APPENDIX C

Literature Review

The measured specific gravity and water absorption of coarse and fine aggregates are used in mix design/proportioning and production of both PCC and HMA. The ability to quickly measure these properties of aggregate materials with a high degree of accuracy and repeatability is essential to agencies and contractors. This appendix provides a literature review of potential test methods that can be used to determine the specific gravity and water absorption of coarse and fine aggregates.

Current Test Methods for Determining Specific Gravity and Water Absorption of Coarse and Fine Aggregates

Current standard test methods for determining the specific gravity and water absorption capacity of coarse and fine aggregates are AASHTO T 85/ASTM C127 and AASHTO T 84/ASTM C128, respectively. A discussion of each test method and its shortcomings follows.

AASHTO T 85 and ASTM C 127

These test methods for determining the specific gravity and absorption of coarse aggregate are essentially the same except for the required time in which a sample of coarse aggregate is submersed in water to fill the pores. While the AASHTO procedure requires the sample be immersed for a period of 15 to 19 hours, the ASTM method specifies an immersed period of 24 ± 4 hours. The two methods determine the volume of aggregate particles based on the mass of the volume of water displaced by the aggregate sample.

The procedures include several main steps. First, the sample of coarse aggregate is prepared and sieved to remove the minus 4.75 mm material. It is then dried to a constant mass and cooled in air until it is comfortable to handle. It is important to have the sample cooled since it can influence the results. Second, the sample is immersed in water for a period of 15 to 19 hours according to the AASHTO standard, or 24 ± 4 hours according to the ASTM procedure. Third, water is decanted, and the sample is rolled in an absorbent towel until all visible films of water are removed, which is defined as the saturated-surface-dry (SSD) condition. It is important that this step be performed consistently. Fourth, the mass of the SSD sample is taken in air, and the mass of the SSD sample is then immediately taken in water. Finally, the sample is dried and the mass of the dry sample is determined. Based on the three mass measurements, the volumes of the sample in SSD and oven-dry conditions are determined by the water displacement method, and the three specific gravities and water absorption of the aggregate are calculated. After the sample is prepared, sieved to remove the minus 4.75 mm material, and dried to constant mass, other steps (water immersion, determination of SSD condition, etc.) take more than one working day to complete.

While the standard test methods are relatively simple to conduct, they share several shortcomings in terms of subjectivity of measurements, precision, and time requirements for conditioning and testing, as follows (*9*):

- **Subjectivity and Precision –** The visual method of determining when aggregate particles have reached an SSD condition is subjective and, therefore, is a source of inconsistency among different operators. Some operators determine the SSD state based on the shine of the water film, while others

judge the condition based on a slight color change in the aggregate (*10*). The determination of the SSD condition is highly operator dependent, especially for highly absorptive aggregate. Thus, the mass of SSD sample and subsequent calculated specific gravity and absorption values are less repeatable and reproducible.
- **Time Requirement –** Both standard methods require more than one working day to complete when aggregate soaking time is included. This makes the test inefficient for quality control purposes, where results are desired as rapidly as possible.

AASHTO T 84 and ASTM C 128

AASHTO T 84 and ASTM C 128 describe procedures for testing fine aggregate. The two procedures are essentially the same except for the required aggregate soaking periods, which are the same as those specified in AASHTO T 85 and ASTM C127, respectively. Like the standard test methods for coarse aggregate, these standard test methods determine the volume of test sample using the water displacement method.

The procedures require the test sample be prepared, dried to constant mass, and cooled in air until it is comfortable to handle. The sample is then soaked in water for 15 to 19 hours according to AASHTO T 84 or 24 ± 4 hours according to ASTM C 128. After the soak time, water is decanted, and the sample is spread on a pan and exposed to a gentle current of warm air until approaching a free flowing condition. The sample is then lightly tamped into a cone-shaped mold with 25 light drops of the tamper. If the fine aggregate retains the molded shape when the mold is removed, the fine aggregate is assumed to have surface moisture and it is dried further. When the cone of fine aggregate just begins to slump upon removal of the mold, it is assumed to have reached the SSD condition. The SSD condition is difficult to determine when testing angular, high dust content, and/or highly absorptive fine aggregate materials. The volume of the SSD sample is then determined using a calibrated flask. Finally, the sample is dried, and the mass is determined in air. The mass and volume information is used to calculate the three specific gravities and water absorption of the aggregate. It takes more than a working day to complete a test after the sample of aggregate is prepared and dried.

Like the standard test methods for coarse aggregate, AASHTO T 84 and ASTM C128 share several shortcomings, as follows (*9*):
- **Subjectivity and Precision –** The cone and tamp technique specified in the standard methods is used with the assumption that the amount of slump of the fine aggregate is only dependent on the presence of surface moisture. However, research has shown that the amount of slump of the fine aggregate was not just dependent on the quantity of surface moisture but also upon the angularity and texture of the fine aggregate (*11*). In addition, the percentage of material passing the No. 200 sieve also influences the slump condition (*10*). Thus, this method does not work well when determining the SSD condition of angular and/or high dust content fine aggregates because they do not readily slump. Inaccurate determination of the SSD condition results in an inaccurate determination of SSD mass, which subsequently affects the accuracy and precision of the standard test methods.
- **Time Requirement –** Both standard test methods, including aggregate soaking time, cannot be completed in a working day. This makes the tests inefficient for quality control purposes.

Modified and New Test Methods for Determining Specific Gravity and Water Absorption of Coarse and Fine Aggregates

There are several modified and new test methods for determining the specific gravity and water absorption of coarse and fine aggregates. They range from simple modifications to procedures for determining the SSD state in the standard test methods to new test methods with more scientific and expensive devices. Brief descriptions of these test methods follow.

Modifications to Determination of SSD Condition in AASHTO T 84 and ASTM C 128

Most modifications to the AASHTO T 84 and ASTM C 128 have been taken in order to better pinpoint the SSD condition of fine aggregate. These modifications include:

- Alternative methods for establishing the SSD condition of fine aggregate proposed by Krugler et al. (*12*). They include (1) comparing the color of test sample with that of oven-dry sample, (2) using a tilted pan to determine the free-flow state of test sample, (3) using a tilted masonry trowel to determine if individual aggregate particles can flow off freely, and (4) using a water-soluble-glue tape to determine the surface dry state of fine aggregate. These methods are featured in Texas Department of Transportation (DOT) test procedure Tex-201-F, *Test Procedure for Bulk Specific Gravity and Water Absorption of Aggregate*. All procedures involve some subjectivity (*13*).
- Colorimetric procedure proposed by Kandhal and Lee (*14*). The procedure determines the SSD condition based on the color of aggregate dyed with a special chemical. The colorimetric procedure is an optional method for determining SSD condition of fine aggregate in ASTM C 128. The problems associated with this method are that the dyes do not show well on dark-colored aggregates and determination of the color change is subjective.
- Other research efforts in development of a method for detecting the SSD condition of fine aggregate include Hughes and Bahramian's saturated air-drying method (*15*), Saxer's absorption time curve procedure (*16*), and Martin's wet and dry bulb temperature method (*17*). These methods either offered little improvement or were impractical for implementation (*13*).

Modification to Materials Tested in AASHTO T 84 and ASTM C 128

Another modification to the standard test procedure for determining specific gravity and absorption of fine aggregate is not including the minus No. 200 material in the test sample. After the test sample is soaked as specified in the standard test methods, the sample of fine aggregate is washed over a No. 200 sieve. The portion of aggregate retained on the sieve is then placed in a pan and dried out to the SSD condition. After the sample reaches the SSD condition, it is then tested as specified in the standard test methods.

This modification would potentially improve the repeatability and reproducibility of the test methods for fine aggregate. Since the minus No. 200 material is removed from the fine aggregate in this technique, the specific gravity of the minus 200 has to be determined separately. Test methods for determining specific gravity of mineral fillers were investigated in NCHRP 09-45, *Test Methods and Specification Criteria for Mineral Filler Used in HMA*. The researchers for that study recommended determination of specific gravity of mineral fillers by the heliun pycmometer method in accordance with ASTM D5550-06, *Specific Gravity of Soil Solids by Gas Pycnometer* (*18*).

SSDrier Device for AASHTO T 84 and ASTM C 128

Dana and Peters (*19*) developed a method for determining the SSD state of fine aggregate using basic principles of thermodynamics. The method was further developed by Kandhal et al. (*13*) at the National Center for Asphalt Technology (NCAT). They then partnered with Gilson Company, Inc. (hereinafter referred to as Gilson) to manufacture the SSDrier device, shown in Figure C.1. The SSDrier unit is designed to pinpoint the SSD condition of fine aggregate using the humidity gradient approach. When a wet sample of aggregate is dried with hot air, the free water on the surface of the aggregate evaporates first, followed by the absorbed water. When there is surface water on the aggregate particles, the rate of evaporation increases until the free water on the surface is dried out, which results in a sudden drop in the rate of evaporation. Therefore, the sudden break point in the evaporation rate is used to determine the SSD condition of aggregate. The SSDrier test procedure includes the use of the SSDrier unit in conjunction with the AASHTO T 84 procedure.

After the test sample is prepared, oven-dried, and soaked according to AASHTO T 84, the water is decanted and the wet sample is placed in the rotating No. 200 mesh drum and dried with hot air that is dispersed evenly through the mesh at a constant temperature of 170°F. The amount of water added to the sample for the soak period of 15 to 19 hours is six percent (the minimum allowed by AASHTO T 84) to prevent the sample from sticking to the ends of the drum. Baker (*20*) reported that the loss of fines through the No. 200 mesh would not occur until after the sample was dried to the SSD condition. The SSDrier unit has sensors located in the outflow air duct to measure the outgoing relative humidity. The data are recorded using an external computer. The SSD condition is achieved when the humidity gradient of incoming and outgoing air drops suddenly. The mass of the SSD sample is then determined, and the following steps are conducted according to AASHTO T 84. One test requires approximately 1,300 grams of fine aggregate. The test takes two days—one day for soaking the sample and the other day for drying the wet sample using the SSDrier unit.

Figure C.1 SSDrier Device.

SSDetect System

This system is manufactured by Thermo Fisher Scientific, Inc. (hereinafter referred to as Thermo Fisher) and includes two parts: automatic volumetric mixer (AVM) and infrared units, as shown in Figure C.2. The AVM unit is used to remove entrapped air. The infrared unit is utilized to detect the SSD condition of the sample. A detailed test procedure is described in ASTM D 7172, *Standard Test Method for Determining the Relative Density (Specific Gravity) and Absorption of Fine Aggregates Using Infrared*. A brief description of the test procedure follows.

After the sample is prepared and dried to constant mass, the test is conducted in two steps. First, a dry sample of 500 ± 0.1 grams is poured into a calibrated 500 ml flask and covered with approximately 250 ml of water. A timer is started immediately after all the sample is poured into the flask and covered with water. After five minutes have elapsed, the flask is filled with water to the calibration mark and weighed. The flask is then agitated and vacuumed using the AVM unit for approximately 11 minutes. After the AVM unit has stopped, the flask is re-filled with water to the calibration mark and weighed. Based on the masses of the flask determined before and after the agitation and vacuum process, the film coefficient is determined, and it is used as a calibration factor for the infrared reflectance measurements to determine the SSD condition of the aggregate in the next step. The first step takes about 30 minutes.

For the second step, another dry sample of 500 ± 0.1 grams is placed in the mixing bowl provided in the infrared unit. The film coefficient determined in the previous step is keyed in the infrared unit. The

infrared unit is then started. It monitors moisture content using the infrared light source and detector while water is injected and mixed with the sample. Once the permeable pores of the aggregate have been filled, water begins to gather on the surface of the aggregate and absorb the infrared signal. Thus, the infrared detection device will no longer see the reflection of the infrared signal. The SSD condition of the aggregate is then recognized, and the infrared unit is automatically stopped. The mass of the sample in SSD condition is then determined. This step takes up to 1½ hours. Based on the masses of the dry sample, SSD sample, and flask filled with water, the three specific gravities and water absorption can be determined. One test can take up to two hours after the sample is prepared and dried.

Figure C.2 Automatic Volumetric Mixer and Infrared Units (Courtesy of Thermo Fisher Scientific).

AggPlus System Using CoreLok Device

InstroTek, Inc. (hereinafter referred to as InstroTek) developed a method using a combination of a calibrated pycnometer and the CoreLok vacuum-sealing device, as shown in Figure C.3. The method can determine the specific gravity and water absorption of coarse, fine, and combined aggregates.

A detailed proposed procedure for the AggPlus system using the CoreLok device (hereinafter referred to as the AggPlus system) in ASTM format is available (*21*). Method A is used for testing fine aggregate, and Method B is applied for coarse and combined aggregates. The two methods are essentially the same, except for the sample size. Method A requires two “small” samples of 500 ± 3 grams for the test in the pycnometer and one “large” sample of 1000 ± 5 grams for the vacuum saturation test. For Method B, two “small” samples of 1,000 ± 10 grams and one “large” sample of 2,000 ± 10 grams are required for the pycnometer test and the vacuum saturation test, respectively. A brief description of the test method follows.

The procedure includes several steps. First, all samples are dried to constant mass. For the bulk specific gravity test, a small test sample is placed into the calibrated pycnometer. The pycnometer is then filled with water and stirred to remove entrapped air. After that, the pycnometer is refilled and weighed. This process must be completed in less than two minutes so that water absorption into the pores of the aggregate can be kept at a minimum level, thus giving the volume of the aggregate and surface voids. The mass of the pycnometer filled with water, the mass of the dry aggregate, and the mass of the aggregate and pycnometer filled with water are determined to calculate the bulk specific gravity using the water displacement method.

Figure C.3 CoreLok Device and Calibrated Pycnometer.

To determine the apparent specific gravity, a large test sample is evacuated in the vacuum chamber inside a plastic bag. The bag is immediately placed in water, then cut for rapid saturation of the aggregate. The sample is left in water until the sample mass in water stays constant, and the mass is recorded. The dry mass and submersed mass of the sample are used for calculating of the apparent specific gravity.

Based on the bulk and apparent specific gravity values, the bulk specific gravity (SSD basis) and water absorption are calculated. All of the calculations can be done using the AggSpec software. One test can be done in approximately 30 minutes after the sample is prepared and dried to constant mass.

Rapid AASHTO T 85 Method with the CoreLok Device

This test method can be used to test coarse aggregate. The procedure is similar to that of AASHTO T 85, except that the CoreLok device is used to vacuum and rapidly saturate the aggregate. First, the oven-dry sample is placed in a plastic bag and evacuated using the CoreLok device. The bag is then immediately submersed and cut to rapidly saturate the aggregate. The AggPlus system is used to determine the apparent specific gravity. Once the mass of the sample is determined in water, the sample is removed. The sample is then dried to the SSD condition, as specified in the AASHTO T 85 method. Subsequently, the mass of the sample in SSD condition is determined. The sample is then dried to a constant mass and weighed. Finally, the three specific gravities and water absorption are determined according to AASHTO T 85. Like the AggPlus procedure described in the previous section, the test for one oven-dry test sample can be completed in approximately 30 minutes.

SG-5 Aggregate Specific Gravity and Absorption System

Gilson has developed the SG-5 system, as shown in Figure C.4, for determining the specific gravity and water absorption of coarse, fine and combined aggregates. It uses a proprietary dry gas displacement measuring system to measure the volume of the aggregate based on Boyle’s Law—the pressure and volume of an ideal gas trapped in an enclosure are inversely proportional if the temperature stays constant. The SG-5 system uses dry air and does not require expensive or consumable gas cylinders for operation. Two 3,000 gram samples of coarse, fine, or combined aggregate are required for a single test.

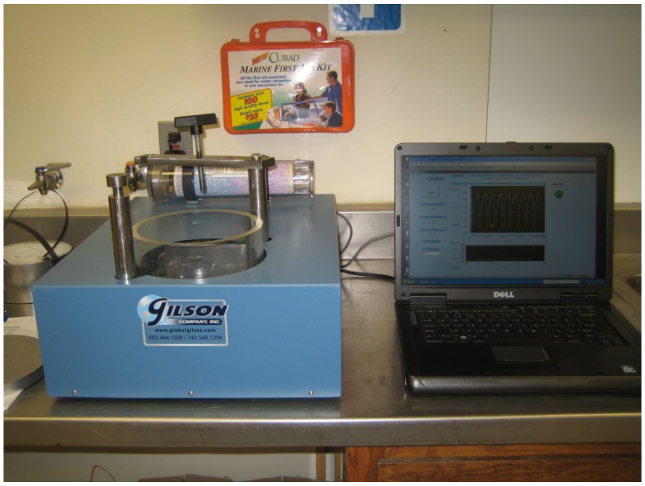


Figure C.4 SG-5 Aggregate Specific Gravity and Absorption System.

To test an aggregate sample, the sample is first dried to constant mass and poured in a calibrated thin-walled container. The container with the sample is then placed in a sealed chamber. Before the device starts, it prompts the user to enter the sample mass to the nearest 0.1 grams. The device then runs ten cycles of pressurization and de-pressurization of the sealed chamber to measure the volume of the sample. The device then automatically calculates and displays specific gravity and absorption results when the test is completed. One test takes approximately 20 minutes after the sample is prepared and oven-dried.

Volumetric Immersion Method Using Phunque Flasks

This test method measures specific gravity and absorption of coarse and fine aggregate using large volume flasks with calibrated long and small diameter necks, as shown in Figure C.5 (*22*). These flasks are available from Humboldt Manufacturing Company (hereinafter referred to as Humboldt). The procedure for coarse aggregate uses a flask that has a neck approximately two inches in diameter and requires an oven-dried test sample of 5,000 ± 50 grams. For fine aggregate, a flask with a neck approximately one inch in diameter is used with an oven-dried sample of 1,200 ± 50 grams. A detailed test method is presented in AASHTO TP 77, and a brief description of the method follows.

First, the flask is filled half-full with distilled water. The neck of the flask is dried, and the sample is poured into the flask as quickly as possible. The time starts when the first “stone” hits the water in the flask. More water is then poured into the flask up to a level that is high enough to allow for accurate readings while the water level drops to its anticipated final level. The flask is remained undisturbed, and the initial reading of water level is taken after 30 seconds. Then, the mass of flask, aggregate, and water is measured.

Figure C.5 Phunque Flasks for Determining Specific Gravity and Absorption of Coarse and Fine Aggregates (Courtesy of Humboldt Manufacturing Company).

The flask is then agitated for three minutes and then set undisturbed for two minutes. The next reading is recorded at five minutes. This step is repeated, and additional readings are taken at 10 minutes, 30 minutes, 60 minutes, 2 hours, 4 hours, and 25 ± 1 hours. Before each reading, the flask is agitated to release all of the air out of the sample and is allowed to settle for at least two minutes. The masses of flask, dry sample and water and the water level readings are then used to determine the three specific gravities and water absorption of the aggregate. One test can take at least 25 hours after the sample is prepared and dried. As shown in the draft test method, the water absorption determined from this test method for fine aggregate is lower than that of AASHTO T 84.

Summary

Table C.1 provides a list of test methods identified previously in this appendix for determining the specific gravity and water absorption of coarse, fine, and combined aggregates.

Table C-1. Test Methods for Determining Specific Gravity and Absorption of Aggregates

ID	Test Method	Equipment Vendor	Ruggedness of Equipment	Ease of Use	Time		Equip. Cost	Aggregate		
					Soaking	Testing		Fine	Crse	Comb.
1	AASHTO T85 / ASTM C127	Various	Very good	Manual	15 hours	30 min.	$100 ~ $600		√	
2	AASHTO T84 / ASTM C128	Various	Very good	Manual	15 hours	30 min.	$100 ~ $300	√		
3	Modifications to Determination of SSD Condition in AASHTO T84 / ASTM C128	Various	Good	Manual	15 hours	30 min.	Unknown	√		
4	Modification to Materials Tested in AASHTO T84 / ASTM C128	Various	Very good	Manual	15 hours	30 min.	$100 ~ $300	√		
5	SSDrier Device	Gilson	Good	Partially automated	15 hours	1 day	$4,500	√		
6	SSDetect System	Thermo Fisher	Good	Automated	None	2 hours	$7,056	√		
7	AggPlus System Using CoreLok Device	InstroTek	Good	Manual	None	30 min.	$7,840	√	√	√
8	Rapid AASHTO T85 with CoreLok Device	InstroTek	Good	Manual	None	30 min.	$6,860		√	
9	SG-5 Specific Gravity and Absorption System	Gilson	Good	Fully automated	None	20 min.	$4,500	√	√	√
10	Volumetric Immersion using Phunque Flasks	Humboldt	Good	Manual	None	25 hours	$1,000	√	√	√

Past Evaluations of Modified and New Test Methods for Determining Specific Gravity and Absorption of Aggregates

Recent studies have evaluated the AggPlus and SSDetect systems. Sensitivity analyses of impact of implementing these systems were also conducted relative to HMA specifications. Main findings from these studies are summarized in the following subsections. Since the methods with Gilson's SG-5, Humboldt's Phunque flasks, and rapid AASHTO T 85 with the CoreLok device are relatively new, evaluations of these methods have not been completed and/or reported at the time of this writing.

Past Evaluations of AggPlus System Using CoreLok Device

A number of investigators have attempted to evaluate the AggPlus system against the current AASHTO methods for determining specific gravity and absorption of coarse, fine, and combined aggregates.

In 2004, Hall (*23*) conducted a study in which the current standard test methods and the AggPlus system were used to measure the G_{sa}, G_{sb}, and absorption of coarse, fine, and combined aggregates. The testing materials included six coarse aggregates with absorption ranging from 0.3 to 2.1 percent, five fine aggregate sources with minus No. 200 material ranging from 0.1 to 25.6 percent, and ten combined aggregates. One operator conducted all testing of five replicates for each aggregate using the three test methods. He reported that the AggPlus system tended to produce higher G_{sb} results and underestimate the absorption of coarse aggregates tested. In addition, G_{sb} results for some fine aggregates determined using the AASHTO T 84 procedure and the AggPlus system were significantly different at the 95% confidence level.

In the same study, Hall also evaluated the relationships between the specific gravity and absorption values mathematically calculated using the AASHTO T 85 and AASHTO T 84 results and those of combined aggregate tested using the AggPlus system. The mathematically combined and directly measured values were not the same, but the relationships were consistent. Test results using the CoreLok system were not sensitive to nominal maximum aggregate size, gradation, or mineralogy. More effort was recommended to improve the test consistency and produce test results comparable to those resulting from the standard test methods if the results are to be used in existing specifications.

Another evaluation of the AggPlus system compared to the current standard test methods was performed by Sholar et al. (*11*). The test plan used 11 coarse aggregates with absorption ranging from 0.5 to 3.8 percent and seven fine aggregate types. One operator tested two replicates for individual aggregates using the three test methods. The main findings include:

- For the coarse aggregate materials, the AggPlus system produced higher G_{sb}, and the difference was greater for higher absorptive aggregates. The AggPlus system determined lower absorption values than did the standard method, and the difference was greater for high-absorptive aggregates (> 1.5 percent). The aggregate gradation did not have a significant effect on G_{sb} results. The repeatability of the AggPlus system was slightly better than the standard test method with respect to the bulk specific gravity.
- For the fine aggregates, the AggPlus and AASHTO T 84 methods had similar G_{sb} results for three low absorptive granite aggregates but different G_{sb} values for four high absorptive limestone aggregates. The AggPlus system produced slightly higher G_{sb} values for the granite aggregates and lower G_{sb} values for limestone aggregates. The repeatability of G_{sb} results using the AggPlus system was slightly better than that of AASHTO T 84.
- The difference in G_{sb} would result in a VMA change of 5.5 percent, which would make it impractical to use in existing HMA specifications.
- The researchers did not recommend the AggPlus system for use as a test procedure for determining the G_{sb} and absorption of aggregate in Florida.

In 2005, Mgonella (*24*) and Cross et al. (*25*) conducted a study to compare the AggPlus system to the AASHTO T 85 and AASHTO T 84 methods. The testing plan consisted of eight crushed coarse aggregates with absorptions ranging from 0.6 to 3.5 percent and 14 fine aggregates of various types, including limestones, sandstones, granites, rhyolites, and natural sands. The tests were performed by two operators to determine the interaction between the test methods and operators. The authors reported that:

- For the coarse aggregates, the G_{sb} determined using the AggPlus and AASHTO T 85 methods were statistically different. The AggPlus system tended to produce higher G_{sb} and lower absorption values. No interactions between G_{sb} values and operators were found. The two test methods had similar reproducibility. The AggPlus procedure was not recommended for replacement of AASHTO T 85.
- For the fine aggregate materials, the study indicated no significant difference in G_{sa}. However, the G_{sb} results using the AggPlus and AASHTO T 84 methods were statistically different, and the AggPlus system tended to produce higher G_{sb} values. The AggPlus system had a better repeatability than AASHTO T 84.

The AggPlus and AASHTO T 84 methods were also evaluated in a round-robin study conducted with 12 laboratories by Prowell and Baker (*26*) using six fine aggregate materials, including four crushed and two natural sources. The study found that the G_{sb} results using the two methods were statistically different for three of six aggregates, including limestone, washed diabase, and blast furnace slag. The AggPlus system produced lower absorption and higher G_{sb} values for two materials (washed diabase and diabase) that had dust contents of 7.5 percent and greater. However, it had higher absorption and lower G_{sb} results for other materials (limestone, slag, rounded natural sand and angular natural sand) with lower dust contents. The precision indices of the AggPlus system were not as good as those of AASHTO T 84. The authors suggested that the precision would be improved as technicians became more familiar with the AggPlus system.

Most recently, Bennert et al. (*27*) conducted a study that compared the AggPlus system to AASHTO T 84 using two operators and 11 fine aggregates, including six natural and five manufactured sands. The authors reported that the AggPlus system produced higher absorptions, which was a different finding from other studies. The G_{sb} results determined using the AggPlus system were statistically different from those of AASHTO T 84. The AggPlus system had a better repeatability when determining G_{sb}.

Past Evaluations of SSDetect System

Several studies have been conducted to evaluate the repeatability and reproducibility of the SSDetect system and compare results of the SSDetect system with those of AASHTO T 84.

In 2005, Prowell and Baker (*20*,*26*) conducted a round-robin study with 12 laboratories using four crushed and two natural fine aggregates. The authors reported that the G_{sb} results using the two methods were statistically different for three aggregates, including washed diabase, rounded natural sand, and angular natural sand. However, these differences were less than those between the AggPlus system and AASHTO T 84 results. Like the AggPlus system, the SSDetect system yielded lower absorption and higher G_{sb} values for washed diabase and diabase with more than 7.5 percent of dust. It produced higher absorption and lower G_{sb} results for limestone, slag, rounded natural sand, and angular natural sand that had lower dust contents. The precision of the SSDetect method was better than that of AASHTO T 84 and the AggPlus system.

In another study, Mgonella (*24*) and Cross et al. (*25*) found significant differences between the G_{sb} and absorption results determined by the SSDetect and AASHTO T 84 methods. In addition, the SSDetect method produced the highest G_{sb} results and the lowest water absorptions, followed by the AggPlus and AASHTO T 84. The higher G_{sb} values would result in a profound effect on HMA mixture properties.

There was no significant difference in the G_{sa} values. The SSDetect system has better reproducibility than the other two methods.

In 2005, Bennert et al. (*27*) evaluated the SSDetect system using 11 fine aggregates, including six natural and five manufactured sands. The materials are common sources for HMA and concrete mixtures in New Jersey. The authors reported that:

- The SSDetect system produces slightly higher water absorptions as well as lower G_{sb} and G_{sa} results than AASHTO T 84; however, the differences are less than those between the AggPlus and AASHTO T 84 methods.
- The SSDetect has the best repeatability among the test methods (SSDetect, AggPlus system, and SSDrier) evaluated in the study.

Most recently, You et al. (*28*) evaluated the SSDetect system using 17 fine aggregate gradations made from natural sand, crushed sand, and steel slag. They found that the SSDetect system proved to have a better precision compared to AASHTO T 84. They also reported that G_{sb} and G_{sb}(SSD) results from the SSDetect and AASHTO T 84 methods were not significantly different; however, G_{sa} results determined using these methods were statistically different.

Evaluation of SSDrier Test Procedure

In 2000, Kandhal et al. (*13*) at NCAT developed the SSDrier device based on basic principles of thermodynamics studied by Dana and Peters (*19*). While the method shows promise, more effort was recommended by the authors to improve the repeatability and reproducibility of the test procedure.

In 2005, Baker (*20*) evaluated the SSDrier device using seven fine aggregate materials and reported that the SSDrier test procedure produced results comparable to those of AASHTO T 84 for clean natural sands. However, the results were more variable than those determining using AASHTO T 84, especially for crushed sands with more than five percent dust.

Bennert et al. (*27*) evaluated the SSDrier test procedure using 11 fine aggregates commonly used in New Jersey. Compared to the AggPlus and SSDetect systems, the SSDrier test procedure produced test results that more closely matched those determined according to AASHTO T 84. However, the SSDrier test procedure had the poorest repeatability among the test methods evaluated in the study.

Summary

This section summarizes the main findings from the past evaluations of the AggPlus system, SSDetect system, and SSDrier device. For the AggPlus system, the results can be summarized as follows:

- The AggPlus system offers significant time savings because it does not require overnight soaking.
- The G_{sb} and absorption results determined using the AggPlus system were statistically different from those of the AASHTO test methods.
- These studies reported mixed results regarding the repeatability and reproducibility of the AggPlus system compared to the current standard test methods (AASHTO T 85 and AASHTO T 84).
- Most studies recommended that the AggPlus system not be used for determining specific gravity and absorption of coarse and fine aggregates in existing HMA specifications because of the differences in the measured G_{sb}. In one study (*11*), the authors reported that the difference in G_{sb} would result in a VMA change up to 5.5 percent if the AggPlus system was used in existing HMA specifications.

With regard to the SSDetect system, the results can be summarized as follows:

- The SSDetect offers significant time savings.

- The SSDetect system had better precision than the AggPlus system and AASHTO T 84 methods.
- Specific gravity and absorption results determined using the SSDetect and AASHTO T 84 methods were statistically different for some fine aggregates. However, these differences were less than those between the AggPlus and AASHTO T 84 test methods.
- The SSDetect has a more scientific approach to determining specific gravity and absorption of fine aggregate compared to the AASHTO T 84 and AggPlus methods. Thus, it is a more desirable procedure.

For the SSDrier device, the test results more closely matched those determined according to AASHTO T 84. However, the SSDrier test procedure had the poorest repeatability among the test methods evaluated (AASHTO T 84, AggPlus, SSDetect, and SSDrier).

Summary of Findings of Task 1

Tables C.2 through C.4 provide comparisons of test methods for determining the specific gravity and absorption capacity of coarse, fine, and combined aggregate, respectively, based on the information presented in previous sections. These test methods were compared in terms of precision, ruggedness of equipment, ease of use, soaking and testing time, equipment cost, and potential problems or problematic materials.

As mentioned in Section 2.4.2, NCHRP Project 09-45, *Test Methods and Specification Criteria for Mineral Filler Used in HMA*, investigated several methods for determining specific gravity and absorption of mineral fillers. The researchers selected the helium pynometer method conducted in accordance with ASTM D5550-06 due to its simplicity, repeatability and familiarity of the method by the FHWA technical staff (*18*).

Although the NCHRP panel requested that the Automatic Dry Pycnometer (ADP) developed by Troxler Electronic Laboratories, Inc. be added to the amplified working plan, the research team was unable to get any information from Troxler about the ADP test procedure. Similarly, the SG-5 system developed by Gilson was also added to the amplified working plan per the panel's request. However, Gilson was unable to complete internal development work and did not provide the SG-5 in time for the NCHRP 4-35 evaluation.

It was thought that both ADP and SG-5 system would use a similar approach based on Boyle's Law, as described in Section 2.4.7, to measure the volumes of aggregate. This approach utilizes air instead of water to measure the volumes of oven-dried aggregate solids and surface voids of oven-dried particles to calculate specific gravity and absorption of aggregate. It was felt that this approach could accurately measure the volume of oven-dried solids, but it would have difficulty determining the surface voids of oven-dried particles.

Table C-2. Comparison of Test Methods for Determining Specific Gravity and Absorption of Coarse Aggregate

ID	Test Method	Vendor	Precision	Ruggedness of Equipment	Ease of Use	Time		Eqmt. Cost
						Soak	Test	
1	AASHTO T 85 and ASTM C 127	Various	Standard	Very good	Manual	15 hrs	30 min.	$100 ~ $600
2	AggPlus System using CoreLok Device	InstroTek	Mixed results	Good	Manual	None	30 min.	$7,840
3	Rapid AASHTO T 85 with the CoreLok	InstroTek	Unknown	Good	Manual	None	30 min.	$6,860
4	SG-5 Specific Gravity and Absorption System	Gilson	Unknown	Good	Fully automated	None	20 min.	$4,500
5	Volumetric Immersion using Phunque Flasks	Humboldt	Unknown	Good	Manual	None	25 hrs	$500

Table C-3. Comparison of Test Methods for Determining Specific Gravity and Absorption of Fine Aggregate

ID	Test Method	Vendor	Precision	Ruggedness of Equipment	Ease of Use	Time		Eqmt. Cost
						Soak	Test	
1	AASHTO T 84 and ASTM C 128	Various	Standard	Very good	Manual	15 hrs	30 min.	$100 ~ $300
2	Modifications to Determination of SSD Condition in AASHTO T 84 / ASTM C 128	Various	Worse	Good	Manual	15 hrs	30 min.	Unknow
3	Modification to Materials Tested in AASHTO T 84 / ASTM C 128	Various	Better	Very good	Manual	15 hrs	30 min.	$100 ~ $300
4	SSDrier Device	Gilson	Worse	Good	Partially automated	15 hrs	1 day	$4,500
5	SSDetect System	Thermo Fisher	Better	Good	Automated	None	2 hrs	$7,056
6	AggPlus System using CoreLok Device	InstroTek	Mixed results	Good	Manual	None	30 min.	$7,840
7	SG-5 Specific Gravity and Absorption System	Gilson	Unknown	Good	Fully automated	None	20 min.	$4,500
8	Volumetric Immersion using Phunque Flasks	Humboldt	Unknown	Good	Manual	None	25 hrs	$500

Table C-4. Comparison of Test Methods for Determining Specific Gravity and Absorption of Combined Aggregate

ID	Test Method	Vendor	Precision	Ruggedness of Equipment	Ease of Use	Time		Eqmt. Cost
						Soak	Test	
1	AggPlus System using CoreLok Device	InstroTek	Unknown	Good	Manual	None	30 min.	$7,840
2	SG-5 Specific Gravity and Absorption System	Gilson	Unknown	Good	Fully automated	None	20 min.	$4,500
3	Volumetric Immersion using Phunque Flasks	Humboldt	Unknown	Good	Manual	None	25 hrs	$1,000

Table C-5. Results of Task 1 Ballot (Courtesy of NCHRP)

ID	Test Method	Select for Evaluation?			Test for Ev
		Yes	No	%Yes	
I. Test Methods for Determining Specific Gravity and Absorption of Coarse Aggregate					
I-1	AASHTO T 85 and ASTM C 127	7	2	78	
I-2	AggPlus System using CoreLok Device	2	7	22	
I-3	Rapid AASHTO T 85 with the CoreLok	7	2	78	
I-4	SG-5 Specific Gravity and Absorption System	7	2	78	
I-5	Volumetric Immersion using Phunque Flasks	5	4	56	
II. Test Methods for Determining Specific Gravity and Absorption of Fine Aggregate					
II-1	AASHTO T 84 and ASTM C 128	7	2	78	
II-2	Modifications to Determination of SSD Condition in AASHTO T 84 / ASTM C 128	2	7	22	
II-3	Modification to Materials Tested in AASHTO T 84/ASTM C 128	8	1	87	
II-4	SSDrier Device	4	5	44	
II-5	SSDetect System	9	0	100	
II-6	AggPlus System using CoreLok Device	2	7	22	
II-7	SG-5 Specific Gravity and Absorption System	7	2	78	
II-8	Volumetric Immersion using Phunque Flasks	8	1	89	
III. Test Methods for Determining Specific Gravity and Absorption of Combined Aggregate					
III-1	AggPlus System using CoreLok Device	3	6	37	
III-2	SG-5 Specific Gravity and Absorption System	7	2	78	
III-3	Volumetric Immersion using Phunque Flasks	7	2	78	

APPENDIX D

Testing Results of Experiment 1

Gradations and Consensus Properties

Table D-1. Gradations of Coarse Aggregate Materials Tested in Experiment 1

Sieve Size (in.)	Sieve Size (mm)	Percent Passing Columbus Granite	 Elmore Gravel	 Florida Limestone
2"	50	100	100	100
1-1/2"	37.5	100	100	100
1"	25	97	100	100
3/4"	19	92	100	100
1/2"	12.5	60	65	87
3/8"	9.5	24	24	53
#4	4.75	3	3	10
#8	2.36	2	1	7
#16	1.18	2	1	7
#30	0.6	2	1	6
#50	0.3	1	0	6
#100	0.15	1	0	6
#200	0.075	0.9	0.2	5.7

Table D-2. Gradations of Fine Aggregate Materials Tested in Experiment 1

Sieve Size (in.)	Sieve Size (mm)	Percent Passing Ottawa Sand	 Natural Sand	 Limestone Screening	 Granite Screening
2"	50	100	100	100	100
1-1/2"	37.5	100	100	100	100
1"	25	100	100	100	100
3/4"	19	100	100	100	100
1/2"	12.5	100	100	100	100
3/8"	9.5	100	100	100	100
#4	4.75	100	99	94	99
#8	2.36	100	89	68	84
#16	1.18	100	70	44	66
#30	0.6	100	40	29	50
#50	0.3	27	9	19	35
#100	0.15	1	2	11	22
#200	0.075	0.4	0.7	8.0	13.5

Table D-3. Angularity of Fine Aggregate Materials Tested in Experiment 1

	Uncompacted Voids (%)			
Replicate	**Ottawa Sand**	**Natural Sand**	**Limestone Screening**	**Granite Screening**
1	44.26	47.08	45.44	49.31
2	44.41	46.45	46.22	48.02
3	44.26	46.60	46.00	48.63
Average	44.31	46.71	45.89	48.65

Table D-4. Gradations of Combined Aggregate Materials Tested in Experiment 1

Sieve	Sieve	Percent Passing		
Size (in.)	**Size (mm)**	**50% Granite Coarse 50% Ottawa Sand**	**60% Gravel 40% Natural Sand**	**60% Limestone Coarse 40% Granite Screening**
2"	50	100	100	100
1-1/2"	37.5	100	100	100
1"	25	99	100	100
3/4"	19	96	100	100
1/2"	12.5	80	79	92
3/8"	9.5	62	54	72
#4	4.75	51	41	46
#8	2.36	51	36	38
#16	1.18	51	28	30
#30	0.6	51	16	24
#50	0.3	14	4	18
#100	0.15	1	1	12
#200	0.075	0.6	0.4	8.8

Results of Petrographic Examination

The petrographic examination of the aggregate materials used in Experiment 1 was conducted by Dr. Mark G. Steltenpohl at the Department of Geology and Geography of Auburn University in accordance with ASTM Method C-295, *Standard Guide for Petrographic Examination of Aggregates for Concrete*. The examination was conducted for granite, gravel, and limestone coarse aggregates and natural sand. Results of the petrographic examination are provided in the following subsections.

Results of Petrographic Examination for Granite Materials

A sample of #67 crushed granite aggregate from Vulcan Materials Barin Quarry, Columbus, Georgia, that had been screened and separated into four size fractions, 1” x ¾”, ¾” x ½”, ½” x ⅜”, and ⅜” x #4 (Figures D-1 to D-4), was used in this examination.

An initial examination with a stereomicroscope was conducted to determine if any deleterious materials that could be removed by washing were present. Each size fraction was then washed, dried, and reexamined visually with a stereomicroscope. Each size fraction was separated into lithologies based on rock type, mineralogy, and texture. Photomicrographs were taken of distinctive features (Figures D-5 through D-7). Representative photographs of each lithology were taken (Figures D-8 to D-10). The weight percentage of each lithology by size fraction was calculated as well as the weight percent by entire sample. Lithologic descriptions and the percentages are shown in Table D-5. Qualitative estimates of volumetric abundances of minerals in class decrease from left to right as stated.

The sample, as received, was coated with light gray dust of fracture. The #67 crushed granite aggregate consists of hard, tough, dense, smooth to rough, durable particles. The sample was

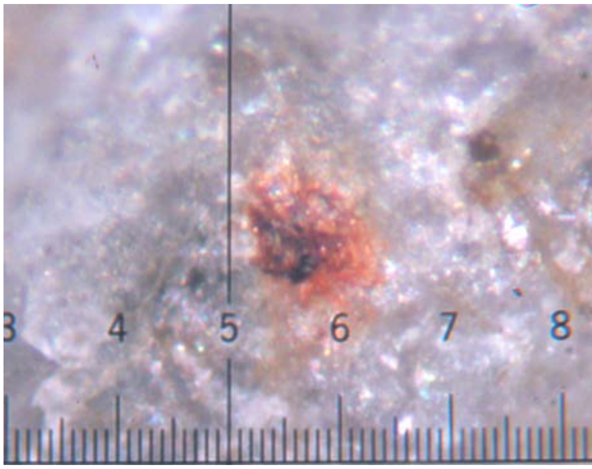
dominated by massive to banded migmatitic gneiss with lesser amounts of felsic and/or mafic material derived from thicker bands (some at least 1.5 cm thick) of the leucosomal and melanosomal layers (bands), respectively. Mineralogy is quartz, feldspar (K-spar dominating in felsic lithology and plagioclase dominating the mafic one), biotite, amphibole (the former two become progressively more abundant from the felsic to the mafic lithologies), with trace titanite, apatite, and magnetite. Weathered rock particles constituted <0.5% of the sample. Some scattered iron staining was observed, mostly in association with magnetite, but the small quantity present should have no impact on quality. Biotite content is lowest in the felsic particles (~2-3% but progressively increases toward the mafic lithology (as high as ~35%); free fragments of biotite broken from particles were observed in most all fractions; durability of the particles, thus, appears to decrease with increasing biotite content. Otherwise, no deleterious constituents were observed. Grains are interlocked in a strong crystalline texture. The results of this petrographic examination indicate the granite is of good quality for use as a construction material.

Figure D-1. 1" x ¾", As Received and Before Washing.

Figure D-2. ¾" x ½", As Received and Before Washing.

Figure D-3. ½" x ⅜", As Received and Before Washing.

Figure D-4. ⅜" x #4, As Received and Before Washing.



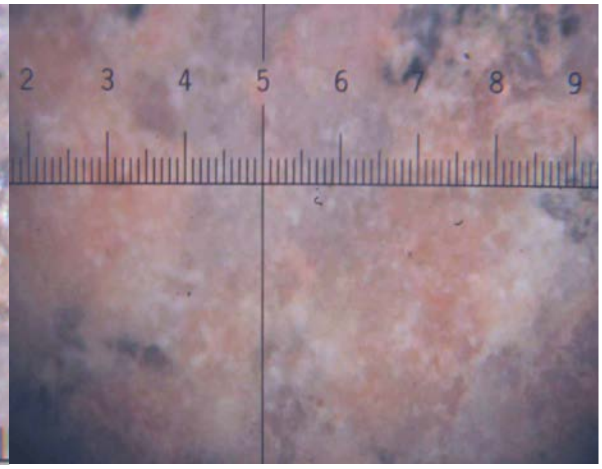


Figure D-5. Photomicrograph of Magnetite (Black) Inclusion Within Quartz Displaying Reddish Colored Staining of Oxidation. Photographed at 3X Such That Integer Scale Increments Are ~0.27 mm.

Figure D-6. Photomicrograph of Salmon Colored, Altered, K-Feldspar in Felsic Lithology. Photographed at 4X Such That Integer Scale Increments Are ~0.2 mm.

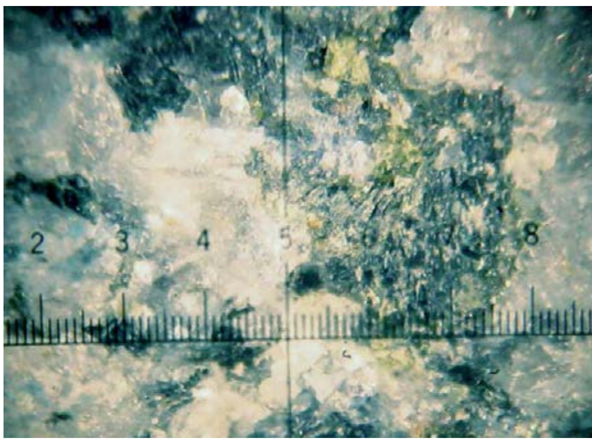


Figure D-7. Microphotograph of a Cluster of Epidote Group Minerals (Pale Green: The Minor Pinkish Stains Likely Result from Alteration of Magnetite) along Periphery of Amphibole (Black) in Intermediate Lithology. Plagioclase (White) and Quartz (Clear) Form The Groundmass. Photographed at 4X Such That Integer Scale Increments Are ~0.2 mm.

Figure D-8. Felsic Lithology, ¾" x ½" Fraction.

Figure D-9. Intermediate Lithology, ¾" x ½" Fraction.

Figure D-10. Mafic Lithology, ¾" x ½" Fraction.

Table D-5. Lithologic Descriptions of the Sample and Calculated Weight Percentages Present in Each Size Fraction and the Weight Percent Present in the Total Sample

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.				WT. % AV.
	¾"	½"	⅜"	#4	
Felsic rock – (Figures D-5, D-6, and D-8) White to light gray, extremely coarsely crystalline (<7.5 mm), massive to weakly foliated granite leucosomal (felsic layer) material from a migmatite (mixture of igneous and metamorphic rock). Rock is spotted with tiny flecks (0.7-0.2 mm) of black to brown biotite, minor (<1% by volume) titanite (brown transluscent, high-resinous luster, wedge-shaped crystals), apatite (<0.5%; greenish brown, translucent, subhedral to anhedral, prismatic crystals), and less abundant (<0.1%) magnetite (opaque, <0.1 mm, with reddish stains due to oxidation; Figure D-5). Rare (<0.1%) clusters of rounded, pale greenish grains (epidote group mineral) are associated with tiny, 10 μ transparent mica. Groundmass comprises potassium feldspar (white, <7.5 mm, two cleavages at ~90^o), plagioclase feldspar (transparent to milky white, <8 mm, striations, two cleavages at ~90^o); quartz (clear, concoidal fractures), and biotite (black to brown, <0.7 mm, platy, one-direction cleavage). In some clasts potassium feldspar has a salmon pink coloration (Figure D-6). Grains are interlocking. The particles are subangular, cubical, with some flattened and elongated ones; the abundance of flattened and elongated particles does not appear to be related to increased mica content. The particles are hard and durable with a rough texture.	23.0	21.1	18.0	17.1	19.8

Table D-5. Continued

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.				WT. % AV.
	¾"	½"	⅜"	#4	
Intermediate rock – (Figure D-9) White to light gray, spotted, extremely coarsely crystalline (<6.5 mm), massive to strongly foliated granite and granitic gneiss, the latter containing mixed leucosomal (felsic layer) and melanosomal (mafic layer) parts of a migmatite. Minerals in this lithology are identical to those described for the felsic lithology with the following exceptions being that the intermediate lithology contains amphibole, has a higher proportion of biotite, and has a higher proportion of plagioclase relative to K-feldspar. Very coarse grained, black amphibole (hornblende) grains are up to 2.9 mm in length (two cleavages at 60^o and 120^o), and contain numerous inclusions of mostly quartz and plagioclase, but minor (<1% by volume) titanite (brown transluscent, high-resinous luster, wedge-shaped crystals), rare (<0.1%) pale greenish grains (<0.3mm epidote group mineral), and even less abundant (<0.1%) magnetite (opaque, <0.1 mm, with reddish stains due to oxidation) may also occur as inclusions or in clusters around the periphery of amphiboles (Figure D-7). Many intermediate particles have distinct dark and light colored mineral segregations defining gneissic bands. In these segregations the lighter bands are essentially the felsic lithology and the darker bands the mafic lithology described above and below, respectively. Grains are interlocking. Particles are subangular, cubical, with some flattened and elongated ones, and they are hard and durable with a smooth to rough texture.	64.3	70.9	76.2	77.6	72.3
Mafic rock – (Figure D-10) Medium to dark gray; very coarsely crystalline (<1.25 mm), weakly-to-well foliated melanosomal (mafic layer) migmatitic gneiss. Rock may be spotted with white to transparent feldspar grains (generally 0.9 mm but up to 7 mm); finer grained particles have a distinct salt-and-pepper appearance. Black to brown biotite predominates, may be up to 3 mm, and many grains are bent and kinked. Very coarse, black amphibole (hornblende) grains are abundant and up to 2.8 mm in length (two cleavages at 60^o and 120^o). Biotite and amphibole are set in a groundmass of plagioclase feldspar (transparent to milky white, <8 mm, striations, two cleavages at ~90^o) and quartz (clear, concoidal fractures); potassium feldspar (white, <7.5 mm, two cleavages at ~90^o) is only a very minor volumetric phase. Grains are mostly interlocking. Minor (<0.1%) magnetite (opaque, <0.1 mm) have reddish stains due to oxidation surrounding them. This lithology is generally finer grained than felsic and intermediate lithologies. The particles are subangular and tabular (coplanar with the gneissic foliation) and few are elongated; flattened and elongated particles have higher biotite content. The particles are hard and durable (though less durable than the felsic and intermediate lithologies due to relatively high biotite content) with a moderately smooth texture.	12.7	8.0	5.8	5.3	8.0

Results of Petrographic Examination for Gravel Materials

A sample of natural gravels from the Elmore Sand & Gravel Company, Elmore, Alabama, that had been screened and separated into three size fractions, ¾" x ½", ½" x ⅜", and ⅜" x #4 (Figures D-11 to D-13), was used in this examination.

An initial examination with a stereomicroscope was conducted to determine if any deleterious materials were present that could be removed by washing. Each size fraction was then washed, dried, and reexamined visually and with a stereomicroscope. Each size fraction was separated into lithologies based on rock type, mineralogy, and texture. Photomicrographs were taken of distinctive features (Figures D-15 through D-17). Representative photographs of each lithology

were taken (Figures D-11 to D-14, D-18, and D-19). The weight percentage of each lithology by size fraction was calculated as well as the weight percent by entire sample. Lithologic descriptions and the percentages are shown in Table D-6. Qualitative estimates of volumetric abundances of minerals in class decrease from left to right as stated.

The natural gravels comprise hard, tough, dense, generally durable particles. The sample, as received, was coated with light olive gray dust of fracture. The sample consisted of varying proportions of quartz, chert, and igneous and metamorphic rocks. Weathered rock particles constituted <0.5% of the sample. Chert composed 7.5% of the total sample by volume with about 75% of that percentage being porous lightweight chert; no thin sections were supplied so it was not possible to evaluate porosity and permeability in the interior of the particles. No ‘soft’ particles (e.g., shale) are present. Some very scattered iron staining was observed but the small quantity present will have no impact on quality. Very minor amounts of finely crystalline to aphanocrystalline muscovite, graphite, biotite, and hornblende were observed in some igneous and metamorphic particles but no free grains were observed. No other deleterious materials were observed. The results of this petrographic examination of the submitted sample indicate the natural gravels are of good quality for use as a construction aggregate.

Figure D-11. ¾” x ½”, As Received and Before Washing.

Figure D-12. ½” x ⅜”, As Received and Before Washing.

Figure D-13. ⅜" x #4, As Received and Before Washing.

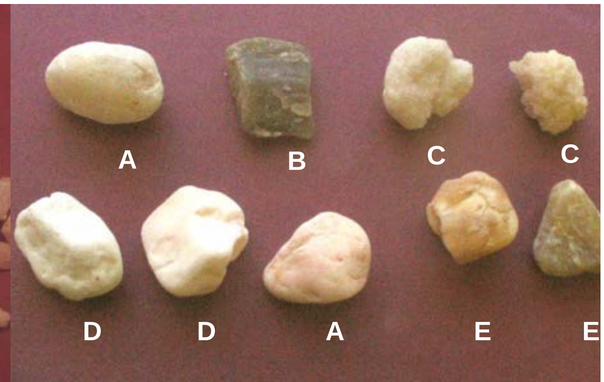


Figure D-14. Photograph Displaying Textural Varieties of Particles (½"X ⅜"): A. Smooth, Rounded And Slightly Frosted Quartzite; B. Subangular, Vitreous, Marbled Metamorphic Quartzite; C. Rough, Weakly Cemented Quartz Arenite; D. Subrounded Powdery White Chert (Note Pitted Surface on Left Hand Particle); E. Subrounded to Subangular Quartzite.

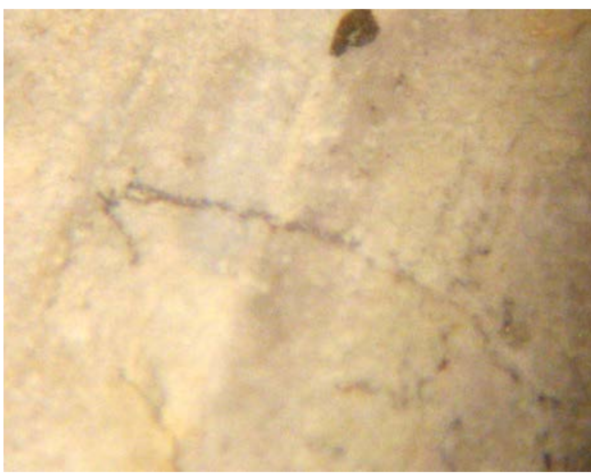


Figure D-15. Photomicrograph of Chert (Darker Gray Bands) and Aphanocrystalline Quartz. Silver Scratch Marks Left by Metal Pen with a Moh's Hardness of 4.5-5.0). Field of View is 2 mm.

Figure D-16. Photomicrograph of Bedding-Parallel Vug Filled With Botryoidal Chert within Quartzite. Field of View is 2.5 mm.

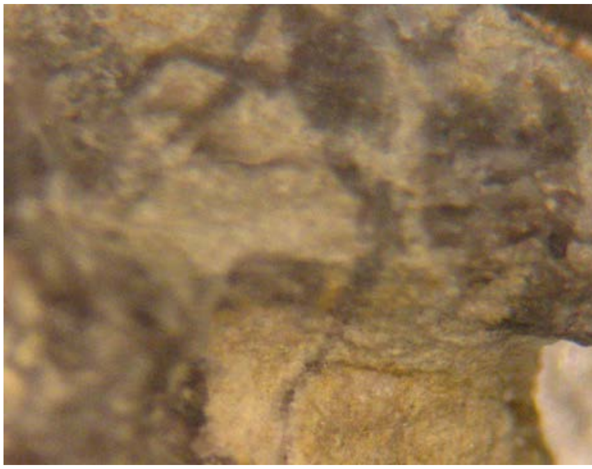


Figure D-17. Photomicrograph of Brecciated Quartzite (Light Gray Tan Stained) and Veined with Chert (Darker Gray). Field of View is 5 mm.

Figure D-18. Quartz and Quartzite Fraction (½" x ⅜").

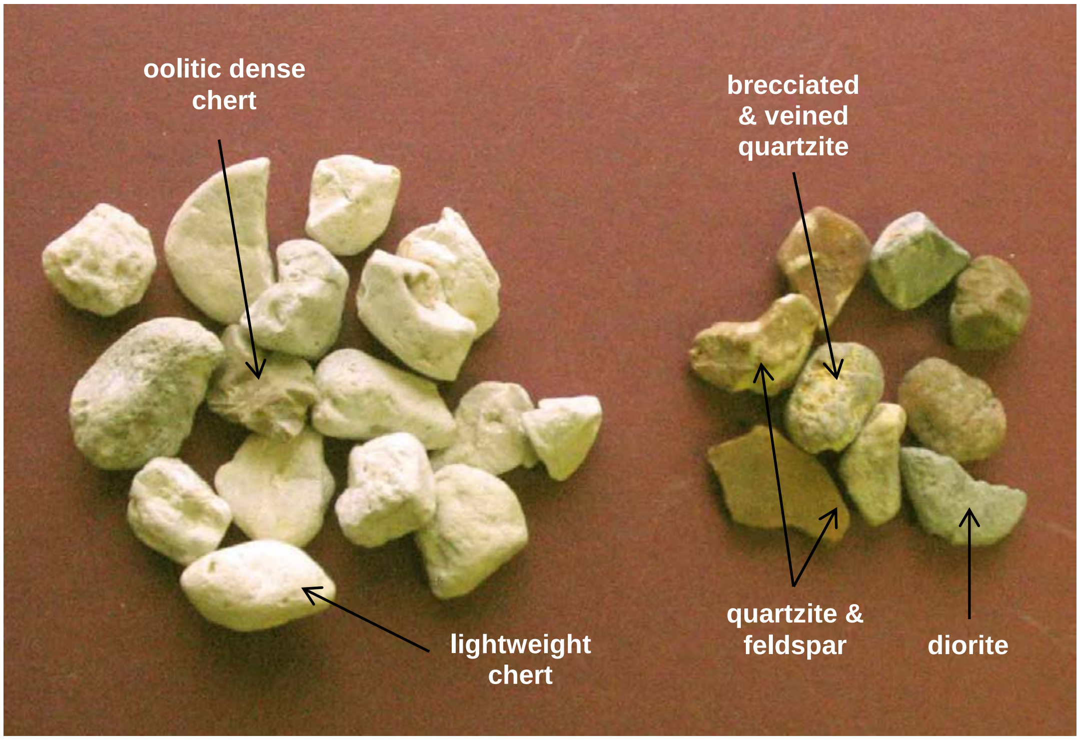


Figure D-19. Chert (Left) And Igneous & Metamorphic (Right) Fractions (½" x ⅜").

Table D-6. Lithologic Descriptions of the Sample and Calculated Weight Percentages Present in Each Size Fraction and the Weight Percent Present in the Total Sample

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.			WT. % AV.
	½"	⅜"	#4	
Quartz – (Figures D-14 and D-18) Two varieties of quartz particles are present - metamorphic 'vein' quartz has an interlocking crystalline texture whereas quartzite (meta-quartz arenite) and quartz arenite have indistinctly rounded to subrounded detrital grains that are mostly tightly cemented by aphanocrystalline quartz. Particles are white, light pink, tan, very light gray to brownish gray with some scattered moderate reddish orange staining (Figure D-18). Most are frosted but some gray to brown, clear, glassy particles; the clear, glassy quartz is probably derived from mechanical breakdown of igneous and metamorphic rocks. Some quartz particles contain very minor and very finely crystalline inclusions of biotite, graphite, and magnetite. Particles are rounded to well-rounded with a few angular ones, and are spherical to flattened (Figures D-14 and D-18). Quartz arenite particles have rounded, <0.5 mm grains cemented by silica. The particles are hard, durable, dense, and tough. A small proportion (~9%) of quartzite particles are very rough (Figure D-14C) and less durable due to weaker silica cements (no carbonate was detected from 10% HCl).	83.8	91.2	90.3	88.4

Table D-6. Continued

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.			WT. % AV.
	½”	⅜”	#4	
Chert – (Figures D-15 – D-17 and D-19) White to dark gray to medium brown (Figure D-19); dense chert is only weakly pitted and may contain oolites and fossil fragments (i.e., silicified limestone, though 10% HCl did not reveal any remaining carbonate); lightweight chert is white with moderate degrees of pitting along rims but dense reddish brown cores are not pitted; lightweight chert particles content of the sample is estimated at about 75% of total chert content but this estimate is based only on surface features; subangular to rounded with dense chert being more angular than lightweight chert (Figure D-19); spherical to flattened with porous lightweight chert tending to be rounded while denser darker colored chert is more blocky (Figures D-14D and D-19). Some chert particles are distinctly banded with thin (<0.2 mm) darker gray bands (Figure D-15); others are brecciated with numerous veins. Powdery white, bulbous, botryoidal masses of chert formed in vuggy openings within quartzite (Figure D-16). These chert particles are subrounded and have a powdery, slightly slippery feel though hardness is above 6 on the Moh’s scale. The particles are generally hard, durable, dense to slightly porous, and tough.	10.4	5.8	6.2	7.5
Igneous and Metamorphic Rocks – (Figure D-19) Igneous rock particles are: medium gray to greenish gray, fine- to coarse-grained, composed of quartz, feldspar, biotite, muscovite, hornblende, and trace magnetite (diorite); red brown, quartz and K-feldspar (granitoidal); and a few particles are weathered to a light brownish gray color. Metamorphic particles are quartzite but they contain higher volumes and larger grains of muscovite, biotite, and magnetite than the more homogeneous quartzite particles partitioned into the quartz lithology described above. Likewise, some quartzite particles in this lithologic category are ‘marbled’ into a linear (stretching) metamorphic (deformational) texture (Figure D-14B), and some are brecciated and veined with more finely crystalline quartz or chert (Figure D-17). Particles are subangular to rounded with coarser-grained particles becoming angular; spherical to flattened parallel to metamorphic foliation. Particles are hard, dense, and durable.	5.8	3.0	3.4	4.1

Results of Petrographic Examination for Limestone Materials

A sample of #67 crushed limestone aggregate from a CEMEX quarry in Brooksville, Florida, that had been screened and separated into three size fractions, ¾” x ½”, ½” x ⅜”, and ⅜” x #4 (Figures D-20 to D-22), was used in this examination.

An initial examination with a stereomicroscope was conducted to determine if there were any deleterious materials that could be removed by washing. Each size fraction was then washed, etched in a solution of 20% hydrochloric acid for 30 seconds to facilitate identification of rock and mineral types and textural features, rinsed, dried, and reexamined visually with a stereomicroscope. Each size fraction was examined to separate lithologies based on rock type, mineralogy, fossil content, and texture. Photomicrographs were taken of distinctive features (Figures D-23 – D-33). Representative photographs of each lithology were taken (Figures D-20 through D-23, D-32, and D-33). The weight percentage of each lithology by size fraction was calculated as well as the weight percent by entire sample. Lithologic descriptions and the percentages are shown in Table D-7. Carbonate classification scheme used is that of Folk (1962).

The sample, as received, was coated with white to light tan dust of fracture. The #67 crushed limestone aggregate was of rather homogeneous mineralogy and fossil types. Lithologies vary broadly, however, in texture. Particles of the dense biosparite lithology are dense, hard, tough, smooth to slightly rough, and durable. Lightweight biosparite is distinctly softer (scratched with my fingernail), more porous, less indurated, and less durable. ‘Intermediate’ biosparite ranges between the dense and lightweight litologies. A minor proportion of chert was noted in the sample but they are present in such small amounts that they should not present problems with

quality. No shale or other deleterious constituents were observed. All particles contain evidence for original textures.

The results of this petrographic examination indicate the crushed limestone may be of sufficient quality for use as a coarse aggregate; appropriate LA abrasion numbers would be needed but I was not supplied with any test information on the aggregate when this report was written. The lightweight biosparite fraction may present problems given its relative softness and high degree of surficial porosity; internal porosity and permeability were indeterminate because no thin sections were supplied.

Figure D-20. ¾" x ½", After Washing.

Figure D-21. ½" x ⅜", After Washing.

Figure D-22. ⅜" x #4, After Washing.

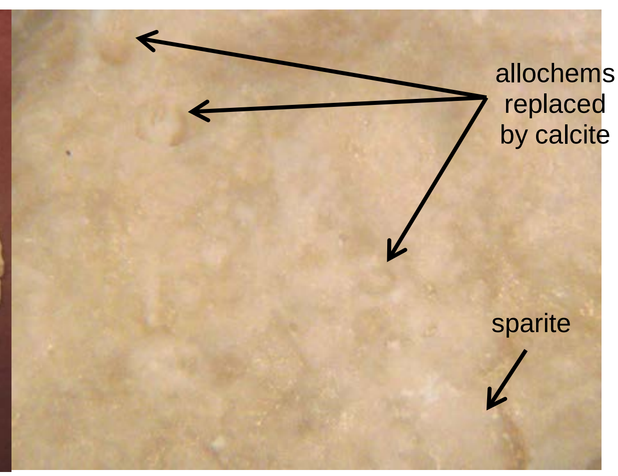


Figure D-23. Photomicrograph of Dense Biosparite. Field of View is 3 mm.

Figure D-24. Photomicrograph of Dense Pelloidal Biosparite. Field of View is 7 mm.

Figure D-25. Photomicrograph of Dense Biosparite. Allochems are Replaced by Sparite. Field of View is 2.5 mm.

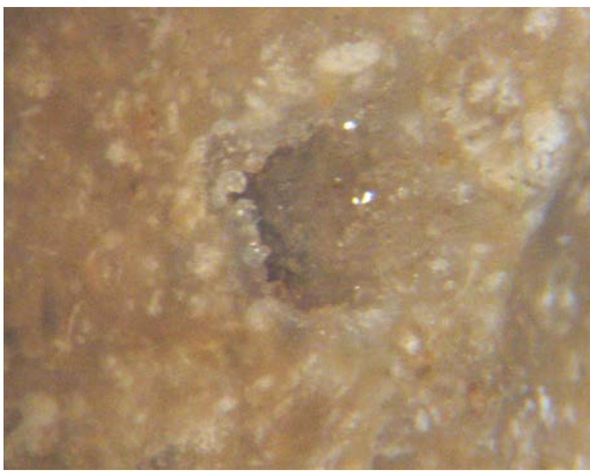


Figure D-26. Photomicrograph of Biomoldic Porosity in Intermediate Biosparite. Pore is 1.2 mm in Diameter.

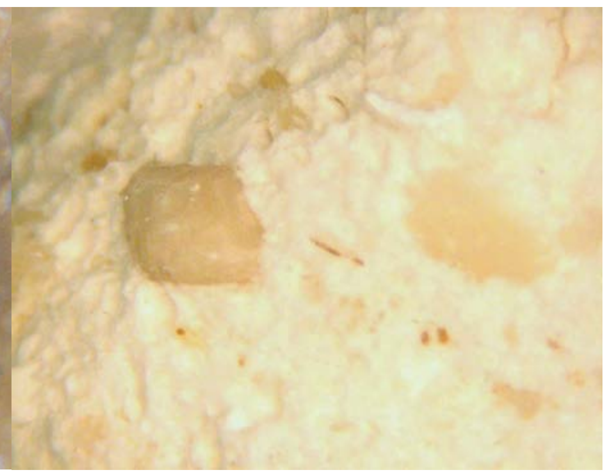


Figure D-27. Photomicrograph of Intermediate Biosparite. The Allochem Left of Center is Replaced by Dolomite (Note Positive Relief). Field of View is 3 mm.

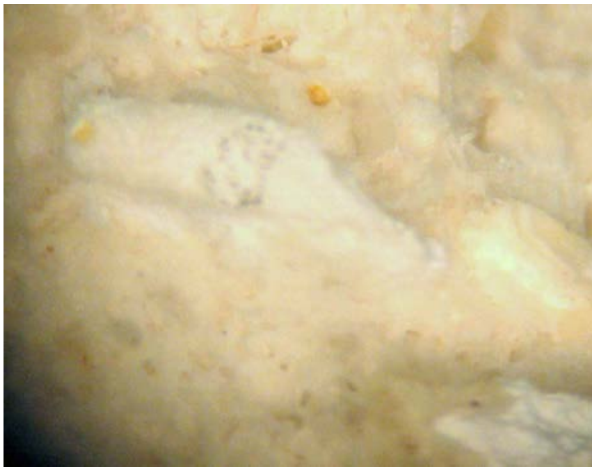


Figure D-28. Photomicrograph of Intermediate Biosparite. The Allochem Left of Center (Mollusk Fragment) is Replaced by Aphanocrystalline Quartz (Note Positive Relief and Silver Scratch Marks Left by Metal Pen with a Moh's Hardness of 4.5-5.0). Field of View is 2 mm.

Figure D-29. Photomicrograph of Lightweight Biosparite Fossil (Mostly Forams) Hash. Field of View is 4 mm.

Figure D-30. Photomicrograph of Lightweight Biosparite with Forams and Biomoldic and Intraparticle Porosity. Field of View is 2 mm.

Figure D-31. Photomicrograph of Lightweight Biosparite with a Large Mollusk Shell (2.3 mm in Diameter) within a Fossil Hash of Mainly Forams.

Figure D-32. Photograph of Dense Chert (Left), Aphanocrystalline Quartz That Has Replaced Carbonate (Middle), and Botryoidal Chert. Field of View is 9 cm.

Figure D-33. Dense (Upper Left), Intermediate (Upper Right), and Lightweight (Lower Center) Particle Fractions (½" x ⅜").

Table D-7. Lithologic Descriptions of the Sample and Calculated Weight Percentages Present in Each Size Fraction and the Weight Percent Present in the Total Sample

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.			WT. % AV.
	½"	⅜"	#4	
Dense Limestone (Biosparite) – (Figures D-23 through D-25 and D-33) Tan to very pale yellow-orange-brown; medium to coarsely crystalline (0.075-0.75 mm); sorted biosparite with recrystallized, white, fossil, oolitic, and pelloidal allochems. Dense limestone particles have very little to no surficial porosity. Some sparite has a brownish to smoky coloration. Less altered allochems are distinguishable as, in order of decreasing abundance, forams, bryozoans, mollusks, pelloids, oolites, and corals (Figures D-24, D-28 through D-31). Rare, clear, glassy or powdery white molds of aphanocrystalline quartz or chert appear to have formed along the margins of some recrystallized allochems (Figure D-28); detrital quartz occurs as subrounded grains, some of which are frosted; some more angular quartz grains likely formed by replacement of carbonate. A few particles have lighter tan to white colored layers (<0.5 mm thick), or irregular-shaped volumes containing translucent and powdery quartz and brownish-gray chert (Figure D-33). Dolomite is not abundant and is generally aphanocrystaline to very finely crystalline, medium tan colored and associated with recrystallized allochems (Figure D-27). Minor subhedral grains of gray dolomite, <0.3 mm, are rarely scattered throughout the carbonate matrix. Scattered opaque grains (magnetite?) are euhedral (octahedral), up to 0.001 mm across and are commonly associated with reddish stains of the adjacent carbonate matrix; brown to black opaque to translucent coatings (MnO?), some dendritic, are rarely found along allochem margins and some pore spaces. The rock has a strong to moderate reaction to a 10% solution of HCl. One particle was totally dissolved in 32% HCl and the insolubles were examined with immersion oils and a petrographic microscope yielding trace amounts of finely crystalline to aphanocrystalline (<0.025 mm) quartz (platelets, euhedral, and rounded frosted grains), dolomite, feldspar, biotite, chlorite, hornblende, and zircon. The particles are angular to subangular, cubical to flattened, hard, nonporous and durable with a smooth texture (Figure D-33).	21.5	18.8	20.4	20.2

Table D-7. Continued

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.			WT. % AV.
	½"	⅜"	#4	
Intermediate Limestone (Biosparite) – (Figures D-26 through D-28 and D-33) Particles in this lithologic category range in texture between those of the dense and lightweight biosparite limestones. They contain low to moderate surficial porosity but particles may be interlayered such that part is dense and part is lightweight limestone. Some particles are wholly single skeletal fossil fragments, and others are fossil fragments or other allochems cemented together. Otherwise, their colors, mineralogies, and allochemical makeup are identical to those described for the dense and lightweight limestones. The particles are subangular to rounded, cubical to flattened with some flat and elongated particles (Figure D-33). The particles are hard to somewhat soft, moderately porous, and somewhat durable with a smooth to rough texture.	44.1	46.8	58.3	49.7
Lightweight Limestone (Biosparite) – (Figures D-29 through D-31 and D-33) Tan to very pale yellow-orange-brown; medium to coarsely crystalline (0.075-0.75 mm); sorted biosparite with white, fossil, pelloidal, and oolitic allochems that are less completely recrystallized, hence less indurated, than those in the dense limestone. Particles have abundant biomoldic and intraparticle pore spaces (Figures D-29 through D-31) that contrasts sharply with the dense limestone particles with a higher degree of dissolution explaining the weaker induration of the former particles; less original cementation may also have contributed to this. Fossil allochems are, in order of decreasing abundance, forams, bryozoans, mollusks, pelloids, oolites, and corals (Figures D-29 through D-31). Where fossil hash is particularly abundant the particle is coquina. A few particles have lighter tan to white colored layers (<0.5 mm thick), or irregular-shaped volumes containing translucent and powdery quartz. Dolomite also is rare. Scattered opaque grains (magnetite?) are subhedral (octahedral), up to 0.001 mm across and are commonly associated with reddish stains on carbonate. Particles are subrounded to rounded, cubical to mostly flattened, soft to moderately hard, very porous, and somewhat durable (much less indurated than the dense limestone) with a rough texture.	32.3	33.4	20.5	28.7
Chert and Quartz - (Figure D-32) Three types of chert and/or quartz particles were observed. Type one is light to medium brown dense chert that contains lighter brown to tan allochemical ghosts with a few moldic pores indicating that these were derived through silica replacement of calcite in the limestone; the rarity of these chert particles may suggest relatively small volumes of the chert, but entire ¾ inch particles are wholly replaced; 10% HCl did not reveal any remaining carbonate. Type two chert occurs together with dense limestone and may form up to half the volume of the particle; it is translucent with a smoky light brown color. Type 3 chert occurs as powdery white, bulbous, botryoidal masses that formed in vuggy openings within the limestone. These chert particles are rounded and have a slightly slippery feel though hardness is above 6 on the Moh's scale; 10% HCl did not reveal any carbonate. Chert and/or quartz particles are angular to subangular, very hard, durable, dense to slightly porous, and tough.	2.1	1.0	0.8	1.3

Results of Petrographic Examination for Natural Sand

A sample of natural sand that had been screened and separated into five size fractions, #4 x #8, #8 x #16, #16 x #30, #30 x #50, and #50 x #100 (Figures D-34 to D-38), was used in this examination.

Each size fraction was separated into lithologies based on rock type, mineralogy, and texture. Representative photomicrographs of each lithology were taken (Figures D-39 through D-47). The volume percentage of each lithology, by size fraction, was calculated as well as the volume percent by entire sample. Lithologic descriptions and the percentages are shown in Table D-8.

The natural sand consists of hard, tough, dense, generally durable particles. The sample consisted of varying proportions of quartz, igneous and metamorphic rocks, with lesser amounts of feldspar, staurolite, muscovite, hornblende, garnet, magnetite, and zircon, all likely sourced from the southern Appalachian Piedmont. Weathered rock particles constituted <0.5% of the sample. No chert was confidently identified. The only carbonate observed was one carbonate-

bearing quartzite particle and one brecciated quartzite particle, thus constituting well below 0.5 % of the fraction. Some scattered iron staining was observed, mostly in association with magnetite, but the small quantity present should have no impact on quality. Mica content averages 0.7%. Mica occurs in some igneous and metamorphic particles as well as free grains in material passing through the #16 sieve. No other deleterious materials were observed. The results of this petrographic examination of the submitted sample indicate the natural sand is of good quality for use as a fine aggregate.

Figure D-34. #4 X #8, As Received and Before Washing.

Figure D-35. #8 X #16, As Received and Before Washing.

Figure D-36. #16 X #30, As Received and Before Washing.

Figure D-37. #30 X #50, As Received and Before Washing.

Figure D-38. #50 X #100, As Received and Before Washing.

Figure D-39. Photomicrograph of 'Singular', Glassy, Transparent to Translucent Quartz Particles. Field of View is 4 mm.

Figure D-40. Photomicrograph of Quartzite Particles Displaying Rounded Clastic Grains (Upper Left and Bottom Center) and Interlocking Crystalline Texture (Right Center). Field of View is 3.0 mm.

Figure D-41. Photomicrograph of K-Feldspar (Left), Metamorphic (Upper Right; Granite Gneiss) and Igneous (Lower Right; Granite) Rock Particles. Field of View is 2.7 mm.

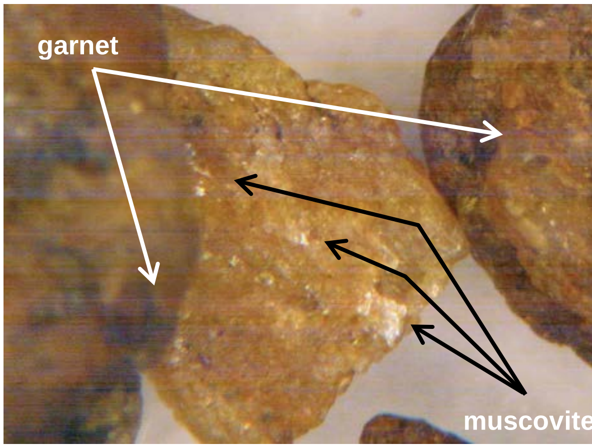


Figure D-42. Photomicrograph of Metamorphic or Igneous Quartzite. Field of View is 3.5 mm.

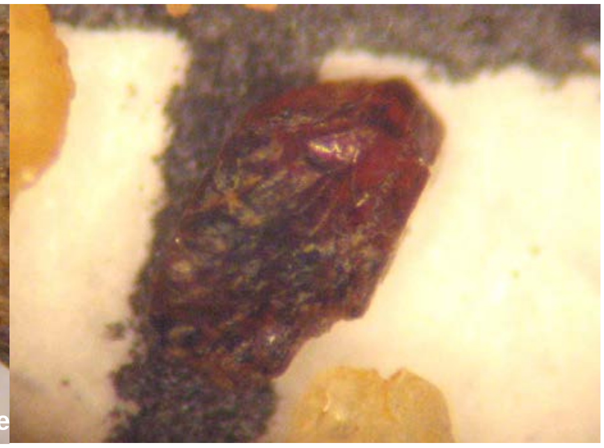


Figure D-43. Photomicrograph of Subhedral Garnet (0.2 mm Long) Displaying Subparallel and Concoidal Fractures.

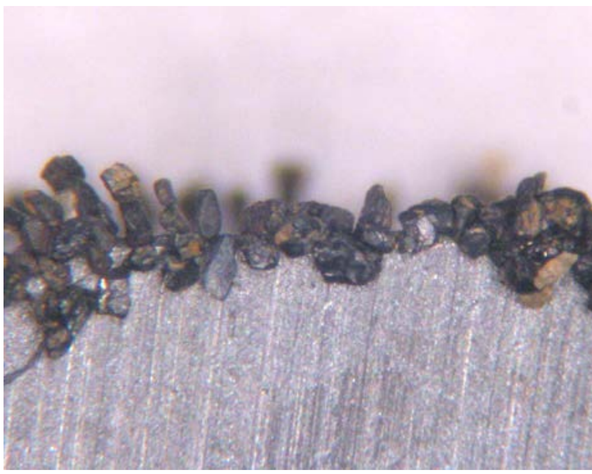


Figure D-44. Photomicrograph of Subhedral to Rounded, Black to Orange-Brown Stained, Magnetite Grains (0.3 to 1.5 mm) Attached to a Magnet (Silver, Streaked Mass Below Magnetite in Photo).

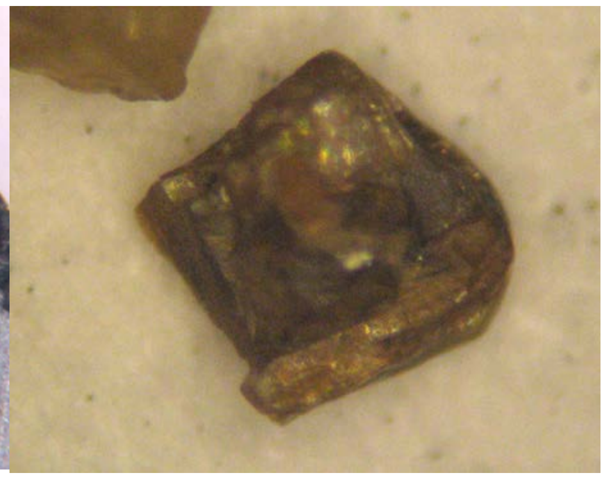


Figure D-45. Photomicrograph of Euhedral Zircon Grains (Translucent, Colorless To Silvery, Adamantine Luster) Attached to Plagioclase (Dark Gray). Field of View is (1 mm).

Figure D-46. Photomicrograph of Translucent, Colorless to Light Gray, Plagioclase Particle Displaying Two Cleavagesat 90o. Field of View is (1.2 mm).

Figure D-47. Photomicrograph of Muscovite (1 mm Long) with Magnetite (Black) and Quartz (Orangish Tan) Inclusions.

Table D-8. Lithologic Descriptions of the Sample and Calculated Weight Percentages Present in Each Size Fraction and the Weight Percent Present in the Total Sample

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.					WT. % AV
	#8	#16	#30	#50	#100	
Quartz – (Figures D-39 and D-40) Three varieties of quartz particles are present: singular quartz grains (Figure D-39); metamorphic 'veined' and/or 'brecciated' quartz; and quartzite and/or quartz arenite (aggregates of quartz grains in an interlocking crystalline or clastic texture; Figure D-40). Singular quartz grains are clear to smoky, glassy angular to subangular particles that become more abundant with decreasing grain size; the clear, glassy quartz is probably derived from mechanical breakdown of igneous and metamorphic rocks andperhaps some medium or coarse grained sandstone; some of these grains are rounded and frosted with an orangish staining. 'Veined' and/or 'brecciated' quartz, and quartzite and/or quartz arenite are tan to very light gray to brownish gray with weak to moderate reddish-yellowish orange staining. Distinct quartz veins and broken and brecciated fragments are a minor component of these particle types. Aggregates of quartz, be they crystalline (interlocking texture) or clastic (agglomerates of distinctly rounded grains; Figure D-40), are the most common particle type (~85%). Some quartz particles contain trace inclusions of opaque grains. Particles are rounded to well-rounded with a few angular ones, spherical to flattened. The particles are hard, durable, dense, and tough.	93	95.3	95.1	92	86.1	92.3

Table D-8. Continued

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.					WT. % AV
	#8	#16	#30	#50	#100	
Igneous and Metamorphic Rocks –Particles of this lithology are of three types – igneous rock (Figure D-41), metamorphic rock (Figure D-41), and crystalline quartzite with metamorphic or igneous minerals (Figure D-42). Igneous rock particles are mostly coarsely crystalline granite (tan feldspar and transparent quartz up to 0.8 mm with black spots of biotite; Figure D-41); minor diorite (containing hornblende and plagioclase dominating feldspar component). Metamorphic rock particles are: biotite schist and granitic gneiss with distinct foliation and/or gneissic banding (Figure D-41); coarsely crystalline greenish-dark gray calcite-bearing quartzite composed of quartz, plagioclase, hornblende, minor chlorite, muscovite, and biotite; and finely layered black to dark green hornblende and plagioclase aggregates (amphibolite). Igneous or metamorphic quartzite particles are mostly quartz (up to 95%) but contain distinctly metamorphic (i.e., staurolite, garnet [Figure D-43], biotite, muscovite, hornblende [two cleavages at 60 X 120^{o}]) or igneous (magnetite [Figure D-44] and zircon [Figure D-45]) minerals that clearly are not detrital grains; some quartzite is slaty with aphanocrystalline sericite. The particles are subangular to rounded with quartzite tending to be more angular; most are spherical to ellipsoidal but the metamorphic clasts are distinctly flattened. The particles are hard, dense, and durable.	6.7	4.7	3.1	4.7	2.8	4.4
Feldspar – Blocky, tan, K-feldspar (Figure D-41) and clear to light gray plagioclase (Figure D-46) display two cleavages at 90^{o}. Contain minor inclusions of quartz. The particles are angular, hard, dense, and durable.	0.1	-	0.5	1.1	0.3	0.2
Staurolite – Subhedral prisms (0.4 mm) of dark brown staurolite with numerous quartz inclusions. The particles are subangular, hard, dense, and durable.	0.1	-	-	-	0.9	0.2
Muscovite – Tabular, subhedral, <1.75 mm diameter, muscovite books; kinks and broad folds observed; rare <0.3 mm inclusions of magnetite and and quartz (Figure D-47). Particles are subrounded, dense, and durable.	-	-	0.2	0.6	2.5	0.7
Hornblende – Black to greenish black, occurs as inclusions in quartz, igneous and metamorphic rocks, and as individual grains, commonly with fine layers of plagioclase and quartz, in the material passing the #16 sieve; displays 60 - 120^{o} cleavage. The particles are angular, elongate, hard, dense, and durable.	-	-	0.2	0.6	2.8	0.7
Garnet – (Figures D-42 and D-43) Translucent, very deep red to red black where thick, inclusions in metamorphic rocks, and as individual grains in the material passing the #30 sieve; displays no cleavage; has rough planar fractures and glassy concoidal ones. The particles are subangular, spherical, very hard, dense, and very durable.	-	-	-	0.3	1.2	0.3
Magnetite – (Figure D-44) Black with brownish orange staining; occurs as inclusions in quartz, muscovite, igneous and metamorphic rocks, and as individual grains in the material passing the #50 sieve; euhedral to anhedral but mostly subhedral grains; magnetic (Figure D-44). The particles are subangular to angular, hard, dense, and durable.	-	-	0.5	1.1	3.1	0.9
Zircon – (Figure D-45) Clear to silvery, translucent, euhedral tetragonal grains with adamantine luster. Most likely of igneous origin. The particles are subangular to angular, very hard, dense, and extremely durable.	-	-	0.2	-	0.3	0.1

Results of Insoluble Residue Test

Table D-9. Summary of Insoluble Residue Test Results

Test Parameter	Natural Sand	Fine Limerock	Coarse Limerock
Plus No. 200 Insoluble Residue (%)	98.6	6.1	5.5
Minus No. 200 Insoluble Resedue (%)	0.1	0.9	1.0
Total Insoluble Residue (%)	98.7	7.0	6.5
Total Acid Solubility (%)	1.3	93.0	93.5

Results of Specific Gravity and Absorption Testing

Table D-10. Specific Gravity and Absorption Results for Coarse Aggregate

Method	Material*	Rep No.	Gsa	Gsb	Gssd	Abs (%)
AASHTO T 85	CG	1	2.717	2.687	2.698	0.4
AASHTO T 85	CG	2	2.718	2.689	2.699	0.4
AASHTO T 85	CG	3	2.717	2.677	2.692	0.5
AASHTO T 85	EG	1	2.637	2.561	2.590	1.1
AASHTO T 85	EG	2	2.629	2.556	2.584	1.1
AASHTO T 85	EG	3	2.629	2.551	2.581	1.2
AASHTO T 85	FL	1	2.564	2.243	2.368	5.6
AASHTO T 85	FL	2	2.569	2.252	2.375	5.5
AASHTO T 85	FL	3	2.568	2.248	2.372	5.5
Rapid T 85	CG	1	2.731	2.683	2.701	0.7
Rapid T 85	CG	2	2.724	2.671	2.690	0.7
Rapid T 85	CG	3	2.725	2.668	2.689	0.8
Rapid T 85	EG	1	2.664	2.569	2.605	1.4
Rapid T 85	EG	2	2.669	2.569	2.607	1.5
Rapid T 85	EG	3	2.654	2.560	2.595	1.4
Rapid T 85	FL	1	2.689	2.020	2.268	12.3
Rapid T 85	FL	2	2.700	2.011	2.266	12.7
Rapid T 85	FL	3	2.688	2.008	2.261	12.6
Phunque Flask	CG	1	2.714	2.708	2.710	0.5
Phunque Flask	CG	2	2.728	2.713	2.719	0.7
Phunque Flask	CG	3	2.727	2.709	2.716	0.8
Phunque Flask	EG	1	2.635	2.613	2.622	1.0
Phunque Flask	EG	2	2.636	2.611	2.621	1.0
Phunque Flask	EG	3	2.635	2.618	2.625	0.8
Phunque Flask	FL	1	2.584	2.468	2.512	3.7
Phunque Flask	FL	2	2.579	2.472	2.513	3.5
Phunque Flask	FL	3	2.576	2.468	2.510	3.5

* CG = Columbus granite; EG = Elmore gravel; FL = Florida limestone

Table D-11. Specific Gravity and Absorption Results for Fine Aggregate

Method	Material*	Rep No.	Gsa	Gsb	Gssd	Abs (%)
AASHTO T 84	OS	1	2.678	2.673	2.678	0.0
AASHTO T 84	OS	2	2.670	2.666	2.667	0.1
AASHTO T 84	OS	3	2.670	2.667	2.668	0.0
AASHTO T 84	NS	1	2.690	2.651	2.665	0.5
AASHTO T 84	NS	2	2.681	2.647	2.664	0.6
AASHTO T 84	NS	3	2.694	2.666	2.677	0.4
AASHTO T 84	LS	1	2.615	2.299	2.420	5.3
AASHTO T 84	LS	2	2.597	2.313	2.422	4.7
AASHTO T 84	LS	3	2.617	2.311	2.428	5.1
AASHTO T 84	GS	1	2.737	2.619	2.662	1.6
AASHTO T 84	GS	2	2.729	2.619	2.659	1.5
AASHTO T 84	GS	3	2.726	2.621	2.659	1.5
Modified T84	LS	1	2.652	2.252	2.403	6.7
Modified T84	LS	2	2.654	2.254	2.405	6.7
Modified T84	LS	3	2.670	2.248	2.388	7
Modified T84	GS	1	2.725	2.693	2.709	0.6
Modified T84	GS	2	2.735	2.698	2.711	0.5
Modified T84	GS	3	2.742	2.718	2.727	0.3
SSDetect	OS	1	2.655	2.639	2.645	0.2
SSDetect	OS	2	2.657	2.643	2.648	0.2
SSDetect	OS	3	2.657	2.643	2.648	0.2
SSDetect	NS	1	2.689	2.657	2.669	0.4
SSDetect	NS	2	2.688	2.660	2.670	0.4
SSDetect	NS	3	2.687	2.658	2.669	0.4
SSDetect	LS	1	2.635	2.376	2.476	4.2
SSDetect	LS	2	2.629	2.390	2.485	3.9
SSDetect	LS	3	2.627	2.371	2.476	4.5
SSDetect	GS	1	2.709	2.675	2.685	0.8
SSDetect	GS	2	2.728	2.687	2.697	0.6
SSDetect	GS	3	2.705	2.660	2.677	0.6
Modified SSDetect	LS	1	2.629	2.414	2.496	3.4
Modified SSDetect	LS	2	2.636	2.398	2.480	4
Modified SSDetect	LS	3	2.630	2.402	2.488	3.6
Modified SSDetect	GS	1	2.726	2.692	2.704	0.5
Modified SSDetect	GS	2	2.709	2.670	2.684	0.5
Modified SSDetect	GS	3	2.723	2.687	2.700	0.5
Phunque Flask	OS	1	2.654	2.652	2.653	0.4
Phunque Flask	OS	2	2.657	2.651	2.653	0.5
Phunque Flask	OS	3	2.654	2.646	2.649	0.6
Phunque Flask	NS	1	2.682	2.674	2.677	0.6
Phunque Flask	NS	2	2.689	2.680	2.683	0.6
Phunque Flask	NS	3	2.682	2.672	2.676	0.6
Phunque Flask	LS	1	2.644	2.484	2.544	4.8
Phunque Flask	LS	2	2.650	2.471	2.538	5.4
Phunque Flask	LS	3	2.660	2.492	2.556	5.0
Phunque Flask	GS	1	2.721	2.699	2.707	0.9
Phunque Flask	GS	2	2.724	2.696	2.706	1.1
Phunque Flask	GS	3	2.726	2.695	2.707	1.1
AASHTO T 133	LS	1	2.734			
AASHTO T 133	LS	2	2.745			
AASHTO T 133	LS	3	2.731			
AASHTO T 133	GS	1	2.777			
AASHTO T 133	GS	2	2.785			
AASHTO T 133	GS	3	2.789			

* OS = Ottawa sand; NS = Natural sand; LS = Limestone screenings; GS = Granite screenings

Table D-12. Specific Gravity and Absorption Results for Complete Gradation

Method	Material*	Rep No.	Gsa	Gsb	Gssd	Abs (%)
Phunque Flask	CG_OS	1	2.693	2.685	2.688	0.6
Phunque Flask	CG_OS	2	2.631	2.620	2.624	0.7
Phunque Flask	CG_OS	3	2.707	2.698	2.702	0.6
Phunque Flask	EG_NS	1	2.655	2.641	2.647	0.7
Phunque Flask	EG_NS	2	2.656	2.634	2.642	1.0
Phunque Flask	EG_NS	3	2.649	2.633	2.639	0.8
Phunque Flask	FL_GS	1	2.612	2.541	2.568	2.3
Phunque Flask	FL_GS	2	2.616	2.555	2.579	2.1
Phunque Flask	FL_GS	3	2.627	2.523	2.563	3.2

* CG = Columbus granite; OS = Ottawa sand; EG = Elmore gravel; NS = Natural sand; FL = Florida limestone; GS = Granite screenings

Table D-13. Mathematical Combination of Specific Gravity for Complete Gradation

Method	Material	Gsa	Gsb	Gssd	Abs (%)
AASHTO T 84	LS	2.610	2.308	2.423	5.03
Modified T 84	LS	2.659	2.251	2.399	6.80
Modified T 84 + T 133	LS	2.665	2.283	2.423	N/A
SSDetect	LS	2.630	2.379	2.479	4.20
Modified SSDetect	LS	2.632	2.405	2.488	3.67
Modified SSDetect + T 133	LS	2.640	2.429	2.506	N/A
Phunque Flask	LS	2.651	2.482	2.546	5.07
AASHTO T 84	GS	2.731	2.620	2.660	1.53
Modified T 84	GS	2.734	2.703	2.716	0.47
Modified T 84 + T 133	GS	2.741	2.714	2.725	N/A
SSDetect	GS	2.714	2.674	2.686	0.67
Modified SSDetect	GS	2.719	2.683	2.696	0.50
Modified SSDetect + T 133	GS	2.728	2.696	2.708	N/A
Phunque Flask	GS	2.724	2.697	2.707	1.03

APPENDIX E

Testing Results of Experiment 2

Gradation and Consensus Properties

Tables E-1 and E-2 compare the gradations of coarse and fine aggregate materials, respectively, determined by the research team according to AASHTO T 27, *Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates*, and AASHTO T 11, *Standard Method of Test for Materials Finer Than 75-μm (No. 200) sieve in Mineral Aggregates by Washing*, with those provided by the aggregate suppliers.

Table E-3 shows the angularity determined according to AASHTO T 304, *Standard Method of Test for Uncompacted Void Content of Fine Aggregate*, for the five fine aggregate materials used in Experiment 2. Based on these results, all of the fine aggregates appear to have very angular and/or rough textured surfaces, except for the natural sand.

Table E-4 summarizes insoluble residue test results determined in accordance with ASTM D 3042, *Standard Test Method for Insoluble Residue in Carbonate Aggregates*, for the three limestone materials. Most of the materials in the three limestone aggregates were soluble in the acid solution used in this test.

A float test was conducted for the rounded natural sand in accordance with ASTM C 123, *Standard Test Method for Lightweight Particles in Aggregate*. Results of this testing, as presented in Table E-5, showed that the natural sand contained no lightweight particles.

Table E-1. Gradations of Coarse Aggregates

Sieve Size	Sieve Size	Percent Passing									
		Elmore Gravel		Preston Sandstone		Blast Furnace Slag		SHRP RC Limestone		Recycled Concrete	
(in.)	(mm)	Supplier	4-35	Supplier	4-35	Supplier	4-35	Supplier	4-35	Supplier	4-35
2"	50	N/A	100	100	100	100	100	N/A	100	100	100
1-1/2"	37.5	N/A	100	100	100	100	100	N/A	100	100	100
1"	25	N/A	100	100	99	100	99	N/A	96	100	100
3/4"	19	N/A	100	83	71	82	83	N/A	86	92	99
1/2"	12.5	N/A	66	47	33	28	33	N/A	63	42	78
3/8"	9.5	N/A	24	30	17	10	12	N/A	45	16	52
#4	4.75	N/A	3	3	2	5	8	N/A	14	3	7
#8	2.36	N/A	1	2	2	4	6	N/A	8	3	4
#16	1.18	N/A	1	N/A	2	4	6	N/A	6	2	3
#30	0.6	N/A	1	N/A	2	4	6	N/A	6	2	3
#50	0.3	N/A	1	N/A	2	4	5	N/A	5	1	2
#100	0.15	N/A	1	N/A	1	3	4	N/A	5	1	2
#200	0.075	N/A	0.5	1.0	1.1	1.8	3.0	N/A	4.4	0.6	1.5

Note: N/A = Not available

Two chemical analyses were performed for the blast furnace slag coarse and fine aggregate materials according to ASTM C 25, *Standard Test Methods for Chemical Analysis of Limestone*,

Quicklime, and Hydrated Lime. Results of these analyses are presented in Table E-6. The two materials contained similar concentration of basic elements.

Testing of sand equivalent was conducted for the fine aggregate materials that pass the No. 4 sieve according to ASTM D 2419, *Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate*. The results of this testing are presented in Table E-7. Both the Preston sandstone and RC limestone fine aggregates had low sand equivalent values which indicated that they contained significant amounts of clay-sized material. Significant quantity of clay sized material may affect specific gravity and water absorption measurements.

Table E-2. Gradations of Fine Aggregates

Sieve Size	Sieve Size	Percent Passing									
		Rounded Natural Sand		Blast Furnace Slag		Preston Sandstone		Limestone Man. Sand		SHRP RC Limestone	
(in.)	(mm)	Supplier	4-35	Supplier	4-35	Supplier	4-35	Supplier	4-35	Supplier	4-35
2"	50	100	100	100	100	100	100	100	100	100	100
1-1/2"	37.5	100	100	100	100	100	100	100	100	100	100
1"	25	100	100	100	100	100	100	100	100	100	100
3/4"	19	100	100	100	100	100	100	100	100	100	100
1/2"	12.5	100	100	100	100	100	100	100	100	100	100
3/8"	9.5	100	100	100	100	100	100	100	100	100	100
#4	4.75	97	97	95	95	93	94	100	100	100	100
#8	2.36	91	92	68	68	66	68	87	89	95	94
#16	1.18	79	81	46	46	49	50	59	60	76	67
#30	0.6	49	58	30	31	40	42	45	42	59	50
#50	0.3	9	14	20	21	35	37	28	27	46	38
#100	0.15	1	1	13	13	24	28	10	12	37	31
#200	0.075	0.1	0.4	8.0	8.8	12.3	16.7	5.4	4.3	31.9	26.5

Table E-3. Angularity of Fine Aggregate Materials

Replicate	Uncompacted Voids (%)				
	Rounded Natural Sand	Blast Furnace Slag	Preston Sandstone	TX Limestone Man. Sand	SHRP RC Limestone
1	40.1	48.9	50.1	49.3	49.6
2	39.8	49.4	49.8	49.4	49.6
3	39.9	49.1	49.5	49.4	49.5
Average	39.9	49.1	49.8	49.4	49.6

Table E-4. Summary of Insoluble Residue Test Results

Test Parameter	SHRP RC Limestone (Coarse)	SHRP RC Limestone (Fine)	Limestone Manufactured Sand
Plus No. 200 Insoluble Residue (%)	6.9	6.0	1.1
Minus No. 200 Insoluble Residue (%)	2.4	3.0	0.7
Total Insoluble Residue (%)	9.3	9.0	1.8
Total Acid Solubility (%)	90.7	91.0	98.2

Table E-5. Lightweight Particles in Rounded Natural Sand

Test Parameter	Lightweight Particles (%)	ASTM C 33 Specification % Max
Coal and Lignite at 2.00 Gs	0.0	0.5

Lightweight Chert at 2.40 Gs	0.0	---

Table E-6. Chemical Analyses of Two Slag Materials

Analysis Description	Blast Furnace Slag (Coarse)	Blast Furnace Slag (Fine)
Calcium (Ca) (%)	19.62	19.03
Calcium Oxide (CaO) (%)	27.45	26.63
Calcium Carbonate ($CaCO_3$) (%)	49.00	47.52
Magnesium (Mg) (%)	7.05	7.21
Magnesium Oxide (MgO) (%)	11.69	11.95
Magnesium Carbonate ($MgCO_3$) (%)	24.45	25.00
Iron Oxide (Fe_2O_3) (%)	0.29	0.41
Aluminum Oxide (Al_2O_3) (%)	5.96	5.81
Silica (Si) (%)	11.60	11.90
Silicon Dioxide (SiO_2) (%)	24.81	25.46

Table E-7. Sand Equivalent of Fine Aggregate Materials

Material	Sand Equivalent (%)
Rounded natural sand	100
Blast furnace slag	86.5
Preston sandstone	26.1
Texas limestone sand	92.8
RC limestone	39.2

Results of Petrographic Examination

In Experiment 2, the petrographic examination was conducted by Mr. Robert S. Fousek, P.G. of FMR, Inc. in Auburn, AL, in accordance with ASTM Method E-295, *Standard Guide for Petrographic Examination of Aggregates for Concrete*. The examination was conducted for sandstone and limestone coarse and fine aggregates, recycled concrete coarse aggregate, and natural sand. These materials were not tested in Experiment 1. Results of the petrographic examination are provided in the following subsections.

Results of Petrographic Examination for Sandstone Coarse Aggregate

A sample of crushed Preston Sandstone (PS) coarse aggregate that had been screened and separated into five size fractions, 1½” x 1”, 1” x ¾”, ¾” x ½”, ½” x $^3/_8$”, and $^3/_8$” x #4 (Figures E-1 to E-5), was used in this examination.

An initial examination with a stereomicroscope was conducted to determine the nature of dust coatings on individual particles and to determine if any deleterious materials that could be removed by washing were present. Each size fraction was then washed, dried, and reexamined visually with a stereomicroscope. Each size fraction was separated into lithologies based on rock type and mineralogy. Microphotographs were taken of distinctive features (Figures E-6 through E-20). Representative photographs of each lithology were taken (Figures B.21 through B.24). The weight percentage of each lithology by size fraction was calculated as well as the weight percent by entire sample. Lithologic descriptions and the percentages are shown in Table E-8.

The sample, as received, was coated with light gray to light olive gray dust of fracture consisting of very fine particles of quartz, feldspar, chert, muscovite and biotite mica, and clay minerals. The crushed stone consists of hard, tough, porous, rough, generally durable particles. The sample consisted primarily of medium-grained sandstone (78.2%) with lesser amounts of

fine-grained sandstone (12.7%), weathered sandstone (5.0%), shale (3.9%), and bitumen-coated sandstone and/or recycled asphalt pavement (RAP) (0.2%). Trace amounts of muscovite and biotite mica, chert, hematite, and carbonized plants were noted in the sample but they are present in such small amounts that no problems with quality are anticipated. Particles counted as shale constituted particles with greater than 50% shale in the particle. Small, generally rounded clasts of shale are common in the coarse-grained sandstone (Figures E-13 and E-14). Numerous shale partings were noted and the rock has a tendency to break along these partings (Figures E-15 and E-16). Five percent of the sample was weathered sandstone. Weathering is mild and no quality control problems are anticipated with the weathered sandstone. Several sandstone particles were coated with black bitumen that may be naturally occurring or, more likely, represents contamination of the sample with RAP (Figure E-12). Numerous open fractures were noted (Figures E-17 and E-18) that probably represent artifacts of crushing and screening. These fractures could result in breakage during stockpiling and use resulting in gradation changes. No pyrite or other deleterious constituents were observed. The results of this petrographic examination indicate the crushed sandstone aggregate is of fair quality for use as a coarse aggregate in construction.

Figure E-1. 1 ½" X 1" as Received and Before Washing.

Figure E-2. 1" X ¾" as Received and Before Washing.

Figure E-3. ¾" X ½" as Received and Before Washing.

Figure E-4. ½" X $^{3}/_{8}$" as Received and Before Washing.

Figure E-5. $^{3}/_{8}$" X #4 as Received and Before Washing.

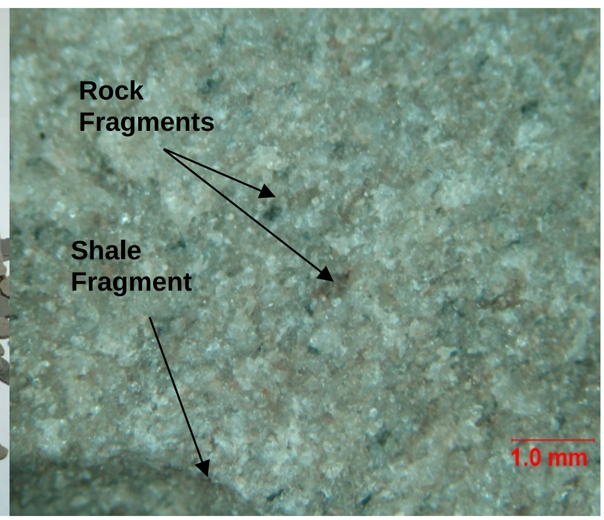


Figure E-6. Microphotograph of Typical Medium Grained Sandstone Particle, Photographed at 10X.

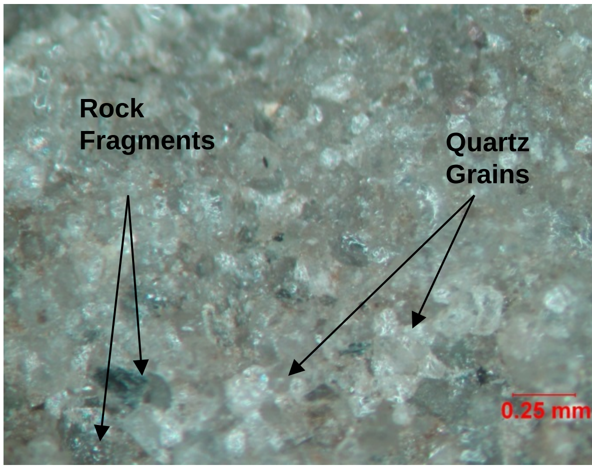


Figure E-7. Microphotograph of Typical Medium Grained Sandstone, same as above in Figure E-6 but Photographed at 30X.

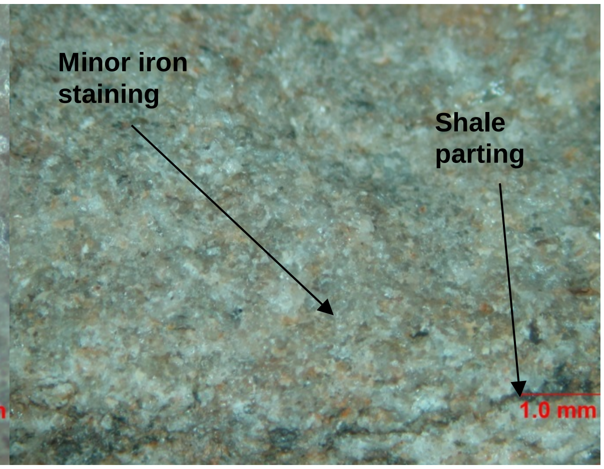


Figure E-8. Microphotograph of Typical Fine-Grained Sandstone Particle, Photographed at 10X.

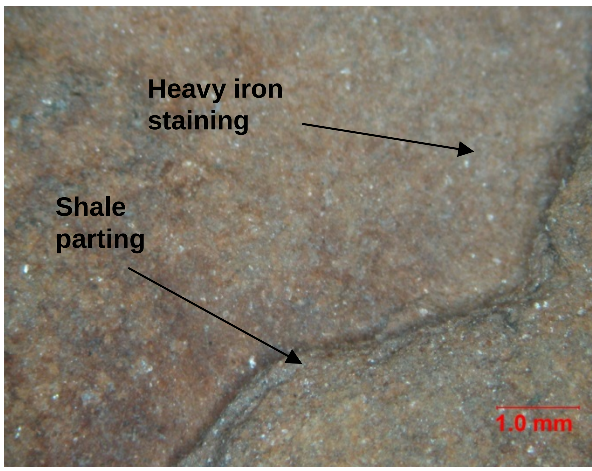


Figure E-9. Microphotograph of Typical Weathered Medium-Grained Sandstone Particle, Photographed at 10X.

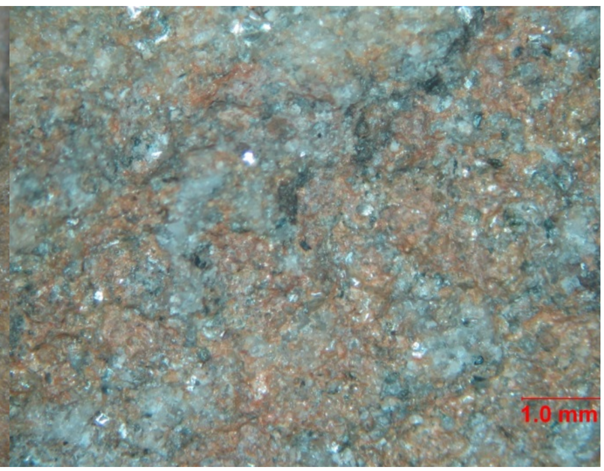


Figure E-10. Microphotograph of a Weathered Medium-Grained Sandstone Particle, Photographed at 10X.

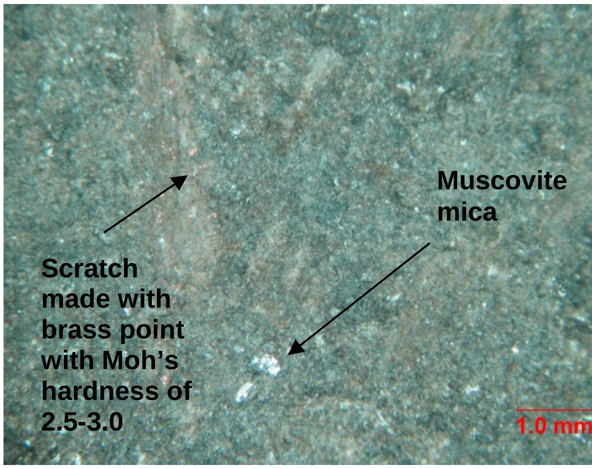


Figure E-11. Microphotograph of Typical Shale Particle, Photographed at 10X.

Figure E-12. Microphotograph of Typical Bitumen Coated Sandstone Particle (RAP), Photographed at 10X.

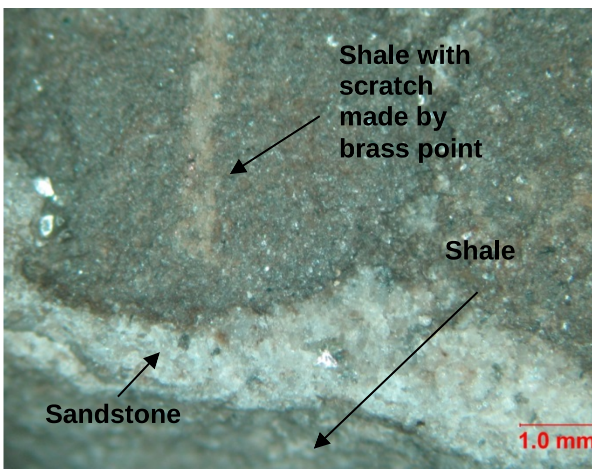


Figure E-13. Microphotograph of Rounded Shale Particles in Medium-Grained Sandstone, Photographed at 10X.

Figure E-14. Microphotograph of Iron-Stained Shale Fragment in Medium-Grained Sandstone, Photographed at 10X.

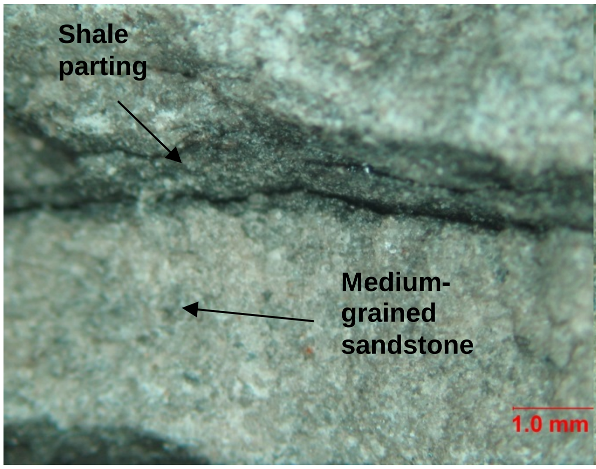


Figure E-15. Microphotograph of Shale Parting in Medium-Grained Sandstone, Photographed at 10X.

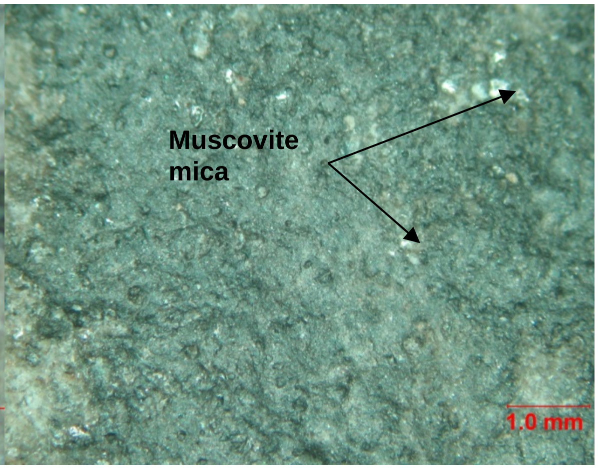


Figure E-16. Microphotograph of Surface on Particle of Fine-Grained Sandstone Created by Breakage along Shale Parting, Photographed at 10X.

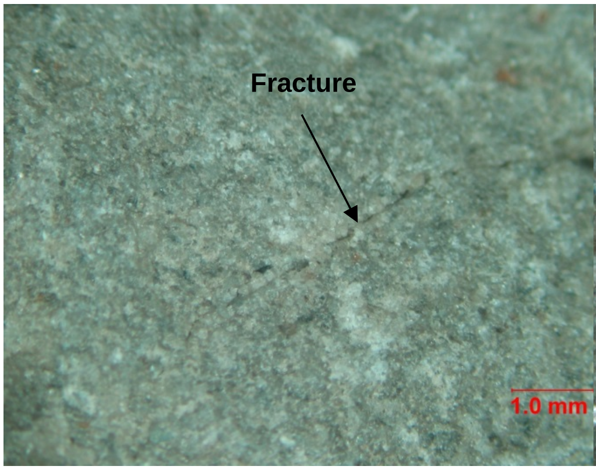


Figure E-17. Microphotograph of Fracture in Medium-Grained Sandstone, Photographed at 10X.

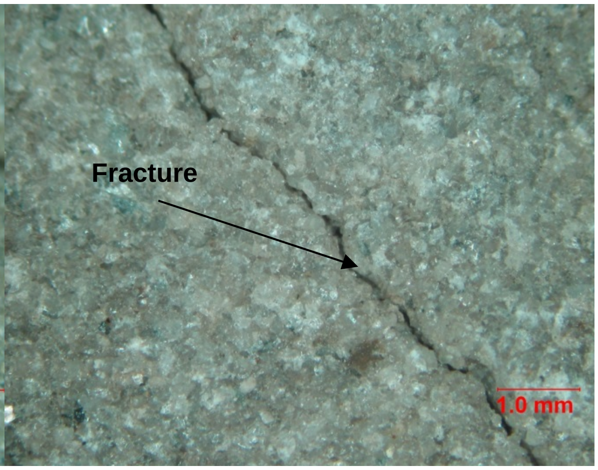


Figure E-18. Microphotograph of Fracture in Medium-Grained Sandstone. Photographed at 10X.

Figure E-19. Microphotograph of Large Chert Fragment in Medium-Grained Sandstone. Photographed at 10X.

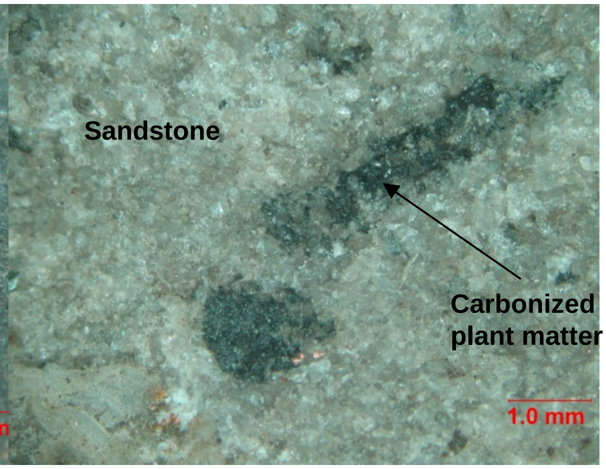


Figure E-20. Microphotograph of Carbon from Plant Matter in Medium-Grained Sandstone, Photographed at 10X.

Figure E-21. Photograph of Medium-Grained Sandstone Particles (½"X $^{3}/_{8}$" Size Fraction).

Figure E-22. Photograph of Fine-Grained Sandstone Particles (½"X $^{3}/_{8}$" Size Fraction).

Figure E-23. Photograph of Weathered Sandstone Particles (½"X $^3/_8$" Size Fraction).

Figure E-24. Photograph of Shale Particles (½"X $^3/_8$" Size Fraction).

Table E-8. Lithologic Descriptions of the Sample and Calculated Weight Percentages Present in Each Size Fraction and the Weight Percent Present in the Total Sample

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.					WT. % AV.
	1"	¾"	½"	$^3/_8$"	#4	
Medium-Grained Sandstone – (Figures E-6, E-7, and E-21) Medium light gray to medium dark gray; medium-grained (0.2-0.5 mm); composed of quartz (80-85%), feldspar (5-8%), muscovite and biotite mica (2-3%), rock fragments (10-15%), and trace amounts of chert, clay, hematite, and carbon; silica cemented; rock fragments are composed of shale with minor amounts of igneous and metamorphic rocks, shale fragments contain clay minerals as well as muscovite mica; shale partings are common (Figures E-15, E-16); numerous open fractures occur that are probably artifacts of mining and production activities (Figures E-17, E-18); minor dense chert occurs as rounded rock fragments (Figure E-19); minor amounts of carbonized plant material are present (Figure E-20); the medium-grained sandstone particles are angular to subangular; flattened to cubical with some flat and elongate particles, the amount of flat and elongate particles increases with decreasing particle size;	60.0	81.8	78.1	72.1	78.5	78.2

porous; rough; hard, and tough.						
Fine-Grained Sandstone – (Figures E-8, E-22) Medium light gray to medium dark gray; fine-grained (0.1-0.25 mm); similar to the medium-grained sandstone described above but with a smaller grain size; composed of quartz (85-90%), feldspar (5-8%), muscovite and biotite mica (2-3%), rock fragments (5-10%), and trace amounts of chert, clay, hematite, and carbon; silica cemented; rock fragments are composed of shale with minor amounts of igneous and metamorphic rocks, shale fragments contain clay minerals as well as muscovite mica; shale partings are common; numerous open fractures occur that are probably artifacts of mining and production activities; minor dense chert occurs as rounded rock fragments; minor amounts of carbonized plant material are present; the fine-grained sandstone particles are flattened to cubical with some flat and elongate particles, the amount of flat and elongate particles increases with decreasing particle size; porous; rough; hard, and tough.	40.0	12.5	13.4	11.0	7.5	12.7
Weathered Sandstone – (Figures E-9, E-10, E-23) Pale yellowish brown to dark yellowish orange; fine- to medium-grained (0.1-0.5 mm); includes weathered fine- and medium-grained sandstone as described above, no attempt was made to separate the two lithologies due to heavy iron staining (Figures E-9, E-10); silica cemented; weathering consists of abundant iron staining and many of the feldspar grains in the weathered sandstone have a milky appearance indicating some possible alteration to clay minerals; the weathered sandstone particles are angular to subangular; flattened to cubical with some flat and elongate particles, the amount of flat and elongate particles increases with decreasing particle size; porous; rough; hard, and tough; although weathered and exhibiting some feldspar alteration and abundant iron staining, the weathered sandstone should not pose a problem with quality issues.	-	4.3	4.1	8.3	6.5	5.0
Shale – (Figures E-11, E-24) Medium gray to black; very fine-grained; soft, can be scratched with a brass point with a Moh's hardness of 2.5-3.0; abundant muscovite mica; the shale particles are subangular to rounded; flattened with some flat and elongate particles, the amount of flat and elongate particles increases with decreasing particle size; porous; smooth; soft, and non-durable.	-	1.4	4.4	7.8	6.0	3.9
Bitumen-Coated Sandstone (RAP) – (Figures E-12, E-25) Black to medium dark gray; particles are coated with a soft bitumen generally obscuring the lithology of the particle; probably represents contamination of the stockpile.	-	-	-	0.8	1.5	0.2

Results of Petrographic Examination for Recycled Concrete Materials

A sample of crushed Recycled Concrete (RC) coarse aggregate that had been screened and separated into four size fractions, 1" x ¾", ¾" x ½", ½" x 3/8", and 3/8" x #4 (Figures E-25 through E-28), was used in this examination.

An initial examination with a stereomicroscope was conducted to determine the nature of dust coatings on individual particles and to determine if any deleterious materials that could be removed by washing were present. Each size fraction was than washed, dried, and reexamined visually and with a stereomicroscope. Each size fraction was separated into lithologies based on the coarse aggregate used in the concrete and by individual rock clasts that had separated from the concrete. The fine aggregate was a quartz-rich natural sand that was similar in all the concrete particles and was not used in the classification of lithologies. Microphotographs were taken of distinctive features (Figures E-29 through E-44). Representative photographs of each lithology were taken (Figures E-45 through E-51). The weight percentage of each lithology by size fraction was calculated as well as the weight percent by entire sample. Estimates of concrete paste were made by sieve size and the results are shown in Table E-9. Concrete paste, for purposes of this report, is defined as the fine aggregate passing the #16 sieve along with hydrated and unhydrated cement, fly ash, additives, ground granulated blast furnace slag, fibers, or other fine

materials. Paste in the recycled concrete particles varies greatly, depending on the amount of coarse and larger clasts of fine aggregate present in the particle. No carbonate rocks were noted in the coarse aggregate or the larger fine aggregate clasts. A more accurate determination of paste could be accomplished by use of acid to remove the cement (acid dissolution). Lithologic descriptions and the percentages are shown in Table E-10.

The sample, as received, was coated with light gray to light olive gray dust of fracture consisting of very fine particles of concrete paste, quartz, feldspar, muscovite, and biotite mica. The crushed recycled concrete consists of hard, tough, porous to dense, rough to smooth, generally durable particles. The sample consisted primarily of potassium feldspar-rich granitic gravel in concrete (33.1 percent), granitic gravel in concrete (22.7 percent), and quartz-rich gravel in concrete (13.6 percent) with lesser amounts of granitic clasts (9.0 percent), potassium feldspar-rich granitic clasts (8.9 percent), quartz clasts (6.6 percent), and concrete paste (no coarse aggregate clasts) (6.1 percent). Particles counted as concrete paste had no coarse aggregate particles and often only fine aggregate particles passing the #16 sieve. Particles counted as rock clasts constituted particles with less than 1 percent paste coating the particle. Trace amounts of pyrite were noted in some particles, but this small amount should not present problems with quality. No clay, shale, chert, or other deleterious constituents were observed. The results of this petrographic examination indicate the crushed recycled concrete aggregate is of good quality for use as a coarse aggregate.

Table E-9. Percentages of Paste by Size

Sieve Size	¾"	½"	3/8"	#4
% Paste	8-10	8-10	12-15	15-20

Notes: Estimates made on potassium feldspar-rich granitic gravel in concrete, granitic gravel in concrete, and quartz gravel in concrete. Rock clasts were not considered, and generally the amount of paste present on surfaces of clasts is less than 1%. Concrete paste particles are generally 95-100% concrete paste. Overall concrete paste content of the entire sample is approximately 9-11%.

Figure E-25. 1" X ¾" as Received and Before Washing.

Figure E-26. ¾" X ½" as Received and Before Washing.

Figure E-27. ½” X $^{3}/_{8}$” as Received and Before Washing.

Figure E-28. $^{3}/_{8}$” X #4 as Received and Before Washing.

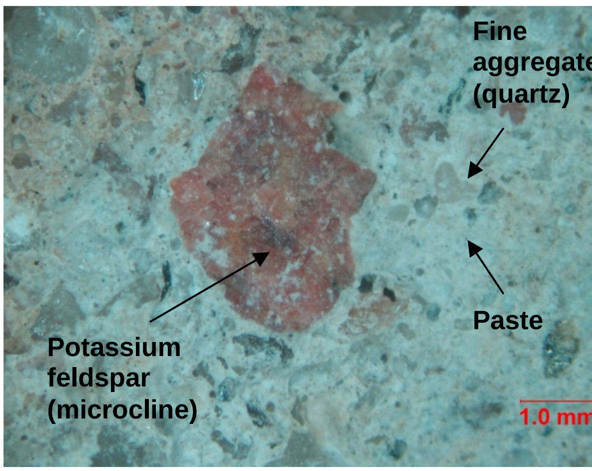


Figure E-29. Microphotograph of Typical Potassium Feldspar-Rich Granitic Gravel in Concrete Particle, Photographed at 10X.

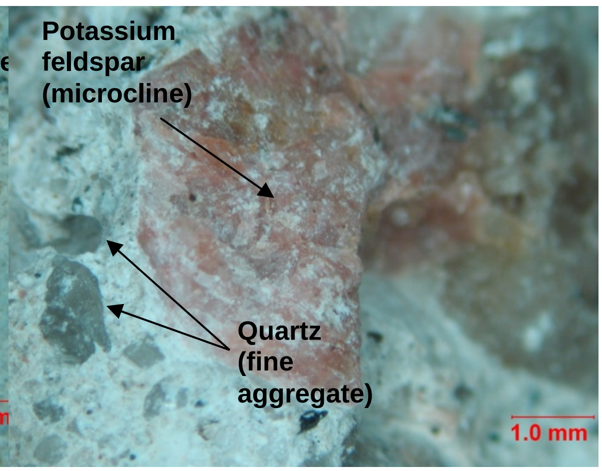


Figure E-30. Microphotograph of Typical Potassium Feldspar-Rich Granitic Gravel in Concrete Particle, Photographed at 10X.

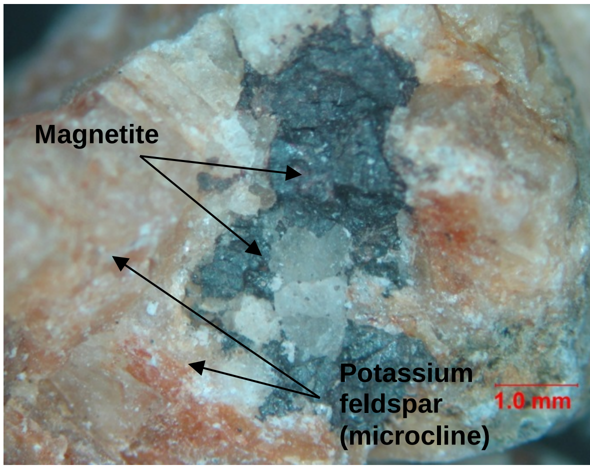


Figure E-31. Microphotograph of Magnetite in Potassium Feldspar-Rich Granitic Gravel in Concrete Particle, Photographed at 10X.

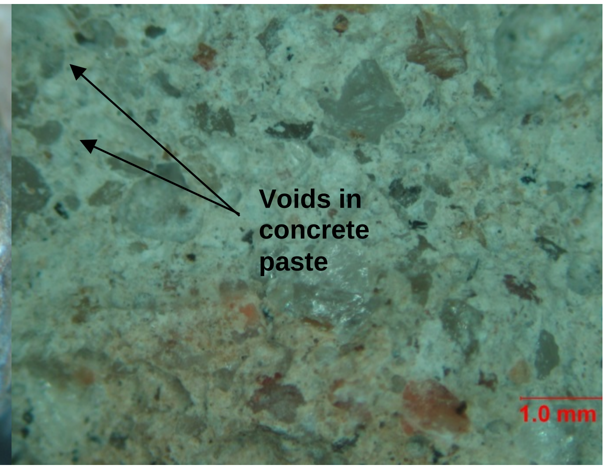


Figure E-32. Microphotograph of Voids in Potassium Feldspar-Rich Granitic Gravel in Concrete Particle, Photographed at 10X.

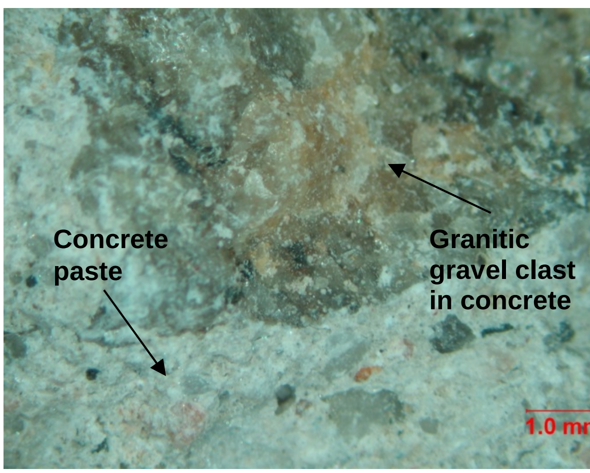


Figure E-33. Microphotograph of a Rounded, Weathered Granitic Gravel Clast in a Concrete Particle, Photographed at 10X.

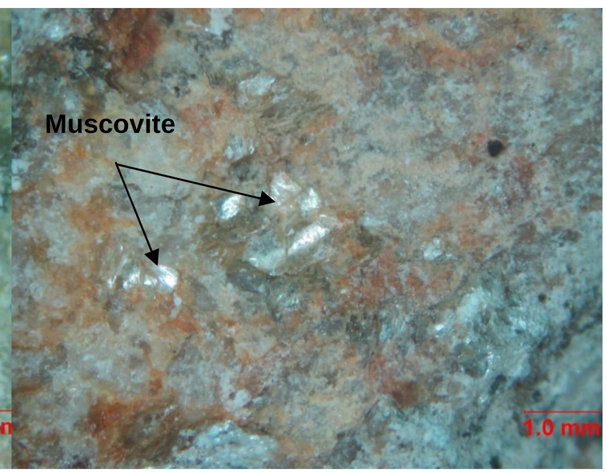


Figure E-34. Microphotograph of Muscovite in a Weathered Granitic Clast in Concrete, Photographed at 10X.

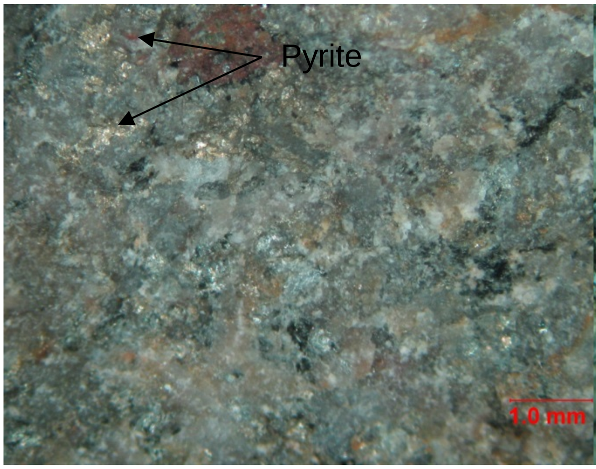


Figure E-35. Microphotograph of Pyrite in a Weathered Granitic Gravel Clast in Concrete, Photographed at 10X.

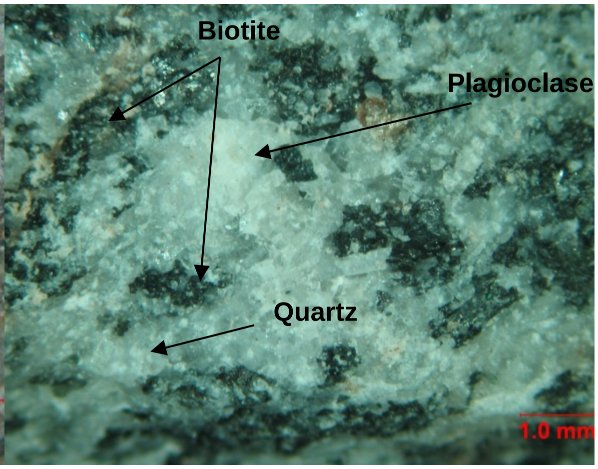


Figure E-36. Microphotograph of Light Colored (Felsic) Granitic Clast, Photographed at 10X.

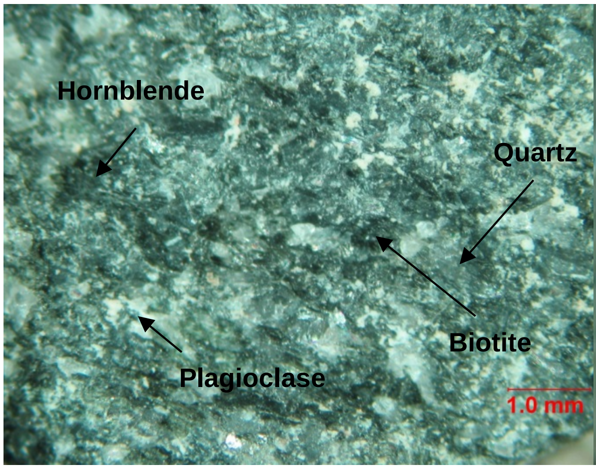


Figure E-37. Microphotograph of Dark Colored (Mafic) Granitic Gravel Clast, Photographed at 10X.

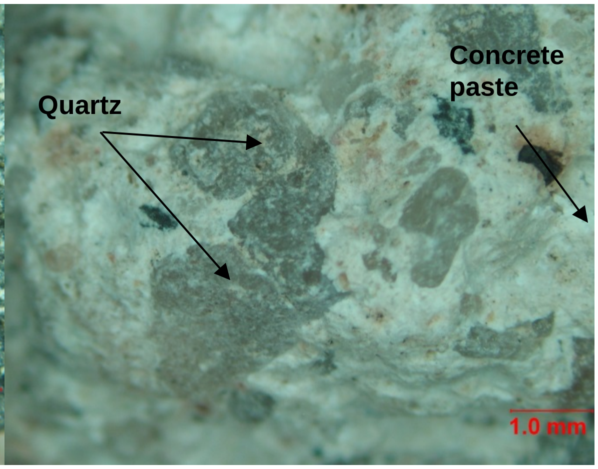


Figure E-38. Microphotograph of Quartz-Rich Gravel Clast, Photographed at 10X.

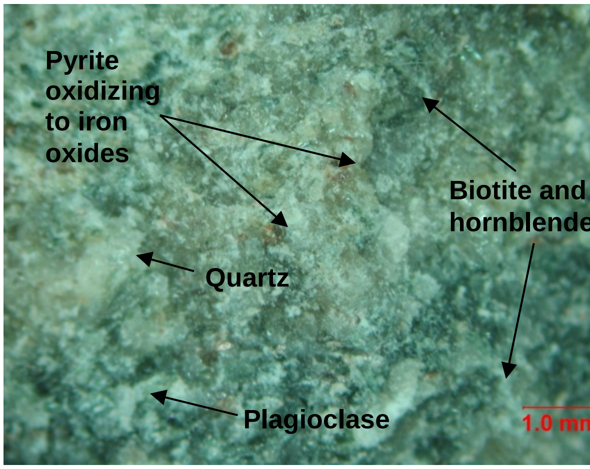


Figure E-39. Microphotograph of Typical Felsic (Light Colored) Granitic Gravel Clast, Photographed at 10X.

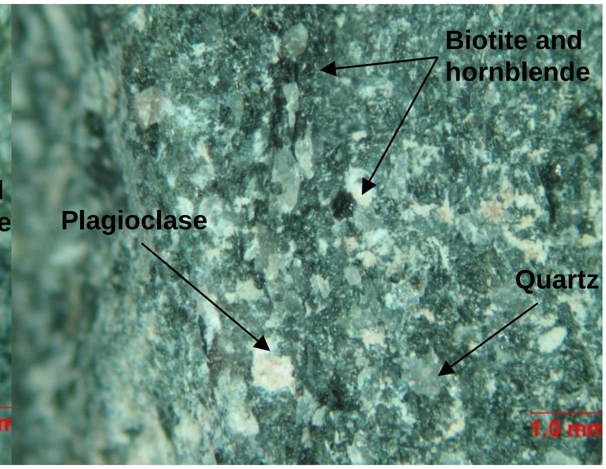


Figure E-40. Microphotograph of Typical Mafic (Dark Colored) Granitic Gravel Clast, Photographed At 10X.

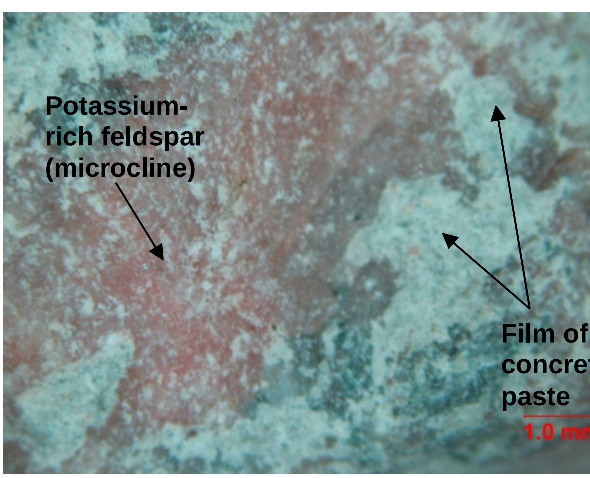


Figure E-41. Microphotograph of Typical Potassium Feldspar-Rich Gravel Clast, Photographed at 10X.

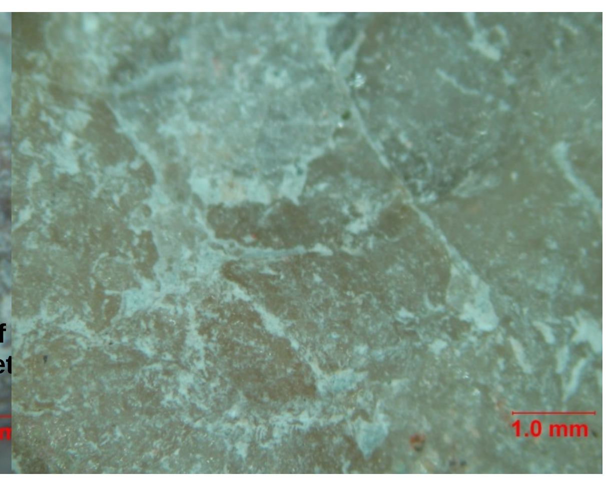


Figure E-42. Microphotograph of Typical Quartz Gravel Clast, Photographed at 10X.

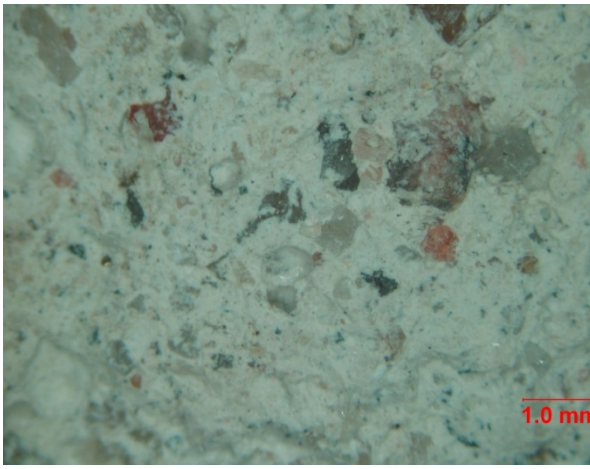


Figure E-43. Microphotograph of Typical Cement Paste Particle, Photographed at 10X.

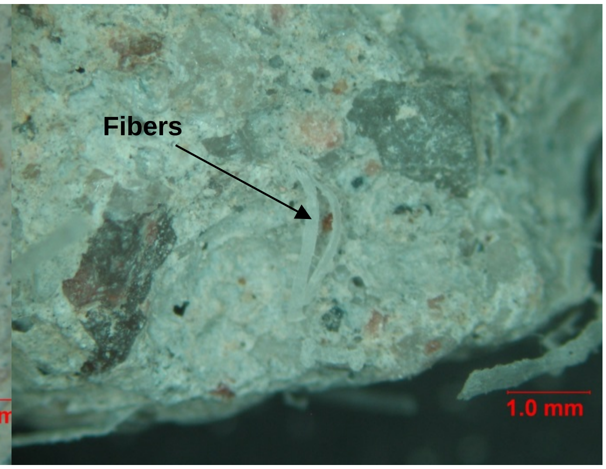


Figure E-44. Microphotograph of Cement Paste Particle with Fibers, Photographed at 10X.

Figure E-45. Photograph of Potassium Feldspar-Rich Granitic Gravel in Concrete Particles (¾" X ½" Size Fraction).

Figure E-46. Photograph of Granitic Gravel in Concrete Particles (¾" X ½" Size Fraction).

Figure E-47. Photograph of Quartz-Rich Gravel in Concrete Particles (¾" X ½" Size Fraction).

Figure E-48. Photograph of Granitic Gravel Clasts (¾" X ½" Size Fraction).

Figure E-49. Photograph of Potassium Feldspar-Rich Granitic Gravel Clasts (¾" X ½" Size Fraction).

Figure E-50. Photograph of Quartz-Rich Gravel Clasts (¾" X ½" Size Fraction).

Figure E-51. Photograph of Concrete Paste (No Coarse Aggregate Clasts) Particles (¾" X ½" Size Fraction).

Table E-10. Lithologic Descriptions of the Sample and Calculated Weight Percentages Present in Each Size Fraction and the Weight Percent Present in the Total Sample

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.				WT. % AV.
	¾"	½"	⅜"	#4	
Potassium Feldspar-Rich Granitic Gravel in Concrete – (Figures E-29, E-30 and E-45) Light gray to moderate orange pink to dark gray; concrete contains a potassium feldspar-rich granitic gravel coarse aggregate and a quartz-rich natural sand fine aggregate; coarse aggregate is well-rounded, spherical to flattened, gravel clasts are coarse-grained to pegmatitic, dominated by pinkish potassium feldspar (probably microcline) with some quartz, plagioclase, muscovite, minor biotite and trace magnetite (Figure E-31); paste forms a good bond with both the fine and coarse aggregate; some entrapped air voids and smaller, more symmetrical entrained air voids (Figure E-32). The potassium feldspar-rich granitic gravel in concrete particles are angular to subangular, cubical with a few flattened particles. The particles are hard, porous, and durable with a smooth to somewhat rough texture.	61.5	35.9	28.0	16.2	33.1
Granitic Gravel in Concrete – (Figures E-33 and E-46) Light gray to medium dark gray to pinkish gray with some scattered moderate orange pink staining; concrete contains a granitic gravel coarse aggregate and a quartz-rich natural sand fine aggregate; coarse aggregate is well-rounded, spherical to flattened,	27.0	27.3	16.9	6.1	22.7

gravel clasts are fine- to medium-grained; composed of plagioclase, quartz, muscovite (Figure E-34), biotite, hornblende, and trace pyrite (Figure E-35); color of granitic clasts varies with light gray (felsic) clasts composed of quartz, plagioclase and minor biotite (Figure E-36), darker colored (mafic) granitic clasts are composed of plagioclase, quartz, biotite, and hornblende (Figure E-37); some clasts are weathered (Figures E-33 through E-39); paste forms a good bond with both the fine and coarse aggregate; some entrapped air voids and smaller, more symmetrical entrained air voids. The granitic gravel in concrete particles are angular to subangular, cubical with a few flattened particles. The particles are hard, porous, and durable with a smooth to somewhat rough texture.					
Quartz-Rich Gravel in Concrete – (Figures E-38 and E-47) Light gray to medium gray with some pale yellowish orange to moderate orange pink staining; concrete contains a quartz-rich gravel coarse aggregate and a quartz-rich natural sand fine aggregate; coarse aggregate is well-rounded, flattened to spherical, gravel clasts are generally polycrystalline and contain inclusions of biotite, muscovite, and magnetite; some clasts are weathered and stained; paste forms a good bond with both the fine and coarse aggregate; some entrapped air voids and smaller, more symmetrical entrained air voids are present. The quartz-rich gravel in concrete particles are angular to subangular, cubical with a few flattened particles. The particles are hard, porous, and durable with a smooth to somewhat rough texture.	11.5	10.7	19.9	16.0	13.6
Granitic Clasts – (Figures E-39, E-40 and E-48) Light gray to medium gray to medium dark gray with some pale yellowish orange to moderate orange pink staining; granitic clasts are fine- to medium-grained; composed of plagioclase, quartz, muscovite, biotite, hornblende, and trace pyrite; color of granitic clasts varies with light gray (felsic) clasts composed of quartz, plagioclase and minor biotite, darker colored (mafic) granitic clasts are composed of plagioclase, quartz, biotite, and hornblende; some clasts are weathered; some clasts are covered with a fine film of paste and others contain patches of paste. The granitic clasts are angular to rounded, spherical to flattened. The particles are hard, dense, and durable with a smooth to somewhat rough texture.	-	8.3	10.7	12.1	9.0
Potassium Feldspar-Rich Granitic Clasts – (Figures E-41 and E-49) Light gray to moderate orange pink to dark gray; potassium feldspar-rich granitic clasts are coarse-grained to pegmatitic, dominated by pinkish potassium feldspar (probably microcline) with some quartz, plagioclase, muscovite, minor biotite and trace magnetite. The potassium feldspar-rich granitic clasts are angular to well-rounded and spherical to flattened. The particles are hard, dense, and durable with a smooth to somewhat rough texture.	-	8.2	9.1	17.8	8.9

Table E-10. Continued

LITHOLOGY	SIEVE SIZE (Retained on) % BY WT.				WT. % AV.
	¾”	½”	⅜”	#4	
Quartz Clasts – (Figures E-42 and E-50) Light gray to medium gray with some pale yellowish orange to moderate orange pink staining; angular to well-rounded, flattened to spherical, gravel clasts are generally polycrystalline and contain inclusions of biotite, muscovite, and magnetite; some clasts are weathered and stained. The quartz clasts are angular to well-rounded, spherical to flattened. The particles are hard, dense, and durable with a smooth texture.	-	5.6	8.8	9.1	6.6
Cement Paste – (Figures E-43, E-44 and E-51) Light gray to medium light gray; contains quartz-rich natural sand fine aggregate and no coarse aggregate; fine aggregate present is generally minus #16 with a minor quantity of larger clasts; paste forms a good bond with the fine aggregate; some entrapped air voids and smaller, more symmetrical entrained air voids; some fibers (Figure E-44) noted in the concrete paste particles. The concrete paste particles are angular to subangular, cubical with a few flattened particles. The particles are hard, porous, and durable with a smooth to somewhat rough texture.	-	-	6.6	22.7	6.1

Results of Petrographic Examination for Natural Sane

A sample of natural sand (NS) that had been screened and separated into eight size fractions, $^{3}/_{8}$" X #4, #4 X #8, #8 X #16, #16 X #30, #30 X #50, #50 X #100, #100 X #200, and the minus #200 (Figures E-52 through E-64), was used in this examination.

The minus #200 fraction was examined by use of immersion mounts and the polarizing microscope, and the composition was quantified by point counting 400 particles. Each size fraction was separated into lithologies based on rock type and mineralogy. Microphotographs were taken of distinctive features (Figures E-65 through E-76). The volume percentage of each lithology, by size fraction, was calculated as well as the volume percent by entire sample. Lithologic descriptions and the percentages are shown in Table E-11.

The natural sand (NS) fine aggregate consists of hard, tough, dense, smooth, generally durable particles. The sample consisted primarily of quartz (81.5%) with lesser amounts of chert (9.8%), igneous and metamorphic rocks (4.2%), sandstone (1.9%), feldspar (0.8%), magnetite (0.8%), limestone (0.4%), shale (0.2%), shell fragments (0.2%), clay (0.2%) and trace amounts of garnet and sphene (observed in the sample but not in the particle counts). Chert consists of both lightweight (2.3%) and dense (7.5%) chert present in the sample. The small amount of lightweight chert present should not present quality problems. Shale is present is such a small amount that no problems with quality are anticipated. Feldspar and magnetite in the sample is probably derived from breakdown of the igneous and metamorphic rock particles. Clay was observed only in the minus #200 portion of the sample and the small amount present should not cause any quality problems. No weathered particles were noted in the sample but some grains did have iron staining. No other deleterious constituents were observed. The results of this petrographic examination indicate the natural sand (NS) fine aggregate is of good quality for use as a fine aggregate.

Figure E-52. $^{3}/_{8}$" X #4 as Received.

Figure E-53. #4 X #8 as Received.

Figure E-54. #8 X #16 as Received.

Figure E-55. #16 X #30 as Received.

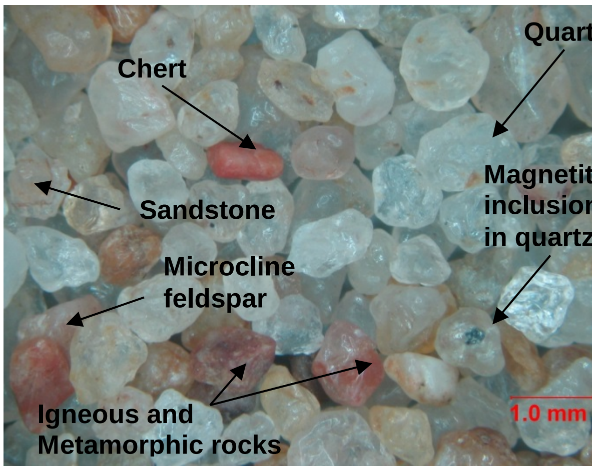


Figure E-56. #16 X #30, Photographed at 10X.

Figure E-57. #30 X #50 as Received.

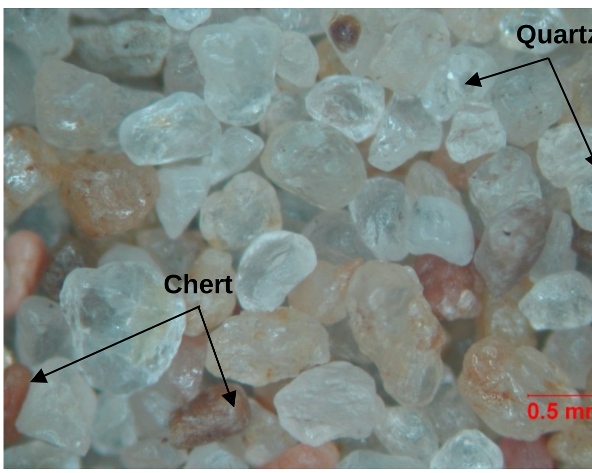


Figure E-58. #30 X #50, Photographed at 20X.

Figure E-59. #50 X #100 as Received.

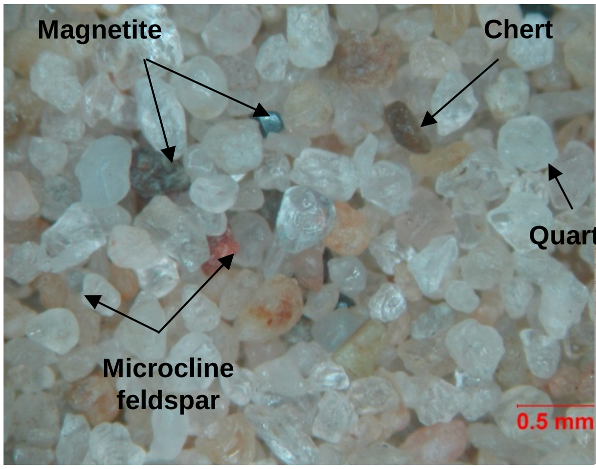


Figure E-60. #50 X #100, Photographed at 20X.

Figure E-61. #100 X #200 as Received.

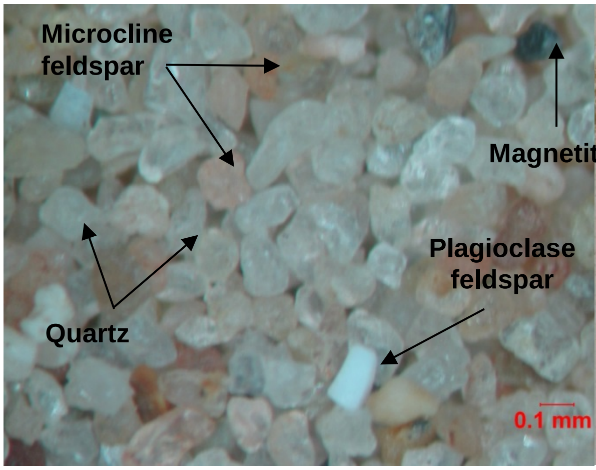


Figure E-62. #100 X #200, Photographed at 40X.

Figure E-63. Minus #200 as Received.

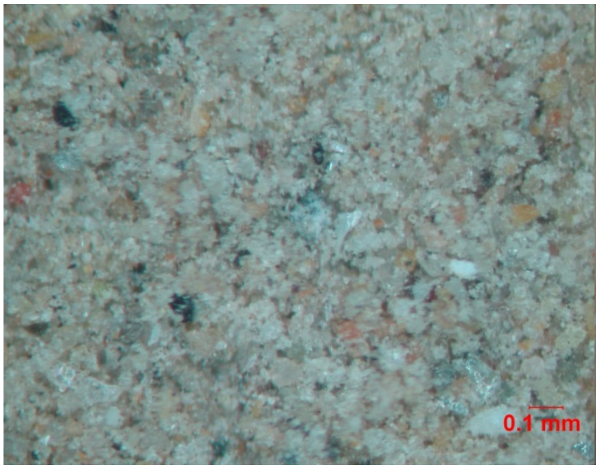


Figure E-64. Minus #200, Black Grains Are Magnetite, Pinkish Grains Are Microcline

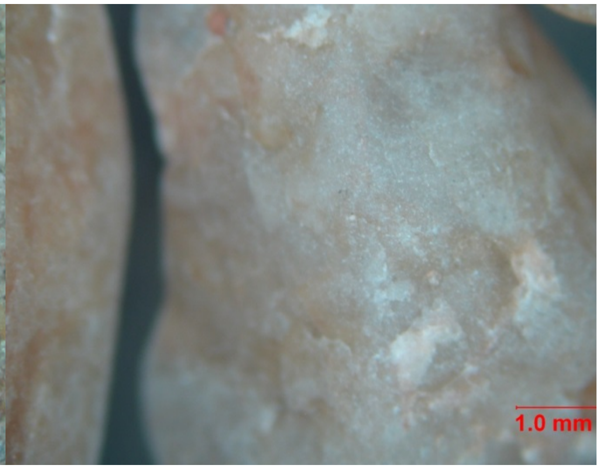


Figure E-65. Microphotograph of Typical Quartz Particles ($^3/_8$" X #4), Photographed

Feldspar, Photographed at 40X.

at 10X.

Figure E-66. Microphotograph of Typical Dense Chert Particle (3/8" X #4). Photographed at 10X.

Figure E-67. Microphotograph of Typical Lightweight Chert Particle (3/8" X #4), Photographed at 10X.

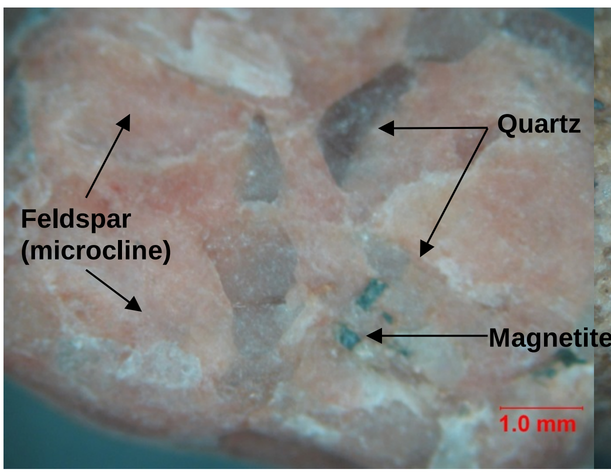
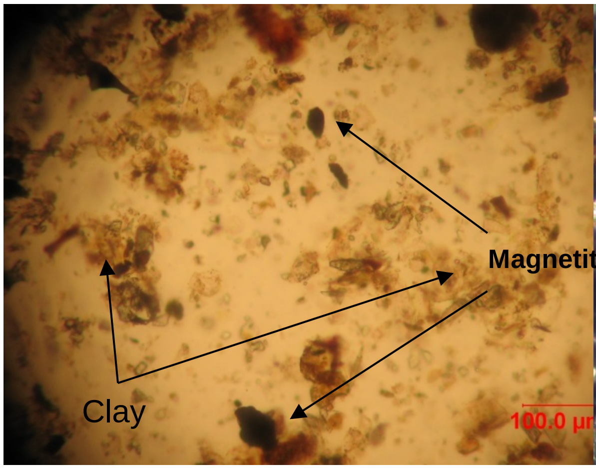


Figure E-68. Microphotograph of Typical Igneous and Metamorphic Rock Particle ($^3/_8$" X #4), Photographed at 10X.

Figure E-69. Microphotograph of Typical Sandstone Particle ($^3/_8$" X #4), Photographed at 10X.



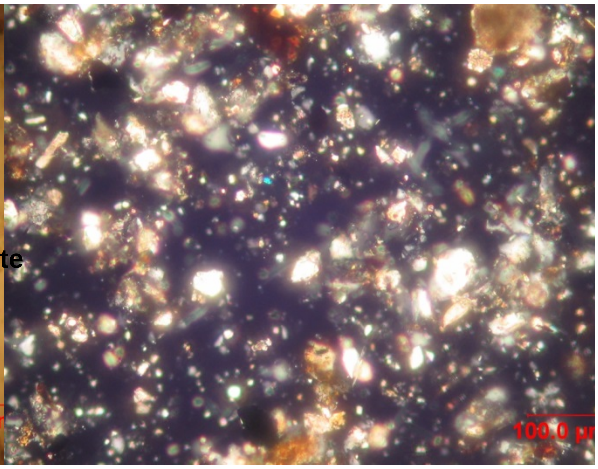
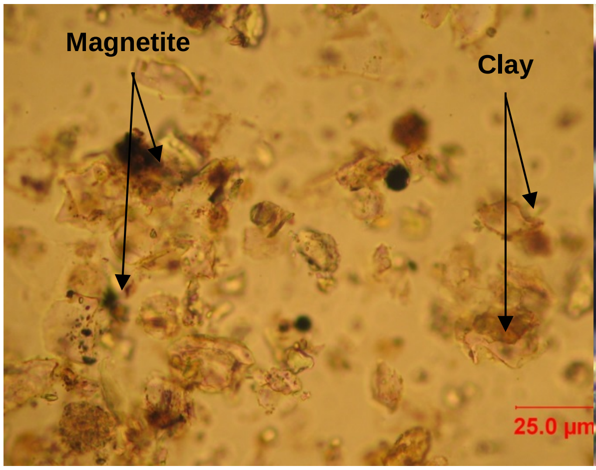


Figure E-70. Microphotograph of A Portion of An Immersion Mount of The Minus #200 Fraction, Photographed at 100X under Plane Light.

Figure E-71. Same View as in Figure E-70 But Photographed at 100X with Polarized Light.



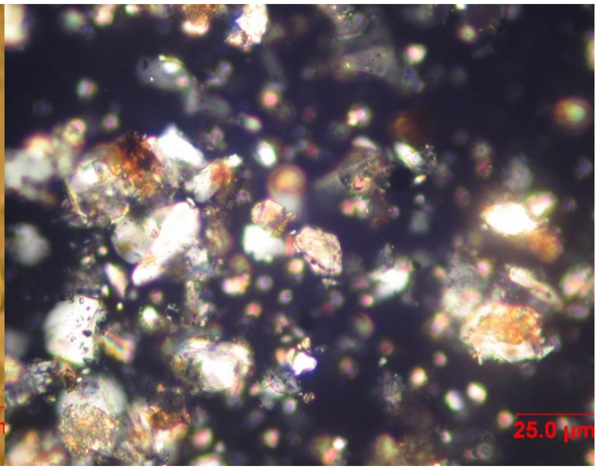


Figure E-72. Microphotograph of A Portion of An Immersion Mount of The Minus #200 Fraction, Photographed at 200X under Plane Light.

Figure E-73. Same View as in Figure E-72 But Photographed at 200X with Polarized Light.

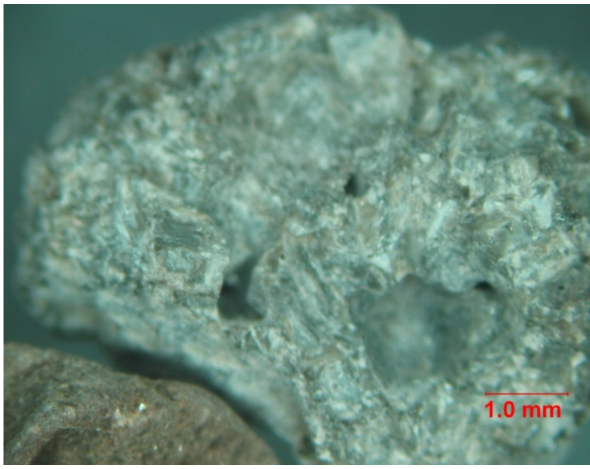


Figure E-74. Microphotograph of Typical Limestone Particles ($^3/_8$" X #4), Photographed at 10X.

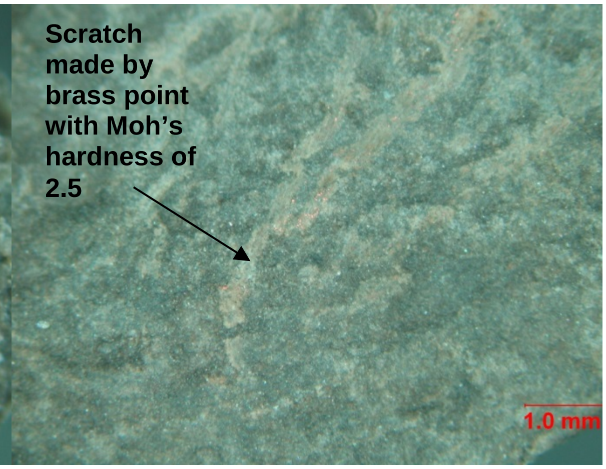


Figure E-75. Microphotograph of Typical Shale Particle ($^3/_8$" X #4), Photographed at 10X.

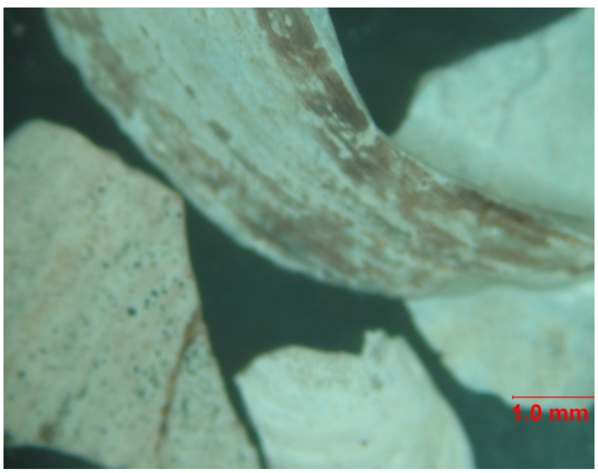


Figure E-76. Microphotograph of Typical Shell Fragments (#4 X #8). Photographed at 10X.

Table E-11. Lithologic Descriptions of the Sample and Calculated Weight Percentages Present in Each Size Fraction and the Weight Percent Present in the Total Sample

LITHOLOGY	SIEVE SIZE (Retained on) % BY VOL.								VOL. % AV.
	#4	#8	#16	#30	#50	#100	#200	Pan	
Quartz – (Figures E-56, E-58, E-60, E-62, and E-65) Light gray to light brownish gray to clear with some minor moderate reddish orange staining; some frosted particles; the quartz is probably derived from mechanical breakdown of sandstone, igneous and metamorphic rock particles; some quartz particles contain inclusions of pinkish potassium feldspar (probably microcline)	13.3	45.4	74.3	89.5	94.3	95.7	95.6	94.5	81.5

and magnetite; rounded to well-rounded, spherical with a few flattened particles. The quartz particles are hard, durable, dense, and tough.									
Chert – (Figures E-56, E-58, E-60, E-66 and E-67) White to light gray to light brownish gray to reddish brown to pale brown; lightweight chert content of the sample is 2.3%; angular to rounded with dense chert being more angular than lightweight chert; spherical to flattened with porous lightweight chert tending to be rounded while denser darker colored chert is angular; the chert is composed of microcrystalline quartz and some chalcedony. The particles are generally hard, durable, dense to porous, and tough.	58.7	25.4	15.1	4.7	4.2	2.5	1.7	-	9.8
Igneous and Metamorphic Rocks – (Figures E-56 and E-68) Moderate red to pale reddish brown to medium gray; medium- to coarse-grained; composed of quartz, plagioclase and potassium feldspar (microcline), some muscovite and biotite mica, and magnetite. The particles are subangular to rounded, spherical to flattened. The particles are hard, dense, and durable.	14.7	17.1	7.0	3.8	-	-	-	-	4.2
Sandstone – (Figures E-56 and E-69) Light gray to medium dark gray to light brownish gray; fine- to medium-grained (0.2-0.6 mm); composed of quartz and feldspar with trace amounts of muscovite and biotite mica,; silica cemented; the sandstone particles are rounded- to well-rounded, spherical to flattened, hard, durable, dense to porous, and tough.	10.7	9.7	2.2	2.0	-	-	-	-	1.9

Table E-11. Continued

LITHOLOGY	SIEVE SIZE (Retained on) % BY VOL.								VOL. % AV.
	#4	#8	#16	#30	#50	#100	#200	Pan	
Feldspar – (Figures E-56, E-58, E-60) Pink to reddish brown to white to translucent; the feldspar is probably derived from mechanical breakdown of igneous and metamorphic rock particles; feldspar consists primarily of pinkish microcline and translucent to white plagioclase, the feldspar was identified by color, cleavage, and polysynthetic twinning (plagioclase); angular to rounded, cubical to spherical with a few flattened particles. The feldspar particles are hard, durable, dense, and tough.	-	-	-	-	1.2	1.0	1.2	1.8	0.8
Magnetite – (Figures E-60, E-62, and E-70 through E-73) Black; occurs as inclusions in quartz, igneous and metamorphic rocks, and as individual grains in the material passing the #30 sieve; some euhedral grains are present; magnetic. The particles are angular, hard, dense, and durable.	-	-	-	-	0.3	0.8	1.5	2.7	0.8
Limestone – (Figure E-74) Medium gray to medium dark gray with some pale yellowish brown staining; finely to medium crystalline with a few coarsely crystalline sparry calcite particles; generally well-cemented with a few soft, weathered particles; strong reaction to a 10% solution of HCl; the limestone is well-rounded with a few angular sparry particles, flattened to spherical, hard, generally dense and durable.	1.2	0.6	1.1	-	-	-	-	-	0.4
Shale – (Figure E-75) Medium gray to black; very fine-grained; soft, can be scratched with a brass point with a Moh's hardness of 2.5-3.0; abundant clay with minor muscovite mica ; the shale particles are rounded, flattened, porous, smooth, soft, and non-durable.	0.7	0.6	-	-	-	-	-	-	0.2
Shell – (Figure E-76) White to very light gray; probably fragments of fresh water mollusks; angular; flattened; the particles are soft, brittle, and non-durable.	0.7	1.2	0.3	-	-	-	-	-	0.2

Clay – (Figures E-70 through E-73) Very fine-grained; occurs as a component of the minus #200 fraction; clay was identified and quantified using immersion mounts of the minus #200 material and a polarizing microscope.	-	-	-	-	-	-	-	1.0	0.2

Results of Petrographic Examination for Preston Sandstone Fine Aggregate

A sample of crushed Preston sandstone (PS) fine aggregate that had been screened and separated into eight size fractions, 3/8" X #4, #4 X #8, #8 X #16, #16 X #30, #30 X #50, #50 X #100, #100 X #200, and the minus #200 (Figures E-77 through E-93), was used in this examination.

Initial examination of the 3/8" X #4 and #4 X #8 size fractions revealed the particles were heavily coated with a very fine (minus #200) coating of dust of fracture. The coating obscured the mineralogy and texture making identification of the lithology impossible. The entirety of the two size fractions were washed and reexamined. The washing had removed the fine particles and allowed the lithologies to be identified. Upon examination it was discovered that the remaining size fractions were also heavily coated with the very fine particles (Figures E-80 through E-92). A representative portion of each size fraction was weighed, washed over a sieve, dried, and weighed again. The loss of the fine particles was calculated and is included in Table E-12. The minus #200 fraction was examined by use of immersion mounts and the polarizing microscope and the composition was quantified by point counting 400 particles. The assumption was made that the material lost by washing was minus #200, and the percentages of components observed in the minus #200 were the same in the fine coating. The amount of clay present in the dust fraction of each size fraction (except the material retained on the #4 and #8 sieves) was calculated and is shown in Table E-12. Each size fraction was separated into lithologies based on rock type and mineralogy. Microphotographs were taken of distinctive features and are shown in the back of this report (Figures E-94 through E-111). The volume percentage by size fraction of each lithology was calculated as well as the volume percent by entire sample. Lithologic descriptions and the percentages are shown in Table E-13.

The Preston sandstone fine aggregate consists of hard to soft, tough, porous to dense, rough, generally durable particles. The sample consisted primarily of medium-grained sandstone (53.7%) and quartz (23.9%) with lesser amounts of shale (8.7%), clay (7.5%), carbon (1.6%), fine-grained sandstone (1.4%), weathered sandstone (1.4%), muscovite mica (1.4%), chert (0.3%), and biotite mica (0.1%). The sample, as received, was coated with light gray to light olive gray dust of fracture consisting of very fine particles (minus #200) of clay (60.7%), quartz (26.0%), carbon from carbonized plants (8.0%), muscovite mica (5.0%), and biotite mica (0.3%). Trace amounts of pyrite, hematite, zircon, and sphene were noted in the sample. Particles counted as shale constituted particles with greater than 50% shale in the particle. Small, generally rounded clasts of shale are common in particles of the coarse-grained sandstone (Figures E-97 and E-98). The amount of shale present in the sample may present problems with quality. Clay in the minus #200 portion of the sample and present as dust coatings on other sizes is probably derived from breakdown of shale. The fair amount of clay present in the minus #200 fraction and as dust coatings on larger sized particles may present problems with quality; however, the fine aggregate has a proven record of satisfactory performance in hot mix asphalt. Weathering is present as iron staining with 1.4% of the sample consisting of weathered sandstone. Weathering is mild and no quality control problems are anticipated with the weathered sandstone. No other deleterious constituents were observed. The results of this petrographic examination indicate the Preston sandstone fine aggregate is of fair quality for use as a coarse aggregate.

Table E-12. Percent Clay in the Dust (Minus #200 Fraction) Present on the Particles in Each Size Fraction

SIEVE SIZE (Retained on)	INITIAL WEIGHT IN GRAMS	SIEVE WASHED OVER	WEIGHT AFTER WASHING AND DRYING	PERCENT LOSS	PERCENT CLAY
#16	68.2	#50	66.7	2.2	1.3
#30	22.8	#50	21.9	3.95	2.4
#50	17.6	#100	13.1	25.6	15.5
#100	25.6	#200	21.3	16.8	10.2
#200	23.7	#200	19.1	19.4	12.1

Note: The initial sample was weighed, washed over the stated sieve, dried on the sieve, weighed, and the percent loss calculated. The percent clay in the minus #200 size fraction (see Table E-13 below) was used to calculate the percent clay in the dust on the particles retained on each sieve.

Figure E-77. $^{3}/_{8}$" X #4, as Received and before Washing.

Figure E-78. #4 X #8 as Received and before Washing.

Figure E-79. #8 X #16, as Received and

Figure E-80. #16 X #30, as Received and

before Washing.

before Washing.

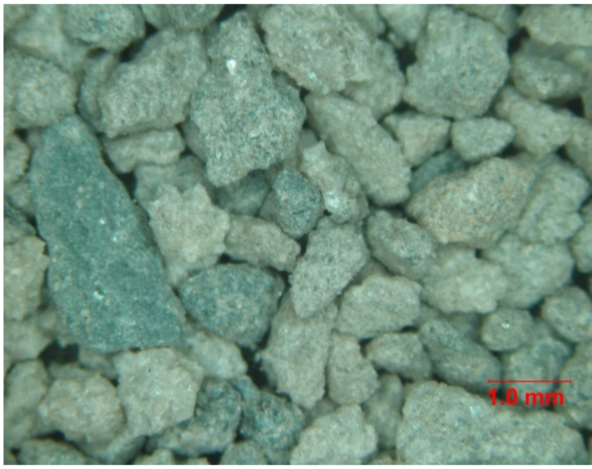


Figure E-81. #16 X #30, Microphotograph of Sample as Received and before Washing, Photographed at 10X.

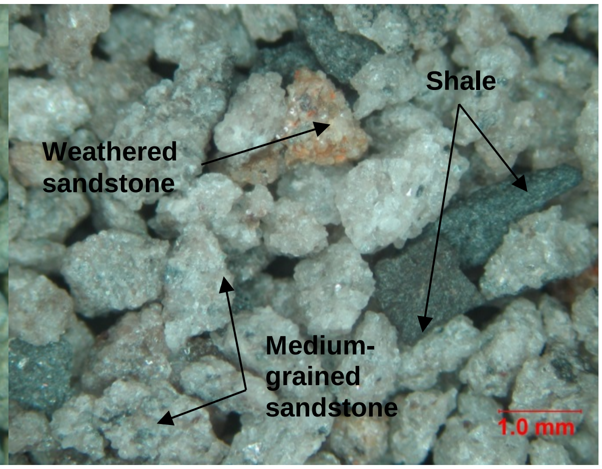


Figure E-82. #16 X #30, Microphotograph of Sample after Washing, Photographed at 10X.

Figure E-83. #30 X #50, as Received and before Washing.

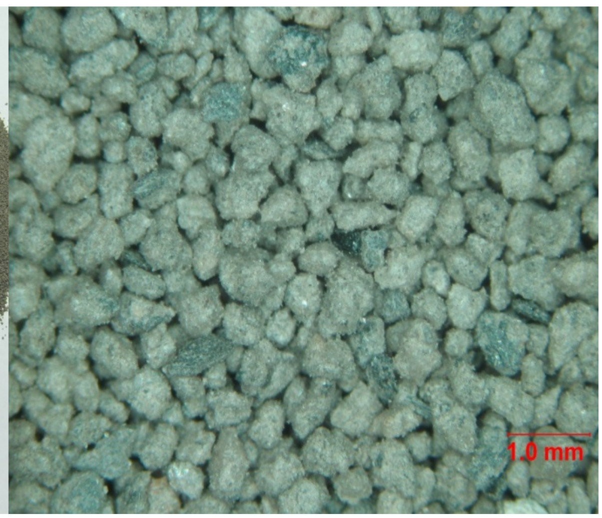


Figure E-84. #30 X #50, Microphotograph of Sample as Received and before Washing, Photographed at 10X.

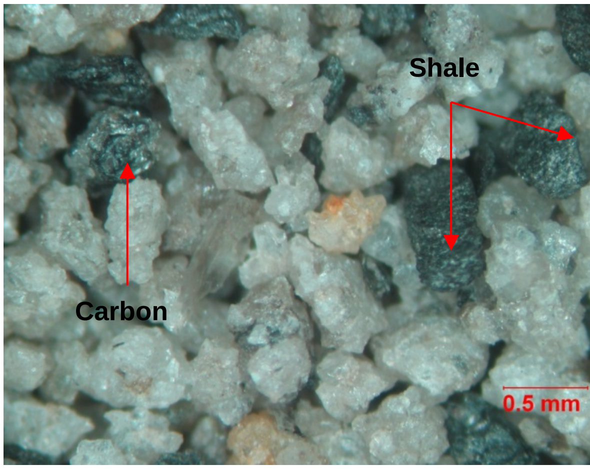


Figure E-85. #30 X #50, Microphotograph of Sample after Washing, Photographed at 20X.

Figure E-86. #50 X #100, as Received and before Washing.

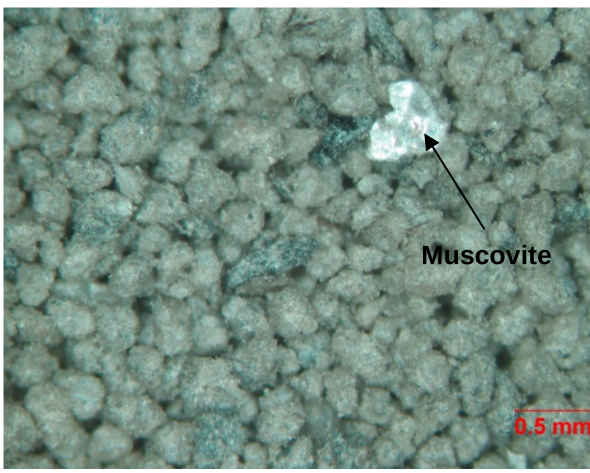


Figure E-87. #50 X #100, Microphotograph of Sample as Received and before Washing, Photographed at 20X.

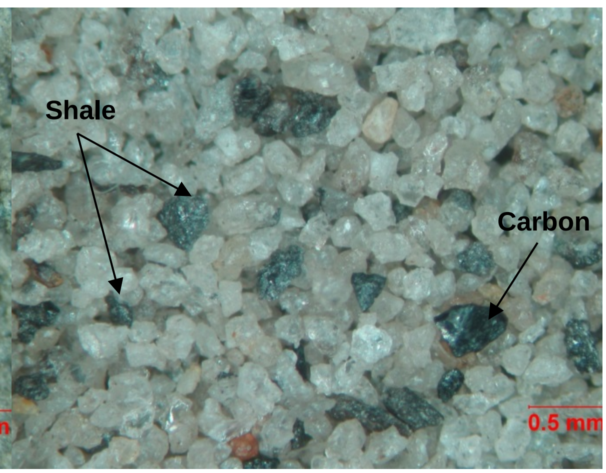


Figure E-88. #50 X #100, Microphotograph of Sample after Washing, Photographed at 20X.

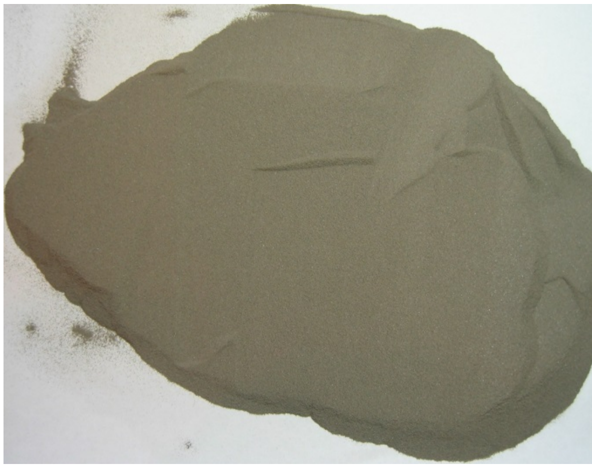


Figure E-89. #100 X #200, as Received and before Washing.

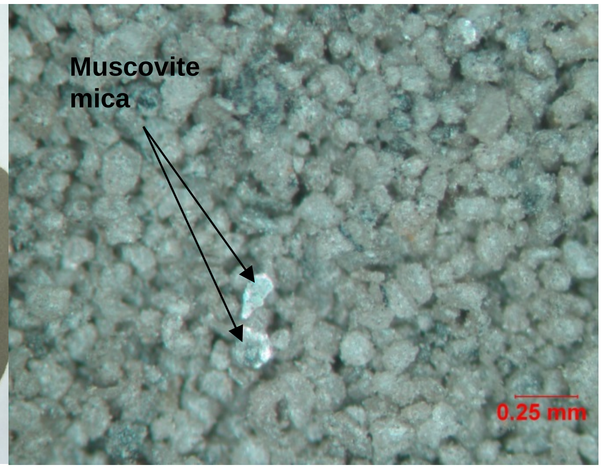


Figure E-90. #100 X #200, Microphotograph of Sample as Received and before Washing, Photographed at 30X.

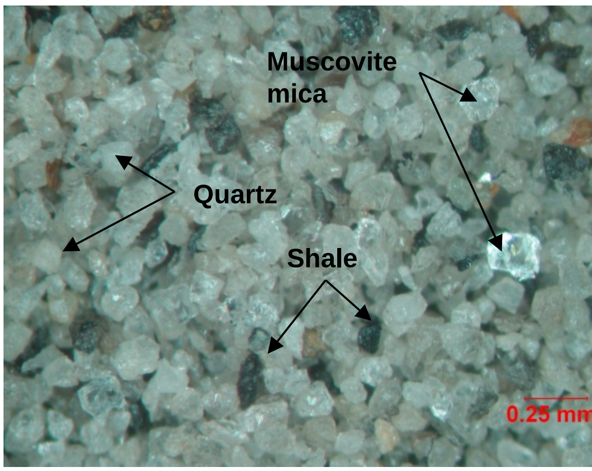


Figure E-91. #100 X #200, Microphotograph of Sample after Washing, Photographed at 30X.

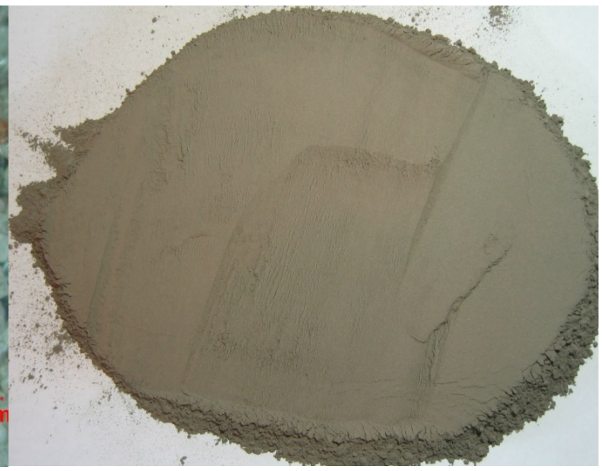


Figure E-92. Minus #200 as Received and before Washing.

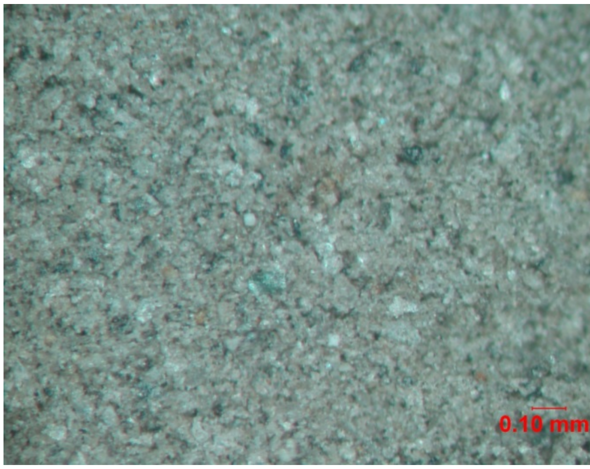


Figure E-93. Minus #200, Microphotograph of Sample as Received, Photographed at 40X

Figure E-94. Microphotograph of Typical Medium-Grained Sandstone Particles (#4 X #8), Photographed at 10X.

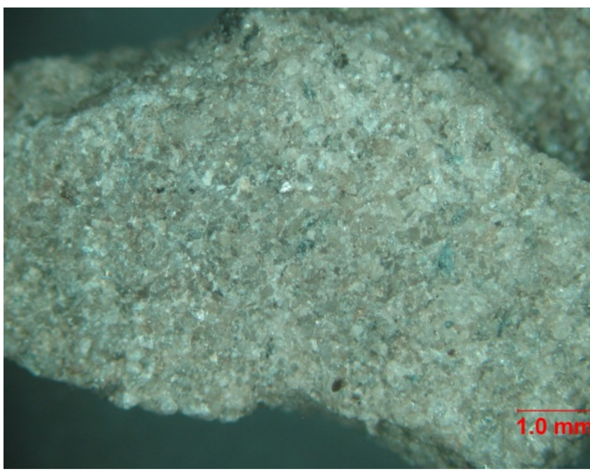


Figure E-95. Microphotograph of Typical Medium-Grained Sandstone Particle ($^3/_8$" X #4), Photographed at 10X.

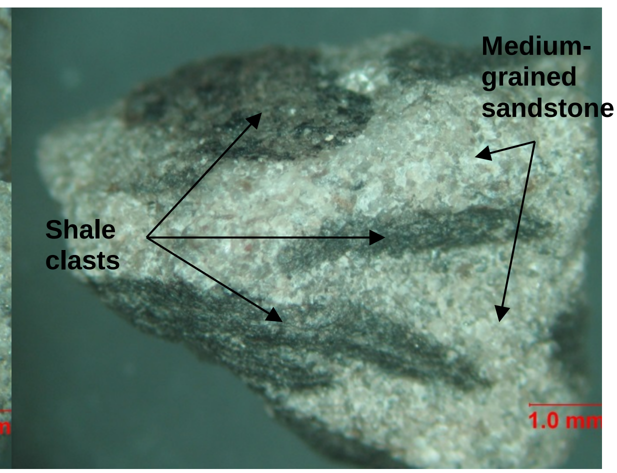


Figure E-96. Microphotograph of Shale Clasts in Medium-Grained Sandstone Particle ($^3/_8$" X #4), Photographed at 10X.

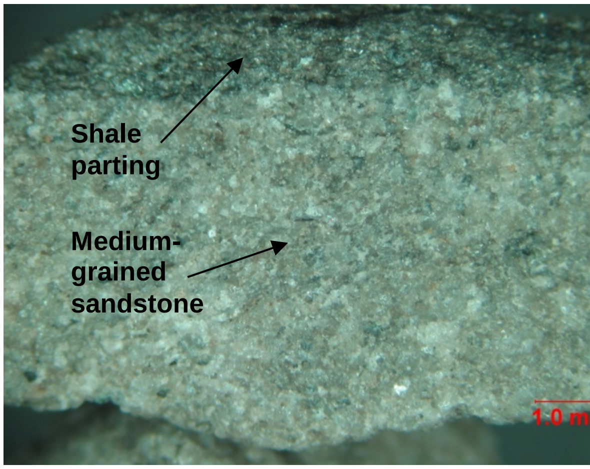


Figure E-97. Microphotograph of Shale Parting on Medium-Grained Sandstone Particle ($^3/_8$" X #4), Photographed at 10X.

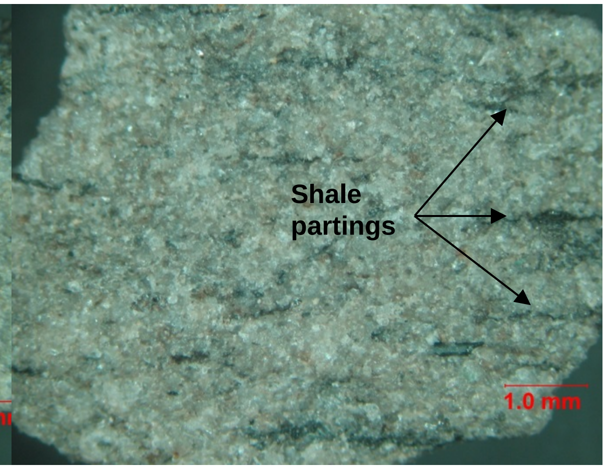


Figure E-98. Microphotograph of Shale Partings in A Medium-Grained Sandstone Particle ($^3/_8$" X #4), Photographed at 10X.

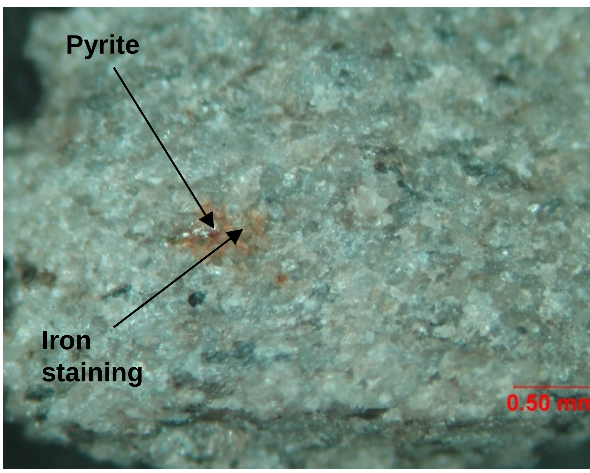


Figure E-99. Microphotograph of Pyrite Surrounded by Iron Staining in Medium-Grained Sandstone (#4 X #8), Photographed at 20X.

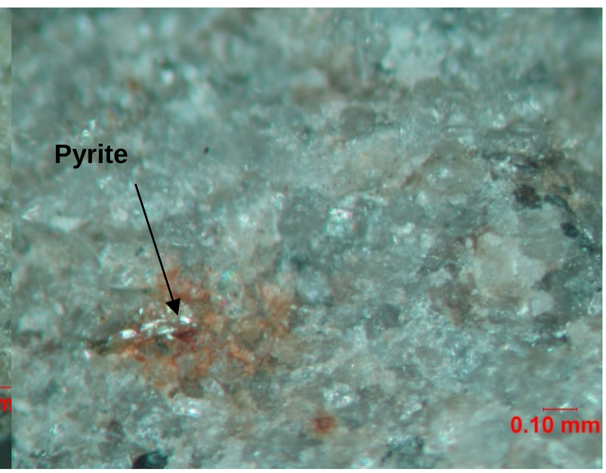


Figure E-100. Same View as in Figure C-99 But Photographed at 40X.

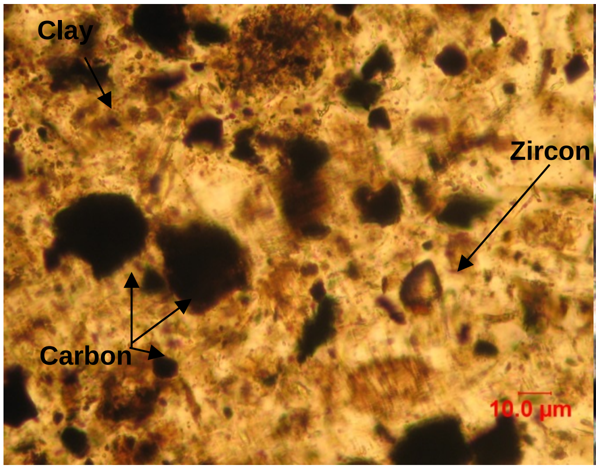


Figure E-101. Microphotograph of A Portion of An Immersion Mount of The Minus #200 Fraction, Photographed at 200X under Plane Light.

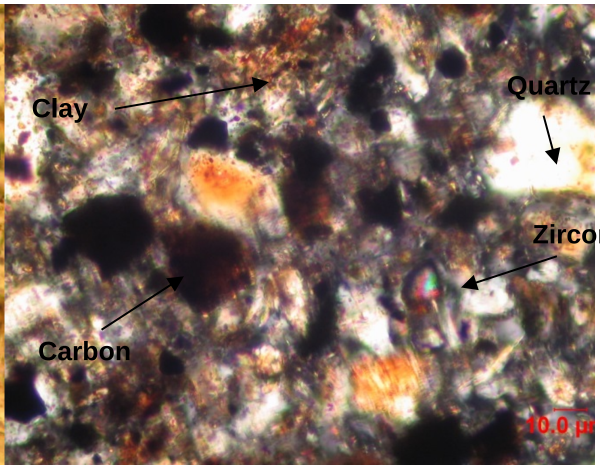


Figure E-102. Same View as in Figure E-101 but Photographed at 200X with Polarized Light.

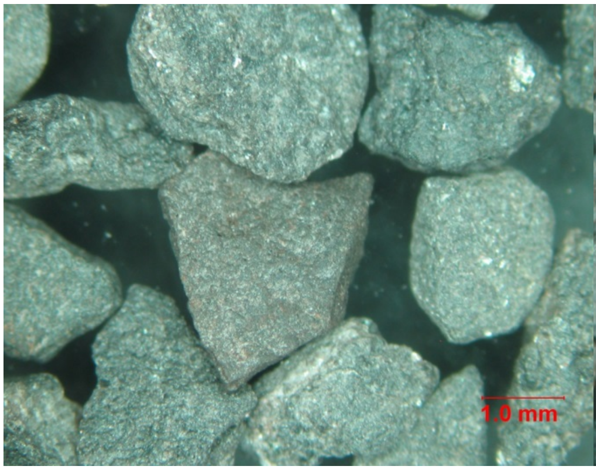


Figure E-103. Microphotograph of Typical Shale Particles (#8 X #16), Photographed at 10X.

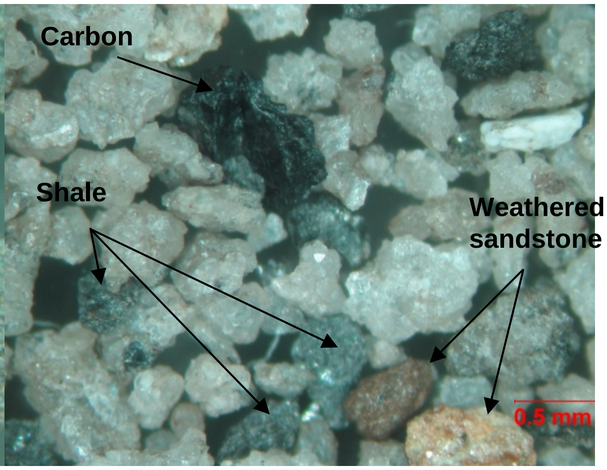


Figure E-104. Microphotograph of Shale and Carbon Particles (#30 X #50), Photographed at 20X.

Figure E-105. Microphotograph of Typical Fine-Grained Sandstone Particles (#8 X #16), Photographed at 10X.

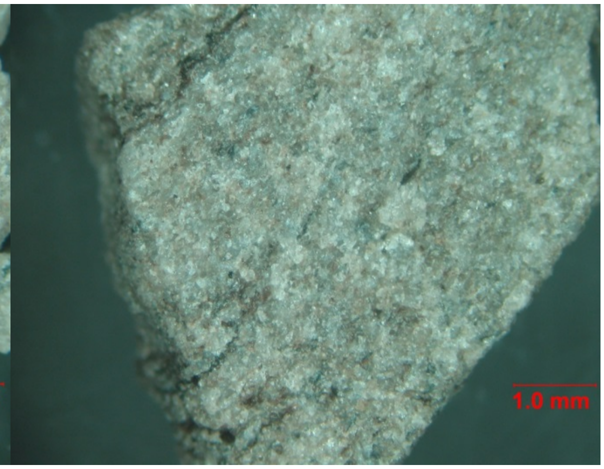


Figure E-106. Microphotograph of A Typical Fine-Grained Sandstone Particle ($^3/_8$" X #4), Photographed at 10X.

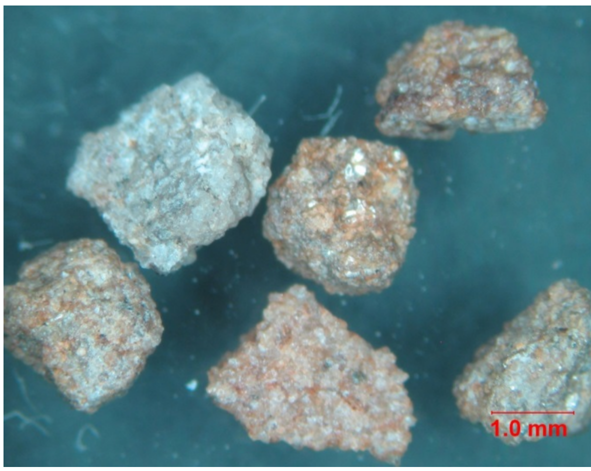


Figure E-107. Microphotograph of Typical Weathered Sandstone Particles (#8 X #16), Photographed at 10X.

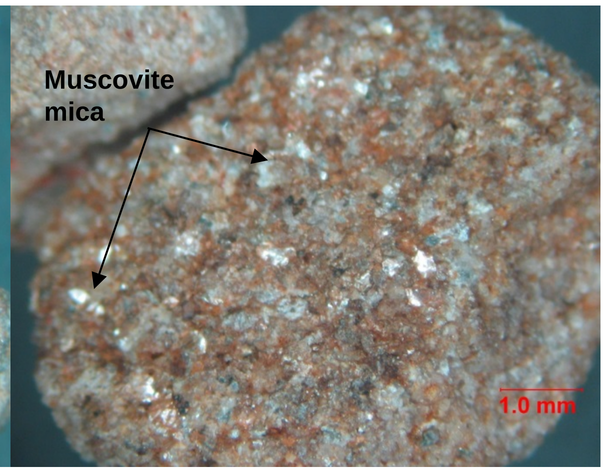


Figure E-108. Microphotograph of Typical Weathered Sandstone Particle ($^3/_8$" X #4), Photographed at 10X.

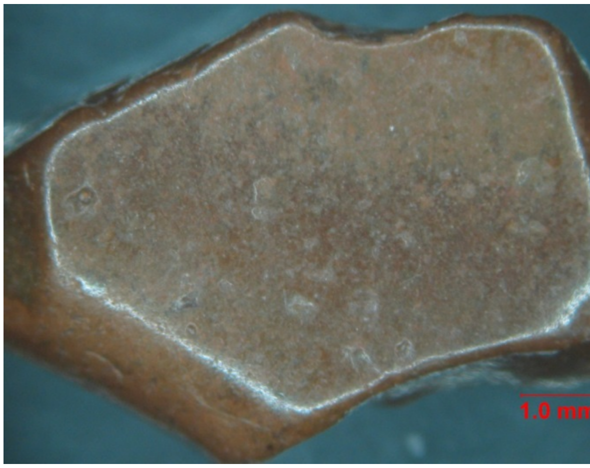


Figure E-109. Microphotograph of Polished and Rounded Chert Particle, Possible Contamination of The Sample ($^3/_8$" X #4), Photographed at 10X.

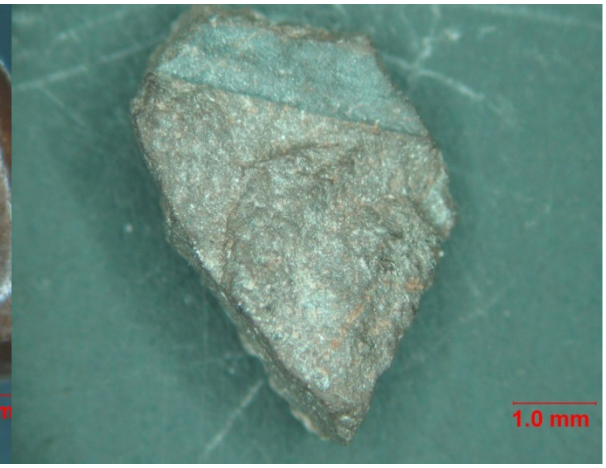


Figure E-110. Microphotograph of Typical Chert Particle (#8 X #16), Photographed at 10X.

Figure E-111. Microphotograph of another Rounded and Polished Chert Particle (#30 X #50), Photographed at 20X.

Table E-13. Lithologic Descriptions of the Sample and Calculated Weight Percentages Present in Each Size Fraction and the Weight Percent Present in the Total Sample

LITHOLOGY	SIEVE SIZE (Retained on) % BY VOL.								VOL. % AV.
	#4	#8	#16	#30	#50	#100	#200	Pan	
Medium-Grained Sandstone – (Figures E-94 and E-95) Medium light gray to medium dark gray; medium-grained (0.2-0.5 mm); composed of quartz (80-85%), feldspar (5-8%), muscovite and biotite mica (2-3%), rock fragments (10-15%), and trace amounts of chert, clay, hematite, pyrite and carbon; silica cemented; rock fragments are composed of shale (Figure E-96) with minor amounts of igneous and metamorphic rocks, shale fragments contain clay minerals as well as muscovite mica; shale partings are common (Figures E-97 and E-98); minor dense chert occurs as rounded rock fragments; minor amounts of carbonized plant material are present; trace amounts of pyrite are present, generally with reddish brown iron staining (Figures E-99 and E-100); the medium-grained sandstone particles are angular to subangular; flattened to cubical with some flat and elongate particles, the amount of flat and elongate particles increases with decreasing particle size; porous; rough; hard, and tough.	81.7	76.0	85.7	85.7	84.9	10.7	3.3	-	53.7
Quartz – (Figures E-91, E-101, and E-102) Clear to medium gray with some scattered moderate reddish orange staining; some frosted particles; the quartz is probably derived from mechanical breakdown of sandstone; some quartz particles contain inclusions of muscovite and biotite mica; rounded to well-rounded with some angular particles, spherical to flattened. The particles are hard, durable, dense, and tough.	-	-	0.2	0.2	1.2	75.1	86.4	26.0	23.9
Shale – (Figures E-103 and E-104) Medium gray to black; very fine-grained; soft, can be scratched with a brass point with a Moh's hardness of 2.5-3.0; abundant clay with lesser muscovite mica ; the shale particles are subangular to rounded; flattened with some flat and elongate particles, the amount of flat and elongate particles increases with decreasing particle size; porous; smooth; soft, and non-durable.	9.8	15.9	12.0	11.2	10.8	8.0	3.6	-	8.7
Clay – (Figures E-101 and E-102) Very fine-grained; occurs as coatings on particles in the #4 X #200 fraction and as the major component of the minus #200 fraction; clay was identified and quantified using immersion mounts of the minus #200 material and a polarizing microscope; only identified as belonging to the clay group of minerals, individual identification of the clay mineral species present will need to be by use of X-ray diffraction.	-	-	-	-	-	-	-	60.7	7.5
Carbon – (Figures E-101, E-102 and E-104) Medium dark gray to black; occurs as clasts of carbonized wood in sandstone particles and as a component of the minus #200 material coating larger particles and in the minus #200 fraction itself.	-	-	-	-	-	-	-	8.0	1.6

Table E-13. Continued

LITHOLOGY	SIEVE SIZE (Retained on) % BY VOL.								VOL. % AV.
	#4	#8	#16	#30	#50	#100	#200	Pan	
Fine-Grained Sandstone – (Figures E-105 and E-106) Medium light gray to medium dark gray; fine-grained (0.1-0.25mm); similar to the medium-grained sandstone described above but with a smaller grain size; composed of quartz (85-90%), feldspar (5-8%), muscovite and biotite mica (2-3%), rock fragments (5-10%), and trace amounts of chert, clay, hematite, and carbon; silica cemented; rock fragments are composed of shale with minor amounts of igneous and metamorphic rocks, shale fragments contain clay minerals as well as muscovite mica; shale partings are common; minor dense chert occurs as rounded rock fragments; minor amounts of carbonized plant material are present; the fine-grained sandstone particles are flattened to cubical with some flat and elongate particles, the amount of flat and elongate particles increases with decreasing particle size; porous; rough; hard, and tough.	6.7	4.6	-	1.0	-	-	-	-	1.4
Weathered Sandstone – (Figures E-107 and E-108) Pale yellowish brown to dark yellowish orange; fine- to medium-grained (0.1-0.5 mm); includes weathered fine- and medium-grained sandstone as described above, no attempt was made to separate the two lithologies due to heavy iron staining; silica cemented; weathering consists of abundant iron staining and many of the feldspar grains in the weathered sandstone have a milky appearance indicating some possible alteration to clay minerals; the weathered sandstone particles are angular to subangular; flattened to cubical with some flat and elongate particles, the amount of flat and elongate particles increases with decreasing particle size; porous; rough; hard, and tough; although weathered and exhibiting some feldspar alteration and abundant iron staining, the weathered sandstone should not pose a problem with quality issues.	1.6	3.3	1.6	1.3	1.0	1.8	1.0	-	1.4
Muscovite Mica – (Figures E-87, E-90, and E-91) Translucent to very light gray; occurs in shale particles and as discrete grains in the minus #30 fraction; the small amount present should not affect quality.	-	-	-	-	0.8	1.5	3.6	5.0	1.4
Chert – (Figures E-109 through E-111) Reddish brown to medium gray; one grain in the 3/8" X #4 and another in the #30 X #50 size fractions were highly polished and rounded and did not resemble the other chert grains, these grains represent probable contamination; chert occurs as rock fragments in the medium-grained, fine-grained, and weathered sandstone as well as discrete particles; no lightweight chert was observed in the sample; angular to subangular to rounded; cubical to flattened; the particles are hard, durable, dense, and tough.	0.2	0.2	0.5	0.6	0.5	0.8	-	-	0.3
Biotite – (Figures E-101 and E-102) Black to dark gray; occurs in shale particles and as discrete grains in the material retained on the #200 sieve and in the minus #200 fraction; the small amount present should not affect quality.	-	-	-	-	-	-	0.5	0.3	0.1

Results of Petrographic Examination for Limestone Aggregates

A quick examination of limestone aggregates was conducted by Nancy Whiting at Purdue University. Pertographic features were documented to better understand the aggregate behavior in the absorption and specific gravity tests. Key characteristics examined included: the crystallinity

or grain size of the minerals; the frequency of pit, vugs or cavities; and clay and silt distribution, whether in distinct seams, stringer or laminae, or dispersed throughout the matrix. Knowing these features and the %insoluble residue (+200 and -200 material) may help better understand any variability in test results using different test procedures.

Most of the following observations were from megascopic examinations. Some features of the fine aggregates were observed under magnifications up to 30 times. The following three aggregate samples were received:

- RC limestone coarse aggregate
- RC limestone fine aggregate
- Texas manufactured limestone fine aggregate

The RC limestone coarse fraction is a quarried carbonate material but not very uniform in appearance. The color varies from slightly purple to tan to grey to yellow-orange (see Figure E-112). Some of the fragments are sandy but most are very fine grained to aphanitic. Based on their mineral grain size, the aggregates were seperated into four general rock types (as shown in Figure E-113). Having a mineral grain size or crystallinity that is very fine grained to aphanitic (microscopic) is usually associated with higher absorptions and a higher %insoubles that are silt and clay size (-#200). The results from the %Insouble Residue Test (ASTM D 3042) will help quantify this feature.

Figure E-112. RC Limestone Aggregate, Coarse Fraction

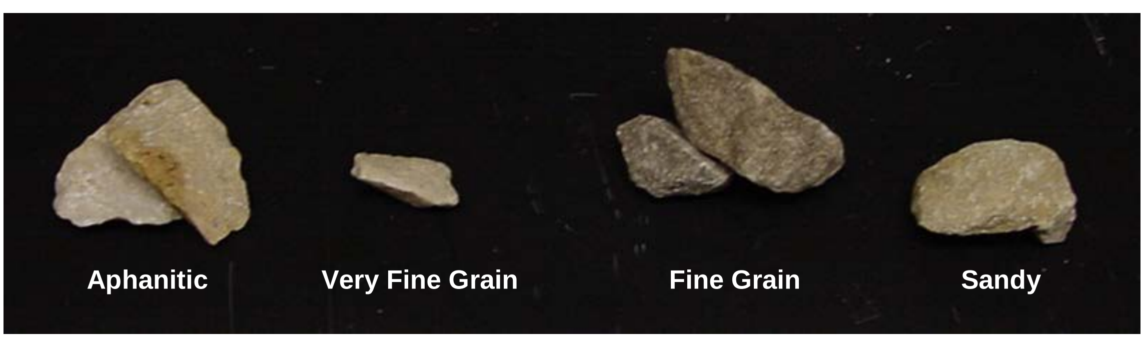
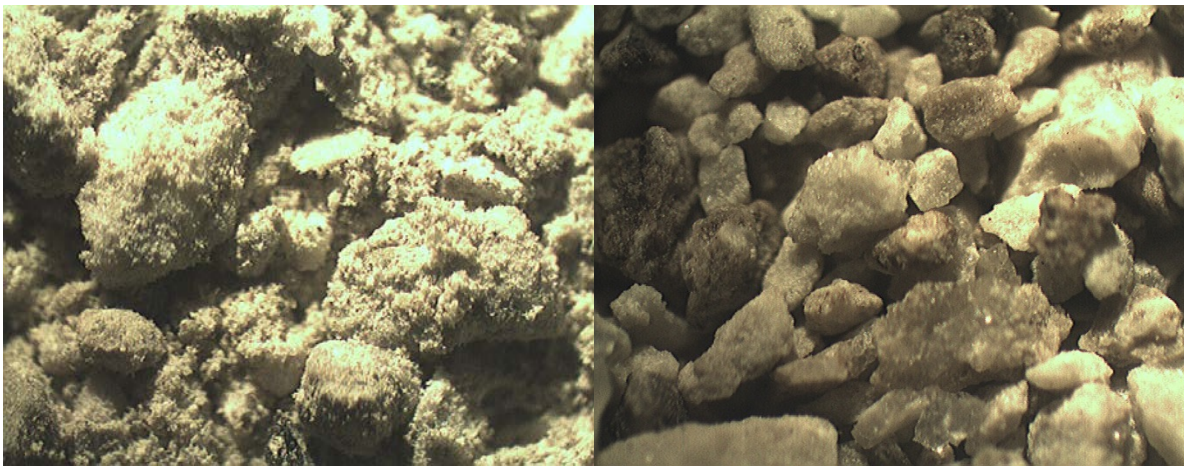


Figure E-113. RC Limetone Rock Types based on Grain Size

Only minor amounts of silts/clay laminae were observed megascopically, although the flat and slabby appearance of some of the rock fragements suggest there are discreat clay or silt seams in this formation that provide weaker planes along which the rock more easily fractures. Although the fragments vary in characteristics, there are very few pits or vugs (ie: very few small visible voids/porosity).

The RC limestone fine aggregate fraction as received was very 'dirty', covered with silty fines (Figure E-114). The aggregate was sieved over the #100 sieve and then washed over the #100 to remove enough of the fines so that the rock characteristics could be examined. Figure E-115 shows the difference between as-received and washed samples microscopically (at 20X).

Figure E-114. RC Fine Aggregate, Megascopically



As Received **Washed**

Figure E-115. RC Fine Aggregate as Received and Washed, under 20x Magnification.

The abundance of silt covering the aggregate fragments should not be surprising since the reported -200 content was 31.9%. As with the coarse fraction, the crystallinity is very fine grained to aphanitic with some amount of flat and slabby pieces, but very few fossils, pits, or vugs.

The Texas manufactured fine aggregate as received was slightly silty (Figure E-116). The aggregate was sieved over the #100 sieve and then washed over the #100 to remove enough of the fines so that the rock characteristics could be easily examined. Figure E-117 shows the difference between as received and washed samples microscopically. The -200 fraction reported in the March 2009 Quarterly Report was 5.4%.

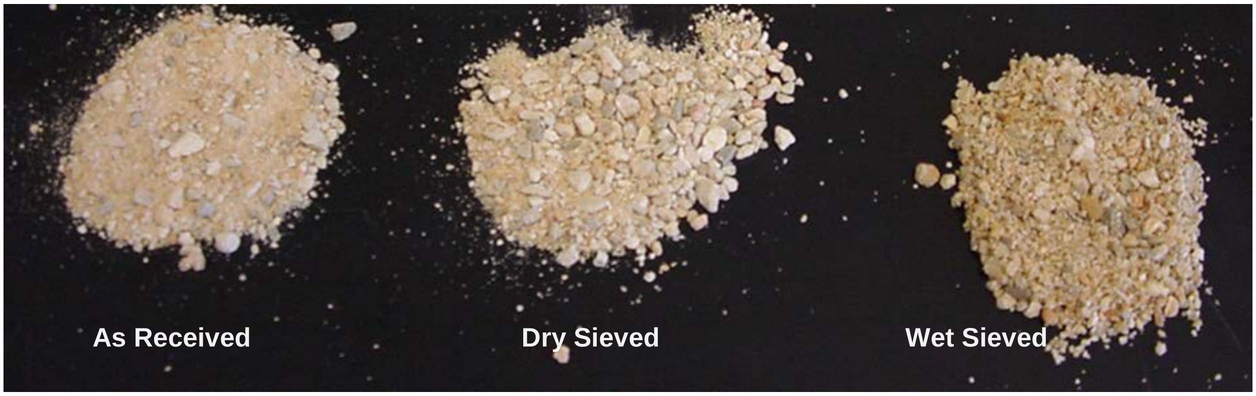
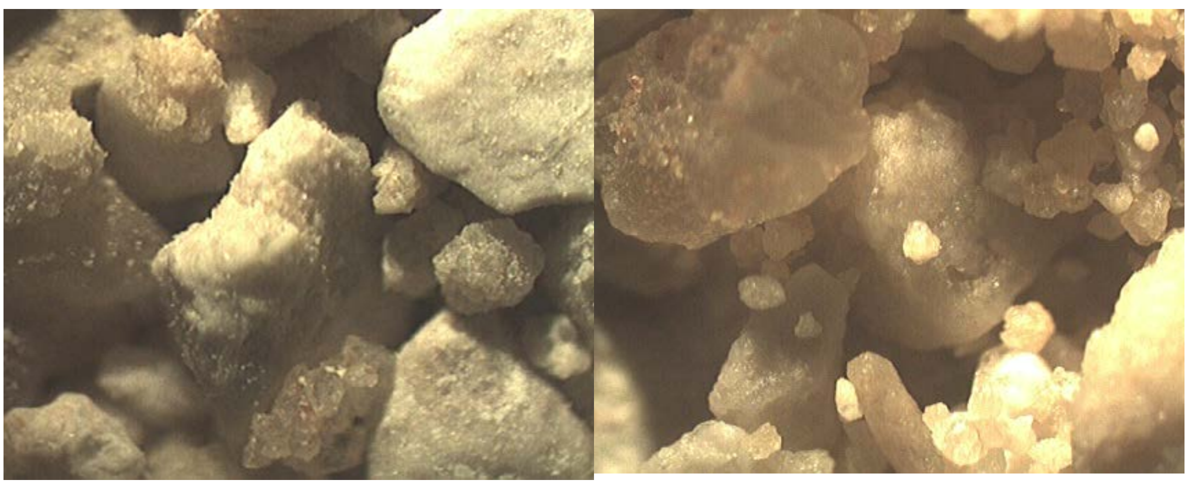


Figure E-116. Texas Manufactured Limestone Fine Aggregate (Megascopically).



As Received **Washed**

Figure E-117. Texas Manufactured Fine Aggregate (Microscopically), as Received and Washed.

The particles are mostly subangular and equant (equa-dimensional) with very few flat and slabby pieces. The mineral crystallinity is generally fine to very fine grained with some aphanitic fragments. There were a few pits and vugs noted but they were not common. No distinct layers or seams of clays and silts were observed.

In summary, the RC limestone coarse aggregate is not very uniform, and there may be variability in the test results because of this. If there are unexplained differences in the test results, it is advisable to look at the rocks types in each sample and see if there are different amounts of different types of limestone in each sample. It is expected that the absorption of this aggregate will be mostly from the silts and clays on the rock surface and in thin laminae and dispersed throughout the limestone matrix, and be higher in the aphanitic than the fine grained crystalline

limestone fragments. There were very few pits and vugs observed, so there is probably only minor related porosity that would influence test results.

The RC limestone fine aggregate contains crystallinity features similar to the coarse fraction; however, the extensive silty/clayey coatings on the aggregate will account for a great deal of quickly absorbed water during testing. The silts and clays finely dispersed in the limestone matrix may take longer to fully take on water. This may account for differences in test results if there are different soak times in the different test procedures.

The Texas manufactured limestone fine aggregate is very different from the RC fine aggregate. There is only a small amount of silts (and possibly clays) on the surface of the aggregate, and the aggregate itself is primarily fine grained crystalline. There are a few pits and vugs that may slightly influence the test results. If test results vary unexplainably with this source, washed samples may be used for testing to see if test results become more consistent. There may be some variability in the amount of silts (and possibly clays) on the surface of the aggregates.

Results of Specific Gravity and Absorption Testing

Table E-14. Specific Gravity and Absorption Results for Coarse Aggregate

Method	Operator	Material	Replicate	Gsa	Gsb	Gssd	Abs (%)
T85	1	Elmore Gravel	1	2.632	2.558	2.586	1.1
T85	1	Elmore Gravel	2	2.634	2.558	2.587	1.1
T85	1	Elmore Gravel	3	2.640	2.563	2.592	1.1
T85	2	Elmore Gravel	1	2.633	2.561	2.588	1.1
T85	2	Elmore Gravel	2	2.633	2.564	2.591	1.0
T85	2	Elmore Gravel	3	2.633	2.564	2.590	1.0
T85	3	Elmore Gravel	1	2.633	2.556	2.586	1.1
T85	3	Elmore Gravel	2	2.629	2.560	2.586	1.0
T85	3	Elmore Gravel	3	2.626	2.547	2.577	1.2
T85	1	Rec Concrete	1	2.607	2.352	2.450	4.2
T85	1	Rec Concrete	2	2.606	2.355	2.451	4.1
T85	1	Rec Concrete	3	2.603	2.341	2.441	4.3
T85	2	Rec Concrete	1	2.590	2.350	2.442	4.0
T85	2	Rec Concrete	2	2.581	2.337	2.432	4.0
T85	2	Rec Concrete	3	2.585	2.354	2.443	3.8
T85	3	Rec Concrete	1	2.614	2.347	2.449	4.3
T85	3	Rec Concrete	2	2.605	2.335	2.439	4.4
T85	3	Rec Concrete	3	2.606	2.342	2.443	4.3
T85	1	BF Slag Coarse	1	2.535	2.341	2.418	3.3
T85	1	BF Slag Coarse	2	2.549	2.344	2.424	3.4
T85	1	BF Slag Coarse	3	2.543	2.346	2.424	3.3
T85	2	BF Slag Coarse	1	2.546	2.333	2.417	3.6
T85	2	BF Slag Coarse	2	2.562	2.348	2.431	3.6
T85	2	BF Slag Coarse	3	2.532	2.319	2.403	3.6
T85	3	BF Slag Coarse	1	2.527	2.314	2.398	3.6
T85	3	BF Slag Coarse	2	2.520	2.312	2.395	3.6
T85	3	BF Slag Coarse	3	2.524	2.315	2.398	3.6
T85	1	PS Coarse	1	2.631	2.493	2.546	2.1
T85	1	PS Coarse	2	2.624	2.485	2.538	2.1
T85	1	PS Coarse	3	2.622	2.486	2.538	2.1
T85	2	PS Coarse	1	2.623	2.489	2.540	2.0
T85	2	PS Coarse	2	2.620	2.489	2.539	2.0
T85	2	PS Coarse	3	2.625	2.488	2.540	2.1
T85	3	PS Coarse	1	2.620	2.489	2.539	2.0
T85	3	PS Coarse	2	2.617	2.488	2.537	2.0
T85	3	PS Coarse	3	2.620	2.490	2.540	2.0

Method	Operator	Material	Replicate	Gsa	Gsb	Gssd	Abs (%)
T85	1	RC LS Coarse	1	2.685	2.521	2.582	2.4
T85	1	RC LS Coarse	2	2.686	2.529	2.587	2.3
T85	1	RC LS Coarse	3	2.683	2.523	2.583	2.4
T85	2	RC LS Coarse	1	2.687	2.521	2.583	2.5
T85	2	RC LS Coarse	2	2.683	2.523	2.583	2.4
T85	2	RC LS Coarse	3	2.685	2.524	2.584	2.4
T85	3	RC LS Coarse	1	2.678	2.527	2.583	2.2
T85	3	RC LS Coarse	2	2.680	2.516	2.577	2.4
T85	3	RC LS Coarse	3	2.684	2.519	2.581	2.4
Phunque Coarse	1	Elmore Gravel	1	2.636	2.614	2.622	0.3
Phunque Coarse	1	Elmore Gravel	2	2.617	2.603	2.609	0.2
Phunque Coarse	1	Elmore Gravel	3	2.639	2.616	2.625	0.3
Phunque Coarse	2	Elmore Gravel	1	2.655	2.628	2.638	0.4
Phunque Coarse	2	Elmore Gravel	2	2.653	2.616	2.630	0.5
Phunque Coarse	2	Elmore Gravel	3	2.654	2.635	2.642	0.3
Phunque Coarse	3	Elmore Gravel	1	2.647	2.619	2.630	0.4
Phunque Coarse	3	Elmore Gravel	2	2.651	2.623	2.634	0.4
Phunque Coarse	3	Elmore Gravel	3	2.647	2.627	2.634	0.3
Phunque Coarse	1	Rec Concrete	1	2.607	2.493	2.536	1.8
Phunque Coarse	1	Rec Concrete	2	2.608	2.463	2.519	2.3
Phunque Coarse	1	Rec Concrete	3	2.610	2.478	2.529	2.0
Phunque Coarse	2	Rec Concrete	1	2.612	2.471	2.525	2.2
Phunque Coarse	2	Rec Concrete	2	2.612	2.475	2.527	2.1
Phunque Coarse	2	Rec Concrete	3	2.615	2.478	2.530	2.1
Phunque Coarse	3	Rec Concrete	1	2.598	2.472	2.521	2.0
Phunque Coarse	3	Rec Concrete	2	2.618	2.471	2.527	2.3
Phunque Coarse	3	Rec Concrete	3	2.623	2.478	2.533	2.2
Phunque Coarse	1	BF Slag Coarse	1	2.587	2.430	2.490	2.5
Phunque Coarse	1	BF Slag Coarse	2	2.588	2.442	2.498	2.3
Phunque Coarse	1	BF Slag Coarse	3	2.607	2.461	2.517	2.3
Phunque Coarse	2	BF Slag Coarse	1	2.600	2.462	2.515	2.1
Phunque Coarse	2	BF Slag Coarse	2	2.594	2.459	2.511	2.1
Phunque Coarse	2	BF Slag Coarse	3	2.574	2.433	2.488	2.2
Phunque Coarse	3	BF Slag Coarse	1	2.569	2.450	2.496	1.9
Phunque Coarse	3	BF Slag Coarse	2	2.574	2.441	2.492	2.1
Phunque Coarse	3	BF Slag Coarse	3	2.586	2.465	2.512	1.9
Phunque Coarse	1	PS Coarse	1	2.634	2.574	2.597	0.9
Phunque Coarse	1	PS Coarse	2	2.632	2.565	2.590	1.0
Phunque Coarse	1	PS Coarse	3	2.630	2.549	2.580	1.2
Phunque Coarse	2	PS Coarse	1	2.645	2.577	2.603	1.0
Phunque Coarse	2	PS Coarse	2	2.639	2.576	2.600	0.9
Phunque Coarse	2	PS Coarse	3	2.637	2.572	2.597	1.0
Phunque Coarse	3	PS Coarse	1	2.632	2.562	2.589	1.0
Phunque Coarse	3	PS Coarse	2	2.620	2.561	2.584	0.9
Phunque Coarse	3	PS Coarse	3	2.626	2.550	2.579	1.1
Phunque Coarse	1	RC LS Coarse	1	2.696	2.610	2.642	1.2
Phunque Coarse	1	RC LS Coarse	2	2.690	2.606	2.637	1.2
Phunque Coarse	1	RC LS Coarse	3	2.682	2.597	2.629	1.2
Phunque Coarse	2	RC LS Coarse	1	2.712	2.624	2.657	1.2
Phunque Coarse	2	RC LS Coarse	2	2.708	2.612	2.648	1.4
Phunque Coarse	2	RC LS Coarse	3	2.705	2.625	2.655	1.1
Phunque Coarse	3	RC LS Coarse	1	2.694	2.611	2.641	1.2
Phunque Coarse	3	RC LS Coarse	2	2.681	2.595	2.627	1.2
Phunque Coarse	3	RC LS Coarse	3	2.693	2.603	2.637	1.3

Table E-15. Specific Gravity and Absorption Results for Fine Aggregate

Method	Operator	Material	Replicate	Gsa	Gsb	Gssd	Abs (%)
T84	1	Natural sand	1	2.643	2.620	2.629	0.3
T84	1	Natural Sand	2	2.626	2.604	2.613	0.3
T84	1	Natural Sand	3	2.635	2.619	2.625	0.2
T84	2	Natural Sand	1	2.636	2.619	2.625	0.2
T84	2	Natural Sand	2	2.645	2.631	2.636	0.2
T84	2	Natural Sand	3	2.642	2.614	2.625	0.4
T84	3	Natural Sand	1	2.647	2.635	2.640	0.2
T84	3	Natural Sand	2	2.633	2.628	2.630	0.1
T84	3	Natural Sand	3	2.641	2.625	2.631	0.2
T84	1	TX LS sand	1	2.650	2.592	2.614	0.8
T84	1	TX LS sand	2	2.651	2.578	2.606	1.1
T84	1	TX LS sand	3	2.653	2.564	2.597	1.3
T84	2	TX LS sand	1	2.664	2.530	2.580	2.0
T84	2	TX LS sand	2	2.663	2.577	2.609	1.3
T84	2	TX LS sand	3	2.671	2.549	2.595	1.8
T84	3	TX LS sand	1	2.663	2.581	2.612	1.2
T84	3	TX LS sand	2	2.662	2.578	2.609	1.2
T84	3	TX LS sand	3	2.663	2.611	2.630	0.7
T84	1	BF Slag Fine	1	2.857	2.688	2.747	2.2
T84	1	BF Slag Fine	2	2.866	2.713	2.767	2.0
T84	1	BF Slag Fine	3	2.866	2.688	2.750	2.3
T84	2	BF Slag Fine	1	2.858	2.705	2.758	2.0
T84	2	BF Slag Fine	2	2.865	2.706	2.761	2.1
T84	2	BF Slag Fine	3	2.838	2.682	2.737	2.1
T84	3	BF Slag Fine	1	2.854	2.723	2.769	1.7
T84	3	BF Slag Fine	2	2.829	2.712	2.754	1.5
T84	3	BF Slag Fine	3	2.839	2.732	2.769	1.4
T84	1	PS Fine	1	2.651	2.563	2.596	1.3
T84	1	PS Fine	2	2.650	2.583	2.608	1.0
T84	1	PS Fine	3	2.651	2.593	2.615	0.8
T84	2	PS Fine	1	2.641	2.499	2.553	2.1
T84	2	PS Fine	2	2.658	2.494	2.556	2.5
T84	2	PS Fine	3	2.658	2.520	2.572	2.1
T84	3	PS Fine	1	2.664	2.590	2.618	1.1
T84	3	PS Fine	2	2.647	2.596	2.616	0.7
T84	3	PS Fine	3	2.659	2.569	2.603	1.3
T84	1	RC LS Fine	1	2.713	2.547	2.608	2.4
T84	1	RC LS Fine	2	2.726	2.589	2.639	1.9
T84	1	RC LS Fine	3	2.717	2.653	2.676	0.9
T84	2	RC LS Fine	1	2.696	2.499	2.573	2.9
T84	2	RC LS Fine	2	2.690	2.486	2.561	3.1
T84	2	RC LS Fine	3	2.712	2.443	2.542	4.1
T84	3	RC LS Fine	1	2.714	2.621	2.655	1.3
T84	3	RC LS Fine	2	2.696	2.613	2.643	1.2
T84	3	RC LS Fine	3	2.712	2.593	2.637	1.7
Modified T84	1	Natural Sand	1	2.646	2.616	2.627	0.4
Modified T84	1	Natural Sand	2	2.642	2.624	2.631	0.3
Modified T84	1	Natural Sand	3	2.653	2.628	2.637	0.4
Modified T84	2	Natural Sand	1	2.640	2.618	2.626	0.3
Modified T84	2	Natural Sand	2	2.652	2.611	2.627	0.6
Modified T84	2	Natural Sand	3	2.643	2.630	2.635	0.2
Modified T84	3	Natural Sand	1	2.647	2.634	2.639	0.2
Modified T84	3	Natural Sand	2	2.640	2.616	2.625	0.3
Modified T84	3	Natural Sand	3	2.641	2.620	2.628	0.3
Modified T84	1	TX LS sand	1	2.655	2.579	2.607	1.1
Modified T84	1	TX LS sand	2	2.663	2.589	2.617	1.1
Modified T84	1	TX LS sand	3	2.649	2.564	2.596	1.3
Modified T84	2	TX LS sand	1	2.664	2.530	2.580	2.0

Method	Operator	Material	Replicate	Gsa	Gsb	Gssd	Abs (%)
Modified T84	2	TX LS sand	2	2.663	2.577	2.609	1.3
Modified T84	2	TX LS sand	3	2.671	2.549	2.595	1.8
Modified T84	3	TX LS sand	1	2.670	2.564	2.604	1.5
Modified T84	3	TX LS sand	2	2.660	2.556	2.595	1.5
Modified T84	3	TX LS sand	3	2.656	2.564	2.599	1.3
Modified T84	1	BF Slag Fine	1	2.862	2.704	2.759	2.0
Modified T84	1	BF Slag Fine	2	2.871	2.710	2.766	2.1
Modified T84	1	BF Slag Fine	3	2.863	2.694	2.753	2.2
Modified T84	2	BF Slag Fine	1	2.855	2.713	2.763	1.8
Modified T84	2	BF Slag Fine	2	2.860	2.702	2.758	2.0
Modified T84	2	BF Slag Fine	3	2.856	2.731	2.775	1.6
Modified T84	3	BF Slag Fine	1	2.872	2.700	2.760	2.2
Modified T84	3	BF Slag Fine	2	2.869	2.659	2.732	2.8
Modified T84	3	BF Slag Fine	3	2.865	2.692	2.753	2.2
Modified T84	1	PS Fine	1	2.653	2.584	2.610	1.0
Modified T84	1	PS Fine	2	2.647	2.589	2.611	0.8
Modified T84	1	PS Fine	3	2.649	2.579	2.606	1.0
Modified T84	2	PS Fine	1	2.648	2.548	2.586	1.5
Modified T84	2	PS Fine	2	2.654	2.516	2.568	2.1
Modified T84	2	PS Fine	3	2.660	2.527	2.577	2.0
Modified T84	3	PS Fine	1	2.666	2.544	2.590	1.8
Modified T84	3	PS Fine	2	2.651	2.529	2.575	1.8
Modified T84	3	PS Fine	3	2.655	2.515	2.568	2.1
Modified T84	1	RC LS Fine	1	2.715	2.477	2.565	3.5
Modified T84	1	RC LS Fine	2	2.713	2.457	2.551	3.8
Modified T84	1	RC LS Fine	3	2.722	2.453	2.552	4.0
Modified T84	2	RC LS Fine	1	2.722	2.557	2.618	2.4
Modified T84	2	RC LS Fine	2	2.714	2.468	2.559	3.7
Modified T84	2	RC LS Fine	3	2.728	2.509	2.589	3.2
Modified T84	3	RC LS Fine	1	2.727	2.431	2.540	4.5
Modified T84	3	RC LS Fine	2	2.719	2.423	2.532	4.5
Modified T84	3	RC LS Fine	3	2.725	2.440	2.544	4.3
SSDetect	2	Natural Sand	1	2.640	2.597	2.614	0.6
SSDetect	2	Natural Sand	2	2.644	2.600	2.617	0.6
SSDetect	2	Natural Sand	3	2.643	2.597	2.615	0.7
SSDetect	3	Natural Sand	1	2.636	2.599	2.613	0.5
SSDetect	3	Natural Sand	2	2.639	2.600	2.615	0.6
SSDetect	3	Natural Sand	3	2.639	2.601	2.616	0.5
SSDetect	1	Natural Sand	1	2.634	2.577	2.599	0.8
SSDetect	1	Natural Sand	2	2.636	2.588	2.606	0.7
SSDetect	1	Natural Sand	3	2.637	2.587	2.606	0.7
SSDetect	2	TX LS sand	1	2.684	2.490	2.562	2.9
SSDetect	2	TX LS sand	2	2.682	2.511	2.575	2.5
SSDetect	2	TX LS sand	3	2.678	2.523	2.581	2.3
SSDetect	3	TX LS sand	1	2.682	2.569	2.611	1.6
SSDetect	3	TX LS sand	2	2.680	2.567	2.609	1.6
SSDetect	3	TX LS sand	3	2.686	2.580	2.620	1.5
SSDetect	1	TX LS sand	1	2.674	2.561	2.603	1.6
SSDetect	1	TX LS sand	2	2.684	2.588	2.624	1.4
SSDetect	1	TX LS sand	3	2.681	2.546	2.596	2.0
SSDetect	2	BF Slag Fine	1	2.909	2.741	2.799	2.1
SSDetect	2	BF Slag Fine	2	2.904	2.743	2.798	2.0
SSDetect	2	BF Slag Fine	3	2.919	2.734	2.797	2.3
SSDetect	3	BF Slag Fine	1	2.882	2.767	2.807	1.4
SSDetect	3	BF Slag Fine	2	2.911	2.807	2.843	1.3
SSDetect	3	BF Slag Fine	3	2.909	2.784	2.827	1.5
SSDetect	1	BF Slag Fine	1	2.872	2.728	2.778	1.8
SSDetect	1	BF Slag Fine	2	2.879	2.694	2.758	2.4

Method	Operator	Material	Replicate	Gsa	Gsb	Gssd	Abs (%)
SSDetect	1	BF Slag Fine	3	2.859	2.704	2.758	2.0
SSDetect	2	PS Fine	1	2.644	2.473	2.538	2.6
SSDetect	2	PS Fine	2	2.651	2.485	2.548	2.5
SSDetect	2	PS Fine	3	2.641	2.476	2.539	2.5
SSDetect	3	PS Fine	1	2.643	2.499	2.553	2.2
SSDetect	3	PS Fine	2	2.642	2.525	2.569	1.8
SSDetect	3	PS Fine	3	2.647	2.515	2.565	2.0
SSDetect	1	PS Fine	1	2.640	2.504	2.555	2.1
SSDetect	1	PS Fine	2	2.640	2.479	2.540	2.5
SSDetect	1	PS Fine	3	2.633	2.506	2.554	1.9
SSDetect	2	RC LS Fine	1	2.700	2.473	2.557	3.4
SSDetect	2	RC LS Fine	2	2.703	2.459	2.549	3.7
SSDetect	2	RC LS Fine	3	2.694	2.458	2.546	3.6
SSDetect	3	RC LS Fine	1	2.707	2.397	2.512	4.8
SSDetect	3	RC LS Fine	2	2.704	2.424	2.528	4.3
SSDetect	3	RC LS Fine	3	2.709	2.459	2.551	3.7
SSDetect	1	RC LS Fine	1	2.690	2.421	2.521	4.1
SSDetect	1	RC LS Fine	2	2.706	2.438	2.537	4.1
SSDetect	1	RC LS Fine	3	2.703	2.360	2.487	5.4
Phunque Fine	1	Natural Sand	1	2.637	2.623	2.629	0.2
Phunque Fine	1	Natural Sand	2	2.635	2.622	2.627	0.2
Phunque Fine	1	Natural Sand	3	2.626	2.622	2.624	0.1
Phunque Fine	2	Natural Sand	1	2.658	2.649	2.653	0.1
Phunque Fine	2	Natural Sand	2	2.661	2.654	2.656	0.1
Phunque Fine	2	Natural Sand	3	2.660	2.649	2.653	0.2
Phunque Fine	3	Natural Sand	1	2.639	2.631	2.634	0.1
Phunque Fine	3	Natural Sand	2	2.638	2.629	2.632	0.1
Phunque Fine	3	Natural Sand	3	2.639	2.630	2.633	0.1
Phunque Fine	1	TX LS sand	1	2.676	2.589	2.622	1.3
Phunque Fine	1	TX LS sand	2	2.671	2.597	2.626	1.1
Phunque Fine	1	TX LS sand	3	2.673	2.598	2.626	1.1
Phunque Fine	2	TX LS sand	1	2.679	2.629	2.647	0.7
Phunque Fine	2	TX LS sand	2	2.698	2.618	2.648	1.1
Phunque Fine	2	TX LS sand	3	2.682	2.606	2.634	1.1
Phunque Fine	3	TX LS sand	1	2.697	2.620	2.649	1.1
Phunque Fine	3	TX LS sand	2	2.693	2.611	2.642	1.2
Phunque Fine	3	TX LS sand	3	2.690	2.606	2.637	1.2
Phunque Fine	1	BF Slag Fine	1	2.866	2.737	2.788	1.9
Phunque Fine	1	BF Slag Fine	2	2.895	2.764	2.809	1.6
Phunque Fine	1	BF Slag Fine	3	2.883	2.749	2.796	1.7
Phunque Fine	2	BF Slag Fine	1	2.881	2.762	2.803	1.5
Phunque Fine	2	BF Slag Fine	2	2.900	2.776	2.819	1.5
Phunque Fine	2	BF Slag Fine	3	2.893	2.760	2.806	1.7
Phunque Fine	3	BF Slag Fine	1	2.882	2.757	2.800	1.6
Phunque Fine	3	BF Slag Fine	2	2.871	2.747	2.790	1.6
Phunque Fine	3	BF Slag Fine	3	2.853	2.726	2.771	1.6
Phunque Fine	1	PS Fine	1	2.652	2.565	2.598	1.3
Phunque Fine	1	PS Fine	2	2.647	2.559	2.593	1.3
Phunque Fine	1	PS Fine	3	2.658	2.556	2.594	1.5
Phunque Fine	2	PS Fine	1	2.670	2.601	2.627	1.0
Phunque Fine	2	PS Fine	2	2.673	2.592	2.622	1.2
Phunque Fine	2	PS Fine	3	2.674	2.587	2.620	1.2
Phunque Fine	3	PS Fine	1	2.651	2.574	2.603	1.1
Phunque Fine	3	PS Fine	2	2.651	2.572	2.602	1.2
Phunque Fine	3	PS Fine	3	2.653	2.576	2.605	1.1
Phunque Fine	1	RC LS Fine	1	2.723	2.597	2.643	1.8
Phunque Fine	1	RC LS Fine	2	2.723	2.596	2.643	1.8
Phunque Fine	1	RC LS Fine	3	2.729	2.593	2.643	1.9

Method	Operator	Material	Replicate	Gsa	Gsb	Gssd	Abs (%)
Phunque Fine	2	RC LS Fine	1	2.739	2.634	2.672	1.5
Phunque Fine	2	RC LS Fine	2	2.734	2.609	2.654	1.7
Phunque Fine	2	RC LS Fine	3	2.737	2.624	2.665	1.6
Phunque Fine	3	RC LS Fine	1	2.727	2.608	2.652	1.7
Phunque Fine	3	RC LS Fine	2	2.727	2.603	2.649	1.7
Phunque Fine	3	RC LS Fine	3	2.730	2.611	2.655	1.7

Results of Analysis of Variance for Specific Gravity and Absorption

General Linear Model: Gsa, Gsb, Gssd, Abs (%) versus Materials, Method, Operator for Test Methods for Coarse Aggregate

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Factor          Type   Levels  Values
Materials       fixed       5  BF Slag Coarse, Elmore Gravel, PS Coarse, RC LS
                               Coarse, Rec Concrete
Method          fixed       2  Phunque Coarse, T85
Operator        fixed       3  1, 2, 3

Analysis of Variance for Gsa, using Adjusted SS for Tests

Source                         DF     Seq SS     Adj SS     Adj MS       F
P
Materials                       4  0.1566914  0.1566914  0.0391728  904.20
0.000
Method                          1  0.0081703  0.0081703  0.0081703  188.59
0.000
Operator                        2  0.0006070  0.0006070  0.0003035    7.01
0.002
Materials*Method                4  0.0050947  0.0050947  0.0012737   29.40
0.000
Materials*Operator              8  0.0021680  0.0021680  0.0002710    6.26
0.000
Method*Operator                 2  0.0007743  0.0007743  0.0003872    8.94
0.000
Materials*Method*Operator       8  0.0009047  0.0009047  0.0001131    2.61
0.016
Error                          60  0.0025994  0.0025994  0.0000433
Total                          89  0.1770099

Analysis of Variance for Gsb, using Adjusted SS for Tests

Source                         DF    Seq SS    Adj SS    Adj MS        F
P
Materials                       4  0.597303  0.597303  0.149326  2322.81
0.000
Method                          1  0.200920  0.200920  0.200920  3125.38
0.000
Operator                        2  0.000833  0.000833  0.000416     6.48
0.003
Materials*Method                4  0.015018  0.015018  0.003754    58.40
0.000
Materials*Operator              8  0.000542  0.000542  0.000068     1.05
0.407
Method*Operator                 2  0.000634  0.000634  0.000317     4.93
0.010
Materials*Method*Operator       8  0.001193  0.001193  0.000149     2.32
0.031
Error                          60  0.003857  0.003857  0.000064
```

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Total	89	0.820300				

Analysis of Variance for Gssd, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Materials	4	0.363257	0.363257	0.090814	1993.85	0.000
Method	1	0.096032	0.096032	0.096032	2108.39	0.000
Operator	2	0.000739	0.000739	0.000369	8.11	0.001
Materials*Method	4	0.007792	0.007792	0.001948	42.77	0.000
Materials*Operator	8	0.000870	0.000870	0.000109	2.39	0.026
Method*Operator	2	0.000620	0.000620	0.000310	6.81	0.002
Materials*Method*Operator	8	0.000647	0.000647	0.000081	1.78	0.100
Error	60	0.002733	0.002733	0.000046		
Total	89	0.472690				

Analysis of Variance for Abs (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Materials	4	70.0288	70.0288	17.5072	1820.27	0.000
Method	1	36.0886	36.0886	36.0886	3752.23	0.000
Operator	2	0.0136	0.0136	0.0068	0.71	0.497
Materials*Method	4	4.3366	4.3366	1.0842	112.72	0.000
Materials*Operator	8	0.2037	0.2037	0.0255	2.65	0.015
Method*Operator	2	0.0618	0.0618	0.0309	3.21	0.047
Materials*Method*Operator	8	0.4831	0.4831	0.0604	6.28	0.000
Error	60	0.5771	0.5771	0.0096		
Total	89	111.7933				

General Linear Model: Gsa, Gsb, Gssd, Abs (%) versus Materials, Method, Operator for Test Methods for Fine Aggregate

Factor	Type	Levels	Values
Materials	fixed	5	BF Slag Fine, Natural Sand, PS Fine, RC LS Fine, TX LS Sand
Method	fixed	4	Modified T84, Phunque Fine, SSDetect, T84
Operator	fixed	3	1, 2, 3

Analysis of Variance for Gsa, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Materials	4	1.294938	1.294938	0.323734	6916.48	0.000
Method	3	0.006592	0.006592	0.002197	46.94	0.000
Operator	2	0.001502	0.001502	0.000751	16.04	0.000
Materials*Method	12	0.012603	0.012603	0.001050	22.44	0.000
Materials*Operator	8	0.000918	0.000918	0.000115	2.45	0.017
Method*Operator	6	0.002052	0.002052	0.000342	7.31	0.000
Materials*Method*Operator	24	0.004579	0.004579	0.000191	4.08	0.000
Error	120	0.005617	0.005617	0.000047		

Total	179	1.328801				

Analysis of Variance for Gsb, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Materials	4	0.964190	0.964190	0.241048	879.07	0.000
Method	3	0.134118	0.134118	0.044706	163.04	0.000
Operator	2	0.003487	0.003487	0.001744	6.36	0.002
Materials*Method	12	0.120022	0.120022	0.010002	36.48	0.000
Materials*Operator	8	0.010345	0.010345	0.001293	4.72	0.000
Method*Operator	6	0.039164	0.039164	0.006527	23.80	0.000
Materials*Method*Operator	24	0.043159	0.043159	0.001798	6.56	0.000
Error	120	0.032905	0.032905	0.000274		
Total	179	1.347390				

Analysis of Variance for Gssd, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Materials	4	0.913530	0.913530	0.228383	1869.02	0.000
Method	3	0.060467	0.060467	0.020156	164.95	0.000
Operator	2	0.001213	0.001213	0.000606	4.96	0.008
Materials*Method	12	0.060500	0.060500	0.005042	41.26	0.000
Materials*Operator	8	0.003979	0.003979	0.000497	4.07	0.000
Method*Operator	6	0.017716	0.017716	0.002953	24.16	0.000
Materials*Method*Operator	24	0.019818	0.019818	0.000826	6.76	0.000
Error	120	0.014663	0.014663	0.000122		
Total	179	1.091886				

Analysis of Variance for Abs (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Materials	4	125.0240	125.0240	31.2560	465.33	0.000
Method	3	27.2458	27.2458	9.0819	135.21	0.000
Operator	2	1.3763	1.3763	0.6881	10.24	0.000
Materials*Method	12	21.5735	21.5735	1.7978	26.76	0.000
Materials*Operator	8	2.8621	2.8621	0.3578	5.33	0.000
Method*Operator	6	7.5094	7.5094	1.2516	18.63	0.000
Materials*Method*Operator	24	9.5284	9.5284	0.3970	5.91	0.000
Error	120	8.0604	8.0604	0.0672		
Total	179	203.1798				

Table E-16. Within- and Between-Laboratory Statistics for AASHTO T 85 for Coarse Aggregate

Parameter	Materials	Average	Standard Deviation		Coefficient of Variation (%)	
			W/L	B/L	W/L	B/L
Gsa	Blast furnace slag	2.537	0.00964	0.01452	0.380	0.572
	Elmore gravel	2.632	0.00328	0.00396	0.124	0.150
	Preston sandstone	2.623	0.00322	0.00424	0.123	0.162
	RC limestone	2.683	0.00235	0.00315	0.088	0.117
	Recycled concrete	2.600	0.00407	0.01286	0.156	0.495
Gsb	Blast furnace slag	2.330	0.00829	0.01671	0.356	0.717
	Elmore gravel	2.559	0.00441	0.00572	0.172	0.224
	Preston sandstone	2.489	0.00275	0.00275	0.111	0.111
	RC limestone	2.523	0.00412	0.00412	0.163	0.163
	Recycled concrete	2.346	0.00750	0.00750	0.320	0.320
Gssd	Blast furnace slag	2.412	0.00835	0.01489	0.346	0.617
	Elmore gravel	2.587	0.00366	0.00467	0.142	0.180
	Preston sandstone	2.540	0.00275	0.00275	0.108	0.108
	RC limestone	2.583	0.00245	0.00281	0.095	0.109
	Recycled concrete	2.443	0.00577	0.00629	0.236	0.257
Absorption (%)	Blast furnace slag	3.503	0.05955	0.16043	1.700	4.580
	Elmore gravel	1.089	0.04943	0.06417	4.541	5.894
	Preston sandstone	2.052	0.02694	0.05770	1.312	2.811
	RC limestone	2.377	0.08122	0.08122	3.417	3.417
	Recycled concrete	4.162	0.09821	0.23473	2.360	5.640

Table E-17. Within- and Between-Laboratory Statistics for AASHTO TP 77 (Phunque Flask) for Coarse Aggregate

Parameter	Materials	Average	Standard Deviation		Coefficient of Variation (%)	
			W/L	B/L	W/L	B/L
Gsa	Blast furnace slag	2.587	0.01138	0.01305	0.440	0.504
	Elmore gravel	2.644	0.00709	0.01354	0.268	0.512
	Preston sandstone	2.633	0.00437	0.00803	0.166	0.305
	RC limestone	2.696	0.00616	0.01207	0.229	0.448
	Recycled concrete	2.611	0.00776	0.00776	0.297	0.297
Gsb	Blast furnace slag	2.449	0.01467	0.01467	0.599	0.599
	Elmore gravel	2.620	0.00712	0.00993	0.272	0.379
	Preston sandstone	2.565	0.00840	0.01125	0.327	0.439
	RC limestone	2.609	0.00732	0.01135	0.280	0.435
	Recycled concrete	2.475	0.00915	0.00915	0.370	0.370
Gssd	Blast furnace slag	2.502	0.01312	0.01312	0.524	0.524
	Elmore gravel	2.629	0.00624	0.01077	0.237	0.410
	Preston sandstone	2.591	0.00597	0.00953	0.230	0.368
	RC limestone	2.641	0.00625	0.01150	0.237	0.436
	Recycled concrete	2.527	0.00629	0.00629	0.249	0.249
Absorption (%)	Blast furnace slag	2.168	0.11093	0.21471	5.117	9.904
	Elmore gravel	0.349	0.09177	0.09664	26.317	27.712
	Preston sandstone	0.998	0.12523	0.12523	12.544	12.544
	RC limestone	1.228	0.07359	0.07359	5.991	5.991
	Recycled concrete	2.107	0.17719	0.17719	8.411	8.411

Table E-18. Within- and Between-Laboratory Statistics for AASHTO T 84 for Fine Aggregate

Parameter	Materials	Average	Standard Deviation		Coefficient of Variation (%)	
			W/L	B/L	W/L	B/L
Gsa	AR Natural Sand	2.639	0.00694	0.00694	0.263	0.263
	Blast furnace slag	2.853	0.01118	0.01457	0.392	0.511
	Preston sandstone	2.653	0.00768	0.00768	0.289	0.289
	RC limestone	2.708	0.00948	0.01240	0.350	0.458
	TX limestone sand	2.660	0.00268	0.00794	0.101	0.298
Gsb	AR Natural Sand	2.622	0.00758	0.00978	0.289	0.373
	Blast furnace slag	2.705	0.01288	0.01808	0.476	0.668
	Preston sandstone	2.556	0.01442	0.04666	0.564	1.825
	RC limestone	2.560	0.03601	0.07909	1.406	3.089
	TX limestone sand	2.573	0.01924	0.02488	0.748	0.967
Gssd	AR Natural Sand	2.628	0.00679	0.00799	0.258	0.304
	Blast furnace slag	2.757	0.01107	0.01107	0.401	0.401
	Preston sandstone	2.593	0.00933	0.02950	0.360	1.138
	RC limestone	2.615	0.02220	0.05214	0.849	1.994
	TX limestone sand	2.606	0.01180	0.01472	0.453	0.565
Absorption (%)	AR Natural Sand	0.243	0.08248	0.10290	33.999	42.413
	Blast furnace slag	1.906	0.14110	0.35361	7.401	18.548
	Preston sandstone	1.436	0.24795	0.71483	17.270	49.788
	RC limestone	2.158	0.59286	1.14872	27.475	53.235
	TX limestone sand	1.273	0.30310	0.43178	23.819	33.931

Table E-19. Within- and Between-Laboratory Statistics for Modified AASHTO T 84 (Removal of P200 Material)

Parameter	Materials	Average	Standard Deviation		Coefficient of Variation (%)	
			W/L	B/L	W/L	B/L
Gsa	AR Natural Sand	2.645	0.00549	0.00549	0.208	0.208
	Blast furnace slag	2.864	0.00374	0.00681	0.131	0.238
	Preston sandstone	2.654	0.00595	0.00620	0.224	0.234
	RC limestone	2.721	0.00556	0.00581	0.204	0.214
	TX limestone sand	2.661	0.00637	0.00746	0.240	0.280
Gsb	AR Natural Sand	2.622	0.00865	0.00865	0.330	0.330
	Blast furnace slag	2.701	0.01576	0.02041	0.584	0.756
	Preston sandstone	2.548	0.01284	0.03294	0.504	1.293
	RC limestone	2.468	0.02724	0.04611	1.104	1.868
	TX limestone sand	2.564	0.01583	0.01812	0.617	0.707
Gssd	AR Natural Sand	2.630	0.00591	0.00591	0.225	0.225
	Blast furnace slag	2.758	0.01041	0.01196	0.377	0.434
	Preston sandstone	2.588	0.00842	0.01947	0.326	0.752
	RC limestone	2.561	0.01811	0.02937	0.707	1.147
	TX limestone sand	2.600	0.01069	0.01069	0.411	0.411
Absorption (%)	AR Natural Sand	0.331	0.14284	0.14284	43.094	43.094
	Blast furnace slag	2.107	0.21964	0.34051	10.422	16.158
	Preston sandstone	1.570	0.21167	0.55521	13.479	35.355
	RC limestone	3.771	0.40283	0.74232	10.683	19.687
	TX limestone sand	1.433	0.23678	0.33155	16.521	23.134

Table E-20. Within- and Between-Laboratory Statistics for ASTM D 7172 (SSDetect) for Fine Aggregate

Parameter	Materials	Average	Standard Deviation		Coefficient of Variation (%)	
			W/L	B/L	W/L	B/L
Gsa	AR Natural Sand	2.639	0.00172	0.00368	0.065	0.139
	Blast furnace slag	2.894	0.01196	0.02336	0.413	0.807
	Preston sandstone	2.642	0.00401	0.00532	0.152	0.201
	RC limestone	2.702	0.00574	0.00633	0.213	0.234
	TX limestone sand	2.681	0.00391	0.00391	0.146	0.146
Gsb	AR Natural Sand	2.594	0.00356	0.00930	0.137	0.358
	Blast furnace slag	2.745	0.01553	0.04095	0.566	1.492
	Preston sandstone	2.496	0.01212	0.02000	0.486	0.801
	RC limestone	2.432	0.03026	0.03808	1.244	1.566
	TX limestone sand	2.548	0.01617	0.03753	0.634	1.473
Gssd	AR Natural Sand	2.611	0.00264	0.00672	0.101	0.257
	Blast furnace slag	2.796	0.01232	0.03203	0.441	1.146
	Preston sandstone	2.551	0.00760	0.01227	0.298	0.481
	RC limestone	2.532	0.01911	0.02382	0.755	0.941
	TX limestone sand	2.598	0.01042	0.02358	0.401	0.908
Absorption (%)	AR Natural Sand	0.649	0.04372	0.11274	6.737	17.375
	Blast furnace slag	1.880	0.19852	0.43160	10.559	22.957
	Preston sandstone	2.224	0.20488	0.34145	9.210	15.350
	RC limestone	4.107	0.53016	0.66720	12.909	16.246
	TX limestone sand	1.949	0.24938	0.58420	12.796	29.976

Table E-21. Within- and Between-Laboratory Statistics for AASHTO TP 77 (Phunque Flask) for Fine Aggregate

Parameter	Materials	Average	Standard Deviation		Coefficient of Variation (%)	
			W/L	B/L	W/L	B/L
Gsa	AR Natural Sand	2.644	0.00351	0.01446	0.133	0.547
	Blast furnace slag	2.880	0.01315	0.01563	0.457	0.543
	Preston sandstone	2.659	0.00346	0.01208	0.130	0.454
	RC limestone	2.730	0.00267	0.00644	0.098	0.236
	TX limestone sand	2.684	0.00642	0.01140	0.239	0.425
Gsb	AR Natural Sand	2.634	0.00180	0.01473	0.068	0.559
	Blast furnace slag	2.753	0.01303	0.01578	0.473	0.573
	Preston sandstone	2.576	0.00501	0.01723	0.195	0.669
	RC limestone	2.608	0.00772	0.01493	0.296	0.572
	TX limestone sand	2.608	0.00834	0.01382	0.320	0.530
Gssd	AR Natural Sand	2.638	0.00185	0.01439	0.070	0.546
	Blast furnace slag	2.798	0.01157	0.01463	0.414	0.523
	Preston sandstone	2.607	0.00273	0.01455	0.105	0.558
	RC limestone	2.653	0.00552	0.01130	0.208	0.426
	TX limestone sand	2.637	0.00584	0.01156	0.222	0.438
Absorption (%)	AR Natural Sand	0.133	0.04841	0.04841	36.310	36.310
	Blast furnace slag	1.635	0.09214	0.12064	5.636	7.380
	Preston sandstone	1.213	0.10400	0.15617	8.574	12.875
	RC limestone	1.707	0.09844	0.14368	5.766	8.415
	TX limestone sand	1.083	0.14893	0.15558	13.756	14.370

APPENDIX F

Testing Results of Experiment 3

Table F-1. Evaluation of Initial Drying Methods for AASHTO T 85

Method	Materials	Rep.	Gsa	Gsb	Gssd	Abs (%)
T85 - Part 2	Elmore Grav	1	2.633	2.561	2.588	1.1
T85 - Part 2	Elmore Grav	2	2.633	2.564	2.591	1.0
T85 - Part 2	Elmore Grav	3	2.633	2.564	2.590	1.0
Natural Moisture	Elmore Grav	1	2.636	2.555	2.586	1.2
Natural Moisture	Elmore Grav	2	2.642	2.571	2.598	1.0
Natural Moisture	Elmore Grav	3	2.640	2.570	2.596	1.0
CoreDry	Elmore Grav	1	2.634	2.568	2.593	1.0
CoreDry	Elmore Grav	2	2.638	2.567	2.594	1.0
CoreDry	Elmore Grav	3	2.628	2.564	2.588	1.0
T85 - Part 2	PS Coarse	1	2.623	2.489	2.540	2.0
T85 - Part 2	PS Coarse	2	2.620	2.489	2.539	2.0
T85 - Part 2	PS Coarse	3	2.625	2.488	2.540	2.1
Natural Moisture	PS Coarse	1	2.630	2.488	2.542	2.2
Natural Moisture	PS Coarse	2	2.639	2.496	2.550	2.2
Natural Moisture	PS Coarse	3	2.630	2.485	2.540	2.2
CoreDry	PS Coarse	1	2.616	2.494	2.541	1.9
CoreDry	PS Coarse	2	2.617	2.496	2.542	1.9
CoreDry	PS Coarse	3	2.613	2.497	2.542	1.8
T85 - Part 2	BF Slag Coarse	1	2.546	2.333	2.417	3.6
T85 - Part 2	BF Slag Coarse	2	2.562	2.348	2.431	3.6
T85 - Part 2	BF Slag Coarse	3	2.532	2.319	2.403	3.6
Natural Moisture	BF Slag Coarse	1	2.613	2.335	2.441	4.6
Natural Moisture	BF Slag Coarse	2	2.619	2.337	2.445	4.6
Natural Moisture	BF Slag Coarse	3	2.608	2.340	2.443	4.4
CoreDry	BF Slag Coarse	1	2.513	2.355	2.418	2.7
CoreDry	BF Slag Coarse	2	2.505	2.367	2.422	2.3
CoreDry	BF Slag Coarse	3	2.499	2.358	2.414	2.4
T85 - Part 2	RC LMS Coarse	1	2.687	2.521	2.583	2.5
T85 - Part 2	RC LMS Coarse	2	2.683	2.523	2.583	2.4
T85 - Part 2	RC LMS Coarse	3	2.685	2.524	2.584	2.4
Natural Moisture	RC LMS Coarse	1	2.708	2.553	2.610	2.2
Natural Moisture	RC LMS Coarse	2	2.714	2.546	2.608	2.4
Natural Moisture	RC LMS Coarse	3	2.706	2.536	2.599	2.5
CoreDry	RC LMS Coarse	1	2.683	2.544	2.596	2.0
CoreDry	RC LMS Coarse	2	2.683	2.557	2.604	1.8
CoreDry	RC LMS Coarse	3	2.681	2.555	2.602	1.8
T85 - Part 2	RE Concrete	1	2.590	2.350	2.442	4.0
T85 - Part 2	RE Concrete	2	2.581	2.337	2.432	4.0
T85 - Part 2	RE Concrete	3	2.585	2.354	2.443	3.8
Natural Moisture	RE Concrete	1	2.618	2.329	2.440	4.7
Natural Moisture	RE Concrete	2	2.625	2.339	2.448	4.7

Method	Materials	Rep.	Gsa	Gsb	Gssd	Abs (%)
Natural Moisture	RE Concrete	3	2.625	2.332	2.444	4.8
CoreDry	RE Concrete	1	2.543	2.395	2.453	2.4
CoreDry	RE Concrete	2	2.521	2.402	2.449	2.0
CoreDry	RE Concrete	3	2.527	2.391	2.445	2.3

Table F-2. Evaluation of Initial Drying Methods for AASHTO T 84

Method	Materials	Rep.	Gsa	Gsb	Gssd	Abs (%)
MT84 - Part 2	Ark NS	1	2.640	2.618	2.626	0.3
MT84 - Part 2	Ark NS	2	2.652	2.611	2.627	0.6
MT84 - Part 2	Ark NS	3	2.643	2.630	2.635	0.2
Natural Moisture	Ark NS	1	2.644	2.631	2.636	0.2
Natural Moisture	Ark NS	2	2.641	2.630	2.634	0.2
Natural Moisture	Ark NS	3	2.644	2.634	2.638	0.1
CoreDry	Ark NS	1	2.650	2.631	2.638	0.3
CoreDry	Ark NS	2	2.653	2.634	2.641	0.3
CoreDry	Ark NS	3	2.651	2.634	2.640	0.2
MT84 - Part 2	BF Slag Fine	1	2.855	2.713	2.763	1.8
MT84 - Part 2	BF Slag Fine	2	2.860	2.702	2.758	2.0
MT84 - Part 2	BF Slag Fine	3	2.856	2.731	2.775	1.6
Natural Moisture	BF Slag Fine	1	2.914	2.708	2.779	2.6
Natural Moisture	BF Slag Fine	2	2.917	2.665	2.751	3.2
Natural Moisture	BF Slag Fine	3	2.908	2.703	2.774	2.6
CoreDry	BF Slag Fine	1	2.861	2.753	2.791	1.4
CoreDry	BF Slag Fine	2	2.856	2.746	2.785	1.4
CoreDry	BF Slag Fine	3	2.866	2.757	2.795	1.4
MT84 - Part 2	PS Fine	1	2.648	2.548	2.586	1.5
MT84 - Part 2	PS Fine	2	2.654	2.516	2.568	2.1
MT84 - Part 2	PS Fine	3	2.660	2.527	2.577	2.0
Natural Moisture	PS Fine	1	2.659	2.582	2.611	1.1
Natural Moisture	PS Fine	2	2.660	2.610	2.628	0.7
Natural Moisture	PS Fine	3	2.662	2.589	2.616	1.1
CoreDry	PS Fine	1	2.663	2.581	2.612	1.2
CoreDry	PS Fine	2	2.666	2.585	2.615	1.2
CoreDry	PS Fine	3	2.668	2.579	2.613	1.3
MT84 - Part 2	RC LMS Fine	1	2.722	2.557	2.618	2.4
MT84 - Part 2	RC LMS Fine	2	2.714	2.468	2.559	3.7
MT84 - Part 2	RC LMS Fine	3	2.728	2.509	2.589	3.2
Natural Moisture	RC LMS Fine	1	2.725	2.523	2.598	2.9
Natural Moisture	RC LMS Fine	2	2.720	2.555	2.616	2.4
Natural Moisture	RC LMS Fine	3	2.730	2.579	2.634	2.1
CoreDry	RC LMS Fine	1	2.737	2.516	2.597	3.2
CoreDry	RC LMS Fine	2	2.743	2.496	2.586	3.6
CoreDry	RC LMS Fine	3	2.737	2.513	2.595	3.3
MT84 - Part 2	TX Sand	1	2.664	2.530	2.580	2.0
MT84 - Part 2	TX Sand	2	2.663	2.577	2.609	1.3
MT84 - Part 2	TX Sand	3	2.671	2.549	2.595	1.8
Natural Moisture	TX Sand	1	2.662	2.593	2.619	1.0
Natural Moisture	TX Sand	2	2.681	2.598	2.629	1.2
Natural Moisture	TX Sand	3	2.674	2.606	2.632	1.0
CoreDry	TX Sand	1	2.673	2.591	2.622	1.2
CoreDry	TX Sand	2	2.671	2.599	2.626	1.0
CoreDry	TX Sand	3	2.669	2.595	2.622	1.1

Table F-3. Evaluation of Soaking Methods for AASHTO T 85

Method	Materials	Rep No.	Gsa	Gsb	Gssd	Abs (%)
15-hr Soak	Elmore Grav	1	2.633	2.561	2.588	1.1
15-hr Soak	Elmore Grav	2	2.633	2.564	2.591	1.0
15-hr Soak	Elmore Grav	3	2.633	2.564	2.590	1.0
5-min Vac Sat	Elmore Grav	1	2.636	2.563	2.591	1.1
5-min Vac Sat	Elmore Grav	2	2.636	2.560	2.589	1.1
5-min Vac Sat	Elmore Grav	3	2.637	2.560	2.589	1.1
10-min Vac Sat	Elmore Grav	1	2.634	2.562	2.589	1.1
10-min Vac Sat	Elmore Grav	2	2.632	2.555	2.584	1.1
10-min Vac Sat	Elmore Grav	3	2.633	2.561	2.588	1.1
15-min Vac Sat	Elmore Grav	1	2.633	2.557	2.586	1.1
15-min Vac Sat	Elmore Grav	2	2.634	2.557	2.587	1.1
15-min Vac Sat	Elmore Grav	3	2.634	2.566	2.592	1.0
15-hr Soak	PS Coarse	1	2.623	2.489	2.540	2.0
15-hr Soak	PS Coarse	2	2.620	2.489	2.539	2.0
15-hr Soak	PS Coarse	3	2.625	2.488	2.540	2.1
5-min Vac Sat	PS Coarse	1	2.617	2.493	2.540	1.9
5-min Vac Sat	PS Coarse	2	2.619	2.491	2.540	2.0
5-min Vac Sat	PS Coarse	3	2.627	2.503	2.550	1.9
10-min Vac Sat	PS Coarse	1	2.618	2.495	2.542	1.9
10-min Vac Sat	PS Coarse	2	2.615	2.496	2.542	1.8
10-min Vac Sat	PS Coarse	3	2.618	2.497	2.543	1.8
15-min Vac Sat	PS Coarse	1	2.627	2.497	2.547	2.0
15-min Vac Sat	PS Coarse	2	2.620	2.488	2.538	2.0
15-min Vac Sat	PS Coarse	3	2.625	2.490	2.541	2.1
15-hr Soak	BF Slag Coarse	1	2.546	2.333	2.417	3.6
15-hr Soak	BF Slag Coarse	2	2.562	2.348	2.431	3.6
15-hr Soak	BF Slag Coarse	3	2.532	2.319	2.403	3.6
5-min Vac Sat	BF Slag Coarse	1	2.718	2.320	2.467	6.3
5-min Vac Sat	BF Slag Coarse	2	2.696	2.331	2.466	5.8
5-min Vac Sat	BF Slag Coarse	3	2.719	2.324	2.469	6.3
10-min Vac Sat	BF Slag Coarse	1	2.686	2.336	2.466	5.6
10-min Vac Sat	BF Slag Coarse	2	2.675	2.335	2.462	5.5
10-min Vac Sat	BF Slag Coarse	3	2.711	2.331	2.471	6.0
15-min Vac Sat	BF Slag Coarse	1	2.709	2.340	2.476	5.8
15-min Vac Sat	BF Slag Coarse	2	2.676	2.324	2.455	5.7
15-min Vac Sat	BF Slag Coarse	3	2.691	2.319	2.457	6.0
15-hr Soak	RC LMS Coarse	1	2.687	2.521	2.583	2.5
15-hr Soak	RC LMS Coarse	2	2.683	2.523	2.583	2.4
15-hr Soak	RC LMS Coarse	3	2.685	2.524	2.584	2.4
5-min Vac Sat	RC LMS Coarse	1	2.675	2.539	2.590	2.0
5-min Vac Sat	RC LMS Coarse	2	2.678	2.540	2.591	2.0
5-min Vac Sat	RC LMS Coarse	3	2.673	2.544	2.592	1.9
10-min Vac Sat	RC LMS Coarse	1	2.677	2.536	2.589	2.1
10-min Vac Sat	RC LMS Coarse	2	2.677	2.540	2.591	2.0
10-min Vac Sat	RC LMS Coarse	3	2.677	2.544	2.594	2.0
15-min Vac Sat	RC LMS Coarse	1	2.679	2.549	2.597	1.9
15-min Vac Sat	RC LMS Coarse	2	2.674	2.541	2.591	2.0
15-min Vac Sat	RC LMS Coarse	3	2.674	2.541	2.591	2.0
15-hr Soak	RE Concrete	1	2.590	2.350	2.442	4.0
15-hr Soak	RE Concrete	2	2.581	2.337	2.432	4.0
15-hr Soak	RE Concrete	3	2.585	2.354	2.443	3.8
5-min Vac Sat	RE Concrete	1	2.600	2.367	2.456	3.8
5-min Vac Sat	RE Concrete	2	2.599	2.376	2.462	3.6
5-min Vac Sat	RE Concrete	3	2.588	2.353	2.444	3.9
10-min Vac Sat	RE Concrete	1	2.592	2.369	2.455	3.6
10-min Vac Sat	RE Concrete	2	2.599	2.362	2.453	3.9
10-min Vac Sat	RE Concrete	3	2.594	2.363	2.452	3.8

Method	Materials	Rep No.	Gsa	Gsb	Gssd	Abs (%)
15-min Vac Sat	RE Concrete	1	2.614	2.363	2.459	4.1
15-min Vac Sat	RE Concrete	2	2.618	2.344	2.448	4.5
15-min Vac Sat	RE Concrete	3	2.615	2.346	2.449	4.4

Table F-4. Evaluation of Soaking Methods for AASHTO T 84

Method	Materials	Rep No.	Gsa	Gsb	Gssd	Abs (%)
15-hr Soak	Ark NS	1	2.640	2.618	2.626	0.3
15-hr Soak	Ark NS	2	2.652	2.611	2.627	0.6
15-hr Soak	Ark NS	3	2.643	2.630	2.635	0.2
5-min Vac Sat	Ark NS	1	2.644	2.623	2.631	0.3
5-min Vac Sat	Ark NS	2	2.645	2.630	2.636	0.2
5-min Vac Sat	Ark NS	3	2.643	2.628	2.634	0.2
10-min Vac Sat	Ark NS	1	2.639	2.627	2.631	0.2
10-min Vac Sat	Ark NS	2	2.641	2.631	2.635	0.1
10-min Vac Sat	Ark NS	3	2.642	2.633	2.636	0.1
15-min Vac Sat	Ark NS	1	2.639	2.618	2.626	0.3
15-min Vac Sat	Ark NS	2	2.644	2.631	2.636	0.2
15-min Vac Sat	Ark NS	3	2.637	2.622	2.628	0.2
15-hr Soak	BF Slag Fine	1	2.855	2.713	2.763	1.8
15-hr Soak	BF Slag Fine	2	2.860	2.702	2.758	2.0
15-hr Soak	BF Slag Fine	3	2.856	2.731	2.775	1.6
5-min Vac Sat	BF Slag Fine	1	2.845	2.733	2.773	1.4
5-min Vac Sat	BF Slag Fine	2	2.847	2.712	2.759	1.8
5-min Vac Sat	BF Slag Fine	3	2.853	2.756	2.790	1.2
10-min Vac Sat	BF Slag Fine	1	2.840	2.748	2.780	1.2
10-min Vac Sat	BF Slag Fine	2	2.835	2.699	2.747	1.8
10-min Vac Sat	BF Slag Fine	3	2.851	2.723	2.768	1.7
15-min Vac Sat	BF Slag Fine	1	2.843	2.698	2.749	1.9
15-min Vac Sat	BF Slag Fine	2	2.849	2.717	2.763	1.7
15-min Vac Sat	BF Slag Fine	3	2.843	2.743	2.778	1.3
15-hr Soak	PS Fine	1	2.648	2.548	2.586	1.5
15-hr Soak	PS Fine	2	2.654	2.516	2.568	2.1
15-hr Soak	PS Fine	3	2.660	2.527	2.577	2.0
5-min Vac Sat	PS Fine	1	2.656	2.581	2.609	1.1
5-min Vac Sat	PS Fine	2	2.654	2.583	2.610	1.0
5-min Vac Sat	PS Fine	3	2.654	2.609	2.626	0.6
10-min Vac Sat	PS Fine	1	2.655	2.583	2.610	1.1
10-min Vac Sat	PS Fine	2	2.650	2.575	2.603	1.1
10-min Vac Sat	PS Fine	3	2.652	2.574	2.604	1.1
15-min Vac Sat	PS Fine	1	2.643	2.558	2.590	1.3
15-min Vac Sat	PS Fine	2	2.648	2.567	2.597	1.2
15-min Vac Sat	PS Fine	3	2.644	2.576	2.601	1.0
15-hr Soak	RC LMS Fine	1	2.722	2.557	2.618	2.4
15-hr Soak	RC LMS Fine	2	2.714	2.468	2.559	3.7
15-hr Soak	RC LMS Fine	3	2.728	2.509	2.589	3.2
5-min Vac Sat	RC LMS Fine	1	2.711	2.543	2.605	2.4
5-min Vac Sat	RC LMS Fine	2	2.717	2.556	2.615	2.3
5-min Vac Sat	RC LMS Fine	3	2.727	2.525	2.599	2.9
10-min Vac Sat	RC LMS Fine	1	2.727	2.502	2.584	3.3
10-min Vac Sat	RC LMS Fine	2	2.728	2.517	2.594	3.1
10-min Vac Sat	RC LMS Fine	3	2.725	2.534	2.604	2.8
15-min Vac Sat	RC LMS Fine	1	2.726	2.532	2.603	2.8
15-min Vac Sat	RC LMS Fine	2	2.728	2.530	2.602	2.9
15-min Vac Sat	RC LMS Fine	3	2.733	2.536	2.608	2.8
15-hr Soak	TX Sand	1	2.664	2.530	2.580	2.0
15-hr Soak	TX Sand	2	2.663	2.577	2.609	1.3

Method	Materials	Rep No.	Gsa	Gsb	Gssd	Abs (%)
15-hr Soak	TX Sand	3	2.671	2.549	2.595	1.8
5-min Vac Sat	TX Sand	1	2.671	2.595	2.623	1.1
5-min Vac Sat	TX Sand	2	2.665	2.581	2.613	1.2
5-min Vac Sat	TX Sand	3	2.672	2.619	2.639	0.8
10-min Vac Sat	TX Sand	1	2.660	2.581	2.611	1.1
10-min Vac Sat	TX Sand	2	2.675	2.588	2.620	1.3
10-min Vac Sat	TX Sand	3	2.673	2.613	2.635	0.9
15-min Vac Sat	TX Sand	1	2.682	2.546	2.597	2.0
15-min Vac Sat	TX Sand	2	2.672	2.551	2.596	1.8
15-min Vac Sat	TX Sand	3	2.669	2.569	2.607	1.5

Table F-5. Evaluation of Vacuum Soaking for AASHTO T 85 Using In-Situ Moisture Samples

Materials	Drying and Soaking Methods	Rep.	Gsa	Gsb	Gssd	Abs (%)
Elmore Grav	Control (oven-dried, 15-hr soaking)	1	2.636	2.570	2.595	0.98
Elmore Grav	Control (oven-dried, 15-hr soaking)	2	2.635	2.553	2.584	1.21
Elmore Grav	Control (oven-dried, 15-hr soaking)	3	2.636	2.562	2.590	1.10
Elmore Grav	Natural moisture, 5-min vacuum	1	2.654	2.567	2.600	1.27
Elmore Grav	Natural moisture, 5-min vacuum	2	2.645	2.567	2.597	1.14
Elmore Grav	Natural moisture, 5-min vacuum	3	2.640	2.567	2.595	1.08
Elmore Grav	Natural moisture, 10-min vacuum	1	2.644	2.567	2.596	1.13
Elmore Grav	Natural moisture, 10-min vacuum	2	2.646	2.565	2.595	1.19
Elmore Grav	Natural moisture, 10-min vacuum	3	2.641	2.564	2.594	1.14
Elmore Grav	Natural moisture, 15-min vacuum	1	2.644	2.557	2.590	1.29
Elmore Grav	Natural moisture, 15-min vacuum	2	2.640	2.566	2.594	1.09
Elmore Grav	Natural moisture, 15-min vacuum	3	2.641	2.563	2.592	1.15
PS Coarse	Control (oven-dried, 15-hr soaking)	1	2.626	2.490	2.542	2.08
PS Coarse	Control (oven-dried, 15-hr soaking)	2	2.622	2.485	2.537	2.11
PS Coarse	Control (oven-dried, 15-hr soaking)	3	2.622	2.491	2.541	2.00
PS Coarse	Natural moisture, 5-min vacuum	1	2.615	2.482	2.533	2.05
PS Coarse	Natural moisture, 5-min vacuum	2	2.620	2.487	2.538	2.04
PS Coarse	Natural moisture, 5-min vacuum	3	2.618	2.491	2.540	1.95
PS Coarse	Natural moisture, 10-min vacuum	1	2.627	2.490	2.542	2.09
PS Coarse	Natural moisture, 10-min vacuum	2	2.629	2.490	2.543	2.12
PS Coarse	Natural moisture, 10-min vacuum	3	2.625	2.493	2.543	2.03
PS Coarse	Natural moisture, 15-min vacuum	1	2.623	2.495	2.544	1.96
PS Coarse	Natural moisture, 15-min vacuum	2	2.637	2.503	2.554	2.03
PS Coarse	Natural moisture, 15-min vacuum	3	2.621	2.492	2.541	1.99
BF Slag Coarse	Control (oven-dried, 15-hr soaking)	1	2.484	2.315	2.383	2.94
BF Slag Coarse	Control (oven-dried, 15-hr soaking)	2	2.503	2.329	2.399	2.99
BF Slag Coarse	Control (oven-dried, 15-hr soaking)	3	2.499	2.328	2.396	2.95
BF Slag Coarse	Natural moisture, 5-min vacuum	1	2.657	2.342	2.460	5.08
BF Slag Coarse	Natural moisture, 5-min vacuum	2	2.678	2.329	2.459	5.26
BF Slag Coarse	Natural moisture, 5-min vacuum	3	2.660	2.347	2.465	5.02
BF Slag Coarse	Natural moisture, 10-min vacuum	1	2.666	2.353	2.470	4.99
BF Slag Coarse	Natural moisture, 10-min vacuum	2	2.661	2.345	2.464	5.07
BF Slag Coarse	Natural moisture, 10-min vacuum	3	2.679	2.328	2.459	5.26
BF Slag Coarse	Natural moisture, 15-min vacuum	1	2.679	2.352	2.474	5.18
BF Slag Coarse	Natural moisture, 15-min vacuum	2	2.675	2.345	2.468	5.26
BF Slag Coarse	Natural moisture, 15-min vacuum	3	2.661	2.333	2.456	5.27
RC LMS Coarse	Control (oven-dried, 15-hr soaking)	1	2.693	2.540	2.596	2.24
RC LMS Coarse	Control (oven-dried, 15-hr soaking)	2	2.681	2.533	2.589	2.18
RC LMS Coarse	Control (oven-dried, 15-hr soaking)	3	2.684	2.545	2.597	2.04
RC LMS Coarse	Natural moisture, 5-min vacuum	1	2.706	2.541	2.602	2.39
RC LMS Coarse	Natural moisture, 5-min vacuum	2	2.708	2.537	2.600	2.49
RC LMS Coarse	Natural moisture, 5-min vacuum	3	2.702	2.542	2.601	2.33

RC LMS Coarse	Natural moisture, 10-min vacuum	1	2.712	2.550	2.610	2.34
RC LMS Coarse	Natural moisture, 10-min vacuum	2	2.713	2.547	2.609	2.40
RC LMS Coarse	Natural moisture, 10-min vacuum	3	2.706	2.539	2.601	2.43
RC LMS Coarse	Natural moisture, 15-min vacuum	1	2.705	2.528	2.593	2.59
RC LMS Coarse	Natural moisture, 15-min vacuum	2	2.713	2.541	2.604	2.50
RC LMS Coarse	Natural moisture, 15-min vacuum	3	2.705	2.544	2.603	2.34
RE Concrete	Control (oven-dried, 15-hr soaking)	1	2.615	2.354	2.454	4.23
RE Concrete	Control (oven-dried, 15-hr soaking)	2	2.607	2.328	2.435	4.60
RE Concrete	Control (oven-dried, 15-hr soaking)	3	2.613	2.338	2.443	4.50
RE Concrete	Natural moisture, 5-min vacuum	1	2.612	2.344	2.446	4.38
RE Concrete	Natural moisture, 5-min vacuum	2	2.615	2.344	2.448	4.41
RE Concrete	Natural moisture, 5-min vacuum	3	2.597	2.326	2.430	4.49
RE Concrete	Natural moisture, 10-min vacuum	1	2.613	2.341	2.445	4.45
RE Concrete	Natural moisture, 10-min vacuum	2	2.610	2.350	2.449	4.24
RE Concrete	Natural moisture, 10-min vacuum	3	2.604	2.347	2.445	4.21
RE Concrete	Natural moisture, 15-min vacuum	1	2.617	2.338	2.445	4.56
RE Concrete	Natural moisture, 15-min vacuum	2	2.622	2.341	2.449	4.57
RE Concrete	Natural moisture, 15-min vacuum	3	2.611	2.334	2.440	4.55

Table F-6. Evaluation of Vacuum Soaking for AASHTO T 84 Using In-Situ Moisture Samples

Materials	Drying and Soaking Methods	Rep.	Gsa	Gsb	Gssd	Abs (%)
AR Sand	Control (oven-dried, 15-hr soaking)	1	2.644	2.633	2.637	0.16
AR Sand	Control (oven-dried, 15-hr soaking)	2	2.654	2.638	2.644	0.24
AR Sand	Control (oven-dried, 15-hr soaking)	3	2.644	2.628	2.634	0.24
AR Sand	Natural moisture, 5-min vacuum	1	2.650	2.632	2.639	0.26
AR Sand	Natural moisture, 5-min vacuum	2	2.649	2.634	2.640	0.22
AR Sand	Natural moisture, 5-min vacuum	3	2.649	2.632	2.639	0.24
AR Sand	Natural moisture, 10-min vacuum	1	2.653	2.631	2.639	0.32
AR Sand	Natural moisture, 10-min vacuum	2	2.645	2.627	2.634	0.26
AR Sand	Natural moisture, 10-min vacuum	3	2.648	2.623	2.632	0.36
AR Sand	Natural moisture, 15-min vacuum	1	2.655	2.631	2.640	0.34
AR Sand	Natural moisture, 15-min vacuum	2	2.656	2.635	2.643	0.30
AR Sand	Natural moisture, 15-min vacuum	3	2.645	2.626	2.633	0.28
TX LMS Fine	Control (oven-dried, 15-hr soaking)	1	2.676	2.585	2.619	1.32
TX LMS Fine	Control (oven-dried, 15-hr soaking)	2	2.682	2.587	2.623	1.37
TX LMS Fine	Control (oven-dried, 15-hr soaking)	3	2.674	2.589	2.621	1.23
TX LMS Fine	Natural moisture, 5-min vacuum	1	2.676	2.563	2.616	1.48
TX LMS Fine	Natural moisture, 5-min vacuum	2	2.679	2.577	2.621	1.32
TX LMS Fine	Natural moisture, 5-min vacuum	3	2.688	2.574	2.609	1.46
TX LMS Fine	Natural moisture, 10-min vacuum	1	2.684	2.583	2.614	1.41
TX LMS Fine	Natural moisture, 10-min vacuum	2	2.684	2.599	2.631	1.21
TX LMS Fine	Natural moisture, 10-min vacuum	3	2.681	2.594	2.627	1.24
TX LMS Fine	Natural moisture, 15-min vacuum	1	2.669	2.584	2.616	1.23
TX LMS Fine	Natural moisture, 15-min vacuum	2	2.679	2.603	2.631	1.09
TX LMS Fine	Natural moisture, 15-min vacuum	3	2.663	2.586	2.615	1.12
BF Slag Fine	Control (oven-dried, 15-hr soaking)	1	2.820	2.572	2.660	3.42
BF Slag Fine	Control (oven-dried, 15-hr soaking)	2	2.813	2.565	2.653	3.44
BF Slag Fine	Control (oven-dried, 15-hr soaking)	3	2.826	2.574	2.663	3.47
BF Slag Fine	Natural moisture, 5-min vacuum	1	2.857	2.630	2.716	2.89
BF Slag Fine	Natural moisture, 5-min vacuum	2	2.840	2.621	2.698	2.94
BF Slag Fine	Natural moisture, 5-min vacuum	3	2.854	2.619	2.696	3.09
BF Slag Fine	Natural moisture, 10-min vacuum	1	2.848	2.608	2.684	2.81
BF Slag Fine	Natural moisture, 10-min vacuum	2	2.843	2.612	2.693	3.02
BF Slag Fine	Natural moisture, 10-min vacuum	3	2.837	2.623	2.708	2.95
BF Slag Fine	Natural moisture, 15-min vacuum	1	2.859	2.604	2.693	3.42
BF Slag Fine	Natural moisture, 15-min vacuum	2	2.842	2.592	2.674	3.54

Materials	Drying and Soaking Methods	Rep.	Gsa	Gsb	Gssd	Abs (%)
BF Slag Fine	Natural moisture, 15-min vacuum	3	2.857	2.609	2.696	3.33
PS Fine	Control (oven-dried, 15-hr soaking)	1	2.648	2.574	2.602	1.09
PS Fine	Control (oven-dried, 15-hr soaking)	2	2.654	2.591	2.615	0.90
PS Fine	Control (oven-dried, 15-hr soaking)	3	2.647	2.573	2.601	1.08
PS Fine	Natural moisture, 5-min vacuum	1	2.672	2.564	2.605	1.58
PS Fine	Natural moisture, 5-min vacuum	2	2.669	2.568	2.606	1.48
PS Fine	Natural moisture, 5-min vacuum	3	2.662	2.564	2.601	1.43
PS Fine	Natural moisture, 10-min vacuum	1	2.652	2.583	2.609	1.00
PS Fine	Natural moisture, 10-min vacuum	2	2.660	2.586	2.613	1.08
PS Fine	Natural moisture, 10-min vacuum	3	2.643	2.567	2.600	0.97
PS Fine	Natural moisture, 15-min vacuum	1	2.658	2.582	2.610	1.10
PS Fine	Natural moisture, 15-min vacuum	2	2.657	2.572	2.604	1.24
PS Fine	Natural moisture, 15-min vacuum	3	2.652	2.583	2.609	1.01
RC LMS Fine	Control (oven-dried, 15-hr soaking)	1	2.714	2.552	2.612	2.34
RC LMS Fine	Control (oven-dried, 15-hr soaking)	2	2.737	2.576	2.635	2.28
RC LMS Fine	Control (oven-dried, 15-hr soaking)	3	2.721	2.556	2.617	2.37
RC LMS Fine	Natural moisture, 5-min vacuum	1	2.708	2.516	2.587	2.81
RC LMS Fine	Natural moisture, 5-min vacuum	2	2.691	2.506	2.574	2.75
RC LMS Fine	Natural moisture, 5-min vacuum	3	2.705	2.497	2.574	2.98
RC LMS Fine	Natural moisture, 10-min vacuum	1	2.710	2.546	2.607	2.48
RC LMS Fine	Natural moisture, 10-min vacuum	2	2.729	2.545	2.612	2.66
RC LMS Fine	Natural moisture, 10-min vacuum	3	2.716	2.524	2.595	2.71
RC LMS Fine	Natural moisture, 15-min vacuum	1	2.718	2.541	2.606	2.76
RC LMS Fine	Natural moisture, 15-min vacuum	2	2.720	2.521	2.588	3.06
RC LMS Fine	Natural moisture, 15-min vacuum	3	2.721	2.515	2.580	2.87

APPENDIX G

Testing Results of Experiment 4

Evaluation of Effects of P200 on AASHTO T 84 Test Results

Table G-1. Evaluation of P200 Effects Using Natural Sand

Materials	Col. No. in Table 8	+200/-200/Clay	Rep No.	Gsa	Gsb	Gssd	Abs (%)
Ark NS	1	100/0/0	1	2.644	2.637	2.639	0.10
Ark NS	1	100/0/0	2	2.640	2.627	2.632	0.18
Ark NS	1	100/0/0	3	2.643	2.626	2.632	0.24
Ark NS	2	95/5/0	1	2.646	2.608	2.622	0.55
Ark NS	2	95/5/0	2	2.645	2.611	2.624	0.49
Ark NS	2	95/5/0	3	2.646	2.619	2.629	0.38
Ark NS	3	95/5/1.25	1	2.647	2.451	2.525	3.03
Ark NS	3	95/5/1.25	2	2.645	2.466	2.533	2.75
Ark NS	3	95/5/1.25	3	2.643	2.465	2.532	2.74
Ark NS	4	95/5/2.5	1	2.644	2.356	2.465	4.62
Ark NS	4	95/5/2.5	2	2.666	2.383	2.489	4.44
Ark NS	4	95/5/2.5	3	2.650	2.345	2.460	4.92
Ark NS	5	90/10/0	1	2.651	2.594	2.616	0.83
Ark NS	5	90/10/0	2	2.645	2.602	2.618	0.62
Ark NS	5	90/10/0	3	2.650	2.596	2.617	0.79
Ark NS	6	90/10/2.5	1	2.667	2.420	2.513	3.83
Ark NS	6	90/10/2.5	2	2.651	2.420	2.507	3.59
Ark NS	6	90/10/2.5	3	2.671	2.394	2.498	4.33
Ark NS	7	90/10/5	1	2.629	2.295	2.422	5.53
Ark NS	7	90/10/5	2	2.640	2.361	2.467	4.47
Ark NS	7	90/10/5	3	2.644	2.281	2.419	6.01
Ark NS	8	80/20/0	1	2.663	2.584	2.614	1.15
Ark NS	8	80/20/0	2	2.656	2.629	2.639	0.38
Ark NS	8	80/20/0	3	2.661	2.627	2.640	0.48
Ark NS	9	80/20/5	1	2.658	2.425	2.512	3.62
Ark NS	9	80/20/5	2	2.637	2.475	2.536	2.47
Ark NS	9	80/20/5	3	2.636	2.447	2.518	2.94
Ark NS	10	80/20/10	1	2.573	2.218	2.356	6.21
Ark NS	10	80/20/10	2	2.551	2.304	2.401	4.20
Ark NS	10	80/20/10	3	2.569	2.261	2.381	5.30
Ark NS	11	70/30/0	1	2.667	2.643	2.652	0.34
Ark NS	11	70/30/0	2	2.666	2.661	2.663	0.08
Ark NS	11	70/30/0	3	2.646	2.642	2.643	0.06
Ark NS	12	70/30/7.5	1	2.628	2.354	2.458	4.42
Ark NS	12	70/30/7.5	2	2.628	2.336	2.447	4.76
Ark NS	12	70/30/7.5	3	2.635	2.295	2.424	5.63

Table G-2. Evaluation of P200 Effects Using RC Limestone

Materials	Col. No. in Table 8	+200/-200/Clay	Rep No.	Gsa	Gsb	Gssd	Abs (%)
RC LMS	1	100/0/0	1	2.725	2.472	2.565	3.75
RC LMS	1	100/0/0	2	2.711	2.503	2.579	3.07
RC LMS	1	100/0/0	3	2.724	2.476	2.567	3.69
RC LMS	2	95/5/0	1	2.722	2.481	2.569	3.57
RC LMS	2	95/5/0	2	2.718	2.536	2.603	2.64
RC LMS	2	95/5/0	3	2.728	2.487	2.575	3.55
RC LMS	3	95/5/1.25	1	2.717	2.392	2.512	4.99
RC LMS	3	95/5/1.25	2	2.703	2.413	2.521	4.44
RC LMS	3	95/5/1.25	3	2.712	2.403	2.517	4.74
RC LMS	4	95/5/2.5	1	2.709	2.319	2.463	6.20
RC LMS	4	95/5/2.5	2	2.715	2.435	2.538	4.25
RC LMS	4	95/5/2.5	3	2.719	2.303	2.456	6.64
RC LMS	5	90/10/0	1	2.737	2.516	2.597	3.20
RC LMS	5	90/10/0	2	2.723	2.454	2.553	4.03
RC LMS	5	90/10/0	3	2.720	2.472	2.563	3.70
RC LMS	6	90/10/2.5	1	2.744	2.350	2.494	6.11
RC LMS	6	90/10/2.5	2	2.724	2.381	2.507	5.29
RC LMS	6	90/10/2.5	3	2.714	2.358	2.489	5.57
RC LMS	7	90/10/5	1	2.719	2.235	2.413	7.96
RC LMS	7	90/10/5	2	2.753	2.218	2.413	8.76
RC LMS	7	90/10/5	3	2.714	2.127	2.344	10.17
RC LMS	8	80/20/0	1	2.713	2.577	2.627	1.96
RC LMS	8	80/20/0	2	2.719	2.555	2.615	2.36
RC LMS	8	80/20/0	3	2.714	2.524	2.594	2.77
RC LMS	9	80/20/5	1	2.725	2.299	2.455	6.80
RC LMS	9	80/20/5	2	2.721	2.318	2.466	6.39
RC LMS	9	80/20/5	3	2.710	2.344	2.479	5.76
RC LMS	10	80/20/10	1	2.593	2.194	2.348	7.01
RC LMS	10	80/20/10	2	2.598	2.154	2.325	7.94
RC LMS	10	80/20/10	3	2.598	2.224	2.368	6.47
RC LMS	11	70/30/0	1	2.719	2.519	2.593	2.92
RC LMS	11	70/30/0	2	2.715	2.531	2.599	2.68
RC LMS	11	70/30/0	3	2.723	2.610	2.652	1.58
RC LMS	12	70/30/7.5	1	2.695	2.485	2.563	3.13
RC LMS	12	70/30/7.5	2	2.660	2.443	2.524	3.34
RC LMS	12	70/30/7.5	3	2.676	2.443	2.530	3.57

Table G-3. Sand Equivalent

Materials	+200	Total P200	Clay	Rep No.	Sand Equivalent (%)
Ark NS	100	0	0	1	100
Ark NS	95	5	0	1	89.1
Ark NS	95	5	1.25	1	76.3
Ark NS	95	5	2.5	1	56.2
Ark NS	90	10	0	1	80.4
Ark NS	90	10	2.5	1	57.1
Ark NS	90	10	5	1	46
Ark NS	80	20	0	1	64.9
Ark NS	80	20	5	1	38.9
Ark NS	80	20	10	1	26.7
RC LMS	100	0	0	1	78.7
RC LMS	95	5	0	1	81.3
RC LMS	95	5	1.25	1	67.9
RC LMS	95	5	2.5	1	59.4
RC LMS	90	10	0	1	69.8
RC LMS	90	10	2.5	1	52.1

Materials	+200	Total P200	Clay	Rep No.	Sand Equivalent (%)
RC LMS	90	10	5	1	40.2
RC LMS	80	20	0	1	51.4
RC LMS	80	20	5	1	31.1
RC LMS	80	20	10	1	26.5
Ark NS	100	0	0	2	100
Ark NS	95	5	0	2	89.4
Ark NS	95	5	1.25	2	72.4
Ark NS	95	5	2.5	2	56.2
Ark NS	90	10	0	2	80.4
Ark NS	90	10	2.5	2	54.8
Ark NS	90	10	5	2	44
Ark NS	80	20	0	2	62.1
Ark NS	80	20	5	2	30.6
Ark NS	80	20	10	2	25.2
RC LMS	100	0	0	2	86.7
RC LMS	95	5	0	2	78.7
RC LMS	95	5	1.25	2	63.3
RC LMS	95	5	2.5	2	55.2
RC LMS	90	10	0	2	74.5
RC LMS	90	10	2.5	2	52.1
RC LMS	90	10	5	2	37.6
RC LMS	80	20	0	2	50
RC LMS	80	20	5	2	31.4
RC LMS	80	20	10	2	26.7

Tukey's Grouping of AASHTO T 84 Test Results

Table G-4. Tukey's Grouping of Gsa Results for Natural Sand Blends

```
Grouping Information Using Tukey's Method and 95.0% Confidence

+200/-200/Clay  N   Mean   Grouping
90/10/2.5       3   2.663  A
80/20/0         3   2.660  A B
70/30/0         3   2.660  A B
95/5/2.5        3   2.653  A B C
90/10/0         3   2.649  A B C
95/5/0          3   2.645  A B C
95/5/1.25       3   2.645  A B C
80/20/5         3   2.643  A B C
100/0/0         3   2.642  A B C
90/10/5         3   2.637  A B C
70/30/7.5       3   2.630      C
80/20/10        3   2.564        D

Means that do not share a letter are significantly different.
```

Table G-5. Tukey's Grouping of Gsb Results for Natural Sand Blends

Grouping Information Using Tukey's Method and 95.0% Confidence

+200/-200/Clay	N	Mean	Grouping
70/30/0	3	2.649	A
100/0/0	3	2.630	A
80/20/0	3	2.614	A
95/5/0	3	2.613	A
90/10/0	3	2.597	A
95/5/1.25	3	2.460	B
80/20/5	3	2.449	B
90/10/2.5	3	2.411	B C
95/5/2.5	3	2.362	C D
70/30/7.5	3	2.328	D E
90/10/5	3	2.312	D E
80/20/10	3	2.261	E

Means that do not share a letter are significantly different.

Table G-6. Tukey's Grouping of Gssd Results for Natural Sand Blends

Grouping Information Using Tukey's Method and 95.0% Confidence

+200/-200/Clay	N	Mean	Grouping
70/30/0	3	2.653	A
100/0/0	3	2.635	A
80/20/0	3	2.631	A
95/5/0	3	2.625	A
90/10/0	3	2.617	A
95/5/1.25	3	2.530	B
80/20/5	3	2.522	B
90/10/2.5	3	2.506	B C
95/5/2.5	3	2.472	C D
70/30/7.5	3	2.443	D
90/10/5	3	2.436	D
80/20/10	3	2.379	E

Means that do not share a letter are significantly different.

Table G-7. Tukey's Grouping of Absorption Results for Natural Sand Blends

Grouping Information Using Tukey's Method and 95.0% Confidence

+200/-200/Clay	N	Mean	Grouping		
90/10/5	3	5.34	A		
80/20/10	3	5.24	A		
70/30/7.5	3	4.94	A		
95/5/2.5	3	4.66	A		
90/10/2.5	3	3.92	A	B	
80/20/5	3	3.01		B	
95/5/1.25	3	2.84		B	
90/10/0	3	0.75			C
80/20/0	3	0.67			C
95/5/0	3	0.47			C
100/0/0	3	0.18			C
70/30/0	3	0.16			C

Means that do not share a letter are significantly different.

Table G-8. Tukey's Grouping of Gsa Results for RC Limestone Blends

Grouping Information Using Tukey's Method and 95.0% Confidence

+200/-200/Clay	N	Mean	Grouping		
90/10/5	3	2.729	A		
90/10/2.5	3	2.727	A		
90/10/0	3	2.727	A		
95/5/0	3	2.722	A		
100/0/0	3	2.720	A		
70/30/0	3	2.719	A		
80/20/5	3	2.719	A		
80/20/0	3	2.716	A		
95/5/2.5	3	2.714	A		
95/5/1.25	3	2.710	A		
70/30/7.5	3	2.677		B	
80/20/10	3	2.596			C

Means that do not share a letter are significantly different.

Table G-9. Tukey's Grouping of Gsb Results for RC Limestone Blends

Grouping Information Using Tukey's Method and 95.0% Confidence

+200/-200/Clay	N	Mean	Grouping
70/30/0	3	2.553	A
80/20/0	3	2.552	A
95/5/0	3	2.501	A B
100/0/0	3	2.483	A B
90/10/0	3	2.481	A B
95/5/1.25	3	2.403	B C
90/10/2.5	3	2.363	C
70/30/7.5	3	2.357	C
95/5/2.5	3	2.352	C
90/10/5	3	2.327	C
80/20/5	3	2.320	C
80/20/10	3	2.191	D

Means that do not share a letter are significantly different.

Table G-10. Tukey's Grouping of Gssd Results for RC Limestone Blends

Grouping Information Using Tukey's Method and 95.0% Confidence

+200/-200/Clay	N	Mean	Grouping
70/30/0	3	2.614	A
80/20/0	3	2.612	A
95/5/0	3	2.582	A B
90/10/0	3	2.571	A B C
100/0/0	3	2.570	A B C
90/10/5	3	2.523	B C D
95/5/1.25	3	2.516	C D
90/10/2.5	3	2.497	D E
95/5/2.5	3	2.486	D E
80/20/5	3	2.467	D E
70/30/7.5	3	2.439	E
80/20/10	3	2.347	F

Means that do not share a letter are significantly different.

Table G-11. Tukey's Grouping of Absorption Results for RC Limestone Blends

Grouping Information Using Tukey's Method and 95.0% Confidence

+200/-200/Clay	N	Mean	Grouping
90/10/5	3	7.30	A
80/20/10	3	7.14	A
70/30/7.5	3	6.35	A B
80/20/5	3	6.32	A B
95/5/2.5	3	5.70	A B
90/10/2.5	3	5.65	A B
95/5/1.25	3	4.72	B C
90/10/0	3	3.64	C D
100/0/0	3	3.50	C D
95/5/0	3	3.25	C D
70/30/0	3	2.40	D
80/20/0	3	2.36	D

Means that do not share a letter are significantly different.

APPENDIX H

Results of Experiment 5

Figure H.1 compares the water absorption measured by two test methods (AASHTO T85 and Phunque Flask for Coarse Aggregate) for the five materials tested in Experiment 2. The Phunque method consistently produced lower absorption values because water had penetrated into the permeable voids within the first 30 seconds before the initial reading was taken. Use of a correlation between the water level and time at which the water level reading was taken (Figure H.2) can help estimate the water level at time zero (it was assumed that no water had been penetrated into the permeable voids at time zero). The research team further evaluated several models to better fit the measured data (Figure H.2). Results of this analysis are presented in this appendix.

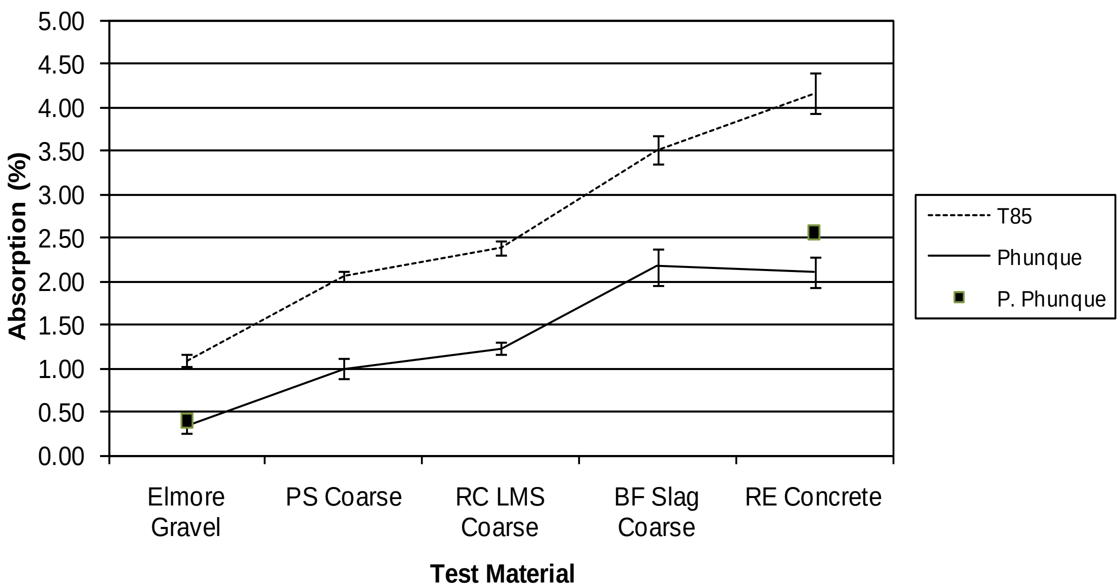

Figure H.1. Comparison of Means of Absorption Measured by Test Methods for Coarse Aggregate.

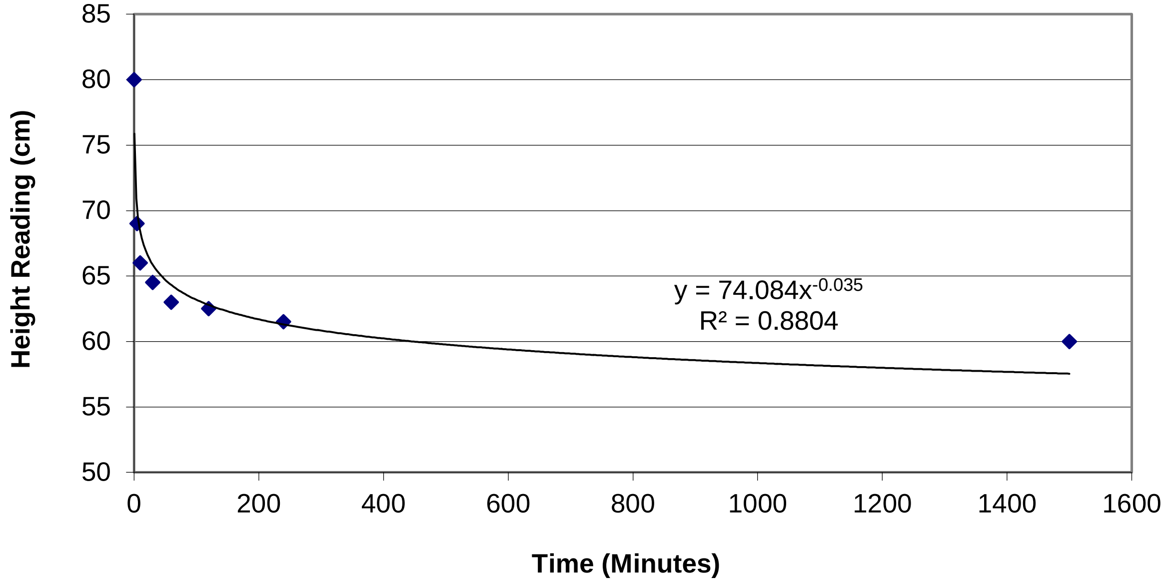

Figure H.2. Correlation between Water Level and Time for Estimating Water Level at Time Zero.

Determining Time-Zero Reading for Phunque Methods

Since the Phunque methods consistently produced lower absorption values than those of the AASHTO procedures evaluated in this project, it was suggested that some water had penetrated into the permeable voids within the first 30 seconds before the initial reading was taken. An analysis was conducted to identify a model that can be used to determine the time-zero reading at which no water has been penetrated into the permeable voids of aggregate. Determining the true time-zero reading for the Phunque method is as difficult as determining the true saturated surface dry (SSD) condition for AASHTO T84 and T85. Therefore, for this analysis, time zero is defined as the moment at which water reading should be taken so that the water absorption measured with the Phunque methods is the same as that measured according to AASHTO T 84 and T 85. This does not mean AASHTO T84 and T85 can measure the true SSD condition for aggregate. However, these methods have been used by state agencies, and design and acceptance criteria have been developed based on the results of these methods. Thus, it is desirable to have test methods that yield results close to those of AASHTO T84 and T85 but have improved repeatability and reproducibility.

The following three models were selected after several models were evaluated using the curve fitting software DataFit® developed by Oakdale Engineering.

- Power: $Y = aX^b$
- Logarithmic: $Y = a \cdot \ln(X) + b$
- Exponential: $Y = e^{aX^\wedge b}$
- In which *Y* is water level, *X* is time at which water level reading is taken, and *a* and *b* are regression coefficients

The three models were fit to the following four subsets of water reading data to determine a combination of model and subset that can be used to best determine the time-zero reading for the Phunque method. A best-fit model can also be used to estimate the final water reading so that the test does not need to run for 1,500 minutes.

- Subset 1: water level readings at 30 sec., 5, 10, 30 min.
- Subset 2: water level readings at 30 sec., 5, 10, 30, 60 min.

- Subset 3: water level readings at 30 sec., 5, 10, 30, 60, 120 min.
- Subset 4: water level readings at 30 sec., 5, 10, 30, 60, 120 (2 hrs), 240 (4 hrs), 1500 min (25 hrs).

Tables H.1 and H.2 show the goodness-of-fit (R^2) of the three models. Each model was fit to the same data for comparison. In each table, the goodness-of-fit values of the three models are shown for the first two materials. Since the goodness-of-fit values of the three models were almost the same for each set of data evaluated, the power model was selected because it has a simple form and is available under the "Add Trendline…" function in Microsoft Excel®. Hence, only goodness-of-fit values of the power model are shown for other materials in Tables H.1 and H.2. Based on the goodness-of-fit results, the power model could be used to reasonably fit the Phunque flask data.

While adding three more data points (water level readings at 120, 240, and 1500 min.) to the regression data slightly changed the goodness-of-fit (R^2) of the power model, it did not significantly change the coefficients (*a* and *b*) of the model and estimated time-zero reading, which were significantly influenced by the first five data points (water level readings at 30 sec., 5, 10, 30, and 60 min.), as shown in Figure H.3, due to the shape of the power model and the number of data points in each subset (Subsets 1 to 4). This suggests that the water reading at 25 hours (1500 min.) may not be needed and the Phunque test can be completed within one working day.

Table H.1. Goodness-of-Fit (R^2) for Test Results of Coarse Aggregate

Material	Rep No.	Model	R^2			
			Subset 1	Subset 2	Subset 3	Subset 4
BF Slag Coarse	1	Power	0.994	0.996	0.997	0.977
		Logarithmic	0.994	0.999	0.999	0.976
		Exponential	0.994	0.999	0.999	0.976
	2	Power	0.985	0.986	0.988	0.987
		Logarithmic	0.985	0.986	0.989	0.986
		Exponential	0.985	0.986	0.989	0.986
	3	Power	0.990	0.992	0.993	0.983
		Logarithmic	0.991	0.993	0.994	0.982
		Exponential	0.991	0.993	0.994	0.982
Elmore Gravel	1	Power	0.910	0.858	0.800	0.851
		Logarithmic	0.910	0.863	0.818	0.891
		Exponential	0.910	0.863	0.818	0.891
	2	Power	0.821	0.734	0.805	0.908
		Logarithmic	0.821	0.735	0.805	0.908
		Exponential	0.821	0.735	0.805	0.908
	3	Power	0.933	0.956	0.963	0.979
		Logarithmic	0.934	0.956	0.963	0.977
		Exponential	0.934	0.956	0.963	0.977
PS Coarse	1	Power	0.911	0.896	0.859	0.784
	2	Power	0.946	0.918	0.873	0.762
	3	Power	0.947	0.898	0.898	0.920
RC Limestone Coarse	1	Power	0.974	0.964	0.968	0.947
	2	Power	0.982	0.970	0.963	0.912
	3	Power	0.979	0.978	0.965	0.941
Recycled Concrete	1	Power	0.947	0.906	0.867	0.813
	2	Power	0.909	0.867	0.837	0.813
	3	Power	0.919	0.897	0.866	0.893

Table H.2. Goodness-of-Fit (R^2) for Test Results of Fine Aggregate

Material	Rep No.	Model	R^2			
			Subset 1	Subset 2	Subset 3	Subset 4
Natural Sand	1	Power	0.955	0.969	0.949	0.976
		Logarithmic	0.955	0.969	0.949	0.976
		Exponential	0.955	0.969	0.949	0.976
	2	Power	0.932	0.893	0.886	0.947
		Logarithmic	0.932	0.893	0.885	0.946
		Exponential	0.932	0.893	0.885	0.946
	3	Power	0.920	0.875	0.906	0.954
		Logarithmic	0.920	0.874	0.905	0.953
		Exponential	0.920	0.874	0.905	0.953
BF Slag Fine	1	Power	0.962	0.943	0.924	0.890
		Logarithmic	0.975	0.962	0.950	0.932
		Exponential	0.975	0.962	0.950	0.932
	2	Power	0.992	0.994	0.993	0.990
		Logarithmic	0.991	0.993	0.994	0.991
		Exponential	0.991	0.993	0.994	0.991
	3	Power	0.991	0.990	0.988	0.982
		Logarithmic	0.992	0.992	0.990	0.985
		Exponential	0.992	0.992	0.990	0.985
PS Fine	1	Power	0.841	0.779	0.742	0.635
	2	Power	0.889	0.839	0.797	0.723
	3	Power	0.897	0.837	0.802	0.672
RC Limestone Fine	1	Power	0.946	0.913	0.880	0.801
	2	Power	0.910	0.881	0.865	0.822
	3	Power	0.978	0.967	0.956	0.880
Texas Sand	1	Power	0.988	0.977	0.982	0.977
	2	Power	0.964	0.968	0.957	0.977
	3	Power	0.999	0.992	0.992	0.988

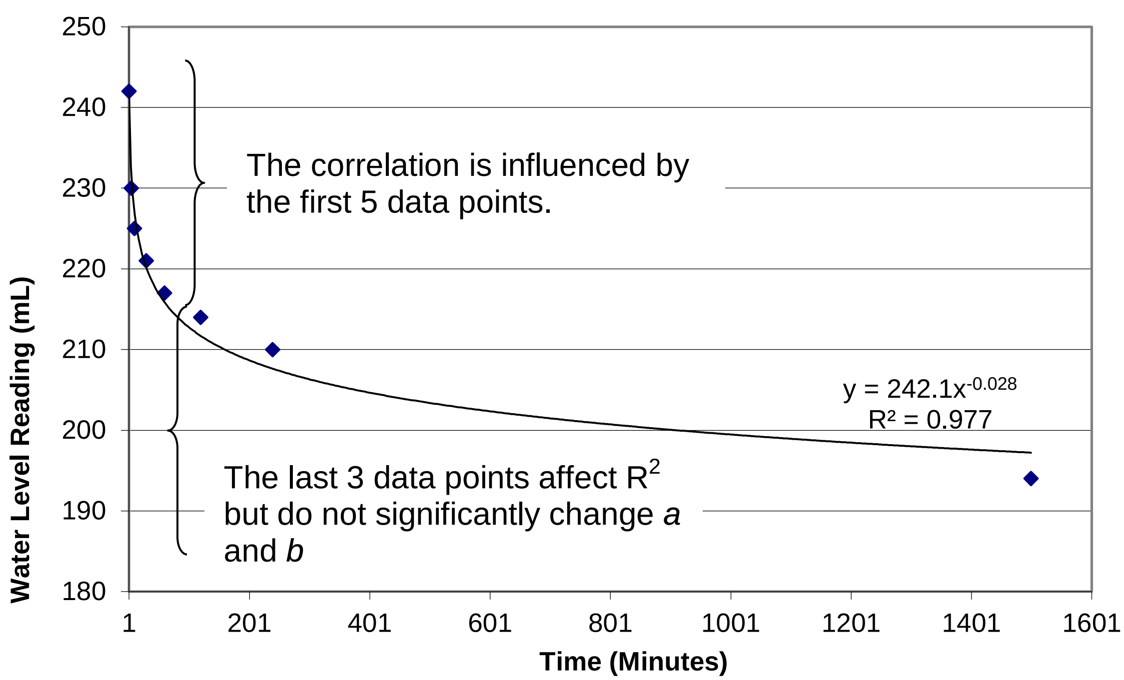

Figure H.3. Example of Correlation between Water Level and Time.

After the coefficients (*a* and *b*) of the fitting model ($Y = aX^b$) were determined for each set of data, time zero (X_0) was determined so that the absorption measured with the Phunque methods would be equal to the absorption measured in accordance with AASHTO T 85 and T 84. Tables H.3 and H.4 show the estimated time-zero (X_0) for three replicates of each material. Column "Phunque %Abs" shows the absorption values measured with the Phunque methods, and column "T 85 %Abs" or "T 84 %Abs" shows the absorption values used to determine the time-zero (X_0). Figures H.4 and H.5 illustrate that the corrected results ("Corrected Phunque") calculated based on the individual time-zero (X_0) shown in Tables H.3 and H.4 are very close to those of AASHTO T 85 and T 84.

Table H.3. Estimated Time-Zero Reading (X_0) for Coarse Aggregates

Material	Rep No.	Model	Parameters			Phungque %Abs	T 85 %Abs*
			a	b	X_0 (min.)		
BF Slag Coarse	1	Power	238.139	-0.02269	0.000338	1.9	3.6
	2	Power	352.385	-0.01829	0.002034	2.1	3.6
	3	Power	173.165	-0.03417	0.000465	1.9	3.6
Elmore Gravel	1	Power	249.964	-0.00597	0.000020	0.4	1.0
	2	Power	258.218	-0.00404	2.74E-07	0.4	1.0
	3	Power	189.314	-0.00426	2.39E-10	0.3	1.0
PS Coarse	1	Power	321.956	-0.01511	0.002459	1.0	2.0
	2	Power	164.875	-0.02689	0.001023	0.9	2.0
	3	Power	151.544	-0.01305	1.38E-08	0.5	2.0
RC Limestone Coarse	1	Power	225.423	-0.02152	0.001151	1.2	2.4
	2	Power	224.816	-0.02472	0.003391	1.2	2.4
	3	Power	199.989	-0.02735	0.003667	1.3	2.4
Recycled Concrete	1	Power	173.966	-0.05597	0.004875	2.0	3.9
	2	Power	331.821	-0.03087	0.007344	2.3	3.9
	3	Power	275.149	-0.03559	0.006469	2.2	3.9
Average X_0 (min.)					**0.002216**		

* Average T 85 absorption values determined in Task 4, Part 2.

Table H.4. Estimated Time-Zero Reading (X_0) for Fine Aggregates

Material	Rep No.	Model	Parameters			Phungque %Abs	T 84 %Abs*
			a	b	X_0 (min.)		
Natural Sand	1	Power	60.822	-0.00419	0.338703	0.2	0.2
	2	Power	67.922	-0.00431	2.144692	0.2	0.2
	3	Power	63.368	-0.00444	0.858009	0.2	0.2
BF Slag Fine	1	Power	57.537	-0.34930	3.335693	3.5	1.9
	2	Power	94.161	-0.03236	0.196009	1.6	1.9
	3	Power	73.047	-0.05134	0.425550	1.9	1.9
PS Fine	1	Power	76.389	-0.04123	0.158553	1.3	1.4
	2	Power	76.249	-0.04731	0.393990	1.5	1.4
	3	Power	64.559	-0.05267	0.203658	1.3	1.4
RC Limestone Fine	1	Power	62.371	-0.13559	0.972016	2.9	2.2
	2	Power	81.342	-0.05054	0.104590	1.8	2.2
	3	Power	83.181	-0.05170	0.134536	1.8	2.2
Texas Sand	1	Power	72.169	-0.02404	0.442071	1.3	1.3
	2	Power	60.075	-0.02493	0.074115	1.1	1.3
	3	Power	71.756	-0.02170	0.090180	1.1	1.3
Average X_0 (min.)					**0.658158**		

* Average T 84 absorption values determined in Task 4, Part 2.

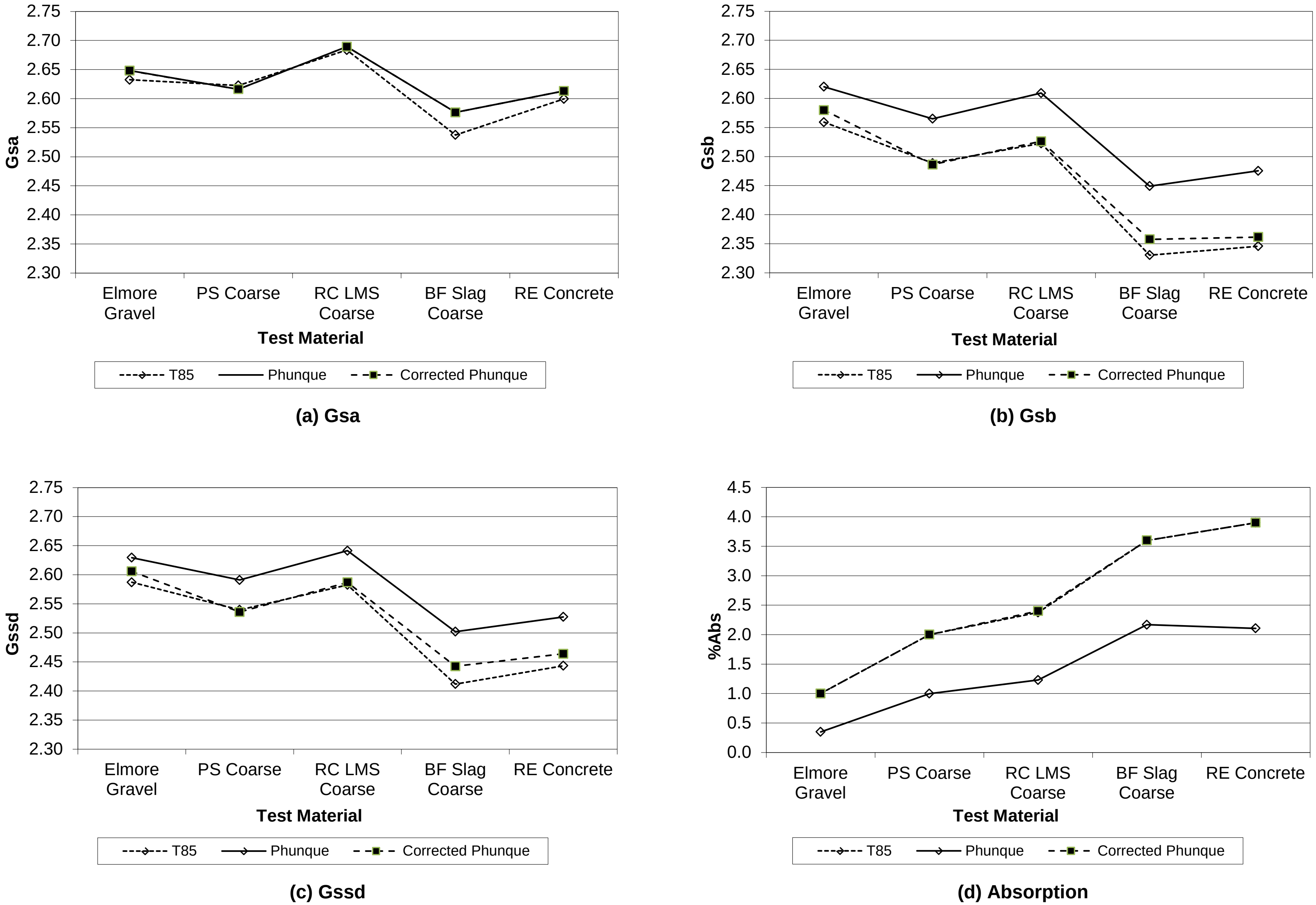

Figure H.4. Comparing Coarse Aggregate Results Determined based on Individual X_0 in Table H.3.

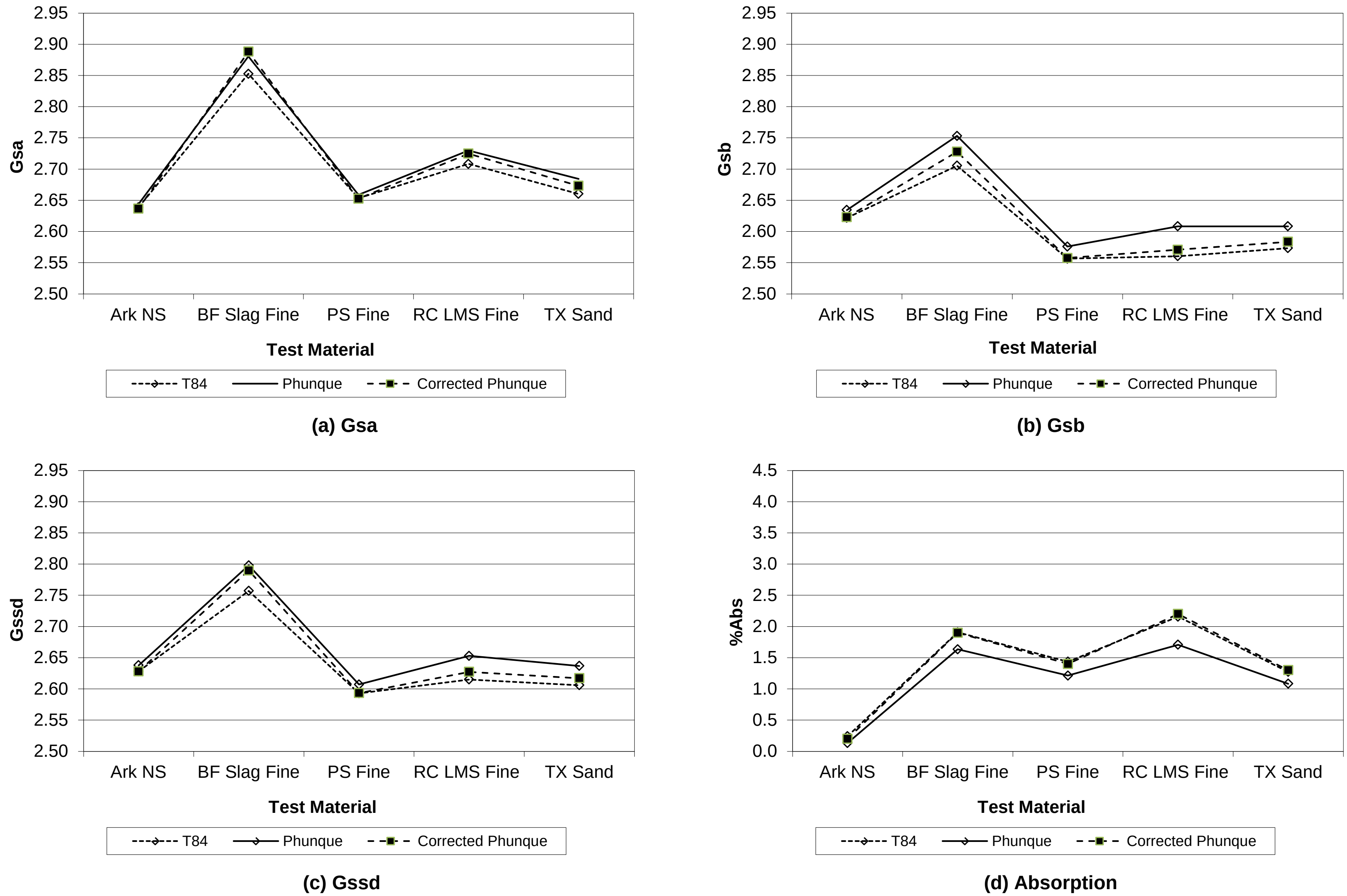

Figure H.5. Comparing Fine Aggregate Results Determined based on Individual X_0 in Table H.4.

Based on the data shown in Tables H.3 and H.4, the average time-zero (X_0) values for coarse and fine aggregates are 0.1 sec. (= 0.002 min. x 60 sec./min) and 39 sec. (= 0.658 min. x 60 sec./min). Thus, for coarse aggregate materials used in this study, the time-zero reading determined at 0.1 sec. should be used in conjunction with the power model to adjust Gsb, Gssd and water absorption. For fine aggregate materials used in this study, since the average time-zero value of 39 sec. is not much different from the initial reading time of 30 sec. in AASHTO TP77, no adjustment is needed.

It should be noted that the Phunque, AASHTO T84 and AASHTO T85 procedures use different methods to determine the volume of SSD aggregate sample; thus, the Gsb, Gssd and water absorption results determined by these procedures will probably be different. The time-zero reading adjustment is needed only when results comparable to AASHTO T84 and T85 are desired by the user. The time-zero value determined may not represent a realistic condition of the test. For example, if the initial reading was taken at 0.1 sec. for a coarse aggregate sample as illustrated in the analysis, most of the sample would not have been in the water yet.

In summary, this analysis shows that the initial water reading can be adjusted using the time-zero reading approach illustrated in this appendix to yield test results that are comparable to those of AASHTO T84 and T85. This approach yields best results when it is conducted for each aggregate source or stockpile.

APPENDIX I

Results of Ruggedness Study

Gradations of Materials Used in Ruggedness Study

Table I-1. Gradations of Coarse Aggregate Materials Used in Ruggedness Study

Sieve Size (in.)	Sieve Size (mm)	Percent Passing Vulcan-VA Granite	AI-MD Gravel	Vulcan-AL Limestone	Alabaster-AL BF Slag
2"	50	100	100	100	100
1-1/2"	37.5	100	100	100	100
1"	25	97	100	100	100
3/4"	19	71	89	90	100
1/2"	12.5	22	48	49	100
3/8"	9.5	10	25	26	80
#4	4.75	2	3	3	7
#8	2.36	1	1	3	3
#16	1.18	1	1	3	2
#30	0.6	1	1	3	2
#50	0.3	1	1	3	1
#100	0.15	1	1	2	1
#200	0.075	0.6	0.5	2.0	0.2

Table I-2. Gradations of Fine Aggregate Materials Used in Ruggedness Study

Sieve Size (in.)	Sieve Size (mm)	Percent Passing Vulcan-VA Granite	AI-MD Limestone	Vulcan-AL Limestone	Alabaster-AL BF Slag
2"	50	100	100	100	100
1-1/2"	37.5	100	100	100	100
1"	25	100	100	100	100
3/4"	19	100	100	100	100
1/2"	12.5	100	100	100	100
3/8"	9.5	100	100	100	100
#4	4.75	98	100	99	100
#8	2.36	80	61	77	75
#16	1.18	60	38	56	50
#30	0.6	46	28	42	34
#50	0.3	34	18	30	24
#100	0.15	24	12	21	16
#200	0.075	16.6	7.3	15.4	11

Table I.1. Ruggedness Results for Coarse Granite Aggregate Tested by NCAT

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		Granite		Aggregate ID:		1				
Laboratory name:		NCAT		Laboratory ID:		1				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparent Specific Gravity : A/(A-C)	Percent Absorption: [(B-A)/A]*100
1C1-1	1	4057.0	643.8	3413.2	3429.1	2137.7	2.643	2.655	2.676	0.47
1C1-1	2	3873.7	551.5	3322.2	3338.5	2081.0	2.642	2.655	2.677	0.49
1C1-2	1	3864.8	522.5	3342.3	3361.4	2093.0	2.635	2.650	2.675	0.57
1C1-2	2	3760.2	505.3	3254.9	3271.2	2038.4	2.640	2.653	2.676	0.50
1C1-3	1	3788.3	387.5	3400.8	3418.9	2129.9	2.638	2.652	2.676	0.53
1C1-3	2	3575.0	290.9	3284.1	3302.4	2057.0	2.637	2.652	2.676	0.56
1C1-4	1	3975.1	571.0	3404.1	3419.5	2132.1	2.644	2.656	2.676	0.45
1C1-4	2	3841.9	558.0	3283.9	3299.9	2055.0	2.638	2.651	2.672	0.49
1C1-5	1	3618.3	279.5	3338.8	3353.9	2090.9	2.644	2.656	2.676	0.45
1C1-5	2	3757.9	472.9	3285.0	3300.2	2057.0	2.642	2.655	2.675	0.46
1C1-6	1	3758.0	372.9	3385.1	3393.4	2115.0	2.648	2.654	2.665	0.25
1C1-6	2	3686.6	373.4	3313.2	3328.7	2073.7	2.640	2.652	2.673	0.47
1C1-7	1	3859.3	570.9	3288.4	3303.7	2059.3	2.643	2.655	2.675	0.47
1C1-7	2	3691.3	558.4	3132.9	3149.8	1961.8	2.637	2.651	2.675	0.54
1C1-8	1	3617.4	505.1	3112.3	3128.4	1949.9	2.641	2.655	2.677	0.52
1C1-8	2	3640.2	522.5	3117.7	3137.3	1953.4	2.633	2.650	2.678	0.63
1C1-Original	1			3289.8	3306.9	2060.3	2.639	2.653	2.676	0.52
1C1-Original	2			3377.9	3397.9	2116.1	2.635	2.651	2.677	0.59
1C1 stands for coarse aggregate with absorption level less than 1% tested by Laboratory #1										

Table I.2. Ruggedness Results for Coarse Granite Aggregate Tested by AAPRL

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		Coarse Granite		Aggregate ID:		1				
Laboratory name:		AAPRL		Laboratory ID:		2				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity: B/(B-C)	Apparent Specific Gravity: A/(A-C)	Percent Absorption: [(B-A)/A]*100
2C1-1	1	4169.3	932.0	3237.3	3250.6	2025.2	2.642	2.653	2.671	0.41
2C1-1	2	4165.3	927.1	3238.2	3250.9	2025.7	2.643	2.653	2.671	0.39
2C1-2	1	3805.3	569.1	3236.2	3249.6	2024.9	2.642	2.653	2.672	0.41
2C1-2	2	4165.1	928.7	3236.4	3249.7	2024.6	2.642	2.653	2.671	0.41
2C1-3	1	3805.5	569.6	3235.9	3252.5	2026.4	2.639	2.653	2.675	0.51
2C1-3	2	3806.0	566.3	3239.7	3254.3	2027.6	2.641	2.653	2.673	0.45
2C1-4	1	4132.0	896.1	3235.9	3249.2	2026.4	2.646	2.657	2.675	0.41
2C1-4	2	4138.7	902.6	3236.1	3249.1	2025.8	2.645	2.656	2.674	0.40
2C1-5	1	4138.7	931.1	3207.6	3220.7	2007.7	2.644	2.655	2.673	0.41
2C1-5	2	4142.6	932.0	3210.6	3224.0	2009.1	2.643	2.654	2.672	0.42
2C1-6	1	3771.9	559.6	3212.3	3223.3	2007.7	2.643	2.652	2.667	0.34
2C1-6	2	3783.4	569.9	3213.5	3224.6	2008.9	2.643	2.652	2.668	0.35
2C1-7	1	3781.1	569.5	3211.6	3224.3	2008.1	2.641	2.651	2.669	0.40
2C1-7	2	3781.7	568.8	3212.9	3225.4	2010.2	2.644	2.654	2.671	0.39
2C1-8	1	3776.5	567.9	3208.6	3222.7	2008.8	2.643	2.655	2.674	0.44
2C1-8	2	3781.8	573.3	3208.5	3223.5	2009.2	2.642	2.655	2.675	0.47
2C1-Original	0	3781.4	554.8	3226.6	3239.8	2019.3	2.644	2.654	2.673	0.41
2C1-Original	0	3791.0	569.8	3221.2	3234.9	2017.0	2.645	2.656	2.675	0.43
2C1 stands for coarse aggregate with absorption between 0% and 1% tested by Laboratory #2										

Table I.3. Ruggedness Results for Coarse Granite Aggregate Tested by NIST

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		Coarse Granite		Aggregate ID:		1				
Laboratory name:		NIST		Laboratory ID:		3				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparent Specific Gravity : A/(A-C)	Percent Absorption: [(B-A)/A]*100
3C1-1	1	4513.2	1280.7	3232.5	3246.2	2022.8	2.642	2.653	2.672	0.42
3C1-1	2	4560.8	1319.6	3241.2	3253.6	2027.8	2.644	2.654	2.671	0.38
3C1-2	1	3880.6	645.4	3235.2	3250.7	2027.5	2.645	2.658	2.679	0.48
3C1-2	2	3869.3	635.9	3233.4	3247.9	2024.5	2.643	2.655	2.675	0.45
3C1-3	1	4525.7	1319.5	3206.2	3221.7	2007.2	2.640	2.653	2.674	0.48
3C1-3	2	4465.4	1280.9	3184.5	3200.7	1995.1	2.641	2.655	2.677	0.51
3C1-4	1	3800.2	645.4	3154.8	3169.9	1976.3	2.643	2.656	2.677	0.48
3C1-4	2	3848.6	636.3	3212.3	3227.8	2011.8	2.642	2.654	2.676	0.48
3C1-5	1	3837.6	645.7	3191.9	3205.4	1998.4	2.644	2.656	2.674	0.42
3C1-5	2	3837.3	636.1	3201.2	3215.0	2003.8	2.643	2.654	2.673	0.43
3C1-6	1	4490.7	1280.7	3210.0	3223.0	2008.8	2.644	2.654	2.672	0.40
3C1-6	2	4491.5	1319.9	3171.6	3184.9	1983.1	2.639	2.650	2.669	0.42
3C1-7	1	4483.3	1280.6	3202.7	3217.1	2004.6	2.641	2.653	2.673	0.45
3C1-7	2	4533.8	1319.6	3214.2	3228.0	2011.7	2.643	2.654	2.673	0.43
3C1-8	1	4436.8	1281.3	3155.5	3171.7	1978.0	2.643	2.657	2.680	0.51
3C1-8	2	4521.0	1319.7	3201.3	3218.4	2005.2	2.639	2.653	2.676	0.53
3C1-Original	1						2.649	2.659	2.674	0.35
3C1-Original	2						2.645	2.655	2.674	0.41
3C1 stands for coarse aggregate with absorption less than 1% tested by Laboratory #3										

Table I.4. Ruggedness Results for Coarse Gravel Aggregate Tested by NCAT

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		Gravel		Aggregate ID:		2				
Laboratory name:		NCAT		Laboratory ID:		1				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparent Specific Gravity : A/(A-C)	Percent Absorption: [(B-A)/A]*100
1C2-1	1	2434.7	224.7	2210.0	2236.8	1368.6	2.545	2.576	2.627	1.21
1C2-1	2	2430.5	224.0	2206.5	2235.0	1366.6	2.541	2.574	2.627	1.29
1C2-2	1	2597.8	394.6	2203.2	2234.8	1363.7	2.529	2.565	2.624	1.43
1C2-2	2	2628.4	419.3	2209.1	2236.7	1369.2	2.547	2.578	2.630	1.25
1C2-3	1	2476.1	265.1	2211.0	2241.0	1371.1	2.542	2.576	2.632	1.36
1C2-3	2	2457.3	247.2	2210.1	2241.6	1369.5	2.534	2.570	2.629	1.43
1C2-4	1	2585.1	373.8	2211.3	2239.0	1372.9	2.553	2.585	2.638	1.25
1C2-4	2	2481.8	269.6	2212.2	2243.4	1369.2	2.531	2.566	2.624	1.41
1C2-5	1	2546.2	402.5	2143.7	2172.2	1326.8	2.536	2.569	2.624	1.33
1C2-5	2	2536.1	391.1	2145.0	2173.3	1327.0	2.535	2.568	2.622	1.32
1C2-6	1	2581.5	437.5	2144.0	2173.3	1326.4	2.532	2.566	2.622	1.37
1C2-6	2	2518.4	372.9	2145.5	2171.2	1327.4	2.543	2.573	2.623	1.20
1C2-7	1	2505.3	375.3	2130.0	2164.5	1318.3	2.517	2.558	2.624	1.62
1C2-7	2	2526.8	378.3	2148.5	2176.5	1330.8	2.540	2.574	2.627	1.30
1C2-8	1	2519.0	371.7	2147.3	2177.0	1331.3	2.539	2.574	2.631	1.38
1C2-8	2	2472.3	338.4	2133.9	2168.8	1323.6	2.525	2.566	2.633	1.64
1C2-Original	1			2137	2167.6	1324.7	2.535	2.572	2.631	1.43
1C2-Original	2			2147.7	2176.5	1329	2.534	2.568	2.623	1.34
1C2 stands for coarse aggregate with absorption between 1% and 2% tested by Laboratory #1										

Table I.5. Ruggedness Results for Coarse Gravel Aggregate Tested by AAPRL

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		Gravel		Aggregate ID:		2				
Laboratory name:		AAPRL		Laboratory ID:		2				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparent Specific Gravity : A/(A-C)	Percent Absorption: [(B-A)/A]*100
2C2-1	1	2802.6	569.9	2232.7	2265.2	1381.4	2.526	2.563	2.623	1.46
2C2-1	2	2802.2	569.6	2232.6	2267.0	1381.5	2.521	2.560	2.623	1.54
2C2-2	1	2791.1	560.5	2230.6	2262.9	1380.9	2.529	2.566	2.625	1.45
2C2-2	2	2789.2	564.1	2225.1	2257.7	1377.8	2.529	2.566	2.626	1.47
2C2-3	1	3115.4	896.0	2219.4	2252.8	1373.8	2.525	2.563	2.625	1.50
2C2-3	2	3127.2	902.7	2224.5	2258.6	1377.9	2.526	2.565	2.628	1.53
2C2-4	1	2790.7	559.4	2231.3	2269.0	1380.1	2.510	2.553	2.621	1.69
2C2-4	2	2805.1	568.8	2236.3	2272.4	1383.9	2.517	2.558	2.624	1.61
2C2-5	1	2750.0	569.1	2180.9	2213.3	1349.3	2.524	2.562	2.623	1.49
2C2-5	2	3112.5	931.8	2180.7	2215.4	1348.9	2.517	2.557	2.622	1.59
2C2-6	1	2752.6	569.5	2183.1	2213.2	1351.5	2.533	2.568	2.625	1.38
2C2-6	2	3104.2	932.0	2172.2	2202.5	1342.5	2.526	2.561	2.618	1.39
2C2-7	1	2751.1	573.4	2177.7	2208.0	1346.5	2.528	2.563	2.620	1.39
2C2-7	2	2746.8	566.3	2180.5	2209.9	1349.6	2.535	2.569	2.624	1.35
2C2-8	1	2748.9	573.2	2175.7	2207.6	1347.8	2.530	2.568	2.628	1.47
2C2-8	2	2751.2	571.1	2180.1	2211.7	1350.2	2.531	2.567	2.627	1.45
2C2-Original	0	2738.0	559.4	2178.6	2207.4	1347.3	2.533	2.566	2.621	1.32
2C2-Original	0	2749.0	571.3	2177.7	2207.0	1346.9	2.532	2.566	2.621	1.35
2C2 stands for coarse aggregate with absorption between 1% and 2% tested by Laboratory #2										

Table I.6. Ruggedness Results for Coarse Gravel Aggregate Tested by NIST

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		Gravel		Aggregate ID:		2				
Laboratory name:		NIST		Laboratory ID:		3				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparent Specific Gravity : A/(A-C)	Percent Absorption: [(B-A)/A]*100
3C2-1	1	3468.9	1280.6	2188.3	2220.4	1353.6	2.525	2.562	2.622	1.47
3C2-1	2	2839.6	635.9	2203.7	2234.5	1364.4	2.533	2.568	2.626	1.40
3C2-2	1	4764.6	2566.8	2197.8	2224.2	1361.6	2.548	2.578	2.628	1.20
3C2-2	2	3475.6	1303.2	2172.4	2198.8	1344.4	2.543	2.574	2.624	1.22
3C2-3	1	2853.4	645.1	2208.3	2239.8	1367.3	2.531	2.567	2.626	1.43
3C2-3	2	2827.3	635.9	2191.4	2222.4	1356.7	2.531	2.567	2.625	1.41
3C2-4	1	3472.5	1280.8	2191.7	2224.5	1356.5	2.525	2.563	2.624	1.50
3C2-4	2	3485.0	1319.7	2165.3	2196.6	1340.5	2.529	2.566	2.625	1.45
3C2-5	1	2782.3	645.3	2137.0	2164.3	1322.1	2.537	2.570	2.622	1.28
3C2-5	2	3439.3	1319.6	2119.7	2146.3	1312.2	2.541	2.573	2.625	1.25
3C2-6	1	2501.8	376.8	2125.0	2150.1	1314.4	2.543	2.573	2.622	1.18
3C2-6	2	3284.2	1182.0	2102.2	2126.4	1300.9	2.547	2.576	2.623	1.15
3C2-7	1	3422.1	1280.8	2141.3	2170.2	1327.0	2.539	2.574	2.630	1.35
3C2-7	2	3466.4	1319.6	2146.8	2174.6	1328.3	2.537	2.570	2.623	1.29
3C2-8	1	2790.2	645.1	2145.1	2174.6	1328.9	2.536	2.571	2.628	1.38
3C2-8	2	2784.5	635.9	2148.6	2179.9	1331.5	2.533	2.569	2.630	1.46
3C2-Original	1	2792.2	645.2	2147.0	2179.1	1329.8	2.528	2.566	2.627	1.50
3C2-Original	2	2786.9	635.9	2151.0	2178.1	1332.6	2.544	2.576	2.628	1.26
3C2 stands for coarse aggregate with absorption between 1% and 2% tested by Laboratory #3										

Table I.7. Ruggedness Results for Coarse AL-LMS Aggregate Tested by NCAT

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		AL-LMS		Aggregate ID:		3				
Laboratory name:		NCAT		Laboratory ID:		1				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity: B/(B-C)	Apparent Specific Gravity: A/(A-C)	Percent Absorption: [(B-A)/A]*100
1C4-1	1	3397.2	250.9	3146.3	3211.3	1958.9	2.512	2.564	2.650	2.07
1C4-1	2	3557.9	399.9	3158.0	3219.1	1965.2	2.519	2.567	2.648	1.93
1C4-2	1	3506.9	348.2	3158.7	3226.3	1966.9	2.508	2.562	2.650	2.14
1C4-2	2	3530.1	372.5	3157.6	3226.8	1964.3	2.501	2.556	2.646	2.19
1C4-3	1	3531.6	378.2	3153.4	3220.8	1963.0	2.507	2.561	2.649	2.14
1C4-3	2	3442.6	290.6	3152.0	3216.8	1962.5	2.513	2.565	2.650	2.06
1C4-4	1	3533.8	375.5	3158.3	3222.2	1965.5	2.513	2.564	2.648	2.02
1C4-4	2	3502.1	338.3	3163.8	3232.4	1968.7	2.504	2.558	2.647	2.17
1C4-5	1	3518.1	391.3	3126.8	3189.7	1945.2	2.512	2.563	2.646	2.01
1C4-5	2	3530.2	402.5	3127.7	3191.0	1945.8	2.512	2.563	2.646	2.02
1C4-6	1	3565.0	437.6	3127.4	3193.6	1946.1	2.507	2.560	2.647	2.12
1C4-6	2	3617.0	481.0	3136.0	3201.8	1951.7	2.509	2.561	2.648	2.10
1C4-7	1	3512.4	373.1	3139.3	3206.0	1954.2	2.508	2.561	2.649	2.12
1C4-7	2	3507.6	371.4	3136.2	3200.3	1951.4	2.511	2.562	2.647	2.04
1C4-8	1	3533.5	398.6	3134.9	3198.1	1952.5	2.517	2.568	2.651	2.02
1C4-8	2	3596.7	472.5	3124.2	3188.1	1946.3	2.516	2.567	2.652	2.05
1C4-8	1						2.507	2.561	2.651	2.16
1C4-8	2						2.506	2.558	2.643	2.05
1C4 stands for coarse aggregate with absorption level between 3% and 4% tested by Laboratory #1										

Table I.8. Ruggedness Results for Coarse AL-LMS Aggregate Tested by AAPRL

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		AL-LMS		Aggregate ID:		3				
Laboratory name:		AAPRL		Laboratory ID:		2				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS -Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparant Specific Gravity: A/(A-C)	Percent Absorption: [(B-A)/A]*100
2C3-1	1	3744.3	569.9	3174.4	3237.6	1974.5	2.513	2.563	2.646	1.99
2C3-1	2	3740.4	567.1	3173.3	3234.1	1973.6	2.517	2.566	2.645	1.92
2C3-2	1	3738.0	569.8	3168.2	3231.8	1972.2	2.515	2.566	2.649	2.01
2C3-2	2	3732.4	568.8	3163.6	3227.2	1969.6	2.516	2.566	2.650	2.01
2C3-3	1	3739.1	565.1	3174.0	3242.2	1979.6	2.514	2.568	2.657	2.15
2C3-3	2	3739.5	569.9	3169.6	3234.8	1976.6	2.519	2.571	2.657	2.06
2C3-4	1	3747.0	568.6	3178.4	3243.6	1980.1	2.516	2.567	2.652	2.05
2C3-4	2	3732.5	554.9	3177.6	3241.3	1980.1	2.520	2.570	2.654	2.00
2C3-5	1	3720.6	567.3	3153.3	3215.0	1961.5	2.516	2.565	2.646	1.96
2C3-5	2	3718.3	568.8	3149.5	3212.2	1959.4	2.514	2.564	2.646	1.99
2C3-6	1	3712.0	565.0	3147.0	3208.6	1959.4	2.519	2.569	2.650	1.96
2C3-6	2	3714.0	569.1	3144.9	3205.5	1956.4	2.518	2.566	2.646	1.93
2C3-7	1	3718.1	568.8	3149.3	3214.6	1963.6	2.517	2.570	2.656	2.07
2C3-7	2	3710.7	568.6	3142.1	3208.0	1960.2	2.518	2.571	2.659	2.10
2C3-8	1	3714.7	571.0	3143.7	3210.3	1960.9	2.516	2.569	2.658	2.12
2C3-8	2	3708.4	562.4	3146.0	3211.0	1962.2	2.519	2.571	2.658	2.07
2C3-Original	1	3727.2	564.1	3163.1	3225.4	1966.7	2.51	2.56	2.64	1.97
2C3-Original	2	3733.6	568.6	3165	3228	1968.6	2.51	2.56	2.65	1.99
2C3 stands for coarse aggregate with absorption between 2% and 3% tested by Laboratory #2										

Table I.9. Ruggedness Results for Coarse AL-LMS Aggregate Tested by NIST

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		AL-LMS		Aggregate ID:		3				
Laboratory name:		NIST		Laboratory ID:		3				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity: B/(B-C)	Apparent Specific Gravity: A/(A-C)	Percent Absorption: [(B-A)/A]*100
3C3-1	1	4519.1	1319.5	3199.6	3266.0	1989.5	2.507	2.559	2.644	2.08
3C3-1	2	4485.9	1303.4	3182.5	3245.5	1980.4	2.516	2.565	2.647	1.98
3C3-2	1	4485.5	1280.6	3204.9	3274.6	1994.0	2.503	2.557	2.647	2.17
3C3-2	2	4500.3	1299.1	3201.2	3268.5	1992.2	2.508	2.561	2.648	2.10
3C3-3	1	4508.4	1299.1	3209.3	3280.5	2000.4	2.507	2.563	2.655	2.22
3C3-3	2	4490.5	1280.5	3210.0	3280.5	1997.6	2.502	2.557	2.648	2.20
3C3-4	1	4390.9	1182.0	3208.9	3280.3	1997.3	2.501	2.557	2.648	2.23
3C3-4	2	4497.9	1291.5	3206.4	3275.2	1997.4	2.509	2.563	2.652	2.15
3C3-5	1	4353.8	1182.0	3171.8	3238.9	1973.1	2.506	2.559	2.646	2.12
3C3-5	2	4455.2	1291.5	3163.7	3230.5	1968.4	2.507	2.560	2.647	2.11
3C3-6	1	4463.3	1294.1	3169.2	3234.2	1971.6	2.510	2.562	2.646	2.05
3C3-6	2	4460.8	1296.6	3164.2	3226.6	1967.8	2.514	2.563	2.645	1.97
3C3-7	1	4470.8	1303.5	3167.3	3236.4	1970.5	2.502	2.557	2.646	2.18
3C3-7	2	4461.9	1296.6	3165.3	3234.4	1969.2	2.502	2.556	2.646	2.18
3C3-8	1	4447.2	1294.1	3153.1	3219.6	1963.9	2.511	2.564	2.651	2.11
3C3-8	2	4493.0	1319.4	3173.6	3240.7	1976.1	2.510	2.563	2.650	2.11
3C3-Original	1	3795.2	645.3	3149.9	3213.8	1960.1	2.512	2.563	2.647	2.03
3C3-Original	2	3786.0	635.6	3150.4	3214.9	1960.6	2.512	2.563	2.648	2.05
3C3 stands for coarse aggregate with absorption between 2% and 3% tested by Laboratory #3										

Table I.10. Ruggedness Results for Coarse AL-Slag Aggregate Tested by NCAT

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		AL-Slag		Aggregate ID:		4				
Laboratory name:		NCAT		Laboratory ID:		1				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparent Specific Gravity : A/(A-C)	Percent Absorption: [(B-A)/A]*100
1C4-1	1	2318.10	261.90	2056.20	2113.10	1264.10	2.422	2.489	2.596	2.77
1C4-1	2	2306.00	257.20	2048.80	2107.20	1262.30	2.425	2.494	2.605	2.85
1C4-2	1	2428.00	374.10	2053.90	2129.70	1283.30	2.427	2.516	2.665	3.69
1C4-2	2	2464.70	437.50	2027.20	2105.20	1270.50	2.429	2.522	2.679	3.85
1C4-3	1	2286.20	236.20	2050.00	2130.40	1279.50	2.409	2.504	2.661	3.92
1C4-3	2	2308.00	258.40	2049.60	2125.10	1279.90	2.425	2.514	2.663	3.68
1C4-4	1	2269.50	218.90	2050.60	2125.30	1282.20	2.432	2.521	2.669	3.64
1C4-4	2	2364.30	302.30	2062.00	2133.10	1280.80	2.419	2.503	2.640	3.45
1C4-5	1	2353.30	391.00	1962.30	2013.70	1205.40	2.428	2.491	2.593	2.62
1C4-5	2	2332.90	373.10	1959.80	2010.30	1204.60	2.432	2.495	2.595	2.58
1C4-6	1	2352.80	387.80	1965.00	2033.10	1225.80	2.434	2.518	2.658	3.47
1C4-6	2	2401.40	434.90	1966.50	2035.30	1226.20	2.430	2.516	2.656	3.50
1C4-7	1	2343.20	398.70	1944.50	2017.60	1215.70	2.425	2.516	2.668	3.76
1C4-7	2	2419.40	472.80	1946.60	2021.20	1217.00	2.421	2.513	2.668	3.83
1C4-8	1	2224.90	284.50	1940.40	2013.30	1217.70	2.439	2.531	2.685	3.76
1C4-8	2	2228.90	267.20	1961.70	2035.20	1224.10	2.419	2.509	2.660	3.75
1C4-Original	1						2.433	2.501	2.610	2.78
1C4-Original	2						2.421	2.490	2.601	2.86
1C4 stands for coarse aggregate with absorption level between 3% and 4% tested by Laboratory #1										

Table I.11. Ruggedness Results for Coarse AL-Slag Aggregate Tested by AAPRL

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		AL-Slag		Aggregate ID:		4				
Laboratory name:		AAPRL		Laboratory ID:		2				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparent Specific Gravity : A/(A-C)	Percent Absorption: [(B-A)/A]*100
2C4-1	1	3008.60	902.70	2105.90	2158.10	1293.40	2.44	2.50	2.59	2.48
2C4-1	2	3038.10	927.00	2111.10	2164.40	1293.90	2.43	2.49	2.58	2.52
2C4-2	1	2672.90	569.50	2103.40	2162.00	1292.70	2.42	2.49	2.59	2.79
2C4-2	2	2666.10	566.20	2099.90	2156.50	1288.80	2.42	2.49	2.59	2.70
2C4-3	1	2671.10	559.40	2111.70	2168.80	1298.80	2.43	2.49	2.60	2.70
2C4-3	2	2681.10	568.70	2112.40	2167.40	1297.50	2.43	2.49	2.59	2.60
2C4-4	1	2696.60	569.90	2126.70	2182.20	1303.40	2.42	2.48	2.58	2.61
2C4-4	2	2678.90	564.10	2114.80	2170.50	1293.80	2.41	2.48	2.58	2.63
2C4-5	1	2595.90	567.90	2028.00	2080.60	1242.70	2.42	2.48	2.58	2.59
2C4-5	2	2956.20	931.10	2025.10	2077.00	1242.30	2.43	2.49	2.59	2.56
2C4-6	1	2602.60	571.20	2031.40	2079.50	1243.00	2.43	2.49	2.58	2.37
2C4-6	2	2958.50	928.60	2029.90	2077.00	1240.20	2.43	2.48	2.57	2.32
2C4-7	1	2936.40	896.00	2040.40	2092.80	1252.60	2.43	2.49	2.59	2.57
2C4-7	2	2970.70	932.00	2038.70	2090.90	1250.40	2.43	2.49	2.59	2.56
2C4-8	1	2602.20	569.10	2033.10	2083.40	1244.70	2.42	2.48	2.58	2.47
2C4-8	2	2595.30	560.50	2034.80	2085.40	1249.50	2.43	2.49	2.59	2.49
2C4-Original	1	2607.70	566.20	2041.50	2091.40	1246.10	2.42	2.47	2.57	2.44
2C4-Original	2	2609.70	568.70	2041.00	2093.00	1247.90	2.42	2.48	2.57	2.55
2C4 stands for coarse aggregate with absorption between 3% and 4% tested by Laboratory #2										

Table I.12. Ruggedness Results for Coarse AL-Slag Aggregate Tested by NIST

Test Method:		Specific Gravity and Absorption of Coarse Aggregate (AASHTO T 85)								
Aggregate Type:		AL-SLAG		Aggregate ID:		4				
Laboratory name:		NIST		Laboratory ID:		3				
Determination	Replicate	Pan and Dry Sample (P&DS)	Pan Tare (Pan)	Oven Dry Sample (A): (P&DS-Pan)	Saturated Surface Dry Sample (B)	Saturated Sample in Water °C	Bulk Specific Gravity: A/(B-C)	Bulk SSD Specific Gravity : B/(B-C)	Apparent Specific Gravity : A/(A-C)	Percent Absorption: [(B-A)/A]*100
3C4-1	1	3271.4	1181.9	2089.5	2143.3	1274.7	2.406	2.468	2.564	2.57
3C4-1	2	3390.4	1296.6	2093.8	2146.4	1285.5	2.432	2.493	2.590	2.51
3C4-2	1	3394.4	1303.2	2091.2	2160.8	1295.6	2.417	2.497	2.628	3.33
3C4-2	2	3373.8	1280.5	2093.3	2161.4	1297.5	2.423	2.502	2.630	3.25
3C4-3	1	3276.7	1182.0	2094.7	2153.3	1284.2	2.410	2.478	2.584	2.80
3C4-3	2	3387.0	1291.6	2095.4	2157.6	1299.3	2.441	2.514	2.632	2.97
3C4-4	1	3388.8	1299.2	2089.6	2153.4	1288.1	2.415	2.489	2.607	3.05
3C4-4	2	3389.6	1296.5	2093.1	2154.6	1291.3	2.425	2.496	2.611	2.94
3C4-5	1	3290.6	1297.9	1992.7	2043.6	1217.7	2.413	2.474	2.571	2.55
3C4-5	2	3319.3	1319.4	1999.9	2051.2	1223.9	2.417	2.479	2.577	2.57
3C4-6	1	3300.0	1294.1	2005.9	2070.3	1240.9	2.418	2.496	2.622	3.21
3C4-6	2	3295.4	1299.1	1996.3	2061.1	1237.7	2.424	2.503	2.632	3.25
3C4-7	1	3317.7	1319.4	1998.3	2058.1	1230.3	2.414	2.486	2.602	2.99
3C4-7	2	3305.8	1297.8	2008.0	2063.2	1231.2	2.413	2.480	2.585	2.75
3C4-8	1	3305.4	1303.1	2002.3	2054.1	1231.6	2.434	2.497	2.598	2.59
3C4-8	2	3277.3	1280.5	1996.8	2050.6	1232.8	2.442	2.507	2.614	2.69
3C4-Original	1	2649.1	645.1	2004.0	2061.6	1234.2	2.422	2.492	2.603	2.87
3C4-Original	2	2639.5	635.6	2003.9	2061.8	1235.4	2.425	2.495	2.608	2.89
3C4 stands for coarse aggregate with absorption between 3% and 4% tested by Laboratory #3										

Table I.13. Ruggedness Results for Fine Granite Aggregate Tested by NCAT

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)								
Aggregate Type:		Granite		Aggregate ID:		1				
Laboratory name:		NCAT		Laboratory ID:		1				
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water+ sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	b spe gra S: E/(
1F1-1	1	232.3	729.8	494.8	1038.9	224.5	717.300	492.800	2.654	2
1F1-1	2	210.9	708.9	493.3	1017.1	222.6	713.900	491.300	2.654	2
1F1-2	1	232.0	729.8	508.9	1047.1	223.3	728.400	505.100	2.636	2
1F1-2	2	210.9	708.9	495.1	1017.9	223.0	716.000	493.000	2.649	2
1F1-3	1	232.3	729.8	499.8	1042.3	220.7	718.600	497.900	2.658	2
1F1-3	2	210.9	708.9	492.8	1016.7	459.4	950.000	490.600	2.652	2
1F1-4	1	232.3	729.8	496.4	1039.4	223.7	718.200	494.500	2.647	2
1F1-4	2	210.8	708.9	503.4	1023.5	201.7	702.800	501.100	2.654	2
1F1-5	1	232.2	729.8	492.9	1038.5	224.0	715.400	491.400	2.668	2
1F1-5	2	210.9	708.9	496.4	1020.2	222.3	717.400	495.100	2.675	2
1F1-6	1	231.9	729.8	503.6	1045.7	202.0	704.500	502.500	2.677	2
1F1-6	2	210.9	708.9	494.4	1018.9	199.3	692.100	492.800	2.672	2
1F1-7	1	181.4	679.3	492.6	987.1	220.6	711.300	490.700	2.655	2
1F1-7	2	185.0	682.8	508.0	1000.9	223.1	729.500	506.400	2.667	2
1F1-8	1	232.3	729.8	492.9	1038.8	224.4	715.900	491.500	2.673	2
1F1-8	2	211.0	708.9	499.1	1021.8	222.6	720.000	497.400	2.671	2
1F1-Original	1			505.0	506.9	679.3	996.000	2.682	2.655	2
1F1-Original	2			490.3	492.2	682.8	990.600	2.687	2.659	2
1F1 stands for fine aggregate with absorption less than 1% tested by Laboratory #1										

Table I.14. Ruggedness Results for Fine Granite Aggregate Tested by AAPRL

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		Granite		Aggregate ID:		1						
Laboratory name:		AAPRL		Laboratory ID:		2						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water+sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content+oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
2F1-1	1	164.2	661.5	503.5	975.4	567.2	1067.6	500.4	2.639	2.656	2.683	0.62
2F1-1	2	164.2	661.5	504.3	975.9	562.4	1063.6	501.2	2.639	2.656	2.683	0.62
2F1-2	1	164.2	661.5	505.1	976.8	927.0	1428.8	501.8	2.644	2.661	2.691	0.66
2F1-2	2	164.2	661.5	507.8	977.9	934.2	1438.7	504.5	2.636	2.653	2.682	0.65
2F1-3	1	164.2	661.5	507.1	978.3	565.1	1069.8	504.7	2.652	2.665	2.686	0.48
2F1-3	2	164.2	661.5	502.4	975.2	567.3	1067.1	499.8	2.649	2.662	2.686	0.52
2F1-4	1	164.2	661.5	504.7	976.4	569.9	1072.8	502.9	2.650	2.659	2.675	0.36
2F1-4	2	164.2	661.5	504.7	976.8	566.4	1069.4	503.0	2.656	2.665	2.680	0.34
2F1-5	1	164.2	661.5	505.8	978.1	570.2	1073.4	503.2	2.660	2.673	2.697	0.52
2F1-5	2	164.2	661.5	503.4	976.6	569.2	1070.0	500.8	2.660	2.673	2.697	0.52
2F1-6	1	164.2	661.5	502.6	976.0	571.3	1072.2	500.9	2.663	2.672	2.687	0.34
2F1-6	2	164.2	661.5	501.5	974.8	571.1	1070.7	499.6	2.655	2.665	2.682	0.38
2F1-7	1	164.2	661.5	503.8	976.3	563.2	1065.1	501.9	2.656	2.666	2.683	0.38
2F1-7	2	164.2	661.5	506.1	978.1	568.7	1073.0	504.3	2.661	2.671	2.687	0.36
2F1-8	1	164.2	661.5	505.0	977.3	555.0	1057.2	502.2	2.654	2.669	2.694	0.56
2F1-8	2	164.2	661.5	504.7	976.9	569.0	1070.8	501.8	2.651	2.666	2.692	0.58
2F1-Original	1								2.663	2.671	2.684	0.30
2F1-Original	2								2.659	2.668	2.683	0.34
2F1 stands for fine aggregate with absorption between 0% and 1% tested by Laboratory #2												

Table I.15. Ruggedness Results for Fine Granite Aggregate Tested by NIST

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)								
Aggregate Type:		Granite		Aggregate ID:		1				
Laboratory name:		NIST		Laboratory ID:		3				
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water+ sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content+ oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bu spe gra SS E/(D F
3F1-1	1	161.8	660.3	504.9	974.8	1181.8	1685.6	503.8	2.646	2.6
3F1-1	2	161.8	660.3	504.8	975.5	1296.5	1800.9	504.4	2.660	2.6
3F1-2	1	161.8	660.3	500.0	970.3	1283.7	1780.3	496.6	2.614	2.6
3F1-2	2	161.8	660.3	501.7	971.9	1274.9	1772.1	497.2	2.615	2.6
3F1-3	1	161.8	660.3	501.1	973.1	1303.2	1802.5	499.3	2.652	2.6
3F1-3	2	161.8	660.3	501.3	973.3	1296.5	1795.8	499.3	2.652	2.6
3F1-4	1	161.8	660.3	500.6	972.0	1299.0	1797.8	498.8	2.641	2.6
3F1-4	2	161.8	660.3	500.4	972.2	1291.6	1790.8	499.2	2.648	2.6
3F1-5	1	161.8	660.3	501.0	971.9	1303.2	1799.9	496.7	2.622	2.6
3F1-5	2	161.8	660.3	500.4	969.5	1296.5	1789.2	492.7	2.577	2.6
3F1-6	1	161.8	660.3	501.3	972.2	1297.9	1796.2	498.3	2.631	2.6
3F1-6	2	161.8	660.3	501.4	971.6	1280.5	1777.4	496.9	2.614	2.6
3F1-7	1	161.8	660.3	501.3	972.2	1270.0	1768.6	498.6	2.633	2.6
3F1-7	2	161.8	660.3	500.2	971.1	1319.5	1817.0	497.5	2.627	2.6
3F1-8	1	161.8	660.3	501.0	971.8	1294.0	1790.7	496.7	2.621	2.6
3F1-8	2	161.8	660.3	500.2	972.2	1182.0	1679.4	497.4	2.642	2.6
3F1-Original	1								2.614	2.6
3F1-Original	2								2.635	2.6
3F1 stands for fine aggregate with absorption between 0% and 1% tested by Laboratory #3										

Table I.16. Ruggedness Results for Fine LS-105 Aggregate Tested by NCAT

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		LS-105		Aggregate ID:		2						
Laboratory name:		NCAT		Laboratory ID:		1						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water+sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content+oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
1F2-1	1		708.7	500.2	1027.7	402.5	897.1	494.6	2.730	2.760	2.817	1.13
1F2-1	2		729.7	500.2	1048.8	391.3	886.0	494.7	2.732	2.762	2.817	1.11
1F2-2	1		681.3	500.1	999.8	472.5	966.7	494.2	2.721	2.754	2.813	1.19
1F2-2	2		680.9	500.1	1000.3	371.5	866.2	494.7	2.738	2.768	2.822	1.09
1F2-3	1		680.9	500.5	1001.0	290.2	785.9	495.7	2.748	2.774	2.823	0.97
1F2-3	2		671.3	500.3	991.0	481.0	975.8	494.8	2.740	2.770	2.826	1.11
1F2-4	1		708.7	500.5	1028.6	398.8	895.2	496.4	2.749	2.771	2.812	0.83
1F2-4	2		729.7	500.1	1049.6	338.2	834.0	495.8	2.751	2.775	2.819	0.87
1F2-5	1		693.4	500.5	1013.0	202.1	697.5	495.4	2.739	2.767	2.818	1.03
1F2-5	2		729.7	500.0	1048.4	226.2	720.0	493.8	2.724	2.758	2.820	1.26
1F2-6	1		681.3	500.3	999.8	231.9	726.1	494.2	2.718	2.752	2.813	1.23
1F2-6	2		682.4	500.5	1000.8	251.2	745.5	494.3	2.714	2.748	2.810	1.25
1F2-7	1		681.3	500.3	999.2	453.7	947.7	494.0	2.708	2.743	2.805	1.28
1F2-7	2		682.4	500.5	1000.6	223.0	717.2	494.2	2.711	2.745	2.808	1.27
1F2-8	1		729.7	500.5	1048.8	262.9	757.0	494.1	2.724	2.759	2.823	1.30
1F2-8	2		708.7	500.4	1027.6	240.6	735.0	494.4	2.724	2.757	2.817	1.21
1F2-Original	1								2.535	2.572	2.631	1.432
1F2-Original	2								2.534	2.568	2.623	1.341
1F2 stands for fine aggregate with absorption between 1% and 2% tested by Laboratory #1												

Table I.17. Ruggedness Results for Fine LS-105 Aggregate Tested by AAPRL

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)								
Aggregate Type:		LS-105		Aggregate ID:		2				
Laboratory name:		AAPRL		Laboratory ID:		2				
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water+ sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content + oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bu spe grav SS E/(D F
2F2-1	1	164.2	661.5	505.2	983.8	567.1	1066.5	499.4	2.730	2.7
2F2-1	2	164.2	661.5	503.4	982.9	568.9	1066.6	497.7	2.735	2.7
1F2-2	1	164.2	661.5	503.1	982.7	931.9	1428.6	496.7	2.731	2.7
2F2-2	2	164.2	661.5	502.8	982.3	929.7	1426.1	496.4	2.727	2.7
2F2-3	1	164.2	661.5	503.1	983.1	563.1	1060.3	497.2	2.739	2.7
2F2-3	2	164.2	661.5	501.9	982.5	569.8	1065.9	496.1	2.742	2.7
1F2-4	1	164.2	661.5	503.0	983.2	932.0	1430.0	498.0	2.747	2.7
1F2-4	2	164.2	661.5	502.2	982.5	929.6	1427.0	497.4	2.745	2.7
2F2-5	1	164.2	661.5	502.7	982.2	568.6	1064.1	495.5	2.723	2.7
2F2-5	2	164.2	661.5	502.6	982.2	570.9	1066.6	495.7	2.725	2.7
2F2-6	1	164.2	661.5	501.5	981.3	568.7	1064.1	495.4	2.726	2.7
2F2-6	2	164.2	661.5	505.2	984.0	570.9	1070.2	499.3	2.733	2.7
2F2-7	1	164.2	661.5	506.1	984.2	568.9	1068.2	499.3	2.722	2.7
2F2-7	2	164.2	661.5	504.8	982.6	567.1	1064.9	497.8	2.710	2.7
2F2-8	1	164.2	661.5	505.7	983.8	563.4	1062.0	498.6	2.719	2.7
2F2-8	2	164.2	661.5	506.1	984.0	570.1	1068.9	498.8	2.717	2.7
2F2-Original	1								2.704	2.7
2F2-Original	2								2.702	2.7
2F2 stands for fine aggregate with absorption between 1% and 2% tested by Laboratory #2										

Table I.18. Ruggedness Results for Fine LS-105 Aggregate Tested by NIST

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		LS-105		Aggregate ID:		2						
Laboratory name:		NIST		Laboratory ID:		3						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water +sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content+oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
3F2-1	1	164.2	661.5	505.5	984.5	568.7	1069.0	500.3	2.741	2.770	2.822	1.04
3F2-1	2	164.2	661.5	506.4	985.1	564.1	1065.1	501.0	2.741	2.770	2.824	1.08
3F2-2	1	164.2	661.5	502.1	982.1	928.7	1424.3	495.6	2.731	2.766	2.832	1.31
3F2-2	2	164.2	661.5	504.8	983.7	932.0	1430.0	498.0	2.727	2.765	2.833	1.37
3F2-3	1	164.2	661.5	505.4	984.5	569.6	1069.0	499.4	2.738	2.771	2.831	1.20
3F2-3	2	164.2	661.5	503.8	983.7	569.1	1067.4	498.3	2.744	2.774	2.830	1.10
3F2-4	1	164.2	661.5	505.7	984.9	931.8	1432.9	501.1	2.749	2.774	2.820	0.92
3F2-4	2	164.2	661.5	503.3	983.7	567.1	1066.1	499.0	2.755	2.779	2.822	0.86
3F2-5	1	164.2	661.5	505.4	983.7	559.4	1057.7	498.3	2.720	2.759	2.830	1.42
3F2-5	2	164.2	661.5	503.2	982.2	571.5	1067.1	495.6	2.716	2.757	2.834	1.53
3F2-6	1	164.2	661.5	504.4	983.5	567.9	1066.6	498.7	2.734	2.765	2.822	1.14
3F2-6	2	164.2	661.5	503.3	982.9	563.2	1061.1	497.9	2.737	2.767	2.821	1.08
3F2-7	1	164.2	661.5	504.0	982.9	569.7	1067.6	497.9	2.727	2.760	2.821	1.23
3F2-7	2	164.2	661.5	505.1	983.6	568.8	1067.9	499.1	2.727	2.760	2.820	1.20

3F2-8	1	164.2	661.5	506.3	984.4	573.3	1072.6	499.3	2.722	2.761	2.830	1.40
3F2-8	2	164.2	661.5	504.0	982.9	896.1	1393.4	497.3	2.723	2.760	2.827	1.35
3F2-Original	1	164.2	661.5	505.1	983.7	931.9	1431.0	499.1	2.729	2.762	2.821	1.20
3F2-Original	2	164.2	661.5	506.5	984.5	569.6	1070.0	500.4	2.727	2.760	2.821	1.22

3F2 stands for fine aggregate with absorption between 1% and 2% tested by Laboratory #3

Table I.19. Ruggedness Results for Fine AL-LMS Aggregate Tested NCAT

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		AL LMS		Aggregate ID:		3						
Laboratory name:		NCAT		Laboratory ID:		1						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc + water + sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content+oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
IF3-1	1		708.70	500.10	1012.50	267.30	754.600	487.300	2.482	2.55	2.66	2.63
IF3-1	2		729.70	500.40	1034.10	284.40	772.400	488.000	2.490	2.55	2.66	2.54
1F3-2	1		680.90	500.20	985.40	251.20	738.500	487.300	2.490	2.56	2.67	2.65
1F3-2	2		679.50	500.40	984.60	231.90	720.500	488.600	2.502	2.56	2.66	2.42
IF3-3	1		681.30	500.40	988.70	235.90	728.500	492.600	2.552	2.59	2.66	1.58
IF3-3	2		680.90	500.80	989.70	219.60	713.800	494.200	2.574	2.61	2.67	1.34
1F3-4	1		729.70	500.00	1037.00	375.20	867.100	491.900	2.553	2.59	2.66	1.65
1F3-4	2		708.70	500.00	1015.50	378.30	869.000	490.700	2.540	2.59	2.67	1.90
IF3-5	1		708.70	500.50	1010.10	246.80	734.300	487.500	2.449	2.51	2.62	2.67
IF3-5	2		722.70	500.60	1032.80	224.60	712.800	488.200	2.563	2.63	2.74	2.54
IF3-6	1		681.30	500.20	982.10	269.60	752.300	482.700	2.421	2.51	2.65	3.63
IF3-6	2		680.90	500.50	983.40	265.20	750.500	485.300	2.451	2.53	2.65	3.13
1F3-7	1		693.40	500.40	997.10	198.50	685.100	486.600	2.474	2.54	2.66	2.84
1F3-7	2		680.90	500.60	985.90	223.90	712.100	488.200	2.496	2.56	2.66	2.54
1F3-8	1		708.70	500.40	1008.90	348.10	833.000	484.900	2.422	2.50	2.63	3.20
1F3-8	2		729.70	500.60	1032.40	372.50	861.400	488.900	2.470	2.53	2.63	2.39
1F3-Original	1								2.475	2.55	2.68	3.14
1F3-Original	2								2.459	2.54	2.68	3.39
1F3 stands for fine aggregate with absorption between 2% and 3% tested by Laboratory #1												

Table I.20. Ruggedness Results for Fine AL-LMS Aggregate Tested AAPRL

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		AL-LMS		Aggregate ID:		3						
Laboratory name:		AAPRL		Laboratory ID:		2						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water + sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content + oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
2F3-1	1.00	164.20	661.50	503.30	969.60	559.50	1051.90	492.40	2.52	2.58	2.67	2.21
2F3-1	2.00	164.20	661.50	505.80	971.90	571.20	1066.10	494.90	2.53	2.59	2.68	2.20
2F3-2	1.00	164.20	661.50	504.60	970.40	560.50	1053.70	493.20	2.52	2.58	2.68	2.31
2F3-2	2.00	164.20	661.50	503.30	969.30	573.30	1065.10	491.80	2.52	2.57	2.67	2.34
2F3-3	1.00	164.20	661.50	506.60	973.00	568.60	1065.10	496.50	2.54	2.60	2.68	2.03
2F3-3	2.00	164.20	661.50	504.60	971.50	567.00	1061.60	494.60	2.54	2.59	2.68	2.02
2F3-4	1.00	164.20	661.50	504.10	971.40	902.60	1397.90	495.30	2.55	2.60	2.67	1.78
2F3-4	2.00	164.20	661.50	506.40	972.70	927.00	1424.30	497.30	2.55	2.59	2.67	1.83
2F3-5	1.00	164.20	661.50	505.20	969.40	567.00	1058.40	491.40	2.49	2.56	2.68	2.81
2F3-5	2.00	164.20	661.50	503.30	967.80	571.10	1060.50	489.40	2.48	2.55	2.67	2.84
2F3-6	1.00	164.20	661.50	505.60	969.00	567.10	1059.60	492.50	2.49	2.55	2.66	2.66
2F3-6	2.00	164.20	661.50	507.20	969.90	563.10	1057.50	494.40	2.49	2.55	2.66	2.59
2F3-7	1.00	164.20	661.50	504.60	968.00	568.50	1059.50	491.00	2.48	2.55	2.66	2.77
2F3-7	2.00	164.20	661.50	503.00	967.10	569.50	1058.40	488.90	2.48	2.55	2.67	2.88

2F3-8	1.00	164.20	661.50	503.90	967.60	569.80	1059.60	489.80	2.48	2.55	2.67	2.88
2F3-8	2.00	164.20	661.50	505.10	969.10	567.90	1059.10	491.20	2.49	2.56	2.68	2.83
2F3-Original	1								2.540	2.587	2.665	1.85
2F3-Original	2								2.547	2.593	2.669	1.79
2F3 stands for fine aggregate with absorption between 2% and 3% tested by Laboratory #2												

Table I.21. Ruggedness Results for Fine AL-LMS Aggregate Tested NIST

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		AL-LMS		Aggregate ID:		3						
Laboratory name:		NIST		Laboratory ID:		3						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc + water + sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content+oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
3F3-1	1	161.8	660.3	501.2	969.0	1182.1	1677.6	495.5	2.574	2.604	2.653	1.15
3F3-1	2	161.8	660.3	500.3	967.4	1296.5	1789.7	493.2	2.553	2.590	2.650	1.44
3F3-2	1	161.8	660.3	501.0	966.4	1274.8	1767.1	492.3	2.526	2.571	2.644	1.77
3F3-2	2	161.8	660.3	500.5	964.4	1299.0	1790.6	491.6	2.503	2.548	2.622	1.81
3F3-3	1	161.8	660.3	500.6	967.1	1303.2	1796.4	493.2	2.545	2.583	2.646	1.50
3F3-3	2	161.8	660.3	500.1	967.9	1284.0	1778.4	494.4	2.568	2.598	2.647	1.15
3F3-4	1	161.8	660.3	500.5	968.1	1291.5	1785.9	494.4	2.566	2.597	2.650	1.23
3F3-4	2	161.8	660.3	501.2	968.4	1298.0	1793.5	495.5	2.566	2.596	2.644	1.15
3F3-5	1	161.8	660.3	500.7	964.3	1294.2	1784.5	490.3	2.493	2.546	2.632	2.12
3F3-5	2	161.8	660.3	501.4	964.5	1319.2	1810.4	491.2	2.491	2.543	2.627	2.08
3F3-6	1	161.8	660.3	500.5	961.7	1270.2	1758.4	488.2	2.452	2.514	2.613	2.52
3F3-6	2	161.8	660.3	501.4	963.1	1280.3	1773.3	493.0	2.482	2.525	2.592	1.70
3F3-7	1	161.8	660.3	501.6	960.5	1294.1	1779.0	484.9	2.408	2.491	2.625	3.44

3F3-7	2	161.8	660.3	501.7	961.1	1319.4	1805.2	485.8	2.418	2.497	2.626	3.27
3F3-8	1	161.8	660.3	501.7	961.2	1296.6	1780.2	483.6	2.408	2.499	2.647	3.74
3F3-8	2	161.8	660.3	501.2	961.4	1181.9	1666.3	484.4	2.421	2.505	2.643	3.47
2F3-Original	1								2.518	2.560	2.630	1.70
2F3-Original	2								2.535	2.571	2.631	1.44

3F3 stands for fine aggregate with absorption between 2% and 3% tested by Laboratory #3

Table I.22. Ruggedness Results for Fine AL-Slag Aggregate Tested by NCAT

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		AL-slag		Aggregate ID:		4						
Laboratory name:		NCAT		Laboratory ID:		1						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water+sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content + oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
1F4-1	1	0.0	729.7	500.2	1046.2	232.2	724.0	491.8	2.677	2.723	2.805	1.71
1F4-1	2	0.0	708.7	500.4	1025.9	251.4	744.2	492.8	2.690	2.731	2.806	1.54
1F4-2	1	0.0	681.3	500.7	996.2	263.5	753.4	489.9	2.637	2.695	2.799	2.20
1F4-2	2	0.0	682.4	500.1	997.3	241.1	731.9	490.8	2.650	2.700	2.790	1.89
1F4-3	1	0.0	682.4	500.1	998.6	372.5	864.9	492.4	2.678	2.719	2.795	1.56
1F4-3	2	0.0	680.9	500.3	998.7	348.3	841.6	493.3	2.703	2.741	2.811	1.42
1F4-4	1	0.0	708.7	500.0	1025.5	375.8	868.7	492.9	2.691	2.729	2.799	1.44
1F4-4	2	0.0	729.7	500.0	1047.8	374.9	869.5	494.6	2.719	2.749	2.802	1.09
1F4-5	1	0.0	708.7	500.6	1023.7	394.6	882.9	488.3	2.631	2.697	2.818	2.52
1F4-5	2	0.0	729.7	500.6	1046.3	402.5	892.5	490.0	2.663	2.721	2.826	2.16
1F4-6	1	0.0	681.3	500.2	995.9	419.3	910.5	491.2	2.647	2.695	2.781	1.83
1F4-6	2	0.0	680.9	500.3	995.0	224.0	714.8	490.8	2.636	2.687	2.778	1.94
1F4-7	1	0.0	681.3	500.3	995.6	224.7	713.8	489.1	2.630	2.690	2.798	2.29
1F4-7	2	0.0	680.9	500.3	995.3	246.8	735.7	488.9	2.630	2.691	2.802	2.33
1F4-8	1	0.0	729.7	500.2	1043.8	265.1	752.8	487.7	2.621	2.688	2.809	2.56
1F4-8	2	0.0	708.7	500.3	1023.0	269.4	756.8	487.4	2.620	2.690	2.816	2.65
1F4-Original	1								2.671	2.721	2.814	1.90
1F4-Original	2								2.669	2.720	2.813	1.92
1F4 stands for fine aggregate with absorption between3% and 4% tested by Laboratory #1												

Table I.23. Ruggedness Results for Fine AL-Slag Aggregate Tested by AAPRL

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		AL-Slag		Aggregate ID:		4						
Laboratory name:		AAPRL		Laboratory ID:		2						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water+sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content+oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
2F4-1	1	164.2	661.5	508.1	983.2	565.0	1063.5	498.5	2.674	2.726	2.820	1.93
2F4-1	2	164.2	661.5	505.2	980.9	569.9	1065.4	495.5	2.667	2.719	2.814	1.96
2F4-2	1	164.2	661.5	503.3	979.7	569.1	1061.3	492.2	2.659	2.719	2.829	2.26
2F4-2	2	164.2	661.5	505.0	981.1	571.1	1065.2	494.1	2.665	2.724	2.832	2.21
2F4-3	1	164.2	661.5	505.2	982.9	571.0	1068.0	497.0	2.704	2.749	2.830	1.65
2F4-3	2	164.2	661.5	502.5	981.7	567.3	1061.7	494.4	2.712	2.756	2.838	1.64
2F4-4	1	164.2	661.5	506.6	983.8	568.6	1068.3	499.7	2.711	2.749	2.817	1.38
2F4-4	2	164.2	661.5	504.6	981.9	568.8	1066.2	497.4	2.700	2.739	2.810	1.45
2F4-5	1	164.2	661.5	506.0	980.5	566.3	1058.7	492.4	2.633	2.706	2.840	2.76
2F4-5	2	164.2	661.5	504.0	978.6	567.1	1057.0	489.9	2.621	2.697	2.835	2.88
2F4-6	1	164.2	661.5	503.4	979.4	568.6	1060.6	492.0	2.652	2.714	2.826	2.32
2F4-6	2	164.2	661.5	505.5	980.5	568.8	1062.8	494.0	2.649	2.710	2.823	2.33
2F4-7	1	164.2	661.5	504.2	979.6	565.1	1057.6	492.5	2.646	2.709	2.824	2.38
2F4-7	2	16	661.5	502	978.5	569.	1061.	491.	2.64	2.70	2.814	2.26

		4. 2		.9		9	7	8	6	5		
2F4-8	1	16 4. 2	661.5	504 .6	979.5	566. 2	1057. 5	491. 3	2.63 3	2.70 4	2.835	2.71
2F4-8	2	16 4. 2	661.5	502 .1	977.1	567. 1	1056. 0	488. 9	2.62 1	2.69 2	2.821	2.70
2F4- Original	1								2.62 5	2.69 5	2.822	2.662
2F4- Original	2								2.62 4	2.69 3	2.818	2.622
2F4 stands for fine aggregate with absorption between 3% and 4% tested by Laboratory #2												

Table I.24. Ruggedness Results for Fine AL-Slag Aggregate Tested by NIST

Test Method:		Specific Gravity and Absorption of Fine Aggregate (AASHTO T 84)										
Aggregate Type:		AL-Slag		Aggregate ID:		4						
Laboratory name:		NIST		Laboratory ID:		3						
ID	Replicate	Mass of pyc (g)	mass of pyc filled with water to calibrated line (g)	mass of ssd sample added (g)	mass of pyc+water +sample to calibrated mark (g)	mass of moisture content container (g)	mass of moisture content + oven dry sample (g)	mass of oven dry sample: I=(H-G)	bulk specific gravity: I/(D+E-F)	bulk specific gravity, SSD: E/(D+E-F)	apparent specific gravity: I/(D+I-F)	absorption (%): [(E-I)/I]*100
3F4-1	1	164.2	661.5	504.9	982.2	569.1	1065.5	496.4	2.695	2.741	2.825	1.71
3F4-1	2	164.2	661.5	507.3	983.5	569.8	1069.0	499.2	2.694	2.738	2.817	1.62
3F4-2	1	164.2	661.5	503.6	980.5	569.7	1063.2	493.5	2.673	2.728	2.828	2.05
3F4-2	2	164.2	661.5	502.8	979.6	568.8	1061.4	492.6	2.667	2.722	2.823	2.07
3F4-3	1	164.2	661.5	505.4	983.5	568.9	1066.6	497.7	2.714	2.756	2.833	1.55
3F4-3	2	164.2	661.5	502.5	981.3	567.2	1062.1	494.9	2.709	2.750	2.826	1.54
3F4-4	1	164.2	661.5	506.2	983.7	573.2	1073.2	500.0	2.717	2.751	2.812	1.24
3F4-4	2	164.2	661.5	506.0	983.6	567.1	1066.6	499.5	2.716	2.751	2.816	1.30
3F4-5	1	164.2	661.5	503.7	979.5	560.6	1053.0	492.4	2.652	2.712	2.823	2.29
3F4-5	2	164.2	661.5	505.6	980.6	564.3	1057.4	493.1	2.644	2.711	2.834	2.53
3F4-6	1	164.2	661.5	503.4	980.5	931.1	1426.0	494.9	2.684	2.730	2.814	1.72
3F4-6	2	164.2	661.5	505.1	982.1	567.8	1064.2	496.4	2.691	2.738	2.824	1.75
3F4-7	1	164.2	661.5	503.8	981.1	928.7	1422.9	494.2	2.683	2.735	2.830	1.94
3F4-7	2	16	661.5	503	980.8	927.	1420.	493.	2.68	2.73	2.832	1.94

		4.2		.2		2	8	6	4	6		
3F4-8	1	164.2	661.5	505.8	981.2	559.5	1053.5	494.0	2.654	2.718	2.834	2.39
3F4-8	2	164.2	661.5	504.7	980.6	568.8	1060.9	492.1	2.651	2.719	2.845	2.56
3F4-Original	1	164.2	661.5	505.7	979.6	569.2	1064.2	495.0	2.639	2.696	2.798	2.16
3F4-Original	2	164.2	661.5	503.8	978.6	568.8	1062.0	493.2	2.642	2.698	2.801	2.15
3F4 stands for fine aggregate with absorption between 3% and 4% tested by Laboratory #3												

APPENDIX J

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