Material Characterization and Inherent Variation Analysis of Asphaltic Field Cores

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A knowledge of the variation in fundamental engineering properties of the construction materials is essential to a comprehensive evaluaton of the performance of various road sections. This study supports the Louisiana Experimental Base Project, an in-service experimental road project that aids in an evaluation of design-performance characteristics of a number of experimental test sections. The expected variation in the static and resilient (fatigue) properties of the materials in the layers of the pavement structure can provide an inherent variation data base from which continuing evaluation and analysis of pavement behavior and performance of these layers could be undertaken. A material characterization and inherent analysis of a resilient (fatigue) test program was undertaken to establish the magnitude, scope, and expected variation in fundamental engineering properties of laboratory-prepared specimens and field cores of the asphaltic materials used in the wearing, binder, and black base layers of the test sections of the base project. Variation analyses were completed for such fundamental properties as modulus, Poisson's ratio, and fatigue cycles to failure. Regression analysis techniques were also used to quantify those factors that significantly affect the fatigue life of the various construction materials used in the Louisiana Experimental Base Project. This information, when combined with the in-service performance results from the base project, should improve knowledge of the important mix variables affecting the fundamental engineering-performance properties and result in improvements in quality control measures.

A knowledge of the magnitude, scope, and expected variation in the fundamental engineering properties of the construction materials used in pavement structural sections is essential to a comprehensive evaluation of the performance of roadway sections. This study supports the Louisiana Experimental Base Project, an in-service experimental road project that aids in an evaluation of design-performance characteristics of a number of experimental test sections.

GENERAL

A repetitive (fatigue) testing program had two goals: to establish the magnitude and scope of inherent variation in the fundamental resilient properties of field cores representative of in-service conditions (Table 1), and to develop material characterization information from laboratory specimens (Table 2) of the three types of asphaltic materials (wearing, binder, and black base materials) used in the Louisiana Experimental Base Project.

Regression analysis techniques were used to quantify those factors that significantly affect the fatigue life of the various construction materials used in the Louisiana Experimental Base Project. This information, when combined with the in-service performance results from the base project, should improve knowledge of the important mix variables affecting the fundamental engineering-performance properties and could lead to improvements in quality control measures.

Louisiana Experimental Base Project

The Louisiana Experimental Base Project is situated on a portion of US-71–167, which accommodates a moderate volume of mixed vehicular traffic. To ensure that the flow of traffic would not be affected by its experimental status, the base project was completed as a part of a construction project upgrading US-71–167 to a four-lane facility.

The terrain at the base project is generally flat with poor drainage. The subgrade material is basically a fine-grained soil ranging from a silty clay loam to a heavy clay. The range in mean ambient air temperature is approximately 39°F (40°C) to 84°F (29°C), and the mean annual rainfall is approximately 55 to 60 in. (140 to 150 cm).

The projected average daily traffic at the time of construction was 7,990 vehicles, including approximately 15 percent trucks. All test sections were included in a portion of a newly constructed two-lane roadway adjacent to an existing two-lane highway.

The base project consists of 18 test sections: 14 experimental sections, and 4 control sections (Figure 1). The factors investigated in the project included three base types, three pavement design lives, and two surface thicknesses.

Each test section is approximately 550 ft (168 m) long with a 50-ft (15-m) transition zone interconnecting each adjacent test section. The randomization scheme for locating the various test sections included a complete randomization of the 10- and 15-year design sections but limited randomization of the 5-year sections. The latter sections were grouped together to allow for maintenance of the 5-year design sections at the same time. Detailed information on the construction of the base project is available from the Louisiana Department of Transportation (*1*).

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TABLE 1 RESILIENT (FATIGUE) TESTING PROGRAM—FIELD CORES

PAVEMENT LAYER	TEST TYPE	VARIATION EVALUATED	FUNDAMENTAL MATERIAL PROPERTIES ESTIMATED
Wearing,	Repetitive	Longitudinal - 10' spacing	N_f, Cycles to Failure
Binder,	Indirect	Longitudinal - 1' spacing	E_r, Resilient Modulus
and Black Base	Tensile	Lateral - 4' spacing	μ_r, Resilient Poisson's Ratio
	Test	Lateral - 1' spacing	ϵ_r, Resilient Tensile Strain
		Depth - vertical	S_r, Resilient Applied Tensile
		Stress levels - 11 to 39 psi	Stress

TABLE 2 RESILIENT (FATIGUE) TESTING PROGRAM—LABORATORY-PREPARED ASPHALT SPECIMENS

PAVEMENT LAYER	TEST TYPE	FACTORS EVALUATED		FUNDAMENTAL MATERIAL CHARACTERISTICS ESTIMATED
		TYPE	LEVELS	
Wearing,	Repetitive	Mix Variables:		N_f, Cycles to Failure
Binder,	Indirect	a)Asphalt	1)Wearing 3.9-4.9%	E_r, Resilient modulus
and	Tensile	content	2)Binder 3.7-4.7%	μ_r, Resilient Poisson's
Black Base	Test		3)Black base 3.5-4.5%	Ratio
		b)Gradation	Varies with layer type	ϵ_r, Resilient Strain
		c)Compaction temperature	235, 250, 275, 300, 314°F	S_r, Resilient Stress
		d)Age at test	35, 56, 112, 224, 343 days	
		e)Stress level	10.1, 14.9, 22.9, 30.9, 35.7 psi	

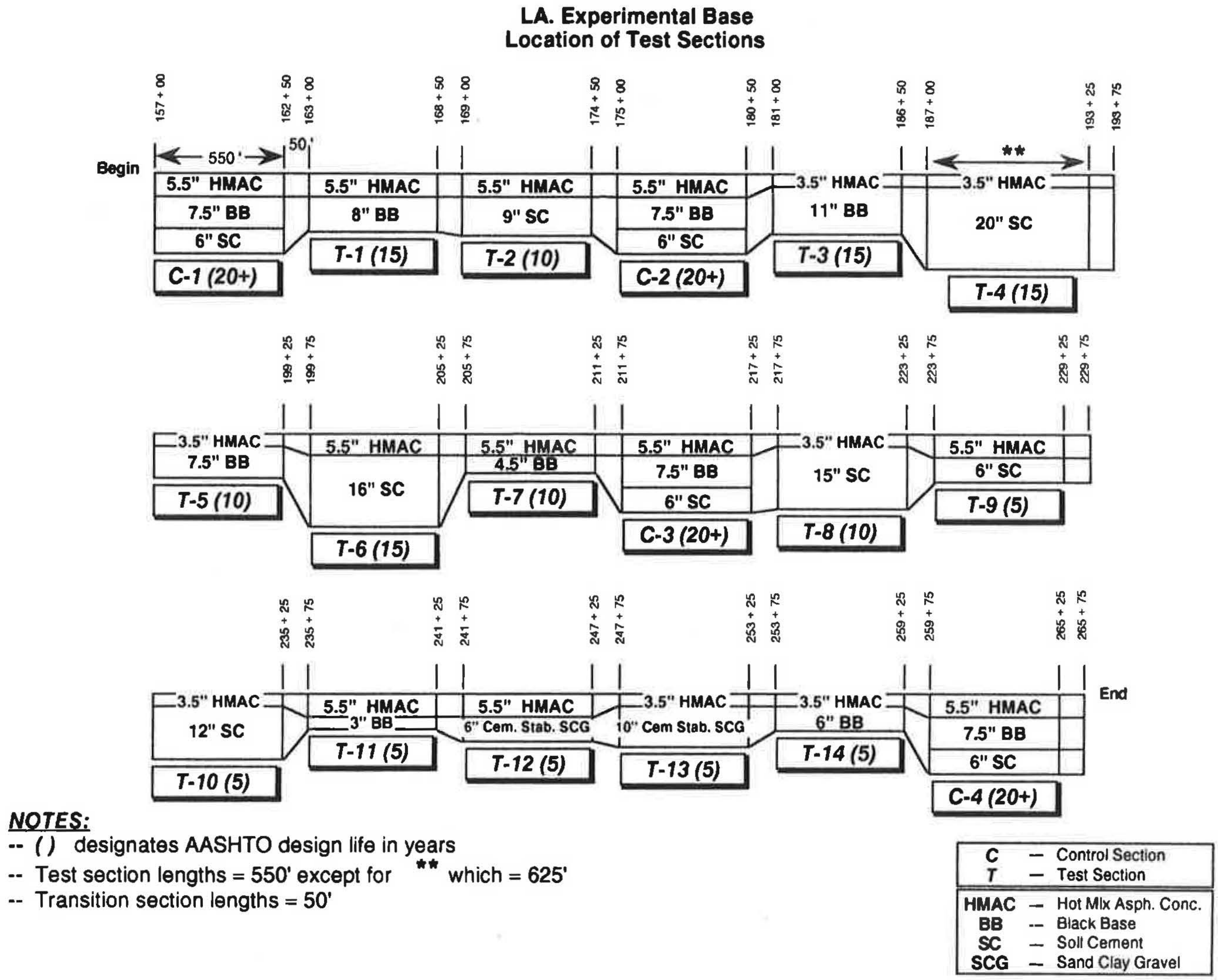

FIGURE 1 Experimental base project layout.

Field Coring Plan

The coring plan established for the Louisiana Experimental Base Project is shown in Table 3. The plan provided for an investigation of the variability in material properties of the various pavement materials used throughout the base project. The coring plan allowed for variational analysis in the longitudinal (along the road), lateral (across the road), and vertical (depth into pavement) directions. In addition, the plan included various spacings of the coring locations to provide for evaluation of inherent variation within close spacings (±1 ft) and larger spacings (±10 ft).

The fundamental engineering properties investigated in this phase included resilient modulus, resilient Poisson's ratio, and Log N_f (cycles to failure). Because the specimens were field cores, the only variable that could actually be varied was the tensile stress repeatedly applied to the specimens during the fatigue test. The properties associated with the cores—such as air voids, density, voids in mineral aggregate, and asphalt content—could be only measured, not established as a fixed value. All tests were conducted at a test temperature of 75°F (24°C) and 1 Hz (sinusoidal waveform).

INHERENT VARIATION ANALYSIS

The inherent variation estimates were obtained from field cores at an approximately similar position, depth, spacing, and material type. The estimates of the inherent variation in the resilient fundamental engineering properties are shown in Tables 4–6 for wearing course, binder course, and black base field cores. Within the tables, the variations are broken down into longitudinal at 1-ft spacing (A), longitudinal at 10-ft spacing (B), lateral at 1-ft spacing (C), lateral at 4-ft spacing (D), and depth (E, for binder and black base only).

Statistical comparisons of inherent variation in the longitudinal and lateral directions allowed the four sets of variations to be pooled. This operation provided better estimates of the in-service inherent variation in the resilient modulus,

TABLE 3 RANDOMIZED CORE PLAN

SECTION DESIGNATION	DESIGN LIFE YRS	SAMPLING DIRECTION AND GROUPING	STATION	LANE	COMMENTS
Control 1	20	longitudinal	160 + 24	outside	outside
		within	160 + 25		wheel path
			160 + 26		
Test 1	15	longitudinal	166 + 74	inside	outside
		within	166 + 75		wheel path
			166 + 76		
Test 2	10	longitudinal	171 + 15	outside	outside
		among	171 + 25		wheel path
			171 + 35		
Control 2	20	longitudinal	178 + 15	outside	outside
		among	178 + 25		wheel path
			178 + 35		
Test 3	15	lateral	185 + 75	outside	9' Rt of CL
		within	185 + 75		10' Rt of CL
			185 + 75		11' RT of CL
Test 4	15	lateral	192 + 25	outside	9' Rt of CL
		within	192 + 25		10' Rt of CL
			192 + 25		11' Rt of CL
Test 5	10	lateral	199 + 00	inside	2' Lt of CL
		among	199 + 00		6' Lt of CL
			199 + 00		10' Lt of CL
Test 6	15	lateral	202 + 00	inside	2' Lt of CL
		among	202 + 00		6' Lt of CL
			202 + 00		10' Lt of CL
Test 7	10	longitudinal	205 + 99	outside	outside
		within	206 + 00		wheel path
			206 + 01		
Control 3	20	lateral	213 + 50	inside	2' Lt of CL
		among	213 + 50		6' Lt of CL
			213 + 50		10' Lt of CL
			213 + 50	outside	2' Rt of CL
			213 + 50		6' Rt of CL
			213 + 50		10' Rt of CL
Test 8	10	longitudinal	221 + 40	outside	outside
		among	221 + 50		wheel path
			221 + 60		

TABLE 3 (*continued on next page*)

TABLE 3 (*continued*)

SECTION DESIGNATION	DESIGN LIFE YRS	SAMPLING DIRECTION AND GROUPING	STATION	LANE	COMMENTS
Test 9	5	longitudinal	227 + 99	inside	outside
		within	228 + 00		wheel path
			228 + 01		
Test 10	5	longitudinal	231 + 49	outside	outside
		within	231 + 50		wheel path
			231 + 51		
Test 11	5	longitudinal	237 + 90	outside	outside
		among	238 + 00		wheel path
			238 + 10		
Test 12	5	lateral	245 + 00	outside	2' Rt of CL
		among	245 + 00		6' Rt of CL
			245 + 00		10' Rt of CL
Test 13	5	longitudinal	251 + 99	outside	outside
		within	252 + 00		wheel path
			252 + 01		
Test 14	5	lateral	257 + 00	outside	2' Rt of CL
		among	257 + 00		6' Rt of CL
			257 + 00		10' Rt of CL
Control 4	20	lateral	261 + 50	outside	9' Rt of CL
		within	261 + 50		10' Rt of CL
			261 + 50		11' Rt of CL

Poisson's ratio, and fatigue life of the wearing, binder, and black base layers. The pooled results are shown in Table 7.

There were significant differences in the variances of the pooled longitudinal and lateral data and the depth data. The varation with depth was significantly greater than the variation in the longitudinal and lateral directions; therefore, the two variances must be considered separately. This finding implies more variation in the vertical direction (depth in the pavement) than in the lateral and longitudinal directions. The inherent variation estimates in the vertical direction are shown as the bottom rows of Tables 5 and 6 for the binder and black base cores, respectively. As noted previously, no data were available for vertical direction variability in the wearing course; however, it is believed that the estimates for the binder course cores could be used for this purpose.

INHERENT VARIATION COMPARISONS

A compilation of the available information on the fundamental engineering properties of the asphaltic field cores has been prepared. The means and standard deviations for resilient modulus, resilient Poisson's ratio, measured resilient strain, and Log N_f of the various asphaltic materials are shown in Table 8. This information was subsequently used in completing several statistical comparisons among the various types of field cores (i.e., surface, binder, and black base).

Comparisons between the field core results of wearing and binder materials and binder and black base materials established whether there were significant differences in means and variances. If there were no significant differences, the results could be combined and any subsequent use of the data could be simplified (i.e., wearing and binder courses could be considered as one layer for a layered theory evaluation).

Comparisons between wearing and binder course materials are shown in Table 9. There was no significant difference in the resilient Poisson's ratio, but there were significant differences in the other material properties. In general, the property values for the wearing course were 9 to 14 percent higher than for the binder course. It is therefore concluded that the fundamental engineering properties of the wearing and binder course materials are generally different and that the two materials must be considered separate entities in any subsequent analysis or in any layered theory type evaluation.

TABLE 4 FUNDAMENTAL MATERIAL PROPERTY VARIATION IN FATIGUE-RESILIENT RESULTS—FIELD CORES OF WEARING COURSE MATERIALS

		RESILIENT MODULUS		RESILIENT POISSON'S RATIO		LOG OF CYCLES TO FAILURE	
TYPE VARIATION	DESIGN LEVEL	MEAN SQUARES	DEGREES FREEDOM	MEAN SQUARES	DEGREES FREEDOM	MEAN SQUARES	DEGREES FREEDOM
A - longitudinal	1,2 *	1.885677	3	0.013197	3	0.004135	3
direction @ 1'	3						
spacing	4	2.762354	6	0.007888	6	0.137140	6
		2.470128	9	0.009658	9	0.092805	9
B - longitudinal	1,2	2.185220	2	0.005924	2	0.174753	2
direction @ 10'	3	0.061894	4	0.001851	4	0.096129	4
spacing	4	5.471106	2	0.024194	2	0.025457	2
		1.945029	8	0.008455	8	0.098114	8
C - lateral	1,2	0.961149	2	0.001075	2	0.041346	2
direction @ 1'	3						
spacing	4	———	-	———	-	———	-
		0.961149	2	0.001075	2	0.041346	2
D - lateral	1,2	3.100015	6	0.015089	6	0.203137	6
direction @ 4'	3	3.564450	1	0.003961	1	0.006705	1
spacing	4	2.549280	1	0.000578	1	0.089535	1
		3.089228	8	0.011884	8	0.164383	8
E - none available							

* Design Level	Test Sections	Design Life
1	C1, C2, C3, C4	Control (20 year)
2	T1, T3, T4, T6	15 Year
3	T2, T5, T7, T8	10 Year
4	T9, T10, T11, T12, T13, T14	5 Year

Similar comparisons in the fundamental engineering properties of binder and black base field cores yielded essentially the same results. In this comparison, the modulus and Poisson's ratio values for the two material types could be combined; however, because there were significant differences in Log N_f, the two material types must be considered separately in any subsequent analyses. The property values for the binder materials were generally 5 to 9 percent higher than for the black base materials (Table 10).

One of the perplexing problems associated with experimental analysis and evaluations based on laboratory-prepared specimens is the uncertainty of the premise that the results are applicable to field conditions. In order to obtain information concerning the existence of a correlation between field and laboratory core results, statistical comparisons were completed between the resilient properties of laboratory specimens and field cores for wearing (Table 11), binder (Table 12), and black base (Table 13) materials. In general, statistically significant differences were found between the resilient-fatigue results for the laboratory and field cores.

However, there was a consistent difference between the field and laboratory cores, indicating a correlation between

TABLE 5 FUNDAMENTAL MATERIAL PROPERTY VARIATION IN FATIGUE-RESILIENT INDIRECT TENSILE TEST RESULTS—FIELD CORES OF BINDER COURSE MATERIALS

		RESILIENT MODULUS		RESILIENT POISSON'S RATIO		LOG OF CYCLES TO FAILURE	
TYPE VARIATION	DESIGN LEVEL	MEAN SQUARES	DEGREES FREEDOM	MEAN SQUARES	DEGREES FREEDOM	MEAN SQUARES	DEGREES FREEDOM
A - longitudinal	1,2	0.422602	4	0.001099	4	0.002644	4
direction @ 1'	3	1.705175	2	0.012951	2	0.079551	2
spacing	4	1.488872	6	0.005270	6	0.156679	6
		1.169499	12	0.005160	12	0.092479	12
B - longitudinal	1,2	1.362684	2	0.004576	2	0.045163	2
direction @ 10'	3	0.071368	2	0.002688	2	0.416775	2
spacing	4	0.425921	2	0.015864	2	0.009743	2
		0.619991	6	0.007709	6	0.157227	6
C - lateral	1,2	0.649841	8	0.008500	8	0.156221	8
direction @ 1'	3						
spacing	4	—	-	—	-	—	-
		0.649841	8	0.008500	8	0.156221	8
D - lateral	1,2	0.367963	4	0.003655	4	0.224174	4
direction @ 4'	3	0.013057	2	0.013129	2	0.082499	2
spacing	4	1.012517	4	0.001686	4	0.116597	4
		0.554803	10	0.004762	10	0.152808	10
E - depth -	1,2	8.180508	20	0.000325	20	0.006539	20
vertical	3	0.124130	7	0.000019	7	0.018656	7
	4	3.637503	7	0.000213	7	0.043754	7
		5.586517	34	0.000239	34	0.016696	34

* Design Level	Test Sections	Design Life
1	C1, C2, C3, C4	Control
2	T1, T3, T4, T6	15 Year
3	T2, T5, T7, T8,	10 Year
4	T9, T10, T11, T12, T13, T14	5 Year

them. For the three materials, the engineering property estimates for the field cores ranged from 9 to 20 percent higher than those for the laboratory cores. The differences could very well be the difference in age (and probably mixture properties) between the core specimens (approximately 2½ years) and the laboratory specimens (from 1 month to a year). The differences between field and laboratory specimens were 13 to 15 percent, 9 to 14 percent, and 12 to 20 percent for wearing, binding, and black base materials, respectively.

ANALYSIS OF VARIANCE: FATIGUE LIFE

The analysis of variance results for the logarithm of fatigue life (i.e., Log N_f) of all combined asphaltic core data are shown in Table 14.

From these results, it can be ascertained that the fatigue life (explicitly the logarithm of fatigue life) of asphalt field cores is significantly influenced by or correlated with four main effects and one interaction. The fatigue life will generally

TABLE 6 FUNDAMENTAL MATERIAL PROPERTY VARIATION IN FATIGUE-RESILIENT INDIRECT TENSILE TEST RESULTS—FIELD CORES OF BLACK BASE MATERIALS

TYPE VARIATION	DESIGN LEVEL	RESILIENT MODULUS		RESILIENT POISSON'S RATIO		LOG OF CYCLES TO FAILURE	
		MEAN SQUARES	DEGREES FREEDOM	MEAN SQUARES	DEGREES FREEDOM	MEAN SQUARES	DEGREES FREEDOM
A - longitudinal	1,2*	0.163828	4	0.004661	4	0.038723	4
direction @ 1'	3						
spacing	4	———	-	———	-	———	-
		0.163828	4	0.004661	4	0.038723	4
B - longitudinal	1,2	4.059316	3	0.038379	3	0.083409	3
direction @ 10'	3						
spacing	4	———	-	———	-	———	-
		4.059316	3	0.038379	3	0.083409	3
C - lateral	1,2	1.122110	4	0.010111	4	0.047001	4
direction @ 1'	3						
spacing	4	———	-	———	-	———	-
		1.122110	4	0.010111	4	0.047001	4
D - lateral	1,2	1.192811	5	0.005342	5	0.022983	5
direction @ 4'	3	2.509904	5	0.020342	5	0.077305	5
spacing	4	2.198857	6	0.006119	6	0.115570	6
		1.981670	16	0.010321	16	0.074679	16
E - depth -	1,2	8.785102	9	0.000275	9	0.074251	9
vertical	3	8.483081	1	0.006728	1	0.029905	1
	4	———	-	———	-	———	-
		8.754900	10	0.000920	10	0.069816	10

* Design Level	Test Sections	Design Life
1	C1, C2, C3, C4	Control (20 Year)
2	T1, T3, T4, T6	15 Year
3	T2, T5, T7, T8,	10 Year
4	T9, T10, T11, T12, T13, T14	5 Year

be greater for higher modulus values, lower applied percent stress levels, higher voids in mineral aggregate, and lower asphalt contents. In addition, a combination of low asphalt content and high percent stress, or high asphalt content and low percent stress, would result in a longer fatigue life.

REGRESSION EQUATIONS: FATIGUE LIFE

The centered data approach was used to develop an overall regression equation for the logarithm of fatigue life (log N_f) of asphaltic field cores using a stepwise regression technique (Table 15). The terms included in this equation correspond to those factors and their interactions found to be of practical engineering significance in the analysis of variance.

Regression analyses were also conducted to develop relationships between Log N_f and logarithm of measured tensile strain for the wearing course, binder, and black base materials. These relatonships are shown in Table 15 as Equations b, c, and d. Although the coefficient of determination values for the equations listed in Table 15 range from 0.524 to 0.723,

TABLE 7 COMBINED VARIATION ESTIMATES (LATERAL AND LONGITUDINAL DIRECTIONS) OF FATIGUE-RESILIENT INDIRECT TENSILE TEST RESULTS—FUNDAMENTAL MATERIAL PROPERTIES OF FIELD CORES

	WEARING COURSE		BINDER COURSE		BLACK BASE	
MATERIAL PROPERTY	MEAN SQUARES	DEGREES FREEDOM	MEAN SQUARES	DEGREES FREEDOM	MEAN SQUARES	DEGREES FREEDOM
Resilient modulus	2.477981	26	0.814305	35	1.885708	26
Resilient Poisson's Ratio	0.009684	26	0.006394	35	0.013052	26
Log of Cycles to Failure	0.116074	26	0.138027	35	0.069060	26

TABLE 8 COMPILATION OF INHERENT VARIATION INFORMATION OF FATIGUE-RESILIENT INDIRECT TENSILE FIELD CORES—OVERALL SAMPLE VARIABILITY (INCLUDING VERTICAL VARIABILITY)

	WEARING SURFACE			BINDER COURSE			BLACK BASE		
MATERIAL PROPERTY	MEAN	MEAN SQUARE	DEGREES FREEDOM	MEAN	MEAN SQUARE	DEGREES FREEDOM	MEAN	MEAN SQUARE	DEGREES FREEDOM
Resilient Modulus, 10^5 psi	6.147	2.4780	26	5.272	3.1658	69	4.986	3.9022	35
Resilient Poisson's Ratio	0.321	0.0097	26	0.326	0.0036	69	0.331	0.0100	35
Measured * Resilient strain, μin/in	129.7	74.6	50	158.6	96.5	100	144.7	59.6	57
Log of Cycles to Failure	4.2488	0.1161	26	3.8679	0.0782	69	3.5669	0.0712	35

* Overall strain variability (i.e., includes all tests conducted).

all four equations have acceptable fit and can be considered adequate for prediction purposes. These four equations can then be used to estimate the fatigue life individually for each of the in-service asphaltic materials.

CONCLUSIONS

The findings and conclusions of this study are limited to the types of asphalt materials considered in this study. On the basis of the data and the analysis described earlier, the following general conclusions were made:

1. The variations in the fundamental resilient engineering properties of cores in the longitudinal (along the road) and lateral (across the road) directions were essentially the same and could be pooled. The variations in material properties with depth, however, were significantly different and could not be combined. Therefore, the variations in fundamental resilient engineering properties in vertical and horizontal di-

TABLE 9 COMPARISON OF INHERENT VARIATION OF WEARING COURSE AND BINDER COURSE (FIELD)

MATERIAL PROPERTY	WEARING SURFACE			BINDER COURSE			SIGNIFICANT DIFFERENCE IN	
	MEAN	MEAN SQUARE	DEGREES FREEDOM	MEAN	MEAN SQUARE	DEGREES FREEDOM	VARIANCE	MEAN
Resilient Modulus, 10^5 psi	6.147	2.4780	26	5.272	3.166	35	Yes	Yes
Resilient Poisson's Ratio	0.321	0.0097	26	0.326	0.0064	35	Yes	No
Measured * Resilient strain, μin/in	129.7	74.6	50	158.6	96.5	100	Yes	Yes
Log of Cycles to Failure	4.2488	0.1161	26	3.8679	0.1380	35	No	Yes

* Overall combined variation in measured tensile strain (all specimens included).

** Mean property values of wearing course are 9 to 14% higher than for binder course (with exception of Poisson's ratio).

TABLE 10 COMPARISON OF INHERENT VARIATION OF BLACK BASE AND BINDER COURSE (FIELD)

MATERIAL PROPERTY	BLACK BASE			BINDER COURSE			SIGNIFICANT DIFFERENCE IN	
	MEAN	MEAN SQUARE	DEGREES FREEDOM	MEAN	MEAN SQUARE	DEGREES FREEDOM	VARIANCE	MEAN
Resilient Modulus, 10^5 psi	4.986	1.886	26	5.272	3.166	35	Yes	No
Resilient Poisson's Ratio	0.331	0.0131	26	0.326	0.0064	35	Yes	No
Measured * Resilient strain, μin/in	144.7	59.6	57	158.6	96.5	100	Yes	No
Log of Cycles to Failure	3.5669	0.0691	26	3.8679	0.1380	35	Yes	Yes

* Overall combined variation in measured tensile strain (all specimens included).

** Mean property values of binder course are 5 to 9% higher than black base values (with exception of Poisson's ratio).

TABLE 13 COMPARISON OF INHERENT VARIATION OF BLACK BASE (FIELD) AND BLACK BASE (LABORATORY)

MATERIAL PROPERTY	LAB * MEAN	LAB * MEAN SQUARE	LAB * DEGREES FREEDOM	FIELD MEAN	FIELD MEAN SQUARE	FIELD DEGREES FREEDOM	SIGNIFICANT DIFFERENCE IN VARIANCE	SIGNIFICANT DIFFERENCE IN MEAN
Resilient Modulus, 10^5 psi	3.982	0.9446	17	4.986	1.866	26	Yes	Yes
Resilient Poisson's Ratio	0.282	0.0113	17	0.331	0.013	26	No	No
Measured ** Resilient strain, μin/in	192.9	116.1	17	144.7	59.6	26	Yes	Yes
Log of Cycles to Failure	3.1375	0.0304	17	3.5669	0.0691	26	Yes	Yes

* Total variability in laboratory prepared specimens was utilized, since field core variability would include inherent as well as factor variability.

** Variability in all laboratory and field cores tested.

*** Mean property values for field cores are 12 to 20% higher than laboratory cores and measured strains are 33% less.

TABLE 14 COMBINED ANALYSIS OF VARIANCE FOR LOG N_f OF FATIGUE-RESILIENT INDIRECT TENSILE TEST RESULTS—ASPHALT FIELD CORES

SOURCE OF VARIATION	DEGREES FREEDOM	MEAN SQUARES	F VALUE	SIGNIFICANCE LEVEL	APPROXIMATE UNIT VARIATION
STL	1	62.72323	525.26	0.01	-0.602
ACxSTL	1	3.86714	32.38	0.01	-0.132
E	1	2.78582	23.33	0.01	+0.114
VMA	1	2.43992	20.43	0.01	+0.536
AC	1	2.29341	19.20	0.01	-0.184
Residual	141	0.75609			
Error	60	0.130814			

Factor Legend

AC - Asphalt Content

E - Modulus

STL - Stress level

VMA - Voids in mineral aggregates

TABLE 11 COMPARISON OF INHERENT VARIATION OF WEARING COURSE (FIELD) AND WEARING COURSE (LABORATORY)

MATERIAL PROPERTY	LAB *			FIELD			SIGNIFICANT DIFFERENCE IN	
	MEAN	MEAN SQUARE	DEGREES FREEDOM	MEAN	MEAN SQUARE	DEGREES FREEDOM	VARIANCE	MEAN
Resilient Modulus, 10^5 psi	5.217	0.9578	17	6.147	2.478	26	Yes	Yes
Resilient Poisson's Ratio	0.280	-0.113	17	0.321	0.010	26	No	No
Measured ** Resilient strain, µin/in	134.8	56.7	17	129.7	74.6	26	No	No
Log of Cycles to Failure	3.6817	0.0516	17	4.2488	0.1161	26	No	Yes

* Total variability in laboratory prepared specimens was utilized, since field core variability would include inherent as well as factor variability.

** Variability in all laboratory field cores tested.

*** Mean property values for field cores are 13 to 15% higher than laboratory cores and measured strains are 4% lower.

TABLE 12 COMPARISON OF INHERENT VARIATION OF BINDER COURSE (FIELD) AND BINDER COURSE (LABORATORY)

MATERIAL PROPERTY	LAB *			FIELD			SIGNIFICANT DIFFERENCE IN	
	MEAN	MEAN SQUARE	DEGREES FREEDOM	MEAN	MEAN SQUARE	DEGREES FREEDOM	VARIANCE	MEAN
Resilient Modulus, 10^5 psi	4.807	0.6898	17	5.272	3.166	69	Yes	No
Resilient Poisson's Ratio	0.288	0.0237	17	0.326	0.0036	69	Yes	No
Measured ** Resilient strain, µin/in	113.11	60.78	17	158.6	96.5	69	Yes	Yes
Log of Cycles to Failure	3.321	0.0689	17	3.8679	0.0782	69	No	Yes

* Total variability in laboratory prepared specimens was utilized, since field core variability would include inherent as well as factor variability.

** Variability in all laboratory and field cores tested.

*** Mean property values for field cores are 9 to 14% higher than laboratory cores and measured strains are 29% higher.

TABLE 15 REGRESSION ANALYSIS OF FATIGUE-RESILIENT INDIRECT TENSILE TEST RESULTS—ASPHALT FIELD CORES

a) LOG OF CYCLES TO FAILURE - COMBINED ANALYSIS

$$L_{Nf} = 3.9647 + 0.3042 \left[\frac{\text{Log E} - 0.7075}{0.1549}\right] - 0.6995 \left[\frac{\text{Log STS} + 0.79053}{0.2209}\right]$$

$$+ 0.1219 \left[\frac{\text{Log VMA} - 1.80441}{0.042}\right] - 0.2462 \left[\frac{\text{Log AC} - 0.63501}{0.0239}\right]$$

$R^2 = 0.5275$ $\hat{Sr} = 0.6682$

b) LOG OF CYCLES TO FAILURE - WEARING COURSE

$$\text{Log}_{Nf} = 9.67 - 2.650 \text{ Log } (\epsilon)$$

$R^2 = .659$ $\hat{Sr} = .4410$

c) LOG OF CYCLES TO FAILURE - BINDER COURSE

$$\text{Log}_{Nf} = 8.736 - 2.255 \text{ Log } (\epsilon)$$

$R^2 = .524$ $\hat{Sr} = .5110$

d) LOG OF CYCLES TO FAILURE - BLACK BASE

$$\text{Log}_{Nf} = 9.779 - 2.925 \text{ Log } (\epsilon)$$

$R^2 = .723$ $\hat{Sr} = .259$

E = Resilient modulus (10^5 psi)

ϵ = Measured tensile strain, μin/in

STS = Applied tensile stress, psi

VMA = Voids in mineral aggregates, %

AC = % Asphalt content

rections must be considered separately (i.e., analogous to a anisotropic condition). In fact, the variability will be greater in the vertical direction.

2. Comparisons of the fundamental engineering properties of the various asphaltic material indicate that the wearing, binder, and black base are significantly different and must be considered as separate material groups (i.e., statistical populations) in any subsequent analysis.

3. Although there were significant differences in the mean resilient properties of the asphaltic laboratory specimens and field cores, there appeared to be a correlation between the two sets of data. For the wearing, binder, and black base materials, the engineering properties of the field cores ranged from 9 to 20 percent greater than those of the laboratory cores. These differences could very well be explained by differences in age at time of test. This correlation indicates that the properties of laboratory-prepared specimens can be used as indicators of the in-service material properties.

4. The inherent variation and fatigue life information developed in this study constitutes a materials variation data base that will be useful in the performance, evaluation, and analysis of the Louisiana Experimental Base Project, as well as other in-service pavement sections.

REFERENCE

1. J. W. Lyon, Jr. *Louisiana Experimental Base Project.* Report 1. Office of Highways, Research and Development Section, Louisiana Department of Transportation, Baton Rouge, Nov. 1979.