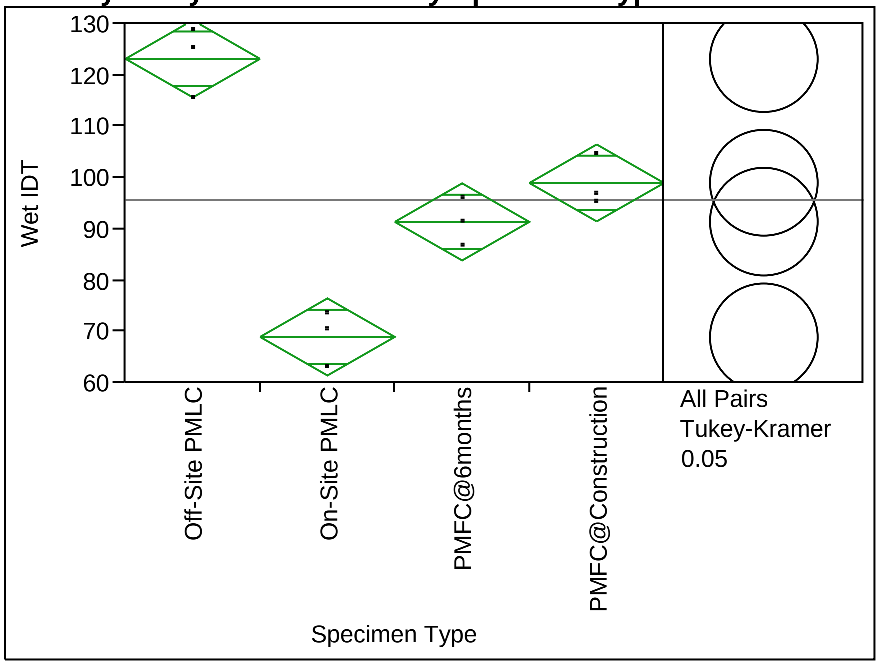


Figure B.38 (a)

HMA

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.946411
Adj Rsquare	0.926315
Root Mean Square Error	5.643176
Mean of Response	95.68917
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	3	4499.2800	1499.76	47.0950	<.0001*
Error	8	254.7635	31.85		
C. Total	11	4754.0435			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-Site PMLC	3	123.247	3.2581	115.73	130.76
On-Site PMLC	3	69.023	3.2581	61.51	76.54
PMFC@6months	3	91.443	3.2581	83.93	98.96
PMFC@Construction	3	99.043	3.2581	91.53	106.56

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	PMFC@Construction	PMFC@6months	On-Site PMLC
Off-Site PMLC	-14.755	9.448	17.048	39.468
PMFC@Construction	9.448	-14.755	-7.155	15.265
PMFC@6months	17.048	-7.155	-14.755	7.665
On-Site PMLC	39.468	15.265	7.665	-14.755

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
Off-Site PMLC	A			123.24667
PMFC@Construction		B		99.04333
PMFC@6months		B		91.44333
On-Site PMLC			C	69.02333

Levels not connected by same letter are significantly different.

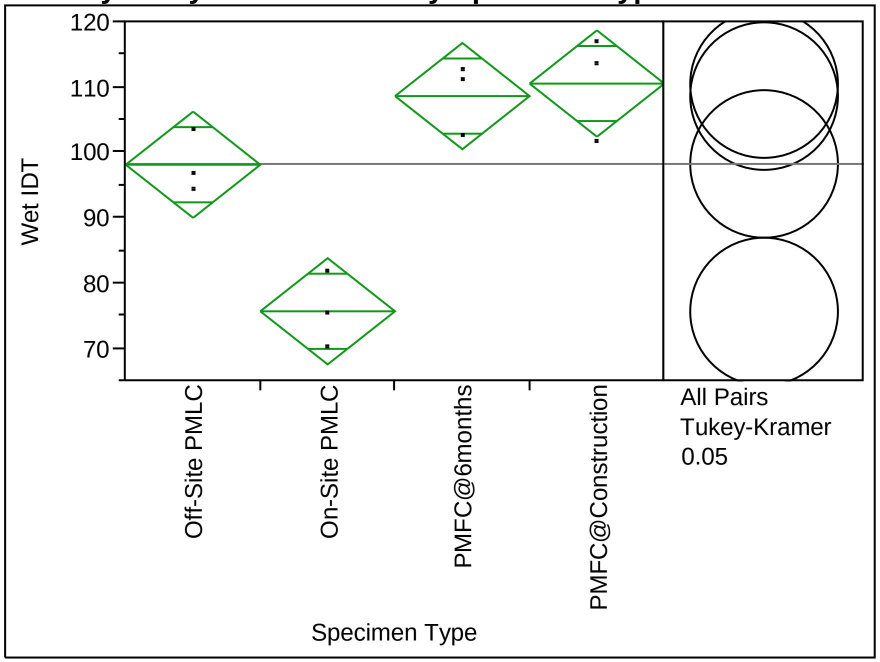
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	On-Site PMLC	54.22333	4.607634	39.4681	68.97856	<.0001*
Off-Site PMLC	PMFC@6months	31.80333	4.607634	17.0481	46.55856	0.0006*
PMFC@Construction	On-Site PMLC	30.02000	4.607634	15.2648	44.77523	0.0008*
Off-Site PMLC	PMFC@Construction	24.20333	4.607634	9.4481	38.95856	0.0034*
PMFC@6months	On-Site PMLC	22.42000	4.607634	7.6648	37.17523	0.0055*
PMFC@Construction	PMFC@6months	7.60000	4.607634	-7.1552	22.35523	0.4063

H-142

Evotherm 3G

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.885297
Adj Rsquare	0.842283
Root Mean Square Error	6.114844
Mean of Response	98.305
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	3	2308.7414	769.580	20.5818	0.0004*
Error	8	299.1305	37.391		
C. Total	11	2607.8719			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-Site PMLC	3	98.180	3.5304	90.04	106.32
On-Site PMLC	3	75.723	3.5304	67.58	83.86
PMFC@6months	3	108.700	3.5304	100.56	116.84
PMFC@Construction	3	110.617	3.5304	102.48	118.76

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMFC@Construction	PMFC@6months	Off-Site PMLC	On-Site PMLC
PMFC@Construction	-15.989	-14.072	-3.552	18.905
PMFC@6months	-14.072	-15.989	-5.469	16.988
Off-Site PMLC	-3.552	-5.469	-15.989	6.468
On-Site PMLC	18.905	16.988	6.468	-15.989

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
PMFC@Construction	A		110.61667
PMFC@6months	A		108.70000
Off-Site PMLC	A		98.18000
On-Site PMLC		B	75.72333

Levels not connected by same letter are significantly different.

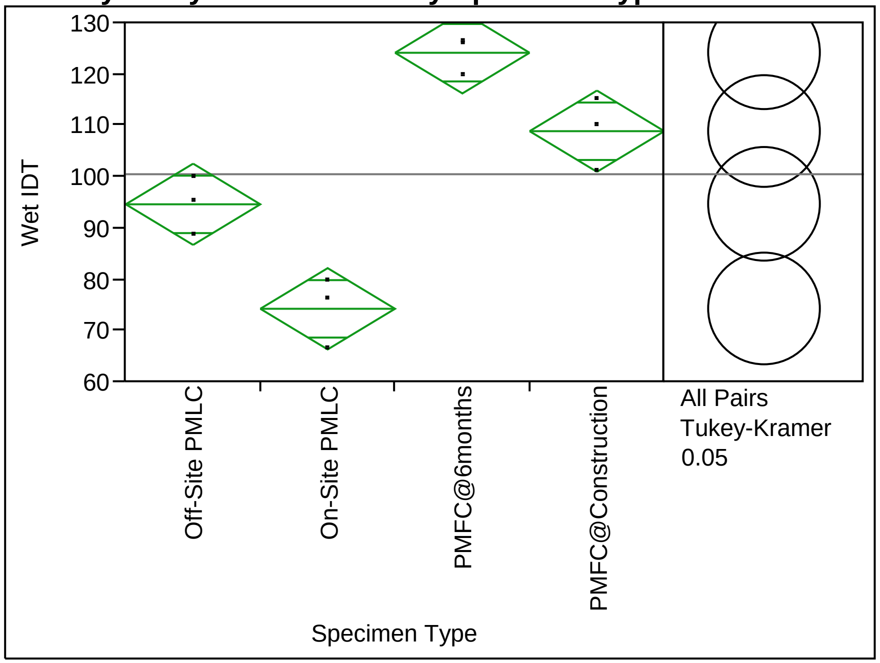
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@Construction	On-Site PMLC	34.89333	4.992749	18.9048	50.88183	0.0005*
PMFC@6months	On-Site PMLC	32.97667	4.992749	16.9882	48.96517	0.0008*
Off-Site PMLC	On-Site PMLC	22.45667	4.992749	6.4682	38.44517	0.0087*
PMFC@Construction	Off-Site PMLC	12.43667	4.992749	-3.5518	28.42517	0.1361

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@6months	Off-Site PMLC	10.52000	4.992749	-5.4685	26.50850	0.2295
PMFC@Construction	PMFC@6months	1.91667	4.992749	-14.0718	17.90517	0.9794

Sasobit

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova

Summary of Fit

Rsquare	0.934799
Adj Rsquare	0.910349
Root Mean Square Error	5.952367
Mean of Response	100.5625
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	3	4063.8074	1354.60	38.2325	<.0001*
Error	8	283.4454	35.43		
C. Total	11	4347.2528			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-Site PMLC	3	94.700	3.4366	86.78	102.62
On-Site PMLC	3	74.330	3.4366	66.41	82.25
PMFC@6months	3	124.260	3.4366	116.34	132.18
PMFC@Construction	3	108.960	3.4366	101.04	116.88

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMFC@6months	PMFC@Construction	Off-Site PMLC	On-Site PMLC
PMFC@6months	-15.564	-0.264	13.996	34.366
PMFC@Construction	-0.264	-15.564	-1.304	19.066
Off-Site PMLC	13.996	-1.304	-15.564	4.806
On-Site PMLC	34.366	19.066	4.806	-15.564

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
PMFC@6months	A			124.26000
PMFC@Construction	A	B		108.96000
Off-Site PMLC		B		94.70000
On-Site PMLC			C	74.33000

Levels not connected by same letter are significantly different.

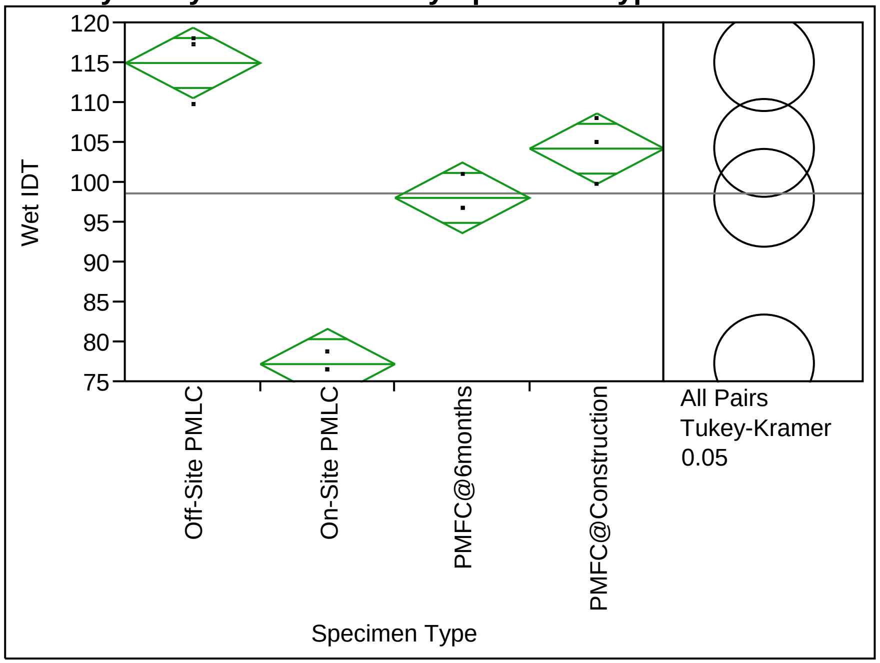
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@6months	On-Site PMLC	49.93000	4.860087	34.3663	65.49367	<.0001*
PMFC@Construction	On-Site PMLC	34.63000	4.860087	19.0663	50.19367	0.0005*
PMFC@6months	Off-Site PMLC	29.56000	4.860087	13.9963	45.12367	0.0013*
Off-Site PMLC	On-Site PMLC	20.37000	4.860087	4.8063	35.93367	0.0129*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@6months	PMFC@Construction	15.30000	4.860087	-0.2637	30.86367	0.0540
PMFC@Construction	Off-Site PMLC	14.26000	4.860087	-1.3037	29.82367	0.0730

Foaming

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova

Summary of Fit

Rsquare	0.962604
Adj Rsquare	0.94858
Root Mean Square Error	3.321261
Mean of Response	98.67583
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	3	2271.5093	757.170	68.6416	<.0001*
Error	8	88.2462	11.031		
C. Total	11	2359.7555			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-Site PMLC	3	115.027	1.9175	110.60	119.45
On-Site PMLC	3	77.273	1.9175	72.85	81.70
PMFC@6months	3	98.120	1.9175	93.70	102.54
PMFC@Construction	3	104.283	1.9175	99.86	108.71

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	PMFC@Construction	PMFC@6months	On-Site PMLC
Off-Site PMLC	-8.684	2.059	8.223	29.069
PMFC@Construction	2.059	-8.684	-2.521	18.326
PMFC@6months	8.223	-2.521	-8.684	12.163
On-Site PMLC	29.069	18.326	12.163	-8.684

Positive values show pairs of means that are significantly different.

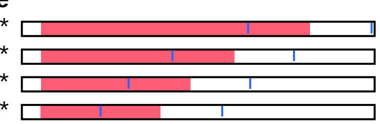
Connecting Letters Report

Level				Mean
Off-Site PMLC	A			115.02667
PMFC@Construction		B		104.28333
PMFC@6months		B		98.12000
On-Site PMLC			C	77.27333

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	On-Site PMLC	37.75333	2.711798	29.0692	46.43744	<.0001*
PMFC@Construction	On-Site PMLC	27.01000	2.711798	18.3259	35.69411	<.0001*
PMFC@6months	On-Site PMLC	20.84667	2.711798	12.1626	29.53078	0.0003*
Off-Site PMLC	PMFC@6months	16.90667	2.711798	8.2226	25.59078	0.0011*

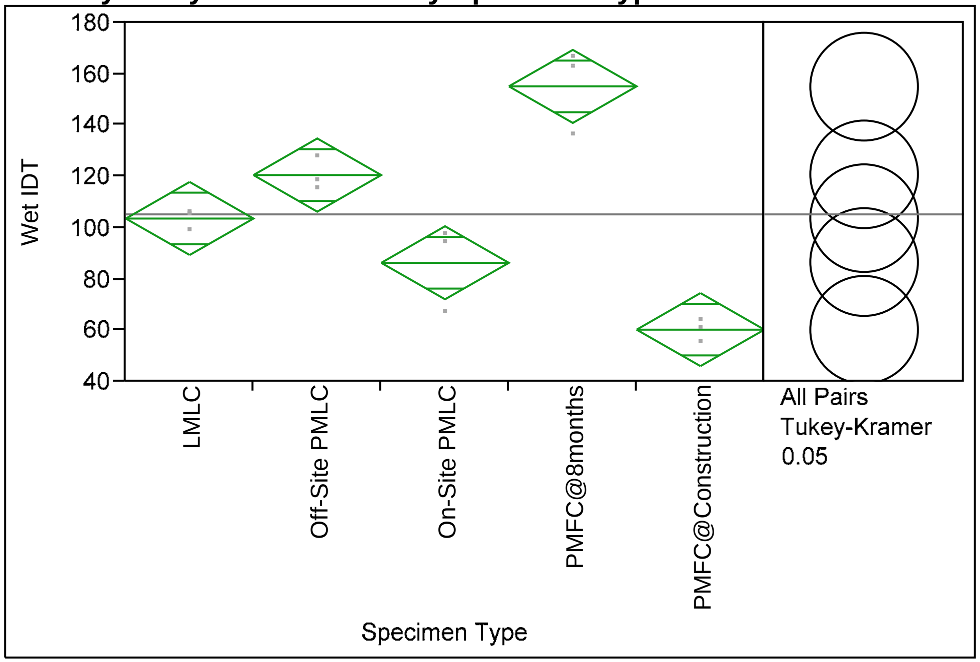


Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	PMFC@Construction	10.74333	2.711798	2.0592	19.42744	0.0175*
PMFC@Construction	PMFC@6months	6.16333	2.711798	-2.5208	14.84744	0.1838

Figure B.39 (a)

HMA

Oneway Analysis of Wet IDT By Specimen Type



Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.925806
Adj Rsquare	0.896128
Root Mean Square Error	11.08657
Mean of Response	105.2325
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	4	15337.111	3834.28	31.1953	<.0001*
Error	10	1229.119	122.91		
C. Total	14	16566.231			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	103.663	6.4008	89.40	117.93
Off-Site PMLC	3	120.607	6.4008	106.35	134.87
On-Site PMLC	3	86.382	6.4008	72.12	100.64
PMFC@8months	3	155.218	6.4008	140.96	169.48
PMFC@Construction	3	60.292	6.4008	46.03	74.55

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.29108	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMFC@8months	Off-Site PMLC	LMLC	On-Site PMLC	PMFC@Construction
PMFC@8months	-29.791	4.820	21.763	39.045	65.134
Off-Site PMLC	4.820	-29.791	-12.848	4.434	30.523
LMLC	21.763	-12.848	-29.791	-12.510	13.580
On-Site PMLC	39.045	4.434	-12.510	-29.791	-3.702
PMFC@Construction	65.134	30.523	13.580	-3.702	-29.791

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
PMFC@8months	A				155.21802
Off-Site PMLC		B			120.60709
LMLC		B	C		103.66333
On-Site PMLC			C	D	86.38154
PMFC@Construction				D	60.29233

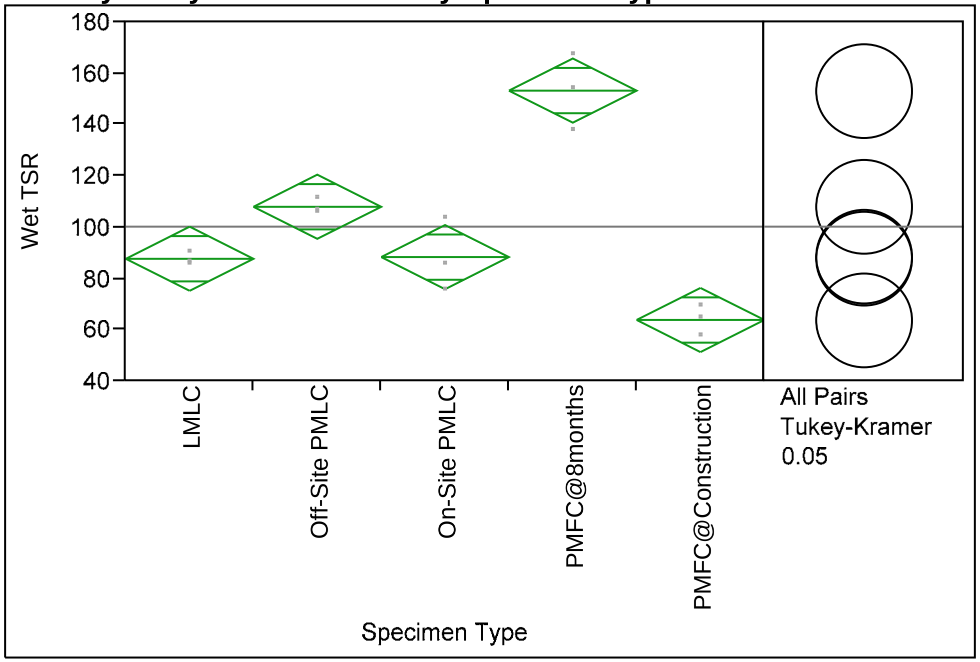
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@8months	PMFC@Construction	94.92569	9.052143	65.1343	124.7170	<.0001*
PMFC@8months	On-Site PMLC	68.83648	9.052143	39.0451	98.6278	0.0001*
Off-Site PMLC	PMFC@Construction	60.31477	9.052143	30.5234	90.1061	0.0004*
PMFC@8months	LMLC	51.55468	9.052143	21.7633	81.3460	0.0014*
LMLC	PMFC@Construction	43.37101	9.052143	13.5797	73.1624	0.0051*
PMFC@8months	Off-Site PMLC	34.61092	9.052143	4.8196	64.4023	0.0219*
Off-Site PMLC	On-Site PMLC	34.22555	9.052143	4.4342	64.0169	0.0234*
On-Site PMLC	PMFC@Construction	26.08922	9.052143	-3.7021	55.8806	0.0940
LMLC	On-Site PMLC	17.28179	9.052143	-12.5096	47.0731	0.3717
Off-Site PMLC	LMLC	16.94376	9.052143	-12.8476	46.7351	0.3891

Evotherm DAT

Oneway Analysis of Wet TSR By Specimen Type



Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.934646
Adj Rsquare	0.908505
Root Mean Square Error	9.712717
Mean of Response	100.3117
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	4	13491.439	3372.86	35.7534	<.0001*
Error	10	943.369	94.34		

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C. Total	14	14434.807			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	87.787	5.6076	75.29	100.28
Off-Site PMLC	3	108.065	5.6076	95.57	120.56
On-Site PMLC	3	88.434	5.6076	75.94	100.93
PMFC@8months	3	153.360	5.6076	140.87	165.86
PMFC@Construction	3	63.912	5.6076	51.42	76.41

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.29108	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMFC@8months	Off-Site PMLC	On-Site PMLC	LMLC	PMFC@Construction
PMFC@8months	-26.100	19.196	38.827	39.474	63.348
Off-Site PMLC	19.196	-26.100	-6.469	-5.821	18.053
On-Site PMLC	38.827	-6.469	-26.100	-25.452	-1.578
LMLC	39.474	-5.821	-25.452	-26.100	-2.225
PMFC@Construction	63.348	18.053	-1.578	-2.225	-26.100

Positive values show pairs of means that are significantly different.

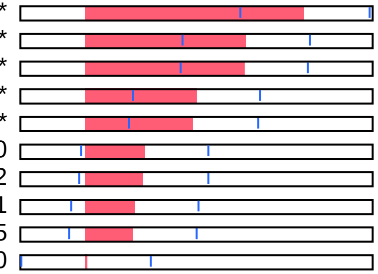
Connecting Letters Report

Level			Mean
PMFC@8months	A		153.36043
Off-Site PMLC	B		108.06488
On-Site PMLC	B	C	88.43405
LMLC	B	C	87.78667
PMFC@Construction		C	63.91236

Levels not connected by same letter are significantly different.

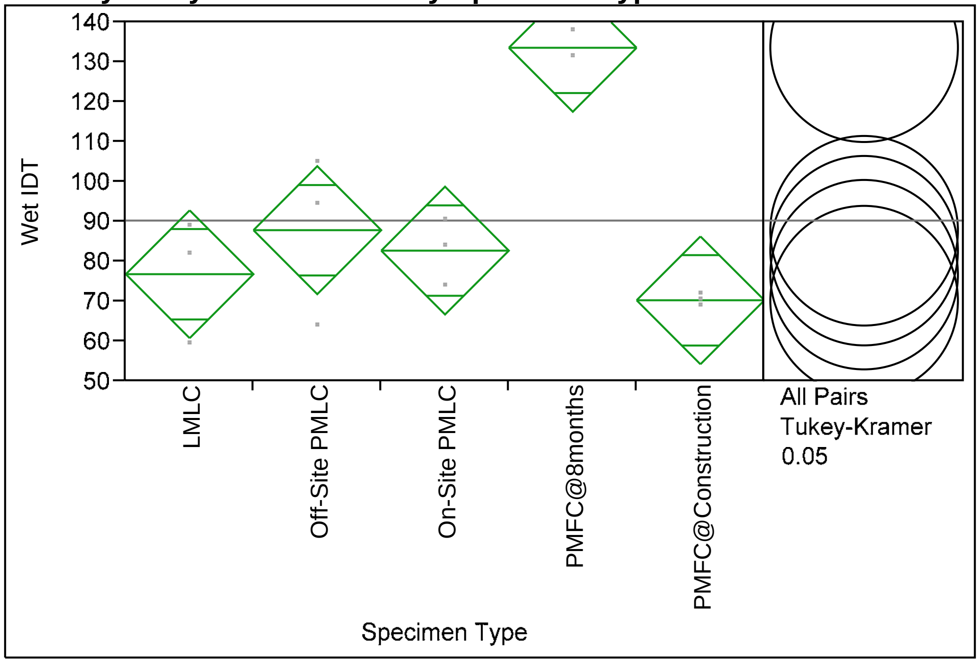
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@8months	PMFC@Construction	89.44807	7.930400	63.3485	115.5477	<.0001*
PMFC@8months	LMLC	65.57376	7.930400	39.4742	91.6734	<.0001*
PMFC@8months	On-Site PMLC	64.92638	7.930400	38.8268	91.0260	<.0001*
PMFC@8months	Off-Site PMLC	45.29555	7.930400	19.1959	71.3951	0.0014*
Off-Site PMLC	PMFC@Construction	44.15252	7.930400	18.0529	70.2521	0.0017*
On-Site PMLC	PMFC@Construction	24.52169	7.930400	-1.5779	50.6213	0.0680
LMLC	PMFC@Construction	23.87431	7.930400	-2.2253	49.9739	0.0772
Off-Site PMLC	LMLC	20.27821	7.930400	-5.8214	46.3778	0.1531
Off-Site PMLC	On-Site PMLC	19.63083	7.930400	-6.4688	45.7304	0.1725
On-Site PMLC	LMLC	0.64738	7.930400	-25.4522	26.7470	1.0000



Foaming

Oneway Analysis of Wet IDT By Specimen Type



Excluded Rows
3

Oneway Anova

Summary of Fit

Rsquare	0.829581
Adj Rsquare	0.761413
Root Mean Square Error	12.45828
Mean of Response	90.28182
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	4	7555.3597	1888.84	12.1697	0.0007*
Error	10	1552.0862	155.21		

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C. Total	14	9107.4459			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	76.843	7.1928	60.82	92.87
Off-Site PMLC	3	87.886	7.1928	71.86	103.91
On-Site PMLC	3	82.771	7.1928	66.74	98.80
PMFC@8months	3	133.602	7.1928	117.58	149.63
PMFC@Construction	3	70.306	7.1928	54.28	86.33

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.29108	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMFC@8months	Off-Site PMLC	On-Site PMLC	LMLC	PMFC@Construction
PMFC@8months	-33.477	12.239	17.354	23.282	29.819
Off-Site PMLC	12.239	-33.477	-28.362	-22.434	-15.897
On-Site PMLC	17.354	-28.362	-33.477	-27.550	-21.013
LMLC	23.282	-22.434	-27.550	-33.477	-26.940
PMFC@Construction	29.819	-15.897	-21.013	-26.940	-33.477

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
PMFC@8months	A		133.60246
Off-Site PMLC		B	87.88649
On-Site PMLC		B	82.77067
LMLC		B	76.84333
PMFC@Construction		B	70.30615

Levels not connected by same letter are significantly different.

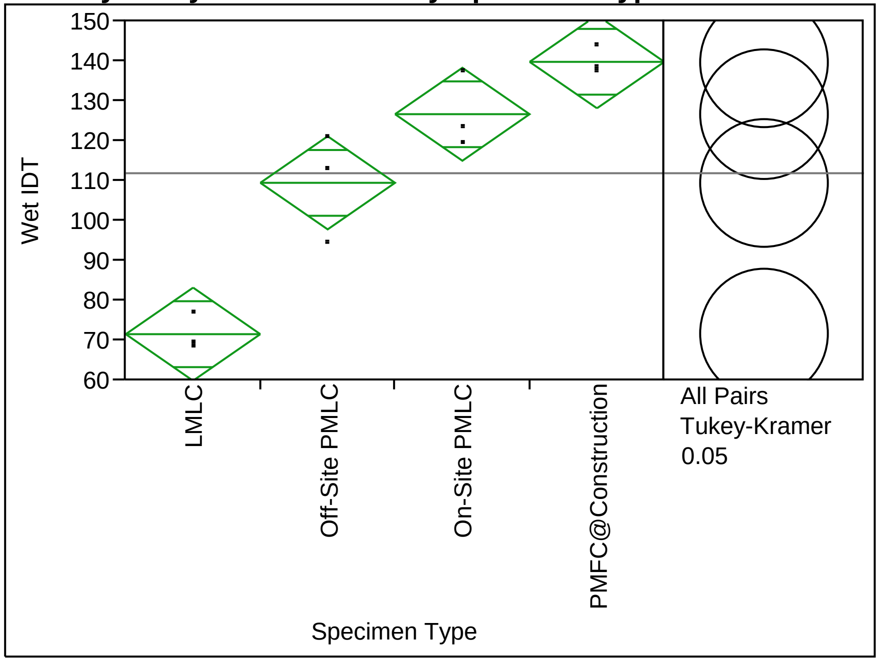
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@8months	PMFC@Construction	63.29631	10.17214	29.8190	96.77365	0.0007*
PMFC@8months	LMLC	56.75913	10.17214	23.2818	90.23647	0.0017*
PMFC@8months	On-Site PMLC	50.83180	10.17214	17.3545	84.30914	0.0038*
PMFC@8months	Off-Site PMLC	45.71597	10.17214	12.2386	79.19331	0.0079*
Off-Site PMLC	PMFC@Construction	17.58034	10.17214	-15.8970	51.05769	0.4603
On-Site PMLC	PMFC@Construction	12.46452	10.17214	-21.0128	45.94186	0.7382
Off-Site PMLC	LMLC	11.04316	10.17214	-22.4342	44.52050	0.8100
LMLC	PMFC@Construction	6.53718	10.17214	-26.9402	40.01453	0.9642
On-Site PMLC	LMLC	5.92733	10.17214	-27.5500	39.40468	0.9747
Off-Site PMLC	On-Site PMLC	5.11583	10.17214	-28.3615	38.59317	0.9852

Figure B.40 (a)

HMA+RAP

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.927881
Adj Rsquare	0.900837
Root Mean Square Error	8.75911
Mean of Response	111.9258
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	3	7896.8790	2632.29	34.3095	<.0001*
Error	8	613.7761	76.72		
C. Total	11	8510.6551			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	71.590	5.0571	59.93	83.25
Off-Site PMLC	3	109.527	5.0571	97.87	121.19
On-Site PMLC	3	126.720	5.0571	115.06	138.38
PMFC@Construction	3	139.867	5.0571	128.21	151.53

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMFC@Construction	On-Site PMLC	Off-Site PMLC	LMLC
PMFC@Construction	-22.902	-9.756	7.438	45.374
On-Site PMLC	-9.756	-22.902	-5.709	32.228
Off-Site PMLC	7.438	-5.709	-22.902	15.034
LMLC	45.374	32.228	15.034	-22.902

Positive values show pairs of means that are significantly different.

Connecting Letters Report

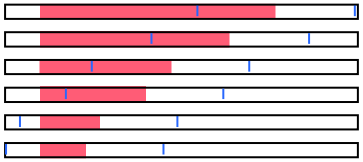
Level				Mean
PMFC@Construction	A			139.86667
On-Site PMLC	A	B		126.72000
Off-Site PMLC		B		109.52667
LMLC			C	71.59000

Levels not connected by same letter are significantly different.

Ordered Differences Report

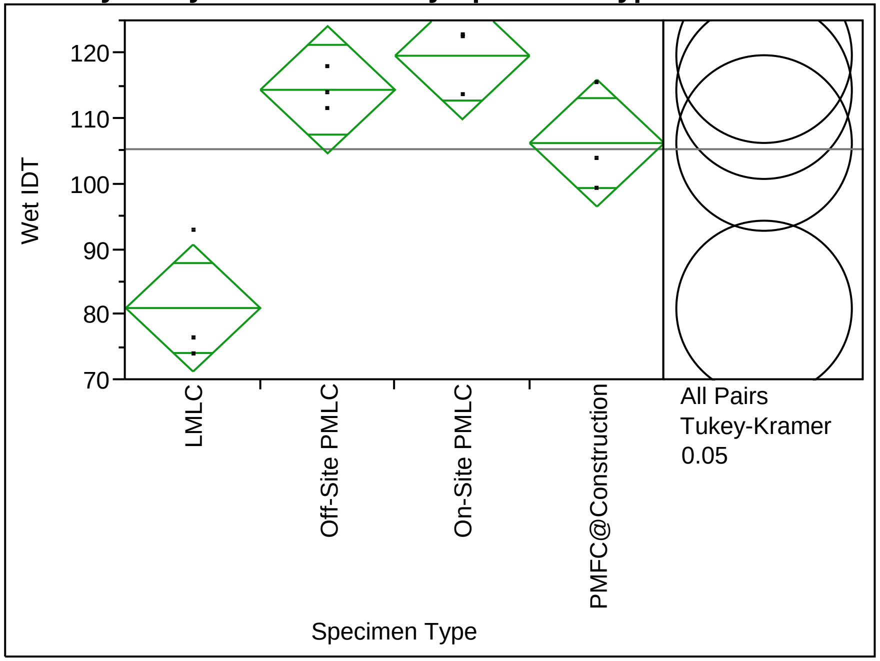
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@Construction	LMLC	68.27667	7.151784	45.3742	91.17914	<.0001*
On-Site PMLC	LMLC	55.13000	7.151784	32.2275	78.03247	0.0003*
Off-Site PMLC	LMLC	37.93667	7.151784	15.0342	60.83914	0.0032*
PMFC@Construction	Off-Site PMLC	30.34000	7.151784	7.4375	53.24247	0.0121*
On-Site PMLC	Off-Site PMLC	17.19333	7.151784	-5.7091	40.09581	0.1535
PMFC@Construction	On-Site PMLC	13.14667	7.151784	-9.7558	36.04914	0.3241



Evotherm 3G+RAP

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.860822
Adj Rsquare	0.80863
Root Mean Square Error	7.311303
Mean of Response	105.4133
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	3	2644.9794	881.660	16.4934	0.0009*
Error	8	427.6413	53.455		
C. Total	11	3072.6207			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	81.063	4.2212	71.33	90.80
Off-Site PMLC	3	114.513	4.2212	104.78	124.25
On-Site PMLC	3	119.733	4.2212	110.00	129.47
PMFC@Construction	3	106.343	4.2212	96.61	116.08

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	On-Site PMLC	Off-Site PMLC	PMFC@Construction	LMLC
On-Site PMLC	-19.117	-13.897	-5.727	19.553
Off-Site PMLC	-13.897	-19.117	-10.947	14.333
PMFC@Construction	-5.727	-10.947	-19.117	6.163
LMLC	19.553	14.333	6.163	-19.117

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
On-Site PMLC	A		119.73333
Off-Site PMLC	A		114.51333
PMFC@Construction	A		106.34333
LMLC		B	81.06333

Levels not connected by same letter are significantly different.

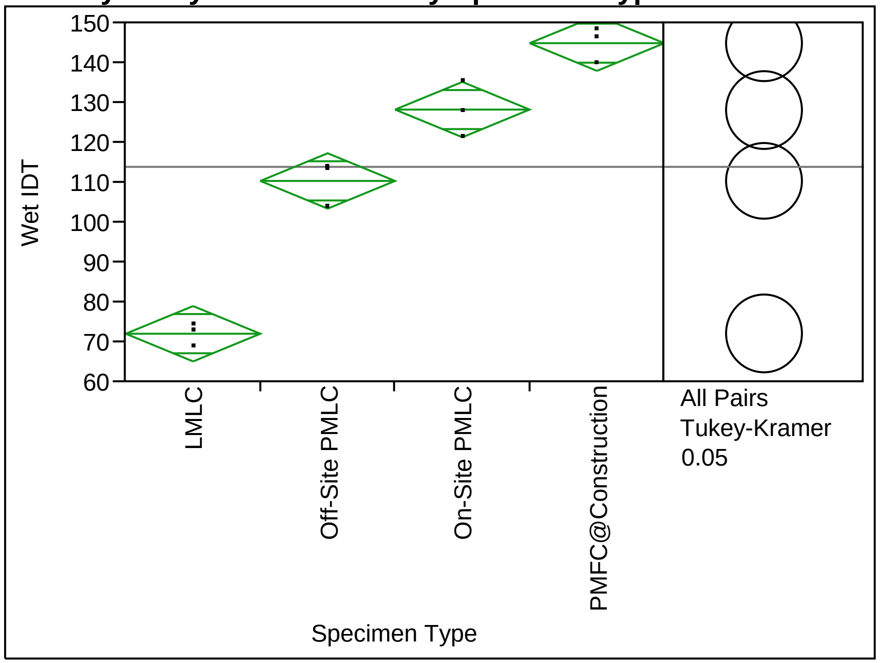
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
On-Site PMLC	LMLC	38.67000	5.969654	19.5531	57.78689	0.0009*
Off-Site PMLC	LMLC	33.45000	5.969654	14.3331	52.56689	0.0023*
PMFC@Construction	LMLC	25.28000	5.969654	6.1631	44.39689	0.0122*
On-Site PMLC	PMFC@Construction	13.39000	5.969654	-5.7269	32.50689	0.1914

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	PMFC@Construction	8.17000	5.969654	-10.9469	27.28689	0.5499
On-Site PMLC	Off-Site PMLC	5.22000	5.969654	-13.8969	24.33689	0.8179

Foaming+RAP

Oneway Analysis of Wet IDT By Specimen Type



Oneway Anova

Summary of Fit

Rsquare	0.975868
Adj Rsquare	0.966818
Root Mean Square Error	5.211267
Mean of Response	114.0167
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	3	8785.6533	2928.55	107.8366	<.0001*
Error	8	217.2584	27.16		
C. Total	11	9002.9117			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	72.193	3.0087	65.26	79.13
Off-Site PMLC	3	110.490	3.0087	103.55	117.43
On-Site PMLC	3	128.367	3.0087	121.43	135.30
PMFC@Construction	3	145.017	3.0087	138.08	151.95

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	PMFC@Construction	On-Site PMLC	Off-Site PMLC	LMLC
PMFC@Construction	-13.626	3.024	20.901	59.197
On-Site PMLC	3.024	-13.626	4.251	42.547
Off-Site PMLC	20.901	4.251	-13.626	24.671
LMLC	59.197	42.547	24.671	-13.626

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
PMFC@Construction	A				145.01667
On-Site PMLC		B			128.36667
Off-Site PMLC			C		110.49000
LMLC				D	72.19333

Levels not connected by same letter are significantly different.

Ordered Differences Report

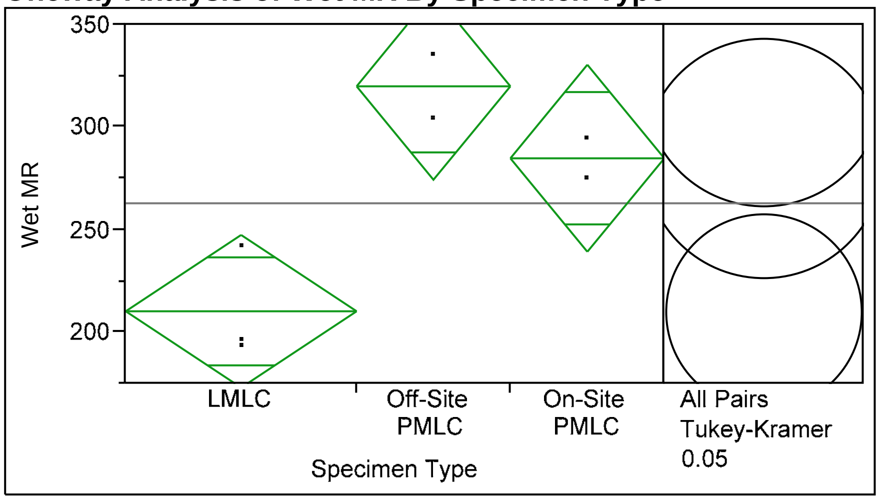
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
PMFC@Construction	LMLC	72.82333	4.254981	59.19742	86.44925	<.0001*
On-Site PMLC	LMLC	56.17333	4.254981	42.54742	69.79925	<.0001*
Off-Site PMLC	LMLC	38.29667	4.254981	24.67075	51.92258	<.0001*
PMFC@Construction	Off-Site PMLC	34.52667	4.254981	20.90075	48.15258	0.0002*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
On-Site PMLC	Off-Site PMLC	17.87667	4.254981	4.25075	31.50258	0.0127*
PMFC@Construction	On-Site PMLC	16.65000	4.254981	3.02409	30.27591	0.0187*

Figure B.41 (a)

HMA+RAP

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.879864
Adj Rsquare	0.819795
Root Mean Square Error	23.22356
Mean of Response	263.0107
Observations (or Sum Wgts)	7

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	15800.049	7900.02	14.6478	0.0144*
Error	4	2157.334	539.33		
C. Total	6	17957.384			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	210.335	13.408	173.11	247.56
Off-Site PMLC	2	320.073	16.422	274.48	365.67
On-Site PMLC	2	284.963	16.422	239.37	330.56

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.56399	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	On-Site PMLC	LMLC
Off-Site PMLC	-82.768	-47.658	34.181
On-Site PMLC	-47.658	-82.768	-0.929
LMLC	34.181	-0.929	-67.580

Positive values show pairs of means that are significantly different.

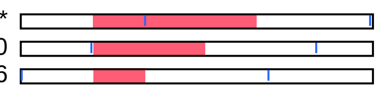
Connecting Letters Report

Level			Mean
Off-Site PMLC	A		320.07250
On-Site PMLC	A	B	284.96250
LMLC		B	210.33500

Levels not connected by same letter are significantly different.

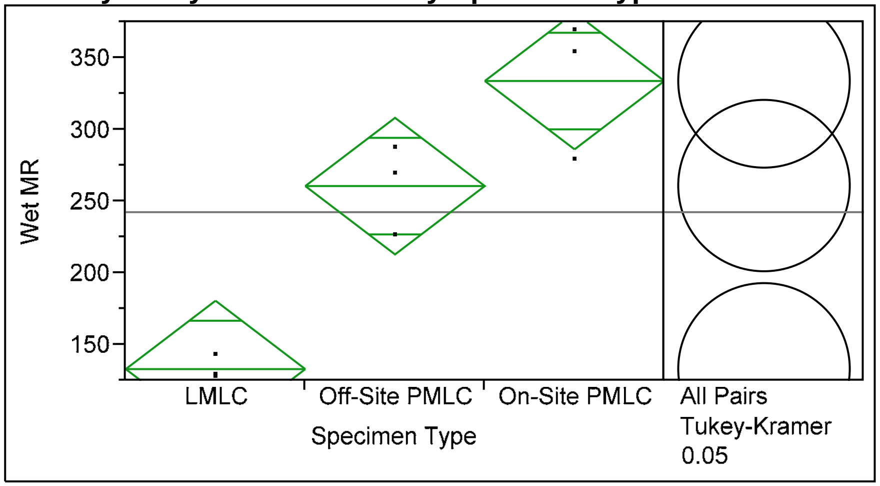
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	LMLC	109.7375	21.20011	34.1806	185.2944	0.0145*
On-Site PMLC	LMLC	74.6275	21.20011	-0.9294	150.1844	0.0520
Off-Site PMLC	On-Site PMLC	35.1100	23.22356	-47.6585	117.8785	0.3776



Evotherm 3G+RAP

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.900774
Adj Rsquare	0.867699
Root Mean Square Error	33.7413
Mean of Response	242.63
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	62010.684	31005.3	27.2341	0.0010*
Error	6	6830.853	1138.5		
C. Total	8	68841.537			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	133.127	19.481	85.46	180.79
Off-Site PMLC	3	260.750	19.481	213.08	308.42
On-Site PMLC	3	334.013	19.481	286.35	381.68

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	On-Site PMLC	Off-Site PMLC	LMLC
On-Site PMLC	-84.53	-11.26	116.36
Off-Site PMLC	-11.26	-84.53	43.10
LMLC	116.36	43.10	-84.53

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
On-Site PMLC	A		334.01333
Off-Site PMLC	A		260.75000
LMLC		B	133.12667

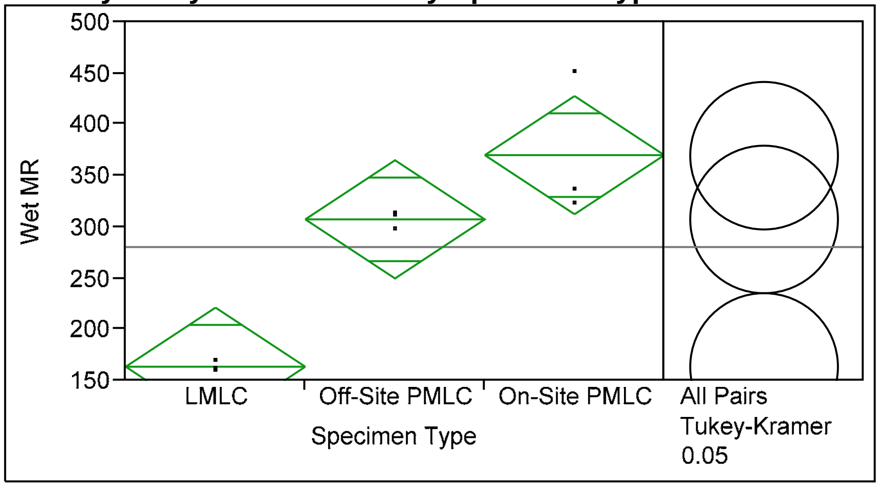
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
On-Site PMLC	LMLC	200.8867	27.54966	116.360	285.4131	0.0008*
Off-Site PMLC	LMLC	127.6233	27.54966	43.097	212.1498	0.0085*
On-Site PMLC	Off-Site PMLC	73.2633	27.54966	-11.263	157.7898	0.0834

Sasobit+RAP

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova

Summary of Fit

Rsquare	0.870585
Adj Rsquare	0.827447
Root Mean Square Error	40.84359
Mean of Response	280.5017
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	67332.878	33666.4	20.1813	0.0022*
Error	6	10009.192	1668.2		
C. Total	8	77342.070			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	163.650	23.581	105.95	221.35
Off-Site PMLC	3	307.600	23.581	249.90	365.30
On-Site PMLC	3	370.255	23.581	312.55	427.96

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	On-Site PMLC	Off-Site PMLC	LMLC
On-Site PMLC	-102.32	-39.66	104.29
Off-Site PMLC	-39.66	-102.32	41.63
LMLC	104.29	41.63	-102.32

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
On-Site PMLC	A		370.25500
Off-Site PMLC	A		307.60000
LMLC		B	163.65000

Levels not connected by same letter are significantly different.

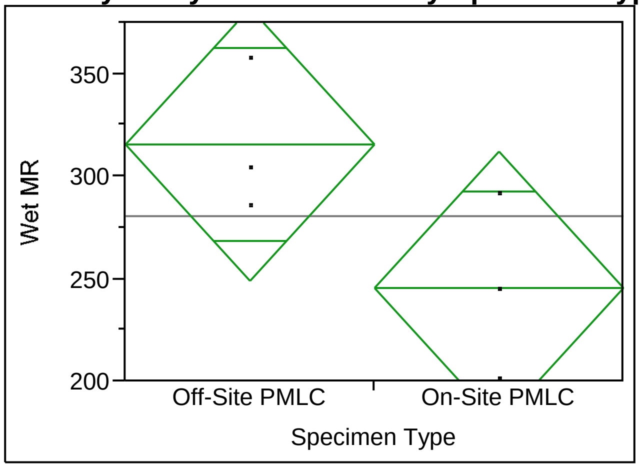
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
On-Site PMLC	LMLC	206.6050	33.34865	104.286	308.9236	0.0020*
Off-Site PMLC	LMLC	143.9500	33.34865	41.631	246.2686	0.0118*
On-Site PMLC	Off-Site PMLC	62.6550	33.34865	-39.664	164.9736	0.2247

Figure B.42 (a)

HMA

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova
Summary of Fit

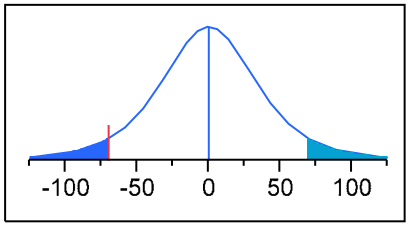
Rsquare	0.515733
Adj Rsquare	0.394666
Root Mean Square Error	41.52399
Mean of Response	280.6467
Observations (or Sum Wgts)	6

t Test
On-Site PMLC-Off-Site PMLC

Assuming equal variances

Difference	-69.98	t Ratio	-2.06395
Std Err Dif	33.90	DF	4
Upper CL Dif	24.16	Prob > |t|	0.1080

Lower CL Dif	-164.11	Prob > t	0.9460
Confidence	0.95	Prob < t	0.0540



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	1	7345.101	7345.10	4.2599	0.1080
Error	4	6896.966	1724.24		
C. Total	5	14242.067			

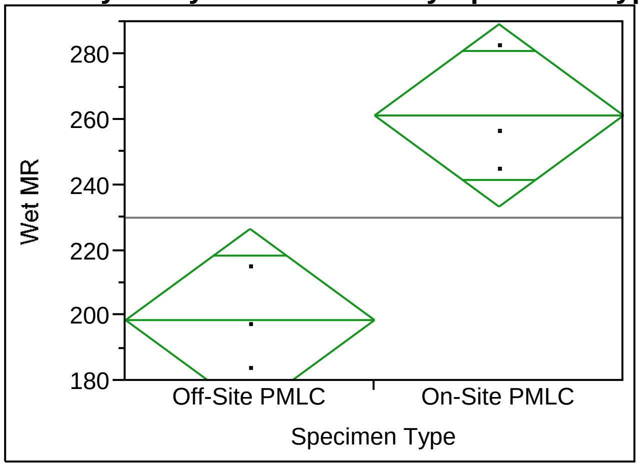
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-Site PMLC	3	315.635	23.974	249.07	382.20
On-Site PMLC	3	245.658	23.974	179.10	312.22

Std Error uses a pooled estimate of error variance

Evotherm 3G

Oneway Analysis of Wet MR By Specimen Type



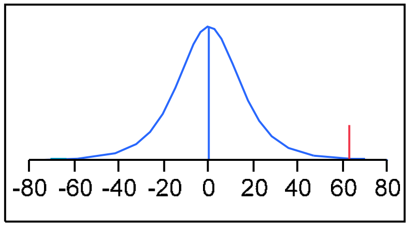
Oneway Anova
Summary of Fit

Rsquare	0.82901
Adj Rsquare	0.786262
Root Mean Square Error	17.45437
Mean of Response	230.0467
Observations (or Sum Wgts)	6

t Test
On-Site PMLC-Off-Site PMLC

Assuming equal variances

Difference	62.760	t Ratio	4.403769
Std Err Dif	14.251	DF	4
Upper CL Dif	102.328	Prob > |t|	0.0117*
Lower CL Dif	23.192	Prob > t	0.0058*
Confidence	0.95	Prob < t	0.9942



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	1	5908.2264	5908.23	19.3932	0.0117*
Error	4	1218.6194	304.65		
C. Total	5	7126.8458			

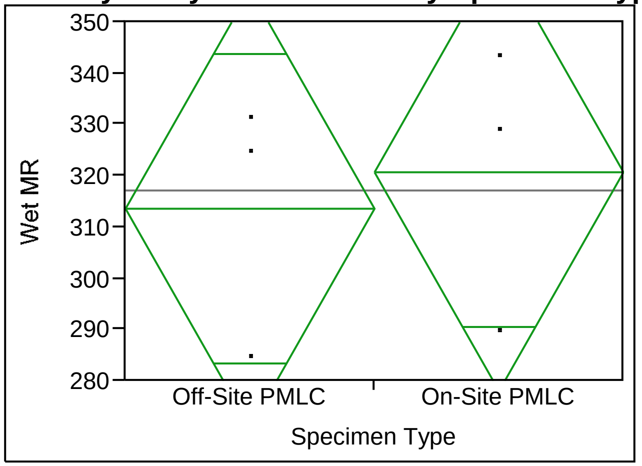
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-Site PMLC	3	198.667	10.077	170.69	226.65
On-Site PMLC	3	261.427	10.077	233.45	289.41

Std Error uses a pooled estimate of error variance

Sasobit

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova

Summary of Fit

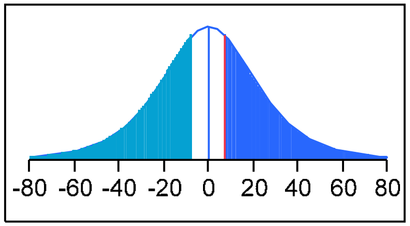
Rsquare	0.026092
Adj Rsquare	-0.21738
Root Mean Square Error	26.64395
Mean of Response	317.1675
Observations (or Sum Wgts)	6

t Test

On-Site PMLC-Off-Site PMLC

Assuming equal variances

Difference	7.122	t Ratio	0.327362
Std Err Dif	21.755	DF	4
Upper CL Dif	67.522	Prob > |t|	0.7598
Lower CL Dif	-53.279	Prob > t	0.3799
Confidence	0.95	Prob < t	0.6201



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	1	76.0772	76.077	0.1072	0.7598
Error	4	2839.6003	709.900		
C. Total	5	2915.6775			

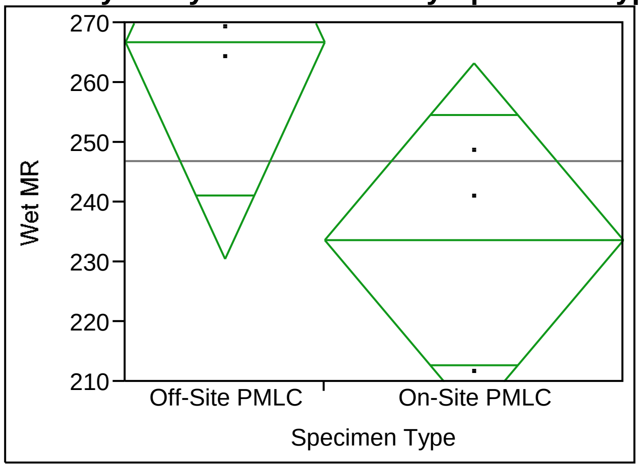
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-Site PMLC	3	313.607	15.383	270.90	356.32
On-Site PMLC	3	320.728	15.383	278.02	363.44

Std Error uses a pooled estimate of error variance

Foaming

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova

Summary of Fit

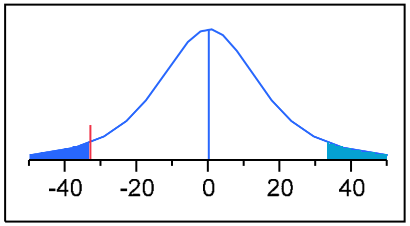
Rsquare	0.628165
Adj Rsquare	0.50422
Root Mean Square Error	16.11281
Mean of Response	246.952
Observations (or Sum Wgts)	5

t Test

On-Site PMLC-Off-Site PMLC

Assuming equal variances

Difference	-33.113	t Ratio	-2.25124
Std Err Dif	14.709	DF	3
Upper CL Dif	13.697	Prob > |t|	0.1098
Lower CL Dif	-79.924	Prob > t	0.9451
Confidence	0.95	Prob < t	0.0549



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	1	1315.7914	1315.79	5.0681	0.1098
Error	3	778.8683	259.62		
C. Total	4	2094.6597			

Means for Oneway Anova

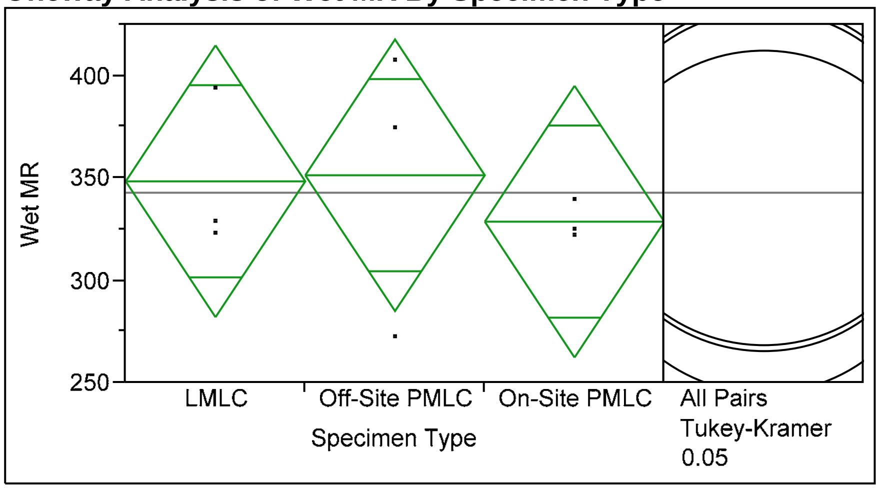
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Off-Site PMLC	2	266.820	11.393	230.56	303.08
On-Site PMLC	3	233.707	9.303	204.10	263.31

Std Error uses a pooled estimate of error variance

Figure B.43 (a)

HMA

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.064452
Adj Rsquare	-0.2474
Root Mean Square Error	46.9976
Mean of Response	342.9561
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	913.012	456.51	0.2067	0.8188
Error	6	13252.647	2208.77		
C. Total	8	14165.659			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	348.547	27.134	282.15	414.94
Off-Site PMLC	3	351.507	27.134	285.11	417.90
On-Site PMLC	3	328.815	27.134	262.42	395.21

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	LMLC	On-Site PMLC
Off-Site PMLC	-117.74	-114.78	-95.04
LMLC	-114.78	-117.74	-98.00
On-Site PMLC	-95.04	-98.00	-117.74

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Off-Site PMLC	A	351.50667
LMLC	A	348.54667
On-Site PMLC	A	328.81500

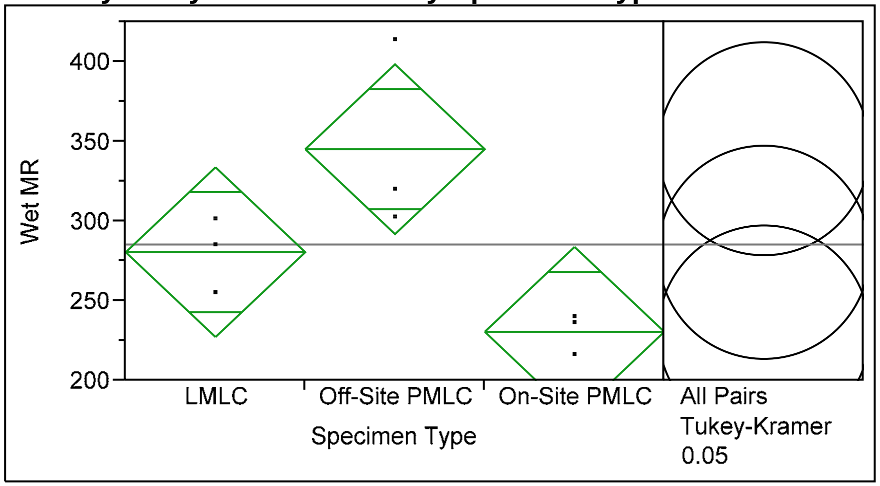
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	On-Site PMLC	22.69167	38.37338	-95.044	140.4269	0.8297
LMLC	On-Site PMLC	19.73167	38.37338	-98.004	137.4669	0.8674
Off-Site PMLC	LMLC	2.96000	38.37338	-114.775	120.6953	0.9967

Evotherm DAT

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.699016
Adj Rsquare	0.598687
Root Mean Square Error	37.72158
Mean of Response	285.5567
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	19827.772	9913.89	6.9673	0.0273*
Error	6	8537.505	1422.92		
C. Total	8	28365.277			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	280.658	21.779	227.37	333.95
Off-Site PMLC	3	345.335	21.779	292.04	398.63
On-Site PMLC	3	230.677	21.779	177.39	283.97

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	LMLC	On-Site PMLC
Off-Site PMLC	-94.498	-29.821	20.161
LMLC	-29.821	-94.498	-44.516
On-Site PMLC	20.161	-44.516	-94.498

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Off-Site PMLC	A		345.33500
LMLC	A	B	280.65833
On-Site PMLC		B	230.67667

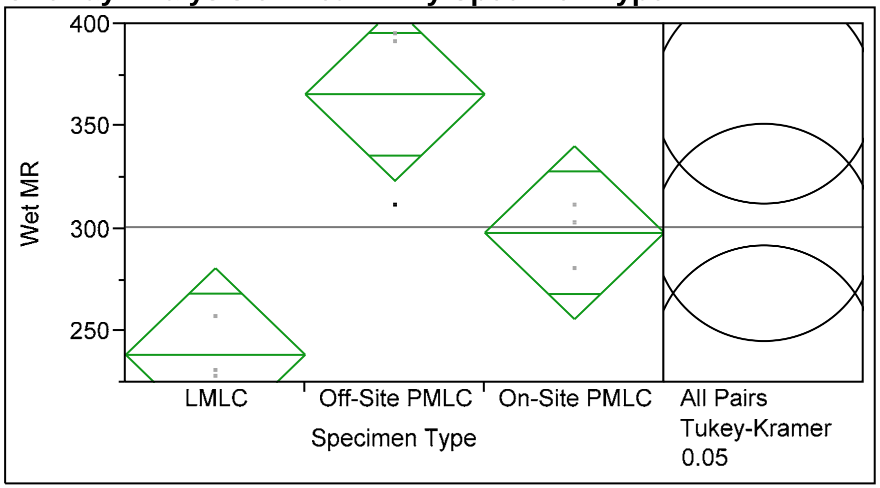
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	On-Site PMLC	114.6583	30.79954	20.1607	209.1559	0.0229*
Off-Site PMLC	LMLC	64.6767	30.79954	-29.8209	159.1743	0.1700
LMLC	On-Site PMLC	49.9817	30.79954	-44.5159	144.4793	0.3074

Foaming

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.818891
Adj Rsquare	0.758521
Root Mean Square Error	29.92688
Mean of Response	300.9133
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	24297.387	12148.7	13.5646	0.0059*
Error	6	5373.711	895.6		
C. Total	8	29671.097			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	238.640	17.278	196.36	280.92
Off-Site PMLC	3	365.830	17.278	323.55	408.11
On-Site PMLC	3	298.270	17.278	255.99	340.55

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	On-Site PMLC	LMLC
Off-Site PMLC	-74.971	-7.411	52.219
On-Site PMLC	-7.411	-74.971	-15.341
LMLC	52.219	-15.341	-74.971

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Off-Site PMLC	A		365.83000
On-Site PMLC	A	B	298.27000
LMLC		B	238.64000

Levels not connected by same letter are significantly different.

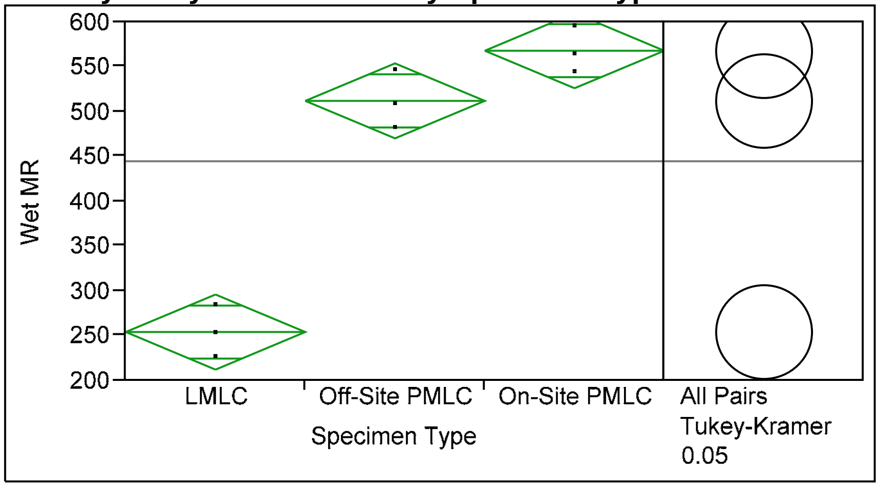
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	LMLC	127.1900	24.43520	52.2192	202.1608	0.0048*
Off-Site PMLC	On-Site PMLC	67.5600	24.43520	-7.4108	142.5308	0.0730
On-Site PMLC	LMLC	59.6300	24.43520	-15.3408	134.6008	0.1101

Figure B.44 (a)

HMA+RAP

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova
Summary of Fit

Rsquare	0.969616
Adj Rsquare	0.959488
Root Mean Square Error	29.63723
Mean of Response	445.0956
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	168184.31	84092.2	95.7371	<.0001*
Error	6	5270.19	878.4		
C. Total	8	173454.50			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	254.493	17.111	212.62	296.36
Off-Site PMLC	3	512.400	17.111	470.53	554.27
On-Site PMLC	3	568.393	17.111	526.52	610.26

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	On-Site PMLC	Off-Site PMLC	LMLC
On-Site PMLC	-74.25	-18.25	239.65
Off-Site PMLC	-18.25	-74.25	183.66
LMLC	239.65	183.66	-74.25

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
On-Site PMLC	A		568.39333
Off-Site PMLC	A		512.40000
LMLC		B	254.49333

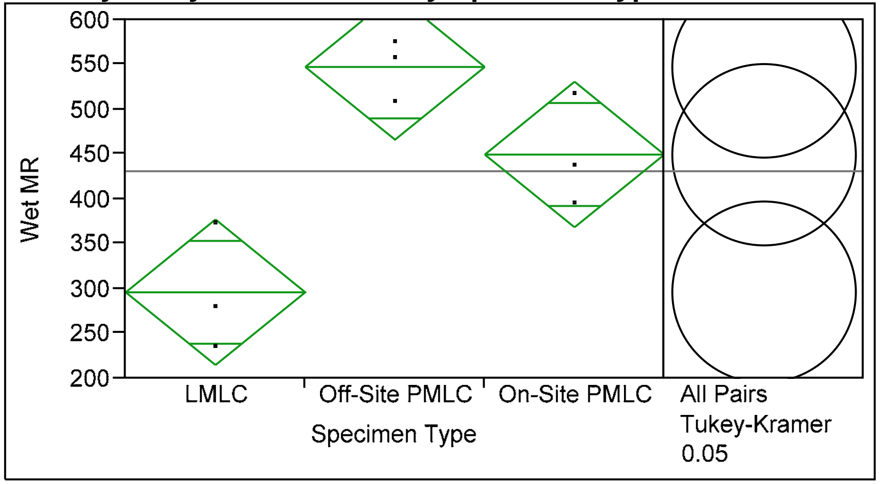
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
On-Site PMLC	LMLC	313.9000	24.19870	239.655	388.1452	<.0001*
Off-Site PMLC	LMLC	257.9067	24.19870	183.661	332.1519	<.0001*
On-Site PMLC	Off-Site PMLC	55.9933	24.19870	-18.252	130.2385	0.1294

Evotherm 3G+RAP

Oneway Analysis of Wet MR By Specimen Type



Oneway Anova

Summary of Fit

Rsquare	0.829442
Adj Rsquare	0.772589
Root Mean Square Error	57.4847
Mean of Response	431.5344
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	96420.48	48210.2	14.5893	0.0050*
Error	6	19826.94	3304.5		
C. Total	8	116247.42			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	296.470	33.189	215.26	377.68
Off-Site PMLC	3	547.937	33.189	466.73	629.15
On-Site PMLC	3	450.197	33.189	368.99	531.41

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	On-Site PMLC	LMLC
Off-Site PMLC	-144.01	-46.27	107.46
On-Site PMLC	-46.27	-144.01	9.72
LMLC	107.46	9.72	-144.01

Positive values show pairs of means that are significantly different.

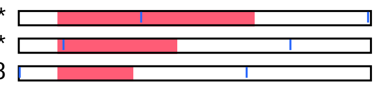
Connecting Letters Report

Level			Mean
Off-Site PMLC	A		547.93667
On-Site PMLC	A		450.19667
LMLC		B	296.47000

Levels not connected by same letter are significantly different.

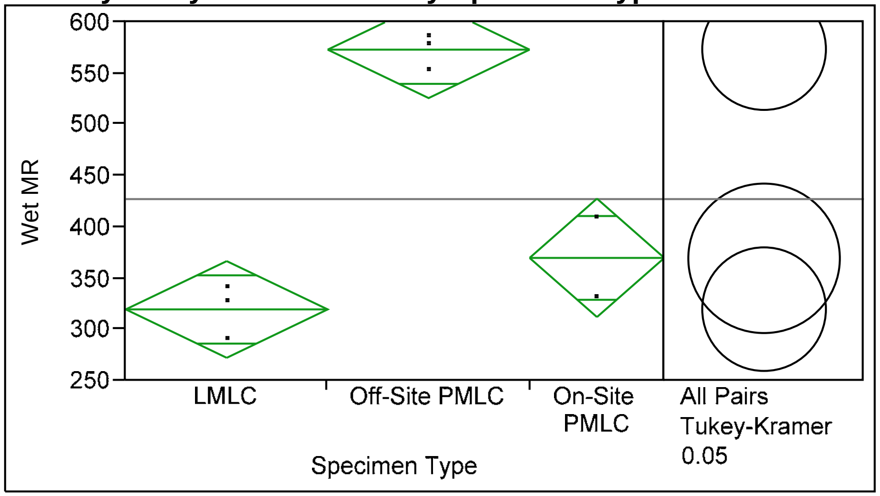
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	LMLC	251.4667	46.93606	107.460	395.4735	0.0042*
On-Site PMLC	LMLC	153.7267	46.93606	9.720	297.7335	0.0388*
Off-Site PMLC	On-Site PMLC	97.7400	46.93606	-46.267	241.7468	0.1738



Foaming+RAP

Oneway Analysis of Wet MR By Specimen Type



Missing Rows
1

Oneway Anova

Summary of Fit

Rsquare	0.95416
Adj Rsquare	0.935824
Root Mean Square Error	31.7964
Mean of Response	427.355
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Specimen Type	2	105221.41	52610.7	52.0377	0.0004*
Error	5	5055.06	1011.0		
C. Total	7	110276.46			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC	3	319.687	18.358	272.50	366.88
Off-Site PMLC	3	573.260	18.358	526.07	620.45

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
On-Site PMLC	2	370.000	22.483	312.20	427.80

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Off-Site PMLC	On-Site PMLC	LMLC
Off-Site PMLC	-84.48	108.81	169.10
On-Site PMLC	108.81	-103.46	-44.13
LMLC	169.10	-44.13	-84.48

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Off-Site PMLC	A		573.26000
On-Site PMLC		B	370.00000
LMLC		B	319.68667

Levels not connected by same letter are significantly different.

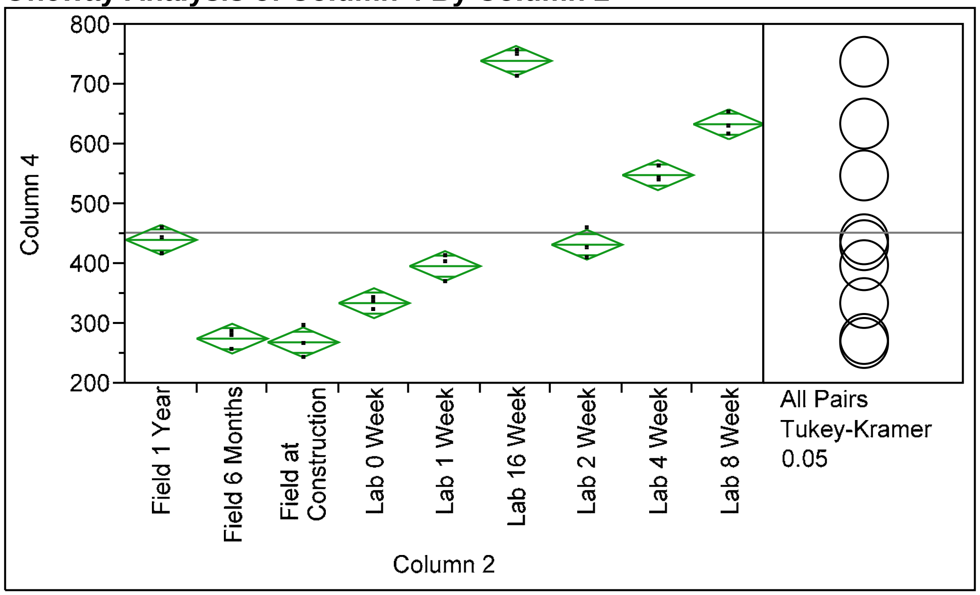
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Off-Site PMLC	LMLC	253.5733	25.96165	169.098	338.0490	0.0005*
Off-Site PMLC	On-Site PMLC	203.2600	29.02601	108.813	297.7067	0.0021*
On-Site PMLC	LMLC	50.3133	29.02601	-44.133	144.7600	0.2820

Figure C.12 (a)

HMA+RAP

Oneway Analysis of Column 4 By Column 2



Excluded Rows
126

Oneway Anova

Summary of Fit

Rsquare	0.987895
Adj Rsquare	0.982515
Root Mean Square Error	20.56524
Mean of Response	452.4407
Observations (or Sum Wgts)	27

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Column 2	8	621263.56	77657.9	183.6192	<.0001*
Error	18	7612.73	422.9		

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C. Total	26	628876.29			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Field 1 Year	3	440.600	11.873	415.66	465.54
Field 6 Months	3	275.467	11.873	250.52	300.41
Field at Construction	3	269.367	11.873	244.42	294.31
Lab 0 Week	3	334.800	11.873	309.86	359.74
Lab 1 Week	3	396.767	11.873	371.82	421.71
Lab 16 Week	3	739.833	11.873	714.89	764.78
Lab 2 Week	3	432.533	11.873	407.59	457.48
Lab 4 Week	3	548.767	11.873	523.82	573.71
Lab 8 Week	3	633.833	11.873	608.89	658.78

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.50386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Lab 16 Week	Lab 8 Week	Lab 4 Week	Field 1 Year	Lab 2 Week	Lab 1 Week	Lab 0 Week	Field 6 Months	Fie Construc
Lab 16 Week	-58.83	47.17	132.23	240.40	248.47	284.23	346.20	405.53	41
Lab 8 Week	47.17	-58.83	26.23	134.40	142.47	178.23	240.20	299.53	30
Lab 4 Week	132.23	26.23	-58.83	49.33	57.40	93.17	155.13	214.47	22
Field 1 Year	240.40	134.40	49.33	-58.83	-50.77	-15.00	46.97	106.30	11
Lab 2 Week	248.47	142.47	57.40	-50.77	-58.83	-23.07	38.90	98.23	10
Lab 1 Week	284.23	178.23	93.17	-15.00	-23.07	-58.83	3.13	62.47	6
Lab 0 Week	346.20	240.20	155.13	46.97	38.90	3.13	-58.83	0.50	
Field 6 Months	405.53	299.53	214.47	106.30	98.23	62.47	0.50	-58.83	-5
Field at Construction	411.63	305.63	220.57	112.40	104.33	68.57	6.60	-52.73	-5

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Lab 16 Week	A	739.83333

Level							Mean
Lab 8 Week	B						633.83333
Lab 4 Week		C					548.76667
Field 1 Year			D				440.60000
Lab 2 Week			D				432.53333
Lab 1 Week			D				396.76667
Lab 0 Week				E			334.80000
Field 6 Months					F		275.46667
Field at Construction					F		269.36667

Levels not connected by same letter are significantly different.

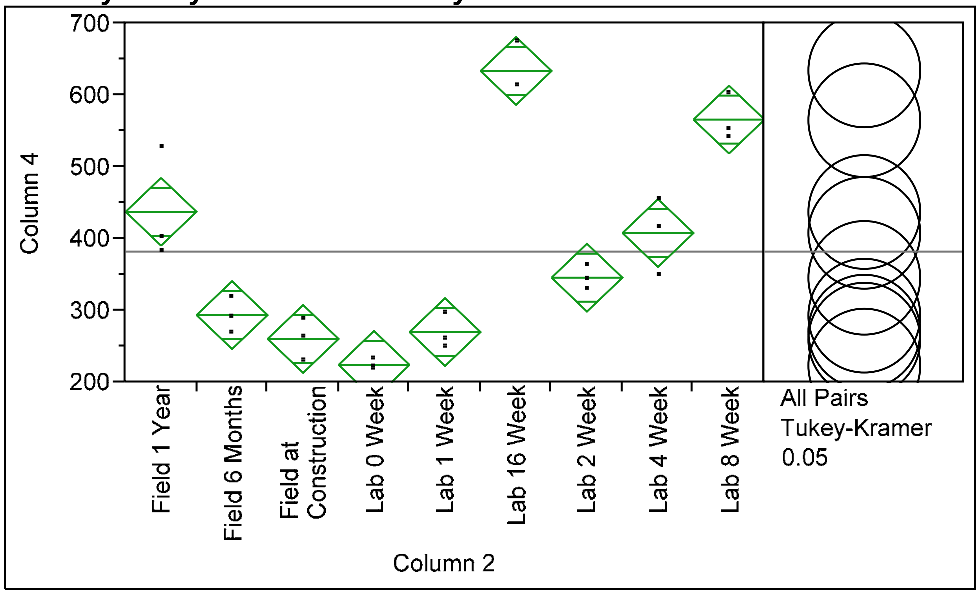
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Lab 16 Week	Field at Construction	470.4667	16.79145	411.632	529.3016	<.0001*
Lab 16 Week	Field 6 Months	464.3667	16.79145	405.532	523.2016	<.0001*
Lab 16 Week	Lab 0 Week	405.0333	16.79145	346.198	463.8683	<.0001*
Lab 8 Week	Field at Construction	364.4667	16.79145	305.632	423.3016	<.0001*
Lab 8 Week	Field 6 Months	358.3667	16.79145	299.532	417.2016	<.0001*
Lab 16 Week	Lab 1 Week	343.0667	16.79145	284.232	401.9016	<.0001*
Lab 16 Week	Lab 2 Week	307.3000	16.79145	248.465	366.1349	<.0001*
Lab 16 Week	Field 1 Year	299.2333	16.79145	240.398	358.0683	<.0001*
Lab 8 Week	Lab 0 Week	299.0333	16.79145	240.198	357.8683	<.0001*
Lab 4 Week	Field at Construction	279.4000	16.79145	220.565	338.2349	<.0001*
Lab 4 Week	Field 6 Months	273.3000	16.79145	214.465	332.1349	<.0001*
Lab 8 Week	Lab 1 Week	237.0667	16.79145	178.232	295.9016	<.0001*
Lab 4 Week	Lab 0 Week	213.9667	16.79145	155.132	272.8016	<.0001*
Lab 8 Week	Lab 2 Week	201.3000	16.79145	142.465	260.1349	<.0001*
Lab 8 Week	Field 1 Year	193.2333	16.79145	134.398	252.0683	<.0001*
Lab 16 Week	Lab 4 Week	191.0667	16.79145	132.232	249.9016	<.0001*
Field 1 Year	Field at Construction	171.2333	16.79145	112.398	230.0683	<.0001*
Field 1 Year	Field 6 Months	165.1333	16.79145	106.298	223.9683	<.0001*
Lab 2 Week	Field at Construction	163.1667	16.79145	104.332	222.0016	<.0001*
Lab 2 Week	Field 6 Months	157.0667	16.79145	98.232	215.9016	<.0001*
Lab 4 Week	Lab 1 Week	152.0000	16.79145	93.165	210.8349	<.0001*
Lab 1 Week	Field at Construction	127.4000	16.79145	68.565	186.2349	<.0001*
Lab 1 Week	Field 6 Months	121.3000	16.79145	62.465	180.1349	<.0001*
Lab 4 Week	Lab 2 Week	116.2333	16.79145	57.398	175.0683	<.0001*
Lab 4 Week	Field 1 Year	108.1667	16.79145	49.332	167.0016	0.0001*
Lab 16 Week	Lab 8 Week	106.0000	16.79145	47.165	164.8349	0.0002*
Field 1 Year	Lab 0 Week	105.8000	16.79145	46.965	164.6349	0.0002*
Lab 2 Week	Lab 0 Week	97.7333	16.79145	38.898	156.5683	0.0004*
Lab 8 Week	Lab 4 Week	85.0667	16.79145	26.232	143.9016	0.0020*
Lab 0 Week	Field at Construction	65.4333	16.79145	6.598	124.2683	0.0228*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Lab 1 Week	Lab 0 Week	61.9667	16.79145	3.132	120.8016	0.0346*
Lab 0 Week	Field 6 Months	59.3333	16.79145	0.498	118.1683	0.0472*
Field 1 Year	Lab 1 Week	43.8333	16.79145	-15.002	102.6683	0.2480
Lab 2 Week	Lab 1 Week	35.7667	16.79145	-23.068	94.6016	0.4847
Field 1 Year	Lab 2 Week	8.0667	16.79145	-50.768	66.9016	0.9999
Field 6 Months	Field at Construction	6.1000	16.79145	-52.735	64.9349	1.0000

Evotherm 3G+RAP

Oneway Analysis of Column 4 By Column 2



Excluded Rows
126

Oneway Anova

Summary of Fit

Rsquare	0.946839
Adj Rsquare	0.923211
Root Mean Square Error	38.97953
Mean of Response	382.3815
Observations (or Sum Wgts)	27

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Column 2	8	487107.63	60888.5	40.0739	<.0001*
Error	18	27349.27	1519.4		
C. Total	26	514456.90			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Field 1 Year	3	437.867	22.505	390.59	485.15
Field 6 Months	3	293.800	22.505	246.52	341.08
Field at Construction	3	260.633	22.505	213.35	307.91
Lab 0 Week	3	224.433	22.505	177.15	271.71
Lab 1 Week	3	270.267	22.505	222.99	317.55
Lab 16 Week	3	634.033	22.505	586.75	681.31
Lab 2 Week	3	346.033	22.505	298.75	393.31
Lab 4 Week	3	408.167	22.505	360.89	455.45
Lab 8 Week	3	566.200	22.505	518.92	613.48

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.50386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Lab 16 Week	Lab 8 Week	Field 1 Year	Lab 4 Week	Lab 2 Week	Field 6 Months	Lab 1 Week	Field at Construction	Lab 0 W
Lab 16 Week	-111.52	-43.68	84.65	114.35	176.48	228.72	252.25	261.88	29
Lab 8 Week	-43.68	-111.52	16.82	46.52	108.65	160.88	184.42	194.05	23
Field 1 Year	84.65	16.82	-111.52	-81.82	-19.68	32.55	56.08	65.72	10
Lab 4 Week	114.35	46.52	-81.82	-111.52	-49.38	2.85	26.38	36.02	7
Lab 2 Week	176.48	108.65	-19.68	-49.38	-111.52	-59.28	-35.75	-26.12	1
Field 6 Months	228.72	160.88	32.55	2.85	-59.28	-111.52	-87.98	-78.35	-4
Lab 1 Week	252.25	184.42	56.08	26.38	-35.75	-87.98	-111.52	-101.88	-6
Field at Construction	261.88	194.05	65.72	36.02	-26.12	-78.35	-101.88	-111.52	-7
Lab 0 Week	298.08	230.25	101.92	72.22	10.08	-42.15	-65.68	-75.32	-11

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Lab 16 Week	A		634.03333
Lab 8 Week	A		566.20000
Field 1 Year		B	437.86667
Lab 4 Week		B	408.16667

Level				Mean
Lab 2 Week	B	C		346.03333
Field 6 Months		C	D	293.80000
Lab 1 Week		C	D	270.26667
Field at Construction		C	D	260.63333
Lab 0 Week			D	224.43333

Levels not connected by same letter are significantly different.

Ordered Differences Report

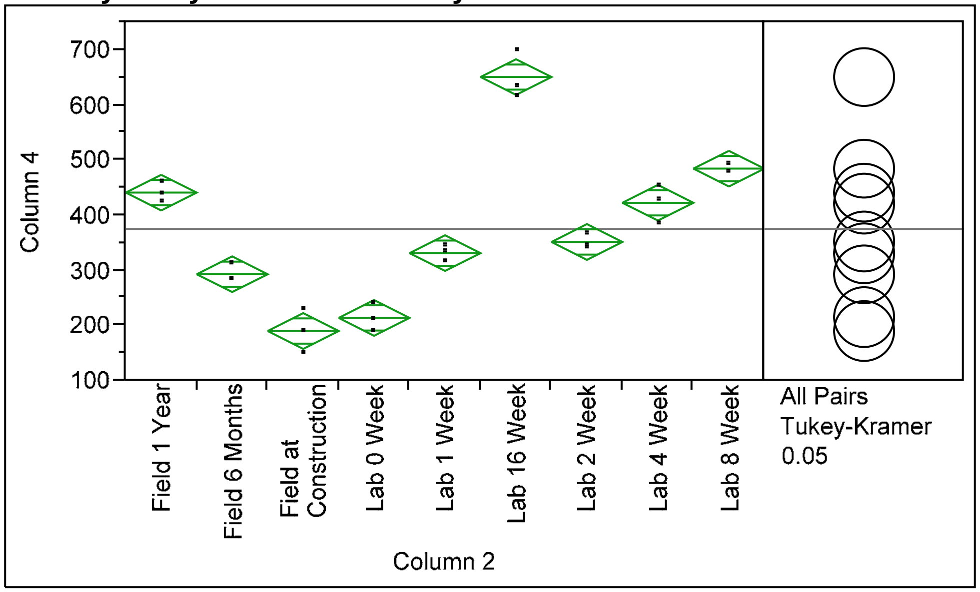
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Lab 16 Week	Lab 0 Week	409.6000	31.82665	298.084	521.1162	<.0001*
Lab 16 Week	Field at Construction	373.4000	31.82665	261.884	484.9162	<.0001*
Lab 16 Week	Lab 1 Week	363.7667	31.82665	252.250	475.2829	<.0001*
Lab 8 Week	Lab 0 Week	341.7667	31.82665	230.250	453.2829	<.0001*
Lab 16 Week	Field 6 Months	340.2333	31.82665	228.717	451.7496	<.0001*
Lab 8 Week	Field at Construction	305.5667	31.82665	194.050	417.0829	<.0001*
Lab 8 Week	Lab 1 Week	295.9333	31.82665	184.417	407.4496	<.0001*
Lab 16 Week	Lab 2 Week	288.0000	31.82665	176.484	399.5162	<.0001*
Lab 8 Week	Field 6 Months	272.4000	31.82665	160.884	383.9162	<.0001*
Lab 16 Week	Lab 4 Week	225.8667	31.82665	114.350	337.3829	<.0001*
Lab 8 Week	Lab 2 Week	220.1667	31.82665	108.650	331.6829	<.0001*
Field 1 Year	Lab 0 Week	213.4333	31.82665	101.917	324.9496	<.0001*
Lab 16 Week	Field 1 Year	196.1667	31.82665	84.650	307.6829	0.0002*
Lab 4 Week	Lab 0 Week	183.7333	31.82665	72.217	295.2496	0.0005*
Field 1 Year	Field at Construction	177.2333	31.82665	65.717	288.7496	0.0007*
Field 1 Year	Lab 1 Week	167.6000	31.82665	56.084	279.1162	0.0014*
Lab 8 Week	Lab 4 Week	158.0333	31.82665	46.517	269.5496	0.0025*
Lab 4 Week	Field at Construction	147.5333	31.82665	36.017	259.0496	0.0050*
Field 1 Year	Field 6 Months	144.0667	31.82665	32.550	255.5829	0.0063*
Lab 4 Week	Lab 1 Week	137.9000	31.82665	26.384	249.4162	0.0093*
Lab 8 Week	Field 1 Year	128.3333	31.82665	16.817	239.8496	0.0173*
Lab 2 Week	Lab 0 Week	121.6000	31.82665	10.084	233.1162	0.0266*
Lab 4 Week	Field 6 Months	114.3667	31.82665	2.850	225.8829	0.0419*
Field 1 Year	Lab 2 Week	91.8333	31.82665	-19.683	203.3496	0.1574
Lab 2 Week	Field at Construction	85.4000	31.82665	-26.116	196.9162	0.2208
Lab 2 Week	Lab 1 Week	75.7667	31.82665	-35.750	187.2829	0.3495
Field 6 Months	Lab 0 Week	69.3667	31.82665	-42.150	180.8829	0.4564
Lab 16 Week	Lab 8 Week	67.8333	31.82665	-43.683	179.3496	0.4840
Lab 4 Week	Lab 2 Week	62.1333	31.82665	-49.383	173.6496	0.5905
Lab 2 Week	Field 6 Months	52.2333	31.82665	-59.283	163.7496	0.7716
Lab 1 Week	Lab 0 Week	45.8333	31.82665	-65.683	157.3496	0.8678
Field at Construction	Lab 0 Week	36.2000	31.82665	-75.316	147.7162	0.9599
Field 6 Months	Field at Construction	33.1667	31.82665	-78.350	144.6829	0.9757

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Field 1 Year	Lab 4 Week	29.7000	31.82665	-81.816	141.2162	0.9876
Field 6 Months	Lab 1 Week	23.5333	31.82665	-87.983	135.0496	0.9973
Lab 1 Week	Field at Construction	9.6333	31.82665	-101.883	121.1496	1.0000

Sasobit+RAP

Sasobit+RAP

Oneway Analysis of Column 4 By Column 2



Excluded Rows
126

Oneway Anova

Summary of Fit

Rsquare	0.974647
Adj Rsquare	0.963379
Root Mean Square Error	26.64506
Mean of Response	375.6556
Observations (or Sum Wgts)	27

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Column 2	8	491278.56	61409.8	86.4977	<.0001*
Error	18	12779.27	710.0		
C. Total	26	504057.83			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Field 1 Year	3	441.300	15.384	408.98	473.62
Field 6 Months	3	293.400	15.384	261.08	325.72
Field at Construction	3	190.400	15.384	158.08	222.72
Lab 0 Week	3	214.167	15.384	181.85	246.49
Lab 1 Week	3	331.567	15.384	299.25	363.89
Lab 16 Week	3	650.700	15.384	618.38	683.02
Lab 2 Week	3	351.800	15.384	319.48	384.12
Lab 4 Week	3	422.833	15.384	390.51	455.15
Lab 8 Week	3	484.733	15.384	452.41	517.05

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.50386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Lab 16 Week	Lab 8 Week	Field 1 Year	Lab 4 Week	Lab 2 Week	Lab 1 Week	Field 6 Months	Lab 0 Week	Fie Construc
Lab 16 Week	-76.23	89.74	133.17	151.64	222.67	242.90	281.07	360.30	38
Lab 8 Week	89.74	-76.23	-32.80	-14.33	56.70	76.94	115.10	194.34	21
Field 1 Year	133.17	-32.80	-76.23	-57.76	13.27	33.50	71.67	150.90	17
Lab 4 Week	151.64	-14.33	-57.76	-76.23	-5.20	15.04	53.20	132.44	15
Lab 2 Week	222.67	56.70	13.27	-5.20	-76.23	-56.00	-17.83	61.40	8
Lab 1 Week	242.90	76.94	33.50	15.04	-56.00	-76.23	-38.06	41.17	6
Field 6 Months	281.07	115.10	71.67	53.20	-17.83	-38.06	-76.23	3.00	2
Lab 0 Week	360.30	194.34	150.90	132.44	61.40	41.17	3.00	-76.23	-5
Field at Construction	384.07	218.10	174.67	156.20	85.17	64.94	26.77	-52.46	-7

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Lab 16 Week	A		650.70000
Lab 8 Week	B		484.73333
Field 1 Year	B		441.30000
Lab 4 Week	B	C	422.83333

Level				Mean
Lab 2 Week	C	D		351.80000
Lab 1 Week		D		331.56667
Field 6 Months		D		293.40000
Lab 0 Week			E	214.16667
Field at Construction			E	190.40000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Lab 16 Week	Field at Construction	460.3000	21.75560	384.071	536.5286	<.0001*
Lab 16 Week	Lab 0 Week	436.5333	21.75560	360.305	512.7620	<.0001*
Lab 16 Week	Field 6 Months	357.3000	21.75560	281.071	433.5286	<.0001*
Lab 16 Week	Lab 1 Week	319.1333	21.75560	242.905	395.3620	<.0001*
Lab 16 Week	Lab 2 Week	298.9000	21.75560	222.671	375.1286	<.0001*
Lab 8 Week	Field at Construction	294.3333	21.75560	218.105	370.5620	<.0001*
Lab 8 Week	Lab 0 Week	270.5667	21.75560	194.338	346.7953	<.0001*
Field 1 Year	Field at Construction	250.9000	21.75560	174.671	327.1286	<.0001*
Lab 4 Week	Field at Construction	232.4333	21.75560	156.205	308.6620	<.0001*
Lab 16 Week	Lab 4 Week	227.8667	21.75560	151.638	304.0953	<.0001*
Field 1 Year	Lab 0 Week	227.1333	21.75560	150.905	303.3620	<.0001*
Lab 16 Week	Field 1 Year	209.4000	21.75560	133.171	285.6286	<.0001*
Lab 4 Week	Lab 0 Week	208.6667	21.75560	132.438	284.8953	<.0001*
Lab 8 Week	Field 6 Months	191.3333	21.75560	115.105	267.5620	<.0001*
Lab 16 Week	Lab 8 Week	165.9667	21.75560	89.738	242.1953	<.0001*
Lab 2 Week	Field at Construction	161.4000	21.75560	85.171	237.6286	<.0001*
Lab 8 Week	Lab 1 Week	153.1667	21.75560	76.938	229.3953	<.0001*
Field 1 Year	Field 6 Months	147.9000	21.75560	71.671	224.1286	<.0001*
Lab 1 Week	Field at Construction	141.1667	21.75560	64.938	217.3953	0.0001*
Lab 2 Week	Lab 0 Week	137.6333	21.75560	61.405	213.8620	0.0002*
Lab 8 Week	Lab 2 Week	132.9333	21.75560	56.705	209.1620	0.0002*
Lab 4 Week	Field 6 Months	129.4333	21.75560	53.205	205.6620	0.0003*
Lab 1 Week	Lab 0 Week	117.4000	21.75560	41.171	193.6286	0.0010*
Field 1 Year	Lab 1 Week	109.7333	21.75560	33.505	185.9620	0.0021*
Field 6 Months	Field at Construction	103.0000	21.75560	26.771	179.2286	0.0041*
Lab 4 Week	Lab 1 Week	91.2667	21.75560	15.038	167.4953	0.0124*
Field 1 Year	Lab 2 Week	89.5000	21.75560	13.271	165.7286	0.0147*
Field 6 Months	Lab 0 Week	79.2333	21.75560	3.005	155.4620	0.0381*
Lab 4 Week	Lab 2 Week	71.0333	21.75560	-5.195	147.2620	0.0791
Lab 8 Week	Lab 4 Week	61.9000	21.75560	-14.329	138.1286	0.1686
Lab 2 Week	Field 6 Months	58.4000	21.75560	-17.829	134.6286	0.2204
Lab 8 Week	Field 1 Year	43.4333	21.75560	-32.795	119.6620	0.5639
Lab 1 Week	Field 6 Months	38.1667	21.75560	-38.062	114.3953	0.7085

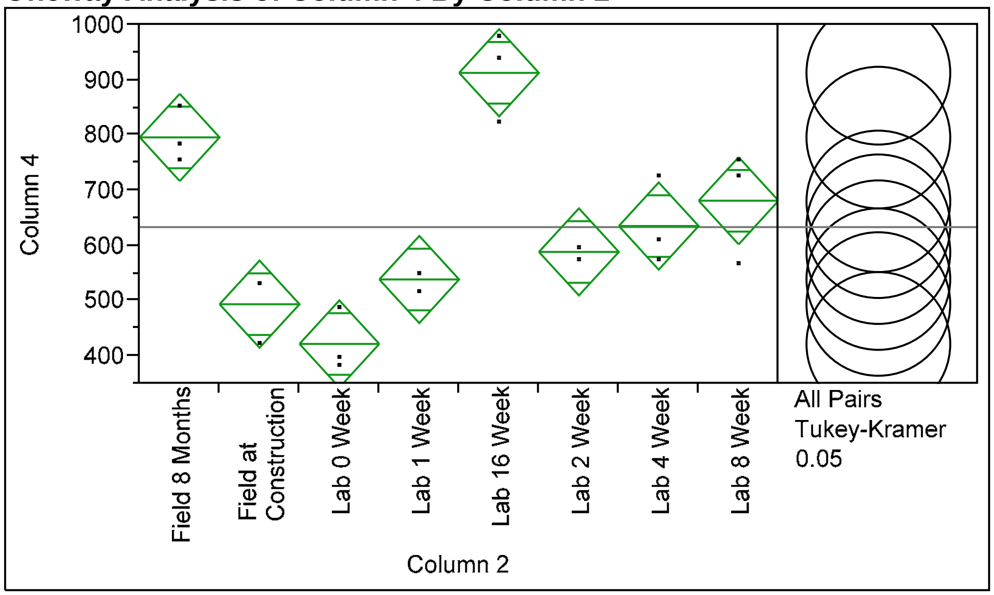
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Lab 0 Week	Field at Construction	23.7667	21.75560	-52.462	99.9953	0.9681
Lab 2 Week	Lab 1 Week	20.2333	21.75560	-55.995	96.4620	0.9878
Field 1 Year	Lab 4 Week	18.4667	21.75560	-57.762	94.6953	0.9932

H-208

Figure C.13 (a)

HMA

Oneway Analysis of Column 4 By Column 2



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.891462
Adj Rsquare	0.843977
Root Mean Square Error	64.46038
Mean of Response	633.8208
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Column 2	7	546042.55	78006.1	18.7734	<.0001*
Error	16	66482.25	4155.1		

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C. Total	23	612524.80			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Field 8 Months	3	796.200	37.216	717.31	875.09
Field at Construction	3	494.233	37.216	415.34	573.13
Lab 0 Week	3	422.133	37.216	343.24	501.03
Lab 1 Week	3	538.867	37.216	459.97	617.76
Lab 16 Week	3	913.167	37.216	834.27	992.06
Lab 2 Week	3	588.800	37.216	509.91	667.69
Lab 4 Week	3	635.700	37.216	556.81	714.59
Lab 8 Week	3	681.467	37.216	602.57	760.36

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.46215	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Lab 16 Week	Field 8 Months	Lab 8 Week	Lab 4 Week	Lab 2 Week	Lab 1 Week	Field at Construction	Lab 0 Week
Lab 16 Week	-182.22	-65.25	49.48	95.25	142.15	192.08	236.71	308.81
Field 8 Months	-65.25	-182.22	-67.49	-21.72	25.18	75.11	119.75	191.85
Lab 8 Week	49.48	-67.49	-182.22	-136.45	-89.55	-39.62	5.01	77.11
Lab 4 Week	95.25	-21.72	-136.45	-182.22	-135.32	-85.39	-40.75	31.35
Lab 2 Week	142.15	25.18	-89.55	-135.32	-182.22	-132.29	-87.65	-15.55
Lab 1 Week	192.08	75.11	-39.62	-85.39	-132.29	-182.22	-137.59	-65.49
Field at Construction	236.71	119.75	5.01	-40.75	-87.65	-137.59	-182.22	-110.12
Lab 0 Week	308.81	191.85	77.11	31.35	-15.55	-65.49	-110.12	-182.22

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
Lab 16 Week	A			913.16667
Field 8 Months	A	B		796.20000
Lab 8 Week		B	C	681.46667

Level					Mean
Lab 4 Week	B	C	D		635.70000
Lab 2 Week		C	D	E	588.80000
Lab 1 Week		C	D	E	538.86667
Field at Construction			D	E	494.23333
Lab 0 Week				E	422.13333

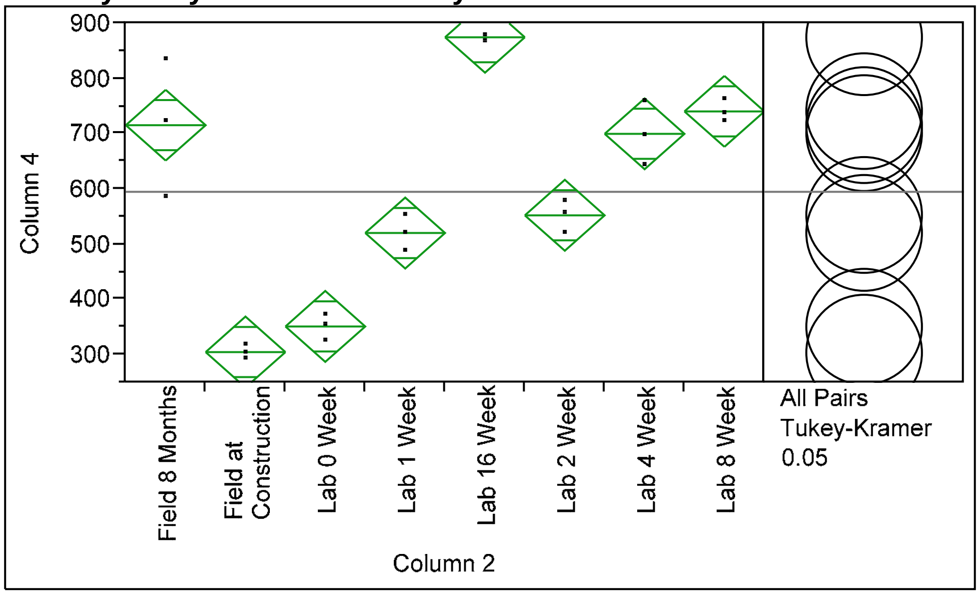
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Lab 16 Week	Lab 0 Week	491.0333	52.63168	308.815	673.2522	<.0001*
Lab 16 Week	Field at Construction	418.9333	52.63168	236.715	601.1522	<.0001*
Lab 16 Week	Lab 1 Week	374.3000	52.63168	192.081	556.5188	<.0001*
Field 8 Months	Lab 0 Week	374.0667	52.63168	191.848	556.2855	<.0001*
Lab 16 Week	Lab 2 Week	324.3667	52.63168	142.148	506.5855	0.0003*
Field 8 Months	Field at Construction	301.9667	52.63168	119.748	484.1855	0.0006*
Lab 16 Week	Lab 4 Week	277.4667	52.63168	95.248	459.6855	0.0015*
Lab 8 Week	Lab 0 Week	259.3333	52.63168	77.115	441.5522	0.0029*
Field 8 Months	Lab 1 Week	257.3333	52.63168	75.115	439.5522	0.0032*
Lab 16 Week	Lab 8 Week	231.7000	52.63168	49.481	413.9188	0.0082*
Lab 4 Week	Lab 0 Week	213.5667	52.63168	31.348	395.7855	0.0160*
Field 8 Months	Lab 2 Week	207.4000	52.63168	25.181	389.6188	0.0201*
Lab 8 Week	Field at Construction	187.2333	52.63168	5.015	369.4522	0.0418*
Lab 2 Week	Lab 0 Week	166.6667	52.63168	-15.552	348.8855	0.0861
Field 8 Months	Lab 4 Week	160.5000	52.63168	-21.719	342.7188	0.1061
Lab 8 Week	Lab 1 Week	142.6000	52.63168	-39.619	324.8188	0.1890
Lab 4 Week	Field at Construction	141.4667	52.63168	-40.752	323.6855	0.1957
Lab 16 Week	Field 8 Months	116.9667	52.63168	-65.252	299.1855	0.3887
Lab 1 Week	Lab 0 Week	116.7333	52.63168	-65.485	298.9522	0.3910
Field 8 Months	Lab 8 Week	114.7333	52.63168	-67.485	296.9522	0.4108
Lab 4 Week	Lab 1 Week	96.8333	52.63168	-85.385	279.0522	0.6051
Lab 2 Week	Field at Construction	94.5667	52.63168	-87.652	276.7855	0.6307
Lab 8 Week	Lab 2 Week	92.6667	52.63168	-89.552	274.8855	0.6520
Field at Construction	Lab 0 Week	72.1000	52.63168	-110.119	254.3188	0.8579
Lab 2 Week	Lab 1 Week	49.9333	52.63168	-132.285	232.1522	0.9757
Lab 4 Week	Lab 2 Week	46.9000	52.63168	-135.319	229.1188	0.9827
Lab 8 Week	Lab 4 Week	45.7667	52.63168	-136.452	227.9855	0.9849
Lab 1 Week	Field at Construction	44.6333	52.63168	-137.585	226.8522	0.9869

Evotherm DAT

Oneway Analysis of Column 4 By Column 2



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.949563
Adj Rsquare	0.927497
Root Mean Square Error	52.4043
Mean of Response	595.0833
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Column 2	7	827239.58	118177	43.0328	<.0001*
Error	16	43939.37	2746		
C. Total	23	871178.95			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Field 8 Months	3	715.667	30.256	651.53	779.81
Field at Construction	3	305.100	30.256	240.96	369.24
Lab 0 Week	3	351.467	30.256	287.33	415.61
Lab 1 Week	3	520.500	30.256	456.36	584.64
Lab 16 Week	3	874.733	30.256	810.59	938.87
Lab 2 Week	3	552.567	30.256	488.43	616.71
Lab 4 Week	3	700.000	30.256	635.86	764.14
Lab 8 Week	3	740.633	30.256	676.49	804.77

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.46215	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Lab 16 Week	Lab 8 Week	Field 8 Months	Lab 4 Week	Lab 2 Week	Lab 1 Week	Lab 0 Week	Field at Construction
Lab 16 Week	-148.14	-14.04	10.93	26.60	174.03	206.10	375.13	421.50
Lab 8 Week	-14.04	-148.14	-123.17	-107.50	39.93	72.00	241.03	287.40
Field 8 Months	10.93	-123.17	-148.14	-132.47	14.96	47.03	216.06	262.43
Lab 4 Week	26.60	-107.50	-132.47	-148.14	-0.70	31.36	200.40	246.76
Lab 2 Week	174.03	39.93	14.96	-0.70	-148.14	-116.07	52.96	99.33
Lab 1 Week	206.10	72.00	47.03	31.36	-116.07	-148.14	20.90	67.26
Lab 0 Week	375.13	241.03	216.06	200.40	52.96	20.90	-148.14	-101.77
Field at Construction	421.50	287.40	262.43	246.76	99.33	67.26	-101.77	-148.14

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
Lab 16 Week	A				874.73333
Lab 8 Week	A	B			740.63333
Field 8 Months		B			715.66667
Lab 4 Week		B	C		700.00000
Lab 2 Week			C	D	552.56667
Lab 1 Week				D	520.50000

Level		Mean
Lab 0 Week	E	351.46667
Field at Construction	E	305.10000

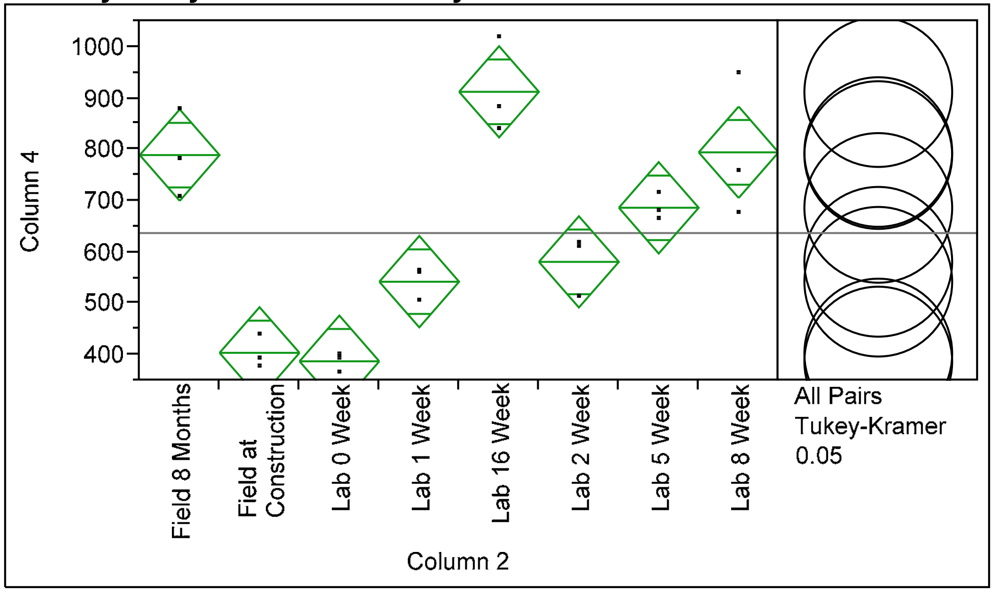
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Lab 16 Week	Field at Construction	569.6333	42.78793	421.495	717.7716	<.0001*
Lab 16 Week	Lab 0 Week	523.2667	42.78793	375.128	671.4050	<.0001*
Lab 8 Week	Field at Construction	435.5333	42.78793	287.395	583.6716	<.0001*
Field 8 Months	Field at Construction	410.5667	42.78793	262.428	558.7050	<.0001*
Lab 4 Week	Field at Construction	394.9000	42.78793	246.762	543.0383	<.0001*
Lab 8 Week	Lab 0 Week	389.1667	42.78793	241.028	537.3050	<.0001*
Field 8 Months	Lab 0 Week	364.2000	42.78793	216.062	512.3383	<.0001*
Lab 16 Week	Lab 1 Week	354.2333	42.78793	206.095	502.3716	<.0001*
Lab 4 Week	Lab 0 Week	348.5333	42.78793	200.395	496.6716	<.0001*
Lab 16 Week	Lab 2 Week	322.1667	42.78793	174.028	470.3050	<.0001*
Lab 2 Week	Field at Construction	247.4667	42.78793	99.328	395.6050	0.0006*
Lab 8 Week	Lab 1 Week	220.1333	42.78793	71.995	368.2716	0.0019*
Lab 1 Week	Field at Construction	215.4000	42.78793	67.262	363.5383	0.0024*
Lab 2 Week	Lab 0 Week	201.1000	42.78793	52.962	349.2383	0.0046*
Field 8 Months	Lab 1 Week	195.1667	42.78793	47.028	343.3050	0.0060*
Lab 8 Week	Lab 2 Week	188.0667	42.78793	39.928	336.2050	0.0083*
Lab 4 Week	Lab 1 Week	179.5000	42.78793	31.362	327.6383	0.0122*
Lab 16 Week	Lab 4 Week	174.7333	42.78793	26.595	322.8716	0.0152*
Lab 1 Week	Lab 0 Week	169.0333	42.78793	20.895	317.1716	0.0197*
Field 8 Months	Lab 2 Week	163.1000	42.78793	14.962	311.2383	0.0257*
Lab 16 Week	Field 8 Months	159.0667	42.78793	10.928	307.2050	0.0308*
Lab 4 Week	Lab 2 Week	147.4333	42.78793	-0.705	295.5716	0.0516
Lab 16 Week	Lab 8 Week	134.1000	42.78793	-14.038	282.2383	0.0913
Lab 0 Week	Field at Construction	46.3667	42.78793	-101.772	194.5050	0.9514
Lab 8 Week	Lab 4 Week	40.6333	42.78793	-107.505	188.7716	0.9755
Lab 2 Week	Lab 1 Week	32.0667	42.78793	-116.072	180.2050	0.9936
Lab 8 Week	Field 8 Months	24.9667	42.78793	-123.172	173.1050	0.9986
Field 8 Months	Lab 4 Week	15.6667	42.78793	-132.472	163.8050	0.9999

Foaming

Oneway Analysis of Column 4 By Column 2



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.900367
Adj Rsquare	0.856777
Root Mean Square Error	72.74879
Mean of Response	637.3167
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Column 2	7	765222.42	109317	20.6556	<.0001*
Error	16	84678.19	5292		
C. Total	23	849900.61			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Field 8 Months	3	789.267	42.002	700.23	878.3
Field at Construction	3	403.867	42.002	314.83	492.9
Lab 0 Week	3	387.567	42.002	298.53	476.6
Lab 1 Week	3	542.633	42.002	453.59	631.7
Lab 16 Week	3	912.633	42.002	823.59	1001.7
Lab 2 Week	3	581.267	42.002	492.23	670.3
Lab 5 Week	3	686.567	42.002	597.53	775.6
Lab 8 Week	3	794.733	42.002	705.69	883.8

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.46215	0.05

LSD Threshold Matrix

H-215

Abs(Dif)-HSD	Lab 16 Week	Lab 8 Week	Field 8 Months	Lab 5 Week	Lab 2 Week	Lab 1 Week	Field at Construction	Lab 0 Week
Lab 16 Week	-205.65	-87.75	-82.28	20.42	125.72	164.35	303.12	319.42
Lab 8 Week	-87.75	-205.65	-200.18	-97.48	7.82	46.45	185.22	201.52
Field 8 Months	-82.28	-200.18	-205.65	-102.95	2.35	40.98	179.75	196.05
Lab 5 Week	20.42	-97.48	-102.95	-205.65	-100.35	-61.72	77.05	93.35
Lab 2 Week	125.72	7.82	2.35	-100.35	-205.65	-167.02	-28.25	-11.95
Lab 1 Week	164.35	46.45	40.98	-61.72	-167.02	-205.65	-66.88	-50.58
Field at Construction	303.12	185.22	179.75	77.05	-28.25	-66.88	-205.65	-189.35
Lab 0 Week	319.42	201.52	196.05	93.35	-11.95	-50.58	-189.35	-205.65

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
Lab 16 Week	A				912.63333
Lab 8 Week	A	B			794.73333
Field 8 Months	A	B			789.26667
Lab 5 Week		B	C		686.56667
Lab 2 Week			C	D	581.26667
Lab 1 Week			C	D	542.63333

Level		Mean
Field at Construction	D	403.86667
Lab 0 Week	D	387.56667

Levels not connected by same letter are significantly different.

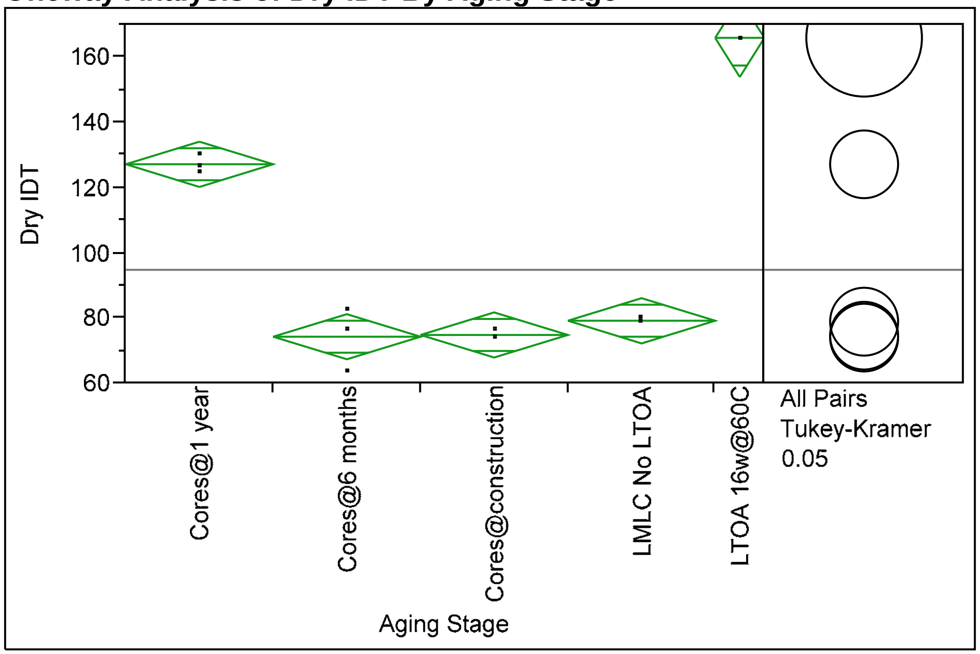
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Lab 16 Week	Lab 0 Week	525.0667	59.39914	319.418	730.7155	<.0001*
Lab 16 Week	Field at Construction	508.7667	59.39914	303.118	714.4155	<.0001*
Lab 8 Week	Lab 0 Week	407.1667	59.39914	201.518	612.8155	<.0001*
Field 8 Months	Lab 0 Week	401.7000	59.39914	196.051	607.3488	<.0001*
Lab 8 Week	Field at Construction	390.8667	59.39914	185.218	596.5155	0.0001*
Field 8 Months	Field at Construction	385.4000	59.39914	179.751	591.0488	0.0002*
Lab 16 Week	Lab 1 Week	370.0000	59.39914	164.351	575.6488	0.0003*
Lab 16 Week	Lab 2 Week	331.3667	59.39914	125.718	537.0155	0.0008*
Lab 5 Week	Lab 0 Week	299.0000	59.39914	93.351	504.6488	0.0024*
Lab 5 Week	Field at Construction	282.7000	59.39914	77.051	488.3488	0.0041*
Lab 8 Week	Lab 1 Week	252.1000	59.39914	46.451	457.7488	0.0111*
Field 8 Months	Lab 1 Week	246.6333	59.39914	40.985	452.2821	0.0133*
Lab 16 Week	Lab 5 Week	226.0667	59.39914	20.418	431.7155	0.0260*
Lab 8 Week	Lab 2 Week	213.4667	59.39914	7.818	419.1155	0.0390*
Field 8 Months	Lab 2 Week	208.0000	59.39914	2.351	413.6488	0.0464*
Lab 2 Week	Lab 0 Week	193.7000	59.39914	-11.949	399.3488	0.0725
Lab 2 Week	Field at Construction	177.4000	59.39914	-28.249	383.0488	0.1184
Lab 1 Week	Lab 0 Week	155.0667	59.39914	-50.582	360.7155	0.2213
Lab 5 Week	Lab 1 Week	143.9333	59.39914	-61.715	349.5821	0.2940
Lab 1 Week	Field at Construction	138.7667	59.39914	-66.882	344.4155	0.3330
Lab 16 Week	Field 8 Months	123.3667	59.39914	-82.282	329.0155	0.4669
Lab 16 Week	Lab 8 Week	117.9000	59.39914	-87.749	323.5488	0.5195
Lab 8 Week	Lab 5 Week	108.1667	59.39914	-97.482	313.8155	0.6163
Lab 5 Week	Lab 2 Week	105.3000	59.39914	-100.349	310.9488	0.6449
Field 8 Months	Lab 5 Week	102.7000	59.39914	-102.949	308.3488	0.6706
Lab 2 Week	Lab 1 Week	38.6333	59.39914	-167.015	244.2821	0.9973
Field at Construction	Lab 0 Week	16.3000	59.39914	-189.349	221.9488	1.0000
Lab 8 Week	Field 8 Months	5.4667	59.39914	-200.182	211.1155	1.0000

Table C.4

HMA+RAP – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



Excluded Rows
119

Oneway Anova
Summary of Fit

Rsquare	0.981313
Adj Rsquare	0.971969
Root Mean Square Error	5.209447
Mean of Response	94.84615
Observations (or Sum Wgts)	13

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	4	11400.806	2850.20	105.0249	<.0001*
Error	8	217.107	27.14		
C. Total	12	11617.912			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	127.233	3.0077	120.30	134.17
Cores@6 months	3	74.333	3.0077	67.40	81.27
Cores@construction	3	74.867	3.0077	67.93	81.80
LMLC No LTOA	3	79.233	3.0077	72.30	86.17
LTOA 16w@60C	1	166.000	5.2094	153.99	178.01

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.45475	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	LMLC No LTOA	Cores@construction	Cores@6 months
LTOA 16w@60C	-25.452	17.985	65.985	70.352	70.885
Cores@1 year	17.985	-14.695	33.305	37.672	38.205
LMLC No LTOA	65.985	33.305	-14.695	-10.328	-9.795
Cores@construction	70.352	37.672	-10.328	-14.695	-14.161
Cores@6 months	70.885	38.205	-9.795	-14.161	-14.695

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 16w@60C	A			166.00000
Cores@1 year		B		127.23333
LMLC No LTOA			C	79.23333
Cores@construction			C	74.86667
Cores@6 months			C	74.33333

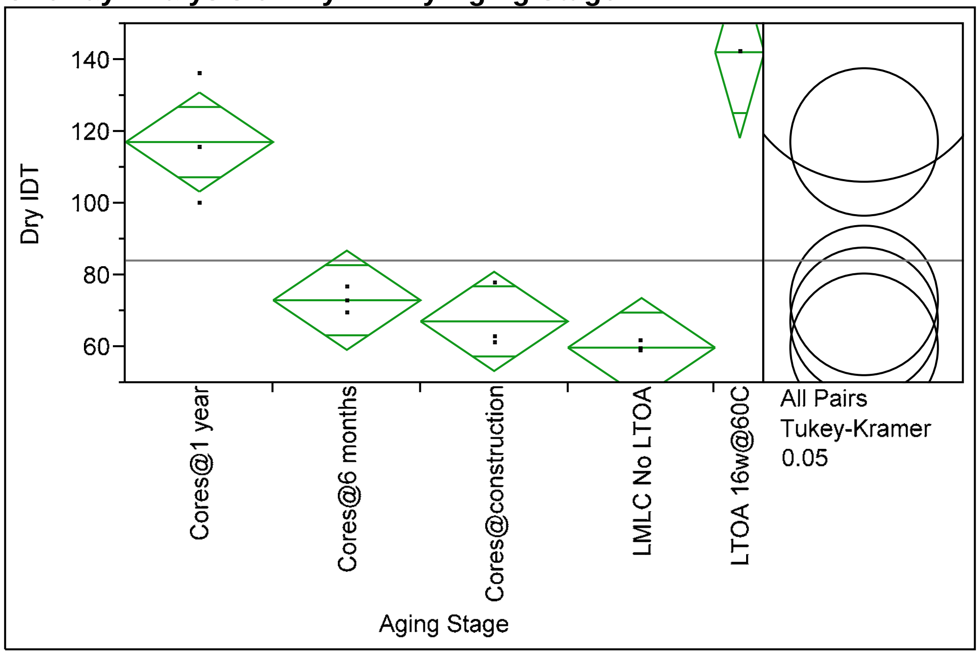
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@6 months	91.66667	6.015351	70.8851	112.4482	<.0001*
LTOA 16w@60C	Cores@construction	91.13333	6.015351	70.3518	111.9149	<.0001*
LTOA 16w@60C	LMLC No LTOA	86.76667	6.015351	65.9851	107.5482	<.0001*
Cores@1 year	Cores@6 months	52.90000	4.253495	38.2052	67.5948	<.0001*
Cores@1 year	Cores@construction	52.36667	4.253495	37.6719	67.0614	<.0001*
Cores@1 year	LMLC No LTOA	48.00000	4.253495	33.3052	62.6948	<.0001*
LTOA 16w@60C	Cores@1 year	38.76667	6.015351	17.9851	59.5482	0.0013*
LMLC No LTOA	Cores@6 months	4.90000	4.253495	-9.7948	19.5948	0.7766
LMLC No LTOA	Cores@construction	4.36667	4.253495	-10.3281	19.0614	0.8367
Cores@construction	Cores@6 months	0.53333	4.253495	-14.1614	15.2281	0.9999

Evotherm 3G+RAP – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



Excluded Rows
119

Oneway Anova

Summary of Fit

Rsquare	0.917725
Adj Rsquare	0.876587
Root Mean Square Error	10.3897
Mean of Response	84.17692
Observations (or Sum Wgts)	13

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	4	9632.496	2408.12	22.3086	0.0002*
Error	8	863.567	107.95		
C. Total	12	10496.063			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	117.167	5.998	103.33	131.00
Cores@6 months	3	73.100	5.998	59.27	86.93
Cores@construction	3	67.200	5.998	53.37	81.03
LMLC No LTOA	3	59.900	5.998	46.07	73.73
LTOA 16w@60C	1	142.200	10.390	118.24	166.16

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.45475	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	Cores@6 months	Cores@construction	LMLC No LTOA
LTOA 16w@60C	-50.761	-16.413	27.653	33.553	40.853
Cores@1 year	-16.413	-29.307	14.760	20.660	27.960
Cores@6 months	27.653	14.760	-29.307	-23.407	-16.107
Cores@construction	33.553	20.660	-23.407	-29.307	-22.007
LMLC No LTOA	40.853	27.960	-16.107	-22.007	-29.307

Positive values show pairs of means that are significantly different.

Connecting Letters Report

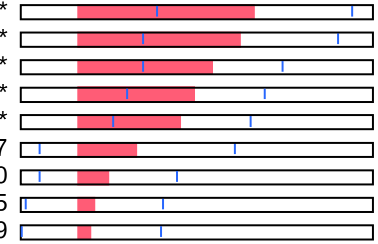
Level			Mean
LTOA 16w@60C	A		142.20000
Cores@1 year	A		117.16667
Cores@6 months		B	73.10000
Cores@construction		B	67.20000
LMLC No LTOA		B	59.90000

Levels not connected by same letter are significantly different.

Ordered Differences Report

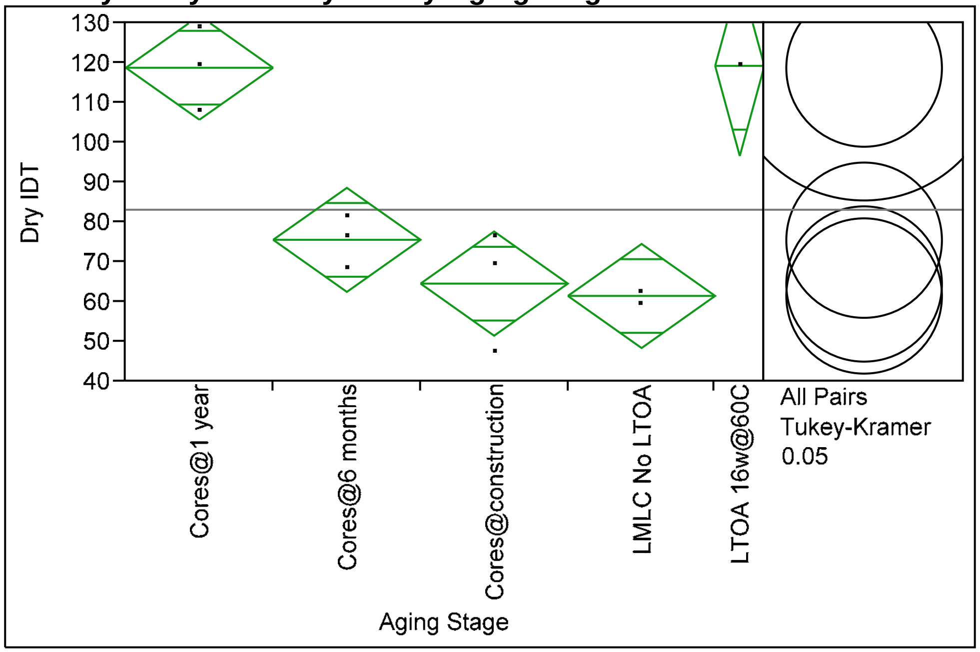
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	LMLC No LTOA	82.30000	11.99699	40.8534	123.7466	0.0009*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	75.00000	11.99699	33.5534	116.4466	0.0016*
LTOA 16w@60C	Cores@6 months	69.10000	11.99699	27.6534	110.5466	0.0028*
Cores@1 year	LMLC No LTOA	57.26667	8.48315	27.9595	86.5738	0.0010*
Cores@1 year	Cores@construction	49.96667	8.48315	20.6595	79.2738	0.0024*
Cores@1 year	Cores@6 months	44.06667	8.48315	14.7595	73.3738	0.0054*
LTOA 16w@60C	Cores@1 year	25.03333	11.99699	-16.4132	66.4799	0.3107
Cores@6 months	LMLC No LTOA	13.20000	8.48315	-16.1072	42.5072	0.5590
Cores@construction	LMLC No LTOA	7.30000	8.48315	-22.0072	36.6072	0.9035
Cores@6 months	Cores@construction	5.90000	8.48315	-23.4072	35.2072	0.9519



Sasobit+RAP – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



Excluded Rows
119

Oneway Anova

Summary of Fit

Rsquare	0.90924
Adj Rsquare	0.86386
Root Mean Square Error	9.824883
Mean of Response	83.14615
Observations (or Sum Wgts)	13

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	4	7736.2056	1934.05	20.0361	0.0003*
Error	8	772.2267	96.53		
C. Total	12	8508.4323			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	118.833	5.6724	105.75	131.91
Cores@6 months	3	75.600	5.6724	62.52	88.68
Cores@construction	3	64.600	5.6724	51.52	77.68
LMLC No LTOA	3	61.500	5.6724	48.42	74.58
LTOA 16w@60C	1	119.300	9.8249	96.64	141.96

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.45475	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	Cores@6 months	Cores@construction	LMLC No LTOA
LTOA 16w@60C	-48.002	-38.727	4.507	15.507	18.607
Cores@1 year	-38.727	-27.714	15.519	26.519	29.619
Cores@6 months	4.507	15.519	-27.714	-16.714	-13.614
Cores@construction	15.507	26.519	-16.714	-27.714	-24.614
LMLC No LTOA	18.607	29.619	-13.614	-24.614	-27.714

Positive values show pairs of means that are significantly different.

Connecting Letters Report

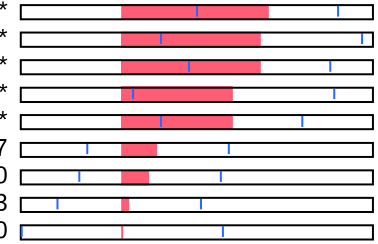
Level			Mean
LTOA 16w@60C	A		119.30000
Cores@1 year	A		118.83333
Cores@6 months		B	75.60000
Cores@construction		B	64.60000
LMLC No LTOA		B	61.50000

Levels not connected by same letter are significantly different.

Ordered Differences Report

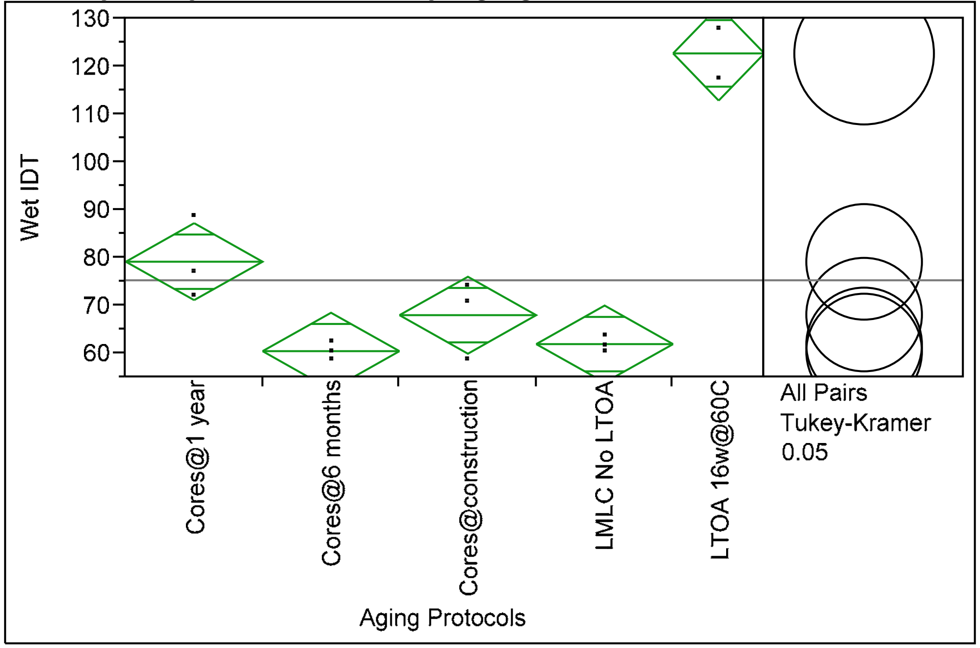
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	LMLC No LTOA	57.80000	11.34480	18.6066	96.99342	0.0061*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Cores@1 year	LMLC No LTOA	57.33333	8.02198	29.6194	85.04727	0.0007*
LTOA 16w@60C	Cores@construction	54.70000	11.34480	15.5066	93.89342	0.0084*
Cores@1 year	Cores@construction	54.23333	8.02198	26.5194	81.94727	0.0010*
LTOA 16w@60C	Cores@6 months	43.70000	11.34480	4.5066	82.89342	0.0293*
Cores@1 year	Cores@6 months	43.23333	8.02198	15.5194	70.94727	0.0043*
Cores@6 months	LMLC No LTOA	14.10000	8.02198	-13.6139	41.81393	0.4547
Cores@6 months	Cores@construction	11.00000	8.02198	-16.7139	38.71393	0.6600
Cores@construction	LMLC No LTOA	3.10000	8.02198	-24.6139	30.81393	0.9943
LTOA 16w@60C	Cores@1 year	0.46667	11.34480	-38.7268	39.66009	1.0000



HMA+RAP – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
124

Oneway Anova

Summary of Fit

Rsquare	0.945348
Adj Rsquare	0.921058
Root Mean Square Error	6.157185
Mean of Response	75.31429
Observations (or Sum Wgts)	14

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	4	5901.9188	1475.48	38.9196	<.0001*
Error	9	341.1983	37.91		
C. Total	13	6243.1171			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	79.200	3.5549	71.16	87.24
Cores@6 months	3	60.467	3.5549	52.43	68.51
Cores@construction	3	68.000	3.5549	59.96	76.04
LMLC No LTOA	3	61.967	3.5549	53.93	70.01
LTOA 16w@60C	2	122.750	4.3538	112.90	132.60

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.36258	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	Cores@construction	LMLC No LTOA	Cores@6 months
LTOA 16w@60C	-20.704	24.650	35.850	41.883	43.383
Cores@1 year	24.650	-16.905	-5.705	0.329	1.829
Cores@construction	35.850	-5.705	-16.905	-10.871	-9.371
LMLC No LTOA	41.883	0.329	-10.871	-16.905	-15.405
Cores@6 months	43.383	1.829	-9.371	-15.405	-16.905

Positive values show pairs of means that are significantly different.

Connecting Letters Report

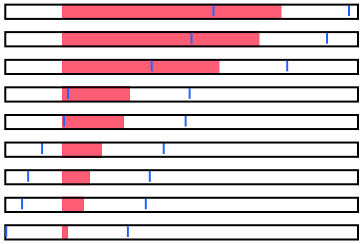
Level			Mean
LTOA 16w@60C	A		122.75000
Cores@1 year	B		79.20000
Cores@construction	B	C	68.00000
LMLC No LTOA		C	61.96667
Cores@6 months		C	60.46667

Levels not connected by same letter are significantly different.

Ordered Differences Report

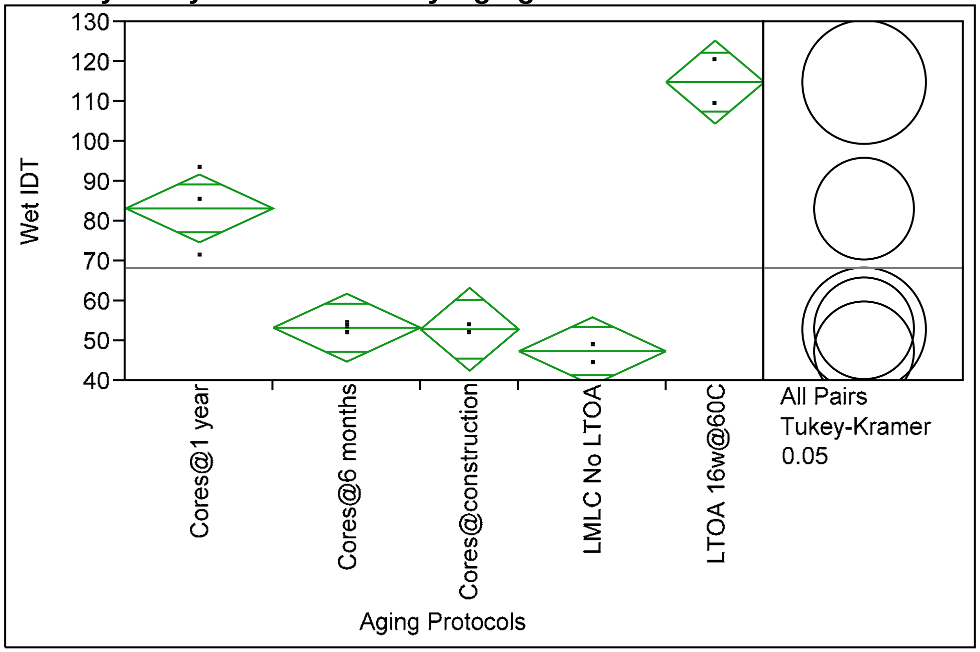
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@6 months	62.28333	5.620715	43.3832	81.18346	<.0001*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	LMLC No LTOA	60.78333	5.620715	41.8832	79.68346	<.0001*
LTOA 16w@60C	Cores@construction	54.75000	5.620715	35.8499	73.65012	<.0001*
LTOA 16w@60C	Cores@1 year	43.55000	5.620715	24.6499	62.45012	0.0002*
Cores@1 year	Cores@6 months	18.73333	5.027320	1.8285	35.63812	0.0294*
Cores@1 year	LMLC No LTOA	17.23333	5.027320	0.3285	34.13812	0.0454*
Cores@1 year	Cores@construction	11.20000	5.027320	-5.7048	28.10478	0.2520
Cores@construction	Cores@6 months	7.53333	5.027320	-9.3715	24.43812	0.5876
Cores@construction	LMLC No LTOA	6.03333	5.027320	-10.8715	22.93812	0.7518
LMLC No LTOA	Cores@6 months	1.50000	5.027320	-15.4048	18.40478	0.9979



Evotherm 3G+RAP – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
125

Oneway Anova

Summary of Fit

Rsquare	0.958124
Adj Rsquare	0.937186
Root Mean Square Error	6.389118
Mean of Response	68.36154
Observations (or Sum Wgts)	13

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	4	7471.8641	1867.97	45.7601	<.0001*
Error	8	326.5667	40.82		
C. Total	12	7798.4308			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	83.333	3.6888	74.83	91.84
Cores@6 months	3	53.400	3.6888	44.89	61.91
Cores@construction	2	53.000	4.5178	42.58	63.42
LMLC No LTOA	3	47.500	3.6888	38.99	56.01
LTOA 16w@60C	2	115.000	4.5178	104.58	125.42

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.45475	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	Cores@6 months	Cores@construction	LMLC No LTOA
LTOA 16w@60C	-22.073	11.517	41.450	39.927	47.350
Cores@1 year	11.517	-18.022	11.911	10.184	17.811
Cores@6 months	41.450	11.911	-18.022	-19.750	-12.122
Cores@construction	39.927	10.184	-19.750	-22.073	-14.650
LMLC No LTOA	47.350	17.811	-12.122	-14.650	-18.022

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 16w@60C	A			115.00000
Cores@1 year		B		83.33333
Cores@6 months			C	53.40000
Cores@construction			C	53.00000
LMLC No LTOA			C	47.50000

Levels not connected by same letter are significantly different.

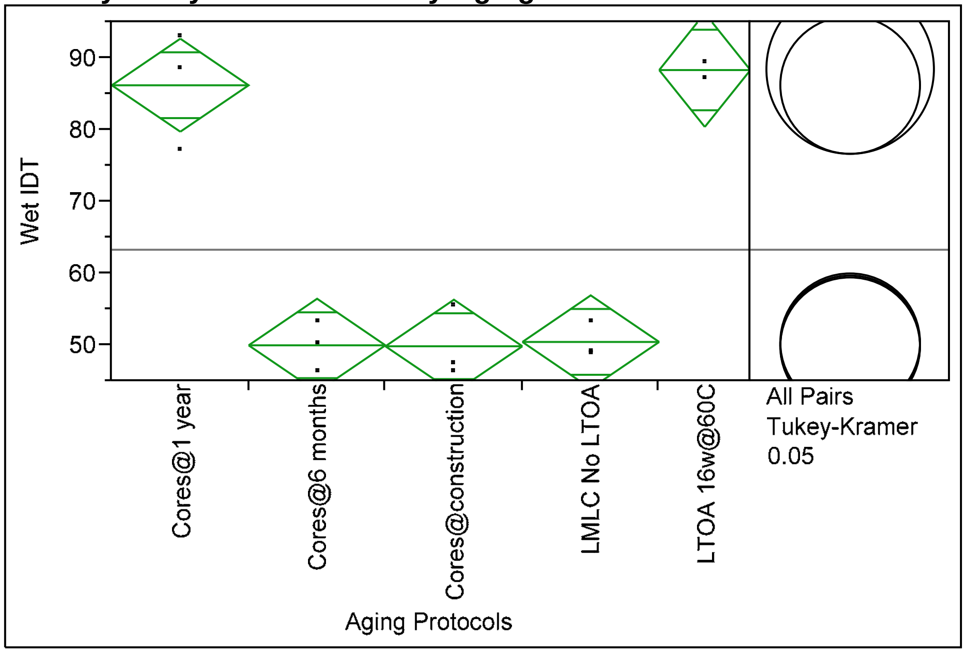
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value	
LTOA 16w@60C	LMLC No LTOA	67.50000	5.832440	47.3504	87.64961	<.0001*	

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	62.00000	6.389118	39.9272	84.07280	<.0001*
LTOA 16w@60C	Cores@6 months	61.60000	5.832440	41.4504	81.74961	<.0001*
Cores@1 year	LMLC No LTOA	35.83333	5.216693	17.8110	53.85570	0.0009*
LTOA 16w@60C	Cores@1 year	31.66667	5.832440	11.5171	51.81628	0.0041*
Cores@1 year	Cores@construction	30.33333	5.832440	10.1837	50.48295	0.0053*
Cores@1 year	Cores@6 months	29.93333	5.216693	11.9110	47.95570	0.0029*
Cores@6 months	LMLC No LTOA	5.90000	5.216693	-12.1224	23.92236	0.7872
Cores@construction	LMLC No LTOA	5.50000	5.832440	-14.6496	25.64961	0.8724
Cores@6 months	Cores@construction	0.40000	5.832440	-19.7496	20.54961	1.0000

Sasobit+RAP – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
124

Oneway Anova

Summary of Fit

Rsquare	0.952068
Adj Rsquare	0.930765
Root Mean Square Error	4.960567
Mean of Response	63.31429
Observations (or Sum Wgts)	14

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	4	4398.9321	1099.73	44.6915	<.0001*
Error	9	221.4650	24.61		
C. Total	13	4620.3971			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	86.2333	2.8640	79.755	92.712
Cores@6 months	3	50.0000	2.8640	43.521	56.479
Cores@construction	3	49.8667	2.8640	43.388	56.345
LMLC No LTOA	3	50.4667	2.8640	43.988	56.945
LTOA 16w@60C	2	88.3500	3.5077	80.415	96.285

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.36258	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	LMLC No LTOA	Cores@6 months	Cores@construction
LTOA 16w@60C	-16.680	-13.110	22.656	23.123	23.256
Cores@1 year	-13.110	-13.619	22.147	22.614	22.747
LMLC No LTOA	22.656	22.147	-13.619	-13.153	-13.019
Cores@6 months	23.123	22.614	-13.153	-13.619	-13.486
Cores@construction	23.256	22.747	-13.019	-13.486	-13.619

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
LTOA 16w@60C	A		88.350000
Cores@1 year	A		86.233333
LMLC No LTOA		B	50.466667
Cores@6 months		B	50.000000
Cores@construction		B	49.866667

Levels not connected by same letter are significantly different.

Ordered Differences Report

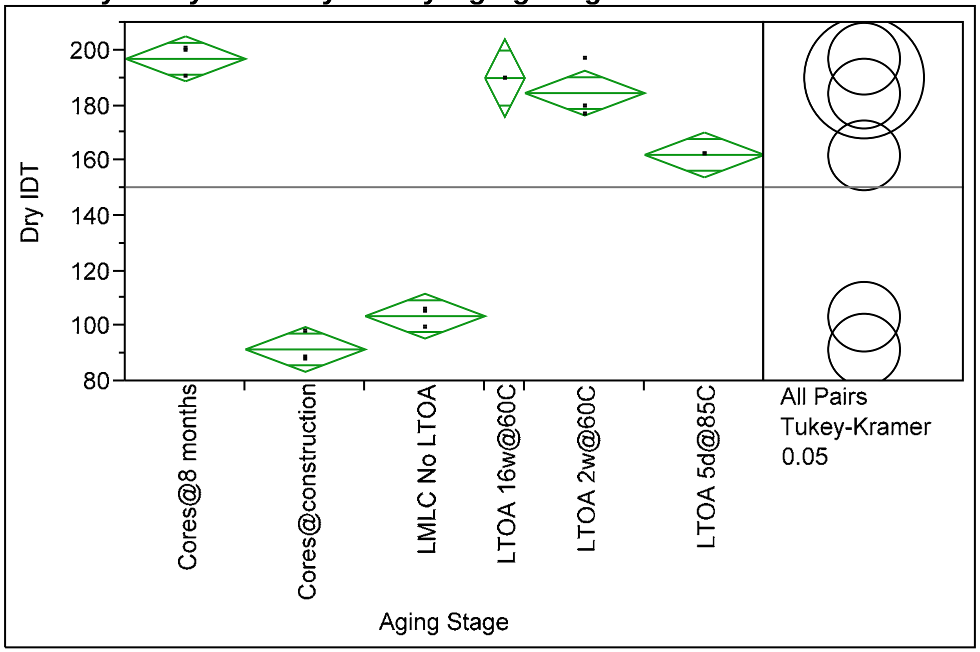
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	38.48333	4.528357	23.2564	53.71031	<.0001*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@6 months	38.35000	4.528357	23.1230	53.57698	0.0001*
LTOA 16w@60C	LMLC No LTOA	37.88333	4.528357	22.6564	53.11031	0.0001*
Cores@1 year	Cores@construction	36.36667	4.050286	22.7472	49.98609	<.0001*
Cores@1 year	Cores@6 months	36.23333	4.050286	22.6139	49.85276	<.0001*
Cores@1 year	LMLC No LTOA	35.76667	4.050286	22.1472	49.38609	<.0001*
LTOA 16w@60C	Cores@1 year	2.11667	4.528357	-13.1103	17.34365	0.9886
LMLC No LTOA	Cores@construction	0.60000	4.050286	-13.0194	14.21942	0.9999
LMLC No LTOA	Cores@6 months	0.46667	4.050286	-13.1528	14.08609	1.0000
Cores@6 months	Cores@construction	0.13333	4.050286	-13.4861	13.75276	1.0000

Table C.6

HMA – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



Excluded Rows
116

Oneway Anova

Summary of Fit

Rsquare	0.986322
Adj Rsquare	0.979483
Root Mean Square Error	6.331403
Mean of Response	150.4188
Observations (or Sum Wgts)	16

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	28906.118	5781.22	144.2181	<.0001*
Error	10	400.867	40.09		
C. Total	15	29306.984			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	196.967	3.6554	188.82	205.11
Cores@construction	3	91.600	3.6554	83.46	99.74
LMLC No LTOA	3	103.667	3.6554	95.52	111.81
LTOA 16w@60C	1	190.000	6.3314	175.89	204.11
LTOA 2w@60C	3	184.533	3.6554	176.39	192.68
LTOA 5d@85C	3	162.133	3.6554	153.99	170.28

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.47332	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Cores@8 months	LTOA 16w@60C	LTOA 2w@60C	LTOA 5d@85C	LMLC No LTOA	Cores@construction
Cores@8 months	-17.956	-18.426	-5.522	16.878	75.344	87.411
LTOA 16w@60C	-18.426	-31.100	-19.926	2.474	60.940	73.007
LTOA 2w@60C	-5.522	-19.926	-17.956	4.444	62.911	74.978
LTOA 5d@85C	16.878	2.474	4.444	-17.956	40.511	52.578
LMLC No LTOA	75.344	60.940	62.911	40.511	-17.956	-5.889
Cores@construction	87.411	73.007	74.978	52.578	-5.889	-17.956

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
Cores@8 months	A			196.96667
LTOA 16w@60C	A			190.00000
LTOA 2w@60C	A			184.53333
LTOA 5d@85C		B		162.13333
LMLC No LTOA			C	103.66667

Level		Mean
Cores@construction	C	91.60000

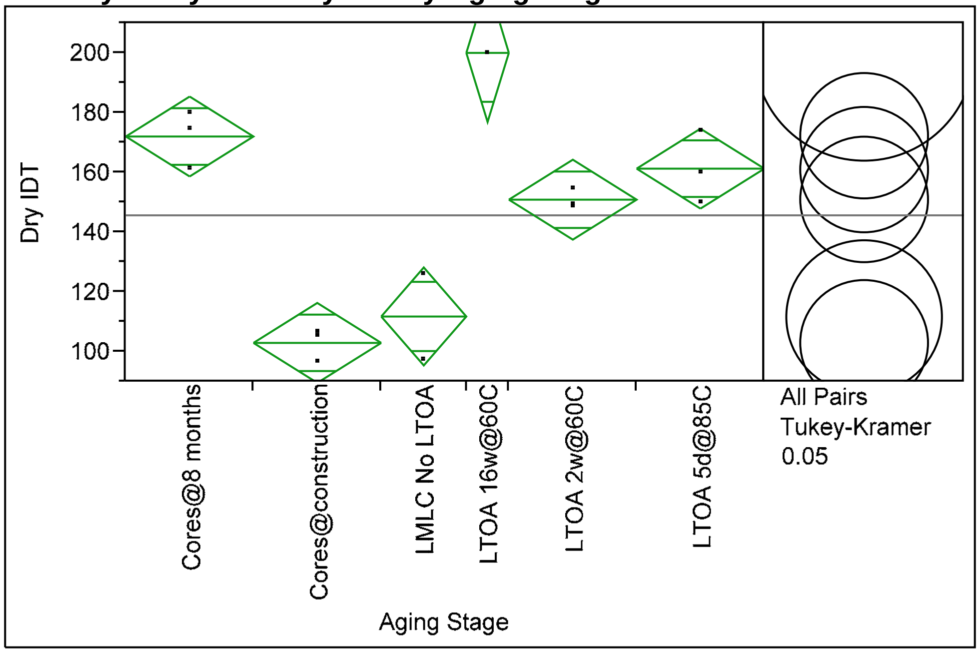
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Cores@8 months	Cores@construction	105.3667	5.169569	87.4111	123.3222	<.0001*
LTOA 16w@60C	Cores@construction	98.4000	7.310875	73.0070	123.7930	<.0001*
Cores@8 months	LMLC No LTOA	93.3000	5.169569	75.3444	111.2556	<.0001*
LTOA 2w@60C	Cores@construction	92.9333	5.169569	74.9778	110.8889	<.0001*
LTOA 16w@60C	LMLC No LTOA	86.3333	7.310875	60.9403	111.7263	<.0001*
LTOA 2w@60C	LMLC No LTOA	80.8667	5.169569	62.9111	98.8222	<.0001*
LTOA 5d@85C	Cores@construction	70.5333	5.169569	52.5778	88.4889	<.0001*
LTOA 5d@85C	LMLC No LTOA	58.4667	5.169569	40.5111	76.4222	<.0001*
Cores@8 months	LTOA 5d@85C	34.8333	5.169569	16.8778	52.7889	0.0005*
LTOA 16w@60C	LTOA 5d@85C	27.8667	7.310875	2.4737	53.2597	0.0299*
LTOA 2w@60C	LTOA 5d@85C	22.4000	5.169569	4.4444	40.3556	0.0137*
Cores@8 months	LTOA 2w@60C	12.4333	5.169569	-5.5222	30.3889	0.2407
LMLC No LTOA	Cores@construction	12.0667	5.169569	-5.8889	30.0222	0.2648
Cores@8 months	LTOA 16w@60C	6.9667	7.310875	-18.4263	32.3597	0.9228
LTOA 16w@60C	LTOA 2w@60C	5.4667	7.310875	-19.9263	30.8597	0.9706

Evotherm DAT – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



Excluded Rows
117

Oneway Anova

Summary of Fit

Rsquare	0.93516
Adj Rsquare	0.899138
Root Mean Square Error	10.24832
Mean of Response	145.6933
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	13632.996	2726.60	25.9607	<.0001*
Error	9	945.253	105.03		
C. Total	14	14578.249			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	172.067	5.917	158.68	185.45
Cores@construction	3	102.967	5.917	89.58	116.35
LMLC No LTOA	2	111.800	7.247	95.41	128.19
LTOA 16w@60C	1	200.100	10.248	176.92	223.28
LTOA 2w@60C	3	150.900	5.917	137.52	164.28
LTOA 5d@85C	3	161.300	5.917	147.92	174.68

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.55216	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@8 months	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA	Cores@construction
LTOA 16w@60C	-51.483	-14.002	-3.235	7.165	43.715	55.098
Cores@8 months	-14.002	-29.724	-18.957	-8.557	27.035	39.376
LTOA 5d@85C	-3.235	-18.957	-29.724	-19.324	16.268	28.610
LTOA 2w@60C	7.165	-8.557	-19.324	-29.724	5.868	18.210
LMLC No LTOA	43.715	27.035	16.268	5.868	-36.404	-24.399
Cores@construction	55.098	39.376	28.610	18.210	-24.399	-29.724

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 16w@60C	A			200.10000
Cores@8 months	A	B		172.06667
LTOA 5d@85C	A	B		161.30000
LTOA 2w@60C		B		150.90000
LMLC No LTOA			C	111.80000
Cores@construction			C	102.96667

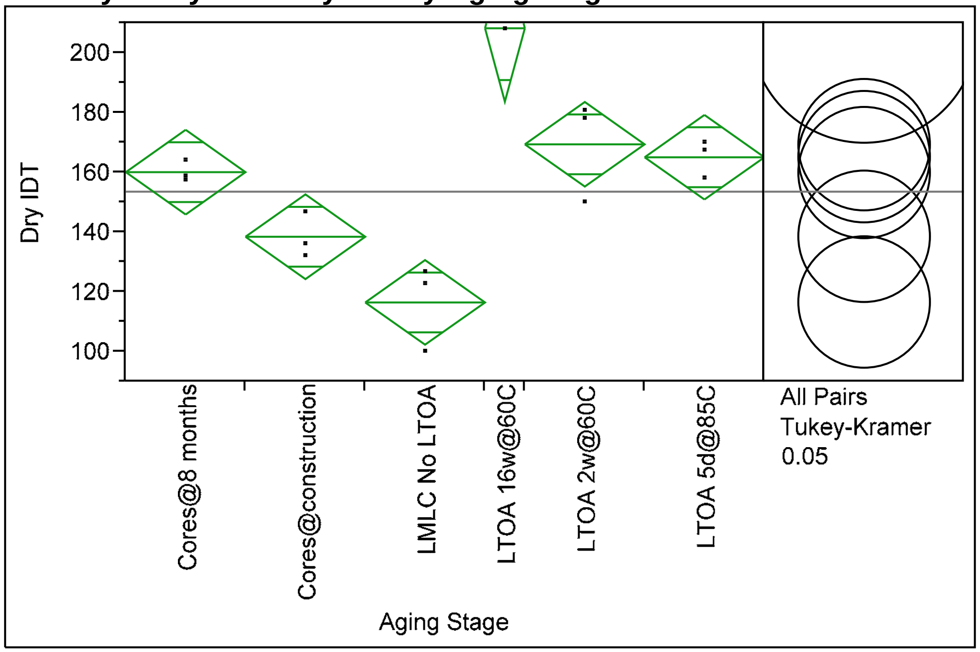
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	97.13333	11.83375	55.0979	139.1687	0.0002*
LTOA 16w@60C	LMLC No LTOA	88.30000	12.55158	43.7147	132.8853	0.0006*
Cores@8 months	Cores@construction	69.10000	8.36772	39.3765	98.8235	0.0002*
Cores@8 months	LMLC No LTOA	60.26667	9.35540	27.0348	93.4986	0.0012*
LTOA 5d@85C	Cores@construction	58.33333	8.36772	28.6098	88.0569	0.0006*
LTOA 5d@85C	LMLC No LTOA	49.50000	9.35540	16.2681	82.7319	0.0047*
LTOA 16w@60C	LTOA 2w@60C	49.20000	11.83375	7.1646	91.2354	0.0212*
LTOA 2w@60C	Cores@construction	47.93333	8.36772	18.2098	77.6569	0.0027*
LTOA 2w@60C	LMLC No LTOA	39.10000	9.35540	5.8681	72.3319	0.0206*
LTOA 16w@60C	LTOA 5d@85C	38.80000	11.83375	-3.2354	80.8354	0.0739
LTOA 16w@60C	Cores@8 months	28.03333	11.83375	-14.0021	70.0687	0.2605
Cores@8 months	LTOA 2w@60C	21.16667	8.36772	-8.5569	50.8902	0.2108
Cores@8 months	LTOA 5d@85C	10.76667	8.36772	-18.9569	40.4902	0.7854
LTOA 5d@85C	LTOA 2w@60C	10.40000	8.36772	-19.3235	40.1235	0.8068
LMLC No LTOA	Cores@construction	8.83333	9.35540	-24.3986	42.0652	0.9245

Foaming – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



Excluded Rows
116

Oneway Anova

Summary of Fit

Rsquare	0.882234
Adj Rsquare	0.823351
Root Mean Square Error	11.01399
Mean of Response	153.5938
Observations (or Sum Wgts)	16

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	9087.709	1817.54	14.9829	0.0002*
Error	10	1213.080	121.31		
C. Total	15	10300.789			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	160.133	6.359	145.96	174.30
Cores@construction	3	138.500	6.359	124.33	152.67
LMLC No LTOA	3	116.500	6.359	102.33	130.67
LTOA 16w@60C	1	208.300	11.014	183.76	232.84
LTOA 2w@60C	3	169.467	6.359	155.30	183.64
LTOA 5d@85C	3	165.133	6.359	150.96	179.30

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.47332	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	LTOA 2w@60C	LTOA 5d@85C	Cores@8 months	Cores@construction	LMLC No LTOA
LTOA 16w@60C	-54.101	-5.340	-1.007	3.993	25.627	47.627
LTOA 2w@60C	-5.340	-31.235	-26.902	-21.902	-0.269	21.731
LTOA 5d@85C	-1.007	-26.902	-31.235	-26.235	-4.602	17.398
Cores@8 months	3.993	-21.902	-26.235	-31.235	-9.602	12.398
Cores@construction	25.627	-0.269	-4.602	-9.602	-31.235	-9.235
LMLC No LTOA	47.627	21.731	17.398	12.398	-9.235	-31.235

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 16w@60C	A			208.30000
LTOA 2w@60C	A	B		169.46667
LTOA 5d@85C	A	B		165.13333
Cores@8 months		B		160.13333
Cores@construction		B	C	138.50000
LMLC No LTOA			C	116.50000

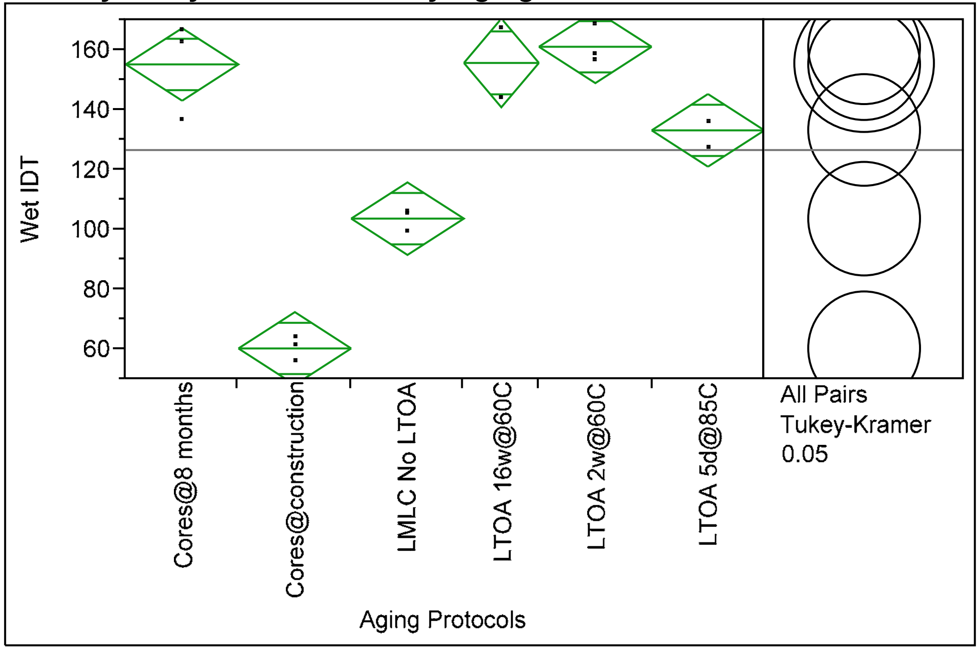
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	LMLC No LTOA	91.80000	12.71786	47.6268	135.9732	0.0003*
LTOA 16w@60C	Cores@construction	69.80000	12.71786	25.6268	113.9732	0.0026*
LTOA 2w@60C	LMLC No LTOA	52.96667	8.99289	21.7315	84.2018	0.0015*
LTOA 5d@85C	LMLC No LTOA	48.63333	8.99289	17.3982	79.8685	0.0029*
LTOA 16w@60C	Cores@8 months	48.16667	12.71786	3.9935	92.3399	0.0310*
Cores@8 months	LMLC No LTOA	43.63333	8.99289	12.3982	74.8685	0.0064*
LTOA 16w@60C	LTOA 5d@85C	43.16667	12.71786	-1.0065	87.3399	0.0564
LTOA 16w@60C	LTOA 2w@60C	38.83333	12.71786	-5.3399	83.0065	0.0944
LTOA 2w@60C	Cores@construction	30.96667	8.99289	-0.2685	62.2018	0.0523
LTOA 5d@85C	Cores@construction	26.63333	8.99289	-4.6018	57.8685	0.1083
Cores@construction	LMLC No LTOA	22.00000	8.99289	-9.2352	53.2352	0.2274
Cores@8 months	Cores@construction	21.63333	8.99289	-9.6018	52.8685	0.2405
LTOA 2w@60C	Cores@8 months	9.33333	8.99289	-21.9018	40.5685	0.8945
LTOA 5d@85C	Cores@8 months	5.00000	8.99289	-26.2352	36.2352	0.9919
LTOA 2w@60C	LTOA 5d@85C	4.33333	8.99289	-26.9018	35.5685	0.9958

HMA – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
121

Oneway Anova

Summary of Fit

Rsquare	0.957575
Adj Rsquare	0.93829
Root Mean Square Error	9.550401
Mean of Response	126.5882
Observations (or Sum Wgts)	17

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	5	22645.526	4529.11	49.6557	<.0001*
Error	11	1003.312	91.21		
C. Total	16	23648.838			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	155.233	5.5139	143.10	167.37
Cores@construction	3	60.267	5.5139	48.13	72.40
LMLC No LTOA	3	103.667	5.5139	91.53	115.80
LTOA 16w@60C	2	155.750	6.7532	140.89	170.61
LTOA 2w@60C	3	161.133	5.5139	149.00	173.27
LTOA 5d@85C	3	133.200	5.5139	121.06	145.34

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.41034	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 2w@60C	LTOA 16w@60C	Cores@8 months	LTOA 5d@85C	LMLC No LTOA	Cores@construction
LTOA 2w@60C	-26.593	-24.349	-20.693	1.340	30.873	74.273
LTOA 16w@60C	-24.349	-32.570	-29.216	-7.182	22.351	65.751
Cores@8 months	-20.693	-29.216	-26.593	-4.560	24.973	68.373
LTOA 5d@85C	1.340	-7.182	-4.560	-26.593	2.940	46.340
LMLC No LTOA	30.873	22.351	24.973	2.940	-26.593	16.807
Cores@construction	74.273	65.751	68.373	46.340	16.807	-26.593

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
LTOA 2w@60C	A				161.13333
LTOA 16w@60C	A	B			155.75000
Cores@8 months	A	B			155.23333
LTOA 5d@85C		B			133.20000
LMLC No LTOA			C		103.66667
Cores@construction				D	60.26667

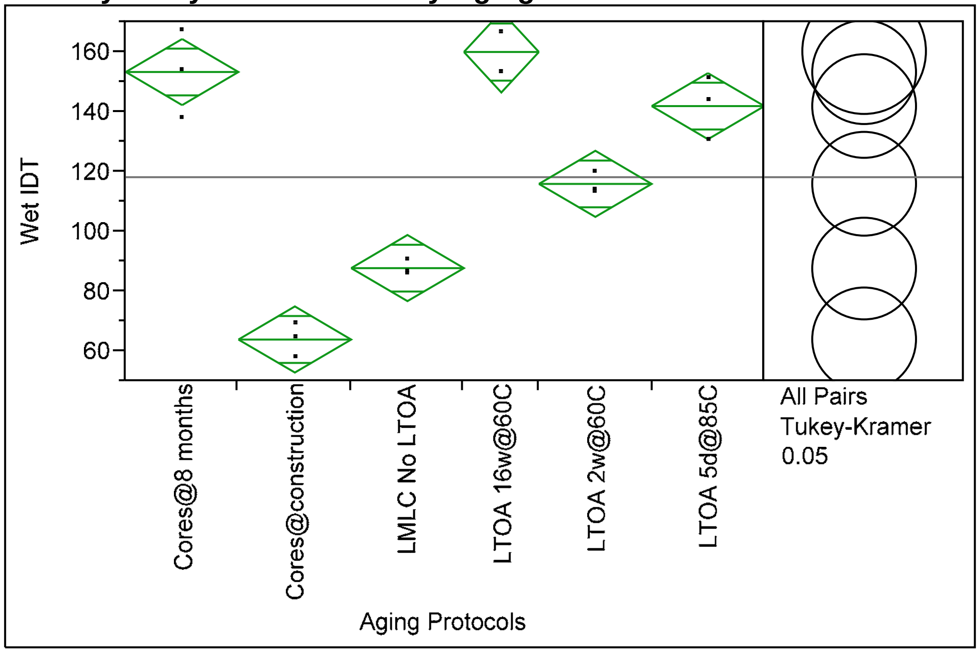
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 2w@60C	Cores@construction	100.8667	7.797869	74.2733	127.4600	<.0001*
LTOA 16w@60C	Cores@construction	95.4833	8.718283	65.7510	125.2156	<.0001*
Cores@8 months	Cores@construction	94.9667	7.797869	68.3733	121.5600	<.0001*
LTOA 5d@85C	Cores@construction	72.9333	7.797869	46.3400	99.5267	<.0001*
LTOA 2w@60C	LMLC No LTOA	57.4667	7.797869	30.8733	84.0600	0.0002*
LTOA 16w@60C	LMLC No LTOA	52.0833	8.718283	22.3510	81.8156	0.0010*
Cores@8 months	LMLC No LTOA	51.5667	7.797869	24.9733	78.1600	0.0004*
LMLC No LTOA	Cores@construction	43.4000	7.797869	16.8066	69.9934	0.0018*
LTOA 5d@85C	LMLC No LTOA	29.5333	7.797869	2.9400	56.1267	0.0273*
LTOA 2w@60C	LTOA 5d@85C	27.9333	7.797869	1.3400	54.5267	0.0379*
LTOA 16w@60C	LTOA 5d@85C	22.5500	8.718283	-7.1823	52.2823	0.1801
Cores@8 months	LTOA 5d@85C	22.0333	7.797869	-4.5600	48.6267	0.1257
LTOA 2w@60C	Cores@8 months	5.9000	7.797869	-20.6934	32.4934	0.9695
LTOA 2w@60C	LTOA 16w@60C	5.3833	8.718283	-24.3490	35.1156	0.9873
LTOA 16w@60C	Cores@8 months	0.5167	8.718283	-29.2156	30.2490	1.0000

Evotherm DAT – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
121

Oneway Anova

Summary of Fit

Rsquare	0.961001
Adj Rsquare	0.943274
Root Mean Square Error	8.70283
Mean of Response	118.1882
Observations (or Sum Wgts)	17

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	5	20529.546	4105.91	54.2111	<.0001*
Error	11	833.132	75.74		
C. Total	16	21362.678			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	153.367	5.0246	142.31	164.43
Cores@construction	3	63.933	5.0246	52.87	74.99
LMLC No LTOA	3	87.800	5.0246	76.74	98.86
LTOA 16w@60C	2	160.050	6.1538	146.51	173.59
LTOA 2w@60C	3	115.967	5.0246	104.91	127.03
LTOA 5d@85C	3	141.967	5.0246	130.91	153.03

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.41034	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@8 months	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA	Cores@construction
LTOA 16w@60C	-29.680	-20.410	-9.010	16.990	45.156	69.023
Cores@8 months	-20.410	-24.233	-12.833	13.167	41.333	65.200
LTOA 5d@85C	-9.010	-12.833	-24.233	1.767	29.933	53.800
LTOA 2w@60C	16.990	13.167	1.767	-24.233	3.933	27.800
LMLC No LTOA	45.156	41.333	29.933	3.933	-24.233	-0.367
Cores@construction	69.023	65.200	53.800	27.800	-0.367	-24.233

Positive values show pairs of means that are significantly different.

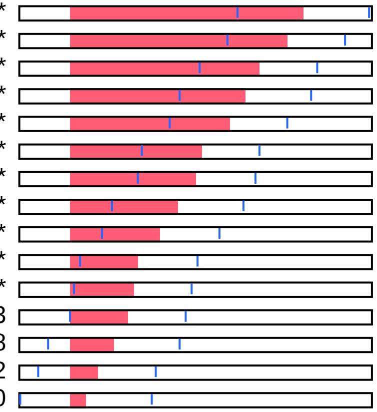
Connecting Letters Report

Level				Mean
LTOA 16w@60C	A			160.05000
Cores@8 months	A			153.36667
LTOA 5d@85C	A			141.96667
LTOA 2w@60C		B		115.96667
LMLC No LTOA			C	87.80000
Cores@construction			C	63.93333

Levels not connected by same letter are significantly different.

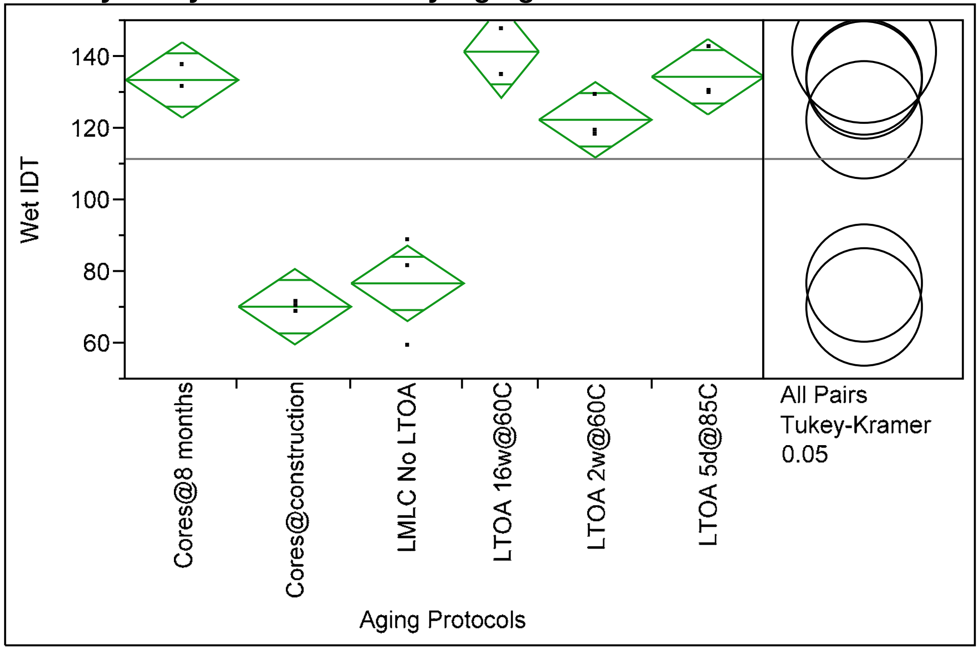
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	96.11667	7.944560	69.0230	123.2103	<.0001*
Cores@8 months	Cores@construction	89.43333	7.105831	65.2000	113.6666	<.0001*
LTOA 5d@85C	Cores@construction	78.03333	7.105831	53.8000	102.2666	<.0001*
LTOA 16w@60C	LMLC No LTOA	72.25000	7.944560	45.1564	99.3436	<.0001*
Cores@8 months	LMLC No LTOA	65.56667	7.105831	41.3334	89.8000	<.0001*
LTOA 5d@85C	LMLC No LTOA	54.16667	7.105831	29.9334	78.4000	0.0001*
LTOA 2w@60C	Cores@construction	52.03333	7.105831	27.8000	76.2666	0.0002*
LTOA 16w@60C	LTOA 2w@60C	44.08333	7.944560	16.9897	71.1770	0.0018*
Cores@8 months	LTOA 2w@60C	37.40000	7.105831	13.1667	61.6333	0.0027*
LTOA 2w@60C	LMLC No LTOA	28.16667	7.105831	3.9334	52.4000	0.0206*
LTOA 5d@85C	LTOA 2w@60C	26.00000	7.105831	1.7667	50.2333	0.0335*
LMLC No LTOA	Cores@construction	23.86667	7.105831	-0.3666	48.1000	0.0543
LTOA 16w@60C	LTOA 5d@85C	18.08333	7.944560	-9.0103	45.1770	0.2798
Cores@8 months	LTOA 5d@85C	11.40000	7.105831	-12.8333	35.6333	0.6122
LTOA 16w@60C	Cores@8 months	6.68333	7.944560	-20.4103	33.7770	0.9530



Foaming – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
121

Oneway Anova

Summary of Fit

Rsquare	0.948507
Adj Rsquare	0.925102
Root Mean Square Error	8.283902
Mean of Response	111.5471
Observations (or Sum Wgts)	17

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	5	13904.609	2780.92	40.5246	<.0001*
Error	11	754.853	68.62		
C. Total	16	14659.462			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	133.600	4.7827	123.07	144.13
Cores@construction	3	70.333	4.7827	59.81	80.86
LMLC No LTOA	3	76.833	4.7827	66.31	87.36
LTOA 16w@60C	2	141.500	5.8576	128.61	154.39
LTOA 2w@60C	3	122.500	4.7827	111.97	133.03
LTOA 5d@85C	3	134.500	4.7827	123.97	145.03

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.41034	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	LTOA 5d@85C	Cores@8 months	LTOA 2w@60C	LMLC No LTOA	Cores@construction
LTOA 16w@60C	-28.251	-18.789	-17.889	-6.789	38.877	45.377
LTOA 5d@85C	-18.789	-23.067	-22.167	-11.067	34.600	41.100
Cores@8 months	-17.889	-22.167	-23.067	-11.967	33.700	40.200
LTOA 2w@60C	-6.789	-11.067	-11.967	-23.067	22.600	29.100
LMLC No LTOA	38.877	34.600	33.700	22.600	-23.067	-16.567
Cores@construction	45.377	41.100	40.200	29.100	-16.567	-23.067

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
LTOA 16w@60C	A		141.50000
LTOA 5d@85C	A		134.50000
Cores@8 months	A		133.60000
LTOA 2w@60C	A		122.50000
LMLC No LTOA		B	76.83333
Cores@construction		B	70.33333

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	71.16667	7.562133	45.3772	96.95610	<.0001*
LTOA 16w@60C	LMLC No LTOA	64.66667	7.562133	38.8772	90.45610	<.0001*
LTOA 5d@85C	Cores@construction	64.16667	6.763778	41.0999	87.23344	<.0001*
Cores@8 months	Cores@construction	63.26667	6.763778	40.1999	86.33344	<.0001*
LTOA 5d@85C	LMLC No LTOA	57.66667	6.763778	34.5999	80.73344	<.0001*
Cores@8 months	LMLC No LTOA	56.76667	6.763778	33.6999	79.83344	<.0001*
LTOA 2w@60C	Cores@construction	52.16667	6.763778	29.0999	75.23344	0.0001*
LTOA 2w@60C	LMLC No LTOA	45.66667	6.763778	22.5999	68.73344	0.0003*
LTOA 16w@60C	LTOA 2w@60C	19.00000	7.562133	-6.7894	44.78944	0.2006
LTOA 5d@85C	LTOA 2w@60C	12.00000	6.763778	-11.0668	35.06677	0.5169
Cores@8 months	LTOA 2w@60C	11.10000	6.763778	-11.9668	34.16677	0.5913
LTOA 16w@60C	Cores@8 months	7.90000	7.562133	-17.8894	33.68944	0.8929
LTOA 16w@60C	LTOA 5d@85C	7.00000	7.562133	-18.7894	32.78944	0.9316
LMLC No LTOA	Cores@construction	6.50000	6.763778	-16.5668	29.56677	0.9211
LTOA 5d@85C	Cores@8 months	0.90000	6.763778	-22.1668	23.96677	1.0000

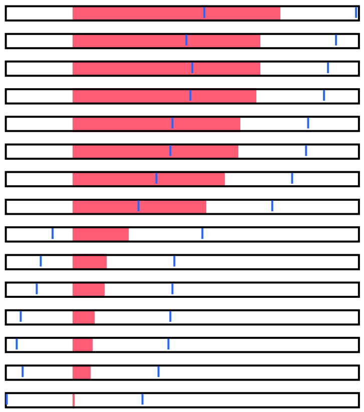
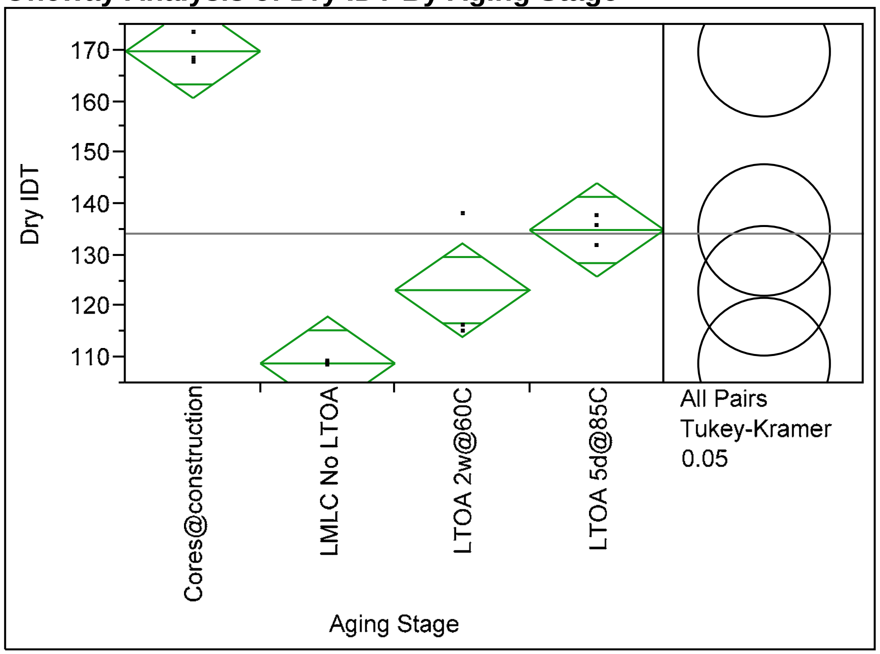


Table C.8

HMA+RAP – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



Excluded Rows
120

Oneway Anova

Summary of Fit

Rsquare	0.941665
Adj Rsquare	0.919789
Root Mean Square Error	6.869619
Mean of Response	134.225
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	3	6094.2292	2031.41	43.0459	<.0001*
Error	8	377.5333	47.19		
C. Total	11	6471.7625			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	3	169.833	3.9662	160.69	178.98
LMLC No LTOA	3	108.900	3.9662	99.75	118.05
LTOA 2w@60C	3	123.200	3.9662	114.05	132.35
LTOA 5d@85C	3	134.967	3.9662	125.82	144.11

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Cores@construction	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA
Cores@construction	-17.962	16.905	28.671	42.971
LTOA 5d@85C	16.905	-17.962	-6.195	8.105
LTOA 2w@60C	28.671	-6.195	-17.962	-3.662
LMLC No LTOA	42.971	8.105	-3.662	-17.962

Positive values show pairs of means that are significantly different.

Connecting Letters Report

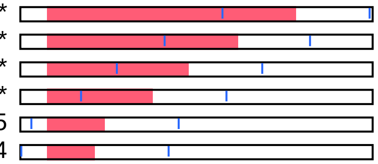
Level			Mean
Cores@construction	A		169.83333
LTOA 5d@85C	B		134.96667
LTOA 2w@60C	B	C	123.20000
LMLC No LTOA		C	108.90000

Levels not connected by same letter are significantly different.

Ordered Differences Report

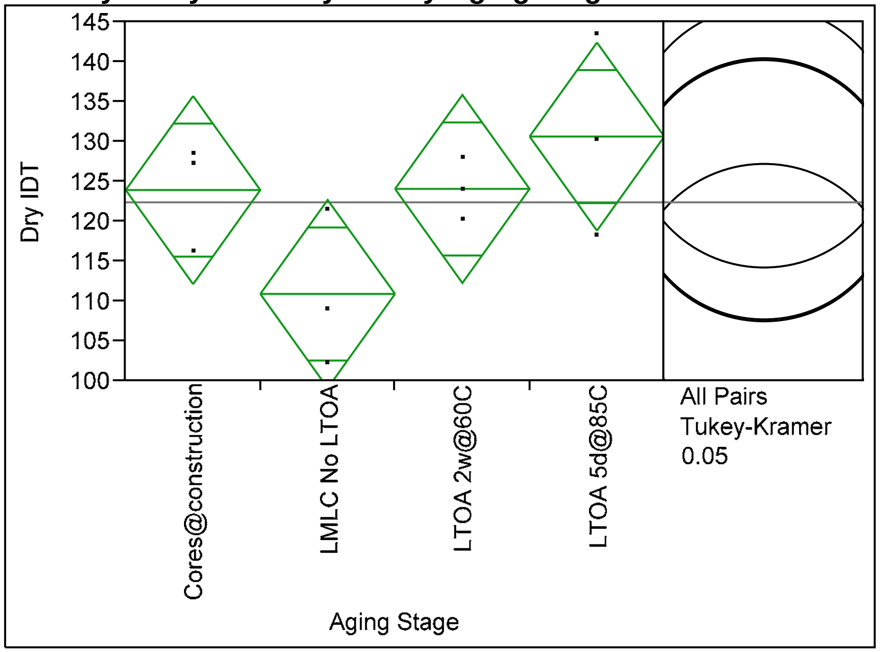
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Cores@construction	LMLC No LTOA	60.93333	5.609021	42.9713	78.89535	<.0001*
Cores@construction	LTOA 2w@60C	46.63333	5.609021	28.6713	64.59535	0.0002*
Cores@construction	LTOA 5d@85C	34.86667	5.609021	16.9047	52.82868	0.0012*
LTOA 5d@85C	LMLC No LTOA	26.06667	5.609021	8.1047	44.02868	0.0072*
LTOA 2w@60C	LMLC No LTOA	14.30000	5.609021	-3.6620	32.26201	0.1255
LTOA 5d@85C	LTOA 2w@60C	11.76667	5.609021	-6.1953	29.72868	0.2324



Evotherm 3G+RAP – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



H-256

Excluded Rows
120

Oneway Anova

Summary of Fit

Rsquare	0.494877
Adj Rsquare	0.305456
Root Mean Square Error	8.861715
Mean of Response	122.4167
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	3	615.4967	205.166	2.6126	0.1234
Error	8	628.2400	78.530		
C. Total	11	1243.7367			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	3	123.967	5.1163	112.17	135.76
LMLC No LTOA	3	110.933	5.1163	99.14	122.73
LTOA 2w@60C	3	124.100	5.1163	112.30	135.90
LTOA 5d@85C	3	130.667	5.1163	118.87	142.46

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 5d@85C	LTOA 2w@60C	Cores@construction	LMLC No LTOA
LTOA 5d@85C	-23.171	-16.604	-16.471	-3.437
LTOA 2w@60C	-16.604	-23.171	-23.037	-10.004
Cores@construction	-16.471	-23.037	-23.171	-10.137
LMLC No LTOA	-3.437	-10.004	-10.137	-23.171

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
LTOA 5d@85C	A	130.66667
LTOA 2w@60C	A	124.10000
Cores@construction	A	123.96667
LMLC No LTOA	A	110.93333

Levels not connected by same letter are significantly different.

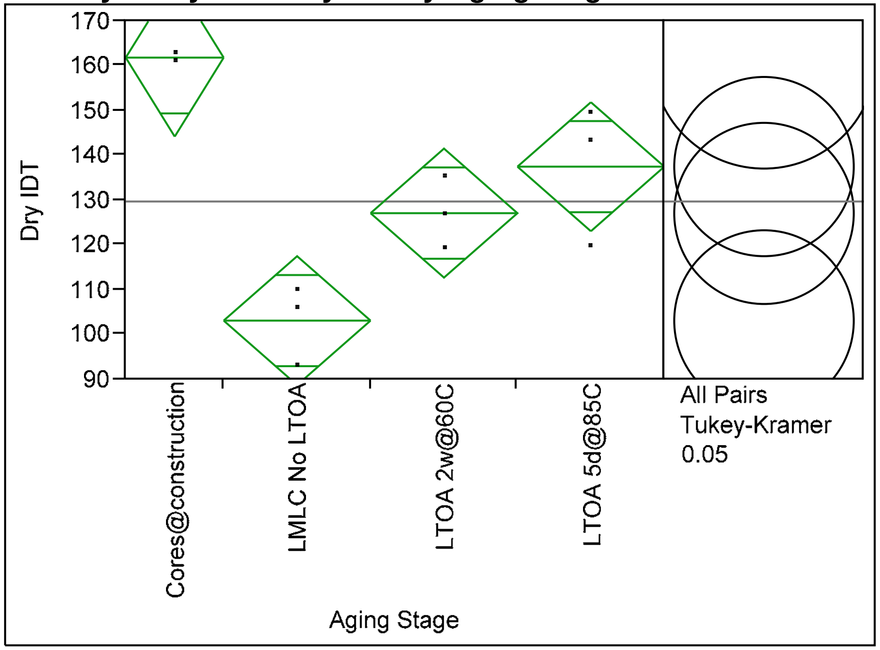
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LMLC No LTOA	19.73333	7.235560	-3.4374	42.90409	0.0978
LTOA 2w@60C	LMLC No LTOA	13.16667	7.235560	-10.0041	36.33742	0.3316
Cores@construction	LMLC No LTOA	13.03333	7.235560	-10.1374	36.20409	0.3392
LTOA 5d@85C	Cores@construction	6.70000	7.235560	-16.4708	29.87075	0.7923

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LTOA 2w@60C	6.56667	7.235560	-16.6041	29.73742	0.8016
LTOA 2w@60C	Cores@construction	0.13333	7.235560	-23.0374	23.30409	1.0000

Foaming+RAP – Dry IDT Strength

Oneway Analysis of Dry IDT By Aging Stage



Excluded Rows
121

Oneway Anova

Summary of Fit

Rsquare	0.849305
Adj Rsquare	0.784721
Root Mean Square Error	10.54758
Mean of Response	129.7636
Observations (or Sum Wgts)	11

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	3	4389.0255	1463.01	13.1505	0.0029*
Error	7	778.7600	111.25		
C. Total	10	5167.7855			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	2	161.900	7.4583	144.26	179.54
LMLC No LTOA	3	103.167	6.0896	88.77	117.57
LTOA 2w@60C	3	127.167	6.0896	112.77	141.57
LTOA 5d@85C	3	137.533	6.0896	123.13	151.93

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.31014	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Cores@construction	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA
Cores@construction	-34.914	-7.505	2.861	26.861
LTOA 5d@85C	-7.505	-28.507	-18.140	5.860
LTOA 2w@60C	2.861	-18.140	-28.507	-4.507
LMLC No LTOA	26.861	5.860	-4.507	-28.507

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
Cores@construction	A			161.90000
LTOA 5d@85C	A	B		137.53333
LTOA 2w@60C		B	C	127.16667
LMLC No LTOA			C	103.16667

Levels not connected by same letter are significantly different.

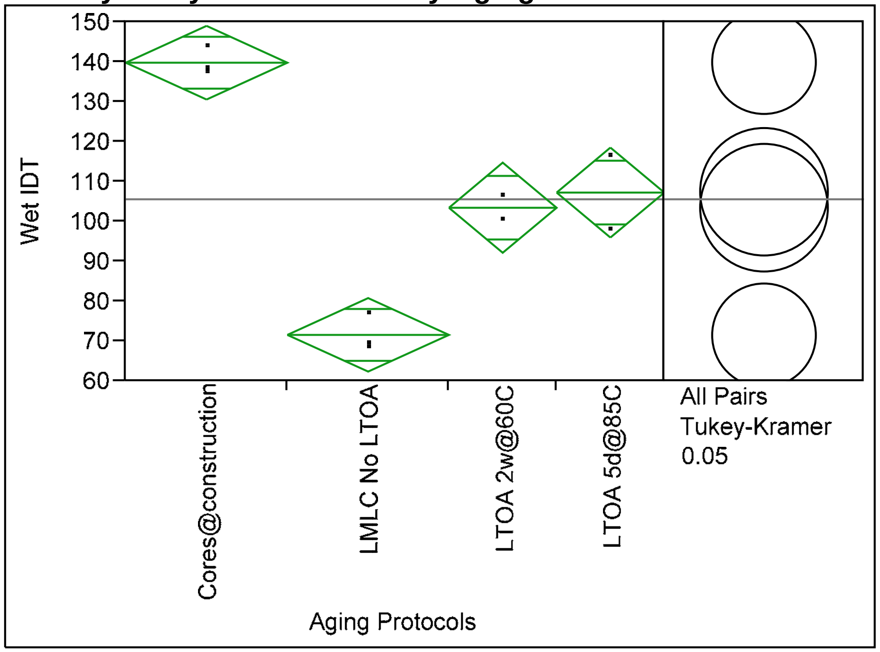
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Cores@construction	LMLC No LTOA	58.73333	9.628578	26.8614	90.60526	0.0021*
Cores@construction	LTOA 2w@60C	34.73333	9.628578	2.8614	66.60526	0.0342*
LTOA 5d@85C	LMLC No LTOA	34.36667	8.612062	5.8595	62.87379	0.0212*
Cores@construction	LTOA 5d@85C	24.36667	9.628578	-7.5053	56.23860	0.1386

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 2w@60C	LMLC No LTOA	24.00000	8.612062	-4.5071	52.50712	0.0991
LTOA 5d@85C	LTOA 2w@60C	10.36667	8.612062	-18.1405	38.87379	0.6438

HMA+RAP – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
128

Oneway Anova

Summary of Fit

Rsquare	0.964802
Adj Rsquare	0.947203
Root Mean Square Error	6.526442
Mean of Response	105.6
Observations (or Sum Wgts)	10

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	3	7005.2133	2335.07	54.8210	<.0001*
Error	6	255.5667	42.59		
C. Total	9	7260.7800			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	3	139.867	3.7680	130.65	149.09
LMLC No LTOA	3	71.600	3.7680	62.38	80.82
LTOA 2w@60C	2	103.500	4.6149	92.21	114.79
LTOA 5d@85C	2	107.300	4.6149	96.01	118.59

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.46171	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Cores@construction	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA
Cores@construction	-18.447	11.943	15.743	49.820
LTOA 5d@85C	11.943	-22.593	-18.793	15.076
LTOA 2w@60C	15.743	-18.793	-22.593	11.276
LMLC No LTOA	49.820	15.076	11.276	-18.447

Positive values show pairs of means that are significantly different.

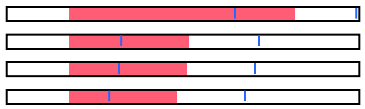
Connecting Letters Report

Level				Mean
Cores@construction	A			139.86667
LTOA 5d@85C		B		107.30000
LTOA 2w@60C		B		103.50000
LMLC No LTOA			C	71.60000

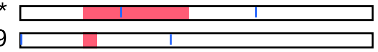
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Cores@construction	LMLC No LTOA	68.26667	5.328818	49.8199	86.71346	<.0001*
Cores@construction	LTOA 2w@60C	36.36667	5.957799	15.7425	56.99081	0.0036*
LTOA 5d@85C	LMLC No LTOA	35.70000	5.957799	15.0759	56.32415	0.0039*
Cores@construction	LTOA 5d@85C	32.56667	5.957799	11.9425	53.19081	0.0063*

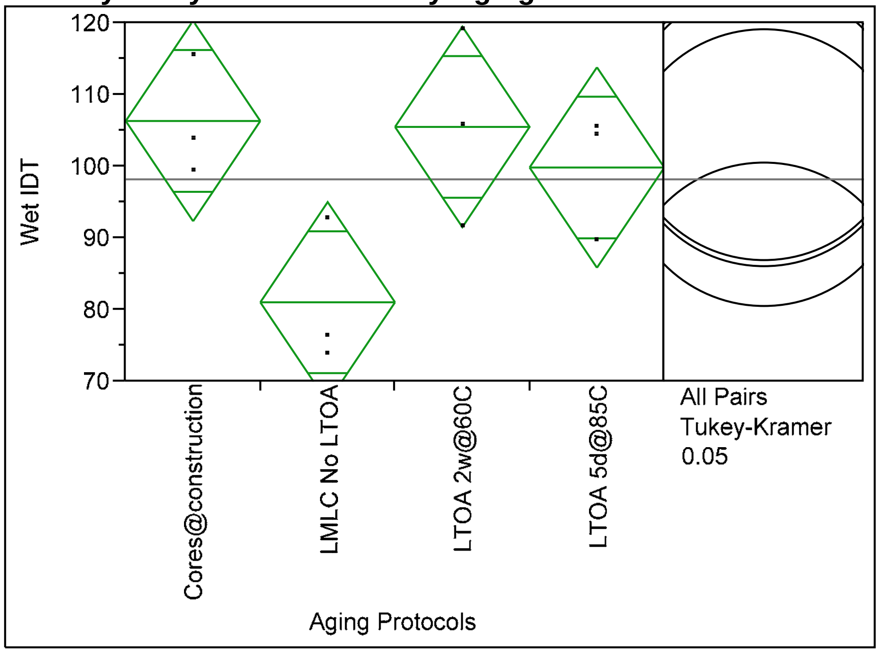


Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 2w@60C	LMLC No LTOA	31.90000	5.957799	11.2759	52.52415	0.0070*
LTOA 5d@85C	LTOA 2w@60C	3.80000	6.526442	-18.7926	26.39262	0.9339



Evotherm 3G+RAP – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
126

Oneway Anova

Summary of Fit

Rsquare	0.586111
Adj Rsquare	0.430902
Root Mean Square Error	10.50587
Mean of Response	98.20833
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	3	1250.4025	416.801	3.7763	0.0590
Error	8	882.9867	110.373		
C. Total	11	2133.3892			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	3	106.367	6.0656	92.379	120.35
LMLC No LTOA	3	81.067	6.0656	67.079	95.05
LTOA 2w@60C	3	105.533	6.0656	91.546	119.52
LTOA 5d@85C	3	99.867	6.0656	85.879	113.85

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Cores@construction	LTOA 2w@60C	LTOA 5d@85C	LMLC No LTOA
Cores@construction	-27.470	-26.636	-20.970	-2.170
LTOA 2w@60C	-26.636	-27.470	-21.803	-3.003
LTOA 5d@85C	-20.970	-21.803	-27.470	-8.670
LMLC No LTOA	-2.170	-3.003	-8.670	-27.470

Positive values show pairs of means that are significantly different.

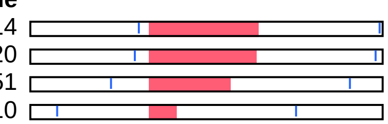
Connecting Letters Report

Level		Mean
Cores@construction	A	106.36667
LTOA 2w@60C	A	105.53333
LTOA 5d@85C	A	99.86667
LMLC No LTOA	A	81.06667

Levels not connected by same letter are significantly different.

Ordered Differences Report

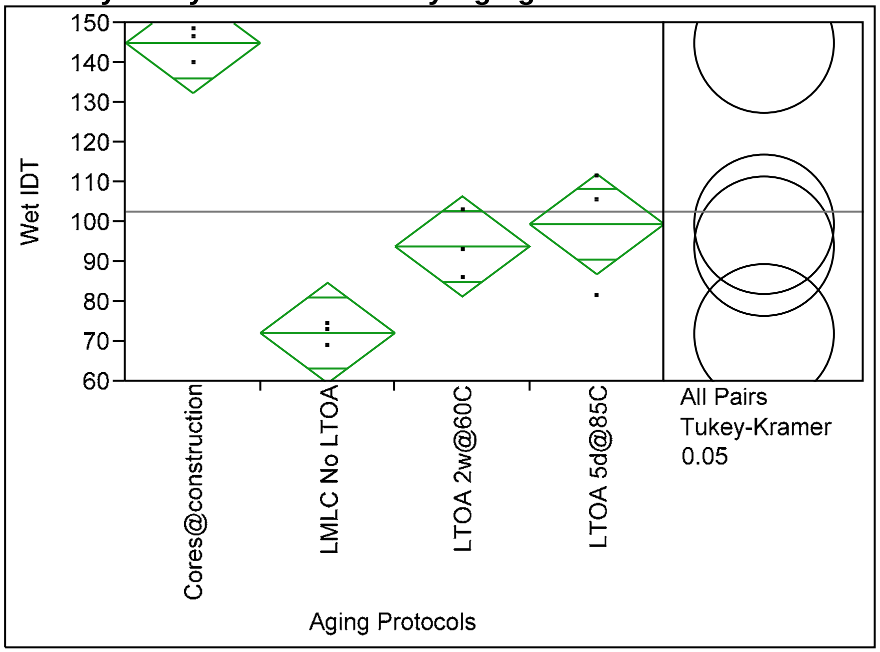
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Cores@construction	LMLC No LTOA	25.30000	8.578008	-2.1697	52.76973	0.0714
LTOA 2w@60C	LMLC No LTOA	24.46667	8.578008	-3.0031	51.93640	0.0820
LTOA 5d@85C	LMLC No LTOA	18.80000	8.578008	-8.6697	46.26973	0.2051
Cores@construction	LTOA 5d@85C	6.50000	8.578008	-20.9697	33.96973	0.8710



Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 2w@60C	LTOA 5d@85C	5.66667	8.578008	-21.8031	33.13640	0.9089
Cores@construction	LTOA 2w@60C	0.83333	8.578008	-26.6364	28.30307	0.9996

Foaming+RAP – Wet IDT Strength

Oneway Analysis of Wet IDT By Aging Protocols



Excluded Rows
126

Oneway Anova

Summary of Fit

Rsquare	0.921751
Adj Rsquare	0.892408
Root Mean Square Error	9.456744
Mean of Response	102.675
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	3	8427.7225	2809.24	31.4127	<.0001*
Error	8	715.4400	89.43		
C. Total	11	9143.1625			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	3	145.033	5.4599	132.44	157.62
LMLC No LTOA	3	72.200	5.4599	59.61	84.79
LTOA 2w@60C	3	93.933	5.4599	81.34	106.52
LTOA 5d@85C	3	99.533	5.4599	86.94	112.12

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Cores@construction	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA
Cores@construction	-24.727	20.773	26.373	48.107
LTOA 5d@85C	20.773	-24.727	-19.127	2.607
LTOA 2w@60C	26.373	-19.127	-24.727	-2.993
LMLC No LTOA	48.107	2.607	-2.993	-24.727

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Cores@construction	A		145.03333
LTOA 5d@85C	B		99.53333
LTOA 2w@60C	B	C	93.93333
LMLC No LTOA		C	72.20000

Levels not connected by same letter are significantly different.

Ordered Differences Report

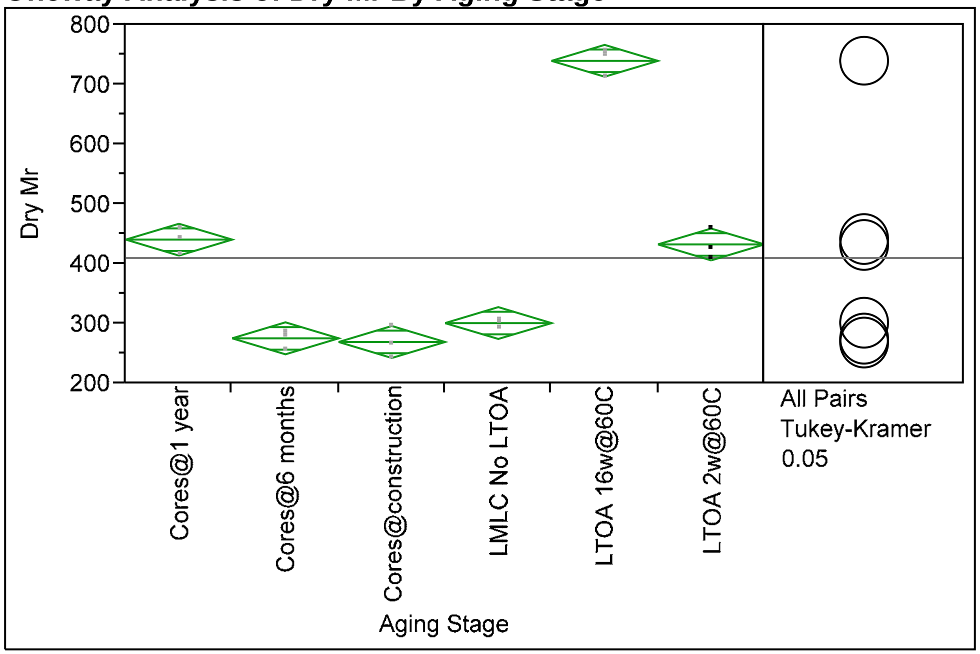
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Cores@construction	LMLC No LTOA	72.83333	7.721399	48.1068	97.55991	<.0001*
Cores@construction	LTOA 2w@60C	51.10000	7.721399	26.3734	75.82658	0.0008*
Cores@construction	LTOA 5d@85C	45.50000	7.721399	20.7734	70.22658	0.0016*
LTOA 5d@85C	LMLC No LTOA	27.33333	7.721399	2.6068	52.05991	0.0312*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 2w@60C	LMLC No LTOA	21.73333	7.721399	-2.9932	46.45991	0.0864
LTOA 5d@85C	LTOA 2w@60C	5.60000	7.721399	-19.1266	30.32658	0.8844

Table C.10

HMA+RAP – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
136

Oneway Anova

Summary of Fit

Rsquare	0.988863
Adj Rsquare	0.984223
Root Mean Square Error	21.22353
Mean of Response	409.81
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	479957.43	95991.5	213.1070	<.0001*
Error	12	5405.26	450.4		
C. Total	17	485362.69			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	440.600	12.253	413.90	467.30
Cores@6 months	3	275.467	12.253	248.77	302.16
Cores@construction	3	269.367	12.253	242.67	296.06
LMLC No LTOA	3	301.033	12.253	274.34	327.73
LTOA 16w@60C	3	739.833	12.253	713.14	766.53
LTOA 2w@60C	3	432.560	12.253	405.86	459.26

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	LTOA 2w@60C	LMLC No LTOA	Cores@6 months	Cores@construction
LTOA 16w@60C	-58.21	241.03	249.07	380.59	406.16	412.26
Cores@1 year	241.03	-58.21	-50.17	81.36	106.93	113.03
LTOA 2w@60C	249.07	-50.17	-58.21	73.32	98.89	104.99
LMLC No LTOA	380.59	81.36	73.32	-58.21	-32.64	-26.54
Cores@6 months	406.16	106.93	98.89	-32.64	-58.21	-52.11
Cores@construction	412.26	113.03	104.99	-26.54	-52.11	-58.21

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 16w@60C	A			739.83333
Cores@1 year		B		440.60000
LTOA 2w@60C		B		432.56000
LMLC No LTOA			C	301.03333
Cores@6 months			C	275.46667

Level		Mean
Cores@construction	C	269.36667

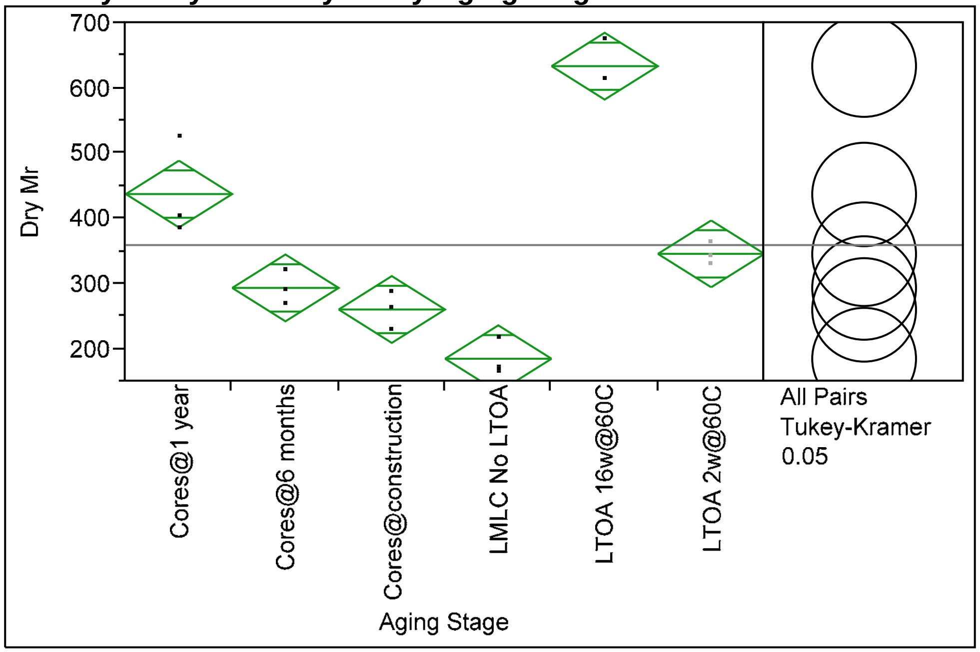
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	470.4667	17.32894	412.261	528.6722	<.0001*
LTOA 16w@60C	Cores@6 months	464.3667	17.32894	406.161	522.5722	<.0001*
LTOA 16w@60C	LMLC No LTOA	438.8000	17.32894	380.594	497.0055	<.0001*
LTOA 16w@60C	LTOA 2w@60C	307.2733	17.32894	249.068	365.4789	<.0001*
LTOA 16w@60C	Cores@1 year	299.2333	17.32894	241.028	357.4389	<.0001*
Cores@1 year	Cores@construction	171.2333	17.32894	113.028	229.4389	<.0001*
Cores@1 year	Cores@6 months	165.1333	17.32894	106.928	223.3389	<.0001*
LTOA 2w@60C	Cores@construction	163.1933	17.32894	104.988	221.3989	<.0001*
LTOA 2w@60C	Cores@6 months	157.0933	17.32894	98.888	215.2989	<.0001*
Cores@1 year	LMLC No LTOA	139.5667	17.32894	81.361	197.7722	<.0001*
LTOA 2w@60C	LMLC No LTOA	131.5267	17.32894	73.321	189.7322	<.0001*
LMLC No LTOA	Cores@construction	31.6667	17.32894	-26.539	89.8722	0.4851
LMLC No LTOA	Cores@6 months	25.5667	17.32894	-32.639	83.7722	0.6847
Cores@1 year	LTOA 2w@60C	8.0400	17.32894	-50.166	66.2455	0.9966
Cores@6 months	Cores@construction	6.1000	17.32894	-52.106	64.3055	0.9991

Evotherm 3G+RAP – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
136

Oneway Anova

Summary of Fit

Rsquare	0.949942
Adj Rsquare	0.929084
Root Mean Square Error	40.77418
Mean of Response	359.58
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	378591.92	75718.4	45.5440	<.0001*
Error	12	19950.40	1662.5		
C. Total	17	398542.32			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	437.867	23.541	386.58	489.16
Cores@6 months	3	293.800	23.541	242.51	345.09
Cores@construction	3	260.633	23.541	209.34	311.92
LMLC No LTOA	3	185.100	23.541	133.81	236.39
LTOA 16w@60C	3	634.033	23.541	582.74	685.32
LTOA 2w@60C	3	346.047	23.541	294.76	397.34

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	LTOA 2w@60C	Cores@6 months	Cores@construction	LMLC No LTOA
LTOA 16w@60C	-111.82	84.34	176.16	228.41	261.58	337.11
Cores@1 year	84.34	-111.82	-20.00	32.24	65.41	140.94
LTOA 2w@60C	176.16	-20.00	-111.82	-59.58	-26.41	49.12
Cores@6 months	228.41	32.24	-59.58	-111.82	-78.66	-3.12
Cores@construction	261.58	65.41	-26.41	-78.66	-111.82	-36.29
LMLC No LTOA	337.11	140.94	49.12	-3.12	-36.29	-111.82

Positive values show pairs of means that are significantly different.

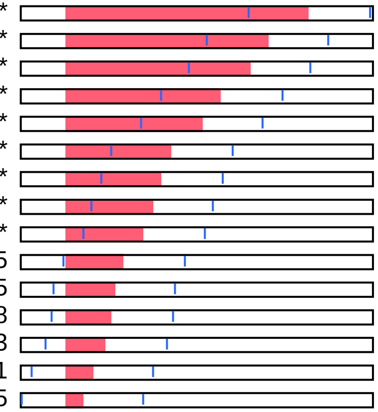
Connecting Letters Report

Level					Mean
LTOA 16w@60C	A				634.03333
Cores@1 year		B			437.86667
LTOA 2w@60C		B	C		346.04667
Cores@6 months			C	D	293.80000
Cores@construction			C	D	260.63333
LMLC No LTOA				D	185.10000

Levels not connected by same letter are significantly different.

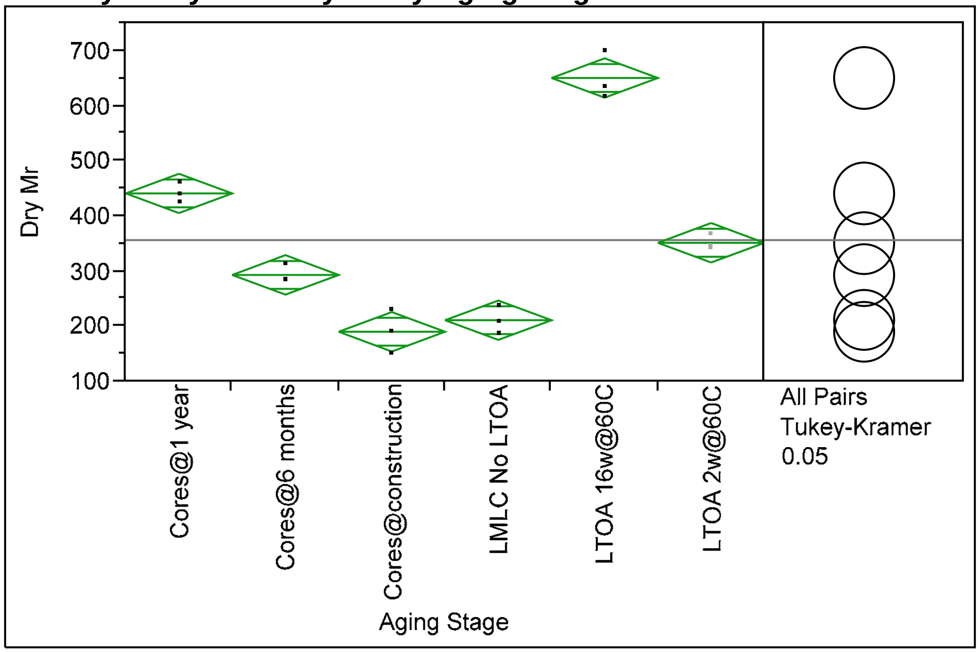
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	LMLC No LTOA	448.9333	33.29198	337.110	560.7566	<.0001*
LTOA 16w@60C	Cores@construction	373.4000	33.29198	261.577	485.2232	<.0001*
LTOA 16w@60C	Cores@6 months	340.2333	33.29198	228.410	452.0566	<.0001*
LTOA 16w@60C	LTOA 2w@60C	287.9867	33.29198	176.163	399.8099	<.0001*
Cores@1 year	LMLC No LTOA	252.7667	33.29198	140.943	364.5899	<.0001*
LTOA 16w@60C	Cores@1 year	196.1667	33.29198	84.343	307.9899	0.0008*
Cores@1 year	Cores@construction	177.2333	33.29198	65.410	289.0566	0.0019*
LTOA 2w@60C	LMLC No LTOA	160.9467	33.29198	49.123	272.7699	0.0042*
Cores@1 year	Cores@6 months	144.0667	33.29198	32.243	255.8899	0.0098*
Cores@6 months	LMLC No LTOA	108.7000	33.29198	-3.123	220.5232	0.0585
Cores@1 year	LTOA 2w@60C	91.8200	33.29198	-20.003	203.6432	0.1335
LTOA 2w@60C	Cores@construction	85.4133	33.29198	-26.410	197.2366	0.1798
Cores@construction	LMLC No LTOA	75.5333	33.29198	-36.290	187.3566	0.2773
LTOA 2w@60C	Cores@6 months	52.2467	33.29198	-59.577	164.0699	0.6311
Cores@6 months	Cores@construction	33.1667	33.29198	-78.657	144.9899	0.9105



Sasobit+RAP – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
136

Oneway Anova

Summary of Fit

Rsquare	0.97834
Adj Rsquare	0.969315
Root Mean Square Error	28.46793
Mean of Response	356.48
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	439262.45	87852.5	108.4033	<.0001*
Error	12	9725.08	810.4		
C. Total	17	448987.52			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@1 year	3	441.300	16.436	405.49	477.11
Cores@6 months	3	293.400	16.436	257.59	329.21
Cores@construction	3	190.400	16.436	154.59	226.21
LMLC No LTOA	3	211.300	16.436	175.49	247.11
LTOA 16w@60C	3	650.700	16.436	614.89	686.51
LTOA 2w@60C	3	351.780	16.436	315.97	387.59

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@1 year	LTOA 2w@60C	Cores@6 months	LMLC No LTOA	Cores@construction
LTOA 16w@60C	-78.07	131.33	220.85	279.23	361.33	382.23
Cores@1 year	131.33	-78.07	11.45	69.83	151.93	172.83
LTOA 2w@60C	220.85	11.45	-78.07	-19.69	62.41	83.31
Cores@6 months	279.23	69.83	-19.69	-78.07	4.03	24.93
LMLC No LTOA	361.33	151.93	62.41	4.03	-78.07	-57.17
Cores@construction	382.23	172.83	83.31	24.93	-57.17	-78.07

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
LTOA 16w@60C	A				650.70000
Cores@1 year		B			441.30000
LTOA 2w@60C			C		351.78000
Cores@6 months			C		293.40000
LMLC No LTOA				D	211.30000
Cores@construction				D	190.40000

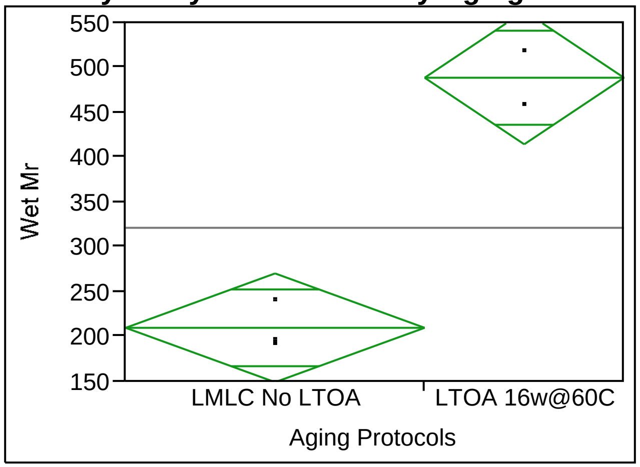
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	460.3000	23.24397	382.227	538.3733	<.0001*
LTOA 16w@60C	LMLC No LTOA	439.4000	23.24397	361.327	517.4733	<.0001*
LTOA 16w@60C	Cores@6 months	357.3000	23.24397	279.227	435.3733	<.0001*
LTOA 16w@60C	LTOA 2w@60C	298.9200	23.24397	220.847	376.9933	<.0001*
Cores@1 year	Cores@construction	250.9000	23.24397	172.827	328.9733	<.0001*
Cores@1 year	LMLC No LTOA	230.0000	23.24397	151.927	308.0733	<.0001*
LTOA 16w@60C	Cores@1 year	209.4000	23.24397	131.327	287.4733	<.0001*
LTOA 2w@60C	Cores@construction	161.3800	23.24397	83.307	239.4533	0.0002*
Cores@1 year	Cores@6 months	147.9000	23.24397	69.827	225.9733	0.0004*
LTOA 2w@60C	LMLC No LTOA	140.4800	23.24397	62.407	218.5533	0.0006*
Cores@6 months	Cores@construction	103.0000	23.24397	24.927	181.0733	0.0082*
Cores@1 year	LTOA 2w@60C	89.5200	23.24397	11.447	167.5933	0.0218*
Cores@6 months	LMLC No LTOA	82.1000	23.24397	4.027	160.1733	0.0374*
LTOA 2w@60C	Cores@6 months	58.3800	23.24397	-19.693	136.4533	0.1951
LMLC No LTOA	Cores@construction	20.9000	23.24397	-57.173	98.9733	0.9394

HMA+RAP – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
78

Oneway Anova

Summary of Fit

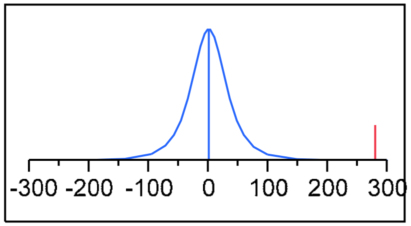
Rsquare	0.966161
Adj Rsquare	0.954882
Root Mean Square Error	33.01319
Mean of Response	321.9
Observations (or Sum Wgts)	5

t Test

LTOA 16w@60C-LMLC No LTOA

Assuming equal variances

Difference	278.917	t Ratio	9.255026
Std Err Dif	30.137	DF	3
Upper CL Dif	374.825	Prob > |t|	0.0027*
Lower CL Dif	183.008	Prob > t	0.0013*
Confidence	0.95	Prob < t	0.9987



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	1	93353.408	93353.4	85.6555	0.0027*
Error	3	3269.612	1089.9		
C. Total	4	96623.020			

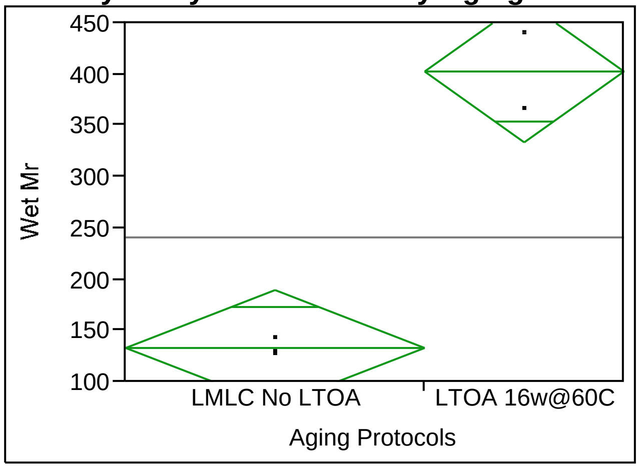
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	210.333	19.060	149.68	270.99
LTOA 16w@60C	2	489.250	23.344	414.96	563.54

Std Error uses a pooled estimate of error variance

Evotherm 3G+RAP – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
78

Oneway Anova

Summary of Fit

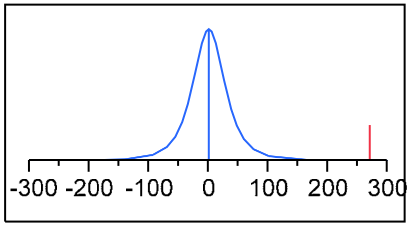
Rsquare	0.968576
Adj Rsquare	0.958101
Root Mean Square Error	30.73145
Mean of Response	241.04
Observations (or Sum Wgts)	5

t Test

LTOA 16w@60C-LMLC No LTOA

Assuming equal variances

Difference	269.767	t Ratio	9.61603
Std Err Dif	28.054	DF	3
Upper CL Dif	359.047	Prob > |t|	0.0024*
Lower CL Dif	180.487	Prob > t	0.0012*
Confidence	0.95	Prob < t	0.9988



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	1	87328.865	87328.9	92.4680	0.0024*
Error	3	2833.267	944.4		
C. Total	4	90162.132			

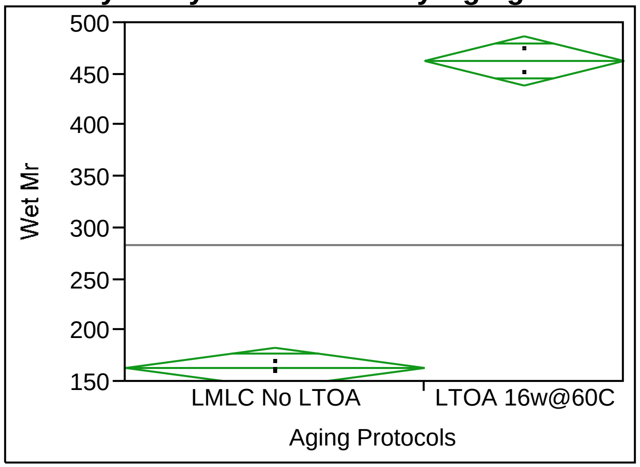
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	133.133	17.743	76.67	189.60
LTOA 16w@60C	2	402.900	21.730	333.74	472.06

Std Error uses a pooled estimate of error variance

Sasobit+RAP – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
78

Oneway Anova

Summary of Fit

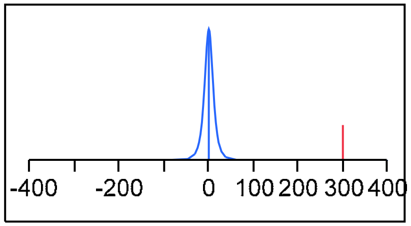
Rsquare	0.996819
Adj Rsquare	0.995759
Root Mean Square Error	10.70283
Mean of Response	283.5
Observations (or Sum Wgts)	5

t Test

LTOA 16w@60C-LMLC No LTOA

Assuming equal variances

Difference	299.583	t Ratio	30.66265
Std Err Dif	9.770	DF	3
Upper CL Dif	330.677	Prob > |t|	<.0001*
Lower CL Dif	268.490	Prob > t	<.0001*
Confidence	0.95	Prob < t	1.0000



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	1	107700.21	107700	940.1980	<.0001*
Error	3	343.65	115		
C. Total	4	108043.86			

Means for Oneway Anova

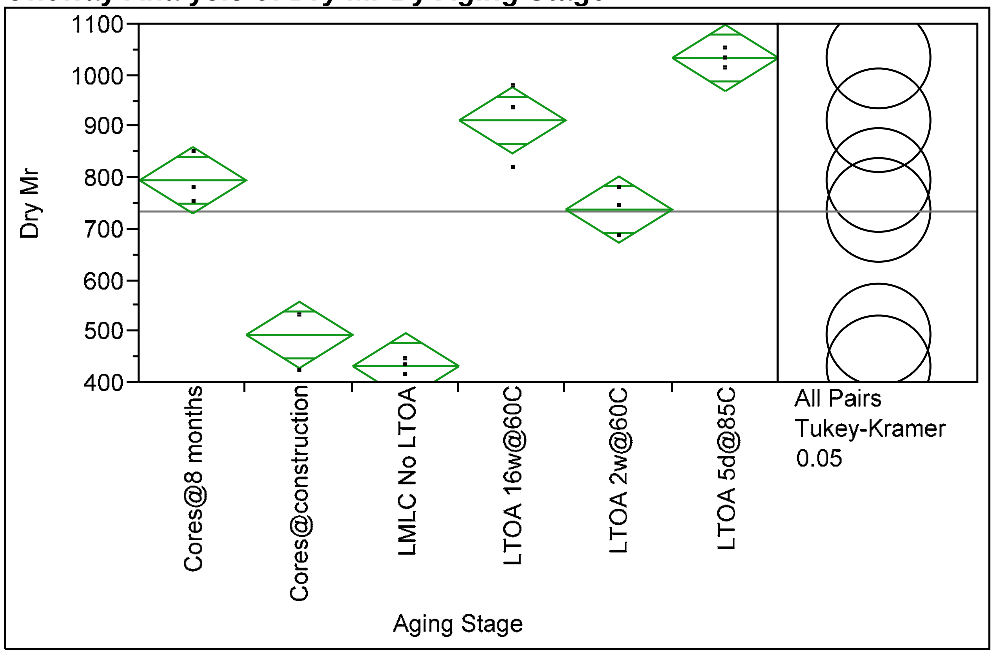
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	163.667	6.1793	144.00	183.33
LTOA 16w@60C	2	463.250	7.5680	439.17	487.33

Std Error uses a pooled estimate of error variance

Table C.12

HMA – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
136

Oneway Anova

Summary of Fit

Rsquare	0.962848
Adj Rsquare	0.947367
Root Mean Square Error	51.46931
Mean of Response	735.0833
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	823850.07	164770	62.1987	<.0001*
Error	12	31789.07	2649		
C. Total	17	855639.15			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	796.20	29.716	731.45	860.9
Cores@construction	3	494.23	29.716	429.49	559.0
LMLC No LTOA	3	433.03	29.716	368.29	497.8
LTOA 16w@60C	3	913.17	29.716	848.42	977.9
LTOA 2w@60C	3	738.93	29.716	674.19	803.7
LTOA 5d@85C	3	1034.93	29.716	970.19	1099.7

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 5d@85C	LTOA 16w@60C	Cores@8 months	LTOA 2w@60C	Cores@construction	LMLC No LTOA
LTOA 5d@85C	-141.15	-19.39	97.58	154.85	399.55	460.75
LTOA 16w@60C	-19.39	-141.15	-24.19	33.08	277.78	338.98
Cores@8 months	97.58	-24.19	-141.15	-83.89	160.81	222.01
LTOA 2w@60C	154.85	33.08	-83.89	-141.15	103.55	164.75
Cores@construction	399.55	277.78	160.81	103.55	-141.15	-79.95
LMLC No LTOA	460.75	338.98	222.01	164.75	-79.95	-141.15

Positive values show pairs of means that are significantly different.

Connecting Letters Report

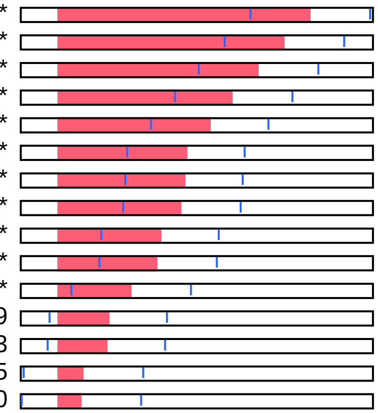
Level					Mean
LTOA 5d@85C	A				1034.9333
LTOA 16w@60C	A	B			913.1667
Cores@8 months		B	C		796.2000
LTOA 2w@60C			C		738.9333
Cores@construction				D	494.2333

Level		Mean
LMLC No LTOA	D	433.0333

Levels not connected by same letter are significantly different.

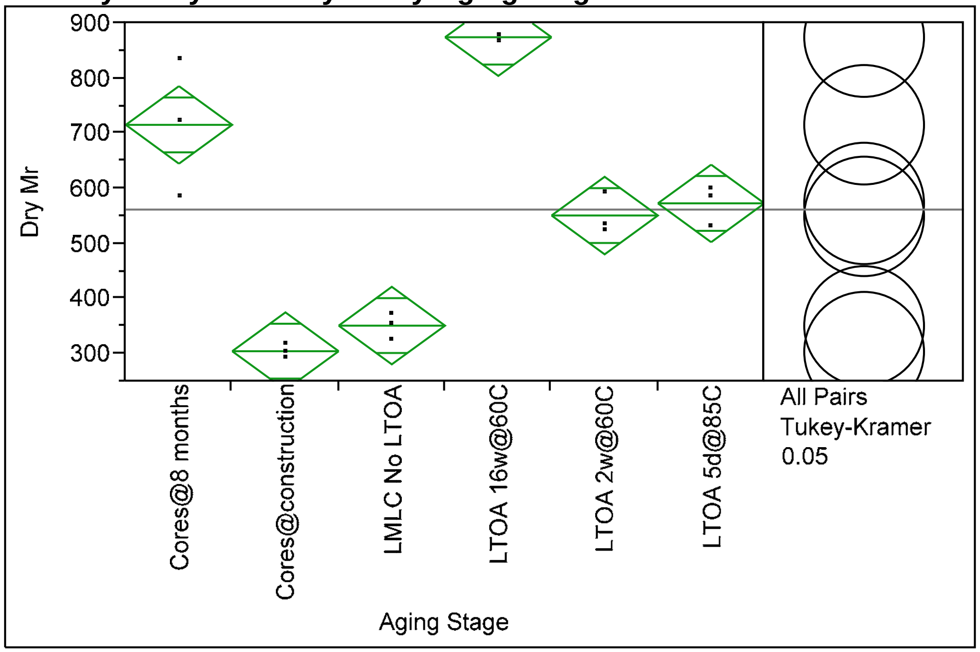
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LMLC No LTOA	601.9000	42.02451	460.745	743.0546	<.0001*
LTOA 5d@85C	Cores@construction	540.7000	42.02451	399.545	681.8546	<.0001*
LTOA 16w@60C	LMLC No LTOA	480.1333	42.02451	338.979	621.2880	<.0001*
LTOA 16w@60C	Cores@construction	418.9333	42.02451	277.779	560.0880	<.0001*
Cores@8 months	LMLC No LTOA	363.1667	42.02451	222.012	504.3213	<.0001*
LTOA 2w@60C	LMLC No LTOA	305.9000	42.02451	164.745	447.0546	0.0001*
Cores@8 months	Cores@construction	301.9667	42.02451	160.812	443.1213	0.0001*
LTOA 5d@85C	LTOA 2w@60C	296.0000	42.02451	154.845	437.1546	0.0002*
LTOA 2w@60C	Cores@construction	244.7000	42.02451	103.545	385.8546	0.0009*
LTOA 5d@85C	Cores@8 months	238.7333	42.02451	97.579	379.8880	0.0011*
LTOA 16w@60C	LTOA 2w@60C	174.2333	42.02451	33.079	315.3880	0.0133*
LTOA 5d@85C	LTOA 16w@60C	121.7667	42.02451	-19.388	262.9213	0.1069
LTOA 16w@60C	Cores@8 months	116.9667	42.02451	-24.188	258.1213	0.1283
Cores@construction	LMLC No LTOA	61.2000	42.02451	-79.955	202.3546	0.6955
Cores@8 months	LTOA 2w@60C	57.2667	42.02451	-83.888	198.4213	0.7470



Evotherm DAT – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
136

Oneway Anova

Summary of Fit

Rsquare	0.948836
Adj Rsquare	0.927517
Root Mean Square Error	55.92223
Mean of Response	561.8889
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	695945.02	139189	44.5078	<.0001*
Error	12	37527.55	3127		
C. Total	17	733472.58			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	715.667	32.287	645.32	786.01
Cores@construction	3	305.100	32.287	234.75	375.45
LMLC No LTOA	3	351.467	32.287	281.12	421.81
LTOA 16w@60C	3	874.733	32.287	804.39	945.08
LTOA 2w@60C	3	551.133	32.287	480.79	621.48
LTOA 5d@85C	3	573.233	32.287	502.89	643.58

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@8 months	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA	Cores@construction
LTOA 16w@60C	-153.37	5.70	148.13	170.23	369.90	416.27
Cores@8 months	5.70	-153.37	-10.93	11.17	210.83	257.20
LTOA 5d@85C	148.13	-10.93	-153.37	-131.27	68.40	114.77
LTOA 2w@60C	170.23	11.17	-131.27	-153.37	46.30	92.67
LMLC No LTOA	369.90	210.83	68.40	46.30	-153.37	-107.00
Cores@construction	416.27	257.20	114.77	92.67	-107.00	-153.37

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
LTOA 16w@60C	A				874.73333
Cores@8 months		B			715.66667
LTOA 5d@85C		B	C		573.23333
LTOA 2w@60C			C		551.13333
LMLC No LTOA				D	351.46667
Cores@construction				D	305.10000

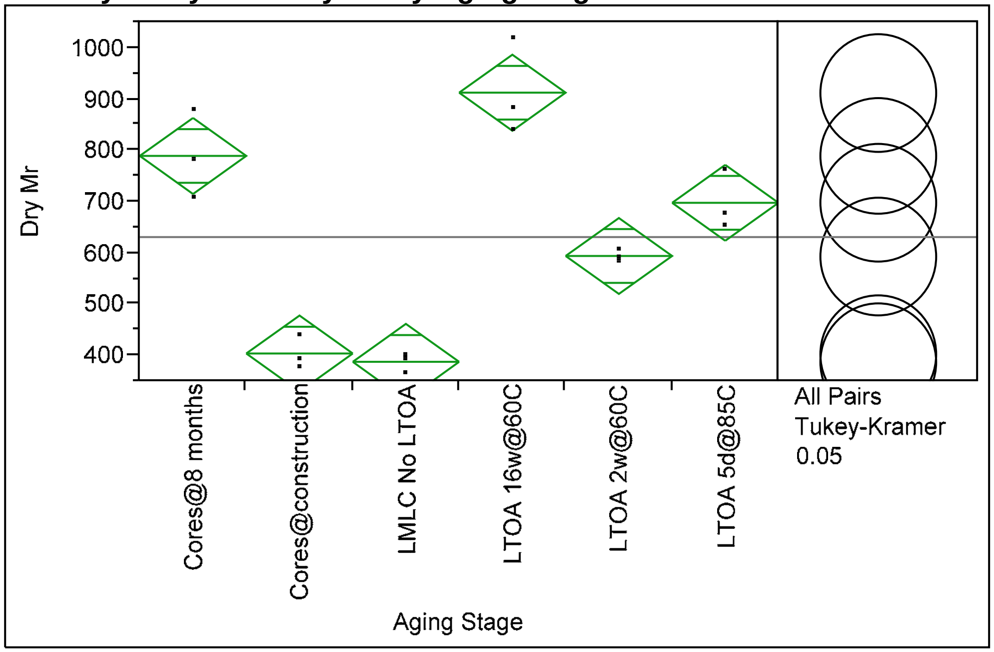
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	Cores@construction	569.6333	45.66031	416.267	723.0001	<.0001*
LTOA 16w@60C	LMLC No LTOA	523.2667	45.66031	369.900	676.6334	<.0001*
Cores@8 months	Cores@construction	410.5667	45.66031	257.200	563.9334	<.0001*
Cores@8 months	LMLC No LTOA	364.2000	45.66031	210.833	517.5668	<.0001*
LTOA 16w@60C	LTOA 2w@60C	323.6000	45.66031	170.233	476.9668	0.0001*
LTOA 16w@60C	LTOA 5d@85C	301.5000	45.66031	148.133	454.8668	0.0003*
LTOA 5d@85C	Cores@construction	268.1333	45.66031	114.767	421.5001	0.0008*
LTOA 2w@60C	Cores@construction	246.0333	45.66031	92.667	399.4001	0.0017*
LTOA 5d@85C	LMLC No LTOA	221.7667	45.66031	68.400	375.1334	0.0041*
LTOA 2w@60C	LMLC No LTOA	199.6667	45.66031	46.300	353.0334	0.0091*
Cores@8 months	LTOA 2w@60C	164.5333	45.66031	11.167	317.9001	0.0331*
LTOA 16w@60C	Cores@8 months	159.0667	45.66031	5.700	312.4334	0.0405*
Cores@8 months	LTOA 5d@85C	142.4333	45.66031	-10.933	295.8001	0.0745
LMLC No LTOA	Cores@construction	46.3667	45.66031	-107.000	199.7334	0.9040
LTOA 5d@85C	LTOA 2w@60C	22.1000	45.66031	-131.267	175.4668	0.9959

Foaming – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
136

Oneway Anova

Summary of Fit

Rsquare	0.940891
Adj Rsquare	0.916262
Root Mean Square Error	58.91918
Mean of Response	630.9
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	5	663100.30	132620	38.2029	<.0001*
Error	12	41657.64	3471		
C. Total	17	704757.94			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@8 months	3	789.267	34.017	715.15	863.38
Cores@construction	3	403.867	34.017	329.75	477.98
LMLC No LTOA	3	387.567	34.017	313.45	461.68
LTOA 16w@60C	3	912.633	34.017	838.52	986.75
LTOA 2w@60C	3	594.233	34.017	520.12	668.35
LTOA 5d@85C	3	697.833	34.017	623.72	771.95

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.35886	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	Cores@8 months	LTOA 5d@85C	LTOA 2w@60C	Cores@construction	LMLC No LTOA
LTOA 16w@60C	-161.59	-38.22	53.21	156.81	347.18	363.48
Cores@8 months	-38.22	-161.59	-70.15	33.45	223.81	240.11
LTOA 5d@85C	53.21	-70.15	-161.59	-57.99	132.38	148.68
LTOA 2w@60C	156.81	33.45	-57.99	-161.59	28.78	45.08
Cores@construction	347.18	223.81	132.38	28.78	-161.59	-145.29
LMLC No LTOA	363.48	240.11	148.68	45.08	-145.29	-161.59

Positive values show pairs of means that are significantly different.

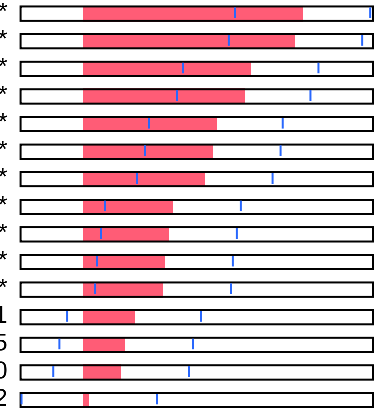
Connecting Letters Report

Level					Mean
LTOA 16w@60C	A				912.63333
Cores@8 months	A	B			789.26667
LTOA 5d@85C		B	C		697.83333
LTOA 2w@60C			C		594.23333
Cores@construction				D	403.86667
LMLC No LTOA				D	387.56667

Levels not connected by same letter are significantly different.

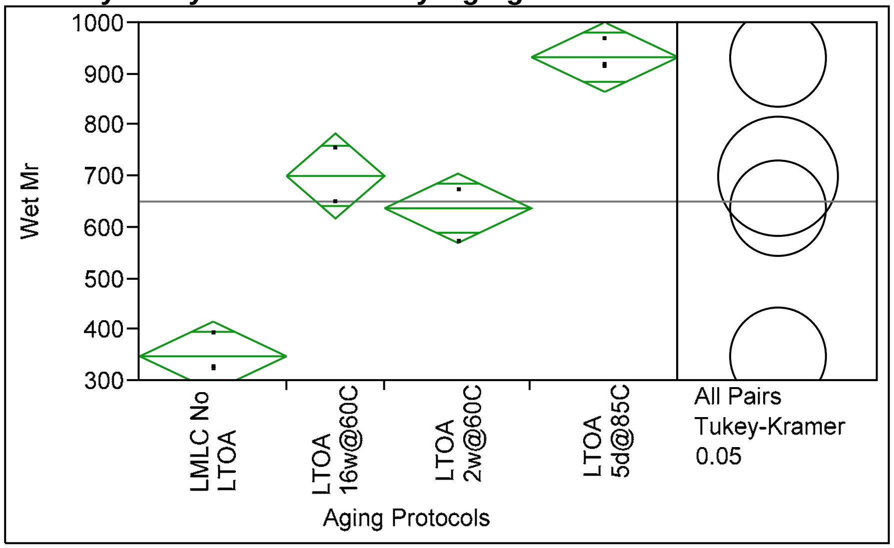
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	LMLC No LTOA	525.0667	48.10731	363.481	686.6526	<.0001*
LTOA 16w@60C	Cores@construction	508.7667	48.10731	347.181	670.3526	<.0001*
Cores@8 months	LMLC No LTOA	401.7000	48.10731	240.114	563.2859	<.0001*
Cores@8 months	Cores@construction	385.4000	48.10731	223.814	546.9859	<.0001*
LTOA 16w@60C	LTOA 2w@60C	318.4000	48.10731	156.814	479.9859	0.0003*
LTOA 5d@85C	LMLC No LTOA	310.2667	48.10731	148.681	471.8526	0.0004*
LTOA 5d@85C	Cores@construction	293.9667	48.10731	132.381	455.5526	0.0006*
LTOA 16w@60C	LTOA 5d@85C	214.8000	48.10731	53.214	376.3859	0.0078*
LTOA 2w@60C	LMLC No LTOA	206.6667	48.10731	45.081	368.2526	0.0103*
Cores@8 months	LTOA 2w@60C	195.0333	48.10731	33.447	356.6192	0.0155*
LTOA 2w@60C	Cores@construction	190.3667	48.10731	28.781	351.9526	0.0182*
LTOA 16w@60C	Cores@8 months	123.3667	48.10731	-38.219	284.9526	0.1801
LTOA 5d@85C	LTOA 2w@60C	103.6000	48.10731	-57.986	265.1859	0.3245
Cores@8 months	LTOA 5d@85C	91.4333	48.10731	-70.153	253.0192	0.4460
Cores@construction	LMLC No LTOA	16.3000	48.10731	-145.286	177.8859	0.9992



HMA – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
72

Oneway Anova

Summary of Fit

Rsquare	0.967743
Adj Rsquare	0.953919
Root Mean Square Error	49.73644
Mean of Response	651.2545
Observations (or Sum Wgts)	11

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	3	519500.65	173167	70.0028	<.0001*
Error	7	17315.99	2474		
C. Total	10	536816.65			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	348.567	28.715	280.67	416.5
LTOA 16w@60C	2	701.400	35.169	618.24	784.6
LTOA 2w@60C	3	638.200	28.715	570.30	706.1
LTOA 5d@85C	3	933.567	28.715	865.67	1001.5

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.31014	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 5d@85C	LTOA 16w@60C	LTOA 2w@60C	LMLC No LTOA
LTOA 5d@85C	-134.42	81.88	160.94	450.58
LTOA 16w@60C	81.88	-164.63	-87.09	202.54
LTOA 2w@60C	160.94	-87.09	-134.42	155.21
LMLC No LTOA	450.58	202.54	155.21	-134.42

Positive values show pairs of means that are significantly different.

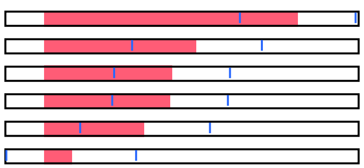
Connecting Letters Report

Level				Mean
LTOA 5d@85C	A			933.56667
LTOA 16w@60C		B		701.40000
LTOA 2w@60C		B		638.20000
LMLC No LTOA			C	348.56667

Levels not connected by same letter are significantly different.

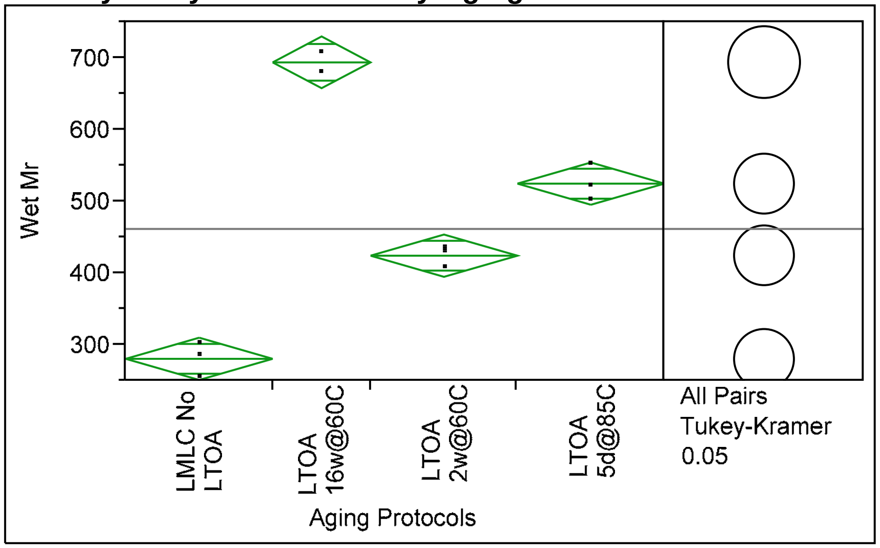
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LMLC No LTOA	585.0000	40.60963	450.576	719.4235	<.0001*
LTOA 16w@60C	LMLC No LTOA	352.8333	45.40295	202.543	503.1234	0.0005*
LTOA 5d@85C	LTOA 2w@60C	295.3667	40.60963	160.943	429.7902	0.0007*
LTOA 2w@60C	LMLC No LTOA	289.6333	40.60963	155.210	424.0568	0.0008*
LTOA 5d@85C	LTOA 16w@60C	232.1667	45.40295	81.877	382.4567	0.0058*
LTOA 16w@60C	LTOA 2w@60C	63.2000	45.40295	-87.090	213.4901	0.5413



Evotherm DAT – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
72

Oneway Anova

Summary of Fit

Rsquare	0.985554
Adj Rsquare	0.979363
Root Mean Square Error	21.58623
Mean of Response	461.6909
Observations (or Sum Wgts)	11

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	3	222532.09	74177.4	159.1907	<.0001*
Error	7	3261.76	466.0		
C. Total	10	225793.85			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	280.667	12.463	251.20	310.14
LTOA 16w@60C	2	694.150	15.264	658.06	730.24
LTOA 2w@60C	3	424.500	12.463	395.03	453.97
LTOA 5d@85C	3	524.933	12.463	495.46	554.40

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.31014	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA
LTOA 16w@60C	-71.45	103.99	204.42	348.26
LTOA 5d@85C	103.99	-58.34	42.09	185.93
LTOA 2w@60C	204.42	42.09	-58.34	85.49
LMLC No LTOA	348.26	185.93	85.49	-58.34

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level					Mean
LTOA 16w@60C	A				694.15000
LTOA 5d@85C		B			524.93333
LTOA 2w@60C			C		424.50000
LMLC No LTOA				D	280.66667

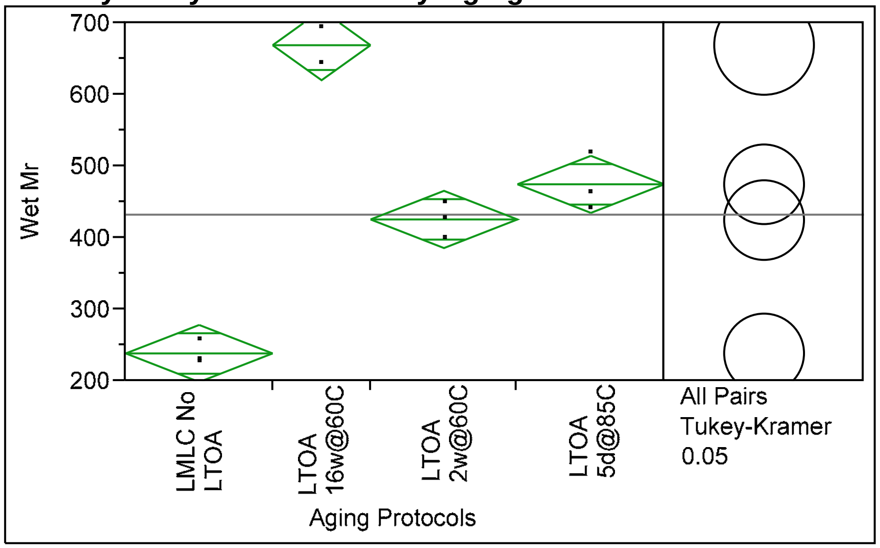
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	LMLC No LTOA	413.4833	19.70545	348.2556	478.7111	<.0001*
LTOA 16w@60C	LTOA 2w@60C	269.6500	19.70545	204.4222	334.8778	<.0001*
LTOA 5d@85C	LMLC No LTOA	244.2667	17.62509	185.9252	302.6081	<.0001*
LTOA 16w@60C	LTOA 5d@85C	169.2167	19.70545	103.9889	234.4444	0.0003*
LTOA 2w@60C	LMLC No LTOA	143.8333	17.62509	85.4919	202.1748	0.0004*
LTOA 5d@85C	LTOA 2w@60C	100.4333	17.62509	42.0919	158.7748	0.0031*

Foaming – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
72

Oneway Anova

Summary of Fit

Rsquare	0.974645
Adj Rsquare	0.963778
Root Mean Square Error	29.26641
Mean of Response	432.4636
Observations (or Sum Wgts)	11

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	3	230471.33	76823.8	89.6926	<.0001*
Error	7	5995.66	856.5		
C. Total	10	236466.99			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	238.633	16.897	198.68	278.59
LTOA 16w@60C	2	669.350	20.694	620.42	718.28
LTOA 2w@60C	3	425.933	16.897	385.98	465.89
LTOA 5d@85C	3	474.900	16.897	434.95	514.85

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.31014	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 16w@60C	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA
LTOA 16w@60C	-96.88	106.01	154.98	342.28
LTOA 5d@85C	106.01	-79.10	-30.13	157.17
LTOA 2w@60C	154.98	-30.13	-79.10	108.20
LMLC No LTOA	342.28	157.17	108.20	-79.10

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 16w@60C	A			669.35000
LTOA 5d@85C		B		474.90000
LTOA 2w@60C		B		425.93333
LMLC No LTOA			C	238.63333

Levels not connected by same letter are significantly different.

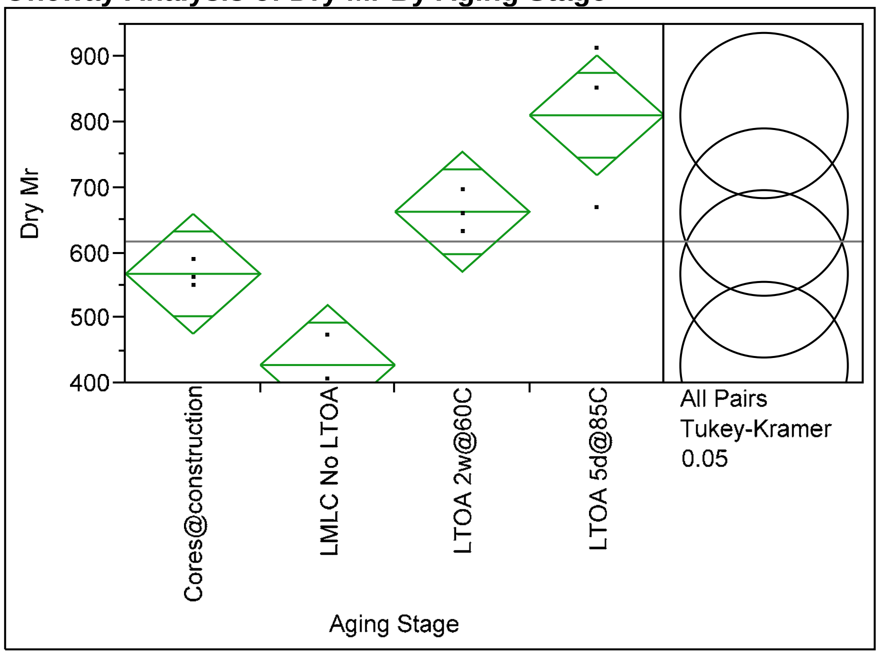
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 16w@60C	LMLC No LTOA	430.7167	26.71645	342.282	519.1518	<.0001*
LTOA 16w@60C	LTOA 2w@60C	243.4167	26.71645	154.982	331.8518	0.0002*
LTOA 5d@85C	LMLC No LTOA	236.2667	23.89592	157.168	315.3655	0.0001*
LTOA 16w@60C	LTOA 5d@85C	194.4500	26.71645	106.015	282.8852	0.0007*
LTOA 2w@60C	LMLC No LTOA	187.3000	23.89592	108.201	266.3988	0.0005*
LTOA 5d@85C	LTOA 2w@60C	48.9667	23.89592	-30.132	128.0655	0.2571

Table C.14

HMA+RAP – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
142

Oneway Anova

Summary of Fit

Rsquare	0.859499
Adj Rsquare	0.806811
Root Mean Square Error	69.11788
Mean of Response	617.7583
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	3	233795.48	77931.8	16.3130	0.0009*
Error	8	38218.25	4777.3		
C. Total	11	272013.73			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	3	568.067	39.905	476.05	660.09
LMLC No LTOA	3	428.300	39.905	336.28	520.32
LTOA 2w@60C	3	663.267	39.905	571.25	755.29
LTOA 5d@85C	3	811.400	39.905	719.38	903.42

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 5d@85C	LTOA 2w@60C	Cores@construction	LMLC No LTOA
LTOA 5d@85C	-180.72	-32.59	62.61	202.38
LTOA 2w@60C	-32.59	-180.72	-85.52	54.24
Cores@construction	62.61	-85.52	-180.72	-40.96
LMLC No LTOA	202.38	54.24	-40.96	-180.72

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 5d@85C	A			811.40000
LTOA 2w@60C	A	B		663.26667
Cores@construction		B	C	568.06667
LMLC No LTOA			C	428.30000

Levels not connected by same letter are significantly different.

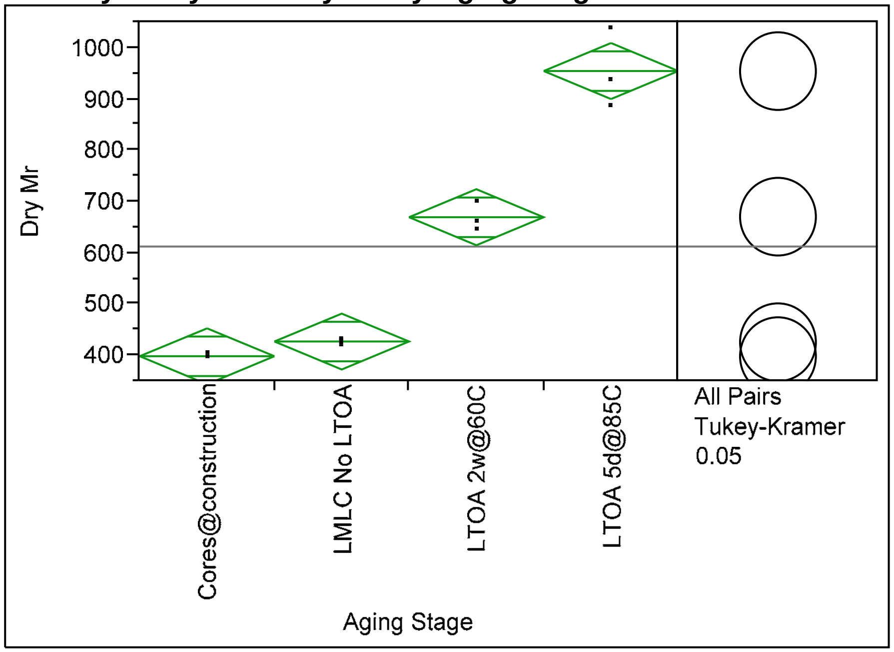
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LMLC No LTOA	383.1000	56.43451	202.377	563.8227	0.0006*
LTOA 5d@85C	Cores@construction	243.3333	56.43451	62.611	424.0561	0.0110*
LTOA 2w@60C	LMLC No LTOA	234.9667	56.43451	54.244	415.6894	0.0134*
LTOA 5d@85C	LTOA 2w@60C	148.1333	56.43451	-32.589	328.8561	0.1129
Cores@construction	LMLC No LTOA	139.7667	56.43451	-40.956	320.4894	0.1389
LTOA 2w@60C	Cores@construction	95.2000	56.43451	-85.523	275.9227	0.3890

Evotherm 3G+RAP – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
142

Oneway Anova

Summary of Fit

Rsquare	0.978151
Adj Rsquare	0.969957
Root Mean Square Error	40.99158
Mean of Response	612.5917
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	3	601793.83	200598	119.3815	<.0001*
Error	8	13442.48	1680		
C. Total	11	615236.31			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	3	398.500	23.667	343.92	453.1
LMLC No LTOA	3	427.267	23.667	372.69	481.8
LTOA 2w@60C	3	669.733	23.667	615.16	724.3
LTOA 5d@85C	3	954.867	23.667	900.29	1009.4

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.20234	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA	Cores@construction
LTOA 5d@85C	-107.18	177.95	420.42	449.19
LTOA 2w@60C	177.95	-107.18	135.29	164.05
LMLC No LTOA	420.42	135.29	-107.18	-78.41
Cores@construction	449.19	164.05	-78.41	-107.18

Positive values show pairs of means that are significantly different.

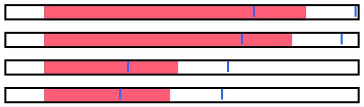
Connecting Letters Report

Level				Mean
LTOA 5d@85C	A			954.86667
LTOA 2w@60C		B		669.73333
LMLC No LTOA			C	427.26667
Cores@construction			C	398.50000

Levels not connected by same letter are significantly different.

Ordered Differences Report

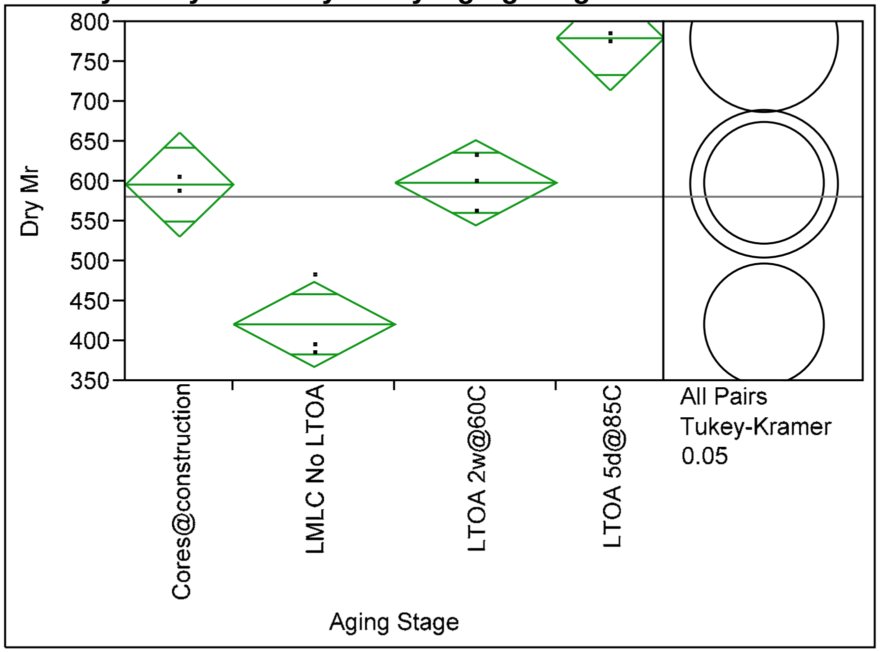
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	Cores@construction	556.3667	33.46949	449.186	663.5475	<.0001*
LTOA 5d@85C	LMLC No LTOA	527.6000	33.46949	420.419	634.7808	<.0001*
LTOA 5d@85C	LTOA 2w@60C	285.1333	33.46949	177.953	392.3142	0.0001*
LTOA 2w@60C	Cores@construction	271.2333	33.46949	164.053	378.4142	0.0002*



Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 2w@60C	LMLC No LTOA	242.4667	33.46949	135.286	349.6475	0.0004*
LMLC No LTOA	Cores@construction	28.7667	33.46949	-78.414	135.9475	0.8251

Foaming+RAP – Dry M_R

Oneway Analysis of Dry Mr By Aging Stage



Excluded Rows
144

Oneway Anova

Summary of Fit

Rsquare	0.948341
Adj Rsquare	0.922511
Root Mean Square Error	37.78955
Mean of Response	581.25
Observations (or Sum Wgts)	10

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Stage	3	157294.25	52431.4	36.7154	0.0003*
Error	6	8568.30	1428.0		
C. Total	9	165862.55			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Cores@construction	2	596.450	26.721	531.07	661.83
LMLC No LTOA	3	421.133	21.818	367.75	474.52
LTOA 2w@60C	3	598.733	21.818	545.35	652.12
LTOA 5d@85C	2	780.000	26.721	714.62	845.38

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.46171	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 5d@85C	LTOA 2w@60C	Cores@construction	LMLC No LTOA
LTOA 5d@85C	-130.82	61.85	52.73	239.45
LTOA 2w@60C	61.85	-106.81	-117.14	70.79
Cores@construction	52.73	-117.14	-130.82	55.90
LMLC No LTOA	239.45	70.79	55.90	-106.81

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 5d@85C	A			780.00000
LTOA 2w@60C		B		598.73333
Cores@construction		B		596.45000
LMLC No LTOA			C	421.13333

Levels not connected by same letter are significantly different.

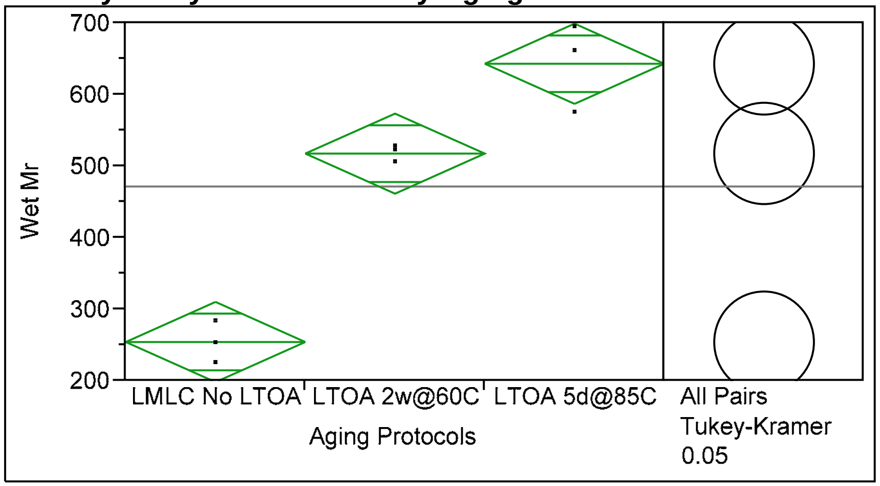
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LMLC No LTOA	358.8667	34.49698	239.448	478.2850	0.0002*
LTOA 5d@85C	Cores@construction	183.5500	37.78955	52.734	314.3663	0.0112*
LTOA 5d@85C	LTOA 2w@60C	181.2667	34.49698	61.848	300.6850	0.0076*
LTOA 2w@60C	LMLC No LTOA	177.6000	30.85503	70.789	284.4110	0.0048*

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Cores@construction	LMLC No LTOA	175.3167	34.49698	55.898	294.7350	0.0090*
LTOA 2w@60C	Cores@construction	2.2833	34.49698	-117.135	121.7017	0.9999

HMA+RAP – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
74

Oneway Anova

Summary of Fit

Rsquare	0.961645
Adj Rsquare	0.94886
Root Mean Square Error	39.63186
Mean of Response	471.8556
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	2	236283.64	118142	75.2168	<.0001*
Error	6	9424.11	1571		
C. Total	8	245707.74			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	254.500	22.881	198.51	310.49
LTOA 2w@60C	3	517.700	22.881	461.71	573.69

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LTOA 5d@85C	3	643.367	22.881	587.38	699.36

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	**LTOA 5d@85C**	**LTOA 2w@60C**	**LMLC No LTOA**
LTOA 5d@85C	-99.28	26.38	289.58
LTOA 2w@60C	26.38	-99.28	163.92
LMLC No LTOA	289.58	163.92	-99.28

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 5d@85C	A			643.36667
LTOA 2w@60C		B		517.70000
LMLC No LTOA			C	254.50000

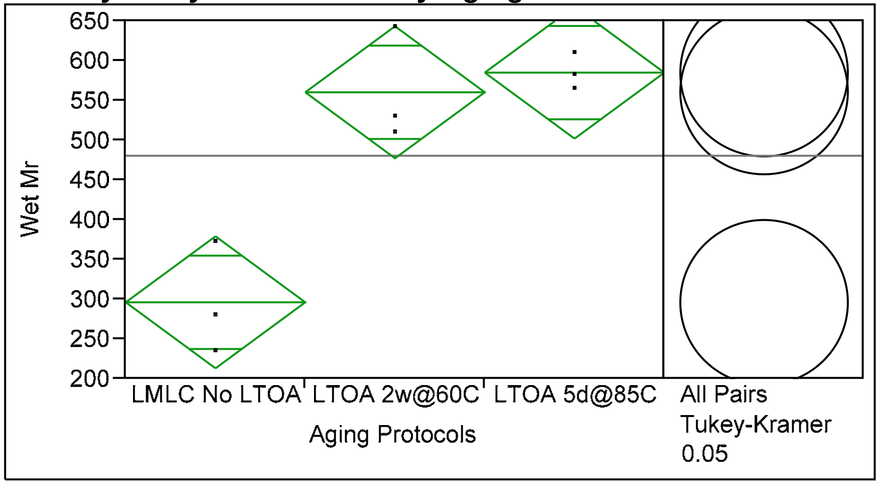
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LMLC No LTOA	388.8667	32.35928	289.5836	488.1498	<.0001*
LTOA 2w@60C	LMLC No LTOA	263.2000	32.35928	163.9169	362.4831	0.0005*
LTOA 5d@85C	LTOA 2w@60C	125.6667	32.35928	26.3836	224.9498	0.0191*

Evotherm 3G+RAP – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
74

Oneway Anova

Summary of Fit

Rsquare	0.881267
Adj Rsquare	0.84169
Root Mean Square Error	58.77642
Mean of Response	480.8222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	2	153849.11	76924.6	22.2668	0.0017*
Error	6	20728.01	3454.7		
C. Total	8	174577.12			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	296.467	33.935	213.43	379.50
LTOA 2w@60C	3	560.700	33.935	477.67	643.73

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LTOA 5d@85C	3	585.300	33.935	502.27	668.33

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA
LTOA 5d@85C	-147.24	-122.64	141.59
LTOA 2w@60C	-122.64	-147.24	116.99
LMLC No LTOA	141.59	116.99	-147.24

Positive values show pairs of means that are significantly different.

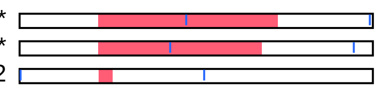
Connecting Letters Report

Level			Mean
LTOA 5d@85C	A		585.30000
LTOA 2w@60C	A		560.70000
LMLC No LTOA		B	296.46667

Levels not connected by same letter are significantly different.

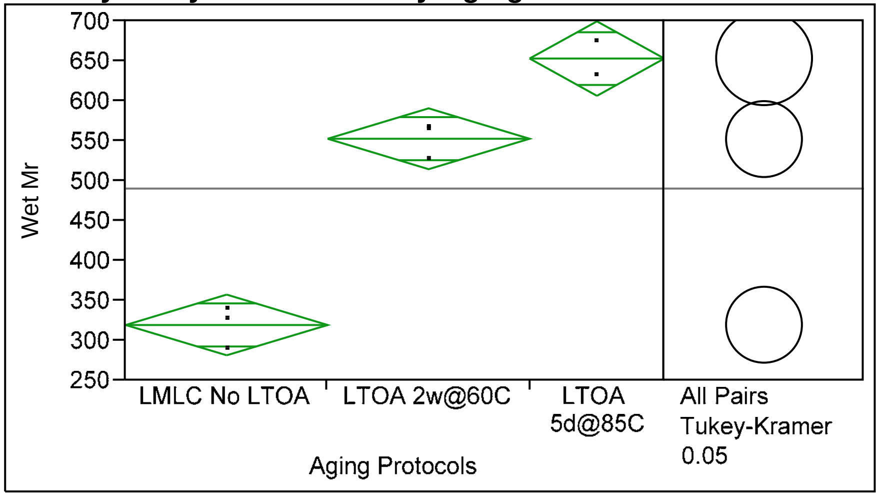
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LMLC No LTOA	288.8333	47.99075	141.591	436.0761	0.0023*
LTOA 2w@60C	LMLC No LTOA	264.2333	47.99075	116.991	411.4761	0.0036*
LTOA 5d@85C	LTOA 2w@60C	24.6000	47.99075	-122.643	171.8428	0.8682



Foaming+RAP – Wet M_R

Oneway Analysis of Wet Mr By Aging Protocols



Excluded Rows
75

Oneway Anova

Summary of Fit

Rsquare	0.97883
Adj Rsquare	0.970362
Root Mean Square Error	25.66364
Mean of Response	490.5875
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Aging Protocols	2	152264.36	76132.2	115.5931	<.0001*
Error	5	3293.11	658.6		
C. Total	7	155557.47			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LMLC No LTOA	3	319.700	14.817	281.61	357.79
LTOA 2w@60C	3	552.967	14.817	514.88	591.05

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
LTOA 5d@85C	2	653.350	18.147	606.70	700.00

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	LTOA 5d@85C	LTOA 2w@60C	LMLC No LTOA
LTOA 5d@85C	-83.51	24.15	257.42
LTOA 2w@60C	24.15	-68.18	165.08
LMLC No LTOA	257.42	165.08	-68.18

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level				Mean
LTOA 5d@85C	A			653.35000
LTOA 2w@60C		B		552.96667
LMLC No LTOA			C	319.70000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
LTOA 5d@85C	LMLC No LTOA	333.6500	23.42759	257.4198	409.8802	<.0001*
LTOA 2w@60C	LMLC No LTOA	233.2667	20.95427	165.0843	301.4490	0.0002*
LTOA 5d@85C	LTOA 2w@60C	100.3833	23.42759	24.1532	176.6135	0.0178*

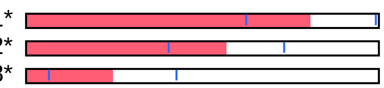
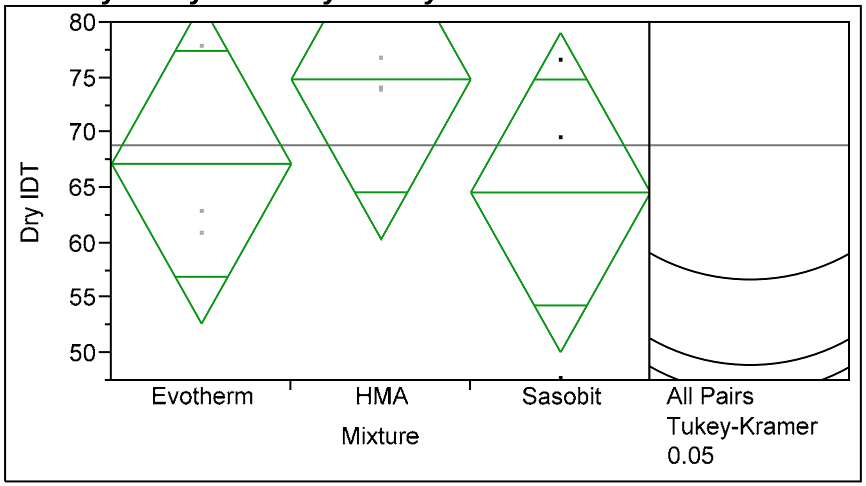


Table C.17

PMFC cores at construction – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.21284
Adj Rsquare	-0.04955
Root Mean Square Error	10.26488
Mean of Response	68.88889
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	170.94222	85.471	0.8112	0.4877
Error	6	632.20667	105.368		
C. Total	8	803.14889			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	67.2000	5.9264	52.699	81.701
HMA	3	74.8667	5.9264	60.365	89.368
Sasobit	3	64.6000	5.9264	50.099	79.101

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Sasobit
HMA	-25.715	-18.048	-15.448
Evotherm	-18.048	-25.715	-23.115
Sasobit	-15.448	-23.115	-25.715

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	74.866667
Evotherm	A	67.200000
Sasobit	A	64.600000

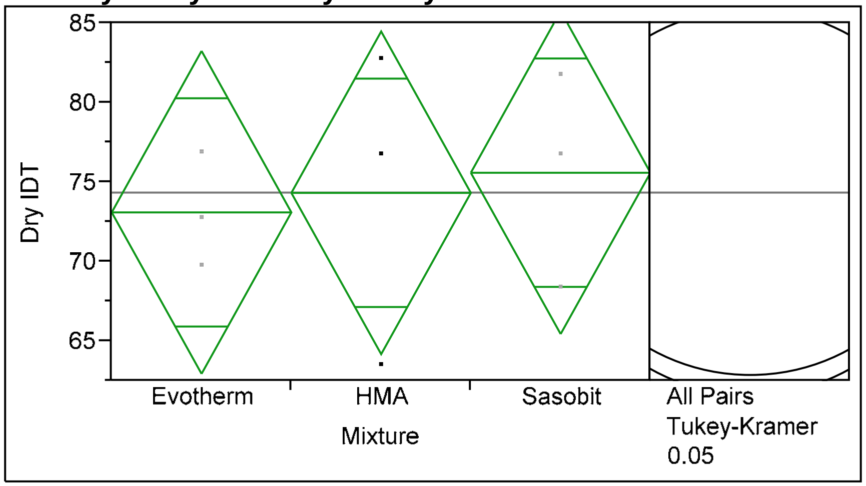
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Sasobit	10.26667	8.381240	-15.4482	35.98156	0.4826
HMA	Evotherm	7.66667	8.381240	-18.0482	33.38156	0.6516
Evotherm	Sasobit	2.60000	8.381240	-23.1149	28.31490	0.9488

PMFC cores after winter at 6 months – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.029368
Adj Rsquare	-0.29418
Root Mean Square Error	7.186407
Mean of Response	74.34444
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	9.37556	4.6878	0.0908	0.9145
Error	6	309.86667	51.6444		
C. Total	8	319.24222			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	73.1000	4.1491	62.948	83.252
HMA	3	74.3333	4.1491	64.181	84.486

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	75.6000	4.1491	65.448	85.752

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Sasobit	HMA	Evotherm
Sasobit	-18.003	-16.736	-15.503
HMA	-16.736	-18.003	-16.770
Evotherm	-15.503	-16.770	-18.003

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Sasobit	A	75.600000
HMA	A	74.333333
Evotherm	A	73.100000

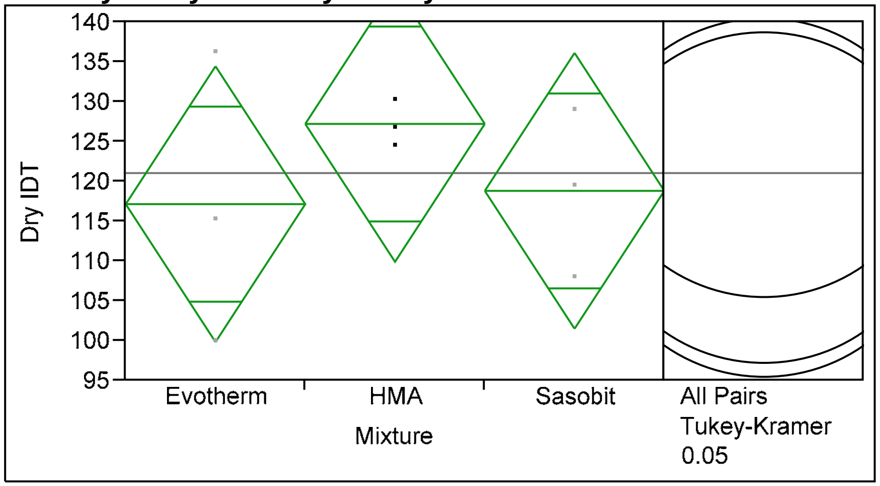
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Sasobit	Evotherm	2.500000	5.867677	-15.5029	20.50291	0.9063
Sasobit	HMA	1.266667	5.867677	-16.7362	19.26957	0.9747
HMA	Evotherm	1.233333	5.867677	-16.7696	19.23624	0.9760

PMFC cores after summer at 12 months – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.162468
Adj Rsquare	-0.11671
Root Mean Square Error	12.25058
Mean of Response	121.0778
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	174.6756	87.338	0.5820	0.5875
Error	6	900.4600	150.077		
C. Total	8	1075.1356			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	117.167	7.0729	99.86	134.47
HMA	3	127.233	7.0729	109.93	144.54

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	118.833	7.0729	101.53	136.14

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-30.689	-22.289	-20.623
Sasobit	-22.289	-30.689	-29.023
Evotherm	-20.623	-29.023	-30.689

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	127.23333
Sasobit	A	118.83333
Evotherm	A	117.16667

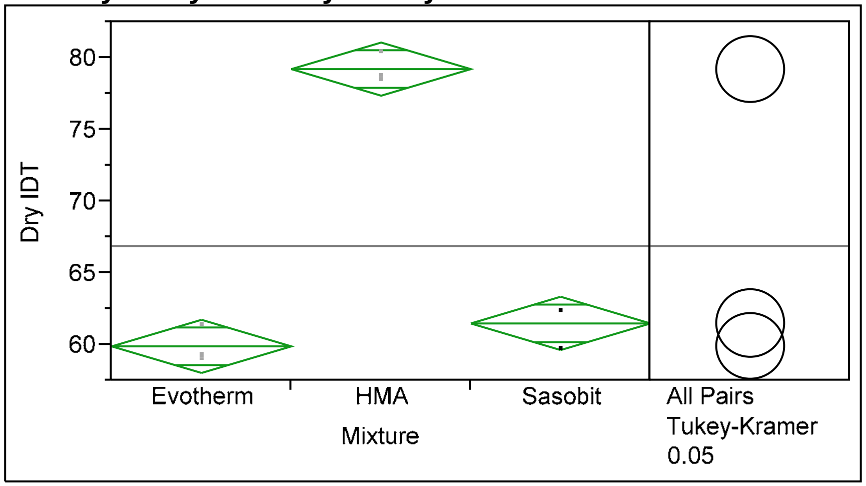
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	10.06667	10.00256	-20.6227	40.75600	0.5999
HMA	Sasobit	8.40000	10.00256	-22.2893	39.08933	0.6942
Sasobit	Evotherm	1.66667	10.00256	-29.0227	32.35600	0.9848

LMLC no LTOA – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.985215
Adj Rsquare	0.980287
Root Mean Square Error	1.31445
Mean of Response	66.87778
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	690.80889	345.404	199.9125	<.0001*
Error	6	10.36667	1.728		
C. Total	8	701.17556			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	59.9000	0.75890	58.043	61.757
HMA	3	79.2333	0.75890	77.376	81.090

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	61.5000	0.75890	59.643	63.357

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-3.293	14.440	16.040
Sasobit	14.440	-3.293	-1.693
Evotherm	16.040	-1.693	-3.293

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		79.233333
Sasobit		B	61.500000
Evotherm		B	59.900000

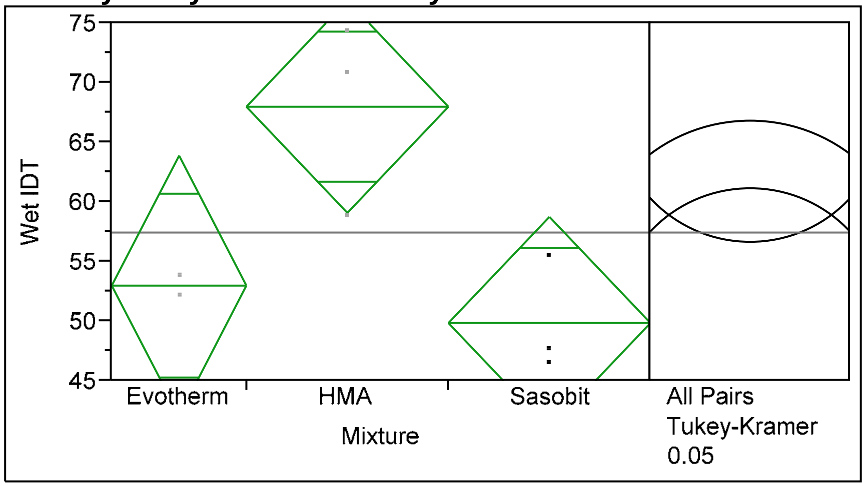
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	19.33333	1.073244	16.0405	22.62620	<.0001*
HMA	Sasobit	17.73333	1.073244	14.4405	21.02620	<.0001*
Sasobit	Evotherm	1.60000	1.073244	-1.6929	4.89287	0.3593

PMFC cores at construction – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
130

Oneway Anova

Summary of Fit

Rsquare	0.752257
Adj Rsquare	0.65316
Root Mean Square Error	5.99711
Mean of Response	57.45
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	546.03333	273.017	7.5911	0.0305*
Error	5	179.82667	35.965		
C. Total	7	725.86000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	2	53.0000	4.2406	42.099	63.901
HMA	3	68.0000	3.4624	59.100	76.900

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	49.8667	3.4624	40.966	58.767

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Sasobit
HMA	-15.933	-2.814	2.200
Evotherm	-2.814	-19.514	-14.680
Sasobit	2.200	-14.680	-15.933

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		68.000000
Evotherm	A	B	53.000000
Sasobit		B	49.866667

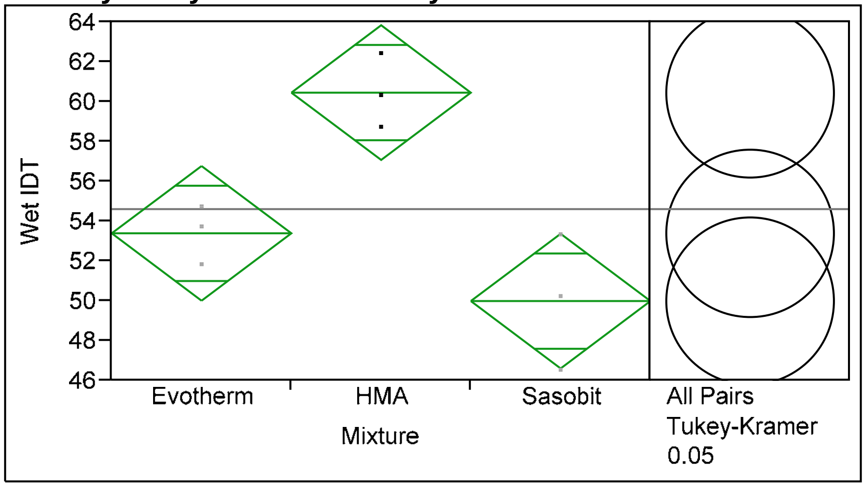
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Sasobit	18.13333	4.896620	2.2004	34.06626	0.0313*
HMA	Evotherm	15.00000	5.474588	-2.8136	32.81356	0.0881
Evotherm	Sasobit	3.13333	5.474588	-14.6802	20.94689	0.8401

PMFC cores after winter at 6 months – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.832535
Adj Rsquare	0.776713
Root Mean Square Error	2.39467
Mean of Response	54.62222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	171.04889	85.5244	14.9142	0.0047*
Error	6	34.40667	5.7344		
C. Total	8	205.45556			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	53.4000	1.3826	50.017	56.783
HMA	3	60.4667	1.3826	57.084	63.850

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	50.0000	1.3826	46.617	53.383

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Sasobit
HMA	-5.9990	1.0677	4.4677
Evotherm	1.0677	-5.9990	-2.5990
Sasobit	4.4677	-2.5990	-5.9990

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		60.466667
Evotherm		B	53.400000
Sasobit		B	50.000000

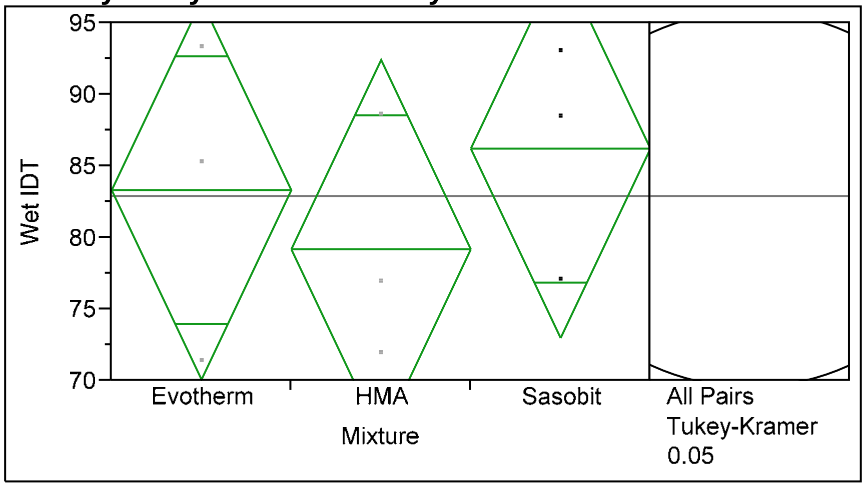
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Sasobit	10.46667	1.955240	4.46770	16.46563	0.0042*
HMA	Evotherm	7.06667	1.955240	1.06770	13.06563	0.0260*
Evotherm	Sasobit	3.40000	1.955240	-2.59897	9.39897	0.2671

PMFC cores after summer at 12 months – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.124664
Adj Rsquare	-0.16712
Root Mean Square Error	9.366192
Mean of Response	82.92222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	74.96222	37.4811	0.4273	0.6707
Error	6	526.35333	87.7256		
C. Total	8	601.31556			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	83.3333	5.4076	70.101	96.565
HMA	3	79.2000	5.4076	65.968	92.432

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	86.2333	5.4076	73.001	99.465

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Sasobit	Evotherm	HMA
Sasobit	-23.464	-20.564	-16.430
Evotherm	-20.564	-23.464	-19.330
HMA	-16.430	-19.330	-23.464

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Sasobit	A	86.233333
Evotherm	A	83.333333
HMA	A	79.200000

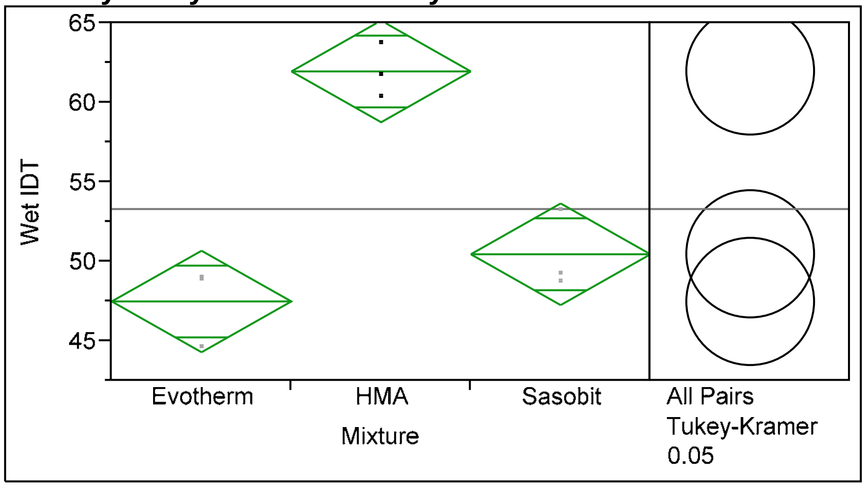
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Sasobit	HMA	7.033333	7.647464	-16.4302	30.49689	0.6488
Evotherm	HMA	4.133333	7.647464	-19.3302	27.59689	0.8549
Sasobit	Evotherm	2.900000	7.647464	-20.5636	26.36356	0.9248

LMLC no LTOA – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.919494
Adj Rsquare	0.892659
Root Mean Square Error	2.261022
Mean of Response	53.31111
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	350.33556	175.168	34.2645	0.0005*
Error	6	30.67333	5.112		
C. Total	8	381.00889			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	47.5000	1.3054	44.306	50.694
HMA	3	61.9667	1.3054	58.772	65.161

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	50.4667	1.3054	47.272	53.661

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-5.6642	5.8358	8.8025
Sasobit	5.8358	-5.6642	-2.6975
Evotherm	8.8025	-2.6975	-5.6642

Positive values show pairs of means that are significantly different.

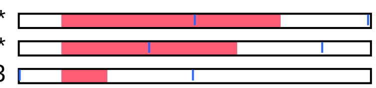
Connecting Letters Report

Level			Mean
HMA	A		61.966667
Sasobit		B	50.466667
Evotherm		B	47.500000

Levels not connected by same letter are significantly different.

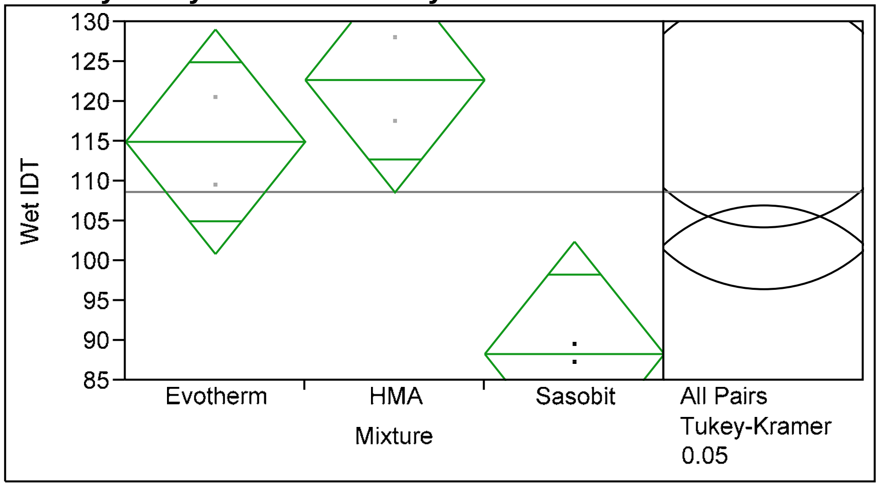
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	14.46667	1.846117	8.80250	20.13083	0.0006*
HMA	Sasobit	11.50000	1.846117	5.83584	17.16416	0.0019*
Sasobit	Evotherm	2.96667	1.846117	-2.69750	8.63083	0.3133



LMLC 16W@60C – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
132

Oneway Anova

Summary of Fit

Rsquare	0.916946
Adj Rsquare	0.861577
Root Mean Square Error	6.270832
Mean of Response	108.7
Observations (or Sum Wgts)	6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	1302.4300	651.215	16.5605	0.0239*
Error	3	117.9700	39.323		
C. Total	5	1420.4000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	2	115.000	4.4341	100.89	129.11
HMA	2	122.750	4.4341	108.64	136.86

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	2	88.350	4.4341	74.24	102.46

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
4.17871	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Sasobit
HMA	-26.204	-18.454	8.196
Evotherm	-18.454	-26.204	0.446
Sasobit	8.196	0.446	-26.204

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		122.75000
Evotherm	A		115.00000
Sasobit		B	88.35000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Sasobit	34.40000	6.270832	8.1960	60.60399	0.0241*
Evotherm	Sasobit	26.65000	6.270832	0.4460	52.85399	0.0479*
HMA	Evotherm	7.75000	6.270832	-18.4540	33.95399	0.5135

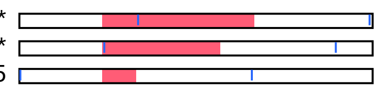
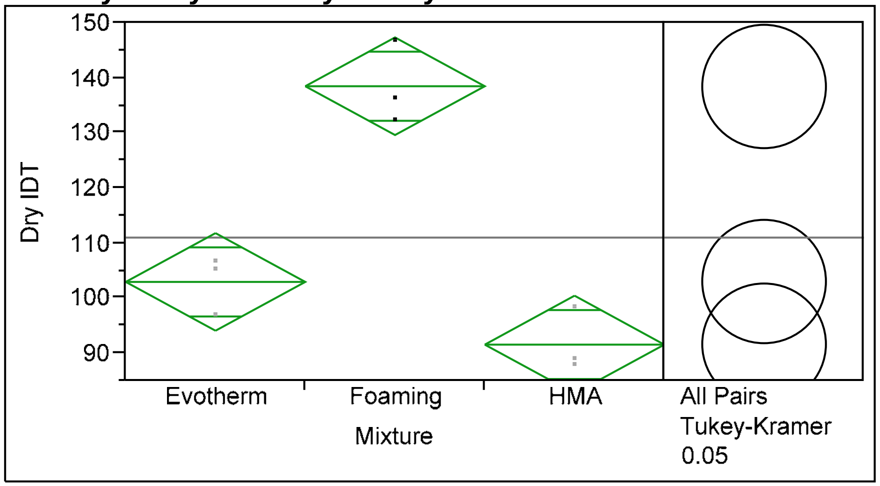


Table C.18

PMFC cores at construction – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.938299
Adj Rsquare	0.917732
Root Mean Square Error	6.273843
Mean of Response	111.0222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	3591.4289	1795.71	45.6215	0.0002*
Error	6	236.1667	39.36		
C. Total	8	3827.5956			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	102.967	3.6222	94.10	111.83
Foaming	3	138.500	3.6222	129.64	147.36
HMA	3	91.600	3.6222	82.74	100.46

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming	Evotherm	HMA
Foaming	-15.717	19.817	31.183
Evotherm	19.817	-15.717	-4.350
HMA	31.183	-4.350	-15.717

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Foaming	A		138.50000
Evotherm		B	102.96667
HMA		B	91.60000

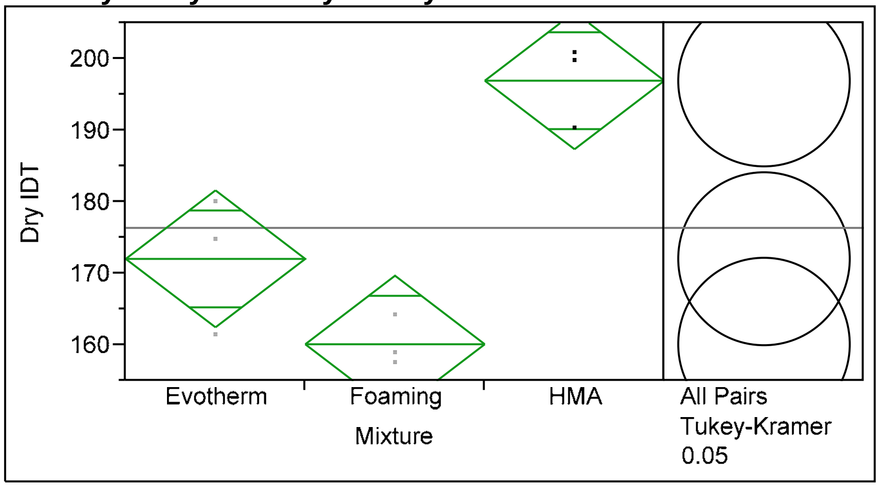
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming	HMA	46.90000	5.122572	31.1832	62.61681	0.0002*
Foaming	Evotherm	35.53333	5.122572	19.8165	51.25015	0.0011*
Evotherm	HMA	11.36667	5.122572	-4.3501	27.08348	0.1461

PMFC cores after summer at 8 months – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.88495
Adj Rsquare	0.8466
Root Mean Square Error	6.776184
Mean of Response	176.3889
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	2119.1089	1059.55	23.0756	0.0015*
Error	6	275.5000	45.92		
C. Total	8	2394.6089			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	172.067	3.9122	162.49	181.64
Foaming	3	160.133	3.9122	150.56	169.71

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	196.967	3.9122	187.39	206.54

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Foaming
HMA	-16.975	7.925	19.858
Evotherm	7.925	-16.975	-5.042
Foaming	19.858	-5.042	-16.975

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		196.96667
Evotherm		B	172.06667
Foaming		B	160.13333

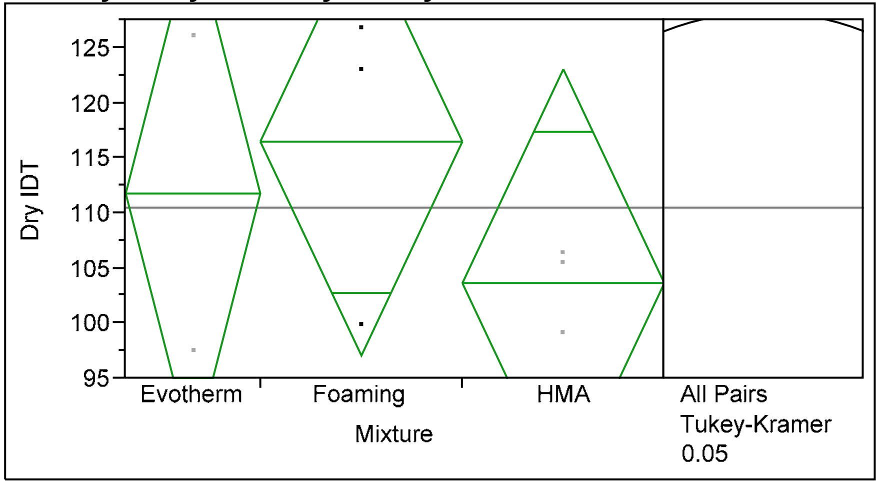
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Foaming	36.83333	5.532731	19.8581	53.80858	0.0014*
HMA	Evotherm	24.90000	5.532731	7.9248	41.87524	0.0098*
Evotherm	Foaming	11.93333	5.532731	-5.0419	28.90858	0.1581

LMLC no LTOA – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
124

Oneway Anova

Summary of Fit

Rsquare	0.227455
Adj Rsquare	-0.08156
Root Mean Square Error	13.06971
Mean of Response	110.5125
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	251.4621	125.731	0.7361	0.5246
Error	5	854.0867	170.817		
C. Total	7	1105.5488			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	2	111.800	9.2417	88.044	135.56
Foaming	3	116.500	7.5458	97.103	135.90

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	103.667	7.5458	84.270	123.06

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming	Evotherm	HMA
Foaming	-34.723	-34.122	-21.890
Evotherm	-34.122	-42.527	-30.688
HMA	-21.890	-30.688	-34.723

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming	A	116.50000
Evotherm	A	111.80000
HMA	A	103.66667

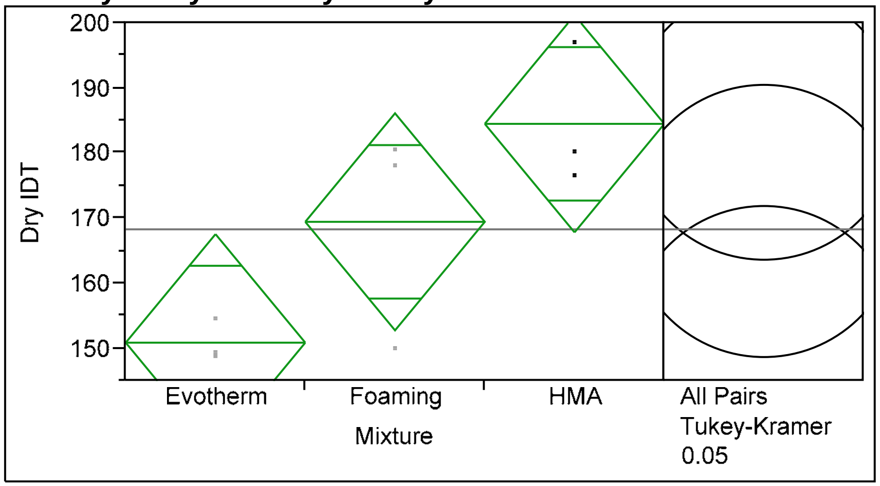
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming	HMA	12.83333	10.67137	-21.8899	47.55652	0.5015
Evotherm	HMA	8.13333	11.93096	-30.6884	46.95504	0.7838
Foaming	Evotherm	4.70000	11.93096	-34.1217	43.52171	0.9193

LMLC 2W@60C – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.67047
Adj Rsquare	0.560627
Root Mean Square Error	11.81082
Mean of Response	168.3
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	1702.9267	851.463	6.1039	0.0358*
Error	6	836.9733	139.496		
C. Total	8	2539.9000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	150.900	6.8190	134.21	167.59
Foaming	3	169.467	6.8190	152.78	186.15

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	184.533	6.8190	167.85	201.22

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-29.588	-14.521	4.046
Foaming	-14.521	-29.588	-11.021
Evotherm	4.046	-11.021	-29.588

Positive values show pairs of means that are significantly different.

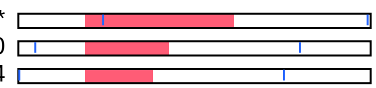
Connecting Letters Report

Level			Mean
HMA	A		184.53333
Foaming	A	B	169.46667
Evotherm		B	150.90000

Levels not connected by same letter are significantly different.

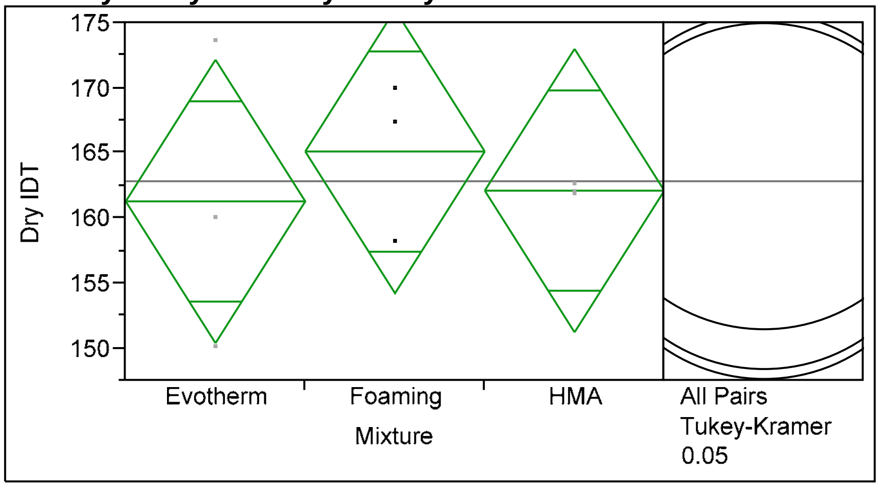
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	33.63333	9.643497	4.0456	63.22102	0.0301*
Foaming	Evotherm	18.56667	9.643497	-11.0210	48.15436	0.2120
HMA	Foaming	15.06667	9.643497	-14.5210	44.65436	0.3304



LMLC 5D@85C – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.064036
Adj Rsquare	-0.24795
Root Mean Square Error	7.707932
Mean of Response	162.8556
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	24.38889	12.1944	0.2053	0.8199
Error	6	356.47333	59.4122		
C. Total	8	380.86222			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	161.300	4.4502	150.41	172.19
Foaming	3	165.133	4.4502	154.24	176.02

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	162.133	4.4502	151.24	173.02

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming	HMA	Evotherm
Foaming	-19.309	-16.309	-15.476
HMA	-16.309	-19.309	-18.476
Evotherm	-15.476	-18.476	-19.309

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming	A	165.13333
HMA	A	162.13333
Evotherm	A	161.30000

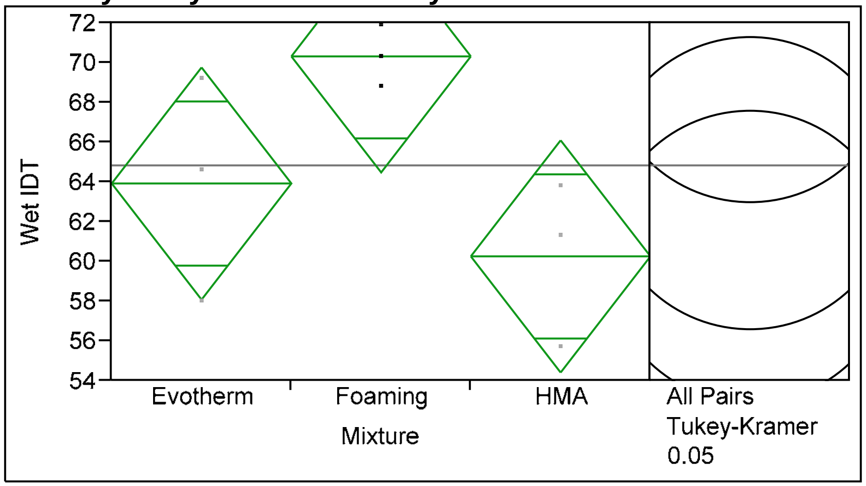
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming	Evotherm	3.833333	6.293500	-15.4761	23.14273	0.8206
Foaming	HMA	3.000000	6.293500	-16.3094	22.30940	0.8846
HMA	Evotherm	0.833333	6.293500	-18.4761	20.14273	0.9904

PMFC cores at construction – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.602852
Adj Rsquare	0.47047
Root Mean Square Error	4.135215
Mean of Response	64.84444
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	155.74222	77.8711	4.5539	0.0626
Error	6	102.60000	17.1000		
C. Total	8	258.34222			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	63.9333	2.3875	58.091	69.775
Foaming	3	70.3333	2.3875	64.491	76.175

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	60.2667	2.3875	54.425	66.109

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming	Evotherm	HMA
Foaming	-10.359	-3.959	-0.293
Evotherm	-3.959	-10.359	-6.693
HMA	-0.293	-6.693	-10.359

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming	A	70.333333
Evotherm	A	63.933333
HMA	A	60.266667

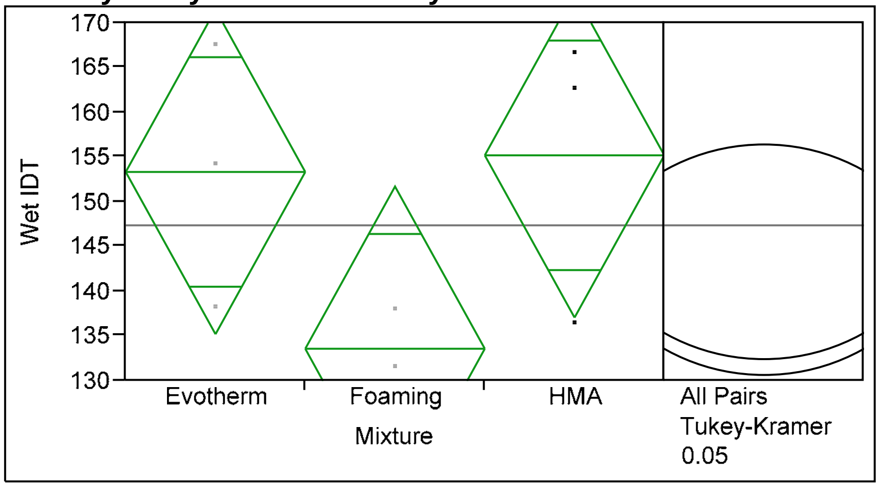
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming	HMA	10.06667	3.376389	-0.29260	20.42593	0.0557
Foaming	Evotherm	6.40000	3.376389	-3.95926	16.75926	0.2200
Evotherm	HMA	3.66667	3.376389	-6.69260	14.02593	0.5559

PMFC cores after summer at 8 months – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.465559
Adj Rsquare	0.287413
Root Mean Square Error	12.84376
Mean of Response	147.4
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	862.2067	431.103	2.6133	0.1527
Error	6	989.7733	164.962		
C. Total	8	1851.9800			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	153.367	7.4153	135.22	171.51
Foaming	3	133.600	7.4153	115.46	151.74

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	155.233	7.4153	137.09	173.38

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Foaming
HMA	-32.175	-30.309	-10.542
Evotherm	-30.309	-32.175	-12.409
Foaming	-10.542	-12.409	-32.175

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	155.23333
Evotherm	A	153.36667
Foaming	A	133.60000

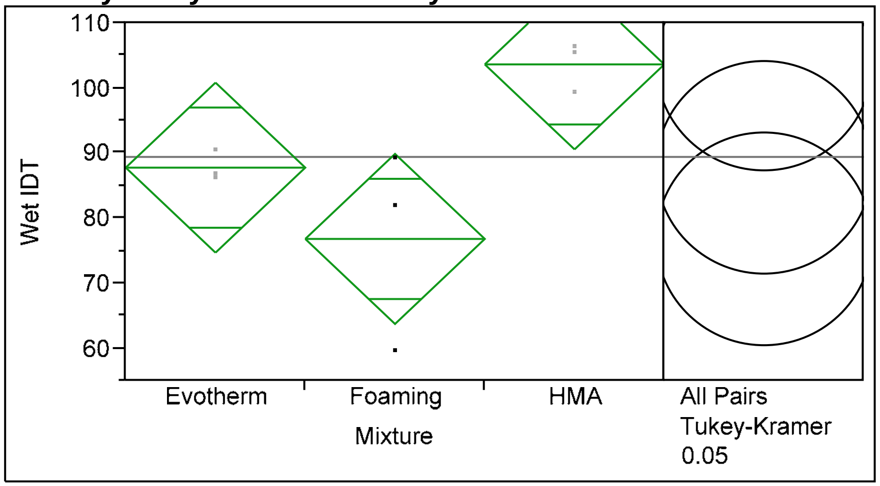
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Foaming	21.63333	10.48689	-10.5420	53.80867	0.1782
Evotherm	Foaming	19.76667	10.48689	-12.4087	51.94200	0.2230
HMA	Evotherm	1.86667	10.48689	-30.3087	34.04200	0.9827

LMLC no LTOA – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.680149
Adj Rsquare	0.573532
Root Mean Square Error	9.251606
Mean of Response	89.43333
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	1092.0467	546.023	6.3794	0.0327*
Error	6	513.5533	85.592		
C. Total	8	1605.6000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	87.800	5.3414	74.730	100.87
Foaming	3	76.833	5.3414	63.763	89.90

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	103.667	5.3414	90.597	116.74

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Foaming
HMA	-23.177	-7.310	3.657
Evotherm	-7.310	-23.177	-12.210
Foaming	3.657	-12.210	-23.177

Positive values show pairs of means that are significantly different.

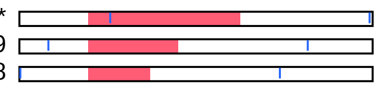
Connecting Letters Report

Level			Mean
HMA	A		103.66667
Evotherm	A	B	87.80000
Foaming		B	76.83333

Levels not connected by same letter are significantly different.

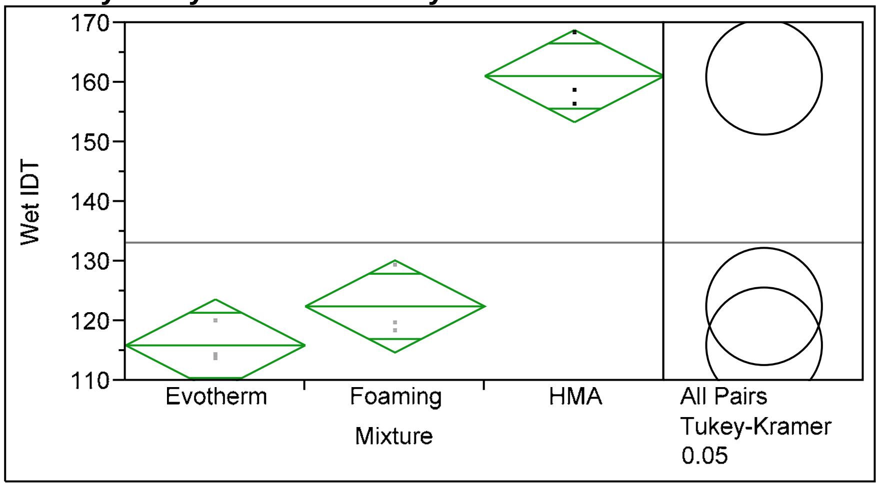
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Foaming	26.83333	7.553905	3.6568	50.00984	0.0279*
HMA	Evotherm	15.86667	7.553905	-7.3098	39.04318	0.1699
Evotherm	Foaming	10.96667	7.553905	-12.2098	34.14318	0.3758



LMLC 2W@60C – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



H-350

Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.952145
Adj Rsquare	0.936193
Root Mean Square Error	5.472558
Mean of Response	133.2
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	3575.2467	1787.62	59.6891	0.0001*
Error	6	179.6933	29.95		
C. Total	8	3754.9400			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	115.967	3.1596	108.24	123.70
Foaming	3	122.500	3.1596	114.77	130.23

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	161.133	3.1596	153.40	168.86

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-13.709	24.924	31.457
Foaming	24.924	-13.709	-7.176
Evotherm	31.457	-7.176	-13.709

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		161.13333
Foaming		B	122.50000
Evotherm		B	115.96667

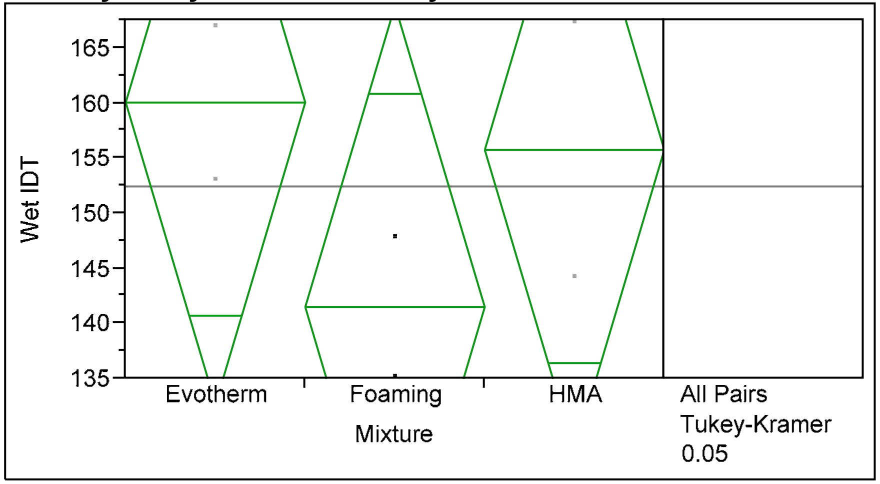
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	45.16667	4.468325	31.4572	58.87615	0.0001*
HMA	Foaming	38.63333	4.468325	24.9238	52.34282	0.0003*
Foaming	Evotherm	6.53333	4.468325	-7.1762	20.24282	0.3714

LMLC 16W@60C – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
132

Oneway Anova

Summary of Fit

Rsquare	0.459942
Adj Rsquare	0.099903
Root Mean Square Error	12.14894
Mean of Response	152.4333
Observations (or Sum Wgts)	6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	377.10333	188.552	1.2775	0.3969
Error	3	442.79000	147.597		
C. Total	5	819.89333			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	2	160.050	8.5906	132.71	187.39
Foaming	2	141.500	8.5906	114.16	168.84

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	2	155.750	8.5906	128.41	183.09

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
4.17871	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm	HMA	Foaming
Evotherm	-50.767	-46.467	-32.217
HMA	-46.467	-50.767	-36.517
Foaming	-32.217	-36.517	-50.767

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm	A	160.05000
HMA	A	155.75000
Foaming	A	141.50000

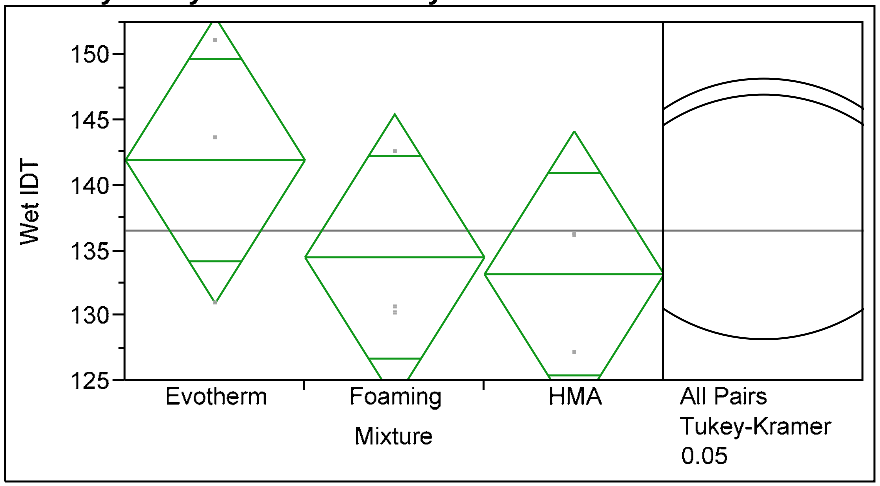
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm	Foaming	18.55000	12.14894	-32.2169	69.31690	0.3964
HMA	Foaming	14.25000	12.14894	-36.5169	65.01690	0.5421
Evotherm	HMA	4.30000	12.14894	-46.4669	55.06690	0.9347

LMLC 5D@85C – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.270113
Adj Rsquare	0.026818
Root Mean Square Error	7.77696
Mean of Response	136.5556
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	134.29556	67.1478	1.1102	0.3888
Error	6	362.88667	60.4811		
C. Total	8	497.18222			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	141.967	4.4900	130.98	152.95
Foaming	3	134.500	4.4900	123.51	145.49
HMA	3	133.200	4.4900	122.21	144.19

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	**Evotherm**	**Foaming**	**HMA**
Evotherm	-19.482	-12.016	-10.716
Foaming	-12.016	-19.482	-18.182
HMA	-10.716	-18.182	-19.482

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm	A	141.96667
Foaming	A	134.50000
HMA	A	133.20000

Levels not connected by same letter are significantly different.

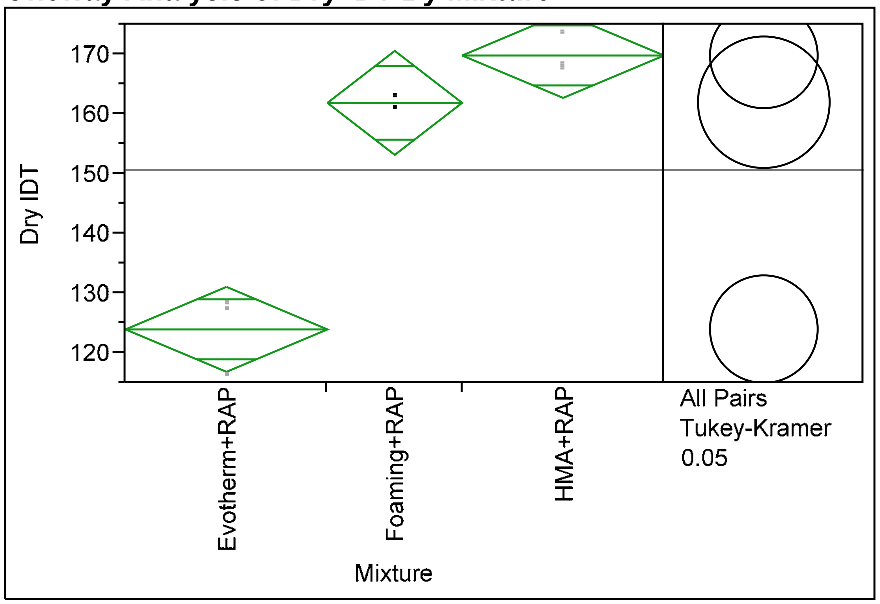
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm	HMA	8.766667	6.349861	-10.7157	28.24899	0.4074
Evotherm	Foaming	7.466667	6.349861	-12.0157	26.94899	0.5079
Foaming	HMA	1.300000	6.349861	-18.1823	20.78232	0.9772

Table C.19

PMFC cores at construction – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
124

Oneway Anova

Summary of Fit

Rsquare	0.968199
Adj Rsquare	0.955479
Root Mean Square Error	4.790268
Mean of Response	150.65
Observations (or Sum Wgts)	8

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**	**Prob > F**
Mixture	2	3493.1267	1746.56	76.1140	0.0002*

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Error	5	114.7333	22.95		
C. Total	7	3607.8600			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	123.967	2.7657	116.86	131.08
Foaming+RAP	2	161.900	3.3872	153.19	170.61
HMA+RAP	3	169.833	2.7657	162.72	176.94

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA+RAP	Foaming+RAP	Evotherm+RAP
HMA+RAP	-12.727	-6.295	33.140
Foaming+RAP	-6.295	-15.587	23.705
Evotherm+RAP	33.140	23.705	-12.727

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA+RAP	A		169.83333
Foaming+RAP	A		161.90000
Evotherm+RAP		B	123.96667

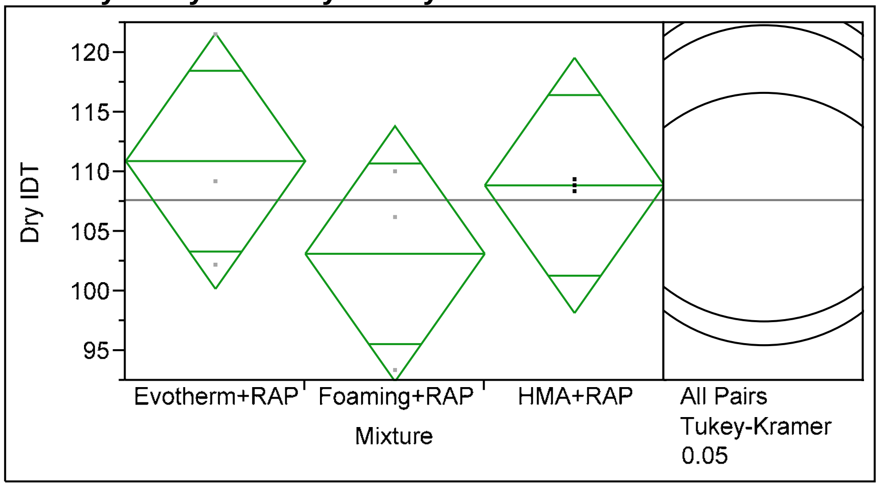
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA+RAP	Evotherm+RAP	45.86667	3.911237	33.1400	58.59330	0.0002*
Foaming+RAP	Evotherm+RAP	37.93333	4.372896	23.7045	52.16214	0.0008*
HMA+RAP	Foaming+RAP	7.93333	4.372896	-6.2955	22.16214	0.2570

LMLC no LTOA – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.220017
Adj Rsquare	-0.03998
Root Mean Square Error	7.583242
Mean of Response	107.6667
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	97.32667	48.6633	0.8462	0.4745
Error	6	345.03333	57.5056		
C. Total	8	442.36000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	110.933	4.3782	100.22	121.65
Foaming+RAP	3	103.167	4.3782	92.45	113.88

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	108.900	4.3782	98.19	119.61

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm+RAP	HMA+RAP	Foaming+RAP
Evotherm+RAP	-18.997	-16.964	-11.230
HMA+RAP	-16.964	-18.997	-13.264
Foaming+RAP	-11.230	-13.264	-18.997

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm+RAP	A	110.93333
HMA+RAP	A	108.90000
Foaming+RAP	A	103.16667

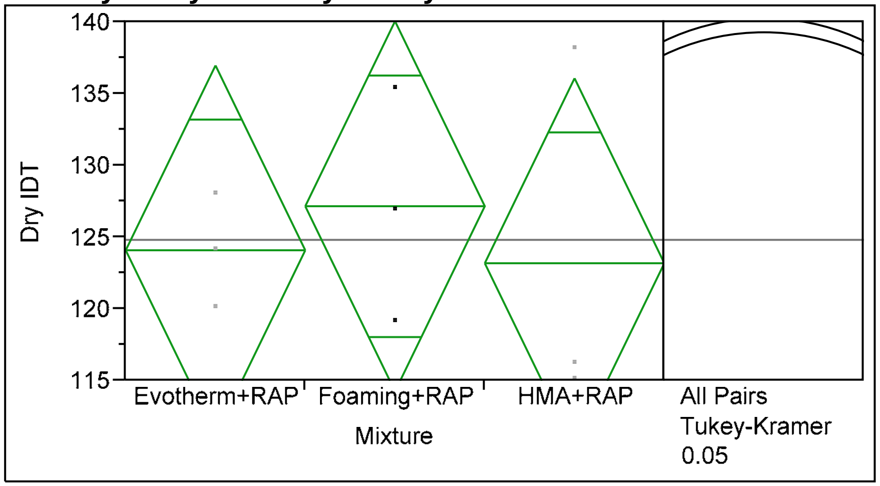
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm+RAP	Foaming+RAP	7.766667	6.191691	-11.2304	26.76370	0.4678
HMA+RAP	Foaming+RAP	5.733333	6.191691	-13.2637	24.73037	0.6452
Evotherm+RAP	HMA+RAP	2.033333	6.191691	-16.9637	21.03037	0.9428

LMLC 2W@60C – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.049361
Adj Rsquare	-0.26752
Root Mean Square Error	9.126396
Mean of Response	124.8222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	25.94889	12.9744	0.1558	0.8591
Error	6	499.74667	83.2911		
C. Total	8	525.69556			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	124.100	5.2691	111.21	136.99
Foaming+RAP	3	127.167	5.2691	114.27	140.06

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	123.200	5.2691	110.31	136.09

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	Evotherm+RAP	HMA+RAP
Foaming+RAP	-22.863	-19.796	-18.896
Evotherm+RAP	-19.796	-22.863	-21.963
HMA+RAP	-18.896	-21.963	-22.863

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming+RAP	A	127.16667
Evotherm+RAP	A	124.10000
HMA+RAP	A	123.20000

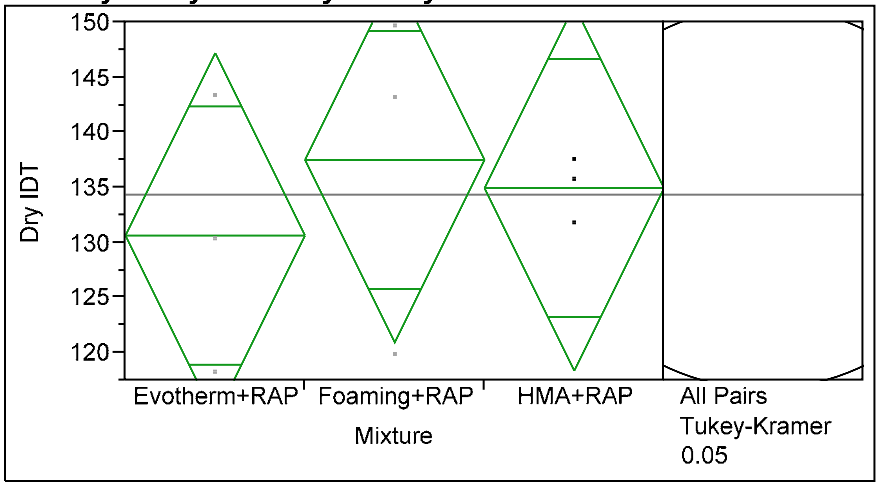
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	HMA+RAP	3.966667	7.451671	-18.8962	26.82951	0.8588
Foaming+RAP	Evotherm+RAP	3.066667	7.451671	-19.7962	25.92951	0.9122
Evotherm+RAP	HMA+RAP	0.900000	7.451671	-21.9628	23.76284	0.9920

LMLC 5D@85C – Dry IDT Strength

Oneway Analysis of Dry IDT By Mixture



Excluded Rows
123

Oneway Anova

Summary of Fit

Rsquare	0.0805
Adj Rsquare	-0.226
Root Mean Square Error	11.72618
Mean of Response	134.3889
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	72.22889	36.114	0.2626	0.7774
Error	6	825.02000	137.503		
C. Total	8	897.24889			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	130.667	6.7701	114.10	147.23
Foaming+RAP	3	137.533	6.7701	120.97	154.10

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	134.967	6.7701	118.40	151.53

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	HMA+RAP	Evotherm+RAP
Foaming+RAP	-29.376	-26.809	-22.509
HMA+RAP	-26.809	-29.376	-25.076
Evotherm+RAP	-22.509	-25.076	-29.376

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming+RAP	A	137.53333
HMA+RAP	A	134.96667
Evotherm+RAP	A	130.66667

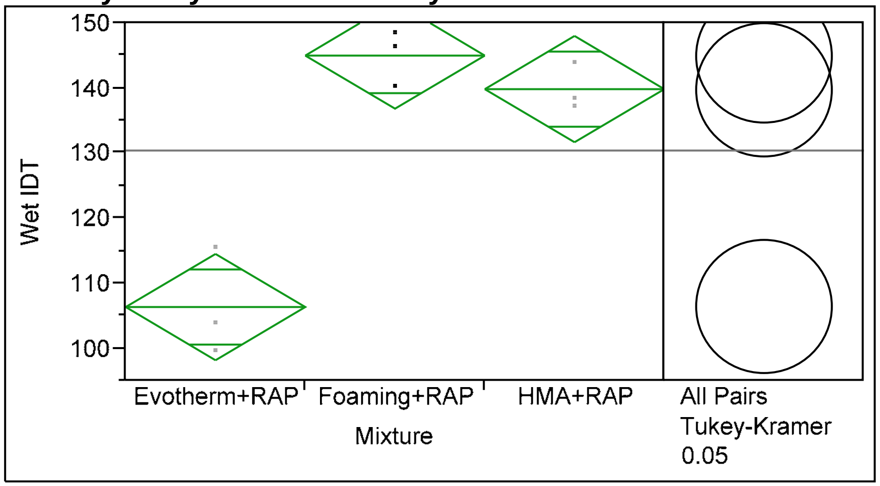
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	Evotherm+RAP	6.866667	9.574387	-22.5090	36.24232	0.7629
HMA+RAP	Evotherm+RAP	4.300000	9.574387	-25.0756	33.67565	0.8966
Foaming+RAP	HMA+RAP	2.566667	9.574387	-26.8090	31.94232	0.9614

PMFC cores at construction – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.929449
Adj Rsquare	0.905932
Root Mean Square Error	5.783597
Mean of Response	130.4222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	2644.0556	1322.03	39.5225	0.0004*
Error	6	200.7000	33.45		
C. Total	8	2844.7556			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	106.367	3.3392	98.20	114.54
Foaming+RAP	3	145.033	3.3392	136.86	153.20

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	139.867	3.3392	131.70	148.04

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	HMA+RAP	Evotherm+RAP
Foaming+RAP	-14.489	-9.322	24.178
HMA+RAP	-9.322	-14.489	19.011
Evotherm+RAP	24.178	19.011	-14.489

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Foaming+RAP	A		145.03333
HMA+RAP	A		139.86667
Evotherm+RAP		B	106.36667

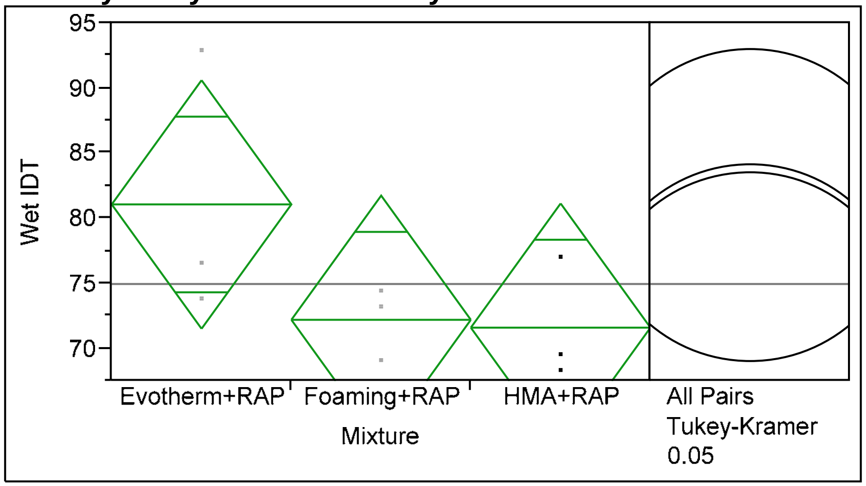
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	Evotherm+RAP	38.66667	4.722288	24.1780	53.15535	0.0004*
HMA+RAP	Evotherm+RAP	33.50000	4.722288	19.0113	47.98868	0.0010*
Foaming+RAP	HMA+RAP	5.16667	4.722288	-9.3220	19.65535	0.5515

LMLC no LTOA – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
129

Oneway Anova

Summary of Fit

Rsquare	0.38073
Adj Rsquare	0.174306
Root Mean Square Error	6.760506
Mean of Response	74.95556
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	168.59556	84.2978	1.8444	0.2375
Error	6	274.22667	45.7044		
C. Total	8	442.82222			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	81.0667	3.9032	71.516	90.617
Foaming+RAP	3	72.2000	3.9032	62.649	81.751

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	71.6000	3.9032	62.049	81.151

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm+RAP	Foaming+RAP	HMA+RAP
Evotherm+RAP	-16.936	-8.069	-7.469
Foaming+RAP	-8.069	-16.936	-16.336
HMA+RAP	-7.469	-16.336	-16.936

Positive values show pairs of means that are significantly different.

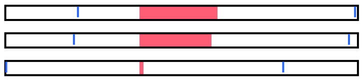
Connecting Letters Report

Level		Mean
Evotherm+RAP	A	81.066667
Foaming+RAP	A	72.200000
HMA+RAP	A	71.600000

Levels not connected by same letter are significantly different.

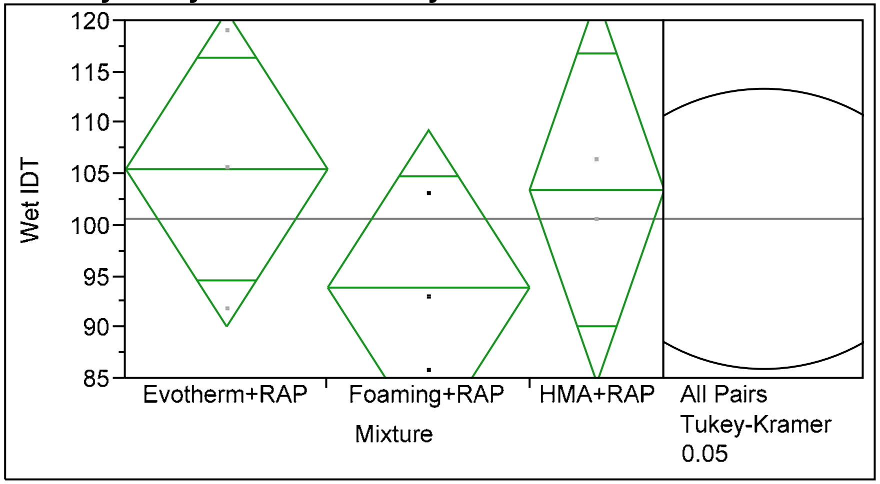
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm+RAP	HMA+RAP	9.466667	5.519930	-7.4693	26.40264	0.2750
Evotherm+RAP	Foaming+RAP	8.866667	5.519930	-8.0693	25.80264	0.3136
Foaming+RAP	HMA+RAP	0.600000	5.519930	-16.3360	17.53597	0.9935



LMLC 2W@60C – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



H-368

Excluded Rows
130

Oneway Anova

Summary of Fit

Rsquare	0.292866
Adj Rsquare	0.010013
Root Mean Square Error	10.38011
Mean of Response	100.675
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	223.12167	111.561	1.0354	0.4205
Error	5	538.73333	107.747		
C. Total	7	761.85500			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	105.533	5.9930	90.128	120.94
Foaming+RAP	3	93.933	5.9930	78.528	109.34

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	2	103.500	7.3398	84.632	122.37

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm+RAP	HMA+RAP	Foaming+RAP
Evotherm+RAP	-27.578	-28.799	-15.978
HMA+RAP	-28.799	-33.775	-21.266
Foaming+RAP	-15.978	-21.266	-27.578

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm+RAP	A	105.53333
HMA+RAP	A	103.50000
Foaming+RAP	A	93.93333

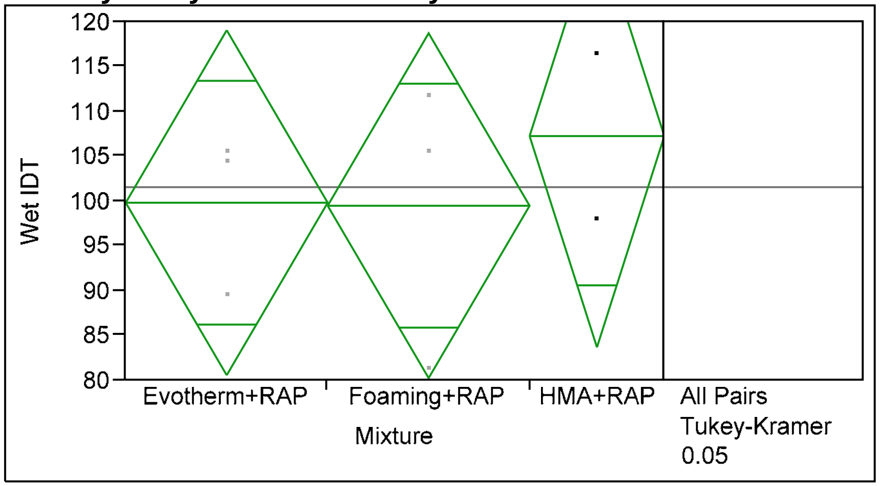
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm+RAP	Foaming+RAP	11.60000	8.475324	-15.9775	39.17754	0.4224
HMA+RAP	Foaming+RAP	9.56667	9.475700	-21.2660	40.39930	0.6030
Evotherm+RAP	HMA+RAP	2.03333	9.475700	-28.7993	32.86596	0.9751

LMLC 5D@85C – Wet IDT Strength

Oneway Analysis of Wet IDT By Mixture



Excluded Rows
130

Oneway Anova

Summary of Fit

Rsquare	0.093628
Adj Rsquare	-0.26892
Root Mean Square Error	12.96405
Mean of Response	101.6
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	86.80667	43.403	0.2583	0.7821
Error	5	840.33333	168.067		
C. Total	7	927.14000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	99.867	7.4848	80.626	119.11
Foaming+RAP	3	99.533	7.4848	80.293	118.77

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	2	107.300	9.1670	83.736	130.86

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA+RAP	Evotherm+RAP	Foaming+RAP
HMA+RAP	-42.183	-31.075	-30.741
Evotherm+RAP	-31.075	-34.442	-34.109
Foaming+RAP	-30.741	-34.109	-34.442

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA+RAP	A	107.30000
Evotherm+RAP	A	99.86667
Foaming+RAP	A	99.53333

Levels not connected by same letter are significantly different.

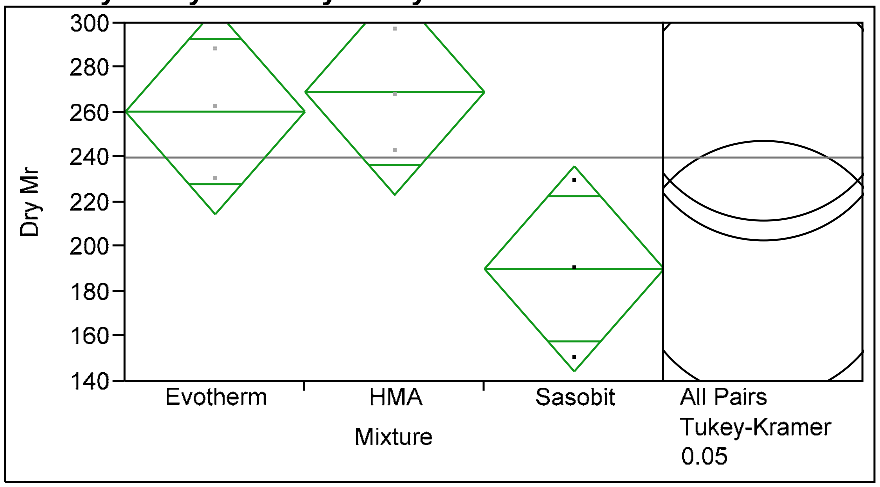
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA+RAP	Foaming+RAP	7.766667	11.83451	-30.7412	46.27453	0.7972
HMA+RAP	Evotherm+RAP	7.433333	11.83451	-31.0745	45.94120	0.8119
Evotherm+RAP	Foaming+RAP	0.333333	10.58510	-34.1091	34.77581	0.9995

Table C.20

PMFC cores at construction – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.640124
Adj Rsquare	0.520165
Root Mean Square Error	32.4596
Mean of Response	240.1333
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	11244.727	5622.36	5.3362	0.0466*
Error	6	6321.753	1053.63		
C. Total	8	17566.480			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	260.633	18.741	214.78	306.49
HMA	3	269.367	18.741	223.51	315.22
Sasobit	3	190.400	18.741	144.54	236.26

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Sasobit
HMA	-81.316	-72.582	-2.349
Evotherm	-72.582	-81.316	-11.082
Sasobit	-2.349	-11.082	-81.316

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	269.36667
Evotherm	A	260.63333
Sasobit	A	190.40000

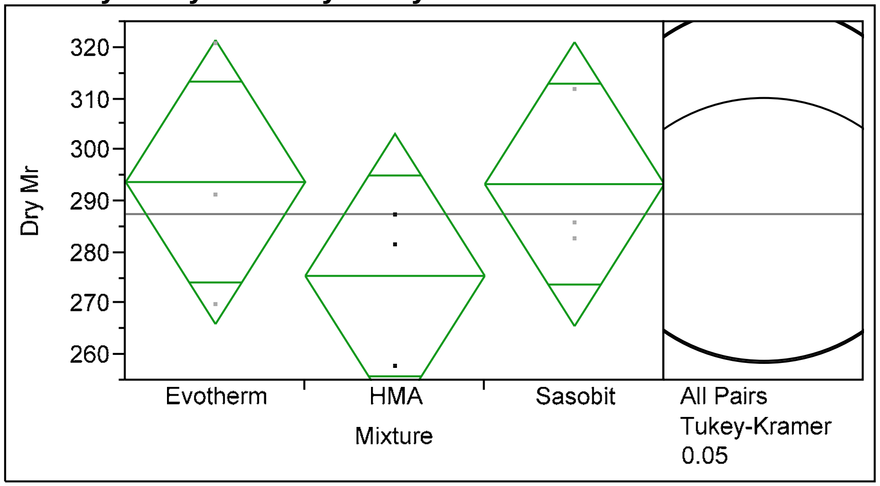
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Sasobit	78.96667	26.50315	-2.3490	160.2823	0.0558
Evotherm	Sasobit	70.23333	26.50315	-11.0823	151.5490	0.0844
HMA	Evotherm	8.73333	26.50315	-72.5823	90.0490	0.9425

PMFC cores after winter at 6 months – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.221386
Adj Rsquare	-0.03815
Root Mean Square Error	19.63732
Mean of Response	287.5556
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	657.8756	328.938	0.8530	0.4720
Error	6	2313.7467	385.624		
C. Total	8	2971.6222			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	293.800	11.338	266.06	321.54
HMA	3	275.467	11.338	247.72	303.21

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	293.400	11.338	265.66	321.14

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm	Sasobit	HMA
Evotherm	-49.194	-48.794	-30.861
Sasobit	-48.794	-49.194	-31.261
HMA	-30.861	-31.261	-49.194

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm	A	293.80000
Sasobit	A	293.40000
HMA	A	275.46667

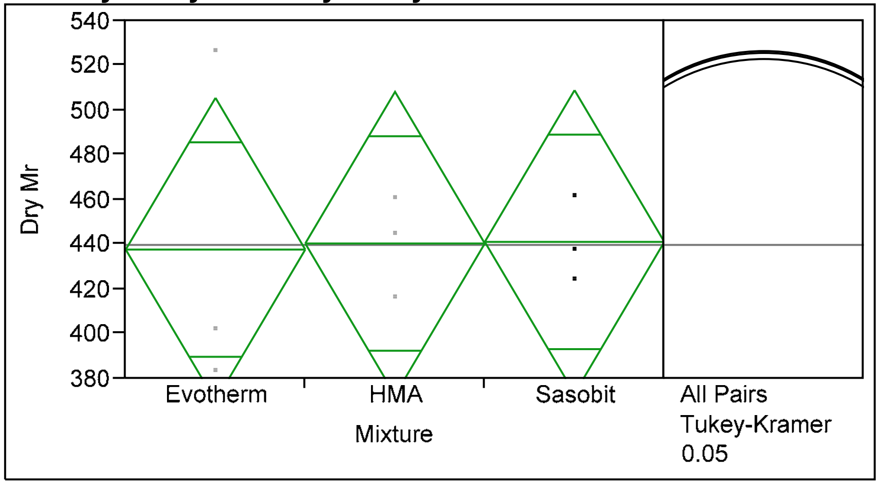
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm	HMA	18.33333	16.03381	-30.8608	67.52745	0.5250
Sasobit	HMA	17.93333	16.03381	-31.2608	67.12745	0.5384
Evotherm	Sasobit	0.40000	16.03381	-48.7941	49.59411	0.9997

PMFC cores after summer at 12 months – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.001426
Adj Rsquare	-0.33143
Root Mean Square Error	48.00734
Mean of Response	439.9222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	19.749	9.87	0.0043	0.9957
Error	6	13828.227	2304.70		
C. Total	8	13847.976			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	437.867	27.717	370.05	505.69
HMA	3	440.600	27.717	372.78	508.42

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	441.300	27.717	373.48	509.12

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Sasobit	HMA	Evotherm
Sasobit	-120.26	-119.56	-116.83
HMA	-119.56	-120.26	-117.53
Evotherm	-116.83	-117.53	-120.26

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Sasobit	A	441.30000
HMA	A	440.60000
Evotherm	A	437.86667

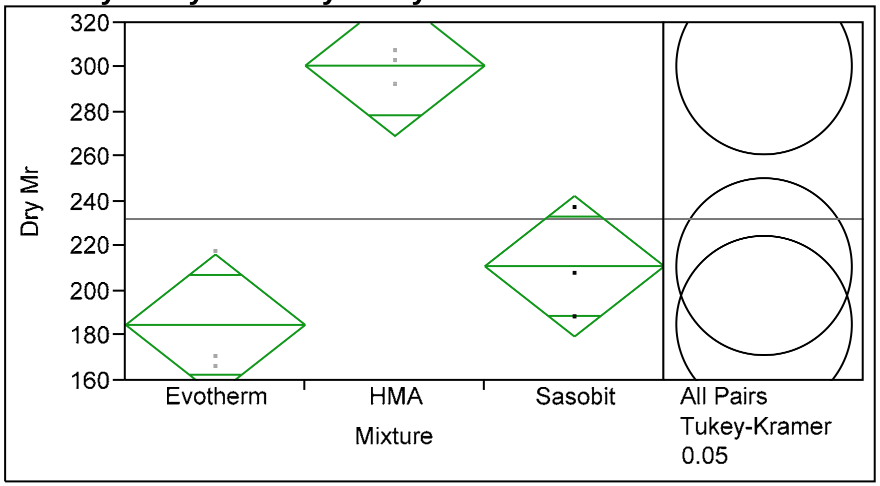
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Sasobit	Evotherm	3.433333	39.19783	-116.831	123.6981	0.9958
HMA	Evotherm	2.733333	39.19783	-117.531	122.9981	0.9973
Sasobit	HMA	0.700000	39.19783	-119.565	120.9648	0.9998

LMLC no LTOA – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.881635
Adj Rsquare	0.842179
Root Mean Square Error	22.27737
Mean of Response	232.4778
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	22179.049	11089.5	22.3452	0.0017*
Error	6	2977.687	496.3		
C. Total	8	25156.736			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	185.100	12.862	153.63	216.57
HMA	3	301.033	12.862	269.56	332.51

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	211.300	12.862	179.83	242.77

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-55.808	33.926	60.126
Sasobit	33.926	-55.808	-29.608
Evotherm	60.126	-29.608	-55.808

Positive values show pairs of means that are significantly different.

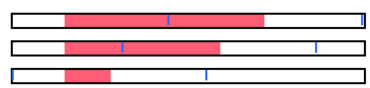
Connecting Letters Report

Level			Mean
HMA	A		301.03333
Sasobit		B	211.30000
Evotherm		B	185.10000

Levels not connected by same letter are significantly different.

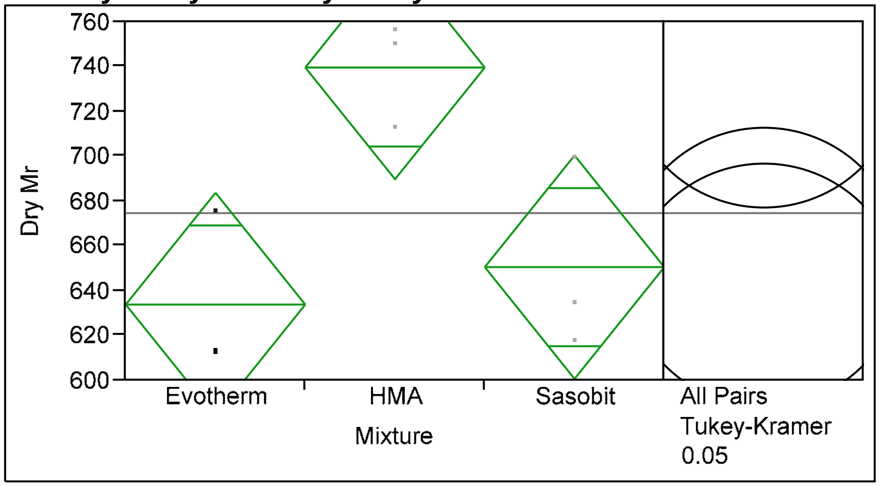
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	115.9333	18.18939	60.1256	171.7411	0.0017*
HMA	Sasobit	89.7333	18.18939	33.9256	145.5411	0.0063*
Sasobit	Evotherm	26.2000	18.18939	-29.6078	82.0078	0.3807



LMLC 16W@60C – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.721829
Adj Rsquare	0.629105
Root Mean Square Error	35.31386
Mean of Response	674.8556
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	19416.169	9708.08	7.7847	0.0215*
Error	6	7482.413	1247.07		
C. Total	8	26898.582			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	634.033	20.388	584.14	683.92
HMA	3	739.833	20.388	689.94	789.72

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	650.700	20.388	600.81	700.59

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-88.466	0.667	17.334
Sasobit	0.667	-88.466	-71.799
Evotherm	17.334	-71.799	-88.466

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		739.83333
Sasobit		B	650.70000
Evotherm		B	634.03333

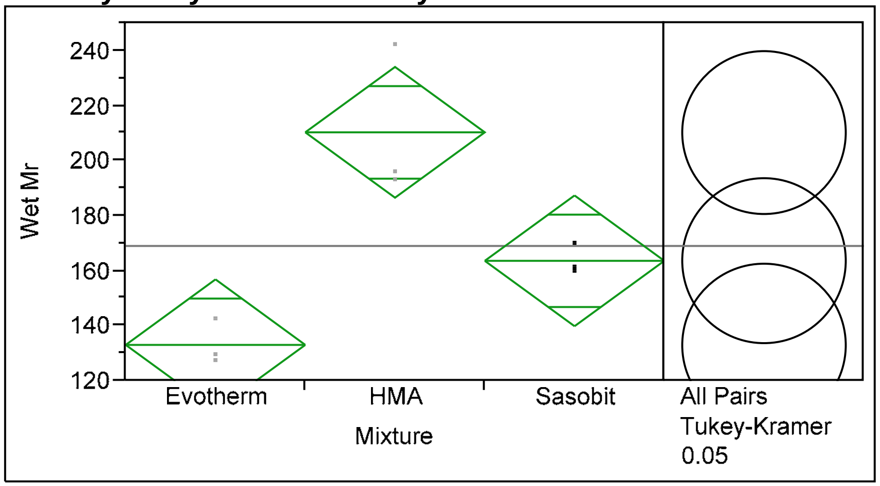
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	105.8000	28.83365	17.3341	194.2659	0.0244*
HMA	Sasobit	89.1333	28.83365	0.6674	177.5993	0.0486*
Sasobit	Evotherm	16.6667	28.83365	-71.7993	105.1326	0.8364

LMLC no LTOA – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
74

Oneway Anova

Summary of Fit

Rsquare	0.842386
Adj Rsquare	0.789848
Root Mean Square Error	16.81775
Mean of Response	169.0444
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	9069.902	4534.95	16.0338	0.0039*
Error	6	1697.020	282.84		
C. Total	8	10766.922			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	133.133	9.7097	109.37	156.89
HMA	3	210.333	9.7097	186.57	234.09

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	3	163.667	9.7097	139.91	187.43

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-42.131	4.536	35.069
Sasobit	4.536	-42.131	-11.597
Evotherm	35.069	-11.597	-42.131

Positive values show pairs of means that are significantly different.

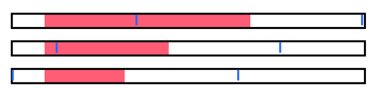
Connecting Letters Report

Level			Mean
HMA	A		210.33333
Sasobit		B	163.66667
Evotherm		B	133.13333

Levels not connected by same letter are significantly different.

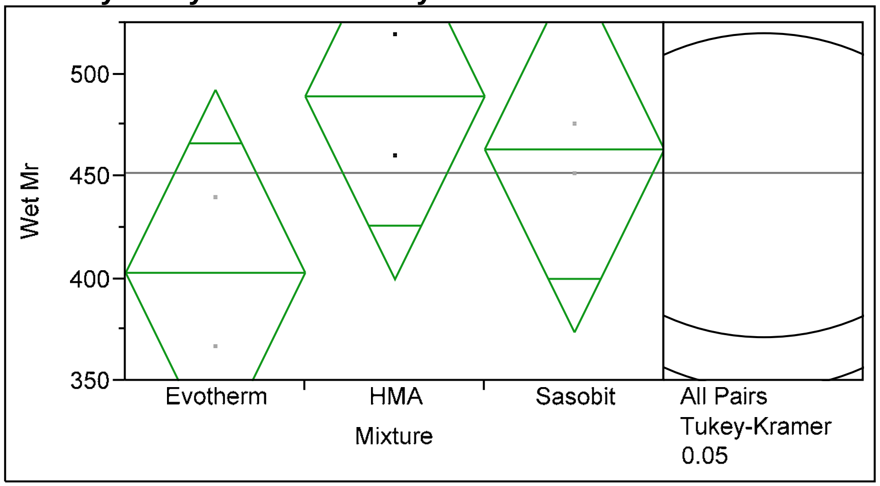
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	77.20000	13.73163	35.0693	119.3307	0.0033*
HMA	Sasobit	46.66667	13.73163	4.5360	88.7974	0.0335*
Sasobit	Evotherm	30.53333	13.73163	-11.5974	72.6640	0.1453



LMLC 16W@60C – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
77

Oneway Anova

Summary of Fit

Rsquare	0.623029
Adj Rsquare	0.371715
Root Mean Square Error	39.78907
Mean of Response	451.8
Observations (or Sum Wgts)	6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	7849.630	3924.82	2.4791	0.2315
Error	3	4749.510	1583.17		
C. Total	5	12599.140			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	2	402.900	28.135	313.36	492.44
HMA	2	489.250	28.135	399.71	578.79

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Sasobit	2	463.250	28.135	373.71	552.79

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
4.17871	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Sasobit	Evotherm
HMA	-166.27	-140.27	-79.92
Sasobit	-140.27	-166.27	-105.92
Evotherm	-79.92	-105.92	-166.27

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	489.25000
Sasobit	A	463.25000
Evotherm	A	402.90000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	86.35000	39.78907	-79.917	252.6170	0.2228
Sasobit	Evotherm	60.35000	39.78907	-105.917	226.6170	0.4000
HMA	Sasobit	26.00000	39.78907	-140.267	192.2670	0.8038

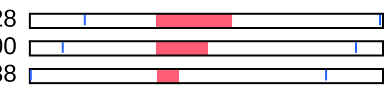
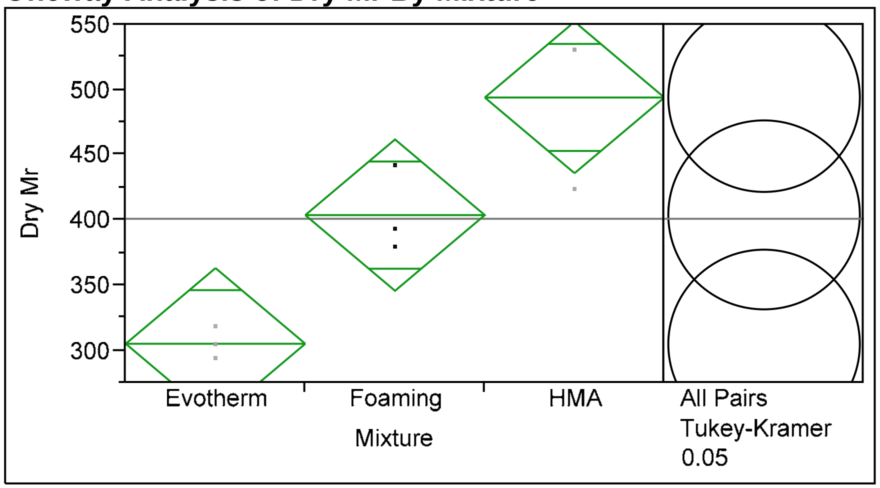


Table C.21

PMFC cores at construction – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.840794
Adj Rsquare	0.787726
Root Mean Square Error	41.16377
Mean of Response	401.0667
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	53692.407	26846.2	15.8436	0.0040*
Error	6	10166.733	1694.5		
C. Total	8	63859.140			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	305.100	23.766	246.95	363.25
Foaming	3	403.867	23.766	345.71	462.02
HMA	3	494.233	23.766	436.08	552.39

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-103.12	-12.75	86.01
Foaming	-12.75	-103.12	-4.35
Evotherm	86.01	-4.35	-103.12

Positive values show pairs of means that are significantly different.

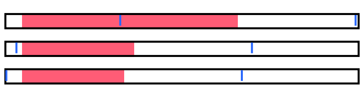
Connecting Letters Report

Level			Mean
HMA	A		494.23333
Foaming	A	B	403.86667
Evotherm		B	305.10000

Levels not connected by same letter are significantly different.

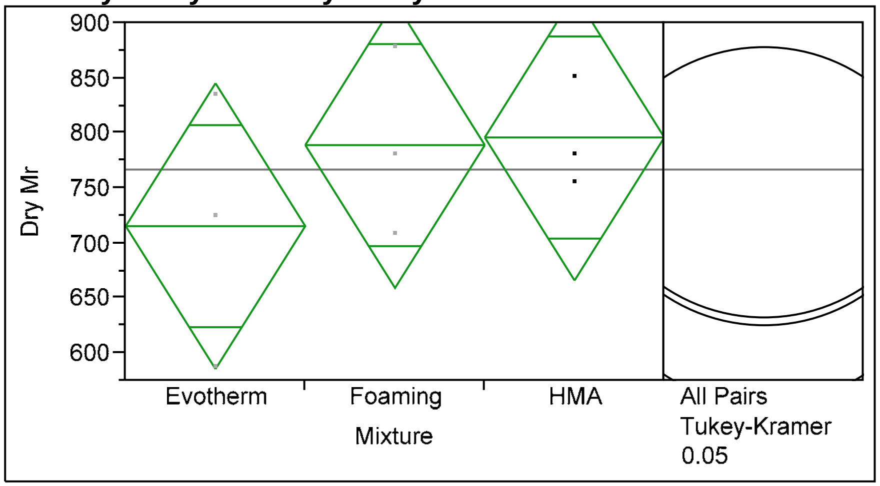
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	189.1333	33.61007	86.0126	292.2541	0.0033*
Foaming	Evotherm	98.7667	33.61007	-4.3541	201.8874	0.0587
HMA	Foaming	90.3667	33.61007	-12.7541	193.4874	0.0803



PMFC cores after winter at 6 months – Dry M_R

Oneway Analysis of Dry Mr By Mixture



H-388

Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.190765
Adj Rsquare	-0.07898
Root Mean Square Error	91.91967
Mean of Response	767.0444
Observations (or Sum Wgts)	9

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**	**Prob > F**
Mixture	2	11950.649	5975.32	0.7072	0.5299
Error	6	50695.353	8449.23		
C. Total	8	62646.002			

Means for Oneway Anova

Level	**Number**	**Mean**	**Std Error**	**Lower 95%**	**Upper 95%**
Evotherm	3	715.667	53.070	585.81	845.52
Foaming	3	789.267	53.070	659.41	919.12

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	796.200	53.070	666.34	926.06

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-230.27	-223.34	-149.74
Foaming	-223.34	-230.27	-156.67
Evotherm	-149.74	-156.67	-230.27

Positive values show pairs of means that are significantly different.

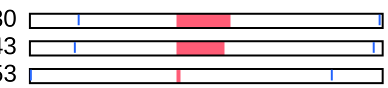
Connecting Letters Report

Level		Mean
HMA	A	796.20000
Foaming	A	789.26667
Evotherm	A	715.66667

Levels not connected by same letter are significantly different.

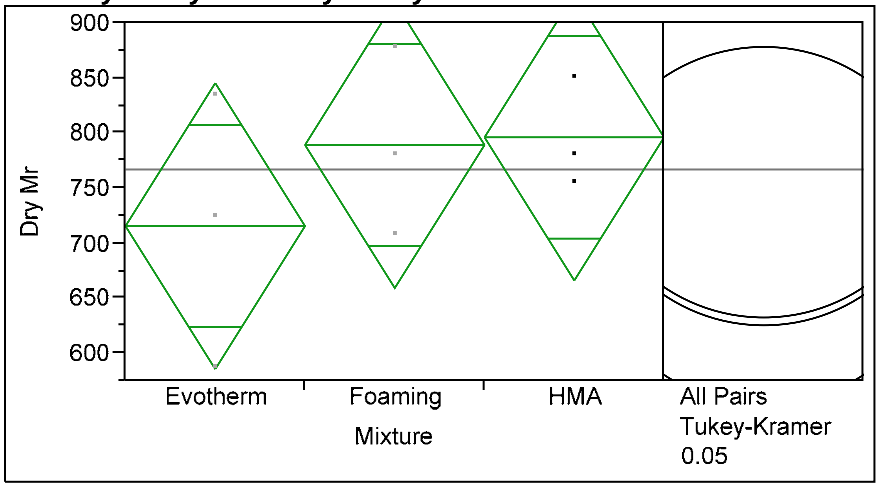
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	80.53333	75.05210	-149.738	310.8044	0.5630
Foaming	Evotherm	73.60000	75.05210	-156.671	303.8710	0.6143
HMA	Foaming	6.93333	75.05210	-223.338	237.2044	0.9953



PMFC cores after summer at 8 months – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.190765
Adj Rsquare	-0.07898
Root Mean Square Error	91.91967
Mean of Response	767.0444
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	11950.649	5975.32	0.7072	0.5299
Error	6	50695.353	8449.23		
C. Total	8	62646.002			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	715.667	53.070	585.81	845.52
Foaming	3	789.267	53.070	659.41	919.12

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	796.200	53.070	666.34	926.06

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-230.27	-223.34	-149.74
Foaming	-223.34	-230.27	-156.67
Evotherm	-149.74	-156.67	-230.27

Positive values show pairs of means that are significantly different.

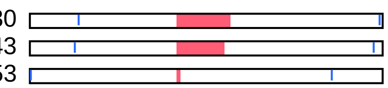
Connecting Letters Report

Level		Mean
HMA	A	796.20000
Foaming	A	789.26667
Evotherm	A	715.66667

Levels not connected by same letter are significantly different.

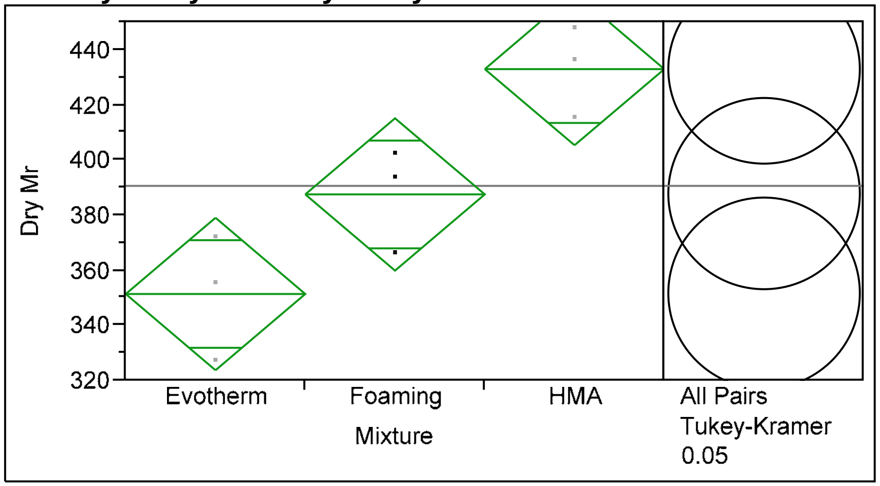
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	80.53333	75.05210	-149.738	310.8044	0.5630
Foaming	Evotherm	73.60000	75.05210	-156.671	303.8710	0.6143
HMA	Foaming	6.93333	75.05210	-223.338	237.2044	0.9953



LMLC no LTOA – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.813698
Adj Rsquare	0.751598
Root Mean Square Error	19.55744
Mean of Response	390.6889
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	10023.549	5011.77	13.1029	0.0065*
Error	6	2294.960	382.49		
C. Total	8	12318.509			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	351.467	11.291	323.84	379.10
Foaming	3	387.567	11.291	359.94	415.20

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	433.033	11.291	405.40	460.66

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-48.994	-3.527	32.573
Foaming	-3.527	-48.994	-12.894
Evotherm	32.573	-12.894	-48.994

Positive values show pairs of means that are significantly different.

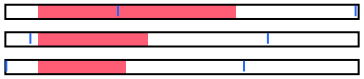
Connecting Letters Report

Level			Mean
HMA	A		433.03333
Foaming	A	B	387.56667
Evotherm		B	351.46667

Levels not connected by same letter are significantly different.

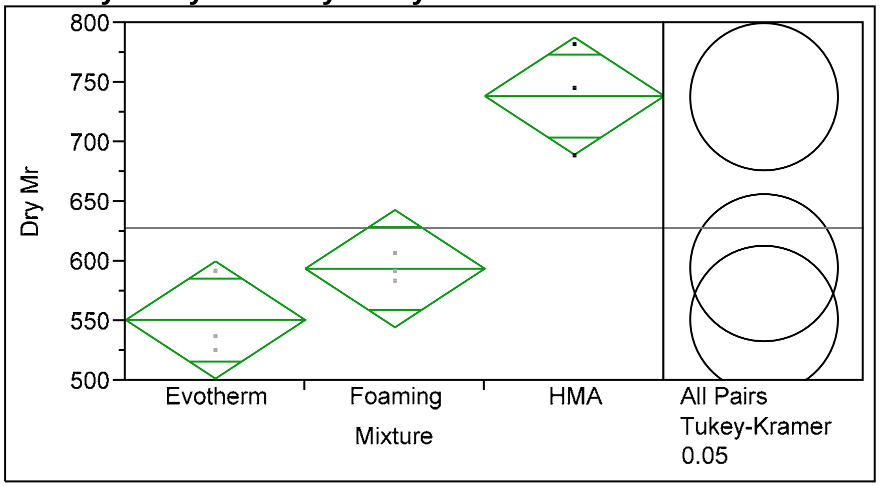
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	81.56667	15.96858	32.5727	130.5607	0.0053*
HMA	Foaming	45.46667	15.96858	-3.5273	94.4607	0.0658
Foaming	Evotherm	36.10000	15.96858	-12.8940	85.0940	0.1385



LMLC 2W@60C – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.8887
Adj Rsquare	0.851601
Root Mean Square Error	34.8136
Mean of Response	628.1
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	58064.540	29032.3	23.9543	0.0014*
Error	6	7271.920	1212.0		
C. Total	8	65336.460			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	551.133	20.100	501.95	600.32
Foaming	3	594.233	20.100	545.05	643.42

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	738.933	20.100	689.75	788.12

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-87.21	57.49	100.59
Foaming	57.49	-87.21	-44.11
Evotherm	100.59	-44.11	-87.21

Positive values show pairs of means that are significantly different.

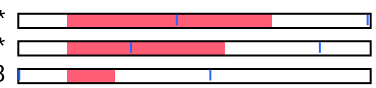
Connecting Letters Report

Level			Mean
HMA	A		738.93333
Foaming		B	594.23333
Evotherm		B	551.13333

Levels not connected by same letter are significantly different.

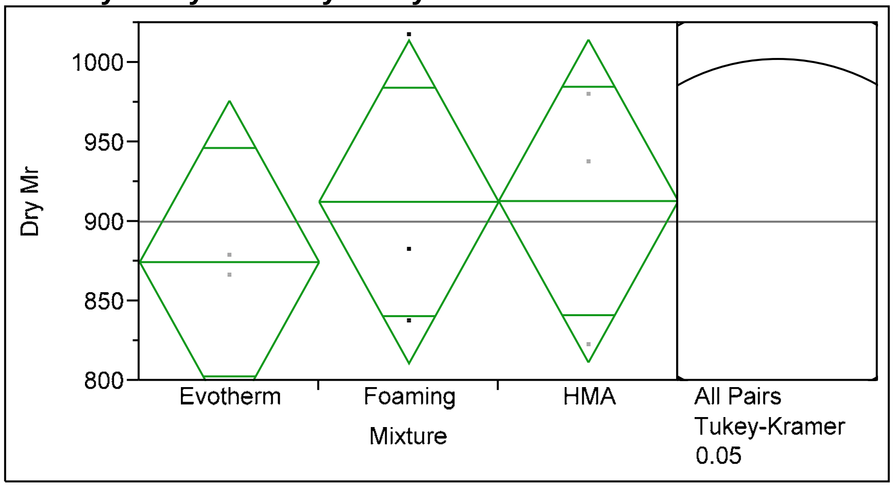
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	187.8000	28.42518	100.587	275.0127	0.0014*
HMA	Foaming	144.7000	28.42518	57.487	231.9127	0.0054*
Foaming	Evotherm	43.1000	28.42518	-44.113	130.3127	0.3488



LMLC 16W@60C – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.085875
Adj Rsquare	-0.21883
Root Mean Square Error	71.89924
Mean of Response	900.1778
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	2913.816	1456.91	0.2818	0.7639
Error	6	31017.000	5169.50		
C. Total	8	33930.816			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	874.733	41.511	773.16	976.3
Foaming	3	912.633	41.511	811.06	1014.2

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	913.167	41.511	811.59	1014.7

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-180.12	-179.58	-141.68
Foaming	-179.58	-180.12	-142.22
Evotherm	-141.68	-142.22	-180.12

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA	A	913.16667
Foaming	A	912.63333
Evotherm	A	874.73333

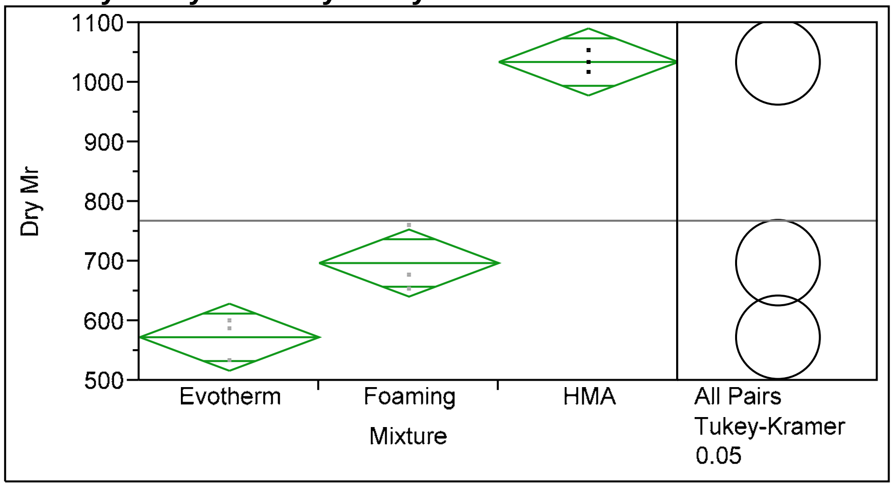
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	38.43333	58.70548	-141.684	218.5505	0.7967
Foaming	Evotherm	37.90000	58.70548	-142.217	218.0172	0.8016
HMA	Foaming	0.53333	58.70548	-179.584	180.6505	1.0000

LMLC 5D@85C – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.97292
Adj Rsquare	0.963893
Root Mean Square Error	39.85035
Mean of Response	768.6667
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	342328.46	171164	107.7826	<.0001*
Error	6	9528.30	1588		
C. Total	8	351856.76			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	573.23	23.008	516.94	629.5
Foaming	3	697.83	23.008	641.54	754.1

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	1034.93	23.008	978.64	1091.2

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-99.83	237.27	361.87
Foaming	237.27	-99.83	24.77
Evotherm	361.87	24.77	-99.83

Positive values show pairs of means that are significantly different.

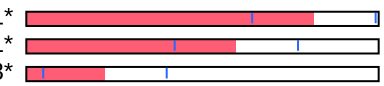
Connecting Letters Report

Level				Mean
HMA	A			1034.9333
Foaming		B		697.8333
Evotherm			C	573.2333

Levels not connected by same letter are significantly different.

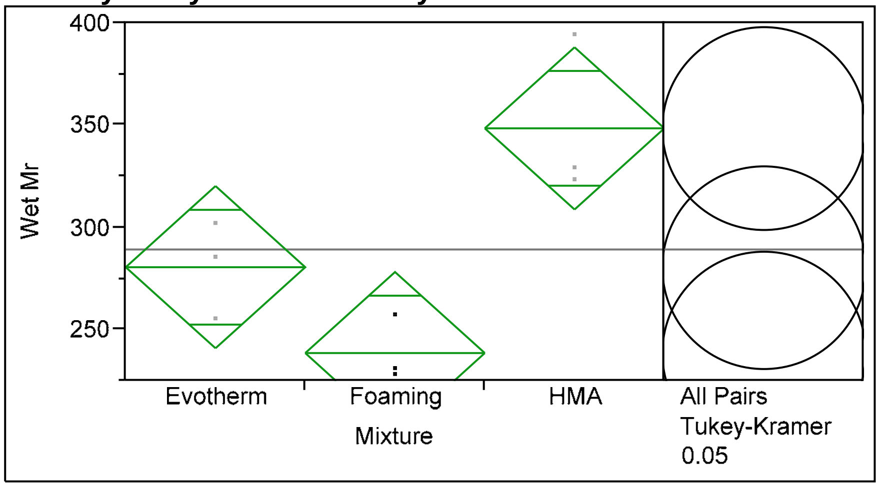
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	461.7000	32.53767	361.8696	561.5304	<.0001*
HMA	Foaming	337.1000	32.53767	237.2696	436.9304	0.0001*
Foaming	Evotherm	124.6000	32.53767	24.7696	224.4304	0.0203*



LMLC no LTOA – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
74

Oneway Anova

Summary of Fit

Rsquare	0.795934
Adj Rsquare	0.727912
Root Mean Square Error	28.08778
Mean of Response	289.2889
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	18462.549	9231.27	11.7011	0.0085*
Error	6	4733.540	788.92		
C. Total	8	23196.089			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	280.667	16.216	240.99	320.35
Foaming	3	238.633	16.216	198.95	278.31

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	348.567	16.216	308.89	388.25

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Foaming
HMA	-70.364	-2.464	39.570
Evotherm	-2.464	-70.364	-28.330
Foaming	39.570	-28.330	-70.364

Positive values show pairs of means that are significantly different.

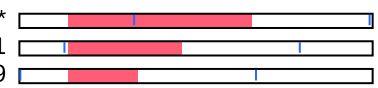
Connecting Letters Report

Level			Mean
HMA	A		348.56667
Evotherm	A	B	280.66667
Foaming		B	238.63333

Levels not connected by same letter are significantly different.

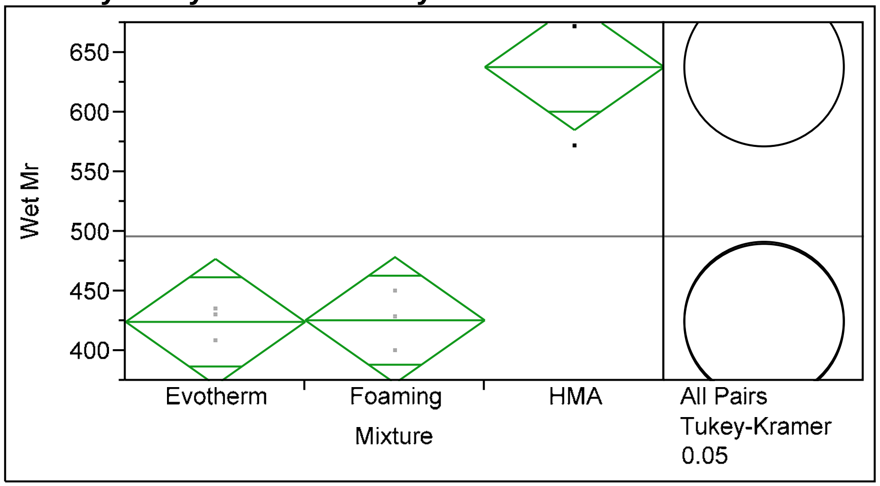
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Foaming	109.9333	22.93358	39.5697	180.2970	0.0072*
HMA	Evotherm	67.9000	22.93358	-2.4636	138.2636	0.0571
Evotherm	Foaming	42.0333	22.93358	-28.3303	112.3970	0.2379



LMLC 2W@60C – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
74

Oneway Anova

Summary of Fit

Rsquare	0.915258
Adj Rsquare	0.887011
Root Mean Square Error	37.41708
Mean of Response	496.2111
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	90726.882	45363.4	32.4016	0.0006*
Error	6	8400.227	1400.0		
C. Total	8	99127.109			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	424.500	21.603	371.64	477.36
Foaming	3	425.933	21.603	373.07	478.79

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	638.200	21.603	585.34	691.06

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Foaming	Evotherm
HMA	-93.73	118.53	119.97
Foaming	118.53	-93.73	-92.30
Evotherm	119.97	-92.30	-93.73

Positive values show pairs of means that are significantly different.

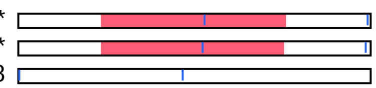
Connecting Letters Report

Level			Mean
HMA	A		638.20000
Foaming		B	425.93333
Evotherm		B	424.50000

Levels not connected by same letter are significantly different.

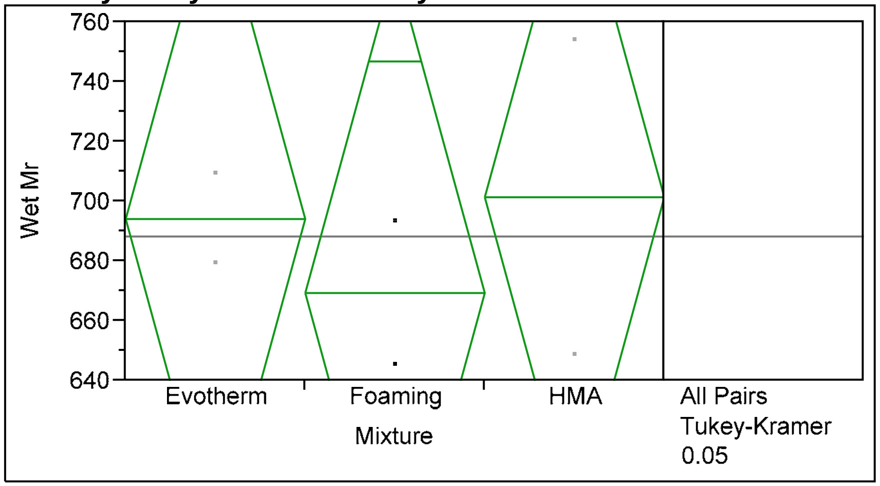
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Evotherm	213.7000	30.55092	119.965	307.4348	0.0010*
HMA	Foaming	212.2667	30.55092	118.532	306.0014	0.0011*
Foaming	Evotherm	1.4333	30.55092	-92.301	95.1681	0.9988



LMLC 16W@60C – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
77

Oneway Anova

Summary of Fit

Rsquare	0.136828
Adj Rsquare	-0.43862
Root Mean Square Error	48.74331
Mean of Response	688.3
Observations (or Sum Wgts)	6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	1129.8700	564.94	0.2378	0.8019
Error	3	7127.7300	2375.91		
C. Total	5	8257.6000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	2	694.150	34.467	584.46	803.84
Foaming	2	669.350	34.467	559.66	779.04

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	2	701.400	34.467	591.71	811.09

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
4.17871	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Foaming
HMA	-203.68	-196.43	-171.63
Evotherm	-196.43	-203.68	-178.88
Foaming	-171.63	-178.88	-203.68

Positive values show pairs of means that are significantly different.

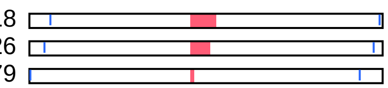
Connecting Letters Report

Level		Mean
HMA	A	701.40000
Evotherm	A	694.15000
Foaming	A	669.35000

Levels not connected by same letter are significantly different.

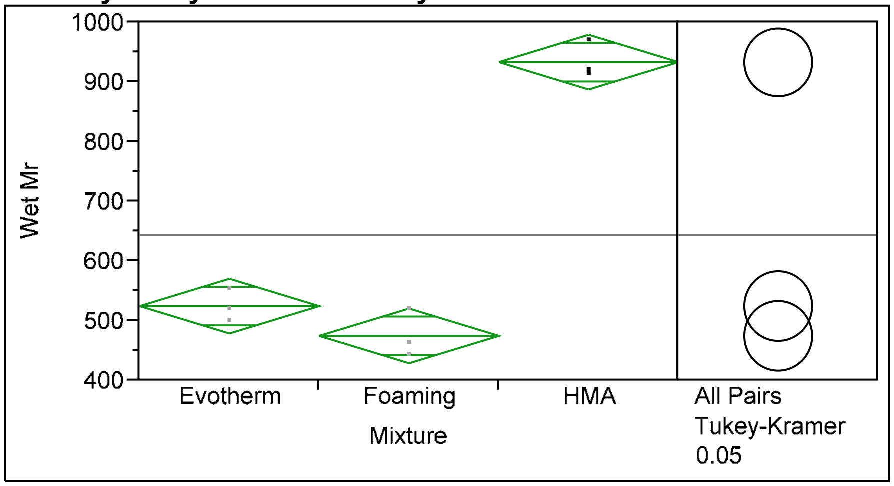
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Foaming	32.05000	48.74331	-171.634	235.7342	0.8018
Evotherm	Foaming	24.80000	48.74331	-178.884	228.4842	0.8726
HMA	Evotherm	7.25000	48.74331	-196.434	210.9342	0.9879



LMLC 5D@85C – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
74

Oneway Anova

Summary of Fit

Rsquare	0.983655
Adj Rsquare	0.978207
Root Mean Square Error	32.43433
Mean of Response	644.4667
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	379859.65	189930	180.5441	<.0001*
Error	6	6311.91	1052		
C. Total	8	386171.56			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm	3	524.933	18.726	479.11	570.75
Foaming	3	474.900	18.726	429.08	520.72

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA	3	933.567	18.726	887.75	979.39

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA	Evotherm	Foaming
HMA	-81.25	327.38	377.41
Evotherm	327.38	-81.25	-31.22
Foaming	377.41	-31.22	-81.25

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
HMA	A		933.56667
Evotherm		B	524.93333
Foaming		B	474.90000

Levels not connected by same letter are significantly different.

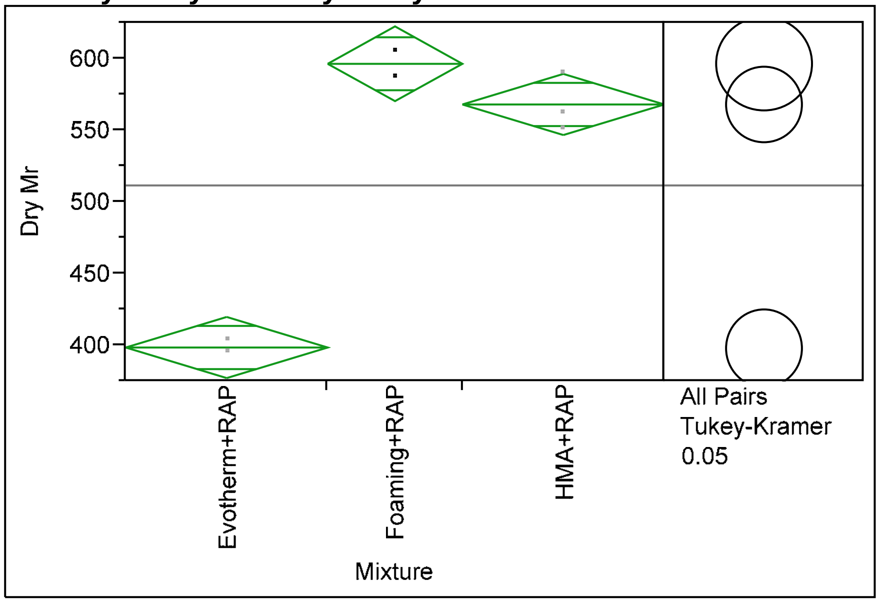
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA	Foaming	458.6667	26.48252	377.414	539.9190	<.0001*
HMA	Evotherm	408.6333	26.48252	327.381	489.8856	<.0001*
Evotherm	Foaming	50.0333	26.48252	-31.219	131.2856	0.2217

Table C.22

PMFC cores at construction – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
146

Oneway Anova

Summary of Fit

Rsquare	0.983722
Adj Rsquare	0.977211
Root Mean Square Error	14.36351
Mean of Response	511.575
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	62339.323	31169.7	151.0814	<.0001*

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Error	5	1031.552	206.3		
C. Total	7	63370.875			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	398.500	8.293	377.18	419.82
Foaming+RAP	2	596.450	10.157	570.34	622.56
HMA+RAP	3	568.067	8.293	546.75	589.38

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	HMA+RAP	Evotherm+RAP
Foaming+RAP	-46.74	-14.28	155.29
HMA+RAP	-14.28	-38.16	131.41
Evotherm+RAP	155.29	131.41	-38.16

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Foaming+RAP	A		596.45000
HMA+RAP	A		568.06667
Evotherm+RAP		B	398.50000

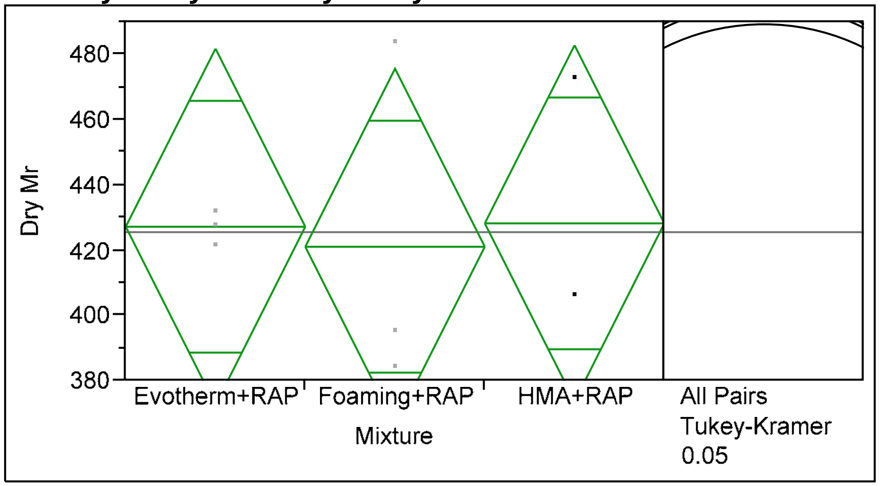
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	Evotherm+RAP	197.9500	13.11203	155.285	240.6147	<.0001*
HMA+RAP	Evotherm+RAP	169.5667	11.72775	131.406	207.7272	<.0001*
Foaming+RAP	HMA+RAP	28.3833	13.11203	-14.281	71.0481	0.1710

LMLC no LTOA – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.009928
Adj Rsquare	-0.3201
Root Mean Square Error	38.68659
Mean of Response	425.5667
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	90.0467	45.02	0.0301	0.9705
Error	6	8979.9133	1496.65		
C. Total	8	9069.9600			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	427.267	22.336	372.61	481.92
Foaming+RAP	3	421.133	22.336	366.48	475.79

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	428.300	22.336	373.65	482.95

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	HMA+RAP	Evotherm+RAP	Foaming+RAP
HMA+RAP	-96.915	-95.882	-89.748
Evotherm+RAP	-95.882	-96.915	-90.782
Foaming+RAP	-89.748	-90.782	-96.915

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
HMA+RAP	A	428.30000
Evotherm+RAP	A	427.26667
Foaming+RAP	A	421.13333

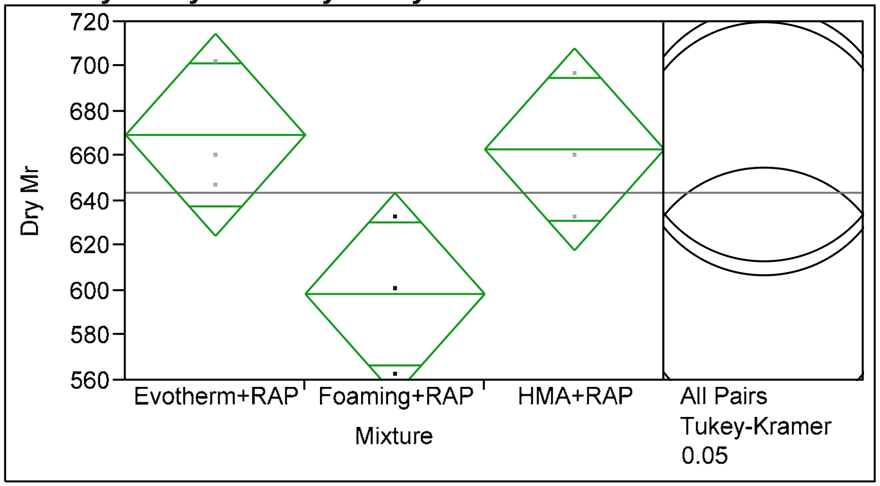
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
HMA+RAP	Foaming+RAP	7.166667	31.58747	-89.7484	104.0817	0.9722
Evotherm+RAP	Foaming+RAP	6.133333	31.58747	-90.7817	103.0484	0.9795
HMA+RAP	Evotherm+RAP	1.033333	31.58747	-95.8817	97.9484	0.9994

LMLC 2W@60C – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
145

Oneway Anova

Summary of Fit

Rsquare	0.601726
Adj Rsquare	0.468968
Root Mean Square Error	31.93927
Mean of Response	643.9111
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	9247.369	4623.68	4.5325	0.0632
Error	6	6120.700	1020.12		
C. Total	8	15368.069			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	669.733	18.440	624.61	714.85
Foaming+RAP	3	598.733	18.440	553.61	643.85

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	663.267	18.440	618.15	708.39

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm+RAP	HMA+RAP	Foaming+RAP
Evotherm+RAP	-80.012	-73.545	-9.012
HMA+RAP	-73.545	-80.012	-15.479
Foaming+RAP	-9.012	-15.479	-80.012

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm+RAP	A	669.73333
HMA+RAP	A	663.26667
Foaming+RAP	A	598.73333

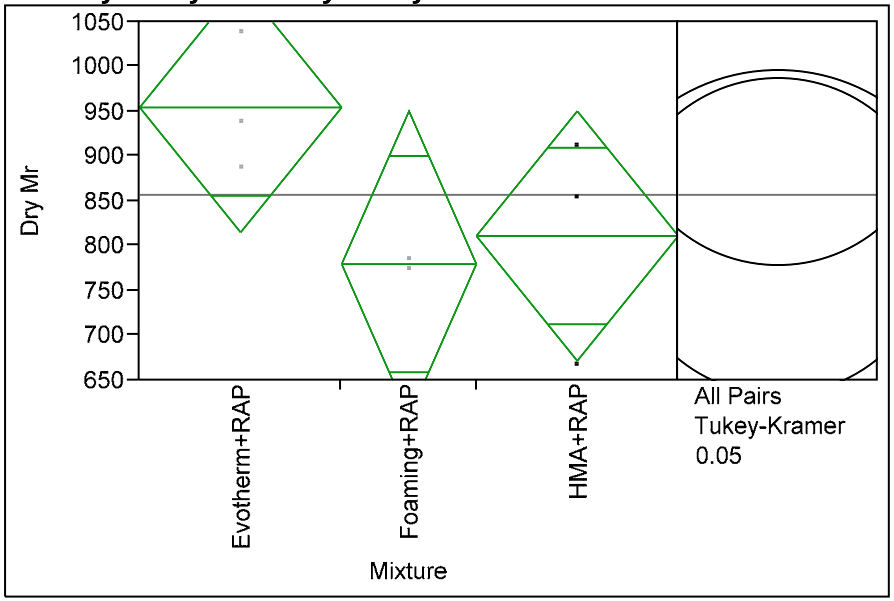
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm+RAP	Foaming+RAP	71.00000	26.07830	-9.0121	151.0121	0.0770
HMA+RAP	Foaming+RAP	64.53333	26.07830	-15.4788	144.5455	0.1054
Evotherm+RAP	HMA+RAP	6.46667	26.07830	-73.5455	86.4788	0.9669

LMLC 5D@85C – Dry M_R

Oneway Analysis of Dry Mr By Mixture



Excluded Rows
146

Oneway Anova

Summary of Fit

Rsquare	0.515023
Adj Rsquare	0.321032
Root Mean Square Error	93.91152
Mean of Response	857.35
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	46828.753	23414.4	2.6549	0.1638
Error	5	44096.867	8819.4		
C. Total	7	90925.620			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	954.867	54.220	815.49	1094.2
Foaming+RAP	2	780.000	66.405	609.30	950.7
HMA+RAP	3	811.400	54.220	672.02	950.8

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm+RAP	HMA+RAP	Foaming+RAP
Evotherm+RAP	-249.50	-106.03	-104.08
HMA+RAP	-106.03	-249.50	-247.55
Foaming+RAP	-104.08	-247.55	-305.58

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm+RAP	A	954.86667
HMA+RAP	A	811.40000
Foaming+RAP	A	780.00000

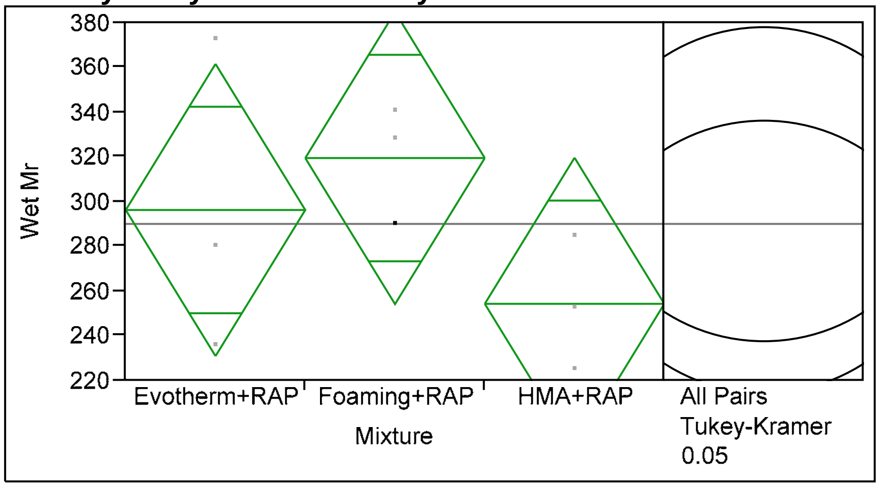
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm+RAP	Foaming+RAP	174.8667	85.72910	-104.084	453.8174	0.1978
Evotherm+RAP	HMA+RAP	143.4667	76.67843	-106.034	392.9678	0.2407
HMA+RAP	Foaming+RAP	31.4000	85.72910	-247.551	310.3507	0.9297

LMLC no LTOA – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
74

Oneway Anova

Summary of Fit

Rsquare	0.338015
Adj Rsquare	0.117353
Root Mean Square Error	46.24541
Mean of Response	290.2222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	6552.029	3276.01	1.5318	0.2901
Error	6	12831.827	2138.64		
C. Total	8	19383.856			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	296.467	26.700	231.13	361.80
Foaming+RAP	3	319.700	26.700	254.37	385.03

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	254.500	26.700	189.17	319.83

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	Evotherm+RAP	HMA+RAP
Foaming+RAP	-115.85	-92.62	-50.65
Evotherm+RAP	-92.62	-115.85	-73.88
HMA+RAP	-50.65	-73.88	-115.85

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming+RAP	A	319.70000
Evotherm+RAP	A	296.46667
HMA+RAP	A	254.50000

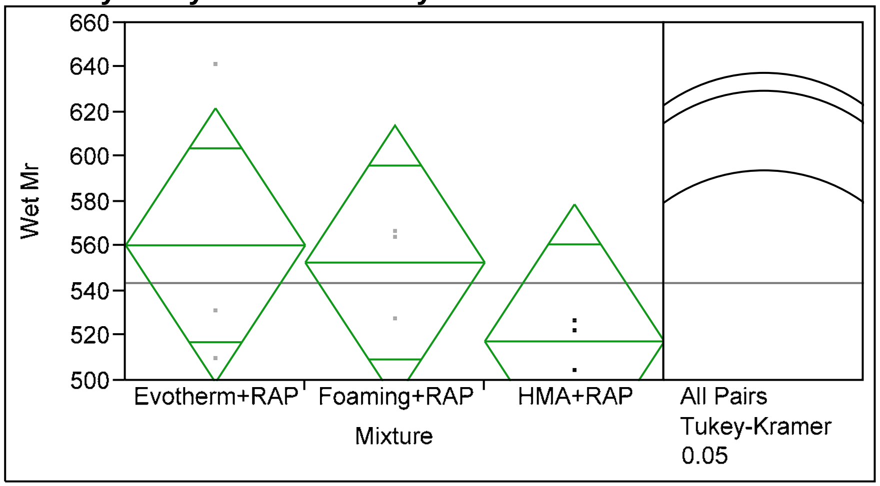
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	HMA+RAP	65.20000	37.75922	-50.6509	181.0509	0.2711
Evotherm+RAP	HMA+RAP	41.96667	37.75922	-73.8843	157.8176	0.5422
Foaming+RAP	Evotherm+RAP	23.23333	37.75922	-92.6176	139.0843	0.8174

LMLC 2W@60C – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
74

Oneway Anova

Summary of Fit

Rsquare	0.21807
Adj Rsquare	-0.04257
Root Mean Square Error	43.40504
Mean of Response	543.7889
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	3152.542	1576.27	0.8367	0.4781
Error	6	11303.987	1884.00		
C. Total	8	14456.529			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	560.700	25.060	499.38	622.02
Foaming+RAP	3	552.967	25.060	491.65	614.29

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
HMA+RAP	3	517.700	25.060	456.38	579.02

Std Error uses a pooled estimate of error variance

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
3.06815	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Evotherm+RAP	Foaming+RAP	HMA+RAP
Evotherm+RAP	-108.74	-101.00	-65.74
Foaming+RAP	-101.00	-108.74	-73.47
HMA+RAP	-65.74	-73.47	-108.74

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Evotherm+RAP	A	560.70000
Foaming+RAP	A	552.96667
HMA+RAP	A	517.70000

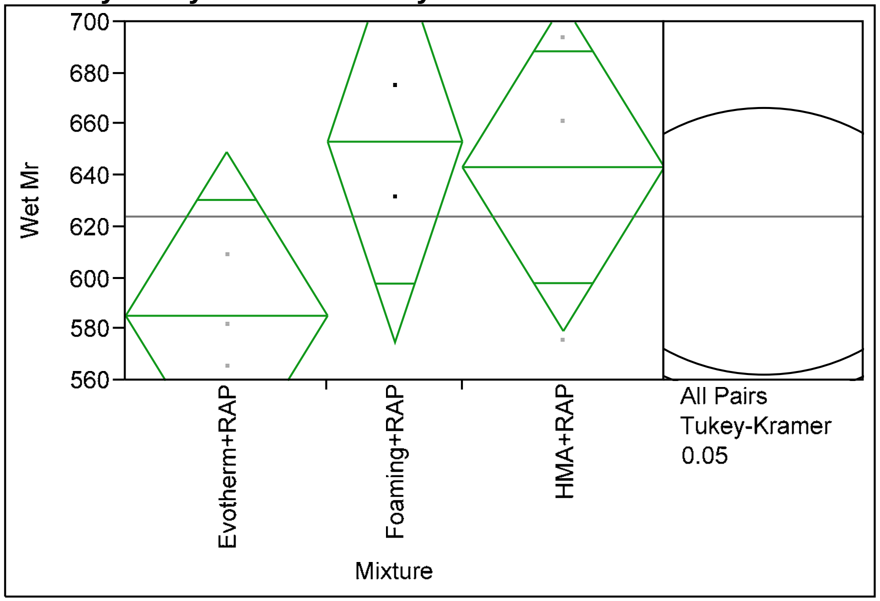
Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Evotherm+RAP	HMA+RAP	43.00000	35.44007	-65.735	151.7354	0.4886
Foaming+RAP	HMA+RAP	35.26667	35.44007	-73.469	144.0021	0.6062
Evotherm+RAP	Foaming+RAP	7.73333	35.44007	-101.002	116.4688	0.9742

LMLC 5D@85C – Wet M_R

Oneway Analysis of Wet Mr By Mixture



Excluded Rows
75

Oneway Anova

Summary of Fit

Rsquare	0.440892
Adj Rsquare	0.217249
Root Mean Square Error	43.14953
Mean of Response	624.0875
Observations (or Sum Wgts)	8

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Mixture	2	7341.057	3670.53	1.9714	0.2337
Error	5	9309.412	1861.88		
C. Total	7	16650.469			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Evotherm+RAP	3	585.300	24.912	521.26	649.34
Foaming+RAP	2	653.350	30.511	574.92	731.78
HMA+RAP	3	643.367	24.912	579.33	707.41

Std Error uses a pooled estimate of error variance

Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
3.25386	0.05

LSD Threshold Matrix

Abs(Dif)-HSD	Foaming+RAP	HMA+RAP	Evotherm+RAP
Foaming+RAP	-140.40	-118.19	-60.12
HMA+RAP	-118.19	-114.64	-56.57
Evotherm+RAP	-60.12	-56.57	-114.64

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Foaming+RAP	A	653.35000
HMA+RAP	A	643.36667
Evotherm+RAP	A	585.30000

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
Foaming+RAP	Evotherm+RAP	68.05000	39.38996	-60.120	196.2195	0.2839
HMA+RAP	Evotherm+RAP	58.06667	35.23145	-56.572	172.7050	0.3107
Foaming+RAP	HMA+RAP	9.98333	39.38996	-118.186	138.1529	0.9655