EVALUATION OF THE AGGPLUS^{TM} SYTEM AND THE SSDETECT SYSTEM AGAINST THE CURRENT AASHTO T-84 AND T-85

By

MSENGI KABALA MGONELLA

Bachelor of Science
University of Dar-es-salaam
Dar-es-salaam, Tanzania
1999

Master of Science
University of Wisconsin
Milwaukee, Wisconsin
2003

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Thesis Approved:

_____Stephen A. Cross____________________
Thesis Advisor

_____Donald R. Snethen___________________

_____Gorman Gilbert______________________

_____A. Gordon Emslie_____________________
Dean of the Graduate College

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TABLE OF CONTENTS

CHAPTER Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Problem Statement

The measured bulk specific gravity and percent absorption of coarse and fine aggregate is regularly used in design and construction of pavement materials. The ability to measure the water absorption and bulk specific gravity of aggregate materials with a high degree of accuracy and repeatability in a short time frame is very important for pavement engineers and designers.

Specifically, in the Superpave mix design system the bulk specific gravity and percent absorption of the aggregates, both fine and coarse, are crucial for the design and control of quality asphalt mixtures. The bulk specific gravity of the coarse and fine aggregate fractions are used to determine the bulk specific gravity of the aggregate blend of hot mix asphalt (HMA). The bulk specific gravity of the blended aggregate is then used in the calculation of the voids in the mineral aggregate (VMA), a critical void parameter used in design and control of HMA mixtures.

The bulk specific gravity of the fine aggregate is used to determine the uncompacted void content, a measure of fine aggregate angularity in the Superpave mix design system. Absorption values are used to screen out aggregates that are porous and could cause performance problems in HMA mixtures. Aggregates with high absorptions can increase asphalt cement demand and result in uneconomical mixtures.

Research Project Description

Current methods to determine bulk specific gravity and absorption of coarse and fine aggregates are time consuming and the repeatability is less than desired. According to AASHTO T- 84 and T-85, the acceptable range of two results for single operator precision is 0.032 and 0.025, respectively (1). For multilaboratory T-84 and T-85 precision, the acceptable range of two results is 0.066 and 0.038, respectively. When combined for VMA calculations, a single operator could expect a maximum variation in VMA of over 0.5% and in a multilaboratory situation, a maximum variation in VMA of approximately 1.5 %.

The current method for determination of fine aggregate specific gravity (AASHTO T-84) has poor repeatability. This is true especially for angular fine aggregates with high absorption and rough surface textures because they do not slump readily. Determining the saturated surface dry (SSD) mass for these samples is difficult with the cone method specified in the current standard. The fundamental problem with fine aggregate SSD condition is the inability to define SSD status of the aggregate grain. Two or more aggregate particles can stack up or attach to each other not allowing the surface of each individual aggregate to reach SSD condition (2).

The current standard for coarse aggregate (AASHTO T-85) requires the user to pat the aggregates with a towel to the surface dry condition and use this weight as the SSD weight of the sample. Again, this procedure is highly operator dependent. In this method if the material is not washed correctly, the towel can remove fines as well as water from the aggregates, indicating reduced SSD mass, hence a lower absorption rate than the true value. Furthermore, using a towel to dry the surface of the aggregate requires that the operator decide the degree of dryness of the aggregate making the procedure subjective.

A new test procedure that could reduce the variability of the bulk specific gravity measurements, especially for fine aggregates, would result in improved precision of VMA calculations and better control of HMA mixtures. A procedure that reduces the minimum 48 hour test time for AASHTO T-84 and T-85 would result in cost savings.

There are two new methods currently available for determining bulk specific gravity and absorption of coarse and fine aggregates. The first procedure is the AggPlus^{tm} system using the CoreLok device. The procedure is applicable to both coarse and fine aggregates. An additional feature of the CoreLok procedure is the ability of determining specific gravity and absorption of a blended aggregate gradation, reducing testing time. The second procedure currently available is using the SSDetect system. This procedure is applicable to fine aggregates and is an alternative method for determining the SSD condition of fine aggregate.

Objectives of Thesis

The objectives of this thesis were to determine if either the AggPlus^{tm} system or the SSDetect system would produce statistically similar results to the current AASHTO T-84 and T-85 procedures and to investigate repeatability and ease of use of each method.

Scope

Four basic aggregate types, which are used in Oklahoma for hot mix asphalt and Portland cement concrete construction, were selected for use in this study. The aggregate types are limestone, sandstone, granite, and natural sands and gravels.

Fine and coarse aggregate samples were selected from four different sources for each of the four aggregate types. Two of the sources from each aggregate type were classified as having high absorptions (> 1.5 %) and two were classified as having low absorptions (≤ 1.5%). Each aggregate sample was tested for bulk specific gravity, apparent specific gravity and percent absorption using AASHTO T-84, AASHTO T-85, CoreLok and SSDetect methods. The data was analyzed using analysis of variance (ANOVA) procedures. Duncan's multiple range test was used to determine which means were significantly different when the ANOVA indicated a statistically significant difference in mean.

CHAPTER 2

LITERATURE REVIEW

The AggPlus^{TM} system using the CoreLok device and the SSDetect system are two procedures which are relatively new to pavement engineers. The AggPlus and SSDetect system were only recently made available. Therefore, minimal research results are available for the two methods.

Definitions

Bulk specific gravity (Gsb) is the ratio of weight in air of a unit volume of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature (3). This unit volume of aggregates is composed of the solid particle, permeable voids, and impermeable voids. The Gsb is calculated using the following formula.

$$Gsb = A/(B-C) \qquad [1]$$

Where: A = Oven dry mass of aggregate

B = SSD mass of aggregate

C = Mass of aggregate in water

Apparent specific gravity (Gsa) is the ratio of the weight in air of a unit volume of impermeable portion of aggregate (does not include the permeable pores in aggregate) to the weight in air of an equal volume of gas-free distilled water at a stated temperature. (3) The Gsa is calculated using the following formula.

$$Gsa = A / (A - C) \qquad [2]$$

Where: A = Oven dry mass of aggregate

C = Mass of aggregate in water

Absorption is the increase in weight of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles and is determined using the following formula (3).

$$\%\ Abs. = [(B-A) / A] \times 100 \qquad [3]$$

Where: A = Oven dry mass of aggregate

B = SSD mass of aggregate

The calculation of VMA is very important to hot mix asphalt design, production, and quality control. The equation for calculating VMA is shown below.

$$VMA = 100 - \frac{Gmb \times Ps}{Gsb} \qquad [4]$$

Where: Gmb = Bulk specific gravity of a compacted HMA specimen

Ps = Percent aggregate in the HMA mixture (equal to 100- binder content)

Gsb = Bulk specific gravity of the aggregate.

VMA is sensitive to changes in Gsb. For example, a 12.5 mm nominal maximum aggregate size mix has a specified minimum VMA of 14.0%. If a sample of this mix has a Gmb 2.442, Ps 94.7 % and Gsb 2.703 the VMA would be 14.4 % change in Gsb to 2.685 for the same mix, results in a VMA of 13.9 % which is below the specified minimum within the single operator precision. This simple equation shows the need for specific gravity values obtained by different testing methods to be statistically similar if they are to be used interchangeably.

$$Pba = 100 \times \frac{Gse - Gsb}{Gsb \times Gse} \times Gb \qquad [5]$$

Where: Pba = Absorbed asphalt, percent by mass of aggregate

Gse = Effective specific gravity of aggregate

Gsb = Bulk specific gravity of aggregate

Gb = Specific gravity of asphalt cement

$$Pbe = Pb - \frac{Pba}{100} \times Ps \qquad [6]$$

Where: Pbe = Effective asphalt content, percent by total mass of mixture

Pb = Asphalt content, percent by total mass of mixture

Pba = Absorbed asphalt, percent by mass of aggregate

Ps = Aggregate content, percent by total mass of mixture

Bulk specific gravity of fine and coarse aggregate is used in Superpave mix design calculations to determine the (VMA), dust percentage (DP) and effective asphalt content (Pbe) and absorbed asphalt content of the mix (Pba). The formulas for VMA, DP, Pbe and Pba are listed below. The three equations below show how bulk specific gravity is important in determining mixture volumetrics during HMA mix design and production..

$$DP = \frac{P200}{Pbe} \qquad [7]$$

Where: DP = Dust percentage

P200 = Percent materials passing No.200 sieve

Pbe = Effective asphalt content, percent by total mass of mixture

Background of Research

Researchers have attempted in the past to pinpoint the SSD condition of aggregates to improve the reproducibility of the bulk specific gravity test results. As mentioned by Kandhal (4) "these include Howard's glass jar method , Martin's wet and dry bulb temperature method , Saxer's absorption time curve procedure and Hughes and Bahramian's saturated air- drying method ". Nevertheless, the various modifications either offered little improvement or were too complicated to be of practical value in the field or average laboratory (4).

Thermo Procedure

A prototype device for determining SSD condition using basic principles of thermodynamics was developed by the Arizona Department of Transportation (DOT) during the 1970's (5). A wet fine aggregate sample was placed in a small rotating drum and hot air was blown into one end of the drum to dry the falling aggregate uniformly. Temperatures of the incoming and outgoing hot air were monitored using thermocouples mounted in the inlet and outlet of the prototype rotating drying drum. The SSD region was determined using the plots of the inlet and outlet temperature and the basic principles of thermodynamics.Encouraging results were obtained from the preliminary prototype; however, the development of the equipment was not finalized and additional testing on variety of fine aggregates was recommended.

Calorimetric Procedure

A calorimetric procedure was developed by Kandhal and Lee (6) to establish the SSD condition of both coarse and fine aggregates. The calorimetric procedure involved soaking the aggregate in water containing a special chemical dye. The aggregate acquires the color of the wet dye on removal from water. The dye changes color when dry (for example cobalt chloride changes color from red to blue. The SSD condition is reached as soon as the fine aggregate particles change color (when subjected to drying with a fan). According to Kandhal and Lee (6), the following problems were associated with this method.

(a) The dyes do not show well on dark colored aggregates

(b) An efficient method of mixing the fine aggregate during the drying operation is needed so that larger particles do not dry out sooner than the finer particles, and

(c) Detection of the color change needs to be automated so that the subjective judgment of the operator is eliminated.

Offset Method

Haddock and Prowell (7) developed a method to determine aggregate bulk specific gravity in hot mix asphalt mixtures. The method was intended to avoid the problems associated with the determination of Gsb. Haddock and Prowell developed a method where an offset between the Gsb and Gse is determined during the mixture design stage and applied during production to the Gse determined from the maximum theoretical specific gravity (Gmm) test. A field Gsb can be calculated by using the offset value and the VMA determined. The following example was used by Prowell and Haddock to illustrate the proposed procedure.

"Suppose that during the design phase of an HMA mixture that the combined Gsb for the aggregate gradation being used is determined to be 2.663 and the Gse to be 2.678. The difference between these two, or 0.015(2.678 – 2.663), is the offset value. To continue the example, during HMA production, the G_{mm} is measured and the Gse calculated to be 2.671. Applying the offset value yields a field Gsb of 2.656 (2.671 – 0.015). This field Gsb value is then used in the calculation of VMA."(7)

Haddock and Prowell (7) concluded that the offset method did a reasonable job of estimating Gsb and that the study should be expanded to include more aggregate types, mixture types, and gradations.

CoreLok Device

Initially, the CoreLok device was developed to measure the bulk specific gravity of compacted HMA samples (Gmb). Measurement of Gmb is critical, especially with the introduction of Superpave volumetrics. The Gmb is the basis for the volumetric calculations used during HMA mix design, field control, and construction acceptance.

Inaccurate measurement of Gmb could result in incorrect calculations for air voids, VMA, voids filled with asphalt (VFA), and correlations for the nuclear density gauge.

AASHTO T-166 covers the determination of bulk specific gravity of specimens of compacted bituminous mixtures which do not contain interconnecting voids and absorb less than 2 percent of water by volume. Method A for laboratory compacted samples and Method C for core samples have proved adequate for mixes that utilize fine-graded aggregate structures. However, incorrect Gmb measurements have occurred with the adoption of the Superpave mix design system and the use of stone matrix asphalt (SMA) mixtures. With the use of Superpave, more coarse –graded mixtures have been utilized and SMA has the properties of a gap –graded mixture. With these types of mixtures, the internal air voids can become interconnected, which allows water to penetrate into the sample quickly during the saturation process. However, when measuring the SSD condition using AASHTO T-166, the water tends to drain quickly from the sample and can not be measured. The infiltration of water, according to AASHTO T-166, should not exceed 2.0 percent; hence, the errors can be introduced into the measurements of bulk specific gravity of compacted hot mix asphalt (8). If the water absorption exceeds 2.0 percent, AASHTO T-275 (Paraffin wax) should be used to seal the sample prior to measuring the Gmb (8).

The CoreLok device and AASHTO T-275 can be used to determine the Gmb of compacted HMA samples with high water absorption. However, AASHTO T-275 is not routinely used because of the difficulty associated with preparing and testing paraffin-coated specimens.

The CoreLok device has been reported as being able to determine maximum specific gravity (Gmm) of HMA, aggregate bulk specific gravity (Gsb), apparent specific gravity (Gsa), and absorption (8).

The CoreLok system uses a controlled vacuum system to seal samples. Samples are placed inside a polymer bag, which is then inserted into the vacuum chamber. Under vacuum, the bag conforms tightly around the sample, which prevents water from infiltrating the sample. The volume of the sample is encapsulated within the bag and considered as the bulk volume (Figure 1). This is different than most other procedures that measure apparent volume. Recently, researchers have attempted to measure bulk specific gravity of aggregates using the CoreLok device. The major concern of the on going research is to find out if the CoreLok method produces results which are statistically similar to the traditional methods AASHTO T-84 and T-85.

Hall (9) conducted a study using a single test to determine the specific gravity and absorption of aggregate blends. In all cases, the CoreLok tests showed relatively low variability compared to the traditional methods (AASHTO T-84 and T-85). The standard deviations from five replicate CoreLok tests were well below the values associated with both the AASHTO T-84 and T-85 tests. Also the CoreLok method overestimated the bulk specific gravity of an aggregate blend (Figure.2). Hall reported that the vacuum sealing method for determining specific gravity and absorption of aggregates showed promise as a substitute to traditional SSD-based test methods but that improvement is needed for the vacuum seal method before it could be substituted for traditional methods due to some actual differences in test values(9).

Figure 1. Corelok device

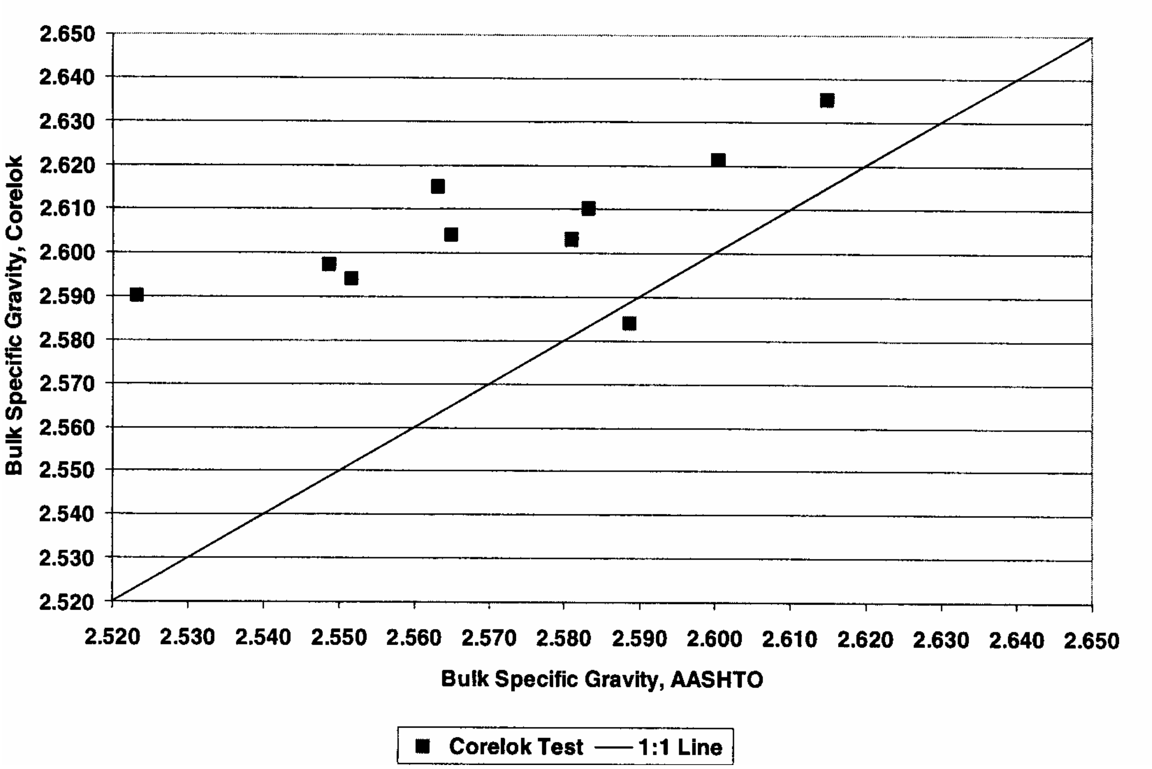

Figure 2. Gsb CoreLok vs. Gsb AASHTO (blend) (9)

SSDetect System

The saturated surface dry condition tester is a two part, automated system which provides the necessary data to determine the bulk specific gravity (dry), bulk specific gravity (SSD), apparent specific gravity, and absorption of fine aggregate (Figure.3) . The device is manufactured by Thermolyne. SSDetect measures the saturated surface dry condition of the fine aggregate by way of an infrared light source tuned to water. This infrared signal looks at the surface of the aggregate for traces of water. By measuring the amount of infrared reflectance, the saturated surface dry condition can be accurately measured (10).

Figure 3. SSDetect System

Prowell and Baker (11) evaluated two automated methods for determining the dry bulk specific gravity (Gsb) of fine aggregates, the Thermolyne SSDetect and Instrotek Corelok methods. Each method was evaluated against the standard method described in AASHTO T-84. The evaluation was based on a round robin study with twelve labs and six materials, four crushed and two uncrushed (natural) fine aggregate sources. Prowell and Baker (11) found that statistical differences existed between the automated methods (Corelok and SSDetect) and AASHTO T-84. The SSDetect method showed lower variability compared to AASHTO T-84, as shown in Table .1. Prowell and Baker (11) concluded that the precision of the Corelok method was not as good as AASHTO T-84 and that the precision of the CoreLok method could improve as technicians become more familiar with the procedure.

Table 1. Precision Estimates (12)

Method	Within Laboratory (Single Operator)			Between Laboratory (Multilaboratory)		
	Corelok	**SSDetect**	**T-84**	**Corelok**	**SSDetect**	**T-84**
	Pooled Standard Deviation					
Gsb	0.0440	0.0138	0.0157	0.0519	0.0222	0.0230
Gsa	0.0230	0.0066	0.0093	0.0238	0.0085	0.0151
Absorption	0.3168	0.1979	0.2170	0.5709	0.3241	0.4380
	Acceptable Differences Between Two Results					
Gsb	0.1245	0.0389	0.0443	0.1468	0.0628	0.0651
Gsa	0.0651	0.0187	0.0264	0.0672	0.0241	0.0428
Absorption	1.0233	0.5598	0.6137	1.6148	0.9166	1.2389

CHAPTER 3

TEST PLAN

Aggregates

Eight coarse aggregates and 15 fine aggregates were chosen for this study. Table 2 lists the aggregates used. The aggregates tested were selected to represent the four basic types of aggregate used in Oklahoma for hot mix asphalt and Portland cement concrete construction, including limestone, sandstone, granite and sands and gravel. There were four limestone quarries sampled. Each limestone quarry supplied chips and screenings, and two of the quarries also produced manufactured sand. Chips were the only material tested from the APAC-OK quarry in Tulsa. There were two sandstone quarries tested that supplied chips and sand. The rhyolite quarry only produced chips and screenings. One crushed gravel source was sampled. The crushed gravel was split on the No.4 sieve and the plus No.4 material tested as coarse aggregate and the minus NO.4 material tested as fine aggregate. Four pits supplied natural sand fine aggregate. All samples were obtained from production facilities by owner's representative, usually quality control personnel. Samples were obtained in accordance with AASHTO T- 2 procedures.

Reduction of Field Samples to Testing Size

The field samples obtained were much larger than the amount of material required to perform the planned testing. Additionally, larger samples were obtained to increase representativeness of the sample and minimize the effect of segregation. The method for reducing field samples to testing size was intended to ensure that the gradation and material characteristics present in the field sample were retained in the test sample, to the greatest degree possible. Reduction of field samples of aggregates to testing size was performed in accordance with AASHTO T-248.

For each coarse aggregate source, two samples were split out for sieve analysis testing and two samples were split out for each of the two specific gravity procedures evaluated. The specific gravity samples were screened and washed over the No.4 sieve to remove fines.

For each fine aggregate source, two samples were split out for sieve analysis testing and two samples were split out for each of the three specific gravity procedures evaluated.

Fine and Coarse Aggregate Sieve Analysis

The gradation of each source was determined by averaging the gradation of two samples determined in accordance with T-11 and T-27. Materials finer than the No.200 (75μm) sieve were determined first in accordance with AASHTO T 11 procedures then sieve analysis(AASHTO T-27) was performed on each sample to determine the distribution of aggregate particles, by size, within a given sample.

Table 2 . Aggregate tested

Supplier	Pit #	County	Quarry	Aggregate	Material
Dolese	905	Canadian	Yukon	Natural Sand	Fill Sand
Dolese	1601	Comanche	Richard Spur	Limestone	Screenings
Tiger Ind.	3101	Haskell	Tiger Ind.	Sandstone	5/8" Chips
Tiger Ind.	3101	Haskell	Tiger Ind.	Sandstone	Screenings
MM.	3502	Johnston	Mill Creek	Granite	5/8" Chips
MM.	3502	Johnston	Mill Creek	Granite	Screenings
MM.	3502	Johnston	Mill Creek	Granite	ManSand
Dolese	3702	Kingfisher	Dover	Natural Sand	Fill Sand
Eagle Sand	4701	Major	Cleo Springs	Natural Sand	Fill Sand
Dolese	5002	Murray	Davis	Limestone	5/8" Chips
Dolese	5002	Murray	Davis	Limestone	Screenings
Dolese	5002	Murray	Davis	Limestone	ManSand
Hanson	5008	Murray	Davis	Rhyolite	1/2" Chips
Hanson	5008	Murray	Davis	Rhyolite	Screenings
Anchor	7201	Tulsa	46th Street	Limestone	3/4" Chips
Anchor	7201	Tulsa	46th Street	Limestone	Screenings
Anchor S	7201	Tulsa	46th Street	Limestone	ManSand
APAC-OK	7203	Tulsa	Tulsa D-Ledge	Limestone	1/2" Chips
E.D. Baker	7808	Hutchinson	Borger	Gravel	Crushed Gravel
Arkhola	7902	Sebastian	Jennylind	Sandstone	1/2" Chips
Arkhola	7902	Sebastian	Jennylind	Sandstone	Screenings
Arkhola	5103	Muskogee	Muskogee	Sand	Fillsand

MM = Martin Marietta

Specific Gravity and Absorption

Fine Aggregate AASHTO T 84

After a representative sample was obtained from the bulk field sample, the test sample was dried to constant weight in an oven at 230 ± 9^{o}F (110 ± 5^{0}C). The sample was then cooled at room temperature for 1 to 3 hours. After the cooling period, the sample was immersed in water at room temperature for a period of 15 to 19 hours then the sample was dried to SSD condition and the weight recorded. A Langly de-airing device was used to remove air bubbles from the sample in a flask for a period of 20 minutes and the weight of the flask and sample at SSD condition was recorded. The sample was dried to a constant weight in an oven then the three weights were used to calculate bulk specific gravity, apparent specific gravity, and absorption of fine aggregates.

Coarse Aggregate AASHTO T 85

After a representative sample was obtained from the bulk field sample, the sample was washed in accordance with AASHTO T 11 procedures then screened over a No.4 sieve to remove the material finer than the No.4 sieve. After washing and screening over the No.4 sieve, the sample was dried to a constant weight in an oven at 230 ± 9°F (110 ± 5^0C). The sample was cooled at room temperature for 1 to 3 hours. After the cooling period, the sample was immersed in water at room temperature for a period of 15 to 19 hours, then the sample was towel dried to SSD condition and the submerged weight recorded. The sample at SSD condition was submerged in water at 77°F and the weight recorded. The sample was then dried in an oven to a constant weight and the weight recorded. The three weights were used to calculate bulk specific gravity, apparent specific gravity and absorption of coarse aggregates.

Corelok Procedures for Coarse Aggregate

The Corelok test for coarse aggregates involves four steps. The calibration of the volumeter, determination of the weight of volumeter including samples, vacuum sealing of samples, and water displacement analysis. Test samples for Corelok test were prepared in the same manner as the AASHTO T-85 test. Detailed procedures for this test are contained in Appendix A.

Corelok Procedures for Fine Aggregate

The Corelok test for fine aggregates involves four steps. The calibration of the entire fixture, determination of the weight of the fixture including samples, vacuum sealing of samples, and water displacement analysis. Test samples for Corelok test were prepared in the same manner as the AASHTO T-84 test. Detailed procedures for this test are contained in Appendix A.

SSDetect System Procedures

The Barnstead Thermolyne SSDetect System is a two part automated system for developing the data necessary to determine the bulk specific gravity and absorption of fine aggregates. This system is based on a dry to wet method unlike the traditional wet to dry method. The test procedure uses an infrared light to detect the SSD condition of the aggregate and an automated de –airing device to remove entrapped air from the volumetric flask (10). Detailed procedures for this test method are contained in Appendix A.

CHAPTER 4

TEST RESULTS

Coarse Aggregate

Sieve Analysis

The results of the sieve analysis performed in accordance with AASHTO T-11 and T-27 are summarized in Table 3. The results present an average of two tests and were used to determine the grain size distribution.

Specific Gravity Testing

Results of the bulk specific gravity, apparent specific gravity and percent absorption for aggregate samples are shown in Table 4. The aggregates were obtained from eight different pits and included four pits with 1/2” chips and four pits with 5/8” chips. The aggregate materials consisted of three limestones, two sandstones, and one each of granite, rhyolite and crushed gravel. Results of the average bulk specific gravities and standard deviations are shown in Table 5.

Table 3. Coarse aggregate gradation analysis

Supplier	**Tiger Ind.**	**Martin Marietta**	**Dolese**	**Hanson**	**Anchor Stone**	**APAC OK**	**ED Baker**	**Arkhola**
Pit	3101	3502	5002	5008	7201	7203	7808	7902
Material	Sandstone	Granite	Limestone	Rhyolite	Limestone	Limestone	Gravel Cr.	Sandstone
Gradation	5/8” Chips	5/8” Chips	5/8” Chips	1/2” Chips	3/4” Chips	1/2” Chips	Gravel*	1/2” Chips
Sieve Size	Percent Passing							
1”					100			
3/4"	100	100	100		99.3	100		
1/2"	81.8	86.5	98.9	100	64.8	99.8	100	100
3/8”	33.7	44.1	73.2	82.8	38.8	80.5	86.1	84.9
No.4	2.9	5.6	4.1	24.7	6.9	10.6	4.3	20.7
No.8	1.6	1.6	1.3	4.3	2.6	4.0	1.1	2.2
No.16	1.4	1.0	1.3	2.8	1.9	3.7	0.6	1.5
No.30	1.3	0.8	1.2	2.5	1.8	3.5	0.5	1.4
No.50	1.3	0.7	1.2	2.2	1.7	3.4	0.4	1.3
No.100	1.3	0.6	1.2	2.0	1.7	3.3	0.3	1.2
No.200	1.0	0.5	1.2	1.8	1.6	3.1	0.3	1.0

* As received gradation. Material split on No. 8 sieve for coarse and fine aggregate testing.

Table 4. Results from coarse aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
7902	Sandstone	1/2" Chips	T85	M	1	2.529	2.633	1.6
7902	Sandstone	1/2" Chips	T85	M	2	2.527	2.633	1.6
7902	Sandstone	1/2" Chips	T85	Y	1	2.532	2.643	1.7
7902	Sandstone	1/2" Chips	T85	Y	2	2.533	2.643	1.6
7902	Sandstone	1/2" Chips	CL	M	1	2.61	2.676	0.9
7902	Sandstone	1/2" Chips	CL	M	2	2.613	2.675	0.9
7902	Sandstone	1/2" Chips	CL	Y	1	2.608	2.675	1.0
7902	Sandstone	1/2" Chips	CL	Y	2	2.611	2.676	0.9
7203	Limestone	1/2" Chips	T85	M	1	2.566	2.694	1.9
7203	Limestone	1/2" Chips	T85	M	2	2.563	2.687	1.8
7203	Limestone	1/2" Chips	T85	Y	1	2.563	2.699	2.0
7203	Limestone	1/2" Chips	T85	Y	2	2.564	2.701	2.0
7203	Limestone	1/2" Chips	CL	M	1	2.65	2.722	1.0
7203	Limestone	1/2" Chips	CL	M	2	2.65	2.723	1.0
7203	Limestone	1/2" Chips	CL	Y	1	2.647	2.726	1.1
7203	Limestone	1/2" Chips	CL	Y	2	2.648	2.725	1.1
3502	Granite	5/8" Chips	T85	M	1	2.76	2.801	0.5
3502	Granite	5/8" Chips	T85	M	2	2.76	2.802	0.5
3502	Granite	5/8" Chips	T85	Y	1	2.768	2.81	0.6
3502	Granite	5/8" Chips	T85	Y	2	2.769	2.812	0.6
3502	Granite	5/8" Chips	CL	M	1	2.777	2.796	0.2
3502	Granite	5/8" Chips	CL	M	2	2.774	2.795	0.3
3502	Granite	5/8" Chips	CL	Y	1	2.78	2.798	0.2
3502	Granite	5/8" Chips	CL	Y	2	2.777	2.797	0.3

T85 = AASHTO T-85
CL = Corelok procedure

Table 4. (Cont.) Results from coarse aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
5002	Limestone	5/8" Chips	T85	M	1	2.677	2.729	0.7
5002	Limestone	5/8" Chips	T85	M	2	2.675	2.728	0.7
5002	Limestone	5/8" Chips	T85	Y	1	2.656	2.709	0.7
5002	Limestone	5/8" Chips	T85	Y	2	2.657	2.710	0.8
5002	Limestone	5/8" Chips	CL	M	1	2.688	2.714	0.4
5002	Limestone	5/8" Chips	CL	M	2	2.685	2.710	0.4
5002	Limestone	5/8" Chips	CL	Y	1	2.691	2.720	0.4
5002	Limestone	5/8" Chips	CL	Y	2	2.690	2.718	0.4
5008	Rhyolite	1/2" Chips	T85	M	1	2.682	2.784	1.4
5008	Rhyolite	1/2" Chips	T85	M	2	2.683	2.785	1.4
5008	Rhyolite	1/2" Chips	T85	Y	1	2.686	2.789	1.4
5008	Rhyolite	1/2" Chips	T85	Y	2	2.687	2.790	1.4
5008	Rhyolite	1/2" Chips	CL	M	1	2.720	2.751	0.4
5008	Rhyolite	1/2" Chips	CL	M	2	2.719	2.753	0.5
5008	Rhyolite	1/2" Chips	CL	Y	1	2.715	2.756	0.5
5008	Rhyolite	1/2" Chips	CL	Y	2	2.718	2.754	0.5
7808	Gravel	1/2" Chips	T85	M	1	2.633	2.671	0.5
7808	Gravel	1/2" Chips	T85	M	2	2.631	2.669	0.6
7808	Gravel	1/2" Chips	T85	Y	1	2.630	2.669	0.6
7808	Gravel	1/2" Chips	T85	Y	2	2.631	2.670	0.6
7808	Gravel	1/2" Chips	CL	M	1	2.659	2.675	0.2
7808	Gravel	1/2" Chips	CL	M	2	2.655	2.673	0.3
7808	Gravel	1/2" Chips	CL	Y	1	2.659	2.675	0.2
7808	Gravel	1/2" Chips	CL	Y	2	2.657	2.675	0.3

T85 = AASHTO T85
CL = Corelok procedure

Table 4.(cont.) Results from coarse aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
3101	Sandstone	5/8" Chips	T85	M	1	2.394	2.615	3.5
3101	Sandstone	5/8" Chips	T85	M	2	2.399	2.612	3.4
3101	Sandstone	5/8" Chips	T85	Y	1	2.395	2.622	3.6
3101	Sandstone	5/8" Chips	T85	Y	2	2.395	2.621	3.6
3101	Sandstone	5/8" Chips	CL	M	1	2.515	2.693	2.6
3101	Sandstone	5/8" Chips	CL	M	2	2.514	2.696	2.7
3101	Sandstone	5/8" Chips	CL	Y	1	2.514	2.697	2.7
3101	Sandstone	5/8" Chips	CL	Y	2	2.516	2.696	2.7
7201	Limestone	5/8" Chips	T85	M	1	2.540	2.679	2.0
7201	Limestone	5/8" Chips	T85	M	2	2.543	2.682	2.0
7201	Limestone	5/8" Chips	T85	Y	1	2.543	2.681	2.0
7201	Limestone	5/8" Chips	T85	Y	2	2.544	2.682	2.0
7201	Limestone	5/8" Chips	CL	M	1	2.625	2.716	1.3
7201	Limestone	5/8" Chips	CL	M	2	2.628	2.714	1.2
7201	Limestone	5/8" Chips	CL	Y	1	2.621	2.724	1.4
7201	Limestone	5/8" Chips	CL	Y	2	2.627	2.720	1.3

T85 = AASHTO T85
CL = Corelok procedure

Table 5. Simple statistics from coarse aggregate specific gravity testing

		Test	Gsb		Gsa		% Abs.	
Pit	Aggregate	Method	Avg	Std	Avg	Std	Avg	Std
7902	Sandstone	T85	2.530	0.003	2.638	0.006	1.6	0.050
7902	Sandstone	CL	2.611	0.002	2.698	0.045	0.9	0.050
7203	Limestone	T85	2.564	0.001	2.695	0.006	1.9	0.096
7203	Limestone	CL	2.649	0.002	2.724	0.002	1.1	0.058
3502	Granite	T85	2.764	0.005	2.806	0.006	0.6	0.058
3502	Granite	CL	2.777	0.002	2.797	0.001	0.3	0.058
5002	Limestone	T85	2.666	0.011	2.719	0.011	0.7	0.050
5002	Limestone	CL	2.689	0.003	2.716	0.004	0.4	0.000
5008	Rhyolite	T85	2.685	0.002	2.787	0.003	1.4	0.000
5008	Rhyolite	CL	2.718	0.002	2.754	0.002	0.5	0.050
7808	Gravel	T85	2.631	0.001	2.670	0.001	0.6	0.050
7808	Gravel	CL	2.658	0.002	2.675	0.001	0.3	0.058
3101	Sandstone	T85	2.396	0.002	2.618	0.005	3.5	0.096
3101	Sandstone	CL	2.515	0.001	2.696	0.002	2.7	0.050
7201	Limestone	T85	2.543	0.002	2.681	0.001	2.0	0.000
7201	Limestone	CL	2.625	0.003	2.719	0.004	1.3	0.082

Fine Aggregates

Sieve Analysis

The results of the sieve analysis performed in accordance with AASHTO T 11 and T-27 are summarized in Table 6. The results present an average of two tests and were used to determine the grain size distribution.

Specific Gravity Testing

Results of the bulk specific gravity, apparent specific gravity and percent absorption for aggregate samples are shown in Table 7. The results represent three pits with fill sand, seven pits with screenings, four pits with manufactured sand, and one pit with crushed gravel. Results of the average bulk specific gravity and standard deviation for fine aggregate are shown in Table 8.

Table 6. Fine aggregate gradation analysis

Supplier	**Dolese**	**Dolese**	**Tiger Ind.**	**Martin Marietta**	**Martin Marietta**	**Dolese**	**Eagle Sand**
Pit	905	1601	3101	3502	3502	3702	4701
Material	Natural Sand	Limestone	Sandstone	Granite	Granite	Natural Sand	Natural Sand
Gradation	Fill Sand	Screenings	Screenings	Screenings	ManSand	Fill Sand	Fill Sand
Sieve Size	Percent Passing						
3/8”		100	100	100	100		
No.4	100	90.8	81.5	71.2	99.0	100	100
No.8	99.9	58.4	38.8	48.2	91.3	99.9	99.8
No.16	99.3	36.4	24.6	34.2	65.9	99.2	99.7
No.30	92.2	24.6	19.0	23.3	41.6	87.0	97.3
No.50	65.3	18.1	16.5	14.8	22.1	48.3	70.9
No.100	13.3	14.0	14.5	8.6	8.3	10.3	15.6
No.200	1.2	11.6	9.2	5.2	3.1	1.0	1.7

Table 4 (Con’t). Fine aggregate gradation analysis.

Supplier	**Dolese**	**Dolese**	**Hanson**	**Arkhola**	**Anchor Stone**	**Anchor Stone**	**Arkhola**
Pit	5002	5002	5008	5103	7201	7201	7902
Material	Limestone	Limestone	Rhyolite	Natural Sand	Limestone	Limestone	Sandstone
Gradation	Screenings	ManSand	Screenings	Fill Sand	Screenings	ManSand	Screenings
Sieve Size	Percent Passing						
3/8”	100	100	100	100	100	100	100
No.4	85.9	99.8	81.6	98.7	92.9	82.1	87.4
No.8	56.6	88.2	50.3	93.3	68.5	57.6	59.4
No.16	34.6	49.5	30.5	78.7	49.7	35.7	44.2
No.30	22.5	23.6	19.3	46.5	37.7	21.4	36.5
No.50	15.8	9.1	13.0	11.6	29.9	11.5	32.0
No.100	11.9	2.6	8.9	1.3	24.5	5.9	23.0
No.200	9.9	1.5	6.3	0.4	20.8	4.4	12.9

Table 7. Results from fine aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
4701	N'Sand	Fill sand	T84	M	1	2.619	2.644	0.4
4701	N'Sand	Fill sand	T84	M	2	2.622	2.648	0.4
4701	N'Sand	Fill sand	T84	Y	1	2.627	2.646	0.3
4701	N'Sand	Fill sand	T84	Y	2	2.628	2.648	0.3
4701	N'Sand	Fill sand	CL	M	1	2.620	2.648	0.4
4701	N'Sand	Fill sand	CL	M	2	2.621	2.646	0.4
4701	N'Sand	Fill sand	CL	Y	1	2.626	2.648	0.3
4701	N'Sand	Fill sand	CL	Y	2	2.635	2.649	0.2
4701	N'Sand	Fill sand	SSDetect	M	1	2.606	2.647	0.6
4701	N'Sand	Fill sand	SSDetect	M	2	2.606	2.646	0.6
4701	N'Sand	Fill sand	SSDetect	Y	1	2.607	2.658	0.7
4701	N'Sand	Fill sand	SSDetect	Y	2	2.612	2.661	0.7
5008	Rhyolite	Screenings	T84	M	1	2.610	2.819	2.8
5008	Rhyolite	Screenings	T84	M	2	2.614	2.818	2.8
5008	Rhyolite	Screenings	T84	Y	1	2.634	2.817	2.5
5008	Rhyolite	Screenings	T84	Y	2	2.650	2.823	2.3
5008	Rhyolite	Screenings	CL	M	1	2.660	2.787	1.7
5008	Rhyolite	Screenings	CL	M	2	2.673	2.789	1.6
5008	Rhyolite	Screenings	CL	Y	1	2.656	2.792	1.8
5008	Rhyolite	Screenings	CL	Y	2	2.659	2.793	1.8
5008	Rhyolite	Screenings	SSDetect	M	1	2.717	2.789	0.9
5008	Rhyolite	Screenings	SSDetect	M	2	2.713	2.781	0.9
5008	Rhyolite	Screenings	SSDetect	Y	1	2.722	2.790	0.9
5008	Rhyolite	Screenings	SSDetect	Y	2	2.725	2.780	1.0

Table 7.(cont.) Results from fine aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
1601	Limestone	Screenings	T84	M	1	2.558	2.717	2.3
1601	Limestone	Screenings	T84	M	2	2.568	2.717	2.1
1601	Limestone	Screenings	T84	Y	1	2.591	2.725	2.0
1601	Limestone	Screenings	T84	Y	2	2.596	2.731	2.0
1601	Limestone	Screenings	CL	M	1	2.654	2.710	0.8
1601	Limestone	Screenings	CL	M	2	2.657	2.710	0.7
1601	Limestone	Screenings	CL	Y	1	2.649	2.709	0.8
1601	Limestone	Screenings	CL	Y	2	2.653	2.711	0.8
1601	Limestone	Screenings	SSDetect	M	1	2.648	2.716	0.9
1601	Limestone	Screenings	SSDetect	M	2	2.650	2.714	0.9
1601	Limestone	Screenings	SSDetect	Y	1	2.665	2.726	0.8
1601	Limestone	Screenings	SSDetect	Y	2	2.660	2.725	0.9
905	N'Sand	Fillsand	T84	M	1	2.622	2.642	0.3
905	N'Sand	Fillsand	T84	M	2	2.609	2.645	0.5
905	N'Sand	Fillsand	T84	Y	1	2.632	2.650	0.3
905	N'Sand	Fillsand	T84	Y	2	2.633	2.648	0.2
905	N'Sand	Fillsand	CL	M	1	2.623	2.648	0.4
905	N'Sand	Fillsand	CL	M	2	2.621	2.646	0.4
905	N'Sand	Fillsand	CL	Y	1	2.627	2.648	0.3
905	N'Sand	Fillsand	CL	Y	2	2.632	2.646	0.2
905	N'Sand	Fillsand	SSDetect	M	1	2.603	2.643	0.6
905	N'Sand	Fillsand	SSDetect	M	2	2.609	2.651	0.6
905	N'Sand	Fillsand	SSDetect	Y	1	2.604	2.646	0.6
905	N'Sand	Fillsand	SSDetect	Y	2	2.604	2.647	0.6

Table 7.(cont.) Results from fine aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
3702	N'Sand	Fillsand	T84	M	1	2.615	2.640	0.3
3702	N'Sand	Fillsand	T84	M	2	2.622	2.647	0.4
3702	N'Sand	Fillsand	T84	Y	1	2.631	2.650	0.3
3702	N'Sand	Fillsand	T84	Y	2	2.642	2.662	0.3
3702	N'Sand	Fillsand	CL	M	1	2.623	2.649	0.4
3702	N'Sand	Fillsand	CL	M	2	2.629	2.651	0.3
3702	N'Sand	Fillsand	CL	Y	1	2.621	2.652	0.4
3702	N'Sand	Fillsand	CL	Y	2	2.627	2.652	0.4
3702	N'Sand	Fillsand	SSDetect	M	1	2.603	2.651	0.7
3702	N'Sand	Fillsand	SSDetect	M	2	2.606	2.651	0.7
3702	N'Sand	Fillsand	SSDetect	Y	1	2.607	2.653	0.7
3702	N'Sand	Fillsand	SSDetect	Y	2	2.607	2.651	0.6
3101	Sandstone	Screenings	T84	M	1	2.409	2.625	3.4
3101	Sandstone	Screenings	T84	M	2	2.393	2.672	4.4
3101	Sandstone	Screenings	T84	Y	1	2.443	2.670	3.5
3101	Sandstone	Screenings	T84	Y	2	2.447	2.670	3.4
3101	Sandstone	Screenings	CL	M	1	2.474	2.696	3.3
3101	Sandstone	Screenings	CL	M	2	2.474	2.692	3.3
3101	Sandstone	Screenings	CL	Y	1	2.461	2.703	3.6
3101	Sandstone	Screenings	CL	Y	2	2.472	2.699	3.4
3101	Sandstone	Screenings	SSDetect	M	1	2.513	2.644	2.0
3101	Sandstone	Screenings	SSDetect	M	2	2.508	2.641	2.0
3101	Sandstone	Screenings	SSDetect	Y	1	2.488	2.625	2.1
3101	Sandstone	Screenings	SSDetect	Y	2	2.500	2.640	2.1

Table 7.(cont.) Results from fine aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
7201	Limestone	ManSand	T84	M	1	2.449	2.760	4.6
7201	Limestone	ManSand	T84	M	2	2.472	2.720	3.6
7201	Limestone	ManSand	T84	Y	1	2.503	2.731	3.3
7201	Limestone	ManSand	T84	Y	2	2.495	2.727	3.4
7201	Limestone	ManSand	CL	M	1	2.537	2.723	2.7
7201	Limestone	ManSand	CL	M	2	2.537	2.721	2.7
7201	Limestone	ManSand	CL	Y	1	2.540	2.720	2.6
7201	Limestone	ManSand	CL	Y	2	2.551	2.723	2.5
7201	Limestone	ManSand	SSDetect	M	1	2.615	2.688	1.0
7201	Limestone	ManSand	SSDetect	M	2	2.611	2.688	1.1
7201	Limestone	ManSand	SSDetect	Y	1	2.614	2.690	1.1
7201	Limestone	ManSand	SSDetect	Y	2	2.623	2.693	1.0
7201	Limestone	Screenings	T84	M	1	2.606	2.721	2.0
7201	Limestone	Screenings	T84	M	2	2.552	2.732	3.0
7201	Limestone	Screenings	T84	Y	1	2.448	2.736	4.3
7201	Limestone	Screenings	T84	Y	2	2.427	2.730	4.6
7201	Limestone	Screenings	CL	M	1	2.432	2.721	4.4
7201	Limestone	Screenings	CL	M	2	2.442	2.719	4.2
7201	Limestone	Screenings	CL	Y	1	2.466	2.725	3.9
7201	Limestone	Screenings	CL	Y	2	2.466	2.721	3.8
7201	Limestone	Screenings	SSDetect	M	1	2.524	2.684	2.4
7201	Limestone	Screenings	SSDetect	M	2	2.529	2.682	2.3
7201	Limestone	Screenings	SSDetect	Y	1	2.532	2.681	2.2
7201	Limestone	Screenings	SSDetect	Y	2	2.525	2.677	2.2

Table 7.(cont.) Results from fine aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
5103	N'Sand	Fill Sand	T84	M	1	2.618	2.645	0.4
5103	N'Sand	Fill Sand	T84	M	2	2.628	2.645	0.2
5103	N'Sand	Fill Sand	T84	Y	1	2.623	2.646	0.3
5103	N'Sand	Fill Sand	T84	Y	2	2.631	2.651	0.3
5103	N'Sand	Fill Sand	CL	M	1	2.619	2.643	0.4
5103	N'Sand	Fill Sand	CL	M	2	2.620	2.643	0.3
5103	N'Sand	Fill Sand	CL	Y	1	2.634	2.648	0.2
5103	N'Sand	Fill Sand	CL	Y	2	2.632	2.646	0.2
5103	N'Sand	Fill Sand	SSDetect	M	1	2.613	2.641	0.4
5103	N'Sand	Fill Sand	SSDetect	M	2	2.610	2.640	0.5
5103	N'Sand	Fill Sand	SSDetect	Y	1	2.604	2.641	0.5
5103	N'Sand	Fill Sand	SSDetect	Y	2	2.610	2.644	0.5
3502	Granite	Screenings	T84	M	1	2.594	2.663	1.0
3502	Granite	Screenings	T84	M	2	2.591	2.661	1.0
3502	Granite	Screenings	T84	Y	1	2.608	2.674	1.0
3502	Granite	Screenings	T84	Y	2	2.618	2.677	0.9
3502	Granite	Screenings	CL	M	1	2.639	2.653	0.2
3502	Granite	Screenings	CL	M	2	2.641	2.664	0.3
3502	Granite	Screenings	CL	Y	1	2.634	2.665	0.4
3502	Granite	Screenings	CL	Y	2	2.627	2.666	0.6
3502	Granite	Screenings	SSDetect	M	1	2.622	2.658	0.5
3502	Granite	Screenings	SSDetect	M	2	2.637	2.667	0.4
3502	Granite	Screenings	SSDetect	Y	1	2.634	2.662	0.4
3502	Granite	Screenings	SSDetect	Y	2	2.629	2.662	0.5

Table 7.(cont.) Results from fine aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
3502	Granite	Mansand	T84	M	1	2.594	2.664	1.0
3502	Granite	Mansand	T84	M	2	2.601	2.668	1.0
3502	Granite	Mansand	T84	Y	1	2.613	2.665	0.8
3502	Granite	Mansand	T84	Y	2	2.612	2.660	0.7
3502	Granite	Mansand	CL	M	1	2.607	2.648	0.6
3502	Granite	Mansand	CL	M	2	2.619	2.646	0.4
3502	Granite	Mansand	CL	Y	1	2.645	2.662	0.2
3502	Granite	Mansand	CL	Y	2	2.642	2.660	0.3
3502	Granite	Mansand	SSDetect	M	1	2.604	2.654	0.7
3502	Granite	Mansand	SSDetect	M	2	2.609	2.655	0.7
3502	Granite	Mansand	SSDetect	Y	1	2.608	2.661	0.8
3502	Granite	Mansand	SSDetect	Y	2	2.596	2.662	1.0
7808	Gravel	Screenings	T84	M	1	2.587	2.669	1.2
7808	Gravel	Screenings	T84	M	2	2.597	2.695	1.4
7808	Gravel	Screenings	T84	Y	1	2.579	2.680	1.5
7808	Gravel	Screenings	T84	Y	2	2.556	2.671	1.7
7808	Gravel	Screenings	CL	M	1	2.642	2.670	0.4
7808	Gravel	Screenings	CL	M	2	2.639	2.673	0.5
7808	Gravel	Screenings	CL	Y	1	2.624	2.672	0.7
7808	Gravel	Screenings	CL	Y	2	2.621	2.671	0.7
7808	Gravel	Screenings	SSDetect	M	1	2.654	2.665	0.2
7808	Gravel	Screenings	SSDetect	M	2	2.651	2.665	0.2
7808	Gravel	Screenings	SSDetect	Y	1	2.650	2.667	0.3
7808	Gravel	Screenings	SSDetect	Y	2	2.650	2.668	0.3

Table 7.(cont.) Results from fine aggregate specific gravity and absorption testing

Pit	Aggregate	Material	Test Method	Engr.	Sample	Gsb	Gsa	% Abs.
5002	Limestone	ManSand	T84	M	1	2.625	2.730	1.5
5002	Limestone	ManSand	T84	M	2	2.635	2.722	1.2
5002	Limestone	ManSand	T84	Y	1	2.647	2.736	1.2
5002	Limestone	ManSand	T84	Y	2	2.657	2.750	1.3
5002	Limestone	ManSand	CL	M	1	2.679	2.718	0.5
5002	Limestone	ManSand	CL	M	2	2.682	2.715	0.5
5002	Limestone	ManSand	CL	Y	1	2.677	2.720	0.6
5002	Limestone	ManSand	CL	Y	2	2.681	2.718	0.5
5002	Limestone	ManSand	SSDetect	M	1	2.667	2.714	0.7
5002	Limestone	ManSand	SSDetect	M	2	2.661	2.713	0.7
5002	Limestone	ManSand	SSDetect	Y	1	2.655	2.710	0.7
5002	Limestone	ManSand	SSDetect	Y	2	2.651	2.707	0.8
5002	Limestone	Screenings	T84	M	1	2.591	2.733	2.0
5002	Limestone	Screenings	T84	M	2	2.580	2.727	2.1
5002	Limestone	Screenings	T84	Y	1	2.634	2.727	1.3
5002	Limestone	Screenings	T84	Y	2	2.620	2.720	1.4
5002	Limestone	Screenings	CL	M	1	2.672	2.690	0.2
5002	Limestone	Screenings	CL	M	2	2.655	2.714	0.8
5002	Limestone	Screenings	CL	Y	1	2.676	2.720	0.6
5002	Limestone	Screenings	CL	Y	2	2.673	2.719	0.6
5002	Limestone	Screenings	SSDetect	M	1	2.648	2.729	1.1
5002	Limestone	Screenings	SSDetect	M	2	2.651	2.734	1.1
5002	Limestone	Screenings	SSDetect	Y	1	2.640	2.725	1.2
5002	Limestone	Screenings	SSDetect	Y	2	2.633	2.723	1.3
7902	Sandstone	Screenings	T84	M	1	2.531	2.671	2.1
7902	Sandstone	Screenings	T84	M	2	2.528	2.649	1.8
7902	Sandstone	Screenings	T84	Y	1	2.564	2.674	1.6
7902	Sandstone	Screenings	T84	Y	2	2.583	2.683	1.4
7902	Sandstone	Screenings	CL	M	1	2.470	2.650	2.8
7902	Sandstone	Screenings	CL	M	2	2.511	2.660	2.2
7902	Sandstone	Screenings	CL	Y	1	2.530	2.663	2.0
7902	Sandstone	Screenings	CL	Y	2	2.537	2.666	2.0
7902	Sandstone	Screenings	SSDetect	M	1	2.549	2.648	1.5
7902	Sandstone	Screenings	SSDetect	M	2	2.538	2.646	1.6
7902	Sandstone	Screenings	SSDetect	Y	1	2.542	2.657	1.7
7902	Sandstone	Screenings	SSDetect	Y	2	2.552	2.661	1.6

Table 8. Simple statistics from fine aggregate specific gravity testing

Pit	Aggregate	Test Method	Gsb Avg	Gsb Std	Gsa Avg	Gsa Std	% Abs. Avg	% Abs. Std
4701	N'Sand	T84	2.624	0.004	2.647	0.002	0.4	0.058
4701	N'Sand	CL	2.626	0.007	2.648	0.001	0.3	0.096
4701	N'Sand	SSDetect	2.608	0.003	2.653	0.008	0.7	0.058
5008	Rhyolite	T84	2.627	0.019	2.819	0.003	2.6	0.245
5008	Rhyolite	CL	2.662	0.008	2.790	0.003	1.7	0.096
5008	Rhyolite	SSDetect	2.719	0.005	2.785	0.005	0.9	0.050
1601	Limestone	T84	2.578	0.018	2.723	0.007	2.1	0.141
1601	Limestone	CL	2.653	0.003	2.710	0.001	0.8	0.050
1601	Limestone	SSDetect	2.656	0.008	2.720	0.006	0.9	0.050
905	N'Sand	T84	2.624	0.011	2.646	0.004	0.3	0.126
905	N'Sand	CL	2.626	0.005	2.647	0.001	0.3	0.096
905	N'Sand	SSDetect	2.605	0.003	2.647	0.003	0.6	0.000
3702	N'Sand	T84	2.628	0.012	2.650	0.009	0.3	0.050
3702	N'Sand	CL	2.625	0.004	2.651	0.001	0.4	0.050
3702	N'Sand	SSDetect	2.606	0.002	2.652	0.001	0.7	0.050
3101	Sandstone	T84	2.423	0.026	2.659	0.023	3.7	0.486
3101	Sandstone	CL	2.470	0.006	2.698	0.005	3.4	0.141
3101	Sandstone	SSDetect	2.502	0.011	2.638	0.009	2.1	0.058

Table 8.(cont.) Simple statistics from fine aggregate specific gravity testing

		Test	Gsb		Gsa		% Abs.	
Pit	Aggregate	Method	Avg	Std	Avg	Std	Avg	Std
7201	Limestone	T84	2.480	0.024	2.735	0.018	3.7	0.597
7201	Limestone	CL	2.541	0.007	2.722	0.002	2.6	0.096
7201	Limestone	SSDetect	2.616	0.005	2.690	0.002	1.1	0.058
7201	Limestone	T84	2.508	0.085	2.730	0.006	3.5	1.204
7201	Limestone	CL	2.452	0.017	2.722	0.003	4.1	0.275
7201	Limestone	SSDetect	2.528	0.004	2.681	0.003	2.3	0.096
5103	N'Sand	T84	2.625	0.006	2.647	0.003	0.3	0.082
5103	N'Sand	CL	2.626	0.008	2.645	0.002	0.3	0.096
5103	N'Sand	SSDetect	2.609	0.004	2.642	0.002	0.5	0.050
3502	Granite	T84	2.603	0.013	2.669	0.008	1.0	0.050
3502	Granite	CL	2.635	0.006	2.662	0.006	0.4	0.171
3502	Granite	SSDetect	2.631	0.007	2.662	0.004	0.5	0.058
3502	Granite	T84	2.605	0.009	2.664	0.003	0.9	0.150
3502	Granite	CL	2.628	0.018	2.654	0.008	0.4	0.171
3502	Granite	SSDetect	2.604	0.006	2.658	0.0041	0.8	0.141
7808	Gravel	T84	2.580	0.017	2.679	0.012	1.5	0.208
7808	Gravel	CL	2.632	0.011	2.672	0.001	0.6	0.150
7808	Gravel	SSDetect	2.651	0.002	2.666	0.002	0.3	0.058

Table 8.(cont.) Simple statistics from fine aggregate specific gravity testing

		Test	Gsb		Gsa		% Abs.	
Pit	Aggregate	Method	Avg	Std	Avg	Std	Avg	Std
5002	Limestone	T84	2.641	0.014	2.735	0.012	1.3	0.141
5002	Limestone	CL	2.680	0.002	2.718	0.002	0.5	0.050
5002	Limestone	SSDetect	2.659	0.007	2.711	0.003	0.7	0.05
5002	Limestone	T84	2.606	0.025	2.727	0.005	1.7	0.408
5002	Limestone	CL	2.669	0.009	2.711	0.014	0.6	0.252
5002	Limestone	SSDetect	2.643	0.008	2.728	0.005	1.2	0.096
7902	Sandstone	T84	2.552	0.027	2.669	0.014	1.7	0.299
7902	Sandstone	CL	2.512	0.030	2.660	0.007	2.3	0.379
7902	Sandstone	SSDetect	2.545	0.006	2.653	0.007	1.6	0.082

CHAPTER 5

ANALYSIS OF TEST RESULTS

This chapter provides an analysis of the test results for the coarse and fine aggregate bulk specific gravity, apparent specific gravity and percent absorption based on AASHTO T-85, T-84, SSDetect and Corelok tests. The analysis was performed to determine if there is a statistical difference between test methods and operators and the in interaction between test methods and operators.

Coarse Aggregates

Bulk Specific Gravity

An analysis of variance (ANOVA) was performed to determine if there is a statistical difference in bulk specific gravity between test methods and operators, and the respective interaction. The results, shown in Table 9, indicate that bulk specific gravity values between test methods were significantly different at a confidence limit exceeding 98 %.

No statistical difference in bulk specific gravity was found between operators or the respective interaction. From the analysis, it means that operator was not a significant factor for either test. AASHTO T-85 and CoreLok gave statistically different bulk specific gravity values. CoreLok method tends to overestimate bulk specific gravity values compared to AASHTO T-85.

Table 9. Analysis of Variance for Bulk Specific Gravity Tests, Corelok and AASHTO T-85

Source	Degrees Freedom	Sum Squares	Mean Square	F Ratio	Prob. > Fcr
Test Method	1	0.053245	0.053246	5.99	0.0173
Operator	1	0.000002	0.000002	0.00	0.9874
Test M * Operator	1	0.000001	0.000001	0.00	0.9937
Error	60	0.533000	0.009000		
Total	63	0.586565			

Figure 4 is a plot of CoreLok versus AASHTO T-85 bulk specific gravity. It can be seen that the Corelok method tends to over estimate the bulk specific gravity values at lower bulk specific gravities, compared to AASHTO T-85 method. The relationship has a coefficient of determination (R^2) of 0.97.

Based on the statistics shown in Table 5 it can be seen that the standard deviations were similar. All eight sources had standard deviation for both methods within the multilaboratory precision range of 0.013 for AASHTO T-85. The Corelok method had standard deviation less than the AASHTO T-85 single operator precision limit of 0.009 for all 8 sources. One source was outside the single operator standard deviation for AASHTO T-85 demonstrating better repeatability for CoreLok procedure.

The CoreLok produced results within AASHTO T-85 acceptable range of results for a single operator for two of eight sources and four of eight sources for multilaboratory situations.

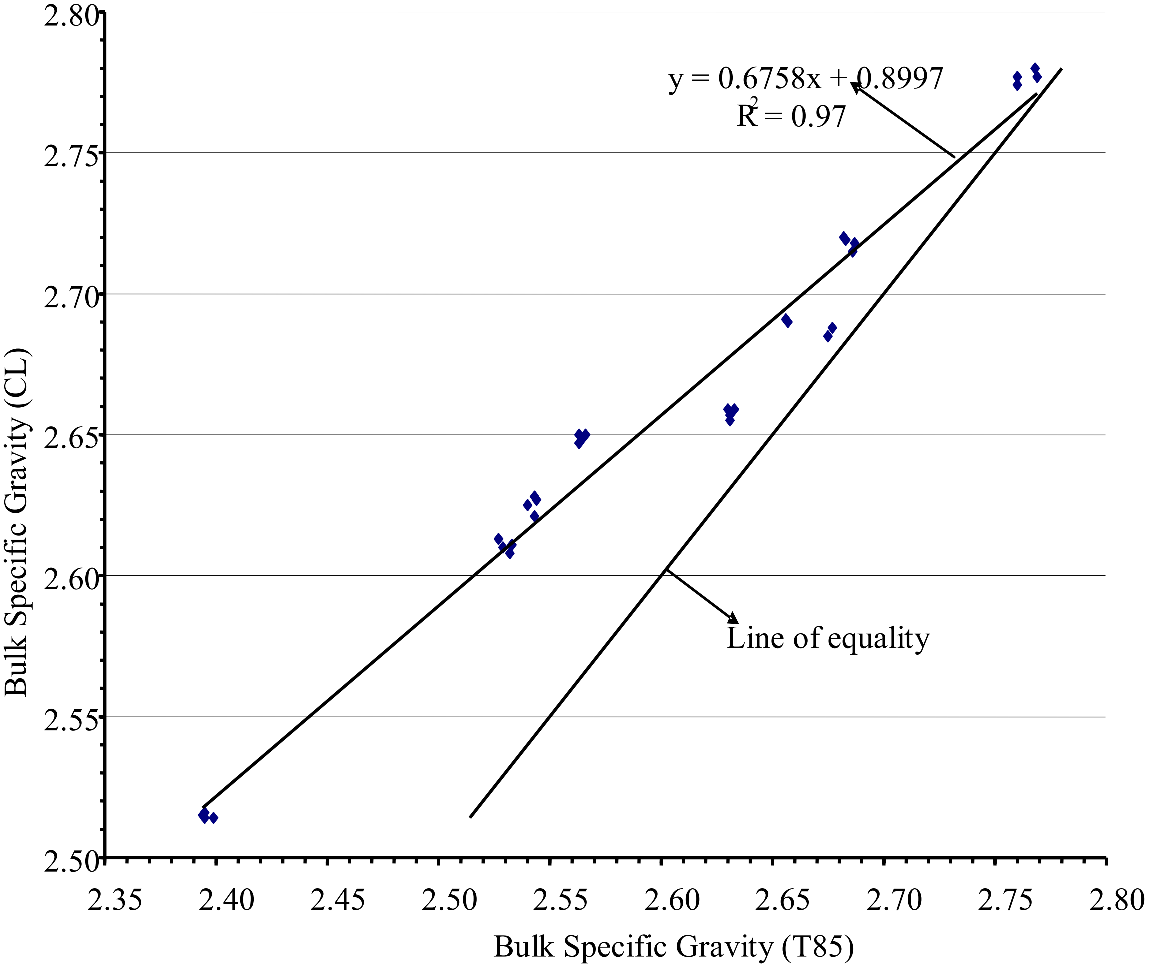

Figure 4. Gsb (Corelok) vs. Gsb (T-85)

Apparent Specific Gravity

The results for the ANOVA for apparent specific gravity are shown in Table 10. The analysis indicates that there was no significant difference in apparent specific gravity values between test methods, operators and the interaction between test method and operator.

Table 10. Analysis of Variance for Apparent Specific Gravity Tests, Corelok and AASHTO T-85

Source	Degrees Freedom	Sum Squares	Mean Square	F Ratio	Prob. > Fcr
Test Method	1	0.00658	0.00658	2.30	0.1345
Operator	1	0.00055	0.00055	0.19	0.6636
Test M * Operator	1	0.00014	0.00013	0.05	0.8286
Error	60	0.17153	0.00286		
Total	63	0.17879			

Figure 5 shows a plot of Corelok versus AASHTO T-85 apparent specific gravity. The relationship has a coefficient of determination (R^2) of 0.68. The data has enough scatter that the differences in means were not significantly different.

From the statistics shown in Table 5 it can be seen that the standard deviations were variable. All sources were within the multilaboratory precision range for AASHTO T-85 for both methods. The standard deviations were less than the single operator precision limit of 0.007for seven of eight sources for both methods.

The CoreLok method produced results within the acceptable range of results for a single operator for three of eight sources when compared to AASHTO T-85 and four of eight sources for multilaboratory situations.

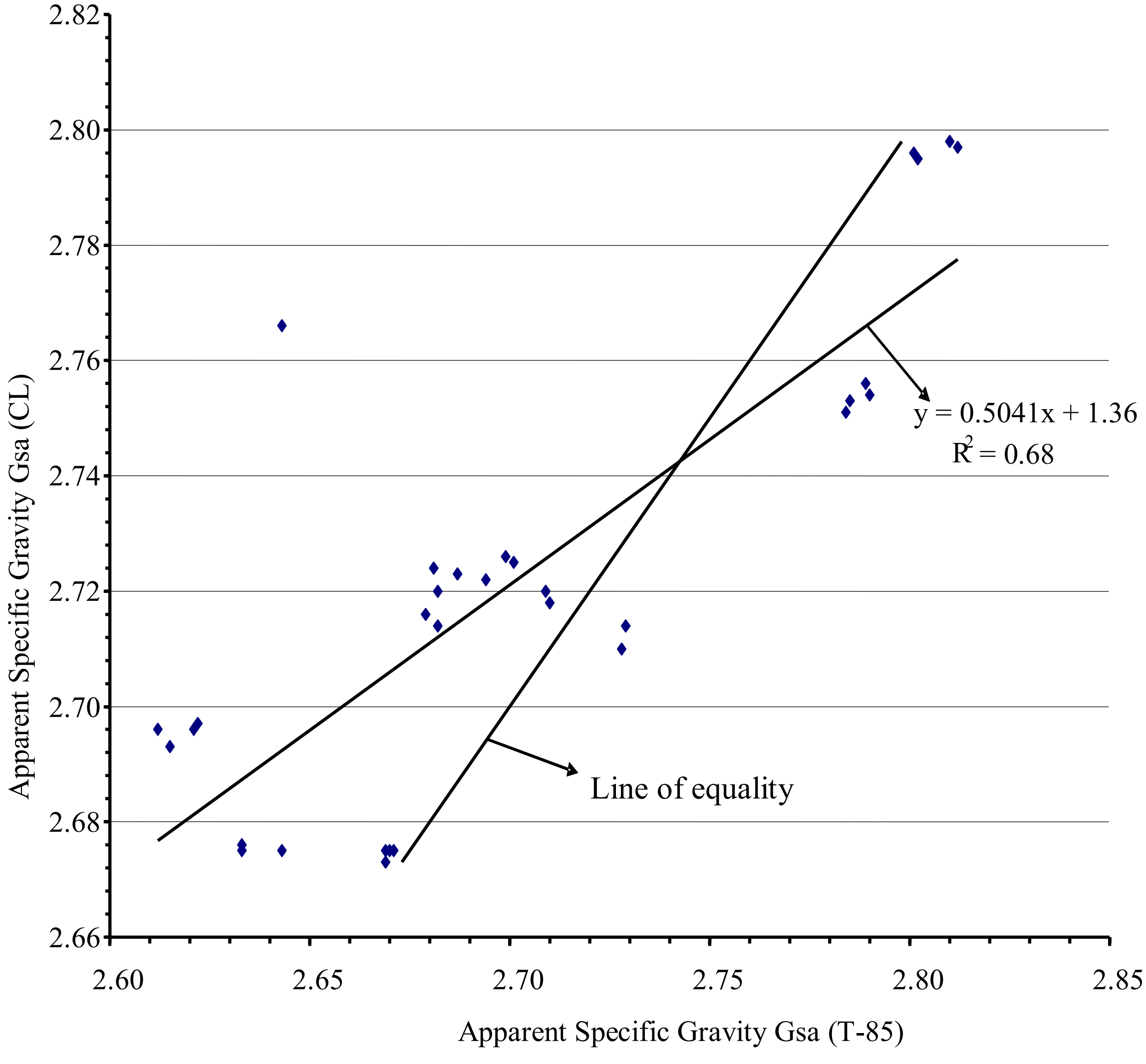

Figure 5. Gsa (CoreLok) vs. Gsa (T-85)

Percent Absorption

The ANOVA results for percent absorption are provided in Table 11. The analysis indicates that absorption values between test methods were significantly different at a confidence limit of 99 %. No statistical difference in percent absorption was found between operators and the interaction between method and operator.

Table 11. Analysis of Variance for Percent Absorption Tests, Corelok and AASHTO T-85

Source	Degrees Freedom	Sum Squares	Mean Square	F Ratio	Prob. > Fcr
Test Method	1	6.250	6.250	8.13	0.0060
Operator	1	0.051	0.051	0.07	0.7984
Test M * Operator	1	0.003	0.003	0.00	0.9547
Error	60	46.146	0.769		
Total	63	52.449			

Figure 6 shows a plot of AASHTO T-85 versus Corelok percent absorption. The results indicate that the AASHTO T-85 method tends to over estimate absorption values compared to Corelok method. The relationship has a coefficient of determination (R^2) of 0.95.

From the statistics shown in Table 5, it can be seen that the standard deviations for both procedures were within the multilaboratory precision range for AASHTO T-85 of 0.0145. The standard deviations were less than the single operator precision limit of 0.088 for all sources for the CoreLok procedure and all but two sources for AASHTO T-85.

For only three sources were the CoreLok absorptions were within the acceptable range of two results of the T-85 values, for multi lab situations.

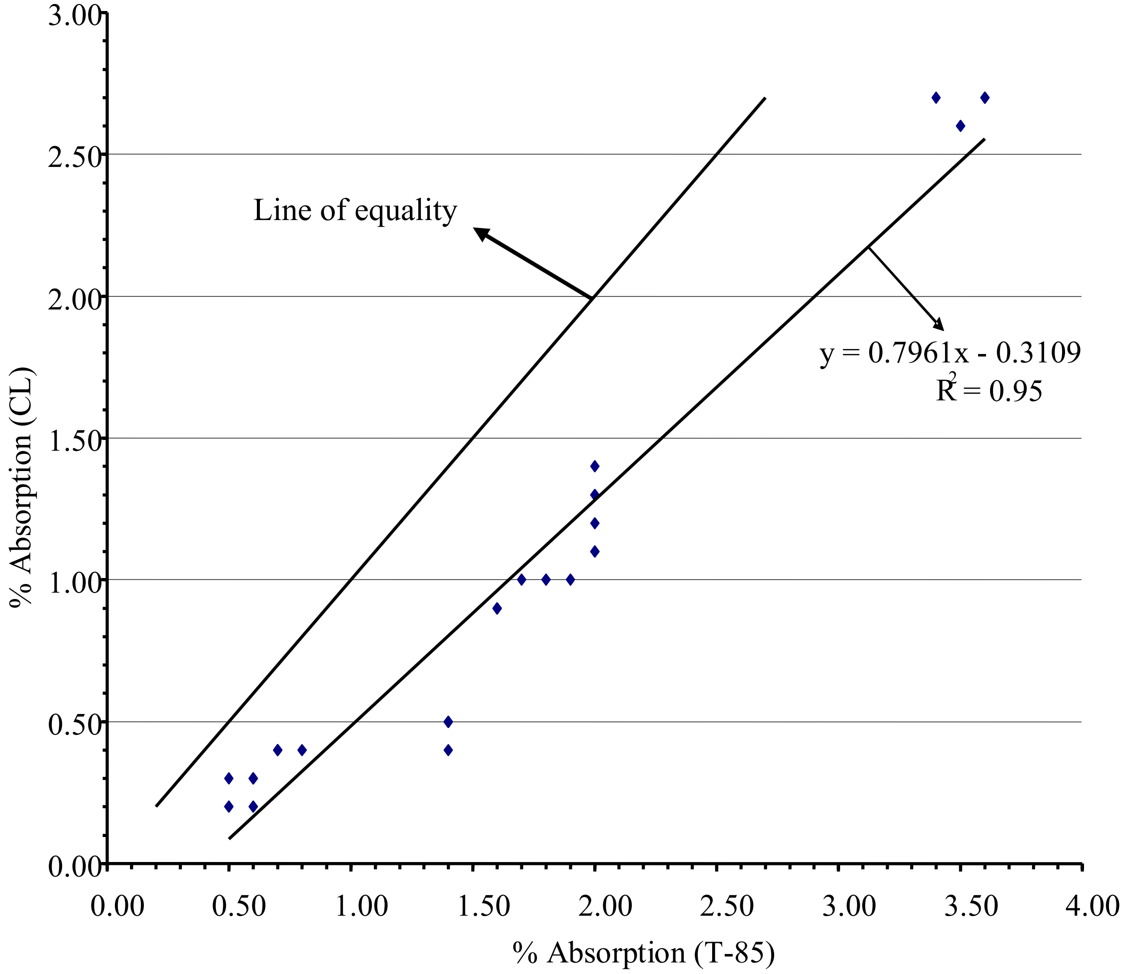

Figure 6. % Absorption (T85) vs. % Absorption (CoreLok)

Fine Aggregates

An analysis of variance (ANOVA) was performed to determine if there is a statistical difference in testing between test methods, operators, and the interaction between test method and operator for fine aggregates. Duncan's Multiple Range Test was performed to determine which means were significantly different from each other when the ANOVA showed a significant different in the means.

Bulk Specific Gravity

The results of the ANOVA, shown in Table 12, indicate that bulk specific gravity between test methods were significantly different at a confidence limit exceeding 97%. No statistical difference exists between operators, and the interaction between test method and operator.

Table 13 shows results from Duncan's Multiple Range Test Means with the same letter are not significantly different at a confidence limit of 95% (alpha = 0.05). No statistical difference in bulk specific gravity exists between SSDetect or CoreLok, and Corelok and AASHTO T-84. A statistical difference exists between SSDetect method and AASHTO T-84. The results are similar to those found by Hall (9) and Prowell (7).

Table 12. Analysis of Variance for Bulk Specific Gravity Tests, Corelok, SSDetect and AASHTO T84

Source	Degrees Freedom	Sum Squares	Mean Square	F Ratio	Prob. > F
Test Method	2	0.0321	0.0160	3.82	0.024
Operator	1	0.0014	0.0014	0.34	0.559
Test M * Operator	2	0.0011	0.0005	0.13	0.878
Error	174	0.7291	0.0042		
Total	179	0.7637			

Table 13. Results of Duncan's Multiple Range Test for Fine Aggregate Bulk Specific Gravity Tests.

Grouping*	Mean Bulk Specific Gravity	N	Test Method
A	2.612	60	SSDetect
A & B	2.602	60	Corelok
B	2.580	60	T84

* Means with the same letter not significantly different

Figure 7 shows a plot of CoreLok versus AASHTO T-84 bulk specific gravity. It can be seen that the CoreLok method tends to over estimate the bulk specific gravity values compared to AASHTO T-84 method. The relationship has a coefficient of determination (R^2) of 0.62.

Figure 8 shows a plot of SSDetect versus AASHTO T-84 bulk specific gravity. It can be seen that the CoreLok method tends to over estimate the bulk specific gravity at lower Gsb values, compared to AASHTO T-84 method. The relationship has a coefficient of determination (R^2) of 0.38.

Figure 9 shows a plot of CoreLok versus SSDetect bulk specific gravity. It can be seen that the CoreLok method tends to under estimate the bulk specific gravity values at lower values of Gsb compared to SSDetect method. The relationship has a coefficient of determination (R^2) of 0.73.

From the statistics shown in Table 8 it can be seen that the standard deviations variable. Five of the 15 sources were outside the multilaboratory precision range for AASHTO T-84. The CoreLok and SSDetect methods were more repeatable, with only one and no sources outside the multilaboratory precision range, respectively. Eleven sources were outside the single operator standard deviation for AASHTO T-84, three for CoreLok and none for SSDetect, demonstrating better repeatability for the CoreLok and SSDetect procedures.

The CoreLok procedure produced results within the acceptable range of results for a single operator for six of 15 sources when compared to AASHTO T-84 and for 14 of the 15 sources for multilaboratory situations. When comparing SSDetect to AASHTO T-84 results, eight of the 15 sources were within the single operator range of acceptable results and ten of the 15 sources were within the multilaboratory range.

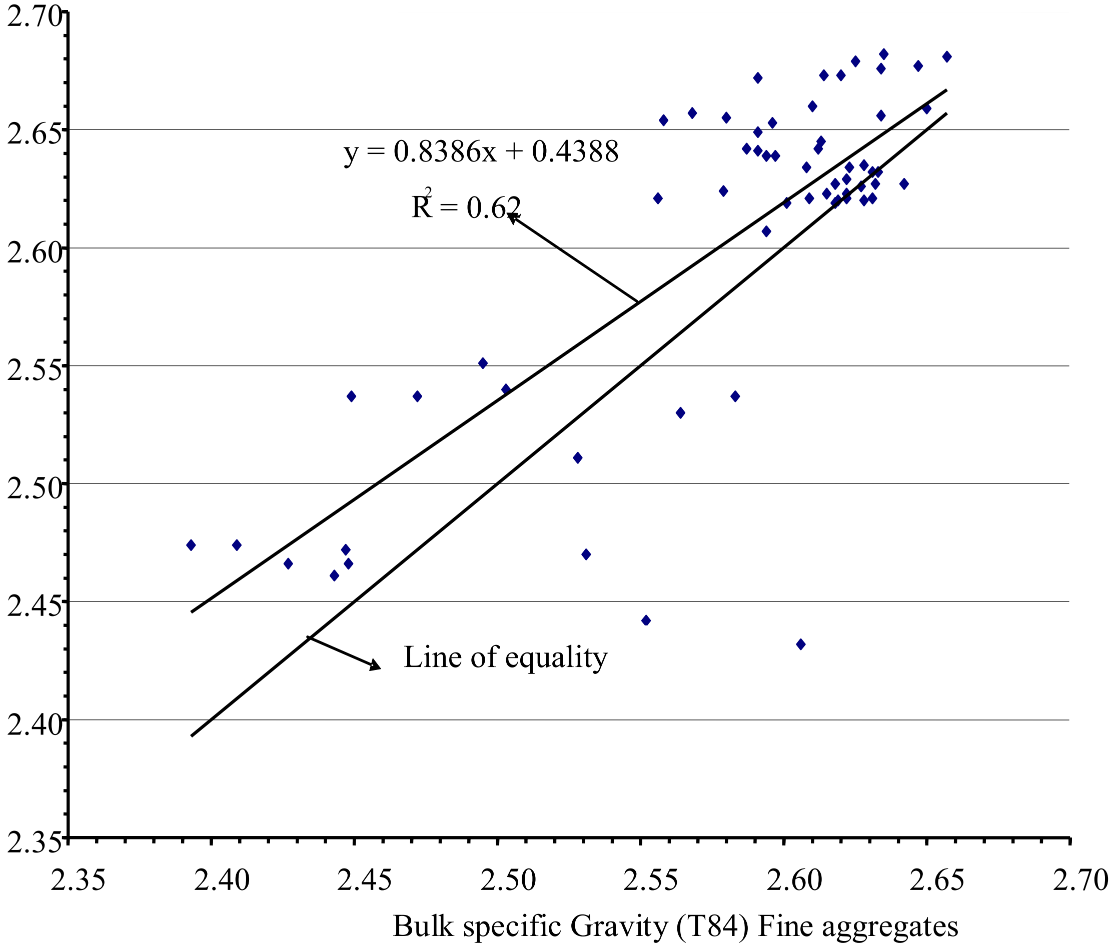

Figure 7. Gsb (CoreLok) vs. Gsb (AASHTO T-84)

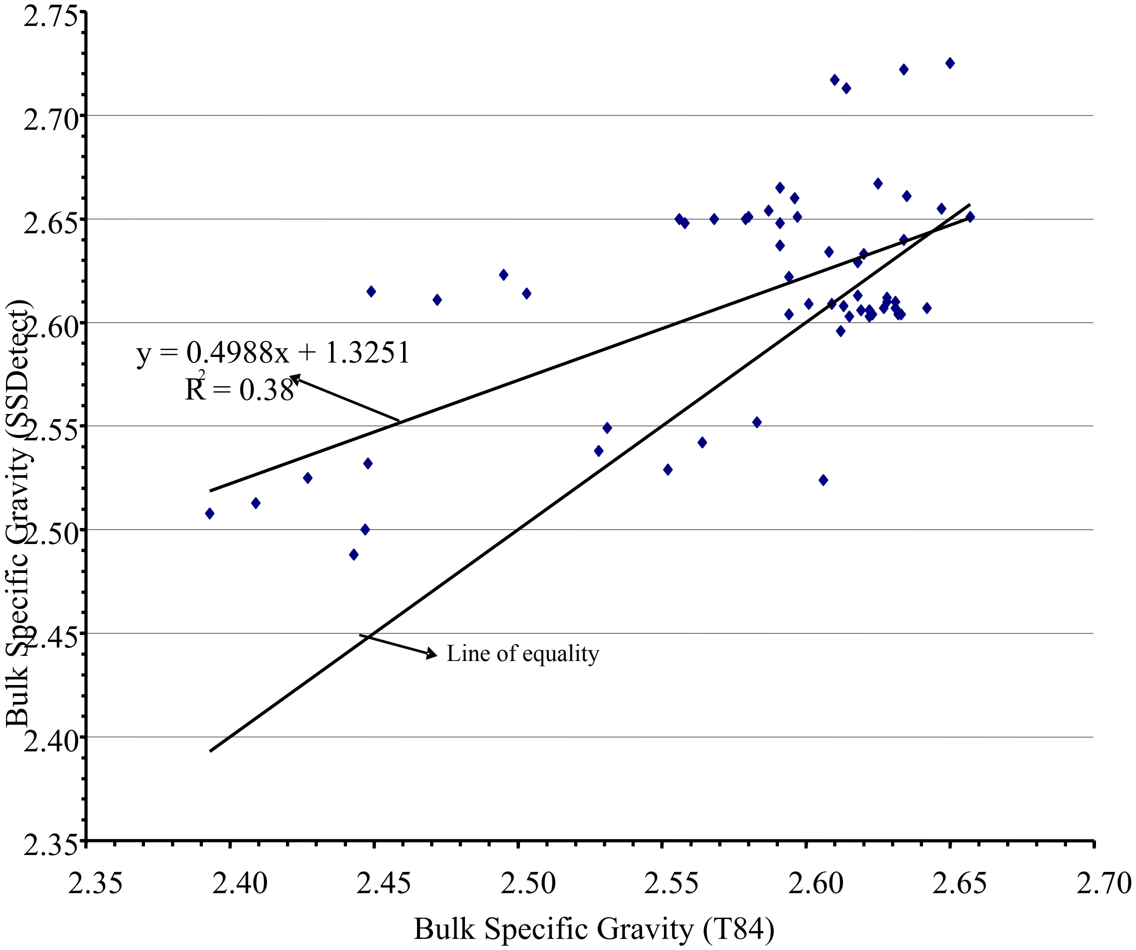

Figure 8. Gsb (SSDetect) vs. Gsb (T-84)

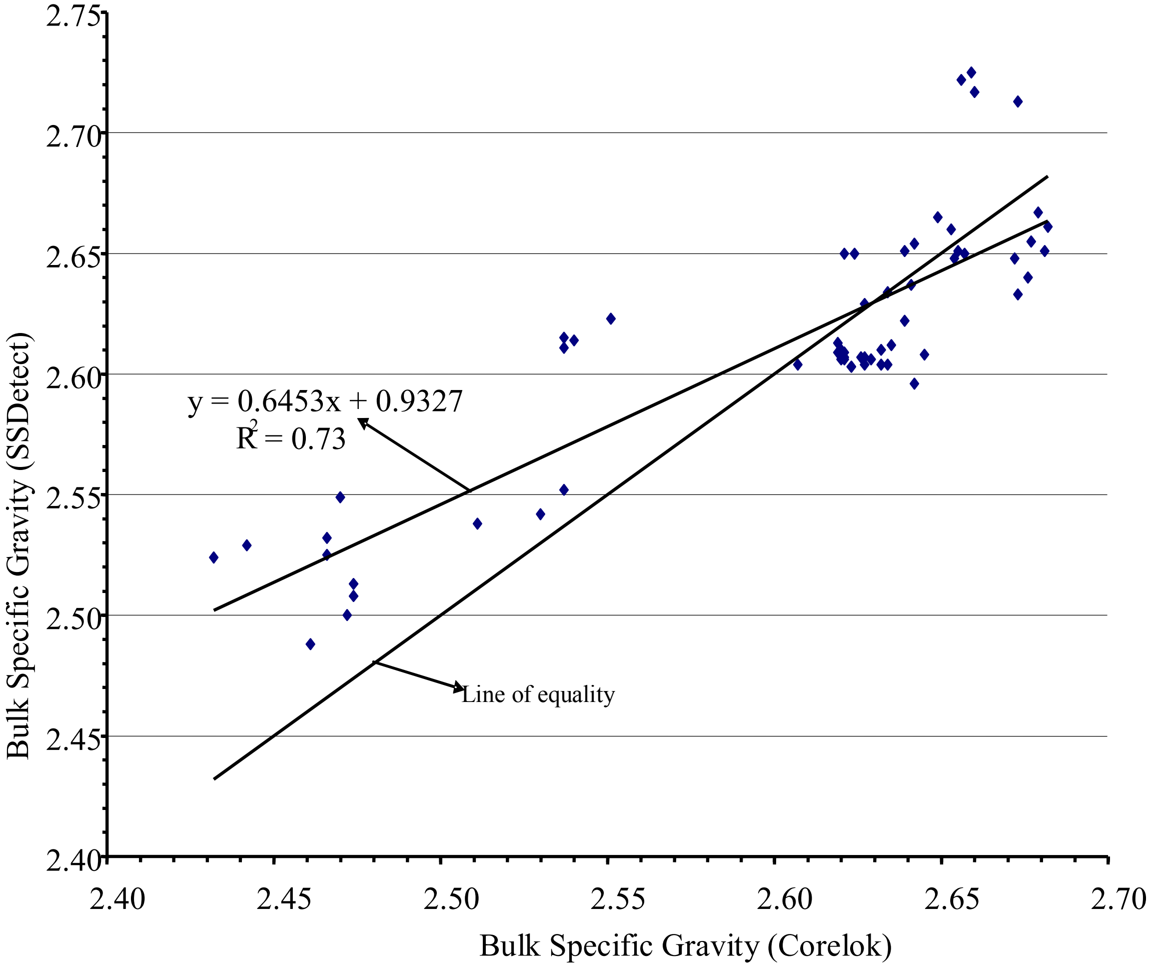

Figure 9. Gsb (SSDetect) vs. Gsb (CoreLok) Fine Aggregates

Apparent Specific Gravity

The results of the ANOVA for apparent specific gravity are shown in Table 14. The analysis indicates that there were no significant different in apparent specific gravity values in test method, operator or interaction. Figures 10, 11 and 12 show the relationship between the three procedures. The relationships are strong ($R^2 > 0.75$), supporting the ANOVA results that no statistically significant difference exists, between the three procedures for Gsa.

Table 14. Analysis of Variance for Apparent Specific Gravity Tests Corelok, SSDetect and AASHTO T-84

Source	Degrees Freedom	Sum Squares	Mean Square	F Ratio	Prob. > F
Test Method	2	0.0061	0.0030	1.57	0.210
Operator	1	0.0007	0.0007	0.38	0.540
Test M * Operator	2	0.0001	0.0001	0.04	0.965
Error	174	0.3348	0.0019		
Total	179	0.3417			

From the statistics shown in Table 8, it can be seen that the standard deviations were variable. One of the 15 sources was outside the multilaboratory precision range for AASHTO-T84. The CoreLok and SSDetect methods were more repeatable with no sources outside the multilaboratory precision range. Five sources were outside the single operator standard deviation for AASHTO T-84, one for CoreLok and none for SSDetect procedures.

The CoreLok procedure produced results within the acceptable range of results for a single operator for 12 of the 15 sources when compared to AASHTO T-84 and 15 of the 15 sources for multilaboratory situations. When comparing SSDetect to AASHTO T-84 results, 13 of the 15 sources were within the single operator range of acceptable results and 15 of the 15 sources were within the multilaboratory range.

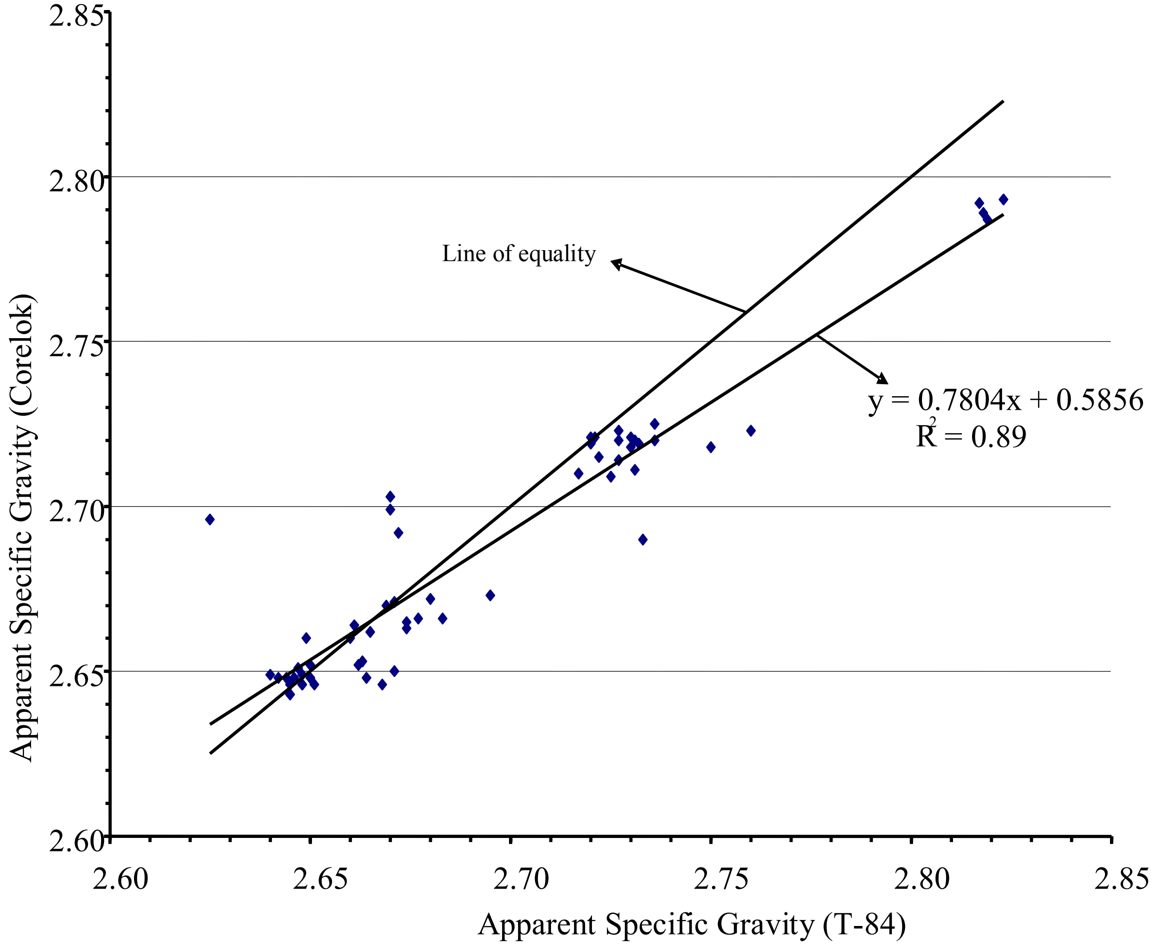

Figure 10. Gsa (T-84) vs. Gsa (CoreLok) Fine Aggregates

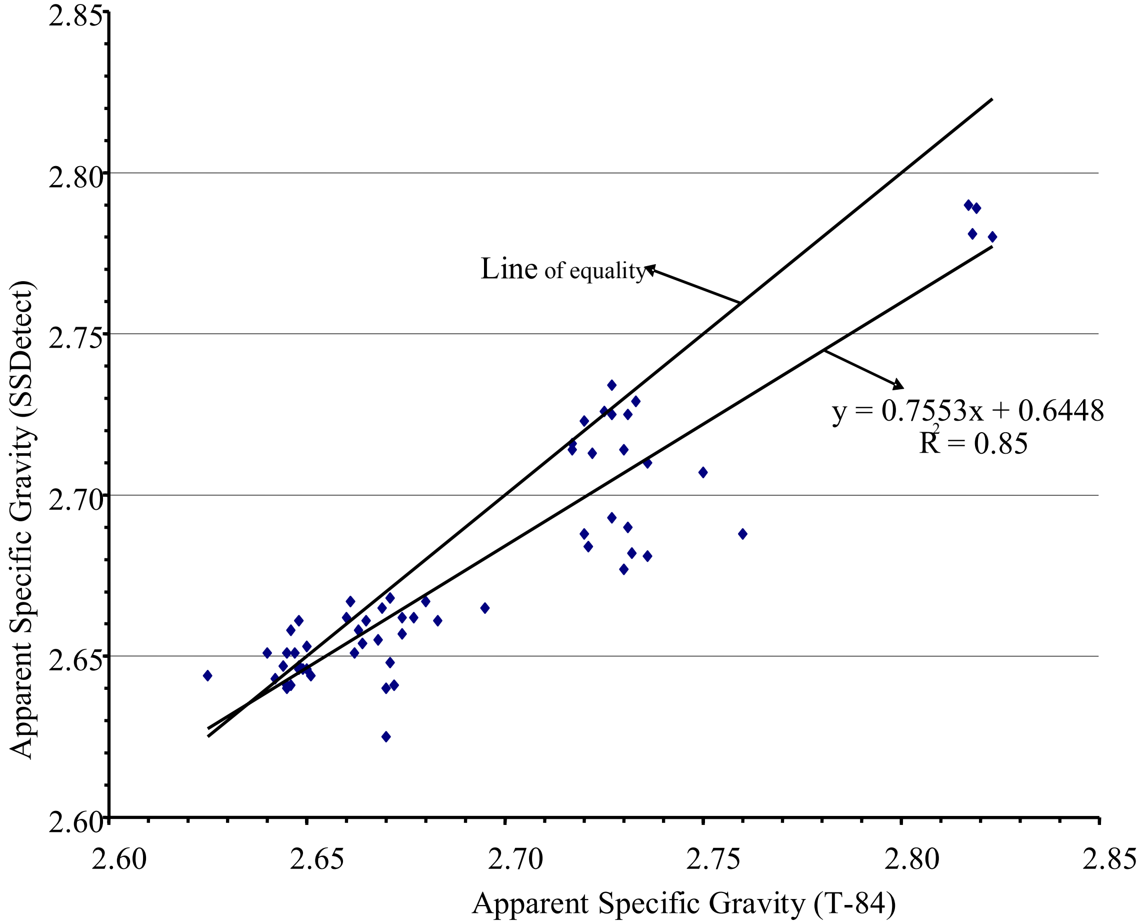

Figure 11. Gsa (SSDetect) vs. Gsa (T-84) Fine Aggregates

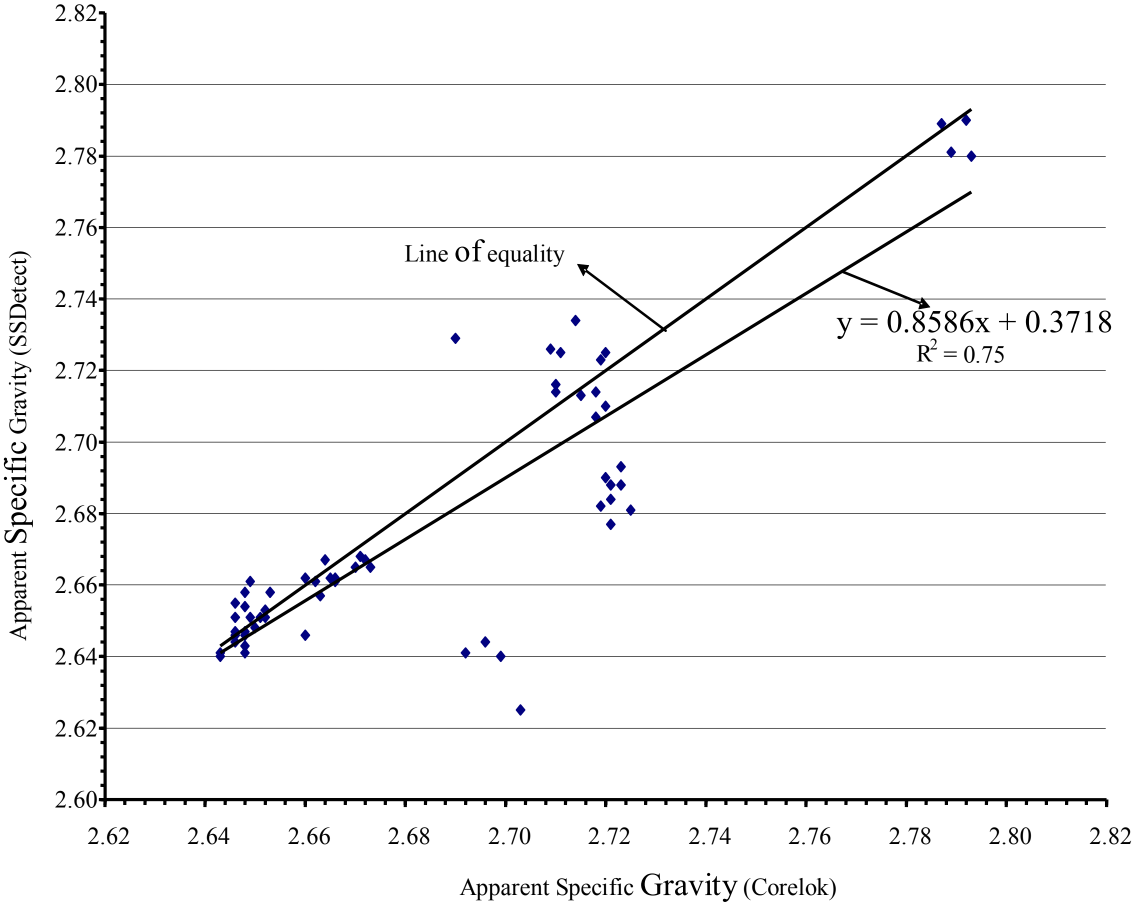

Figure 12. Gsa (SSDetect) vs. Gsa (CoreLok) Fine Aggregates

Percent Absorption

The results of the ANOVA for percent absorption are shown in Table 15. It can be seen that a statistical difference exists between test methods for absorption at a confidence limit of 99%.No statistical difference exists between operators or the interaction between test method and operator.

Table 16 shows the results from Duncan's Multiple Range Test. No statistical significant difference exists between SSD etect and Corelok method. A statistically significant difference exists between AASHTO T-84 and Corelok, and AASHTO T-84 and SSDetect methods.

Table 15. Analysis of Variance for Percent Absorption Tests Corelok, SSDetect and AASHTO T-84

Source	Degrees Freedom	Sum Squares	Mean Square	F Ratio	Prob. > F
Test Method	2	14.465	7.232	6.24	0.002
Operator	1	0.047	0.047	0.04	0.841
Test M * Operator	2	0.145	0.072	0.06	0.940
Error	174	201.774	1.160		
Total	179	216.430			

Table 16. Results of Duncan's Multiple Range Test for Fine Aggregate Percent Absorption Tests.

Grouping*	Mean Percent Absorption	N	Test Method
B	0.972	60	SSDetect
B	1.237	60	Corelok
A	1.660	60	T84

* Means with the same letter not significantly different

Figures 13 and 14 are plots of AASHTO T-84 versus CoreLok percent absorption and AASHTO T-84 versus SSDetect percent absorption. The results indicate that, at higher Gsa values, the CoreLok procedure tends to slightly underestimate absorption values compared to AASHTO T-84. The relationship has a coefficient of determination (R^2) of 0.70. Figure 14 shows that, at higher absorption values, the SSDetect method tends to underestimate the percent absorption values compared to AASHTO T-84. The relationship has a low coefficient of determination (R^2) of 0.47.

Figure 15 shows a plot of CoreLok versus SSDetect percent absorption. It can be seen that the CoreLok method overestimates the absorption values compared to SSDetect at high absorption values. The relationship has a coefficient of determination (R^2) of 0.78.

From the statistics shown in Table 8, it can be seen that the standard deviations were variable. Six of the 15 sources were outside the multilaboratory precision range for AASHTO T-84. The CoreLok and SSDetect methods were more repeatable with three and no sources outside the multilaboratory precision range, respectively. Ten of the 15 sources were outside the single operator standard deviation for AASHTO T-84, seven for

CoreLok and only one source for SSDetect, demonstrating better repeatability for the CoreLok and SSDetect procedures.

The CoreLok procedure produced results within the acceptable range of results for a single operator for five of the 15 sources when compared to AASHTO T-84 and for nine of the 15 sources for multilaboratory situations. When comparing SSDetect to AASHTO T-84 results, five of the 15 sources were within the single operator range of acceptable results and nine of the 15 sources were within the multilaboratory range.

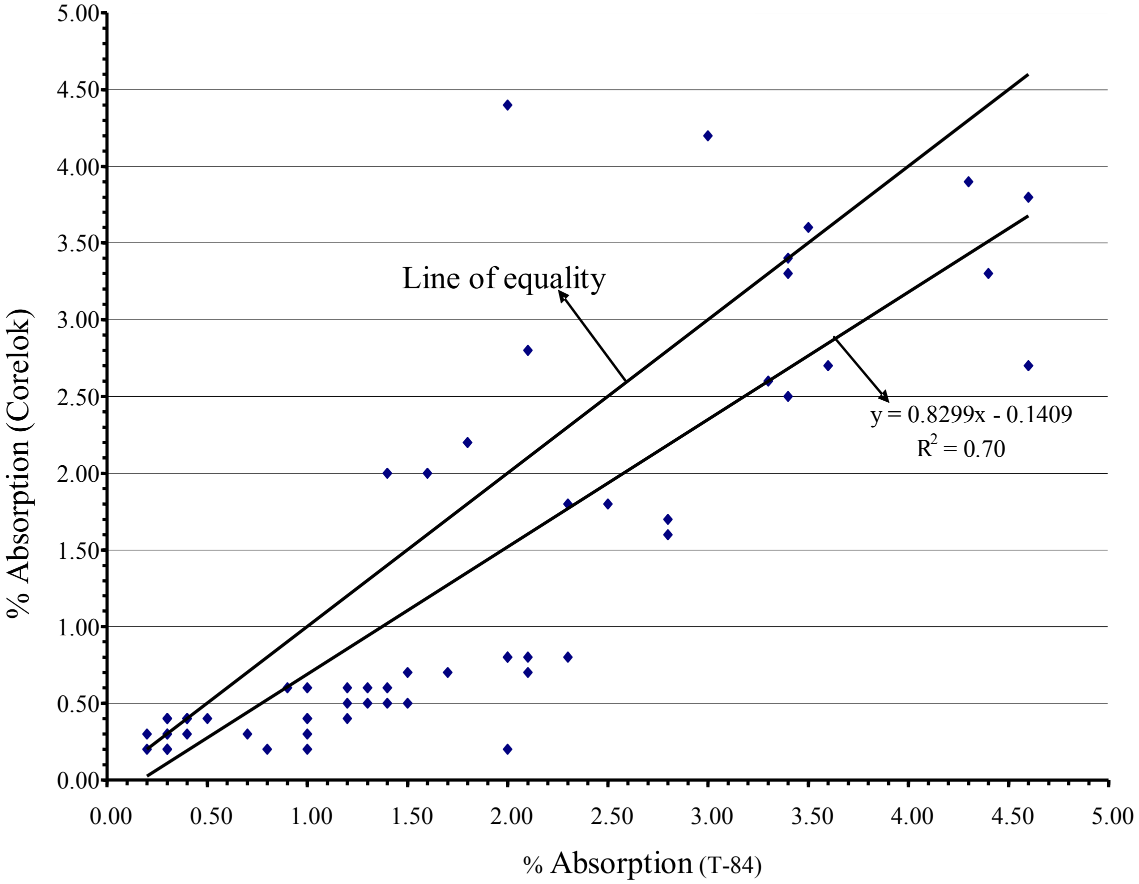

Figure 13. % Absorption (T-84) vs. % Absorption (CoreLok) Fine Aggregates

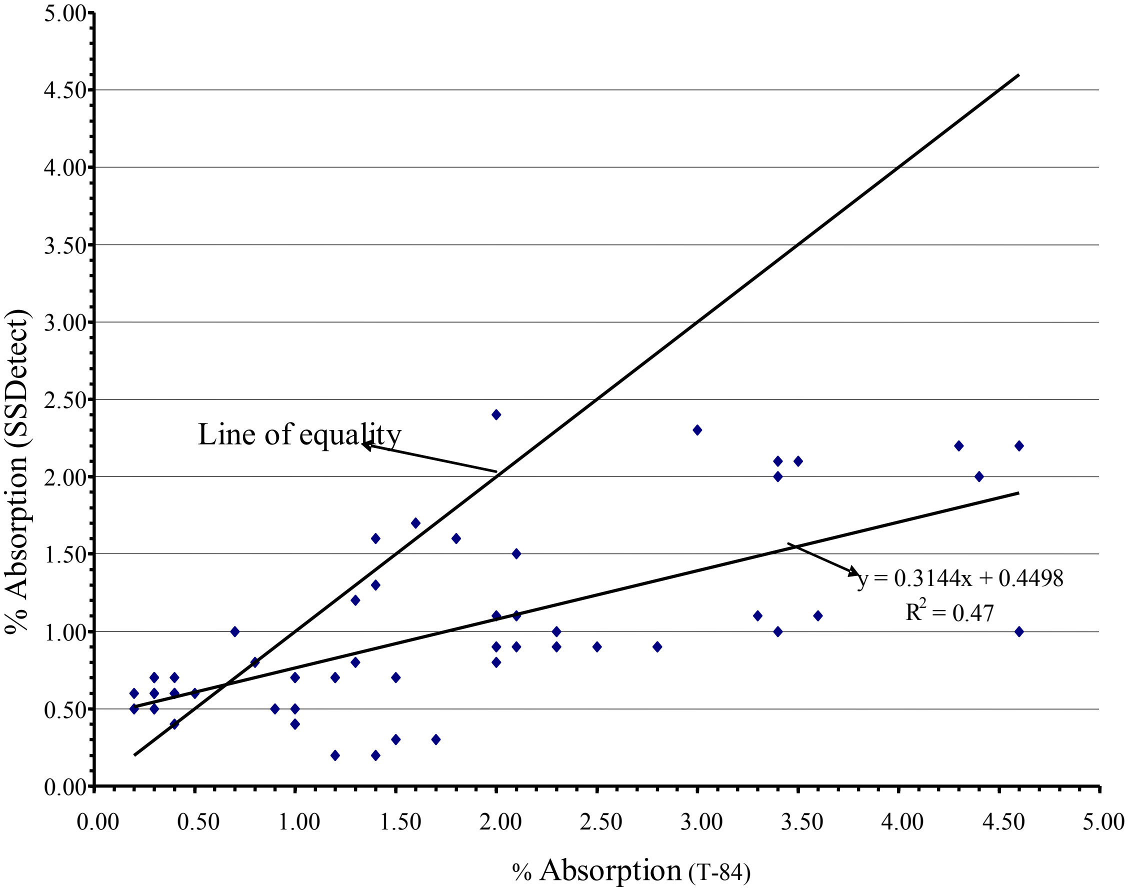

Figure 14. % Absorption (T-84) vs. % Absorption (SSDetect)

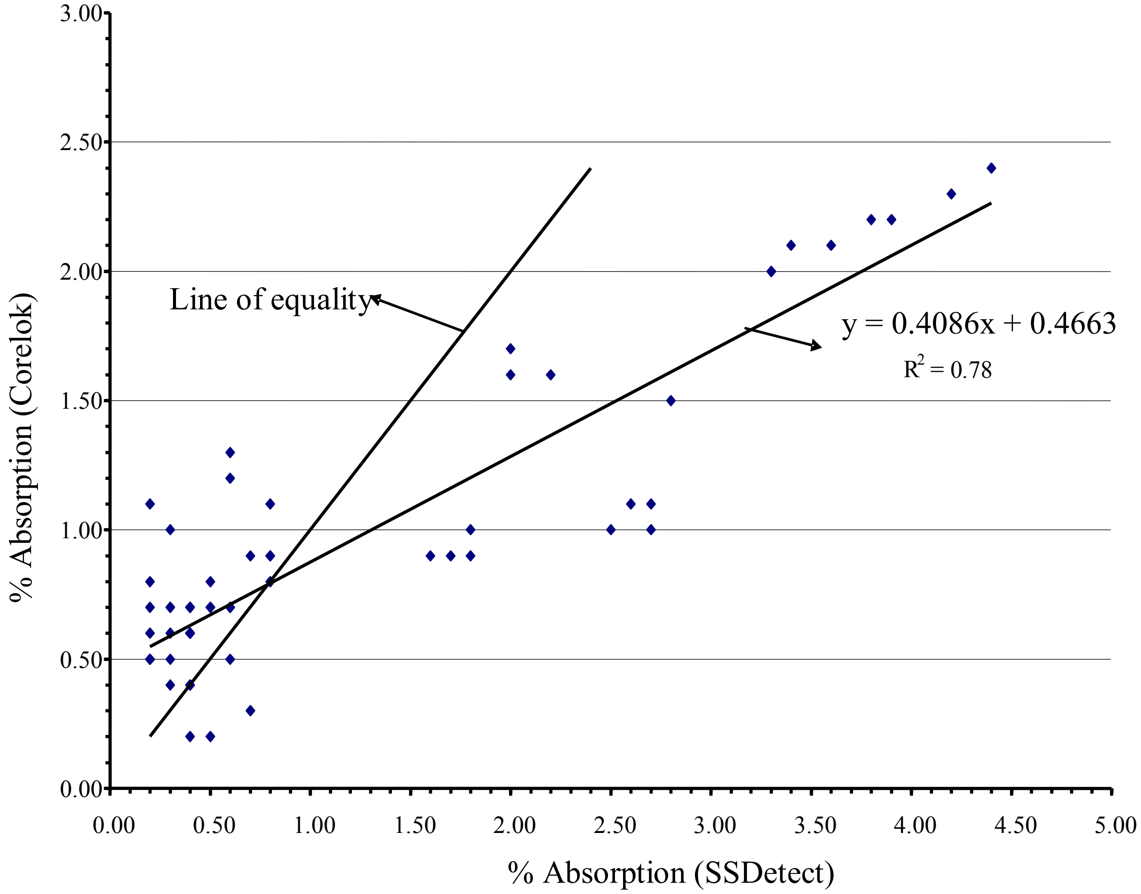

Figure 15. % Absorption (CoreLok) vs. % Absorption (SSDetect)

CHAPTER 8

CONCLUSIONS and RECOMMENDATIONS

Based on the test results obtained and analysis performed, the following conclusions are made concerning the evaluation of the AggPlus^{TM} system using Corelok Device and SSDetect system. There is a limitation for the data presented in this study, the aggregates used were all sampled in Oklahoma and test results were based on two operators.

Coarse Aggregates

1. CoreLok method was not statistically similar to AASHTO T-85 for bulk specific gravity and absorption test results.
2. CoreLok method tends to overestimate bulk specific gravity values compared to AASHTO T-85.
3. Operator and the interaction between test method and operator did not have significant effect on test results.
4. Overall, CoreLok method had the lower standard deviation than AASHTO T-85.
5. For all eight sources the standard deviations for CoreLok were within the single and multilaboratory precision limits. When comparing CoreLok Gsb to AASHTO T-85 Gsb, two of eight sources were within the acceptable range of

results for a single operator and four of eight sources were within multilaboratory limits.

Fine Aggregates

1. CoreLok method was statistically similar to AASHTO T-85 for bulk specific gravity test results.
2. CoreLok method was not statistically similar to AASHTO T-84 for Gsa and percent absorption test results.
3. SSDetect method was not statistically similar to AASHTO T-84 for bulk specific gravity, apparent specific gravity and absorption test results.
4. CoreLok method tends to overestimate bulk specific gravity values compared to AASHTO T-84.
5. SSDetect method tends to overestimate bulk specific test results compared to AASHTO T-84.
6. Operator or the interaction between test method and operator did not have significant effect on bulk specific gravity, apparent specific gravity and percent absorption test results.
7. Overall, SSDetect had the lower standard deviation than AASHTO T-84
8. Three sources were outside the single operator standard deviation for CoreLok and only one source was outside the multilaboratory precision range. Six of 15 sources were within the acceptable range of results for a single operator when compared to AASHTO T-84 and 14 of 15 sources were within the multilaboratory range.

9. Ten of 15 sources were within the single operator range of acceptable results for SSDetect when comparing SSDetect to AASHTO T-84 results, and eleven of 15 sources were within multilaboratory range.

RECOMMENDATIONS

1. It is not recommended to use either CoreLok or SSDetect procedure to replace traditional methods (AASHTO T-85 and T-84) at this time. More research should be performed in order to improve the accuracy of the Corelok and SSDetect methods before using the two procedures in the current specifications.
2. For the Corelok test, care should be taken during water displacement analysis especially for fine aggregates. There is a tendency of loosing fines during water displacement analysis therefore trained and experienced operators should only be allowed to perform this test if consistent results are desired.
3. For the SSDetect test readings should be taken from the same reference point (upper or lower meniscus) during automated vacuum mixing procedure in order to obtain consistent results.

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APPENDIX A

CORELOK PROCEDURES

<u>Procedure – *Fine Aggregates*</u>

A. STEP 1 – Calibrate the Volumeter (small container) for Fine Aggregate
(Illustrations on pgs. 23-24)

Important: Make certain the water temperature is 77±2 degrees Fahrenheit.

Important: Be sure your fixture and volumeter are on a level surface. Use a level indicator to set up the fixture position.

Note: Make certain you have all the necessary accessories. See attached picture for the required accessories.

Important: To achieve the best repeatability, it is extremely important that the empty volumeter temperature remains at 77±2 degrees Fahrenheit. A simple way to keep the volumeter at the correct temperature is to fill a 5-gallon bucket with 77±2 degrees Fahrenheit water. Before each test, rinse the empty volumeter in this water and dry it with a towel. This will quickly stabilize the volumeter temperature and will allow you to start your testing. This step is particularly important on very cold or very hot days, when the volumeter temperature can change drastically by the use of tap water or by normal changes in ambient temperature in the lab.

1. Place the volumeter in the fixture and push it back until it makes contact with the stops. Fill the small spray bottle with isopropyl (rubbing) alcohol.

Make sure the volumeter is pushed all the way back to the stops!

2. Fill the volumeter with water to the level of the line indicated inside the volumeter. Approximately 0.375” (3/8”) from the top. It is important that you keep the water level at or below the line to avoid spills during lid placement.
3. Using the alcohol spray bottle, spray the surface of the water to remove bubbles.
4. Gently place the lid on the volumeter with the 1/8” hole facing the front. Close the clamps.

When placing the lid on the bowl, make sure the 1/8-inch hole beside the lid post faces the front (see illustrations pg 23). Always locate lid this way.

5. Using the syringe, slowly fill the volumeter through he large hole through the lid post (**see illustration pg 21 & 23**). Make sure the syringe tip is far enough in the volumeter to be below the water level. Gentle application in this step prevents formation of air bubbles inside the volumeter.

6. Fill the volumeter until you just see the water coming out the 18” hole on the su8rface of the lid.
7. Wipe the excess water form the top of the lid with a towel.
8. Immediately place the entire fixture with the volumeter on the scale and obtain the weight.
9. Record the weight in the top portion of the Aggregate Worksheet on “Fine Aggregate Only” row.
10. Repeat the above steps 2 more times and average the weights.
11. If the range between the 3 calibration weights is larger than 0.5 grams, then you are not performing the test correctly. Check to see if the fixture is level. Make certain the water injection with the syringe is done below the volumeter water surface and is applied gently. Check the water temperature. Check the volumeter temperature. Repeat the test until you have three weights that are within 0.5-gram range.
12. Record the average of the three weights.
13. The volumeter and the fixture are now calibrated and ready for testing. Re-calibrate the volumeter prior to changes in each aggregate source or a minimum of once per week.

B. Step 2 – Test Fine Aggregate sample

(Illustrations pgs. 25-28 Volumeter Procedure & pgs 35-37 CoreLok Procedure)

Again, be sure your fixture and volumeter are level.

1. Oven dry a sufficient quantity of aggregate to perform this test. A single test may require 2500 grams of sample. Split the sample into four portions. You will need two or three 500-gram samples for the test in the volumeter and one 1000-gram sample for vacuum test in the CoreLok.

Note: Oven dry the sample for a minimum of 24 hours at 105ºC. You can make certain you have completely dried the sample to a constant weight by periodically weighing the sample.

2. Cool the sample to 77±2º F. Use appropriate state or national standard procedure to split the sample.

It is important that proper splitting technique be used for dividing the test samples.

3. Submerge the volumeter (bowl and lid) into a 77±2º F rinse water to stabilize the temperature. Completely dry the AggPlus volumeter inside and out.

Important: Steps 6 through 16 shall be completed within 2 minutes. Increased test time will affect the accurate determination of absorption during this process.

4. Weigh a 500±1 gram of oven dry material and record in column A of the worksheet. Make certain the aggregates are at 77±2 degrees Fahrenheit. Do not test the aggregates if they are still hot.
5. Place the empty dry volumeter in the fixture and push the volumeter until it makes contact with the stops.

Make sure the volumeter is pushed all the way back to the stops.

6. Place approximately 500 ml (halfway full) of 77±2 º F water in the volumeter.
7. Slowly and evenly pour the sample into the volumeter.

Caution: Make certain you don't lose any aggregate in the process of filing the volumeter. Use the provided pouring container to help in transferring the aggregate into the AggPlus volumeter. Use the provided brush to sweep the remaining fines into the volumeter. If you loose any aggregates in the process of filling the volumeter you will have to start the test over.

8. Use the provided aluminum spatula and push it to the bottom of the volumeter against the inside circumference.
9. Slowly and gently drag the spatula to the center of the volumeter, removing the spatula after reaching the center.
10. Repeat this same procedure 7 more times so that the entire circumference is covered in 8 equal angles, i.e. every 45 degrees until the starting point is reached. If necessary use a squeeze bottle to rinse any sample residue off the spatula into the volumeter.
11. Fill the volumeter with water to the level of the line indicated inside the volumeter. Approximately 0.375" from the top. It is important that you keep the water level at or below the line to avoid spills during lid placement.
12. Use the spray bottle filled with isopropyl alcohol and spray the top of the water to remove air bubbles.
13. Gently place the lid on the volumeter and lock the clamps.

When placing the lid on the volumeter, make sure the 1/8-inch hole beside the lid post faces the front. Do this each time you perform this test.

14. Using the syringe, slowly fill the volumeter through the large center hole on top of the lid. Make sure the syringe tip is far enough in the volumeter to be below the water level. Gentle application in this step will prevent formation of air bubbles inside the volumeter (**see pg 21 & 23**).
15. Fill the volumeter until you just see water coming out the 1/8" hole on the surface of the lid.
16. Wipe the excess water from around the 1/8" hole with a towel.

Note: <u>Do not</u> wipe water from the rim of the volumeter if it seeps between the lid and volumeter. Allow this water to remain on fixture.

17. Immediately weight the volumeter and the fixture. Record this weight in column B of the worksheet.
18. Repeat steps 4 to 17.
19. If the difference in weight of column B for the two samples tested is less than or equal to 1 gram, go to step 21.
20. Repeat steps 4 to 17, if the column B weights for the first two tests, is larger than 1 gram.
21. Average the weights in column A and then average the weights in column B of the worksheet. Use the average values when using the AggSpec program.
22. Set the CoreLok unit to run on Program 1 (all settings of Program 1 are preset at the factory). Note: The CoreLok unit is setup at the factory to run this and other tests. Simply run program 1. For varying the settings use the Menu key and the Up or Down arrows.

Important: For the following test you need a large water tank with the InstroTek cushioned weighing basket connected to a scale capable of reading to ±0.1 gram. The temperature of the water should be maintained at 77±2 º F. The bath should be setup with an overflow system to correct for variations in weight resulting from changes in the water level.

23. Place the three white filler plates into the CoreLok chamber. The plates fit in the chamber without touching the sealing bar assembly. Rotate them 90º if they touch or are above the sealing bar assembly.
24. Tear a small bag from the roll. Inspect the bag to make sure there are no holes, stress points or discontinuity in the side seals. Never use damaged bags.
25. Weigh the bag. Record the weight in column C.
26. Column D asks for rubber sheet weight. These are normally only used with coarse aggregates to prevent punctures. Enter ‘0’ unless rubber sheets were used.

Caution: Always handle the bag with extreme care to avoid creating weak points and punctures.

27. Weigh 1000±1 grams of aggregate and record the weight in column E.
28. Place the sample in the small bag. Support the bottom of the bag on a smooth tabletop when pouring to protect against puncture and impact points.
29. Place the bag inside the CoreLok.
30. Grab the two sides of the bag and spread the sample flat by gentle shaking.

Important: Do not use your hand to press down or spread the sample from outside the bag. Pressing down on the sample from outside the bag will cause the bag to puncture and will negatively impact your results.

31. Place the open end of the bag over the seal bar and close the chamber door.
32. After the chamber door opens, gently remove the sample from the chamber.
33. Immediately submerge the sample in the water tank for water displacement analysis.

Note: It is extremely important that you remove the sample form the CoreLok and immediately place it in the water bath. Leaving the bag in the CoreLok or on a bench top after sealing can cause air to slowly enter the bag and can result in low apparent gravity measurements.

34. Cut one corner of the bag, approximately 1 to 2 inch from the side while the top of the bag is at least 2" down in the water. Make sure the bag is completely submerged before cutting. Introducing air into the bag will produce inaccurate results.
35. Open the cut portion of the bag with your fingers and hold open for 45 seconds. Allow the water to freely flow into the bag. Allow any small residual air bubbles to escape. Do not shake or push on the bag. This ation can make the fines escape from the bag.
36. After water has filled in, cut the other corner of the bag approximately 1-2 inches. Squeeze any residual air bubbles out of the cut corners by running your fingers across the top of the bag.
37. Place the bag containing the aggregate on the weighing basket in the water to obtain the under water weight. You may fold the bag to place it on the basket. However, once on the basket under water, unfold the bag and allow water to freely flow into the bag. Keep the sample and bag under water at all times.

Caution: Make certain the bags or the sample are not touching the bottom, the sides, or floating out of the water tank. If the bag contacts the sides it can negatively impact the results of this test.

38. Allow the sample to stay in the water bath for ten (15) minutes.
39. Record the submerged weight and wait one minute. If after this time the weight increases by more than one-gram wait an additional five minutes. Record the weight and continue this process until the weight stops increasing.

Note: In our experience fine aggregate samples should stabilize in less than 15 minutes. However, there might be some aggregates that require a longer soak time.

40. Record the submerged weight in column F.
41. Open the AggSpec program.
42. Be sure that Fine Aggregate is selected.
43. Enter the weights from the Worksheet for sample A and B (average of two or three tests) into the program. The program will calculate the apparent density, percent absorption, Bulk Specific Gravity (SSD) and Bulk Specific Gravity (Bsg). If you have used the rubber sheets for your test, make sure that the rubber Vc is entered correctly. You may export the data into an Excel spreadsheet template and print the data as well as other functions provided under the excel program. Simply click on "Export to Excel" and the AggSpec program will automatically pull the data into Excel.
44. If your absorption is zero, there might be two problems. First, the results (apparent gravity) of your vacuum test in the bag is low. There might have been a puncture in the bag. Repeat the test in the bag under vacuum with another 1000-gram sample. Second, you are possibly spending more than 2 minutes performing the tests in the volumeter or the temperatures during the test. Increased test time during the volumeter test will cause the weights in column B to be higher than the actual values. Repeat this test with another 500-gram sample paying special attention to time and temperature (sample, water and volumeter).

Procedure – *Course Aggregates*

C. STEP 1 – Calibration of the Large Volumeter for Coarse Aggregate

(Illustrations pgs. 29-30)

Important: Make certain the water temperature is 77±2 degrees Fahrenheit.

Caution: Be sure your volumeter is on a level surface. Use a level indicator to setup the volumeter position!

Note: Make certain you have all the necessary accessories. See picture for the required accessories.

Important: To achieve the best repeatability, it is extremely important that the empty volumeter temperature remains at 77±2 degrees Fahrenheit. A simple way to keep the volumeter at the correct temperature is to fill a 5-gallon bucket with 77±2 degrees Fahrenheit water. Before each test, rinse the empty volumeter in this water and dry it with a towel. This will quickly stabilize the volumeter temperature and will allow you to start your testing. This step is particularly important on very cold or very hot days, when the volumeter temperature can change drastically by the use of tap water or by normal changes in ambient temperature in the lab.

1. Fill the large volumeter with water to the top of the volumeter.
2. Place the lid on the volumeter gently pressing it down so that water flows through the hole in the lid post. Be sure the lid is well seated by gently rotating the lid on top of the volumeter.
3. Make sure the small 1/8" hole on the lid is facing forward. Use the provided syringe and fill the container through the large hole in the post until water starts to flow through the small 1/8" hole.
4. Wipe the excess water from the volumeter with a towel. Place on a towel to wipe water from the bottom of the unit.
5. Place the volumeter filled with water on the scale and obtain the weight.
6. Record the weight in the top portion of the Aggregate Worksheet, on "Coarse Aggregate Only" row.
7. Repeat the above steps 2 more times and average the weights.
8. If the range in these weights is larger than 1.0 gram, then you are not performing the test correctly. Check to see if the volumeter is level. Check the water temperature. Check the volumeter temperature. Repeat the test until you have three weights that are within a 1-gram range.
9. Record the average weight on the worksheet.
10. The volumeter is now calibrated and ready for testing. Re-calibrate the volumeter prior to changes in each aggregate source or a minimum of once per week.

D. STEP 2 – Testing Coarse Aggregate samples

(Illustrations on pgs 31-33 Volumeter & pgs 35-37 CoreLok procedure)

Be sure your volumeter is on a level surface by checking with a level.

1. Oven dry a sufficient quantity of aggregate to perform this test. A single test may require 5000 grams of sample. You will need two or three 1000 grams samples for tests in the volumeter and one 2000-gram sample for vacuum test in the CoreLok.

Note: Oven dry the sample for a minimum of 24 hours at 105° C. Make certain you have achieved constant weight.

Note: This test is designed for washed coarse aggregates. For coarse aggregates with high fine content or blended aggregates, small adjustments have to be made to the procedure. Contact InstroTek for more information on these procedures.

2. Cool the sample to 77±2° F. Use appropriate state or national standards to split the sample into three individual 1000 gram and one 2000 gram samples.

Important: Steps 4 through 10 should be completed within 2 minutes. Increased test time without the lid on the volumeter will affect the accurate determination of absorption during this process.

3. Weigh 1000±2 grams of the oven dry material and record weight in column A of the worksheet.
4. Fill the volumeter halfway with 77±2º F water.
5. Slowly and evenly distribute the sample into the volumeter. Make sure the water completely covers the aggregate.
6. Using the aluminum spatula gently move the aggregate sample around to ensure that there is no trapped air between the particles.
7. Fill the volumeter with water to the top and spray with rubbing alcohol to remove air bubbles.
8. Place the lid on the volumeter and press gently so that water flows smoothly from the post and the sides. Continue to press until the lid is properly seated. Rotate the lid on top of the volumeter making sure good contact is achieved and the 1/8" hole is facing forward.
9. Using the syringe, slowly fill the volumeter through the large center hole on top of the lid. Make sure the syringe tip is far enough in the volumeter to be below the water level. Gentle application in this step will prevent formation of air bubbles inside the volumeter (**see pg 21 & 23**).
10. Wipe the excess water from the volumeter with a towel. Place the volumeter on a towel to dry the bottom. Do not tilt or spill any of the water in the volumeter.
11. Obtain the total weight of the volumeter, aggregate, and water and record in column B of the worksheet.
12. Repeats Steps 3 to 10.
13. If the difference in weight in column B for the two samples tested is less than or equal to 2 grams, go to step 13.
14. Repeat steps 3 to 10, if the first two test with the volumeter indicate weights that are more than 2 grams from each other.
15. Average the weights in column A and then average the weights in column B of the worksheet and use this average when entering numbers in AggSpec software.
16. Set unit to run on Program 1 (all settings of Program 1 are preset at the factory). Note: The CoreLok unit is setup at the factory to run this and other tests. Simply run program 1. For varying the settings use the Menu key and the Up or Down arrows.
17. Place the three white filler blocks into the CoreLok chamber. The plates fit in the chamber without touching the sealing bar assembly. If they appear too close to the seal bar or are above the seal bar, rotate them 90º.
18. Tear one large bag and one small off bag rolls. Inspect each bag for holes and tears.
19. Weigh the bags (one large and one small). Record the total weight in column C.
20. Weigh the two rubber sheets and record the weight in column D.

21. Weigh approximately 2000±2 grams of aggregate and record in column E.
22. Place the sample in the small bag. When filling, support the bottom of the bag on a tabletop to protect against puncture and impact points.
23. Place the large bag into the CoreLok chamber, then place one of the rubber sheets in the large bag. The rubber sheet should be flat, centered, and pushed all the way to the back of the large external bag.
24. Place the bag containing the sample into the large external bag centered on top of the rubber sheet.
25. Use your hand and spread and flatten the sample in the internal small bag. Be sure area taken up by the sample inside the small bag remains completely contained within the area of the rubber sheet.
26. Place the other rubber sheet on top of the small internal bag inside the large external bag.

Note: The internal bag should be completely sandwiched between the two rubber sheets. The rubber sheets are cut to a size so as to not cover the opening of the small bag. If the rubber sheets cover the small bag opening this will restrict the airflow from the bag causing error in the readings.

27. Place the open end of the large external bag over the seal bar and close the chamber door.
28. After the chamber door opens, gently remove the sample from the chamber.
29. Immediately place the sample in the water, for water displacement analysis.
30. Cut one corner of the bag, approximately 3 to 4 inch from the side. Make sure the bag is completely submerged before cutting. Introducing air into the bag will produce inaccurate results.
31. Open the cut portion of the large bag and the uncut small bag with your fingers and hold open for 25 seconds. Allow the water to freely flow into the bag. Allow any small residual air bubbles to escape from the bag.
32. After water has filled in, cut the other corner of the bag approximately 3-4 inches. Squeeze any residual air bubbles out of the cut corners by running your fingers across the top of the bag.
33. Place the bags containing the rubber sheets and the aggregate on the provided weighing basket under water. You may fold the bag to place it on the basket. However, once on the basket under water, unfold the bag and allow water to freely flow into the bag.

Caution: Make certain the bag or the sample are not touching the bottom, the sides, or floating out of the water tank. If the bag contacts the sides it can negatively impact the results of this test.

34. Allow the sample to stay in the water bath for twenty (20) minutes.

35. Record the submerged weight and wait one minute. If after this time the weight increases by more than one-gram wait an additional five minutes. Record the weight and continue this process until the weight stabilizes.

Note: In our experience most aggregates are fully saturated after 20 minutes. However, we have seen some aggregates with more than 8% absorption that requires longer soak times.

36. If your aggregate size is such that more than 2000 grams need to be tested, repeat steps 3-28. Average the results of the tests for the total aggregate amount required by ASTM C127 and AASHTO T-85.

Note: AggPlus tests should only be done with 2000 g or less samples.

37. Open the Gravity Suite program and select AggSpec.
38. Enter the average weight on the container with water only above the chart.
39. Enter sample identification. Tab over and select “coarse” aggregate.
40. Fill in columns 3 and 4 with the average weight (2 or 3 test) from column A and B of the worksheet.
41. In column 5 the combined weight of the rubber sheets is entered. The **first time** you try to enter this weight, a window will appear saying you must enter a value for “rubber sheet VC”. This value is the density of the rubber sheets and is written on the sheets (gm/cm^3). Select OK. Click on ‘EDIT’ and then select ‘SETTINGS’. You now must enter a password – the password is **density**. In the next window, enter the numerical value from the rubber sheets and click OK. **Tab back to the rubber sheet weight column and enter the combined weight of the sheets.** The ‘Rubber Sheet VC’ will display above the chart and will not need to be re-entered for future tests unless the rubber sheets are replaced or damaged. As a precaution, record the rubber sheet density value in this manual in case it wears off the rubber sheets.
42. Continue by entering the weights from the worksheet and the sealed sample weight. The program will calculate the apparent density, percent absorption, Bulk Specific Gravity (SSD) and Bulk Specific Gravity (Bsg).
43. You may export the data into an Excel spreadsheet template and print the data as well as other functions provided under the excel program. Simply click on “Export to Excel” and the AggSpec program will automatically pull the data into Excel.
44. If your absorption is zero, there might be two problems. First, the results (apparent gravity) of your vacuum test in the bag is low. There might have been a puncture in the bag. Repeat the test in the bag under vacuum with another 1000-gram sample. Second, you are possibly spending more than 2 minutes performing the tests in the volumeter or the temperatures during the test (of water, sample or volumeter) is changing drastically during the test. Increased test time during the volumeter test will cause the weights in column B to be higher than the actual values. Repeat this test

with another 500-gram sample paying special attention to time and temperature (sample, water and volumeter).

SSDETECT PROCEDURES

Pump Priming Procedure

Your SSDetect utilizes a methodology that requires the use of distilled water. This water can be purchased locally.

This procedure must be followed after the reservoir has been filled and prior to operating the unit. Before priming the pump, the reservoir should be filled with distilled water.

1. Place a small beaker or container under the injection tubing (See Figure 8).
2. Close lid and turn power on. When the screen is activated and displays "Barnstead/Thermolyne SSDetect", immediately touch screen anywhere to enter into advanced functions.
3. "Manual Controls" will be displayed.
4. Press LEFT ARROW until "Prime Pump" is displayed.
5. Press ENTER.
6. Press START to begin priming pump.
7. Prime pump until water starts exiting through the injection tubing and bubbles are no longer preset in the injection tubing. (This will insure that all air has been removed from the injection tubing). Allow approximately two minutes for this process.
8. Press STOP to end pump priming or the unit will self time out in approximately 10 minutes.
9. If the pump will not prime, it is sometimes necessary to bleed the water supply feed line into the pump. Return to step 6 to begin the pump priming again.
10. Turn unit off and wait 5 seconds before restoring power. The unit will be in a normal operation mode when the power is turned back on.

Pump Calibration Procedure

1. The calibration process needs to be performed upon initial startup. Pump calibration should be verified on a monthly basis after the initial calibration.
2. Fill the water reservoir to the bottom of the rubber gasket and attach the cover.
3. Turn on the power switch on the rear of the unit.
4. When Barnstead/Thermolyne is displayed, immediately press the center of the screen to go to the Manual Controls screen.

5. Press right arrow key to advance to the Pump Calibration screen and press the enter key.
6. Place a clean, pre-weighed container capable of holding 50 ml of liquid under the nozzle in the lid to collect the water. Position the container so as to minimize splashing.
7. Press the start key to begin the water collection cycle. Pump will inject 3000 times.
8. At the end of the collection cycle, remove the container and place it on a scale to obtain the total weight. Subtract the empty container weight obtained in step 5 from this value and enter the resulting amount in grams, as directed on the touch screen, using the up and down arrow keys. Press the exit key to end the routine. Pump calibration is now complete.

Unit Calibration Procedure

1. Unit should be powered on and allowed to warm up for the displayed 30 minute warm up period.
2. Remove the injection muzzle from the water tubing. Screw the nozzle into the lid containing the sapphire lenses. Take care NOT to cross thread the nozzle in the lid.
3. Screw the water tubing back onto the injection nozzle.
4. Turn unit off and wait for several seconds. Turn unit back on and press on the center of the screen when Barnstead Termolyne SSDetect is shown. Unit will enter into manual controls mode.
5. Press the left arrow on the display screen until “Unit Calibration” is displayed. Press enter.
6. The screen will display “Unit Calibration, press skip to enter value manually”. Press skip to OBSERVE the value currently entered into the system. Make certain there is a value entered. The value should be approximately .140-.200. If no value is entered, manually enter a value of .177.
7. Press “exit” to leave this screen.
8. Press OK to revert back to the Unit Calibration screen. Press Enter to being unit calibration.
9. The screen will now display “Press skip or start”. Press the Start button.
10. The screen will now display “Insert aggregate for unit calibration”. Mount the test bowl onto the mixing platform of the SSDetect by centering the bowl on the platform with the square protrusion on the side of the bowl. Push down slightly 9on the “D” ring in the center of the bowl and turn ¼ clockwise to latch bowl to platform.
11. Using the calibration sand that was included with the SSDetect, measure 500 grams of this material and place in test bowl. Place lid on bowl securely.
12. Close SSDetect chamber door and latch. Press Start to begin calibration test. This test should take approximately 40 minutes to complete.
13. Unit will beep when calibration test is complete. Press OK to end.
14. Refill water reservoir after unit calibration test.

This procedure is automatic and the unit will store the calibration data upon completion. The unit calibration procedure should be performed monthly.

Theory Of Operation

The Barnstead Thermolyne SSDetect System is a two-part automated system for developing the data necessary to determine the Bulk Specific Gravity and absorption of fine aggregates. This system is based on a dry to wet method unlike the traditional wet to dry method.

1. Begin by acquiring two samples of the material to be tested. Each sample should be 500 grams +/- .1 gram and should be completely dried.
2. The first sample is placed in the volumetric flask included with the system. The material is poured in and weighed after 250 mL of water have already been placed in the flask.
3. Wait 5 minutes, fill to calibration line and weigh. Record this weight.
4. Place the flask on the mixing platform of the Automated Vacuum Mixer and insert stopper with vacuum hose. Press start. The unit will begin to mix and vacuum, at different levels of vacuum, for 11 minutes and stop.
5. Refill the flask to calibration line and weigh. This is the Apparent Specific Gravity weight. Subtract the initial weight of the flask from the final weight.
6. Apply the difference to the following mathematical formula: $52+(4*X)-(0.11*X*X)$ using the difference in flask weights as "X". The number developed from this formula will be used as a "Film Coefficient" that will be input into the SSDetect device.
7. While the AVM is running, place the other 500 gram sample into the test bowl for the SSDetect.
8. Weigh the bowl and material as a total and record the weight.
9. Mount the bowl onto the mixing platform inside the SSDetect. Place the lid on the bowl, close the door of the SSDetect and enter the "Film Coefficient" into the display screen when ready. Press Start.
10. The SSDetect will begin to mix the material inside the bowl by using an orbital motion. While material is flowing in a counter clockwise direction in the bowl, the SSDetect will begin to inject water into the flow of material 8 ul per injection. This is a very small stream of water. While the water injection is occurring, an infrared source of a specific wavelength that is absorbed by water or "tuned to water", is looking at the surface of the aggregate for signs of water.

The water being injected into the river of material flowing in the bowl is being absorbed into the pores of the aggregate through capillary action and hysteresis. These forces act very strongly to pull water into the aggregate pores quickly. Once the pores have filled and water begins to gather on the surface of the aggregate, the infrared signal detects the water and is absorbed. This means that the infrared detection device on the system will no longer see the reflection of the infrared signal as it is being absorbed by the water. Once the SSD condition has been recognized by the system, the unit will automatically stop and signal the user that the test has ended. The bowl can then be removed from the system and weighed. This value is the weight of the material at SSD.

You have now determined all of the values necessary to determine Apparent Specific Gravity, Bulk, Specific Gravity Dry and Bulk Specific Gravity at SSD. These can all be determined in 90 minutes or less.

The use of infrared energy or a light source to detect very small traces of particular elements is a science that has been available for many, many years. Barnstead International manufactures a full line of Fluorometers and Spectrophotometers, so we are quite experienced with this type of equipment and its applications. This type of technology is used today in many applications to repeatedly detect certain elements down to parts per million.

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Candidate for the degree of

Master of Science

Thesis: EVALUATION OF THE AGGPLUS^{TM} SYSTEM AND SSDETECT SYSTEM AGAINST THE CURRENT AASHTO T-84 AND T-85

Major Field: Civil Engineering

Biographical:

Education: Graduated from Mkwawa High School, Iringa, Tanzania in May 1994; received Bachelor of Science degree in Chemical and Process Engineering from the University of Dar-es-salaam, Dar-es-salaam, Tanzania in November 1999. Received Master of Science degree in Environmental Engineering from the University of Wisconsin, Milwaukee, Wisconsin in June 2003. Completed the requirements for the Master of Science degree with a major in Civil Engineering at Oklahoma State University in (May, 2005).

Experience: Employed by Oklahoma State University, Department of Civil and Environmental Engineering as a graduate research assistant, Oklahoma State University, Department of Civil and Environmental Engineering January 1, 2004 to January 15, 2005.

Professional Membership: Oklahoma State University Civil Engineering Society

Name: Msengi K. Mgonella Date of Degree: May, 2005

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: EVALUATION OF THE AGGPLU^{TM} SYSTEM AND SSDETECT SYSTEM AGAINST THE CURRENT AASHTO T-84 AND T-85

Pages in Study: 90 Candidate for the Degree of Master of Science

Major Field: Civil and Environmental Engineering

Current AASHTO T-85 and T-84 procedures for determination of bulk specific gravity and absorption of coarse and fine aggregates are time consuming and repeatability is poor especially for angular fine aggregates with high absorption and rough surface texture. A total of eight coarse and 15 fine aggregate sources from Oklahoma were selected for evaluation of the Aggplus^{TM} system using the CoreLok device and the SSDetect system

The objectives of this study were to determine if either the Aggplus^{tm} system or the SSDetect system could produce statistically similar results to the current AASHTO procedures.

It was concluded that the CoreLok procedure for fine aggregate was the only procedure that produced statistically similar results to the AASHTO T-84 procedure. Also, It was concluded that the CoreLok and SSDetect methods for determining bulk specific gravity show better repeatability compared to AASHTO T-85 and T-84 and offer significant time savings over traditional methods.

ADVISOR'S APPROVAL: __Stephen A. Cross____________________