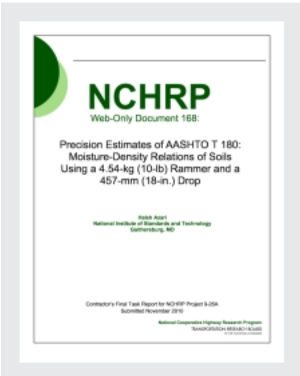
NCHRP
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Precision Estimates of AASHTO T 180: Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop

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DETAILS

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Oklahoma Department of Transportation, Oklahoma City, Oklahoma
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Other Participating Laboratories:
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NTH Consultants, Ltd., Farmington Hills, Michigan
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ABSTRACT

This report presents the results of an interlaboratory study (ILS) and data mining of Proficiency Sample Program (PSP) to prepare precision estimates for AASHTO T180 test method used for determining the relationship between the moisture content and density of soil materials. The materials for the ILS included two coarse- and two fine-grained soil-aggregate mixtures that were prepared according to Grading A and Grading E of AASHTO M147, "Materials for Aggregate and Soil-Aggregate Subbase, Base, and Surface Courses." Each of the blends had less than 10% material passing #200 sieve opening to represent suitable base and subbase materials. The materials used for PSP included three sets of lean clay with sand with each blend having about 85% materials passing #200 sieve opening. The comparison of statistics of the maximum dry density and optimum moisture content from ILS and PSP data indicated that the variability of the maximum density increases with the level of coarseness and the variability of the optimum moisture content increases with the level of fineness. It was also observed that the variability of optimum moisture content of clayey blends is higher than those of silty blends. A precision statement for AASHTO T180 including precision estimates computed from the ILS and PSP statistics has been prepared and provided in the report.

CHAPTER 1- INTRODUCTION AND RESEARCH APPROACH

1.1 Background

Under the National Cooperative Highway Research Program (NCHRP) Project 09-26A, the AASHTO Materials Reference Laboratory (AMRL) is conducting a multi-phase research project to determine or update estimates of precision of selected AASHTO test methods. The AASHTO T180 standard test method, “Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop” [1] is among the test methods that lack precision estimates. The test method is used to determine the required degree of compaction and a method to obtain the required compaction of soil-aggregate mixtures. An interlaboratory study (ILS) was designed to develop the precision estimates for AASHTO T180. The precision statistics from analysis of AMRL soil proficiency sample data [2] were also incorporated in the development of the AASHTO T180 precision statement provided in this report.

1.2 Problem Statement

The design and control of compaction of soils is an important aspect of a pavement construction process. The level of accuracy in which a degree of compaction of soil-aggregate mixture is specified has a significant effect on the performance of a pavement as a whole. Currently, there are no precision estimates that would define the accuracy requirements for laboratory measurement of maximum density and optimum water content as specified in AASHTO T 180. Therefore, this study aims to determine repeatability and reproducibility precision of maximum density and optimum moisture content measured according AASHTO T 180 test method.

1.3 Research Objectives

The overall objective of this study is to determine precision estimates for the AASHTO T 180, “Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop” test method. The change in precision estimates of maximum density and optimum water content with the change in soil-aggregate type and gradation is also being investigated.

1.4 Scope of Study

The scope of the project involves the following major activities:

I. Design and conduct an interlaboratory study (ILS):
   a. Select four soil-aggregate mixtures using two different grading (coarse and fine) and two types of filler (silt and clay) that satisfy the grading requirements of pavement base and subbase (Chapter 2).
   b. Conduct preliminary testing on the selected materials (Chapter 2).
   c. Produce 420 specimens to send to 35 participating laboratories for the ILS

(Chapter 2).

d. Prepare instructions for testing the specimens.

e. Analyze ILS results and develop precision estimates for maximum dry density and optimum moisture content (Chapter 3).

II. Analyze AMRL Soil Classification and Compaction Proficiency Sample Program (PSP) data to develop precision estimates for maximum density and optimum moisture content. The data used were obtained according to AASHTO T180 or ASTM D1557 [3] test methods in the past three years (Chapter 4).

III. Recommend a precision statement for AASHTO T180 based on the precision estimates developed from ILS and PSP data (Chapter 5).

IV. Make conclusions and recommendations based on the findings of the study (Chapter 6).

CHAPTER 2- DESIGN AND CONDUCT OF THE ILS

The AASHTO T180 standard test method is intended for determining the relationship between the moisture content and density of soils when compacted with 4.54-kg (10-lb) rammer, dropped from a height of 457 mm (18 in.). Four alternative procedures, Methods A through D, are provided in the test method for determining the soil moisture content- density relationship. The differences between the four procedures are in the size of the molds and the gradation of the soil. Methods A and B applies to fine-graded soil blends passing 4.75-mm sieve, and Methods C and D applies to coarse-graded soil blends passing 19.0 mm sieve. Methods A and C provides instructions for compacting each of the soil types in a 4" mold and Methods B and D provides instructions for compacting each of the soil types in a 6" mold.

The AASHTO Subcommittee on Materials has requested the precision estimates of AASHTO T180 to be determined for Method B and Method D, which are specific to compacting fine- and coarse-grained soil blends in 6" mold. The following sections will report the details of the design of an ILS specific to the two methods. The approach used for the design of the ILS was based on ASTM E691 [4], "Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method." The development of the precision statement for T 180 required participation of a minimum of 6 laboratories with a preferred number of 30 as specified in E691.

2.1 Materials Selection

The materials used in the study were blended according to the Grading A and Grading E requirements of AASHTO M 147, "Materials for Aggregate and Soil-Aggregate Subbase, Base, and Surface Courses" [5]. The Grading A, which is a coarser gradation was used for preparing samples for Method D of AASHTO T 180. The Grading E, which is a finer gradation, was used for preparing samples for Method A of AASHTO T180. Four blends were prepared according to the two fine and coarse gradations. The fine-graded blends had a 4.75-mm nominal maximum aggregate size and the coarse blends had a 19.0-mm nominal maximum aggregate size. The two fine blends were similar in gradation but different in type of mineral filler (material passing # 200 sieve) used. While one blend had silt as a mineral filler, the other blend had clay. Similarly, the two coarse blends, which were similar in gradation had different mineral fillers, either silt or clay. The amount of filler was limited to 7% in all four mixtures to meet a requirement for good quality subbase and base materials. The gradations of the four mixtures as well as Gradings A and E from AASHTO M 147 are provided in Table 2-1. The sources of aggregate materials utilized in the study and their classifications according to AASHTO M 145 [5] are provided in Table 2-2.

Table 2-1. Gradation of ILS fine and coarse blends and Grading E and A of AASHTO M147

Sieve Size	Fine w/Clay	Fine w/Silt	Grading E	Coarse w/Clay	Coarse w/Silt	Grading A
1"	100.0	100.0	100	100.0	100.0	100
1/2"	100.0	100.0	100	90.0	90.8	-
3/8"	100.0	100.0	100	64.0	64.0	30-65
# 4	99.8	99.8	55-100	45.9	46.9	25-55
#8	45.2	46.2	-	29.8	30.8	-
# 10	41.6	42.5	40-100	23.6	24.6	15-40
# 40	22.5	23.0	20-50	11.3	11.8	8-20
# 200	7.1	6.9	6-20	7.0	7.0	2-8

Table 2-2. Sources and classifications of ILS soil-aggregate blends according to AASHTO M145

Soil-Aggregate-Type	Soil-Aggregate Classification (AASHTO M145)	Materials	Source
Fine-Graded (**Grading E of AASHTO M147)**	A3	Crushed Limestone (particle size passing #4 and retained on #8)	Lafarge Frederick, MD
		Washed Concrete Sand (Natural Sand Passing #8)	Aggtrans in Hanover, MD
		Lean Clay (CL)	Aggregate Transport Corporation in Harwood, MD
		Silt (ML)	U.S. Army Corps of Engineers, Waterways Experimental Station in Vicksburg, MS
Coarse-Graded (**Grading A of AASHTO M147)**	A1	Crushed Limestone	Lafarge Frederick, MD
		Manufactured Fine Aggregate (Limestone Buell Dust)	Lafarge Frederick, MD
		Lean Clay (CL)	Aggregate Transport Corporation in Harwood, MD
		Silt (ML)	U.S. Army Corps of Engineers, Waterways Experimental Station in Vicksburg, MS

2.2 Preliminary Study of AASHTO T180

A preliminary study was conducted at the AMRL laboratory to examine the compactibility of the selected materials and the rationality of the measured density and optimum moisture contents. Three replicates of each of the four materials were compacted using a 4.54-kg manually-operated rammer according to procedures B and D of AASHTO T 180. Prior to the compaction, specific gravity of the soil-aggregate blends were determined according to AASHTO T 84 and T 85 [1]. The specific gravity values were used to calculate the percent moisture that results in 100% saturation of the blends. The measured specific gravities are provided in Table 2-3.

Table 2-3. Specific gravities (Gsb) of the soil-aggregate components and blends

Materials	Specific Gravity
Fine	
Crushed Limestone (+ # 4)	2.765
Sand (- #200)	2.680
Sand (- # 4 to + # 200)	2.682
Silt and Clay (- #200)	2.675
Blend	**2.682**
Coarse	
Limestone Buell Dust (+ # 4)	2.722
Limestone Buell Dust (- #200)	2.675
Limestone Buell Dust (- # 4 to + # 200)	2.714
Silt and Clay (- #200)	2.673
Blend	**2.715**

The soil-aggregate blend samples for compaction were prepared by first drying the blends in the oven at 60°C (140°F). Representative samples of appropriate size, 7 kg (16 lb) for fine-graded blend and 11 kg (25 lb) for coarse graded blend, were taken to be moistened for compaction. Each sample was prepared at initial moisture content of about 2%. The test specimens were then compacted in approximately five equal layers. After compaction and testing of the first moisture content trial, the compacted samples were broken up into particles small enough to pass a 4.75-mm (No. 4) or 19-mm sieve depending on the gradation of the blends. An increment of water (about 1.5%) was added to obtain the appropriate water content and to re-compact the material for the second trial. The testing process involving breaking up the compacted soil and adding water increments for further re-compactions was continued until sufficient test points were acquired to draw the compaction curve.

The compaction curves resulted from compactions of the four soil-aggregate blends in the preliminary study are demonstrated in Figure 2-1. The maximum density and optimum water content of the four blends are shown in Table 2-4. As indicated from the compaction curves and the values in the table, the coarse blends achieved higher maximum density at lower optimum moisture content than the fine blends. In addition, the blends with silt demonstrated higher optimum moisture content than the blends with clay. Based on the rationality of the compaction results, the tested blends were selected for the interlaboratory study.

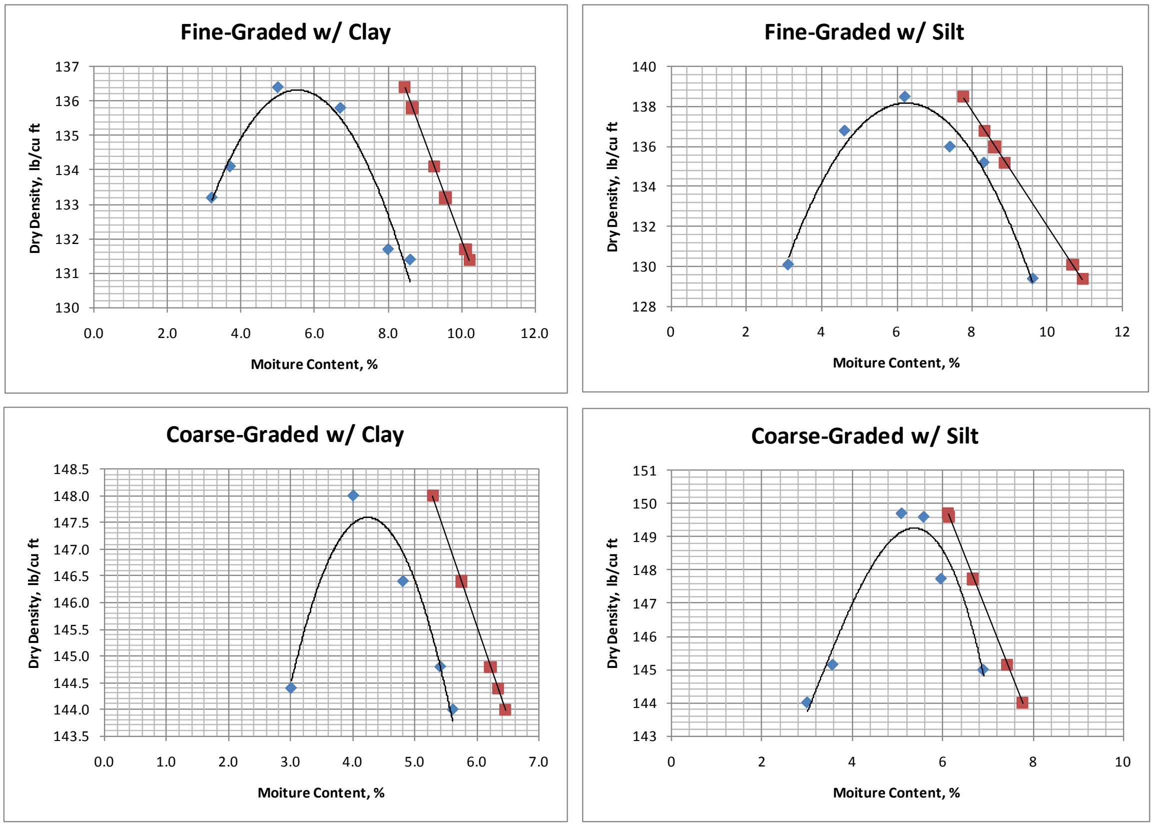

Figure 2-1. Compaction curves and 100% saturation line of samples in the preliminary study

Table 2-4. Optimum moisture content and maximum density values from the preliminary study

Soil-Aggregate Type	Dry Density, lb/ft^3	Moisture, %
Fine-Graded w/ Clay	136.4	5.6
Fine-Graded w/ Silt	136.1	6.2
Coarse-Graded w/ Clay	147.6	4.3
Coarse-Graded w/ Silt	149.3	5.4

2.3 Participating Laboratories

Hundreds of laboratories that are certified by the AASHTO Accreditation Program (AAP) [2] for soil and aggregate testing were contacted and invited to participate in the T180 ILS. The laboratories were ranked by their scores earned through accreditation process. Thirty-five laboratories including commercial, governmental, and research laboratories with the maximum score of 5 were selected to participate in the study.

2.4 Interlaboratory Sample Preparation and Shipping

The ILS samples were prepared by AMRL staff in the Proficiency Sample Facility located at the National Institute of Standards and Technology (NIST) using procedures developed for the AMRL Proficiency Sample Program [2]. A total of four hundred twenty samples were prepared to be sent to the 35 selected laboratories. Each laboratory received 12 samples that consisted of three replicates of each of the four soil-aggregate blends. The coarse blend samples weighed about 14 kg and the fine blends samples weighed about 9 kg. The laboratories were asked to take representative samples of 11 kg (25 lbs) and 7 kg (16 lbs) for testing from the coarse and fine blends, respectively.

2.5 Interlaboratory Study Instructions

Laboratory participants were provided with the testing instructions and data sheets to record the data. The laboratories were requested to follow Method B and Method D of T 180 to compact the three replicates of the four soil-aggregate blends at 5 different moisture contents. In addition to maximum density and optimum moisture content, the laboratories were asked to report all the measured weights and computed dry density and moisture content values. The moisture contents used in the study were selected based on the optimum moisture content of the blends that were determined as part of the preliminary study. The laboratories were asked to prepare the blends at 5 different moisture contents; two below the optimum, two above the optimum, and one at about the optimum. The interval between the consecutive moisture contents was asked to be kept at 1.5%. The specific gravity values of the blends (Table 2-3) for calculating the 100% saturation line were given to the laboratories. The instructions and the data entry sheet are provided in Appendix A.

CHAPTER 3- **INTERLABORATORY TEST RESULTS AND ANALYSIS**

3.1 Test Data

The maximum density and optimum moisture content test data are provided in Table B-1 and Table B-2 of Appendix B. Empty cells in the tables indicate that the laboratory did not submit data. Twenty-one laboratories submitted full sets of data for coarse-graded blends (CC and CS). Twenty-two laboratories submitted full sets of data for fine-graded blend with clay (FC) and twenty-three laboratories submitted full sets of data for the fine graded blend with silt (FS).

The maximum dry density and optimum moisture content and their corresponding error bands are displayed in Figure 3-1 and Figure 3-2. It is indicated from the figures that the amount of error in determining maximum density is much smaller than the amount of error in determining optimum moisture content.

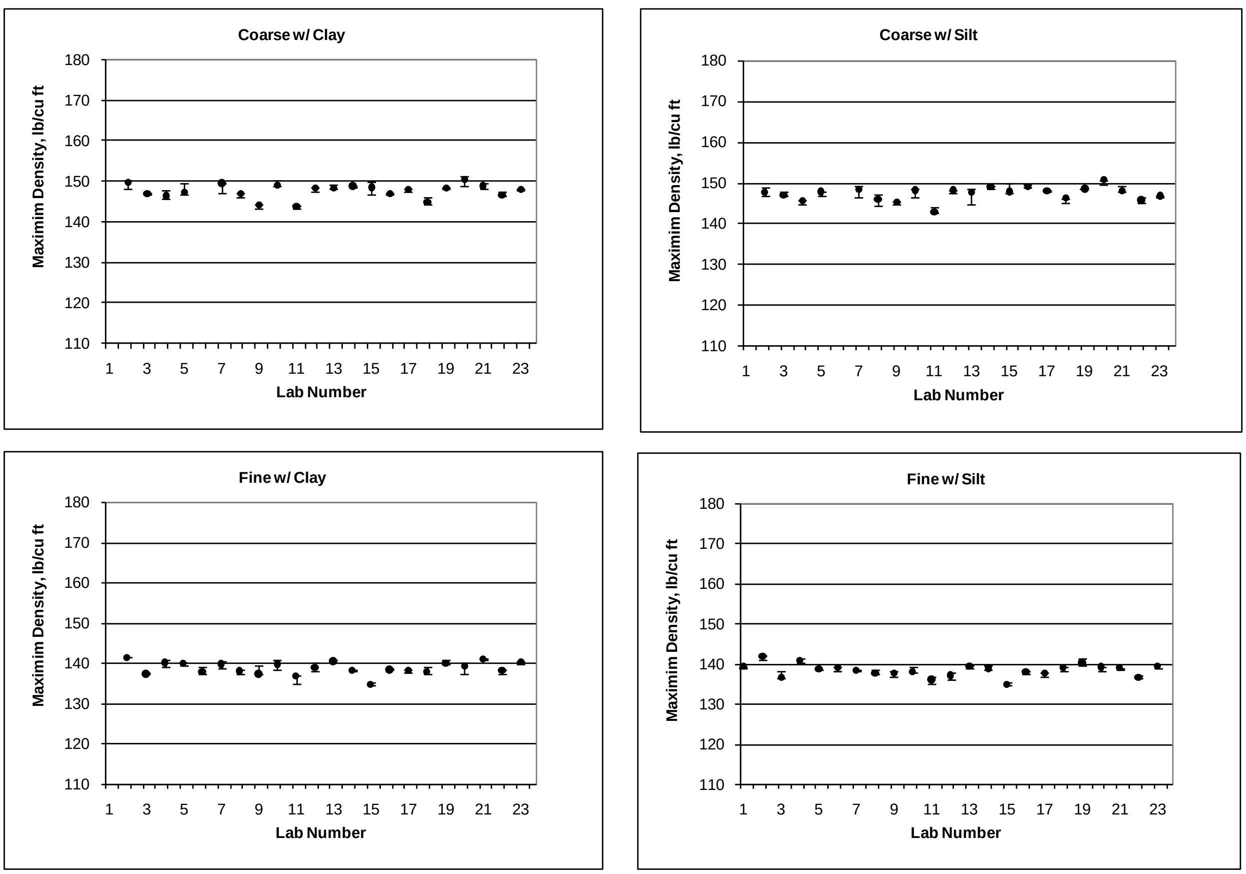

Figure 3-1. Maximum density values (lb/cu ft) and their corresponding error bands

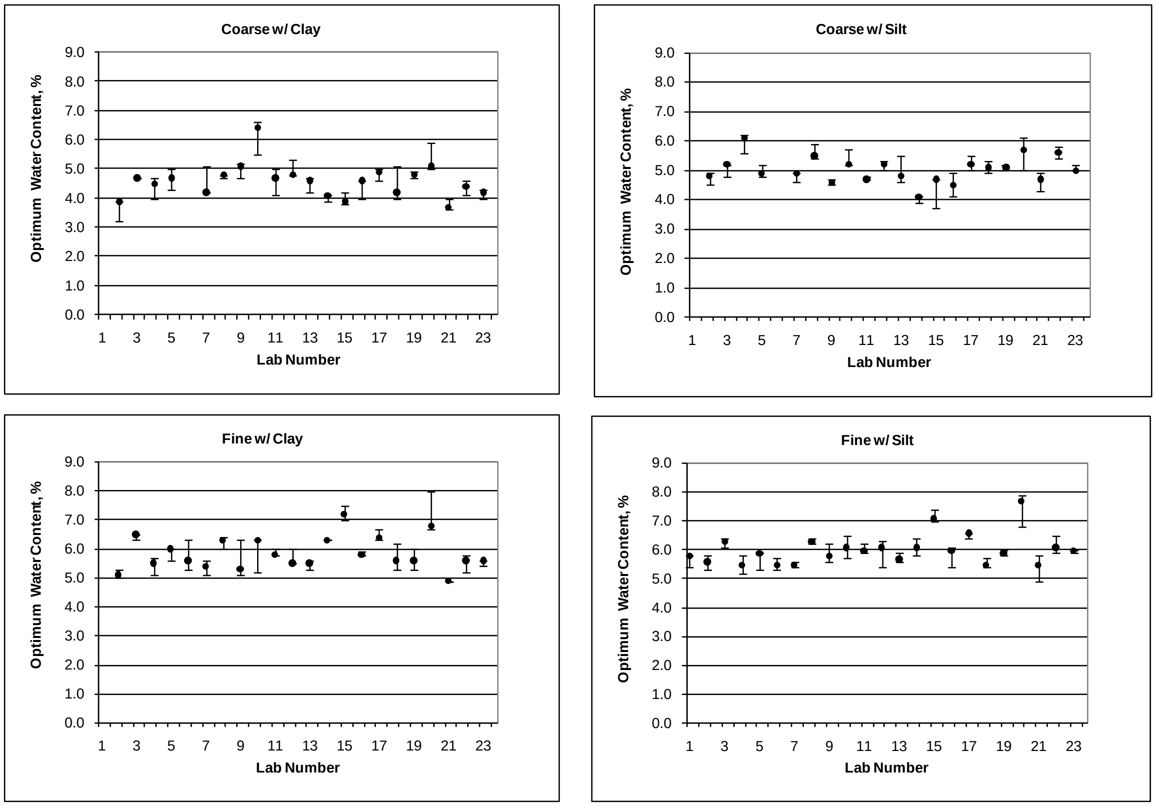

Figure 3-2. Optimum Moisture Contents (%) and their corresponding error bands

3.2 Method of Analysis

Test results of the ILS were analyzed for precision in accordance to ASTM E 691[4]. Prior to the analysis, any partial sets of data were eliminated by following the procedures described in E691 in determining repeatability (S_r) and reproducibility (S_R) estimates of precision. Data exceeding critical *h* and *k* values were eliminated from the analysis, where, as described in E 691, the h-statistic indicates the between-laboratory consistency and the k-statistic indicate the within-laboratory consistency of the measurements. Once identified for elimination, the same data were eliminated from any smaller subsets analyzed.

3.3 Precision Estimates

Precision estimates of maximum density and optimum moisture content were determined after eliminating the outlier data. One set of data were eliminated from the maximum density and 2 sets of data were eliminated from the moisture content analysis based on the exceedance of the computed from critical h- and k-statistics. The eliminated data are shown shaded in Table B-1 and Table B-2 of Appendix B and are shown in Figure 3-3 and Figure 3-4. All remaining data were re-analyzed according to E691 method to determine the S_r and S_R precision estimates shown in Table 3-1 and Table 3-2.

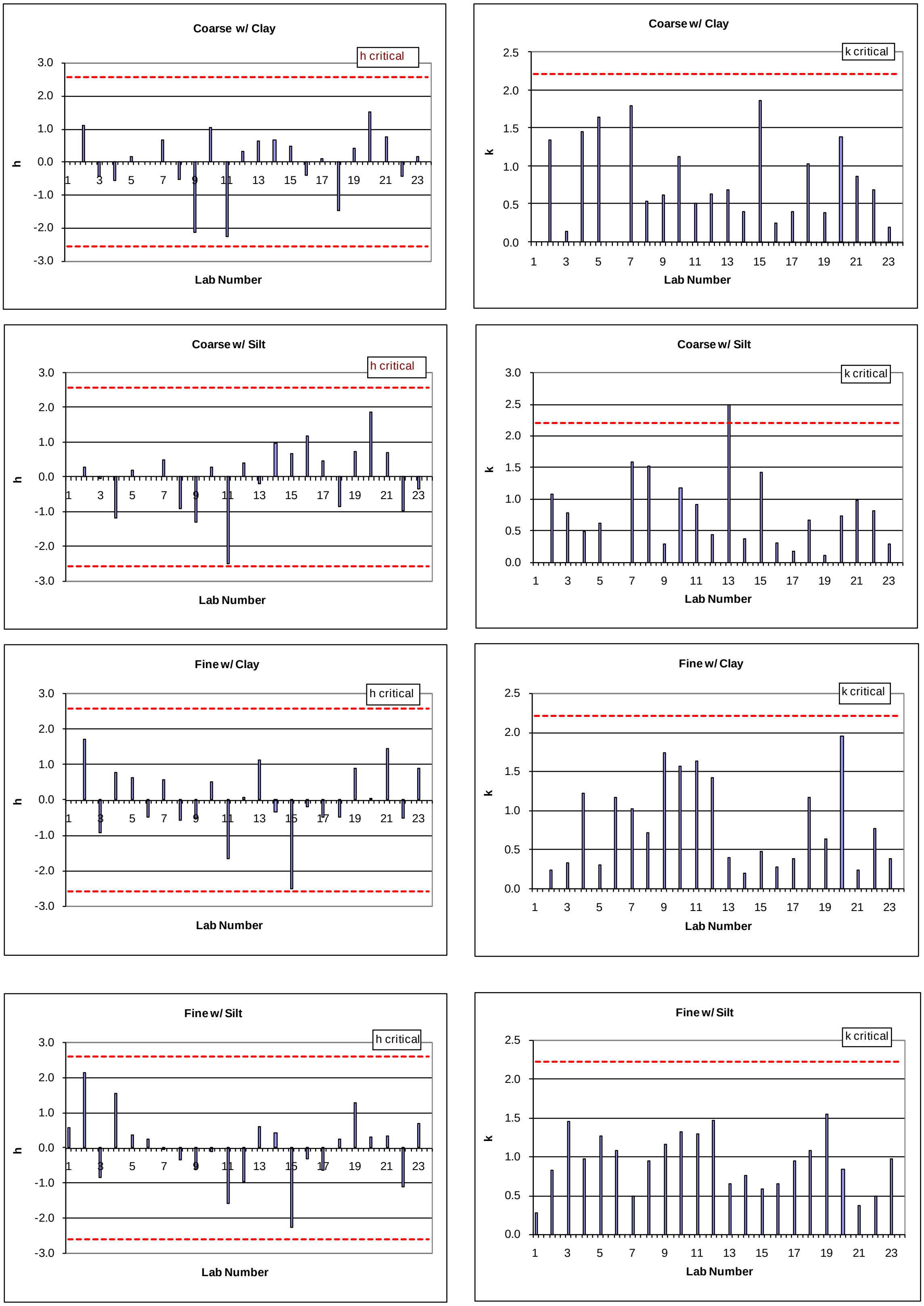

Figure 3-3. h and k consistency statistics of maximum density from ILS

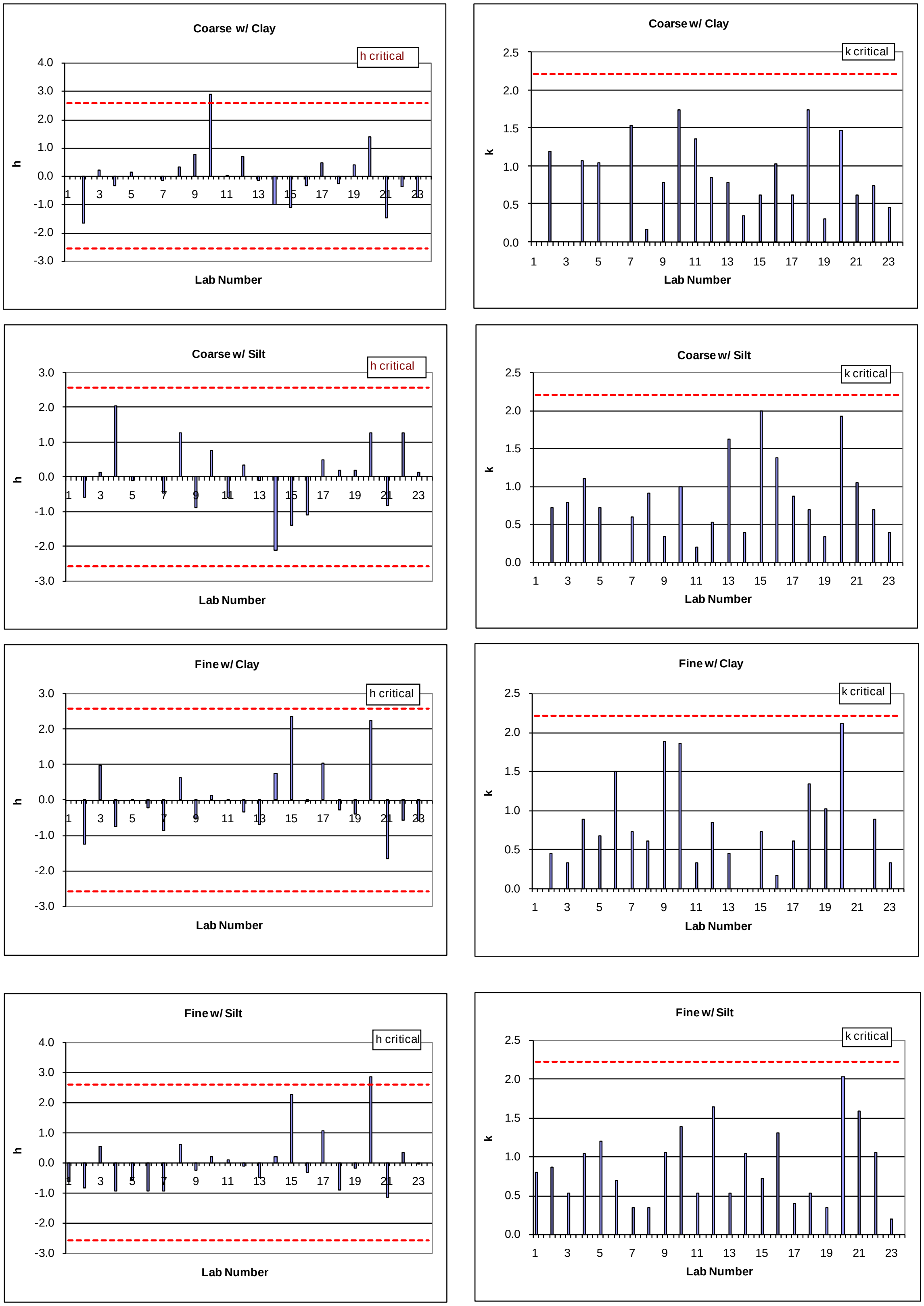

Figure 3-4. h and k consistency statistics of optimum moisture content from ILS

Table 3-1. Summary of Statistics of maximum dry density (lb/cu. ft.) from ILS

Sample Type	# of Labs	Average	S_x	CV %	Repeatability (S_r)		Reproducibility (S_R)	
					1s	d2s	1s	d2s
Coarse Aggregate w/Clay	21	147.7	1.71	1.16	0.81	2.26	1.89	5.34
Coarse aggregate w/ Silt	21	147.3	1.68	1.14	0.74	2.06	1.83	5.17
Fine Aggregate w/ Clay	22	139.0	1.54	1.11	0.74	2.08	1.71	4.83
Fine Aggregate w/ Silt	23	138.5	1.52	1.09	0.62	1.73	1.63	4.62

Table 3-2. Summary of Statistics of optimum moisture content (%) from ILS

Sample Type	# of Labs	Average	S_x	CV %	Repeatability (S_r)		Reproducibility (S_R)	
					1s	d2s	1s	d2s
Coarse Aggregate w/Clay	21	4.5	0.42	9.41	0.34	0.94	0.49	1.38
Coarse aggregate w/ Silt	21	5.0	0.46	9.28	0.28	0.80	0.55	1.54
Fine Aggregate w/ Clay	22	5.9	0.58	9.91	0.33	0.93	0.50	1.41
Fine Aggregate w/ Silt	23	5.9	0.41	6.96	0.27	0.74	0.41	1.15

3.4 Tests for Significance

Tests of statistical significance on the ILS data were performed using *t*-test and *F*-test. All *t*-tests assumed a one-tailed t distribution for 5% level of significance. The t-test was to determine if the difference in maximum density and optimum moisture content of various blends were statistically significant. The *F*-test was to determine if S_r and S_R precision estimates of the properties for different blends were significantly different. The results of tests for statistical significance on the averages and standard deviations of properties of the four blends are shown in Table 3-3 through Table 3-6 and are discussed in the following sections.

3.4.1 Maximum Dry Density

3.4.1.1 Comparison of the Average Maximum Dry Densities

The results of t-test on average maximum density values are provided in Table 3-3 . The comparison of computed and critical t values for 5% level of significance indicates that the average maximum density of the fine-graded blends is significantly smaller than those of coarse-graded blends. However, the maximum densities of the blends with the same gradation but different fillers (clay or silt) are not significantly different.

3.4.1.2 Comparison of the Variability of Maximum Dry Density

The results of *F*-test on variances of maximum density are shown in Table 3-4.

The comparison of the computed and critical F values for 5% level of significance indicates that there is no significant difference in either S_r or S_R estimates of maximum dry density of the coarse-graded and fine-graded blends. The variability of the results from the blends with clay and silt were also not significantly different as indicated by the F values in the table. Therefore, the precision estimates for maximum dry density of the four blends can be combined.

Table 3-3. t-values on comparison of the average maximum dry densities of the blends in the ILS

Compare	Degrees of Freedom	Critical t	Computed t	Decision
Coarse w/ Clay & Coarse w/ Silt	40	1.687	0.75	Accept
Coarse w/ clay & fine w/ Clay	41	1.688	17.54	Reject
Coarse w/ Silt & Fine w/ Silt	42	1.687	18.18	Reject
Fine w/ Clay & Fine w/ Silt	43	1.686	0.96	Accept

Note: The critical t values are for 95% level of confidence for one tailed test.

Table 3-4. F-value on comparison of variability of maximum density of the blends in the ILS

Compare	Degrees of Freedom	Critical F	Computed F (S_r)	Decision	Computed F (S_R)	Decision
Coarse w/ Clay & Coarse w/ Silt	20 & 20	2.17	1.21	Accept	1.07	Accept
Coarse w/ clay & fine w/ Clay	20 & 21	2.18	1.90	Accept	1.74	Accept
Coarse w/ Silt & Fine w/ Silt	20 & 22	2.10	1.91	Accept	1.26	Accept
Fine w/ Clay & Fine w/ Silt	21 & 22	2.08	1.45	Accept	1.09	Accept

Note: The critical F values are for 95% level of confidence for one tailed test.

3.4.2 Optimum Moisture Content

3.4.2.1 Comparison of the Average Optimum Moisture Content

The results of the *t*-test on optimum moisture content are shown in Table 3-5. The comparison of the computed and critical t values for 5% level of significance indicates that the optimum moisture content of fine-graded blends is significantly higher than that of coarse graded blends. Also shown from the results of t-test, the optimum moisture content of the coarse blend with silt is significantly greater than that of the coarse blend with clay. However, the average optimum moisture content of the fine blends with silt and clay were not significantly different. This could be due to presence of other filler types (limestone dust from sand) in the fine-grained materials.

Table 3-5. t-values on comparison of average optimum moisture content of the blends in ILS

Compare	Degrees of Freedom	Critical t	Computed t	Decision
Coarse w/ Clay & Coarse w/ Silt	40	1.687	3.76	Reject
Coarse w/ clay & fine w/ Clay	41	1.688	8.81	Reject
Coarse w/ Silt & Fine w/ Silt	42	1.687	6.90	Reject
Fine w/ Clay & Fine w/ Silt	43	1.686	0.38	Accept

Note: The critical t values are for 95% level of confidence for one tailed test.

3.4.2.2 Comparison of the Precision Estimates of Optimum Moisture Content

The results of *F*-test on precision estimates of optimum water content are shown in Table 3-6. The comparison of computed and critical F values for 5% level of significance indicates that there is no significant difference in either S_r or S_R estimates of optimum moisture content of the coarse-graded and fine-graded blends. The variability of the results from testing the silt and clay blends were also not significantly different as indicated by the computed F values in the table. Therefore, the optimum moisture content precision estimates of the four blends can be combined.

Table 3-6. F-values on comparison of variability of optimum moisture content of the blends in ILS

Compare	Degrees of Freedom	Critical F	Computed F (S_r)	Decision	Computed F (S_R)	Decision
Coarse w/ Clay & Coarse w/ Silt	20 & 20	2.17	1.69	Accept	1.52	Accept
Coarse w/ clay & fine w/ Clay	20 & 21	2.18	1.39	Accept	1.04	Accept
Coarse w/ Silt & Fine w/ Silt	20 & 22	2.10	1.14	Accept	1.81	Accept
Fine w/ Clay & Fine w/ Silt	21 & 22	2.08	1.54	Accept	1.01	Accept

Note: The critical F values are for 95% level of confidence for one tailed test.

3.5 Precision Estimates based on the ILS data

Table 3-7 provides the repeatability and reproducibility precision estimates for maximum density and optimum moisture content measurements of the soil-aggregate blends in the ILS. Since the variability of the measurements were not significantly different for the different blends as was indicated by the F-test, the standard deviations were combined to prepare the 1s and d2s limits for single-operator and multilaboratory precisions in Table 3-7.

Table 3-7. Precision estimates of maximum density and optimum moisture content from ILS

Condition of Test and Test Property	1s	d2s
Maximum Unit Weight (lbf/ft^3)		
Single-Operator Precision	0.73	2.06
Multilaboratory Precision	1.77	5.00
Optimum Water Content (percent)		
Single-Operator Precision	0.31	0.86
Multilaboratory Precision	0.49	1.39

CHAPTER 4- **ANALYSIS OF PROFICIENCY SAMPLE RESULTS**

4.1 Proficiency Sample Data

The results of three most recent rounds of AMRL Soil Classification and Compaction Proficiency Sample Program were analyzed to determine precision estimates for AASHTO T 180. For each round of testing, test results were obtained for a pair of samples. The samples for the first round of testing were identified as 147 and 148. The samples for the second round of testing were identified as 155 and 156. The samples for the third round of testing were identified as 157 and 158.

Testing was performed using AASHTO Test Method T 180 and ASTM Test Method D 1557. The test methods are similar and both are commonly used to determine the compaction characteristics of soil. Special instructions were provided to the participating laboratories to minimize testing variations between the two methods.

4.2 Description of Samples

The materials and their sources for the blends used in the three rounds of PSP Soil Classification and Compaction are provided in Table 4-1. The classification of the soils in Column 2 is determined in accordance to AASHTO Standard Practice M145. As indicated from Table 2-2 and Table 4-1, classification of the PSP and ILS materials are very different. While the ILS materials consist of only about 7% material passing #200 sieve, the PSP materials consist of about 85% filler material. This would provide a wide range of maximum dry density and optimum water content for the development of final precision estimates.

Table 4-1. Sources and classifications of PSP soil blends according to AASHTO M 147

Sample #	Classification	Materials	Source
147 & 148	Lean Clay &	#30 mesh bonding clay	Resco Products in Oak Hill, OH
	Lean Clay with Sand	Ball diamond soil mix	Aggtrans in Harman, MD
		Agricultural lime	Aggtrans in Harman, MD
155 & 156	Sandy Lean Clay	Core trench clay	Aggtrans in Harman, MD
		Silica building sand	Lafarge in Frederick, MD
		Ground fire clay	Resco Products in Oak Hill, OH
157 & 158	Sandy Lean Clay	Bonding clay	Resco Products in Oak Hill, OH
		Masonry sand	Lafarge in Frederick, MD

4.3 Testing Instructions

Laboratory participants were provided with the testing instructions. The copies of the instructions are provided in Appendix C. In addition to specific instructions for AASHTO T180 and ASTM D 1557 [3], the instructions included instructions for sample preparation and a full battery of tests covered by the proficiency testing program. The testing in the AMRL proficiency testing program allowed testing to be performed using either ASTM or AASHTO test methods. It was assumed that ASTM D 1557 and AASHTO T180 are sufficiently similar that test results using either of the two methods display the same degree of testing variation. In addition, special instructions that minimize differences between the two methods were provided for laboratories using ASTM D 1557. Laboratories using ASTM D 1557 were instructed to perform testing in accordance to the test method with one exception as follows: due to restrictions inherent in the proficiency testing program, the quantity of material provided to the laboratories was limited. Therefore, there was not enough material to allow preparation of a separate specimen at each trial water content. After compaction testing at the first water content, laboratories were required to thoroughly break up the compacted soil into particles small enough to pass a 4.75-mm (No. 4) sieve, add an increment of water to attain the appropriate water content for the second trial, and then re-compact the material. This testing process of breaking up the compacted soil and adding water increments was continued until sufficient test points were acquired to draw the compaction curve.

4.4 Description of Equipment/Apparatus

The equipment/apparatus used for this study is as described in the test methods, AASHTO T180 and ASTM D 1557. Testing for samples 155 and 156 was performed using either a 4-inch or a 6-inch diameter mold and either a manual or mechanical rammer having a weight of 10 lbf and a drop height of 18 inches. Testing for samples 147- 148 and 157-158 were performed using a 4-inch diameter mold and either a manual or mechanical rammer having a weight of 10 lbf and a drop height of 18 inches.

4.5 PSP Data

Each laboratory was provided with a data report form for the collection of data. A copy of the data received from the laboratories is provided in Appendix D. The first three columns list the data as reported by the participating laboratories. The fourth column shows what results were identified as invalid or as outliers during the analysis.

4.6 Statistical Data Summary

A summary of the statistics calculated from the data returned by the participating laboratories is provided in Table 4-2 and Table 4-3.The analysis was performed in accordance with the procedure described in NCHRP 09-26, Phase 3 report [6]. As indicated from the tables, the average maximum density and optimum moisture content values from PSP are very different from those obtained in the ILS (Table 3-1 and Table 3-2. The average maximum density of PSP materials is significantly lower than that of

ILS materials and the average optimum moisture content of the PSP materials is significantly higher than that of the ILS samples. Therefore, inclusion of PSP statistics in the development of precision statement provides precision coverage for a wide range of materials.

Table 4-2. Summary of Statistics of maximum dry density (lb/cu. ft.) from PSP

Sample ID	Sample Type	# of Labs	Average		Repeatability	Reproducibility	
			Odd	Even		Odd	Even
147 & 148	**Lean Clay with Sand**	144	125.80	126.26	0.71	1.76	1.85
155 & 156	**Sandy Lean Clay**	253	132.23	132.33	0.52	1.17	1.13
157 & 158	**Sandy Lean Clay**	237	131.68	132.55	0.73	1.73	1.76

Table 4-3. Summary of Statistics of optimum moisture content (%) from PSP

Sample ID	Sample Type	# of Labs	Average		Repeatability	Reproducibility	
			Odd	Even		Odd	Even
147 & 148	**Lean Clay with Sand**	149	10.40	10.29	0.49	0.96	1.03
155 & 156	**Sandy Lean Clay**	247	8.58	8.51	0.24	0.45	0.43
157 & 158	**Sandy Lean Clay**	239	8.32	7.96	0.40	0.78	0.81

4.7 Precision Estimates based on the PSP data

The repeatability and reproducibility standard deviations for the three sample pairs were pooled to prepare precision estimates for maximum density and optimum moisture content as provided in Table 4-4. The pooled estimates were derived using the following equation from Ku [7]:

$$s_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2 + \ldots + (n_k - 1)s_k^2}{n_1 + n_2 + \ldots + n_k - k}} \qquad \text{(Equation 1)}$$

Where:

s_p = Pooled standard deviation

s_k = kth standard deviation

n_k = Number of laboratories analyzed resulting in kth standard deviation

Table 4-4. Precision estimates of maximum density and optimum moisture content from PSP data

Condition of Test and Test Property	1s	d2s
Maximum Unit Weight (lbf/ft^3)		
Single-Operator Precision	0.65	1.84
Multilaboratory Precision	1.55	4.39
Optimum Water Content (percent)		
Single-Operator Precision	0.37	1.05
Multilaboratory Precision	0.74	2.09

CHAPTER 5- **PRECISION STATEMENT FOR AASHTO T180**

5.1 Comparison of the ILS and PSP Precisions

In preparing a precision statement for AASHTO T180, the precision estimates from ILS and PSP will be statistically compared. This is to examine if they can be combined or should be reported separately. In the following sections the results from statistical comparison of the precision estimates are discussed:

An F-test on variances was conducted to compare the repeatability and reproducibly standard deviation from the ILS and PSP data. The comparison of the standard deviations of maximum dry density from Table 3-7 and Table 4-4 indicates that both single-operator and multilaboratory precisions of the ILS coarse-graded materials are larger than those of the PSP fine-graded soil. This is expected since compaction of coarse-graded materials encounters more resistance than compaction of fine-graded materials, which results in more variability in maximum dry density measurements. The results of the F-test are shown in Table 5-1. As indicated in the table, the repeatability of the maximum dry density from ILS is significantly larger than that from PSP (compare computed F value of 1.31 with the critical F of 1.28). Although not quite significant, the reproducibility of the maximum dry density from ILS is larger than that from the PSP (compare computed F of 1.25 with critical F of 1.28). Therefore, the precision estimates for maximum density would be presented separately in the precision statement of AASHTO T180.

The results of an F test on comparison of variability of the optimum moisture content values from PSP and ILS from Table 3-7 and Table 4-4 is provided in Table 5-1. The comparison of single-laboratory and multilaboratory variability of the optimum moisture content measurements indicates that both within and between-laboratory precisions of the ILS samples are significantly smaller than those of PSP samples (compare computed F values of 1.47 and 2.26 with the critical F value of 1.33). The reason for this could be the high clay content of PSP blends. Due to the difference in the repeatability and reproducibility statistics of ILS and PSP, the precision estimates for optimum moisture content would be presented separately in the precision statement of AASHTO T180.

Table 5-1. Summary of Statistics for comparison of maximum dry density (lb/cu. ft.) and optimum moisture content (%) of PSP and ILS samples

Compare	Degrees of Freedom	Critical F	Repeatability		Reproducibility	
			Computed F (S_r)	Decision	Computed F (S_R)	Decision
Maximum Dry Density	87 & 635	1.28	1.25	Accept	1.31	Reject
Optimum Moisture Content	635 & 87	1.33	1.47	Reject	2.26	Reject

Note: The critical F values are for 95% level of confidence for one tailed test.

5.2 Proposed Precision Estimates for AASHTO T180

Table 5-2 provides the precision estimates for maximum dry density and optimum moisture content measurements resulted from the ILS and PSP data. As indicated earlier, based on the significant difference between the repeatability and reproducibility statistics of maximum density and optimum moisture content computed from ILS and PSP data, the precisions from the two sources will be presented separately in a proposed precision statement of AASHTO T180 presented in Appendix E.

Table 5-2. Repeatability and reproducibility standard deviations of maximum dry density and optimum moisture content of sandy clay (PSP) and sand and gravel (ILS) materials

Property	Material	Repeatability Standard Deviation	Reproducibility standard Deviation
Maximum Dry Density	Sandy Clay	0.65	1.55
	Sand and Gravel	0.73	1.76
Moisture Content	Sandy Clay	0.37	0.74
	Sand and Gravel	0.30	0.49

CHAPTER 6- CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

This study was conducted to prepare precision estimates for AASHTO T180, "Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop." An interlaboratory study (ILS) was conducted to collect data from testing four aggregate -soil blends that were found suitable for construction of base and subbase. In addition, the data from the three most recent rounds of AMRL Soil Classification and Compaction Proficiency Sample Program were utilized to compute precision estimates. The four blends in the ILS, included two coarse- and two fine-grained soil-aggregate mixtures that were prepared according to Grading A and Grading E of AASHTO M147, "Materials for Aggregate and Soil-Aggregate Subbase, Base, and Surface Courses." Each of the blends had less than 10% material passing #200 sieve opening to represent suitable base and subbase materials. The materials used for PSP included three sets of lean clay with sand with each blend having about 85% materials passing #200 sieve opening. Since the materials used for the ILS and PSP samples were very different, the developed precision estimates cover a wide range of maximum densities and optimum moisture contents. The following presents a summary of the findings:

- The average maximum density of the fine-graded blends was significantly smaller than those of coarse-graded blends. However, the standard deviations of the maximum density of the fine and coarse graded blends were the same. Therefore, the repeatability and reproducibility standard deviations of the maximum dry density of the ILS blends were combined.
- The average optimum moisture content of the fine-graded blends is significantly larger than those of coarse-graded blends. However, the standard deviations of the optimum moisture content of the fine and coarse blends were the same. Therefore, the repeatability and reproducibility standard deviations of optimum moisture content of the ILS blends were combined.
- The average maximum density of the ILS blends was significantly larger than that of PSP blends. In addition, the pooled standard deviations of maximum dry density from PSP were significantly smaller than those of ILS. Therefore, the standard deviations from the two sources were presented separately in the precision statement of AASHTO T180.
- The average optimum moisture content of the ILS blends was significantly smaller than that of PSP. In addition, the pooled standard deviations of optimum moisture content from PSP were significantly larger than those of ILS. Therefore, the standard deviations from the two sources were presented separately in the precision statement of AASHTO T180.

6.2 Conclusions

Based on the results of AASHTO T180 interlaboratory study and AMRL Soil

Classification and Compaction Proficiency Sample Program data a precision statement was prepared. Since the difference between the precision of maximum density and optimum moisture content from ILS and PSP were significantly different, the S_r and S_R estimates computed from the two sources were presented separately in the prepared precision statement. The proposed precision statement is provided in Appendix E of this report.

6.3 Recommendations

The design and control of compaction of soils is an important aspect of a pavement construction process. The level of accuracy in which a degree of compaction of soil-aggregate mixture is measured has a significant effect on the performance of a pavement as a whole. Currently, there are no precision estimates that would define the accuracy requirements for measuring maximum dry density and optimum moisture content of the soil-aggregate blends compacted according to AASHTO T 180. Therefore, it is recommended that the precision statement in Appendix E, which is prepared based on analysis of the data collected through an interlaboratory study and from the three most recent rounds of AMRL Soil classification and Compaction Proficiency Sample Program to be published in AASHTO T180 test method.

REFERENCES

1. AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing (Part 2 – Tests), Twenty-Eight Edition, American Association of State Highway and Transportation Officials, Washington, DC. 2008.

2. AMRL Web Site: **http://www.nist.gov/amrl**

3. ASTM Book of Standards, Vol. 04.08, Soil and Rock, West Conshohocken, PA, 2008.

4. ASTM Standards on Precision and Bias for Various Applications, Fifth Edition, West Conshohocken, PA, 1997.

5. AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing (Part 1A – specifications), Twenty-Eight Edition, American Association of State Highway and Transportation Officials, Washington, DC. 2008.

6. National Cooperative Highway Research Program (NCHRP) Web-Only Document 71 (Project 09-26, Phase 3), "Precision Estimates for AASHTO T308 and the Test Methods for Performance-Graded Binder in AASHTO Specification M320." **http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_w71.pdf**.

7. Ku, Harry H., "Statistical Concepts in Metrology," NIST Special Publication 300, Volume 1, 1969: p 316-40.

APPENDIX A- INSTRUCTIONS AND DATA SHEET FOR INTERLABORATORY STUDY

INSTRUCTIONS TO THE PARTICIPANTS OF ILS FOR THE PRECISION ESTIMATES OFAASHTO T180, MOISTURE–DENSITY RELATIONS OF SOILS USING A 4.54-KG (10-LB) RAMMER AND A 457-MM (18-IN.) DROP

Each lab should have received total of 12 bags:

a. Three bags of fine graded aggregate (Grading E) with silt
b. Three bags of fine graded (Grading E) aggregate with clay
c. Three bags of coarse graded (Grading A) aggregate with silt
d. Three bags of coarse graded aggregate(Grading A) with clay

The fine graded samples are used with Method B and the coarse graded samples are used with method D of AASHTO T 180. For testing the fine graded samples follow Steps 1 through 4 and for testing coarse graded samples follow Steps 5 through 8.

Testing of fine graded blends

1. Dry the content of each bag in 60°C (140°F) oven. Then break up the aggregation in such a manner as to avoid reducing the natural size of individual particles.
2. Sieve the aggregate-soil blend over the 4.75-mm sieve. Discard the coarse material, if any, retained on the 4.75-mm sieve.
3. Select a representative sample, with a mass of approximately 7 kg (16 lb) or more.
4. Prepare and Compact the specimens in accordance with Section 7, which also follows Section 5 of T 180.

    a. For the first compaction add 3.5% water (i.e., 3.5% of 7 kg = 245 g (cc)).
    b. Increase the moisture by 1.5% for each subsequent compaction.
    c. Total of 5 compactions shall be conducted at 3.5%, 5%, 6.5%, 8%, and 9.5 % water contents.
    d. For water content determination use 150-g samples and follow AASHTO T 265.

Testing of coarse graded blends

5. Dry the content of each bag at 60°C (140°F) oven. Then break up the aggregation in such a manner as to avoid reducing the natural size of individual particles.
6. Sieve the aggregate-soil blend over the 19-mm sieve. Discard the coarse material, if any, retained on the 19-mm sieve.
7. Select a representative sample, with a mass of approximately 11 kg (25 lb) or more.
8. Prepare and Compact the specimens in accordance with Section 11, which also follows Section 9 of T 180.

a. For the first compaction add 2% water (i.e., 2% of 11 kg = 220 g (cc)).

b. Increase the moisture by 1.5% for each subsequent compaction.

c. Total of 5 compactions shall be conducted at 2%, 3.5%, 5%, 6.5%, and 8% water contents.

d. For water content determination use 350-g samples and follow AASHTO T 265.

Calculation and Report

9. Please use the attached Excel worksheet to calculate and report the data.

    a. Use one excel file for the three replicates of each material. The data for the four materials shall be reported in four separate excel files. Please rename the files to match the sample names.

    b. Use aggregate specific gravity of 2.715 for the coarse blend and 2.682 for the fine blend.

    c. Record the measurements with the precisions requested in the worksheet.

10. Report the optimum moisture content, as a percentage, to the nearest tenth of a percent.

11. Report the maximum density in pounds per cubic feet to the nearest tenth.

12. Please send the four excel files to AMRL through email: **hazari@amrl.net**.

WORKSHEET FOR ENTERING T 180 ILS DATA

Moisture Density AASHTO T180

Name:
Date:

Input data only into yellow cells!

Specific Gravity of Soil		

Water Content %		2.0%	3.5%	5.0%	6.5%	8.0%
Container ID		1	2	3	4	5
Mass of Can + Wet Soil (g)	to the nearest tenth					
Mass of Can + Dry Soil (g)	to the nearest tenth					
Mass of Can (g)	to the nearest tenth					
Mass of Soil + Mold (g)	to the whole number					
Mass of Mold (g)	to the whole number					

Mass of Soil in Mold (g)		0	0	0	0	0
Mass of Water (g)		0	0	0	0	0
Mass of Dry Soil (g)		0	0	0	0	0
Water Content (%)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Wet Unit Weight (lb/ft^3)		0	0	0	0	0
Dry Unit Weight (lb/ft^3)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Maximum Density (lb/ft^3):	
Optimum Moisture Content (%):	

APPENDIX B- MAXIMUM DENSITY AND OPTIMUM MOISTURE CONTENT OF ILS SAMPLES AND COMPUTED ASTM E691 STATISTICS

Table B-1. Maximum Density (lb/ft^3) of three replicates of four aggregate –soil blends in the ILS study and the computed statistics according to ASTM E 691; CC stands for coarse-graded aggregate with clay, CS stands for coarse-graded aggregate with silt, FC stands for fine-graded aggregate with clay, and FS stands for fine-graded aggregate with silt

Maximum Density, lb/cu. ft.					X_bar				S				h				k				X_bar_corr				S_corr			
Lab No	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS
1				139.2				139.4				0.17				0.57				0.28				139.4				0.17
				139.5																								
				139.5																								
2	150.5	147.5	141.5	142.2	149.6	147.8	141.6	141.8	1.08	0.93	0.17	0.51	1.12	0.30	1.70	2.13	1.34	1.09	0.23	0.83	149.6	147.8	141.6	141.8	1.08	0.93	0.17	0.51
	149.9	147.0	141.5	141.9																								
	148.4	148.8	141.8	141.2																								
3	147.1	146.8	137.6	138.3	147.0	147.2	137.6	137.3	0.12	0.67	0.25	0.90	-0.42	-0.03	-0.91	-0.84	0.14	0.78	0.34	1.45	147.0	147.2	137.6	137.3	0.12	0.67	0.25	0.90
	146.9	148.0	137.3	136.8																								
	146.9	146.9	137.8	136.7																								
4	148.0	145.7	140.3	140.9	146.7	145.4	140.2	140.9	1.17	0.42	0.91	0.60	-0.56	-1.17	0.77	1.56	1.45	0.49	1.22	0.97	146.7	145.4	140.2	140.9	1.17	0.42	0.91	0.60
	145.7	145.5	141.0	141.5																								
	146.5	144.9	139.2	140.3																								
5	149.5	148.0	139.7	138.6	148.0	147.6	140.0	139.1	1.32	0.53	0.23	0.78	0.18	0.20	0.64	0.37	1.64	0.62	0.31	1.27	148.0	147.6	140.0	139.1	1.32	0.53	0.23	0.78
	147.5	147.8	140.1	140.0																								
	147.0	147.0	140.1	138.7																								
6			139.2	139.5			138.2	138.9			0.87	0.67			-0.48	0.26			1.17	1.08			138.2	138.9			0.87	0.67
			138.0	139.1																								
			137.5	138.2																								
7	149.7	148.3	140.0	138.4	148.9	148.1	139.8	138.5	1.44	1.37	0.76	0.31	0.69	0.48	0.56	-0.05	1.79	1.60	1.03	0.50	148.9	148.1	139.8	138.5	1.44	1.37	0.76	0.31
	147.2	149.3	139.0	138.8																								
	149.7	146.6	140.5	138.2																								
8	146.3	144.5	138.3	137.6	146.8	145.8	138.1	138.0	0.44	1.30	0.53	0.59	-0.52	-0.90	-0.57	-0.33	0.54	1.52	0.71	0.95	146.8	145.8	138.1	138.0	0.44	1.30	0.53	0.59
	147.1	145.8	138.5	138.7																								
	147.0	147.1	137.5	137.8																								
9	144.3	144.9	139.7	137.8	144.1	145.1	138.2	137.6	0.49	0.25	1.30	0.72	-2.12	-1.31	-0.50	-0.62	0.61	0.29	1.75	1.17	144.1	145.1	138.2	137.6	0.49	0.25	1.30	0.72
	143.5	145.1	137.5	138.2																								
	144.4	145.4	137.4	136.8																								
10	150.5	148.5	140.0	138.0	149.5	147.7	139.8	138.4	0.91	1.00	1.17	0.81	1.04	0.28	0.51	-0.11	1.12	1.17	1.57	1.32	149.5	147.7	139.8	138.4	0.91	1.00	1.17	0.81
	148.8	146.6	140.8	137.8																								
	149.1	148.1	138.5	139.3																								
11	143.4	144.1	137.0	135.3	143.8	143.2	136.4	136.1	0.40	0.78	1.22	0.80	-2.25	-2.49	-1.67	-1.59	0.50	0.91	1.64	1.30	143.8	143.2	136.4	136.1	0.40	0.78	1.22	0.80
	144.2	142.7	137.2	136.2																								
	143.9	142.8	135.0	136.9																								
12	148.7	148.2	138.0	136.1	148.3	147.9	139.1	137.1	0.51	0.38	1.05	0.91	0.34	0.40	0.08	-0.97	0.64	0.44	1.42	1.47	148.3	147.9	139.1	137.1	0.51	0.38	1.05	0.91
	148.4	148.1	139.2	137.9																								
	147.7	147.5	140.1	137.2																								

Table B-1. Continued

Maximum Density, lb/cu. ft.					X_bar				S				h				k				X_bar_corr				S_corr			
No	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS
13	149.4	144.6	140.4	139.8	148.8	147.0	140.7	139.4	0.55	2.12	0.30	0.40	0.63	-0.19	1.12	0.59	0.68	2.48	0.40	0.66	148.8	FALSE	140.7	139.4	0.55	FALSE	0.30	0.40
	148.4	148.7	141.0	139.5																								
	148.5	147.6	140.7	139.0																								
14	149.1	149.1	138.6	138.8	148.9	148.9	138.5	139.2	0.32	0.32	0.15	0.47	0.69	0.97	-0.33	0.42	0.40	0.38	0.21	0.77	148.9	148.9	138.5	139.2	0.32	0.32	0.15	0.47
	149.0	149.0	138.5	139.0																								
	148.5	148.5	138.3	139.7																								
15	147.0	147.8	134.8	134.8	148.5	148.4	135.1	135.1	1.50	1.22	0.36	0.36	0.49	0.68	-2.51	-2.27	1.86	1.42	0.48	0.58	148.5	148.4	135.1	135.1	1.50	1.22	0.36	0.36
	150.0	149.8	135.5	135.5																								
	148.6	147.6	135.0	135.0																								
16	147.2	149.0	138.9	138.5	147.0	149.2	138.7	138.1	0.20	0.26	0.21	0.40	-0.40	1.17	-0.20	-0.31	0.25	0.31	0.28	0.66	147.0	149.2	138.7	138.1	0.20	0.26	0.21	0.40
	146.8	149.5	138.6	138.0																								
	147.0	149.1	138.5	137.7																								
17	147.5	148.0	138.4	137.8	147.9	148.0	138.2	137.6	0.32	0.15	0.29	0.59	0.10	0.46	-0.48	-0.64	0.40	0.18	0.39	0.95	147.9	148.0	138.2	137.6	0.32	0.15	0.29	0.59
	148.1	148.2	138.4	138.0																								
	148.0	147.9	137.9	136.9																								
18	144.5	146.2	139.2	139.5	145.2	145.9	138.2	138.9	0.83	0.58	0.87	0.67	-1.47	-0.86	-0.48	0.26	1.03	0.68	1.17	1.08	145.2	145.9	138.2	138.9	0.83	0.58	0.87	0.67
	144.9	146.2	138.0	139.1																								
	146.1	145.2	137.5	138.2																								
19	148.1	148.4	140.9	139.6	148.4	148.5	140.4	140.5	0.31	0.10	0.47	0.95	0.43	0.74	0.90	1.30	0.38	0.12	0.64	1.55	148.4	148.5	140.4	140.5	0.31	0.10	0.47	0.95
	148.7	148.5	140.2	140.4																								
	148.5	148.6	140.0	141.5																								
20	151.3	150.7	139.5	139.3	150.3	150.3	139.0	139.0	1.11	0.64	1.46	0.52	1.52	1.86	0.04	0.31	1.38	0.74	1.96	0.84	150.3	150.3	139.0	139.0	1.11	0.64	1.46	0.52
	149.1	149.6	137.4	138.4																								
	150.5	150.7	140.2	139.3																								
21	149.7	148.0	141.3	139.2	149.0	148.4	141.2	139.1	0.70	0.84	0.17	0.23	0.77	0.70	1.44	0.35	0.87	0.98	0.23	0.37	149.0	148.4	141.2	139.1	0.70	0.84	0.17	0.23
	149.0	147.9	141.3	139.2																								
	148.3	149.4	141.0	138.8																								
22	146.7	145.7	138.5	137.2	147.0	145.7	138.2	136.9	0.55	0.70	0.58	0.31	-0.42	-0.96	-0.52	-1.10	0.68	0.82	0.78	0.50	147.0	145.7	138.2	136.9	0.55	0.70	0.58	0.31
	147.6	146.4	137.5	136.6																								
	146.6	145.0	138.5	136.8																								
23	148.0	146.7	140.5	140.2	148.0	146.7	140.3	139.6	0.15	0.25	0.29	0.60	0.16	-0.33	0.88	0.70	0.19	0.29	0.39	0.97	148.0	146.7	140.3	139.6	0.15	0.25	0.29	0.60
	148.1	146.5	140.0	139.6																								
	147.8	147.0	140.5	139.0																								
Number of Labs With Data					21	21	22	23	21	21	22	23	21	21	22	23	21	21	22	23	21	20	22	23	21	20	22	23
					X_dbl_bar / Sx				Sr / SR				h Critical				k Critical				Corrected X_dbl_bar / Sx				Corrected Sr / SR			
					147.7	147.3	139.0	138.5	0.81	0.85	0.74	0.62	2.57	2.57	2.58	2.59	2.21	2.21	2.21	2.22	147.7	147.3	139.0	138.5	0.81	0.74	0.74	0.62
					1.71	1.64	1.54	1.52	1.89	1.84	1.71	1.63									1.71	1.68	1.54	1.52	1.89	1.83	1.71	1.63

Table B-2. Optimum moisture content (%) of three replicates of four aggregate –soil blends in the ILS study and the computed statistics according to ASTM E 691 ; CC stands for coarse-graded aggregate with clay, CS stands for coarse-graded aggregate with silt, FC stands for fine-graded aggregate with clay, and FS stands for fine-graded aggregate with silt

Optimum Moisture Content, %					X_bar				S				h			
Lab No	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS
1				5.4 5.8 5.8				5.7				0.23				-0.62
2	3.2 3.9 3.9	4.5 4.9 4.8	5.3 5.0 5.1	5.6 5.3 5.8	3.7	4.7	5.1	5.6	0.40	0.21	0.15	0.25	-1.65	-0.59	-1.26	-0.82
3	4.7 4.7 4.7	4.8 5.2 5.2	6.5 6.3 6.5	6.1 6.3 6.4	4.7	5.1	6.4	6.3	0.00	0.23	0.12	0.15	0.23	0.12	0.98	0.54
4	4.5 4.0 4.7	5.6 6.2 6.1	5.1 5.7 5.5	5.2 5.5 5.8	4.4	6.0	5.4	5.5	0.36	0.32	0.31	0.30	-0.31	2.06	-0.74	-0.95
5	4.7 5.0 4.3	5.2 4.8 4.9	6.0 5.6 6.0	5.3 5.9 5.9	4.7	5.0	5.9	5.7	0.35	0.21	0.23	0.35	0.17	-0.09	0.01	-0.56
6			5.3 5.6 6.3	5.5 5.7 5.3			5.7	5.5			0.51	0.20			-0.22	-0.95
7	4.2 5.1 4.2	4.6 4.9 4.9	5.6 5.1 5.4	5.4 5.6 5.5	4.5	4.8	5.4	5.5	0.52	0.17	0.25	0.10	-0.13	-0.45	-0.86	-0.95
8	4.8 4.8 4.7	5.9 5.5 5.4	6.0 6.3 6.4	6.3 6.2 6.4	4.8	5.6	6.2	6.3	0.06	0.26	0.21	0.10	0.35	1.27	0.64	0.60
9	5.2 5.1 4.7	4.6 4.7 4.5	5.1 6.3 5.3	5.6 6.2 5.8	5.0	4.6	5.6	5.9	0.26	0.10	0.64	0.31	0.78	-0.88	-0.51	-0.24
10	5.5 6.4 6.6	5.2 5.7 5.2	6.3 6.3 5.2	6.5 6.1 5.7	6.2	5.4	5.9	6.1	0.59	0.29	0.64	0.40	2.89	0.77	0.12	0.22
11	5.0 4.1 4.7	4.7 4.8 4.7	6.0 5.8 5.8	6.0 6.2 5.9	4.6	4.7	5.9	6.0	0.46	0.06	0.12	0.15	0.05	-0.59	0.01	0.09
12	4.8 4.8 5.3	5.0 5.3 5.2	6.0 5.5 5.5	5.4 6.1 6.3	5.0	5.2	5.7	5.9	0.29	0.15	0.29	0.47	0.71	0.34	-0.34	-0.11

	k				X_bar_corr				S_corr			
Lab No	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS
1				0.80				5.7				0.23
2	1.19	0.72	0.45	0.87	3.7	4.7	5.1	5.6	0.40	0.21	0.15	0.25
3	0.00	0.80	0.34	0.53	4.7	5.1	6.4	6.3	0.00	0.23	0.12	0.15
4	1.06	1.11	0.90	1.04	4.4	6.0	5.4	5.5	0.36	0.32	0.31	0.30
5	1.04	0.72	0.68	1.20	4.7	5.0	5.9	5.7	0.35	0.21	0.23	0.35
6			1.50	0.69			5.7	5.5			0.51	0.20
7	1.53	0.60	0.74	0.35	4.5	4.8	5.4	5.5	0.52	0.17	0.25	0.10
8	0.17	0.91	0.61	0.35	4.8	5.6	6.2	6.3	0.06	0.26	0.21	0.10
9	0.78	0.35	1.88	1.06	5.0	4.6	5.6	5.9	0.26	0.10	0.64	0.31
10	1.73	1.00	1.86	1.39	FALSE	5.4	5.9	6.1	FALSE	0.29	0.64	0.40
11	1.35	0.20	0.34	0.53	4.6	4.7	5.9	6.0	0.46	0.06	0.12	0.15
12	0.85	0.53	0.85	1.64	5.0	5.2	5.7	5.9	0.29	0.15	0.29	0.47

Table B-2. Continued

Optimum Moisture Content, %					X_bar				S				h				k				X_bar_corr				S_corr			
No	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS	CC	CS	FC	FS
13	4.2	5.5	5.3	5.6	4.5	5.0	5.5	5.7	0.26	0.47	0.15	0.15	-0.13	-0.09	-0.68	-0.49	0.78	1.63	0.45	0.53	4.5	5.0	5.5	5.7	0.26	0.47	0.15	0.15
	4.6	4.8	5.6	5.9																								
	4.7	4.6	5.5	5.7																								
14	3.9	3.9	6.3	6.4	4.0	4.0	6.3	6.1	0.12	0.12	0.00	0.30	-0.98	-2.10	0.75	0.22	0.34	0.40	0.00	1.04	4.0	4.0	6.3	6.1	0.12	0.12	0.00	0.30
	4.1	4.1	6.3	5.8																								
	4.1	4.1	6.3	6.1																								
15	4.2	4.7	7.5	7.4	4.0	4.4	7.2	7.2	0.21	0.58	0.25	0.21	-1.10	-1.38	2.36	2.28	0.61	1.99	0.74	0.72	4.0	4.4	7.2	7.2	0.21	0.58	0.25	0.21
	3.8	3.7	7.0	7.0																								
	3.9	4.7	7.2	7.1																								
16	4.0	4.1	5.8	5.4	4.4	4.5	5.8	5.8	0.35	0.40	0.06	0.38	-0.31	-1.10	-0.05	-0.30	1.02	1.38	0.17	1.31	4.4	4.5	5.8	5.8	0.35	0.40	0.06	0.38
	4.6	4.5	5.8	6.0																								
	4.6	4.9	5.9	6.1																								
17	4.9	5.0	6.4	6.4	4.8	5.2	6.5	6.5	0.21	0.25	0.21	0.12	0.47	0.48	1.04	1.06	0.61	0.87	0.61	0.40	4.8	5.2	6.5	6.5	0.21	0.25	0.21	0.12
	5.0	5.2	6.3	6.6																								
	4.6	5.5	6.7	6.6																								
18	5.1	4.9	5.3	5.5	4.4	5.1	5.7	5.5	0.59	0.20	0.46	0.15	-0.25	0.19	-0.28	-0.88	1.73	0.69	1.34	0.53	4.4	5.1	5.7	5.5	0.59	0.20	0.46	0.15
	4.0	5.1	5.6	5.7																								
	4.2	5.3	6.2	5.4																								
19	4.7	5.1	5.6	6.0	4.8	5.1	5.6	5.9	0.10	0.10	0.35	0.10	0.41	0.19	-0.40	-0.17	0.29	0.35	1.03	0.35	4.8	5.1	5.6	5.9	0.10	0.10	0.35	0.10
	4.9	5.0	5.3	5.9																								
	4.8	5.2	6.0	5.8																								
20	5.0	5.7	6.8	6.8	5.3	5.6	7.2	7.5	0.49	0.56	0.72	0.59	1.38	1.27	2.24	2.87	1.46	1.92	2.12	2.04	5.3	5.6	7.2	FALSE	0.49	0.56	0.72	FALSE
	5.9	6.1	8.0	7.9																								
	5.1	5.0	6.7	7.7																								
21	3.6	4.7	4.9	5.8	3.8	4.6	4.9	5.4	0.21	0.31	0.00	0.46	-1.46	-0.81	-1.66	-1.14	0.61	1.05	0.00	1.59	3.8	4.6	4.9	5.4	0.21	0.31	0.00	0.46
	3.7	4.9	4.9	4.9																								
	4.0	4.3	4.9	5.5																								
22	4.6	5.4	5.6	6.1	4.4	5.6	5.5	6.2	0.25	0.20	0.31	0.31	-0.37	1.27	-0.57	0.35	0.74	0.69	0.90	1.06	4.4	5.6	5.5	6.2	0.25	0.20	0.31	0.31
	4.1	5.8	5.8	6.5																								
	4.4	5.6	5.2	5.9																								
23	4.2	5.2	5.6	5.9	4.2	5.1	5.5	6.0	0.15	0.12	0.12	0.06	-0.74	0.12	-0.57	-0.04	0.45	0.40	0.34	0.20	4.2	5.1	5.5	6.0	0.15	0.12	0.12	0.06
	4.3	5.0	5.6	6.0																								
	4.0	5.0	5.4	6.0																								
Number of Labs With Data					21	21	22	23	21	21	22	23	21	21	22	23	21	21	22	23	20	21	22	22	20	21	22	22

X_dbl_bar / Sx				Sr / SR				h Critical				k Critical				Corrected X_dbl_bar / Sx				Corrected Sr / SR			
4.6	5.0	5.9	6.0	0.34	0.29	0.34	0.29	2.57	2.57	2.58	2.59	2.21	2.21	2.21	2.22	4.5	5.0	5.9	5.9	0.32	0.29	0.34	0.27
0.55	0.46	0.58	0.52	0.64	0.54	0.67	0.59									0.42	0.46	0.58	0.41	0.53	0.54	0.67	0.49

APPENDIX C- INSTRUCTIONS FOR TESTING SOIL CLASSIFICATION AND COMPACTION OF PROFICIENCY SAMPLES

Instructions for Testing and Reporting
Soil Classification and Compaction Proficiency Samples No. 147 and No. 148

All tests should be conducted on each of the two samples according to the AASHTO or ASTM methods indicated. Report the results of a single determination only, not the average of two or more. Indicate any tests you do not choose to do by inserting "N" in the appropriate spaces on the data sheet. Please place your telephone number (and email address) on the data sheet in the space provided.

Preparation of Samples: Prepare the soil in accordance with Method T87-86 or D421-85 or Method T146-96 or D2217-85.

Particle Size Analysis of Soils T88-00 or D422-63: Determine the hygroscopic moisture and perform the sieve and hydrometer analysis. Report the sieve and hydrometer analysis as a percent passing. *Use the same nest of sieves for both samples*, and report the results to the nearest 0.1 percent.

Liquid Limit of Soils T89-02 or D4318-00: Determine the liquid limit by the Referee Test, Method A. Report the results to the nearest 0.1 percent.

Plastic Limit of Soils T90-00 or D4318-00: Determine the plastic limit and report the results to the nearest 0.1 percent. *Do not report the plasticity index*. If the material is found to be non-plastic report "NP" in the space provided on the data sheet. (Please indicate if the plastic limit-rolling device is used.)

Shrinkage Factors of Soils by Mercury Method T92-97 or D427-98: Determine the shrinkage limit and report the results to the nearest 0.1 percent.

Moisture-Density Relations of Soils T99-01, D698-00a or T180-01 (T180 is optional. Perform T180, rather than T99 or D698, only if your laboratory wishes to participate voluntarily in an inter-laboratory study to estimate the precision of T180): Determine the moisture-density relations by Method A, using a 101.6-mm (4-in.) diameter mold. Report the optimum moisture content to the nearest 0.1 percent. Report the maximum dry density to the nearest 0.1 lb/ft^3. **(Note: If performing D698, the material must be reused. There is not sufficient soil to prepare a separate sample at each trial moisture content. After each compaction, take a moisture content specimen and thoroughly break up the remainder of the compacted soil into particles small enough to pass a 4.75-mm (No. 4) sieve and reuse. Mix each water increment thoroughly with the soil sample prior to compaction.)**

Specific Gravity of Soils T100-01 or D854-02: Determine the specific gravity of material passing the 2.00-mm (No. 10) sieve [or passing 0.425-mm (No. 40), if T146/D2217 was used]. Oven dry the soil in accordance with Section 8.3 (T100) or Section 9.3 (D854) and determine the specific gravity at a temperature T_X=20°C. Report the results to the nearest 0.001 specific gravity unit.

Instructions for Testing and Reporting
Soil Classification and Compaction Proficiency Samples No. 157 and No. 158

All tests should be conducted on each of the two samples according to the AASHTO or ASTM methods indicated. Report the results of a single determination only, not the average of two or more. For any tests you do not choose to perform, leave the appropriate spaces on the data sheet blank.

Preparation of Samples: Prepare the soil in accordance with Method T87-86 or D421-85 or Method T146-96.

Particle Size Analysis of Soils T88-00 or D422-63: Determine the hygroscopic moisture and perform the sieve and hydrometer analysis. Report the sieve and hydrometer analysis as a percent passing. *Use the same nest of sieves for both samples*, and report the results to the nearest 0.1 percent.

Liquid Limit of Soils T89-02 or D4318-05: Determine the liquid limit by the Referee Test, Method A. Report the results to the nearest 0.1 percent.

Plastic Limit of Soils T90-00 or D4318-05: Determine the plastic limit and report the results to the nearest 0.1 percent. *Do not report the plasticity index*. If the material is determined to be non-plastic, leave the space blank on the data sheet.

Shrinkage Factors of Soils by Mercury Method T92-97 or D427-04: Determine the shrinkage limit and report the results to the nearest 0.1 percent.

Specific Gravity of Soils T100-06 or D854-06: Determine the specific gravity of material passing the 2.00-mm (No. 10) sieve [or passing the 0.425-mm (No. 40) sieve, if T146 was used]. Oven dry the soil in accordance with Section 8.3 (T100) or Section 9.3 (D854) and determine the specific gravity based on water at 20°C. Report the results to the nearest 0.001 specific gravity unit.

Testing for Compaction (Below): Testing for Moisture-Density Relations of Soils may be performed using either the Standard Effort (T99/D698) or the Modified Effort (T180/D1557). It is not necessary to perform both types of testing. A 4-in. mold (Method A) must be used.

Moisture-Density of Soils (Standard Effort) Using a 2.5-kg (5.5-lb) Rammer T99-01, D698-07: Determine the moisture-density relations using a 101.6-mm (4-in.) diameter mold (AASHTO Method A or ASTM Method A). Report the optimum moisture content to the nearest 0.1 percent. Report the maximum dry density to the nearest 0.1 lb/ft^3. **(Note: If performing D698, the material must be reused. There is not sufficient soil to prepare a separate sample at each trial moisture content. After each compaction, take a moisture content specimen and thoroughly break up the remainder of the compacted soil into particles small enough to pass a 4.75-mm (No. 4) sieve and reuse. Mix each water increment thoroughly with the soil sample prior to compaction.)**

Moisture-Density of Soils (Modified Effort) Using a 5.54-kg (10-lb) Rammer T180-01, D1557-07: Determine the moisture-density relations using a 101.6-mm (4-in.) diameter mold (AASHTO Method A or ASTM Method A). Report the optimum moisture content to the nearest 0.1 percent. Report the maximum dry density to the nearest 0.1 lb/ft^3. **(Note: If performing D1557, the material must be reused. There is not sufficient soil to prepare a separate sample at each trial moisture content. After each compaction, take a moisture content specimen and thoroughly break up the remainder of the compacted soil into particles small enough to pass a 4.75-mm (No. 4) sieve and reuse. Mix each water increment thoroughly with the soil sample prior to compaction.)**

APPENDIX D- MAXIMUM DENSITY AND MOISTURE CONTENT OF PROFICIENCY SAMPLES

Maximum Unit Weight (lb/ft3) Data for Samples 147 & 148

LAB	Sample 147	Sample 148	status
1	124.6	125.9	
2	126.5	126.4	
3	115.9	122.1	invalid
4	124.5	124.0	
5	131.0	130.0	outlier
6	127.3	127.5	
7	119.2	118.0	outlier
8	126.6	120.5	invalid
9	127.5	128.2	
10	123.5	124.0	
11	126.5	128.0	
12	123.8	121.0	outlier
13	119.0	124.3	outlier
14	125.5	126.0	
15	127.9	127.3	
16	122.4	127.4	outlier
17	126.9	127.7	
18	128.0	128.8	
19	123.8	123.9	
20	124.9	126.3	
21	117.6	114.9	outlier
22	124.4	125.3	
23	118.0	118.2	outlier
24	123.9	124.6	
25	124.0	123.6	
26	123.7	125.5	
27	127.7	127.7	
28	126.0	123.0	outlier
29	127.1	127.7	
30	120.4	117.8	outlier
31	118.5	119.5	outlier
32	126.9	127.5	
33	126.0	126.9	
34	126.0	126.8	
35	120.5	123.0	
36	125.8	127.5	
37	126.2	127.0	
38	123.7	124.6	
39	125.1	125.9	
40	127.2	127.0	
41	127.0	127.5	
42	127.5	128.2	
43	125.5	126.5	
44	124.8	124.1	
45	126.9	127.2	
46	127.8	128.0	
47	115.7	118.2	outlier
48	124.9	126.6	
49	126.4	126.9	
50	127.5	128.5	
51	114.9	115.0	outlier
52	122.4	122.6	
53	126.4	127.5	
54	127.2	127.4	
55	123.5	126.0	
56	120.7	120.4	
57	125.7	124.4	
58	125.6	126.4	
59	125.5	125.3	
60	125.2	125.7	
61	128.2	129.0	
62	124.1	124.2	
63	126.5	127.0	
64	125.7	126.5	
65	126.1	126.0	
66	125.7	124.9	
67	123.1	124.0	
68	123.7	116.4	invalid
69	129.5	129.5	
70	127.2	127.7	
71	127.1	127.2	
72	126.1	126.0	
73	126.7	123.6	outlier
74	119.7	119.2	outlier
75	126.2	125.7	
76	126.8	125.8	
77	124.7	127.0	
78	119.8	124.0	outlier
79	128.2	128.1	
80	125.1	123.8	
81	125.7	127.2	
82	127.8	127.8	
83	125.5	126.5	
84	125.6	126.0	
85	125.7	125.0	
86	122.0	121.0	
87	127.5	127.4	
88	126.6	126.1	
89	124.5	125.8	
90	126.7	127.6	
91	126.1	125.8	
92	122.5	125.1	
93	126.2	129.5	
94	116.6	116.6	outlier
95	125.5	125.3	
96	127.2	127.8	
97	127.2	127.3	
98	126.2	126.0	
99	116.5	116.9	outlier
100	126.4	127.7	
101	125.5	127.3	
102	125.0	128.0	
103	128.2	128.7	
104	125.9	126.9	
105	122.8	122.0	
106	126.4	125.7	
107	125.0	125.8	
108	126.0	123.0	outlier
109	126.1	125.0	
110	127.6	128.3	
111	125.0	125.0	
112	126.7	127.0	
113	124.9	125.9	
114	126.7	125.2	
115	126.9	127.4	
116	125.5	127.0	
117	122.5	122.0	
118	126.2	127.8	
119	124.8	125.6	
120	124.0	126.3	
121	126.4	125.5	
122	124.5	126.7	
123	127.1	126.9	
124	119.6	120.1	
125	126.3	126.7	
126	126.5	127.0	
127	125.7	124.6	
128	127.4	128.0	
129	123.3	123.8	
130	127.0	127.0	
131	126.7	125.9	
132	125.8	125.5	
133	127.1	127.1	
134	128.1	128.4	
135	128.0	128.0	
136	126.7	126.8	
137	126.7	124.8	
138	123.8	125.2	
139	123.4	125.4	
140	126.6	127.2	
141	124.7	126.8	
142	127.5	128.0	
143	126.0	127.0	
144	128.5	128.1	
145	127.5	128.5	
146	124.4	127.5	
147	124.4	122.2	
148	127.4	128.1	
149	128.6	129.8	
150	122.3	122.0	
151	124.3	127.3	
152	126.8	127.1	
153	125.4	127.3	
154	127.8	128.4	
155	127.7	126.6	
156	122.0	123.0	
157	125.9	124.6	
158	127.5	127.7	
159	130.7	131.0	
160	123.9	123.3	
161	125.0	125.8	
162	125.3	125.0	
163	125.4	125.9	
164	126.8	126.5	
165	125.2	125.3	

Optimum Water Content (%) Data for Samples 147 & 148

LAB	Sample 147	Sample 148	status	LAB	Sample 147	Sample 148	status	LAB	Sample 147	Sample 148	status
1	10.8	11.1		61	9.5	9.2		121	9.3	8.2	
2	9.7	10		62	10	9.9		122	10	9.6	
3	15.5	14.1	outlier	63	9	8.5		123	8.9	9.5	
4	10.5	11		64	9.7	10.2		124	13.1	12.9	
5	6.3	7.4	outlier	65	11	10.3		125	10.3	10.1	
6	10.1	10.3		66	9.9	10.4		126	9.1	8	
7	14.4	14.9	outlier	67	12.6	11.3		127	10.8	11.7	
8	9	12	outlier	68	11.8	13		128	9.8	9.3	
9	10.5	10.3		69	8	9.5		129	11.6	12.9	
10	11.5	12.5		70	9.8	9.7		130	10.5	10.5	
11	10	10.2		71	11.2	11.3		131	10.4	10.5	
12	10.3	11.4		72	10	9.9		132	11	11.1	
13	14.8	10	invalid	73	9.5	9.9		133	11.6	11.4	
14	10	8.5		74	12.9	12.4		134	9.3	9.5	
15	9.4	9.8		75	10.8	11.2		135	11	11	
16	9.7	10		76	9.7	10.5		136	10.7	10.8	
17	9.9	9.5		77	12.2	9.1	outlier	137	9.2	9.7	
18	10.2	9.3		78	13.1	10.5	outlier	138	11	11.5	
19	10.8	11.9		79	9	9		139	10.2	9.5	
20	11.4	10.3		80	11.4	9.9		140	10.4	9.8	
21	13.2	13.2		81	7.2	9.3	outlier	141	11.1	9.5	
22	11	10		82	9.9	9.7		142	9	9.5	
23	14	14.3	outlier	83	10.9	11		143	10.2	9.6	
24	9.4	9.3		84	9.7	10		144	9.8	10	
25	10.6	9.1		85	10.9	9.5		145	10.5	10	
26	9.3	9.4		86	12	11.7		146	10.4	7.5	outlier
27	9.5	10.1		87	9.8	10.5		147	11.6	11	
28	10.5	11.5		88	9.2	10.1		148	10.3	9.3	
29	10.3	8.8		89	11	10.8		149	8	7.5	outlier
30	13.7	14.9	outlier	90	10.5	10.1		150	12.6	12.1	
31	14.4	14	outlier	91	10.3	9.8		151	9.2	9.8	
32	10.1	9.4		92	12.4	10.5		152	10.3	10.2	
33	10.8	9.5		93	11.6	9	outlier	153	11.3	10.3	
34	10.3	9.3		94	12.1	12.1		154	10.3	10	
35	11.3	11		95	9.7	9		155	9.7	9.1	
36	9.6	9.4		96	10.3	10		156	11	11	
37	8.3	8		97	10.6	9.6		157	8.5	9.7	
38	10.2	10.2		98	11	11		158	9.6	10.2	
39	11.4	10.9		99	15.4	14.3	outlier	159	9.7	10.5	
40	10	10.1		100	10.1	9.9		160	12.1	12.5	
41	10.5	10.3		101	10.1	9.5		161	11	11.5	
42	10.3	10.2		102	9	9		162	10.8	9.5	
43	9.2	8.9		103	10.3	9.3		163	9.1	10.5	
44	9.9	10.5		104	10.3	10.7		164	9	9.5	
45	10.2	10.4		105	12	12.3		165	12	11.7	
46	10.2	9.9		106	10	9.9					
47	11.5	12.1		107	10.1	9.8					
48	10.3	10.1		108	12	10.8					
49	9.8	9.9		109	9.4	10					
50	9.5	9.7		110	9.9	9.3					
51	14	14	outlier	111	11.5	11					
52	11.5	10.5		112	10.7	10.5					
53	9.1	9.5		113	10.1	9					
54	10	9.7		114	10.2	11					
55	12	11		115	10.1	10					
56	11.1	11.8		116	11	11.2					
57	11.2	12.1		117	9.5	10					
58	11.1	10.8		118	10.4	10.3					
59	10.5	10.7		119	9.6	8.6					
60	11	10.7		120	11.3	11.5					

Maximum Unit Weight (lb/ft3) Data for Samples 155 & 156

LAB	Sample 155	Sample 156	status	LAB	Sample 155	Sample 156	status	LAB	Sample 155	Sample 156	status	LAB	Sample 155	Sample 156	status
1	132.6	132.6		73	131.0	130.5		145	127.9	129.2	outlier	217	133.6	133.2	
2	133.0	133.2		74	133.5	134.0		146	132.0	132.3		218	132.2	131.8	
3	132.3	132.4		75	131.4	130.0		147	131.8	132.2		219	132.2	132.2	
4	131.3	131.3		76	132.2	133.7		148	130.6	131.2		220	133.7	133.3	
5	130.1	132.2		77	131.9	132.1		149	131.2	131.6		221	133.5	132.8	
6	134.4	134.9		78	131.9	131.3		150	130.1	128.5	outlier	222	130.4	130.9	
7	132.6	132.7		79	131.2	130.6		151	133.7	132.5		223	132.2	132.1	
8	133.2	133.2		80	132.0	132.3		152	131.3	132.2		224	132.3	131.9	
9	132.2	131.3		81	132.9	133.0		153	129.6	130.0		225	133.3	132.7	
10	131.0	131.4		82	131.1	132.4		154	135.4	133.5		226	133.6	133.4	
11	132.9	131.4		83	126.0	131.3	invalid	155	131.9	131.1		227	132.8	132.8	
12	132.2	132.6		84	132.0	132.4		156	131.2	130.3		228	133.0	133.5	
13	133.5	133.5		85	70.0	70.0	invalid	157	122.2	126.7	invalid	229	132.5	131.7	
14	135.2	135.4		86	131.0	132.0		158	132.1	132.6		230	131.8	132.7	
15	129.2	129.4		87	132.5	132.6		159	132.6	132.6		231	132.3	130.8	
16	131.1	130.2		88	130.8	131.7		160	127.9	130.3	outlier	232	135.3	133.9	
17	130.5	131.2		89	132.9	132.6		161	129.3	128.9		233	129.8	130.5	
18	133.1	131.6		90	131.5	130.5		162	133.1	132.3		234	131.8	131.8	
19	134.5	143.8	invalid	91	132.2	131.0		163	131.7	131.7		235	135.1	133.0	outlier
20	131.0	131.3		92	130.1	129.8		164	132.0	134.0		236	130.0	131.0	
21	133.0	132.8		93	132.0	132.5		165	133.6	133.3		237	131.0	131.0	
22	133.0	132.7		94	130.4	132.7	outlier	166	130.1	129.8		238	132.3	132.2	
23	133.9	134.0		95	132.2	133.1		167	133.7	133.9		239	122.0	125.0	invalid
24	132.2	132.6		96	122.4	123.6	invalid	168	131.2	130.6		240	130.5	131.1	
25	132.2	132.5		97	129.0	132.7	outlier	169	133.4	132.9		241	133.0	133.0	
26	133.7	132.0		98	126.2	125.3	outlier	170	134.0	133.9		242	131.9	131.3	
27	132.9	132.8		99	132.0	132.5		171	131.8	132.9		243	132.8	132.2	
28	132.9	133.0		100	134.5	134.0		172	132.9	131.5		244	133.2	133.4	
29	133.3	132.4		101	133.2	133.2		173	132.0	132.5		245	132.5	131.6	
30	132.8	132.1		102	131.0	132.0		174	130.5	133.5	outlier	246	130.8	131.5	
31	127.8	128.2	outlier	103	133.0	133.0		175	130.8	132.1		247	126.1	126.9	outlier
32	131.5	132.6		104	133.7	132.9		176	132.0	132.5		248	131.7	131.9	
33	130.5	131.5		105	132.0	130.0		177	132.5	132.0		249	131.5	132.2	
34	130.0	131.2		106	123.7	123.0	invalid	178	132.2	132.4		250	131.3	133.3	
35	132.7	132.5		107	131.6	135.0	outlier	179	129.6	129.8		251	132.2	132.0	
36	132.5	131.5		108	133.1	133.7		180	129.8	131.3		252	132.0	132.0	
37	131.7	132.0		109	131.5	132.7		181	134.0	134.0		253	131.5	131.9	
38	131.5	131.5		110	131.3	130.5		182	131.5	131.4		254	131.1	132.7	
39	132.2	132.2		111	132.0	133.0		183	131.3	131.0		255	133.0	132.0	
40	131.6	131.8		112	133.4	133.4		184	132.5	132.9		256	133.0	133.0	
41	132.0	132.5		113	134.0	134.5		185	131.0	130.5		257	131.5	133.0	
42	132.0	131.8		114	133.0	133.2		186	131.5	131.7		258	132.5	132.8	
43	132.8	133.8		115	131.3	131.6		187	132.0	132.8		259	131.9	132.2	
44	132.8	133.0		116	131.9	133.3		188	132.9	132.2		260	128.5	125.2	outlier
45	133.5	134.0		117	134.2	134.0		189	130.3	131.2		261	133.0	133.5	
46	133.0	132.6		118	131.5	133.8	outlier	190	130.9	130.7		262	132.5	132.0	
47	131.5	131.4		119	130.7	130.3		191	132.7	132.7		263	131.1	131.0	
48	130.9	130.4		120	131.8	131.9		192	130.5	132.5		264	127.2	129.6	outlier
49	132.5	132.0		121	132.8	133.0		193	129.1	131.4	outlier	265	132.5	134.5	
50	132.9	131.1		122	132.6	131.8		194	132.8	132.7		266	134.2	133.6	
51	132.8	133.3		123	130.8	130.3		195	131.9	132.6		267	119.2	131.0	invalid
52	133.0	134.0		124	133.0	132.7		196	129.2	129.4		268	130.8	132.0	
53	133.2	133.3		125	132.8	133.6		197	132.4	132.7		269	129.5	129.9	
54	123.3	122.0	invalid	126	131.8	131.4		198	134.5	134.5		270	132.0	132.7	
55	131.7	132.6		127	133.7	133.8		199	132.6	133.1		271	133.1	133.0	
56	133.5	133.4		128	131.9	132.3		200	133.0	132.5		272	131.9	132.2	
57	133.6	134.1		129	132.3	132.0		201	132.3	132.2		273	131.5	132.0	
58	129.4	131.0		130	132.5	132.7		202	127.2	125.9	outlier	274	133.9	133.6	
59	132.3	132.3		131	131.5	133.0		203	133.3	133.3		275	130.5	131.6	
60	134.2	134.5		132	130.7	130.9		204	133.2	133.4		276	125.1	125.1	invalid
61	132.9	133.6		133	131.0	131.3		205	126.0	127.0	outlier	277	132.7	133.3	
62	132.5	132.3		134	129.4	126.8	outlier	206	134.0	133.0		278	133.4	133.6	
63	132.0	131.0		135	131.8	132.3		207	131.0	130.9		279	133.6	132.7	
64	133.0	133.0		136	124.2	121.3	invalid	208	133.0	133.2		280	132.8	132.9	
65	132.0	131.0		137	131.5	133.0		209	133.0	133.8		281	123.1	117.3	invalid
66	134.0	133.3		138	132.8	133.7		210	131.9	131.9		282	133.6	133.8	
67	133.5	133.1		139	131.1	132.3		211	133.1	133.3		283	132.3	132.3	
68	133.0	133.0		140	131.5	132.7		212	133.9	134.0		284	132.0	132.0	
69	132.3	132.5		141	133.6	132.3		213	131.5	132.0		285	131.4	131.3	
70	131.7	132.2		142	130.7	131.8		214	125.2	129.1	outlier	286	133.6	133.4	
71	133.8	133.7		143	134.8	135.2		215	131.3	131.3					
72	133.0	134.0		144	128.5	128.0	outlier	216	120.4	120.7	invalid				

Optimum Water Content (%) Data for Samples 155 & 156

LAB	Sample 155	Sample 156	status
1	9	9	
2	8.9	8.9	
3	9	9.3	
4	9	8.3	
5	8.2	8.4	
6	7.7	8	
7	9.1	9.2	
8	8.4	8.4	
9	8.6	8.5	
10	9	8.3	
11	8	8.2	
12	9.1	8.6	
13	8.5	8.5	
14	8.2	8.2	
15	9.4	9.7	outlier
16	8.9	8.9	
17	9.2	8.8	
18	8.6	9.1	
19	8.5	8	
20	9.5	8.9	
21	9	9	
22	8.7	8.6	
23	9	7.9	outlier
24	8	8.2	
25	9	9	
26	7.8	8	
27	9.4	8.3	outlier
28	8.7	8.6	
29	8.9	8.8	
30	8.5	8.2	
31	9.5	9	
32	7.9	9	outlier
33	9.1	9	
34	8.6	8.7	
35	9	8.9	
36	8.5	9	
37	9.3	9	
38	8.5	8.3	
39	8.9	8.7	
40	8.3	8.4	
41	9	9	
42	8.4	8.5	
43	8.2	8.2	
44	8.5	8.2	
45	8	8	
46	8.8	8.6	
47	8.9	8.6	
48	9.7	10.1	outlier
49	9	9	
50	7.9	8.1	
51	8.2	8.3	
52	9	8	
53	8.9	8.6	
54	11.5	12	invalid
55	8.2	8.1	
56	7.4	7.5	
57	8.5	8.3	
58	9.1	9.2	
59	8.4	8.2	
60	8.4	8.4	
61	9.1	8.4	
62	7.8	8	
63	8.3	8.5	
64	8.6	8.6	
65	8	9	outlier
66	8.1	8.7	
67	8.5	7.8	
68	8.5	8.5	
69	8.8	8.8	
70	9.2	7.8	outlier
71	8.4	8.4	
72	8.5	8.5	

LAB	Sample 155	Sample 156	status
73	8.5	8.7	
74	9	9	
75	8.5	8.9	
76	9.8	8.8	
77	8.5	8.4	
78	8.8	9	
79	8.8	10.6	invalid
80	8.5	8.8	
81	8.5	8.6	
82	9.2	8.9	
83	7.5	8.1	
84	8.4	7.4	
85	0	0	invalid
86	9	9	
87	8.6	8.5	
88	9.2	8.9	
89	9	8.9	
90	8.8	8.7	
91	8.3	8.3	
92	8.9	8.9	
93	9	8.5	
94	10	10	outlier
95	8.9	8.8	
96	6.7	6.4	outlier
97	9.5	8.8	
98	7.2	10	invalid
99	8.5	8	
100	8.5	8	
101	8.8	8.1	
102	9	8.5	
103	8.8	9	
104	8.8	8.9	
105	8.3	7.9	
106	10.9	13	invalid
107	9.3	8.9	
108	8.4	8.3	
109	9	8.6	
110	8.4	8.8	
111	8	8	
112	8.6	8.6	
113	8.2	8.1	
114	7.9	7.9	
115	8.4	8.3	
116	8.8	8.9	
117	8	8.2	
118	8.2	8.2	
119	8.4	8	
120	8.8	8.6	
121	9	8.9	
122	8.5	8.8	
123	9.1	9	
124	8.1	8.3	
125	7.7	8.1	
126	10.4	9.4	outlier
127	8.3	8.6	
128	7.5	7.5	
129	8.6	8.3	
130	8.3	8.5	
131	8.9	8.4	
132	9.2	8.7	
133	8.7	8.8	
134	9.5	9.2	
135	8	8.1	
136	9.5	8.7	
137	8.5	8.5	
138	8.1	7.7	
139	8.4	7.6	
140	8.7	8.3	
141	8.3	8.5	
142	7.9	7.8	
143	8.3	8.2	
144	10	10	outlier

LAB	Sample 155	Sample 156	status
145	7	7.1	outlier
146	8.9	8.7	
147	8.7	9.1	
148	10.4	9.8	outlier
149	9.1	9	
150	8.5	9.5	outlier
151	8.4	9.2	
152	8.5	8.3	
153	9.2	8.8	
154	7.7	7.6	
155	9.3	8.8	
156	8.8	9.1	
157	7.9	7.9	
158	7.7	8.6	outlier
159	8.8	8.8	
160	9.1	9.2	
161	8.9	9.1	
162	7.6	7.6	
163	8.8	8.7	
164	7	8	outlier
165	8.5	8.5	
166	8.8	9	
167	9.1	9	
168	9.1	9	
169	8.7	8.4	
170	8.1	8.3	
171	8.9	8.3	
172	8.8	9.2	
173	8.7	8.3	
174	8	7.6	
175	8.3	8.1	
176	8	8	
177	8.5	8.7	
178	8.8	8.4	
179	7.7	7.5	
180	9.1	8.7	
181	8.3	8.5	
182	9	8.7	
183	8.3	8.5	
184	8.5	8.8	
185	9	9	
186	8.3	8.3	
187	8.6	9	
188	8.7	8.9	
189	9	9.4	
190	8.6	9.2	
191	8.4	8.1	
192	9	7.8	outlier
193	8.5	9.8	outlier
194	8.7	8.4	
195	8.6	8.6	
196	9	8	
197	8.4	8.5	
198	8	8.1	
199	9	8.2	
200	9.5	9.5	
201	7.8	8.6	
202	10	9	outlier
203	8.5	8.3	
204	8.3	8.2	
205	11	11	invalid
206	8	8	
207	8.6	8.2	
208	7.7	8.1	
209	8.7	8.5	
210	9	8.9	
211	8.5	8.4	
212	8.5	7.8	
213	8.5	9	
214	11.4	9.2	invalid
215	8.3	9.2	outlier
216	12.5	12.4	invalid

LAB	Sample 155	Sample 156	status
217	7.5	7.5	
218	8.8	8.8	
219	8.5	8.2	
220	8.3	8.5	
221	8.7	7.7	
222	9.2	8.7	
223	8.4	8.7	
224	8.5	8.8	
225	8.7	8.9	
226	8.1	7.9	
227	8.5	8.7	
228	8.5	8.5	
229	7.8	8.1	
230	8.7	9.1	
231	8.9	9	
232	7.5	9.7	invalid
233	9.1	9.3	
234	7.5	7.5	
235	8.2	10.2	invalid
236	9	9	
237	9	9	
238	8.7	8.6	
239	10	8	invalid
240	8.5	8.5	
241	9	9	
242	8.6	8.3	
243	8.2	8.6	
244	8.3	8.2	
245	8.6	8.9	
246	9.4	8.5	
247	8	8	
248	8.7	8.5	
249	8.6	8.5	
250	9	9.2	
251	8.8	9	
252	7.9	8.5	
253	8.9	8.6	
254	8.6	8	
255	8.5	8.5	
256	8.5	9.6	outlier
257	8	8.3	
258	8	7.8	
259	8.9	8.8	
260	9.2	6	invalid
261	8	8.5	
262	8.5	8	
263	9.1	8.7	
264	10	8.5	outlier
265	8.7	6.2	invalid
266	8.4	8.2	
267	12.7	7	invalid
268	8.6	8.6	
269	7.9	8.8	outlier
270	8.4	8.1	
271	8.5	8.6	
272	8.1	8.2	
273	8.5	9	
274	8.1	8.2	
275	8.3	8.6	
276	17.1	17.1	invalid
277	8.5	8.3	
278	9.6	9	
279	8.5	8.5	
280	8	7.9	
281	11	8.8	invalid
282	8	7.4	
283	8.9	8.9	
284	9	9	
285	8.4	8.5	
286	8.6	8.4	

Maximum Unit Weight (lb/ft^3) Data for Samples 157 & 158

LAB	Sample 157	Sample 158	status	LAB	Sample 157	Sample 158	status	LAB	Sample 157	Sample 158	status	LAB	Sample 157	Sample 158	status
1	125.2	125.3	outlier	69	127.3	122.8	outlier	137	129.7	132.1		205	131.2	132.5	
2	132	131.7		70	133.5	133.5		138	131.5	131		206	135.1	133.6	
3	126.6	127.9		71	132	133.3		139	132.8	133.7		207	131.9	133	
4	132.6	133.7		72	135	134		140	131.5	133.3		208	132.8	134.2	
5	133	134.5		73	131.5	131.2		141	133.9	134.1		209	127.4	133.3	outlier
6	133.2	134.2		74	133	133.5		142	133.4	133.6		210	122.1	124.4	outlier
7	131.5	132.5		75	134	136		143	132.6	133.6		211	128.1	128.4	
8	130.6	133.6		76	132.8	132.6		144	124	125	outlier	212	132.1	133.4	
9	132.7	132.5		77	130	132.5		145	134.6	134.2		213	132.3	133.8	
10	129.1	129		78	133.8	134		146	131.1	131.1		214	130.5	133.5	
11	131.5	132		79	133.2	134.7		147	132.8	132.7		215	128.8	130.9	
12	130.4	128.9		80	130.4	130.9		148	131.5	132.5		216	128	130	
13	121	122	invalid	81	134.2	135.2		149	125.6	125.2	outlier	217	130.5	131.5	
14	135.2	134.6		82	131.8	130.9		150	132.5	143.8	invalid	218	132.1	132	
15	129.5	128.9		83	133.5	132.5		151	132	132.5		219	134	134.9	
16	131.7	134.3		84	129.8	133.5	outlier	152	131.1	131		220	130.8	131.8	
17	133.4	133.2		85	133.7	133.9		153	130.3	129.9		221	133.5	134.5	
18	129	130		86	130.7	131.1		154	134	134.5		222	131.7	133.2	
19	132.9	134.3		87	126	128		155	130.9	130.9		223	131	131.5	
20	129	133	outlier	88	132.5	133.2		156	131	131.7		224	128	127.2	
21	132.6	133.2		89	133.4	134.9		157	129.4	130.4		225	130	128.9	
22	132	131.5		90	121.4	122.9	outlier	158	132.5	134		226	131.7	132.9	
23	131.4	131.9		91	131.8	132.8		159	133	134.9		227	130.9	132.2	
24	133	133.5		92	130.8	132.4		160	129.2	130.7		228	132	136	outlier
25	130.5	130		93	133.8	134.5		161	118	121.3	invalid	229	133.2	134	
26	131.7	132.9		94	132.6	135.2		162	131	130.5		230	131.5	132.8	
27	130.6	131.4		95	133	133		163	128.3	133.8	outlier	231	130.1	132	
28	124.9	125.3	outlier	96	132.6	133		164	132.6	132.7		232	130.1	131.1	
29	137	136	outlier	97	127.2	131.5	outlier	165	129	130.4		233	136	135.4	
30	132.2	134.6		98	129.8	129.2		166	131.5	133		234	128.3	131.5	
31	130.3	131.5		99	128.6	128.7		167	131.3	133.7		235	132.6	131.3	
32	131.3	132.2		100	133	134.3		168	131.5	133		236	133	135	
33	131.7	133.3		101	130	131		169	130.8	132.1		237	131.8	134.4	
34	130.5	131.8		102	132.4	132.3		170	130.3	132		238	130.3	131.7	
35	129.6	130.8		103	136.7	132.9	outlier	171	132.7	133.6		239	132	130.4	
36	132	133.4		104	132.1	133.6		172	127.8	128.1		240	132.5	134	
37	133.2	135.3		105	131.5	131.3		173	124	125	outlier	241	131	132	
38	131	134		106	128.6	129.8		174	132.3	132.3		242	130.6	133.3	
39	133.8	133.9		107	133.4	134.8		175	131.5	131.3		243	124	123	outlier
40	130.3	128	outlier	108	135.9	134.4		176	131.7	132.2		244	133.9	134.5	
41	130	134	outlier	109	133.4	134.7		177	127.6	128.4		245	131.2	132	
42	131.6	132.2		110	131.3	132		178	132	131.2		246	131	132.5	
43	133.1	134.3		111	131.5	132.6		179	133	134		247	133.5	133.7	
44	131	130.5		112	132.5	133.4		180	131	132		248	132.6	130.2	outlier
45	133.5	135.5		113	130.8	132		181	132.6	133.1		249	132	134	
46	132.6	133		114	132.3	134.3		182	131.1	133.1		250	134.5	135.2	
47	132.5	133.1		115	126	126	outlier	183	133.6	133.4		251	133	135	
48	136.9	137.9	outlier	116	133.7	134		184	131.7	133.5		252	131	135	outlier
49	131	134		117	134	135.5		185	131	133		253	133.4	135.2	
50	131.2	131.6		118	132	134		186	134.6	134.5		254	132	134	
51	134.8	132.5	outlier	119	132.7	133.7		187	120.9	122.4	invalid	255	130.7	132.3	
52	132.5	134.5		120	132.7	130.5	outlier	188	130	134	outlier	256	132.8	132.1	
53	132.9	134.2		121	131	132.2		189	132.3	133.8		257	132.6	133	
54	133.2	133.8		122	130.7	131.4		190	133.2	133.8		258	134.2	133.6	
55	133.7	133.2		123	130.5	131.5		191	139.5	139.5	outlier	259	130.9	132	
56	131	132		124	133.7	133.4		192	129.8	131.8		260	132.3	134	
57	133	132.7		125	129.3	131.2		193	130.9	130.5		261	133	133.4	
58	133.2	132.9		126	129.9	130.2		194	129.8	131.7		262	132	133	
59	128.1	129.4		127	133.4	134.7		195	131.1	133.6		263	131.5	133	
60	128.2	128.2		128	131.3	131.6		196	130.8	129.6		264	131.5	134	
61	127	129		129	130.3	129.5		197	130	130.8		265	132.3	132.9	
62	132.5	133.9		130	130.6	131.7		198	132.5	133		266	125.1	125.1	outlier
63	129.9	132.9		131	134.9	136.1		199	132.3	133		267	131.2	134.1	
64	128.5	129.1		132	111.7	110.7	invalid	200	131.4	132.5		268	128.3	129.1	
65	132	132		133	132.9	134.8		201	127.2	130.1		269	131.6	132.2	
66	132	131		134	130.4	130.4		202	129.2	131.4		270	134.2	126.2	invalid
67	131.7	133.3		135	128.8	131.3		203	133	135		271	133.6	134.3	
68	130.7	134.1		136	132	132		204	134	132.8					

Optimum Water Content (%) Data for Samples 157 & 158

LAB	Sample 157	Sample 158	status
1	13	13	invalid
2	9	8.1	
3	9.6	9.3	
4	7.7	7.5	
5	7.9	7.7	
6	7.2	7.3	
7	8.5	7.8	
8	8.4	8.2	
9	7.7	7.1	
10	9.7	9	
11	9.3	8	
12	8.2	9.8	outlier
13	10.5	10	
14	8.1	8.6	
15	9.8	9.8	
16	9	8.3	
17	8.2	7.7	
18	9	9	
19	8.5	7.7	
20	9.5	7.5	outlier
21	8.6	7.9	
22	9	9	
23	8	7.9	
24	8	7.5	
25	8	8	
26	10.3	9.3	
27	8.6	8.2	
28	10.4	9.5	
29	7	6	
30	10.1	9	
31	9	9	
32	8.9	8.5	
33	8	9	
34	8.7	8	
35	9.1	8.2	
36	6.5	6.2	
37	7.7	6.2	
38	7	8	
39	7	7.1	
40	5.8	7.8	outlier
41	9	8	
42	8.5	7.9	
43	7.6	7.4	
44	7.5	7.5	
45	8	7.5	
46	8	8.3	
47	8.5	8	
48	8.1	6.6	
49	8	7	
50	9	8.7	
51	8.4	6.8	
52	8	7.5	
53	7.7	7.5	
54	7.5	7.1	
55	7.3	7.2	
56	8.5	7.5	
57	8.6	8.8	
58	7.3	7.1	
59	9.9	9	
60	9.3	9.4	
61	11.5	9.5	outlier
62	8.7	7.3	
63	8.4	9.1	
64	9.8	8.7	
65	8.6	6.9	
66	8.6	8.2	
67	8.5	8.1	
68	8	6.4	

LAB	Sample 157	Sample 158	status
69	11	12.8	invalid
70	8	7.2	
71	7.7	7.6	
72	8	7.5	
73	7.6	7.7	
74	8.5	8.5	
75	8	7	
76	5	4.8	outlier
77	8.5	7.5	
78	8.1	7.5	
79	8.7	8.8	
80	8.9	8.8	
81	8.2	8	
82	12.8	14.6	invalid
83	9	9.5	
84	8.5	8	
85	8	7.6	
86	9.1	8.9	
87	9	10	
88	8.2	8.1	
89	7.6	7.6	
90	11.3	10.5	outlier
91	8.4	7.8	
92	8.4	7.5	
93	8.1	7.8	
94	7.5	7	
95	8	7.8	
96	9	9.4	
97	9.9	7.3	outlier
98	8.3	7.6	
99	11.5	11.9	outlier
100	7.5	7.2	
101	9	9	
102	7.9	7.8	
103	8.3	5.8	outlier
104	7.5	7.7	
105	8	8.3	
106	8.9	8.5	
107	7.2	7	
108	6.5	5.7	
109	7.9	8.1	
110	8.9	8.4	
111	8.5	7.7	
112	7.9	7.7	
113	9	7.5	
114	7.9	7.4	
115	9	9	
116	5.8	5.9	outlier
117	7	6.9	
118	7.5	8	
119	7.5	7.5	
120	8.6	10	outlier
121	8	8.2	
122	8	8.3	
123	8.5	8.5	
124	7.1	7.7	
125	9.8	8	
126	9.7	7.6	outlier
127	8	7.6	
128	8.5	8.6	
129	7.3	8.7	outlier
130	8.2	7.4	
131	7.8	6.9	
132	19.7	19.1	invalid
133	7.2	6.4	
134	8.6	8.5	
135	6.2	8.4	outlier
136	8.3	8	

LAB	Sample 157	Sample 158	status
137	9.3	7.9	
138	7.5	8	
139	10.6	11.4	outlier
140	7.5	7.6	
141	7.7	7.4	
142	7.3	7.5	
143	7.7	7.5	
144	10	11	outlier
145	7.5	7.4	
146	8	9	
147	7.5	7.4	
148	8.5	8.5	
149	9.2	10.9	outlier
150	7.7	7.8	
151	8	7.5	
152	8.9	8.8	
153	9.4	9.5	
154	8	7.8	
155	8.3	7.9	
156	9.1	9	
157	8.6	7.7	
158	8	7.5	
159	8.1	7.5	
160	7.8	8.9	
161	4.3	4.8	outlier
162	8	7	
163	9.5	7.5	outlier
164	8.5	7.6	
165	10.5	8.8	
166	8.6	8.4	
167	8.8	7.6	
168	8.5	7	
169	8.8	8.5	
170	9.5	9	
171	8.6	8.2	
172	10.5	10.1	
173	10	10	
174	8.5	7.7	
175	8	8.3	
176	7.5	7.7	
177	6.7	6.4	
178	7	8.9	outlier
179	8	8	
180	9	8	
181	8	8.5	
182	8.4	7.6	
183	8.1	8.1	
184	7.7	7.3	
185	8	7	
186	7.7	7.5	
187	11.9	10.8	outlier
188	10	7	outlier
189	8.2	7.6	
190	7.5	7.6	
191	8.2	8.3	
192	8.5	7.8	
193	7.5	8.1	
194	8.4	8.4	
195	8.1	7.4	
196	8.6	6	outlier
197	9	9.1	
198	7	7	
199	8.3	7.9	
200	8.3	8	
201	11.5	10.2	outlier
202	9.3	8.4	
203	8	8	
204	7	8	

LAB	Sample 157	Sample 158	status
205	8.1	7.9	
206	6.3	6.3	
207	8.8	8.7	
208	7.6	7.6	
209	8.2	8.4	
210	10.5	10.2	
211	8.5	8.3	
212	7.5	7.4	
213	7.9	7.2	
214	8.5	7.4	
215	7.5	9.4	outlier
216	9	10.1	
217	8.5	8.5	
218	8	8.1	
219	8	7.8	
220	9.5	8.7	
221	8.5	7.5	
222	8.7	7.7	
223	9	9	
224	8.4	8.7	
225	9.2	7.8	
226	8.1	7.9	
227	9.1	8.5	
228	6.9	6.1	
229	7.8	7.5	
230	8	7.5	
231	8.3	7.7	
232	8.4	7.4	
233	6.6	6.9	
234	9.8	8.6	
235	8	7.9	
236	8.2	7.6	
237	7.4	7.1	
238	8.6	8.4	
239	7.5	9.5	outlier
240	8.5	7.5	
241	8.6	8.1	
242	8.4	7.8	
243	11.5	12.5	outlier
244	8.1	8.1	
245	9.6	10	
246	9.8	8.4	
247	8	7.9	
248	8.4	8.6	
249	7.5	7	
250	8.1	7.7	
251	8.5	8	
252	8	7	
253	8.3	7.4	
254	8	7	
255	8.2	7.9	
256	8.5	8.8	
257	9	9.4	
258	7.2	7.4	
259	8.6	7.3	
260	8.6	8.1	
261	7.5	7.3	
262	7	7	
263	8.5	7	
264	9	8	
265	8.1	8.5	
266	9.6	9.6	
267	8.2	7.4	
268	9.9	8.5	
269	8.5	7.8	
270	10.5	10.5	outlier
271	8.4	7.3	

APPENDIX E- PRECISION STATEMENT FOR AASHTO T180

Precision Statement for AASHTO Standard Test Method T180, Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop

X. Precision and Bias

X.1 Precision - Criteria for judging the acceptability of maximum dry density and optimum water content results obtained by this method are given in Table X.

X.1.1 Single-Operator Precision (Repeatability) – The figures in Columns 2 of Table X are the within standard deviations that have been found to be appropriate for the conditions of tests described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceeds the values given in Table X, Column 3.

X.1.2 Multilaboratory Precision (Reproducibility) – The figures in Column 4 of Table X are the between standard deviations that have been found to be appropriate for the conditions of tests described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the values given in Table X, Column 5.

Table X – Precision Estimates

Conditions of Test and Test Property	Standard Deviation (1s)[a]	Acceptable Range of Two Test Results (d2s)[a]	Standard Deviation (1s)[a]	Difference Between Two Tests (d2s)[a]
	Single Operator Precision:		Multilaboratory Precision:	
Maximum Dry Density (lb/ ft^3):				
Sandy clay	0.6	1.8	1.6	4.4
Sand and Gravel	0.7	2.1	1.8	5.0
Moisture Content (%):				
Sandy Clay	0.4	1.0	0.7	2.0
Sand and Gravel	0.3	0.9	0.5	1.4

[a] These values represent the 1s and d2s limits described in ASTM Practice C670

Note – The precision estimates given in Table X are based on the analysis of test results from AMRL interlaboratory study (ILS) and proficiency sample Program (PSP). The ILS data consisted of results from 21 to 23 laboratories tested three replicates of four sets of samples. The materials included coarse and fine-graded aggregate-soil blends with about 7% passing #200. The average maximum density ranged from 138.5 lb/ft^3 to 147.7 lb/ft^3. The average optimum water contents ranged from 4.5% to 5.9%. The PSP data consisted of results from 144 to 253 laboratories tested pairs of three sets of Soil Classification and Compaction Proficiency samples. The materials included fine grained soil with 85% or more passing #200. The average maximum density ranged from 125.8 lb/ft^3 to 132.6 lb/ft^3. The average optimum water contents ranged from 8.0% to 10.4%. The details of this analysis are in NCHRP Web-Only Document 168.

X.2 Bias – No information can be presented on the bias of the procedure because no comparison with the material having an accepted reference value was conducted.