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16. Abstract

Test method Tex-113-E prepares laboratory aggregate base test specimens with an impact hammer compactor. These specimens are used for compaction characteristics and design tests. Although the historical Tex-113-E required a certain amount of compaction energy, no method to validate attainment of that energy existed until Texas Department of Transportation (TxDOT) Project 0-5135 developed the Soil Compactor Analyzer (SCA). The SCA measures the kinetic energy applied by each drop of the impact hammer. In this project, the SCA system was modified to control the compactor, where the SCA starts the machine and then turns off the compactor when the prescribed amount of energy is attained. This project then evaluated how changing the machine operational parameters, such as hammer weight, drop height, and number of blows per lift, impacted test results. In this evaluation, the SCA was used in all cases to control the compactor, so the prescribed amount of total energy was always applied regardless of machine operational parameters. The results showed that while using the current TxDOT-approved SCA to control total energy per lift between 740 and 765 ft-lbf, the number of blows per lift may vary between 45 and 60 with no impact on test results. Finally, this project conducted an interlaboratory study to develop precision statistics of Tex-113-E compaction. This study showed that the SCA enables excellent precision of total compaction energy. Total compaction energy should be repeatable and reproducible within about 27 ft-lbf, or approximately 1 percent of the specification value. Compacted dry density should be repeatable within about 2.5 pounds per cubic foot (pcf) and reproducible within about 3.3 pcf.

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IMPLEMENTATION OF THE SOIL COMPACTOR ANALYZER INTO TEST METHOD TEX-113-E: TECHNICAL REPORT

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Report 5-5135-01-1
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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. The researcher in charge was Stephen Sebesta.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. The guidance provided by the project director, Caroline Herrera, P.E., and the input and assistance of Jaime Gandera, P.E., significantly contributed to the success of this project. Finally, the participation of labs in the interlaboratory study is greatly appreciated.

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EXECUTIVE SUMMARY

In Test Method Tex-113-E, the Texas Department of Transportation (TxDOT) employs an impact hammer method of sample compaction for laboratory preparation of road base materials for testing. Although the historical Tex-113-E required a certain amount of compaction energy, no method to validate attainment of that energy existed until TxDOT Project 0-5135 developed the Soil Compactor Analyzer (SCA). The SCA measures the kinetic energy applied by each drop of the impact hammer. In this implementation project, the research team modified the SCA to not only measure the compaction energy, but also to control the automatic tamper and stop the machine upon attainment of the prescribed energy per lift. Fifteen SCA units with machine control capability were delivered to TxDOT in this implementation project. Additionally, the 12 SCA units delivered to TxDOT in prior Project 0-5135 were retrofitted with machine control capability in this implementation project, yielding 27 SCA systems in TxDOT with machine control capability.

As TxDOT prepared to officially implement the SCA into Test Method Tex-113-E, the researchers also investigated the influence of changing machine operational parameters on test results while using the SCA to maintain the prescribed amount of energy per lift. Machine operational parameters include the hammer weight, drop height, and number of drops per lift. Varying the hammer weight and drop height will result in different energies per drop, which results in a different number of drops per lift to attain the prescribed energy. In this project, parameters were varied to perform test series with average energies per drop between approximately 12.5 and 16.7 ft-lbf, which resulted in a range of 45 to 60 drops per lift. Tests investigated included the moisture-density relationship; the dielectric constant and seismic modulus, both at the time of molding and after Tex-117-E Part II conditioning; the unconfined compressive strength (UCS) per Tex-117-E Part II; and the moisture content after compressive strength testing. The results showed that while using the current TxDOT-approved SCA to control total energy per lift between 740 and 765 ft-lbf, the number of blows per lift may vary between 45 and 60 with no impact on test results.

As a final stage in this project, an interlaboratory study was conducted to develop precision statistics for Tex-113-E compaction. This study showed that the SCA enables excellent precision of total compaction energy. Total compaction energy should be repeatable and reproducible within about 27 ft-lbf, or approximately 1 percent of the specification value. Compacted dry density should be repeatable within about 2.5 pounds per cubic foot (pcf) and reproducible within about 3.3 pcf.

CHAPTER 1. EVALUATION OF IMPACT HAMMER ADJUSTMENTS ON MEASURED MATERIAL PROPERTIES

INTRODUCTION

With TxDOT's recent inclusion of the SCA in Tex-113-E, labs can now control and obtain the required amount of total energy applied to each lift during compaction of flexible base test specimens. The current Tex 113-E requires 750 ft-lbf per lift to be reached within 50 ± 5 blows of a 10 ± 0.02 lb hammer. To investigate these tolerances, researchers at the Texas Transportation Institute (TTI) employed a Grade 2 flexible base and systematically varied the automatic tamper's drop height and weight to yield blows per lift during sample fabrication ranging from 45 to 60 while still maintaining a total energy per lift of approximately 750 ft-lbf. Test series with three different target numbers of blows per lift were conducted. The results showed that while using the current TxDOT-approved SCA to control total energy per lift between 740 and 765 ft-lbf, the number of blows per lift may vary between 45 and 60 with no impact on test results. Tests investigated included the moisture-density relationship from Tex-113-E; the dielectric constant and seismic modulus, both at the time of molding and after Tex-117-E Part II conditioning; the UCS per Tex-117-E Part II; and the moisture content after compressive strength testing.

Kinetic energy during compaction with the automatic tamper used in Tex-113-E is most effectively increased by obtaining increases in the impact velocity. With the tampers used in TxDOT, this is best accomplished through decreasing friction losses as much as possible and increasing the drop height. If additional adjustment is necessary to obtain the prescribed total energy per lift within 45 and 60 blows, adding weight to the hammer is the next step to take.

SUMMARY OF EXPERIMENT

Table 1.1 presents the experiment used to investigate energy tolerances and drop height adjustments. In essence, the experiment was designed to use varying hammer drop heights and hammer weights to obtain the different target energies per blow. These different energies per blow in turn result in the different levels of target number of blows per lift while maintaining the total sample compaction energy requirement of 750 ft-lbf per lift.

Table 1.1. Experimental Design to Investigate Impact of Number of Drops per Lift on Test Results.

<table>
<tr><th>Target Average Impact Energy per Blow (ft-lbf)</th><th>Target Number of Drops per Lift</th><th>Tests Performed in Triplicate for Each Target Level</th></tr>
<tr><td>12.5</td><td>60</td><td rowspan="3">• Tex-113-E moisture-density relationship.
• Compressive strength at 0 psi lateral pressure (Tex-117-E Part II).
• Dielectric constant at molding and immediately before breaking.
• Seismic modulus at molding and immediately before breaking.
• Moisture content after breaking.</td></tr>
<tr><td>15.0</td><td>50</td></tr>
<tr><td>16.7</td><td>45</td></tr>
</table>

MATERIAL USED IN TESTING

For these tests, researchers used a Grade 2 base from the Vulcan Groesbeck pit. Appendix A presents the TxDOT test report from the material used.

PRESENTATION OF RESULTS

Appendix B presents the results from the specimens tested. In summary, the results revealed that when the target compaction energy was controlled by the current TxDOT-approved SCA and achieved within 45 to 60 drops per lift:

- No statistical difference existed in the maximum dry density or optimum water content.
- No statistical difference existed in the dielectric constant at time of molding or after Tex 117-E Part II conditioning.
- No statistical difference existed in the seismic modulus at the time of molding or after Tex 117-E Part II conditioning.
- No statistical difference existed in the unconfined compressive strength after Tex-117-E Part II conditioning.
- The moisture content after breaking was less with specimens compacted at average energies of 16.7 ft-lbf per drop (i.e., samples only requiring 45 blows to reach the target energy per lift). Although statistically significant, in terms of performance this difference is insignificant since the mean strengths did not differ among the treatments.

SUMMARY OF MACHINE PARAMETERS USED

Table 1.2 summarizes the machine parameters and average effort applied for each treatment. The research team tested a total of 45 specimens (15 for each treatment). The desired range of blows per lift and average energy per blow were obtained while maintaining efforts within the range implied in TxDOT's allowable tolerances on sample height. The average drop height of

18.6 inches when targeting 16.7 ft-lbf per blow was obtained by maximizing the distance between the engager and the releaser body on the automatic tamper (i.e., with this particular tamper, that drop height was the maximum drop height attainable).

Table 1.2. Summary of Machine Parameters for Treatments Investigated.

Target Energy per Blow (ft-lbf)	Hammer weight used (lb)	AVG # blows per lift	AVG Drop Ht (in.)	AVG Energy per blow (ft-lbf)	AVG Total Energy per Lift (ft-lbf)	AVG Effort (ft-lbf/in3)
12.5	10.31	61	16.2	12.4	750.7	13.3
15	11.04	52	18	14.6	751.3	13.6
16.7	12.21	45	18.6	16.8	759.2	13.2

RESULTS FROM MOISTURE DENSITY RELATIONSHIP

Figures 1.1–1.3 illustrate the moisture-density relationships measured in triplicate for the three target energies per blow. Table 1.2 showed these target energies per blow were 12.5, 15, and 16.7 ft-lbf while maintaining total compaction energy of 750 ft-lbf per lift. Since each moisture-density curve requires 4 samples, a total of 36 samples were required to generate these data. Appendix B presents the entirety of each sample's results in the column labeled "113-E Moisture-Density Samples."

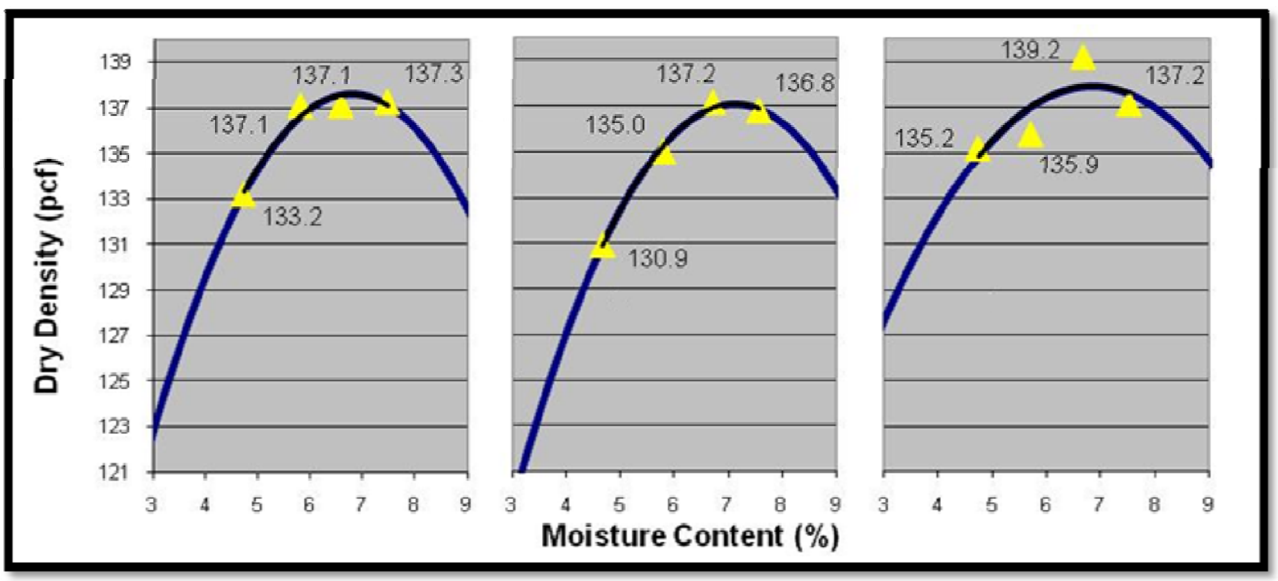


Figure 1.1. Triplicate Moisture-Density Curves for Samples Molded at Energies per Blow of 12.5 ft-lbf and Total Energy per Lift of 750 ft-lbf.
Left to right: Replicate 1, 2, and 3

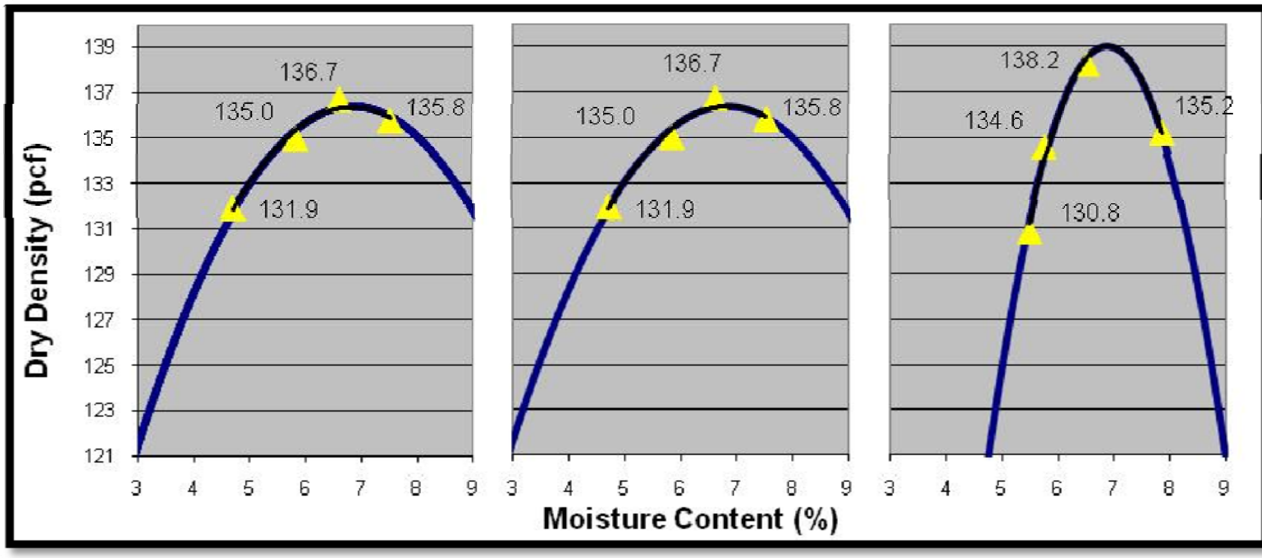


Figure 1.2. Triplicate Moisture-Density Curves for Samples Molded at Energies per Blow of 15 ft-lbf and Total Energy per Lift of 750 ft-lbf.
Left to right: Replicate 1, 2, and 3

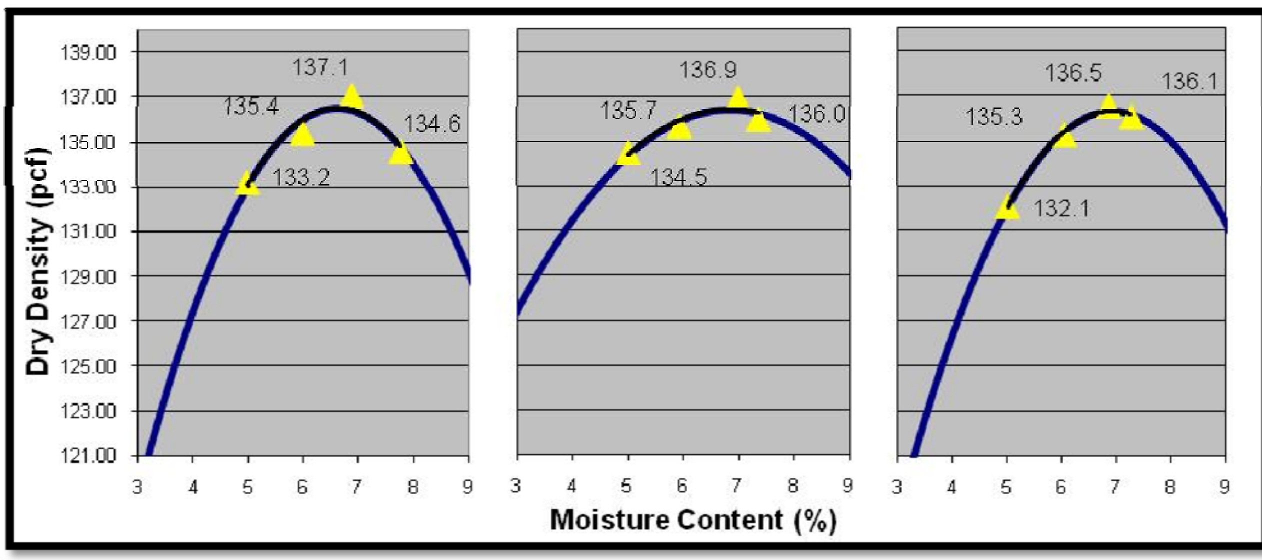


Figure 1.3. Triplicate Moisture-Density Curves for Samples Molded at Energies per Blow of 16.7 ft-lbf and Total Energy per Lift of 750 ft-lbf.
Left to right: Replicate 1, 2, and 3

Each replicate in Figures 1.1–1.3 generated optimum moisture content (OMC) and maximum dry density output using TxDOT's approved Tex-113-E spreadsheet. Table 1.3 summarizes these OMC and maximum dry density results from each replicate. The data suggest, and statistical tests confirm, that no significant difference in the average maximum dry density or optimum water content existed among the treatments. So long as the SCA was used to control the compaction energy at 750 ft-lbf per lift, the optimum moisture and max density were statistically equivalent regardless of whether the average energy per blow was 12.5, 15, or 16.7 ft-lbf.

Table 1.3. Tex-113-E Moisture-Density Results with Varying Energies per Blow.

	12.5 ft-lbf per blow			15 ft-lbf per blow			16.7 ft-lbf per blow		
Replicate	Max Density (pcf)	OMC (%)	AVG Total Energy per Sample (ft-lbf)	Max Density (pcf)	OMC (%)	AVG Total Energy per Sample (ft-lbf)	Max Density (pcf)	OMC (%)	AVG Total Energy per Sample (ft-lbf)
1	137.6	6.8	3002	138.7	7	3000	136.5	6.6	3034
2	137.1	7.1	2997	136.4	6.8	2991	136.5	6.8	3036
3	138	6.8	3025	139	6.9	3023	136.3	6.9	3036
AVG	137.6	6.9	3008.0	138.0	6.9	3004.7	136.4	6.8	3035.3

RESULTS FROM DIELECTRIC, MODULUS, AND STRENGTH TESTS

To evaluate the potential impact of the different energy treatments on the dielectric, modulus, and strength tests, specimens were made at each treatment level while targeting the appropriate average maximum density and optimum water content from Table 1.3. The dielectric and modulus tests were performed on the same specimens used for strength testing. Table 1.4 presents the machine parameters from these tests; the results are the average of three replicates per target energy level. Appendix B presents the entirety of each sample's results in the column labeled "Test Samples at 113-E Optimum."

Table 1.4. Machine Parameters for Dielectric, Modulus, and Strength Specimens.

Target Energy per Blow (ft-lbf)	Hammer weight (lb)	AVG # blows per lift	AVG Drop Ht (in.)	AVG Energy per blow (ft-lbf)	Avg Effort (ft-lbf/in3)
12.5	10.31	59	17.2	12.8	13.4
15	11.04	52	18.2	14.6	13.45
16.7	12.21	45	18.6	16.9	13.45

Figure 1.4 illustrates, and statistical tests confirm, that no difference in mean sample dry density or compaction effort existed among the specimens compacted at the different energies per blow for the dielectric, modulus, and strength testing experiments. This is important since varying efforts could potentially impact density, which in turn could impact modulus and strength.

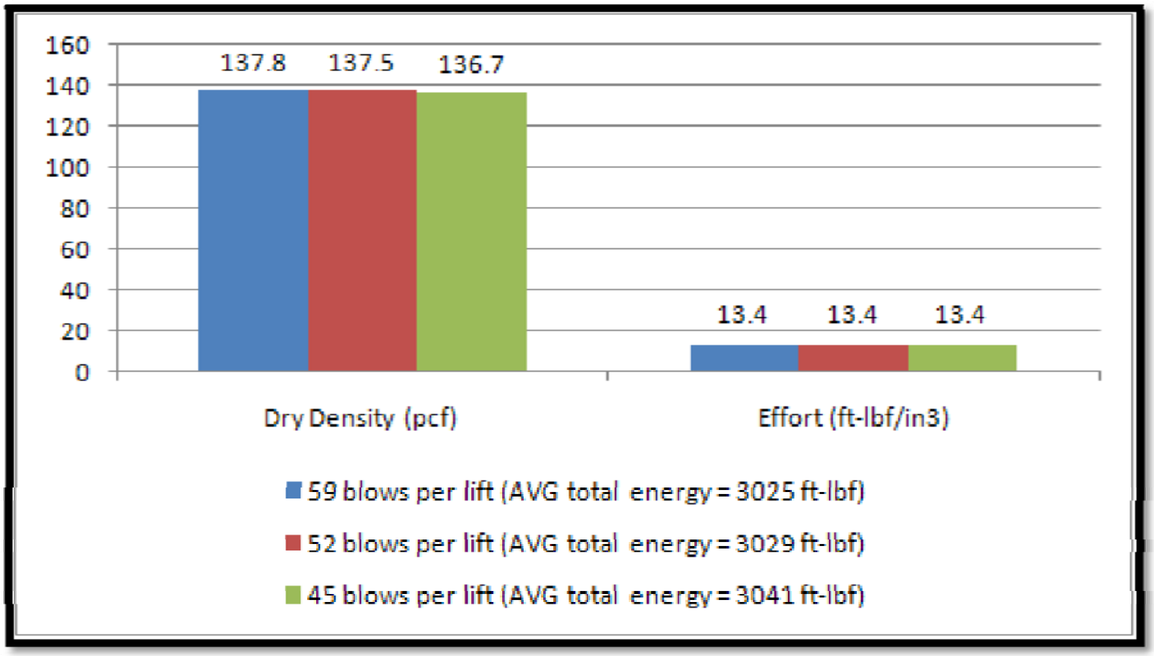


Figure 1.4. No Difference in Dry Density or Effort Observed among Samples from Different Energies per Blow.

Note: Each result is the average of three specimens. No significant difference exists among means.

Figures 1.5 through 1.8 illustrate that no statistically significant differences existed among the means for dielectric, seismic modulus, or compressive strength at 0 psi lateral pressure per Tex-17-E Part II. Figure 1.8 presents the moisture content results after breaking, which showed specimens prepared with 45 blows per lift had average water content 0.2 percentage points lower than the other treatments. This observation was deemed unimportant from a performance standpoint, since no differences in modulus or strength were observed.

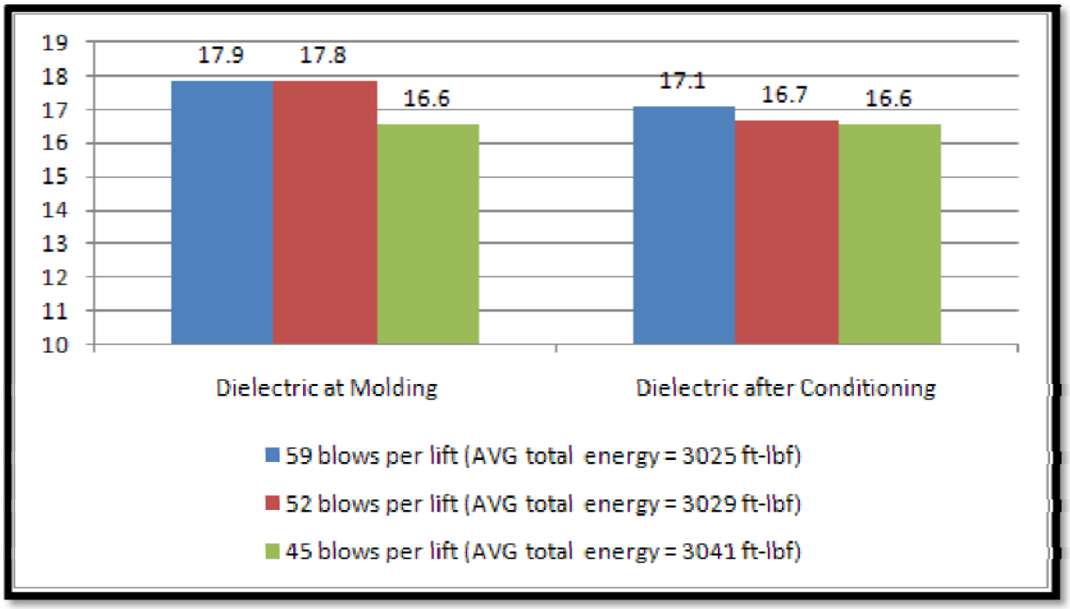


Figure 1.5. Summary of Results from Dielectric Testing.

Note: Each result is the average of three specimens. No significant difference exists among means.

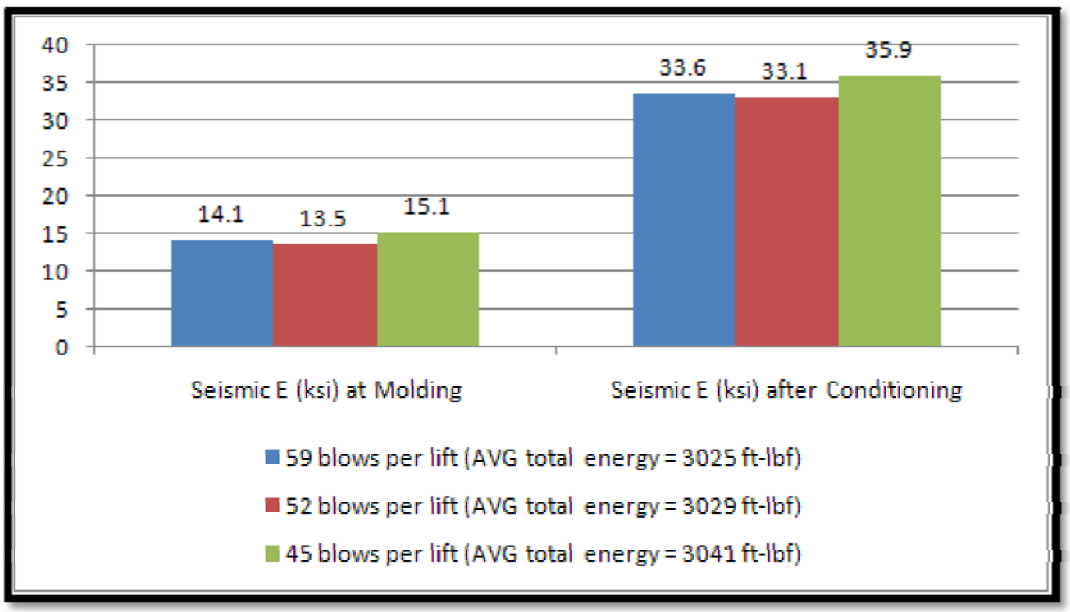


Figure 1.6. Summary of Results from Modulus Testing.

Note: Each result is the average of three specimens. No significant difference exists among means.

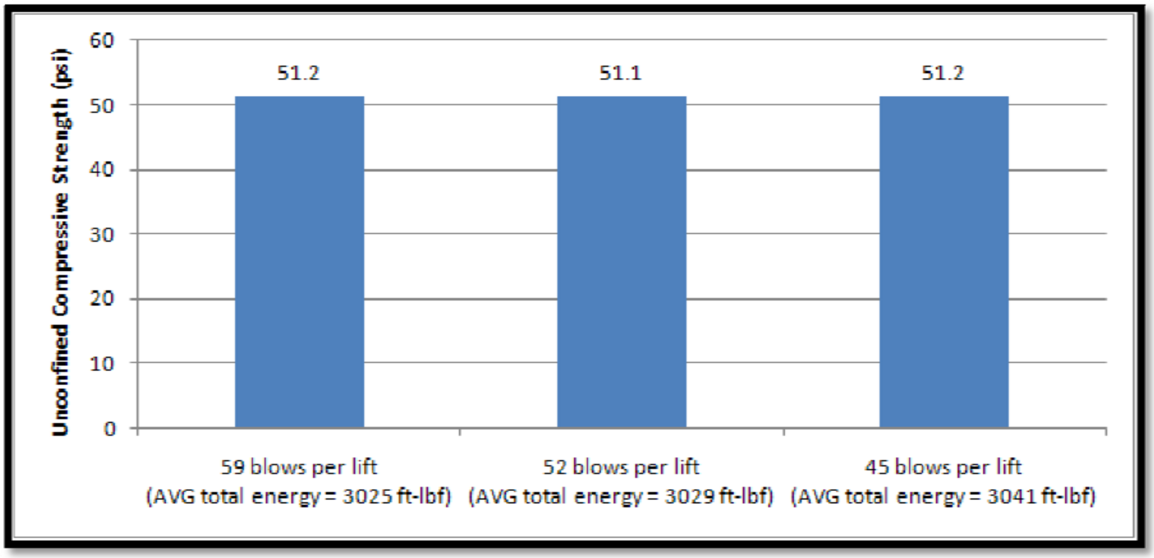


Figure 1.7. Summary of Results from Unconfined Strength Testing after Tex-117-E Part II.
Note: Each result is the average of three specimens. No significant difference exists among means.

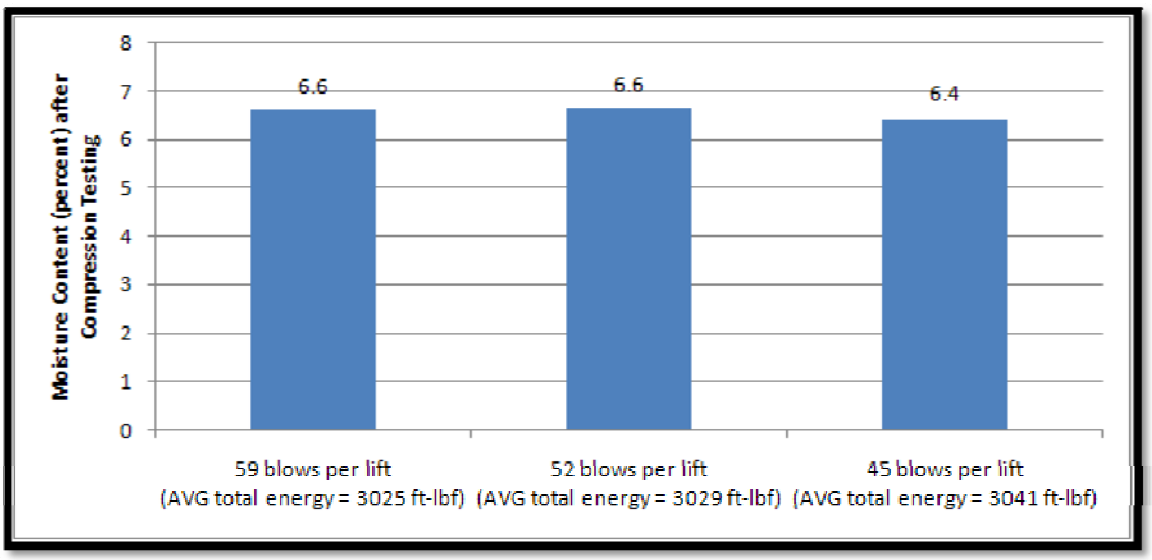


Figure 1.8. Summary of Moisture Contents after Strength Testing.
Note: Each result is the average of three specimens. Mean water content after conditioning from specimens with 45 blows per lift was lower than other treatments.

CONCLUSIONS

The data show the range of blows per lift in Tex-113-E can vary from at least 45 to 60 as long as the total energy per lift is controlled by the SCA to average approximately 750 ft-lbf. In the experiment conducted to determine this finding, the total energy per lift was always between 740 and 765 ft-lbf. When achieving this energy per lift with no less than 45 and no more than 60 blows, no differences in important test results, such as maximum dry density, optimum water content, dielectric constant, seismic modulus, or unconfined compressive strength, existed.

CHAPTER 2. PRECISION OF TEX-113-E COMPACTION WITH THE SCA

SUMMARY

With the implementation of the SCA into Test Method Tex-113-E, TxDOT desired to determine if the precision of the test method improved. To facilitate answering this question, an interlaboratory study was conducted to develop precision statistics for both the applied total compaction energy and effort, and for important measured sample properties including moisture content and specimen dry density. The end of this chapter presents precision statements for each of these parameters. The results show excellent precision of total compaction energy when the SCA is used to control the compactor. Total compaction energy should be repeatable and reproducible within 30 ft-lbf, or approximately 1 percent of the specification value. Compacted dry density should be repeatable within 2 to 3 pounds per cubic foot and reproducible within 3 to 4 pcf.

METHOD FOR INTERLABORATORY STUDY

To develop precision statistics for Tex-113-E compaction, TTI researchers followed American Society for Testing and Materials (ASTM) E691-09. With the help of TxDOT, the participation of six laboratories was obtained. Next, three materials were selected for use in the experiment. These are the minimum participatory and testing requirements for conducting an interlaboratory study (ILS) per E691-09.

To gather the necessary data, the research team recombined samples from each of the materials and delivered three samples of each material to each participating lab. The laboratories then:

- Molded the samples at the provided optimum moisture content.
- Dried the samples and determined sample compacted dry density.
- Reported the compaction energy and density results to TTI.

MATERIALS USED IN ILS

In conjunction with the TxDOT project director, two limestones and one sandstone base were selected for use in the interlaboratory study. Table 2.1 summarizes the key properties of the materials reconstituted for distribution to the participating laboratories.

Table 2.1. Summary of Materials Used in Interlaboratory Study.

		Groesbeck	Spicewood	Oklahoma
Dry Screen Gradation Cumulative Percent Retained	1 3/4	2.5	0.0	0.0
	1 1/4	14.7	4.7	1.0
	7/8	29.2	15.9	11.6
	5/8	41.0	26.9	28.9
	3/8	54.7	42.1	44.1
	#4	66.8	59.3	61.5
	#40	89.3	95.3	81.5
Plasticity Index		2*	7	6
Wet Ball Mill Value		40	24	36
Percent Soil Binder Increase		16	6	10
Molding Moisture (Tex-113-E Optimum)		6.9	5.4	7.6

*Calculated from linear shrinkage.

RESULTS FROM INTERLABORATORY STUDY

Appendix C presents reported data by testing laboratory. The following sections present the worksheets and consistency evaluation for the parameters evaluated. These parameters included:

- Total compaction energy.
- Total compaction effort.
- Sample dry density.

In this ILS, with the number of labs and number of replicates, the critical value of the between-lab consistency statistic h was 1.92, and the critical value of the within-lab consistency statistic k was 1.98. Data generating consistency statistics exceeding these values were investigated for possible sources of error.

Calculation and Display of Statistics—Total Compaction Energy

Tables 2.2–2.4 present each lab's data and the ILS worksheet for the measured total compaction energy. Figures 2.1 and 2.2 present the between-lab consistency statistic, h, and the within-lab consistency statistic, k, for these data. No problematic patterns were observed in the consistency statistics, and no consistency statistic exceeded the critical value.

Table 2.2. ILS Worksheet for Total Compaction Energy (ft-lbf)—Groesbeck.

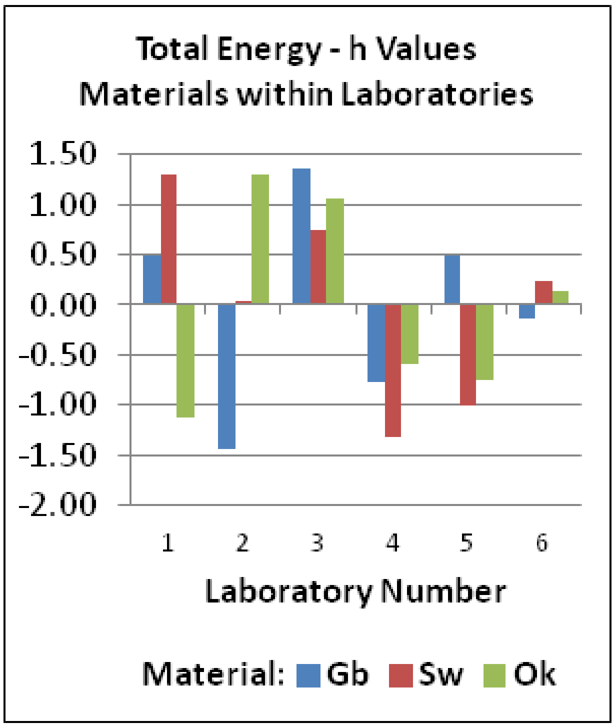
	Sample							
Lab	1	2	3	x_{bar}	s	d	h	k
1	3023.16	3032.44	*	3027.80	6.56	3.04	0.48	0.63
2	3017.43	3034.27	2995.33	3015.68	19.53	-9.08	-1.44	1.88
3	3031.28	3031.61	3037.05	3033.31	3.24	8.56	1.36	0.31
4	3014.39	3022.75	3022.8	3019.98	4.84	-4.78	-0.76	0.47
5	3034.335	3021.4	*	3027.87	9.15	3.11	0.49	0.88
6	3035.69	3019.35	3016.66	3023.90	10.30	-0.86	-0.14	0.99
*not tested due to sample damage			x_{barbar}	3024.76				
			s_{xbar}	6.30				
			s_r	10.39				
			$(s_r)^*$	10.57				

Table 2.3. ILS Worksheet for Total Compaction Energy (ft-lbf)—Spicewood.

	Sample							
Lab	1	2	3	x_{bar}	s	d	h	k
1	3028.21	3019.16	3045.63	3031.00	13.45	6.54	1.30	1.50
2	3025.36	3032.06	3016.49	3024.64	7.81	0.17	0.03	0.87
3	3033.85	3022.51	*	3028.18	8.02	3.72	0.74	0.89
4	3006.88	3024.14	3022.59	3017.87	9.55	-6.59	-1.31	1.06
5	3022.79	3010.16	3025.29	3019.41	8.11	-5.05	-1.00	0.90
6	3023.57	3022.59	3030.88	3025.68	4.53	1.22	0.24	0.50
*Not tested due to sample prep error			x_{barbar}	3024.463				
			s_{xbar}	5.040589				
			s_r	8.979374				
			$(s_r)^*$	8.897208				

Table 2.4. ILS Worksheet for Total Compaction Energy (ft-lbf)—Oklahoma.

	Sample							
Lab	1	2	3	x_{bar}	s	d	h	k
1	3026.96	3020.14	3011.80	3019.63	7.59	-6.91	-1.13	0.82
2	3034.71	3038.00	3030.67	3034.46	3.67	7.91	1.29	0.40
3	3029.24	3038.46	3031.31	3033.00	4.84	6.46	1.06	0.52
4	3025.74	3015.02	3027.91	3022.89	6.90	-3.66	-0.60	0.74
5	3031.00	3015.45	3019.37	3021.94	8.09	-4.61	-0.75	0.87
6	3025.58	3010.71	3045.75	3027.35	17.59	0.80	0.13	1.89
			x_{barbar}	3026.546				
			s_{xbar}	6.121048				
			s_r	9.281308				
			$(s_r)^*$	9.741442				



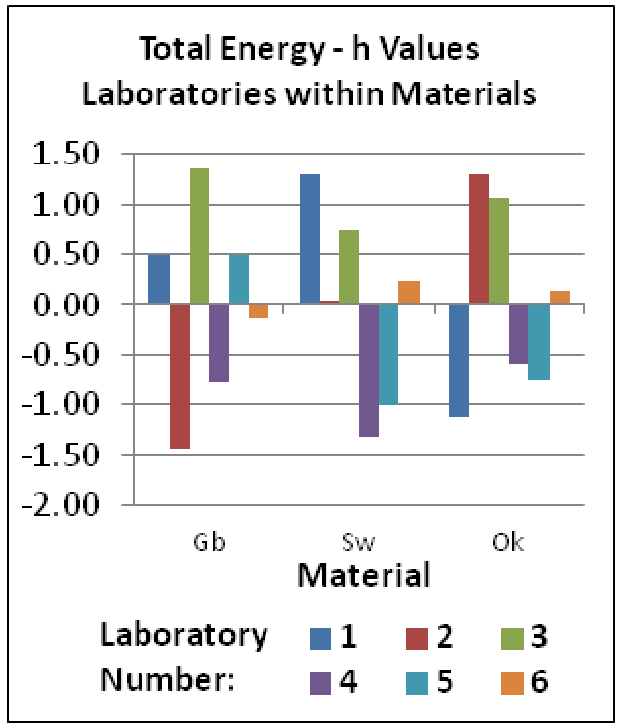


Figure 2.1. Between-Lab Consistency Statistics for Total Compaction Energy.

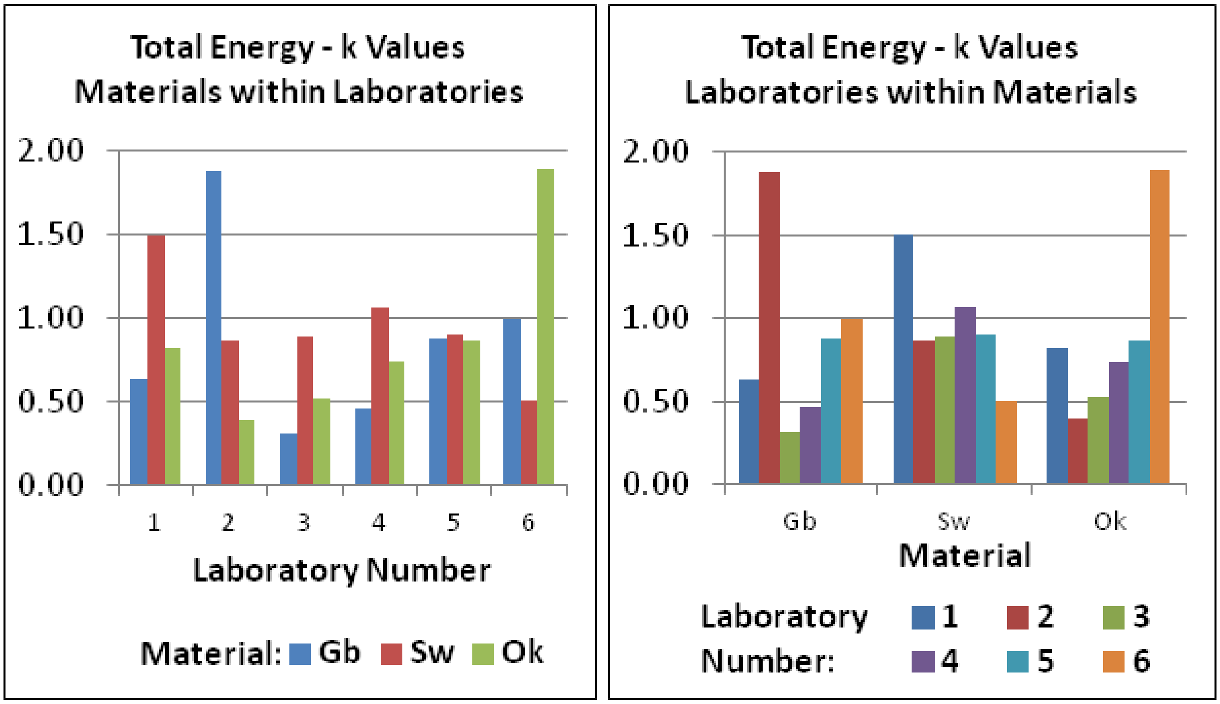


Figure 2.2. Within-Lab Consistency Statistics for Total Compaction Energy.

Calculation and Display of Statistics—Total Compaction Effort

Tables 2.5–2.7 present each lab's data and the ILS worksheet for the measured total compaction effort. Figures 2.3 and 2.4 present the between-lab consistency statistic, *h*, and the within-lab consistency statistic, *k*, for these data. No problematic patterns were observed in the consistency statistics, and no consistency statistic exceeded the critical value.

Table 2.5. ILS Worksheet for Total Compaction Effort (ft-lbf/in^3)—Groesbeck.

	Sample ft-lbf/in3							
Lab	1	2	3	x_{bar}	s	d	h	k
1	13.27	13.36	*	13.32	0.06	0.11	0.90	0.57
2	13.17	13.20	12.97	13.11	0.13	-0.09	-0.71	1.18
3	13.02	13.07	12.96	13.02	0.06	-0.19	-1.49	0.55
4	13.28	13.39	13.38	13.35	0.06	0.15	1.18	0.57
5	13.22	13.16	*	13.19	0.04	-0.02	-0.12	0.38
6	13.26	13.02	13.42	13.23	0.20	0.03	0.24	1.87
*not tested due to sample damage			x_{barbar}	13.203				
			s_{xbar}	0.1252				
			s_r	0.1067				
			(s_r)*	0.1526				

Table 2.6. ILS Worksheet for Total Compaction Effort (ft-lbf/in^3)—Spicewood.

	Sample							
Lab	1	2	3	x_{bar}	s	d	h	k
1	13.57	13.57	13.64	13.59	0.04	0.06	0.48	0.30
2	13.73	13.41	13.60	13.58	0.16	0.05	0.36	1.25
3	13.46	13.41	*	13.44	0.04	-0.09	-0.73	0.31
4	13.75	13.77	13.67	13.73	0.05	0.20	1.57	0.41
5	13.66	13.46	13.29	13.47	0.19	-0.06	-0.49	1.43
6	13.37	13.20	13.57	13.38	0.19	-0.15	-1.19	1.43
*Not tested due to sample prep error			x_{barbar}	13.53099				
			s_{xbar}	0.129047				
			s_r	0.129985				
			$(s_r)^*$	0.167084				

Table 2.7. ILS Worksheet for Total Compaction Effort (ft-lbf/in^3)—Oklahoma.

	Sample							
Lab	1	2	3	x_{bar}	s	d	h	k
1	13.42	13.01	13.54	13.32	0.28	-0.06	-0.25	1.82
2	13.52	13.54	13.53	13.53	0.01	0.15	0.67	0.09
3	13.23	13.23	13.25	13.24	0.01	-0.14	-0.64	0.04
4	13.83	13.77	13.69	13.76	0.07	0.38	1.72	0.45
5	13.09	13.27	13.27	13.21	0.11	-0.17	-0.77	0.69
6	13.05	13.15	13.47	13.22	0.22	-0.16	-0.72	1.41
			x_{barbar}	13.3808				
			s_{xbar}	0.22271				
			s_r	0.15388				
			$(s_r)^*$	0.25571				

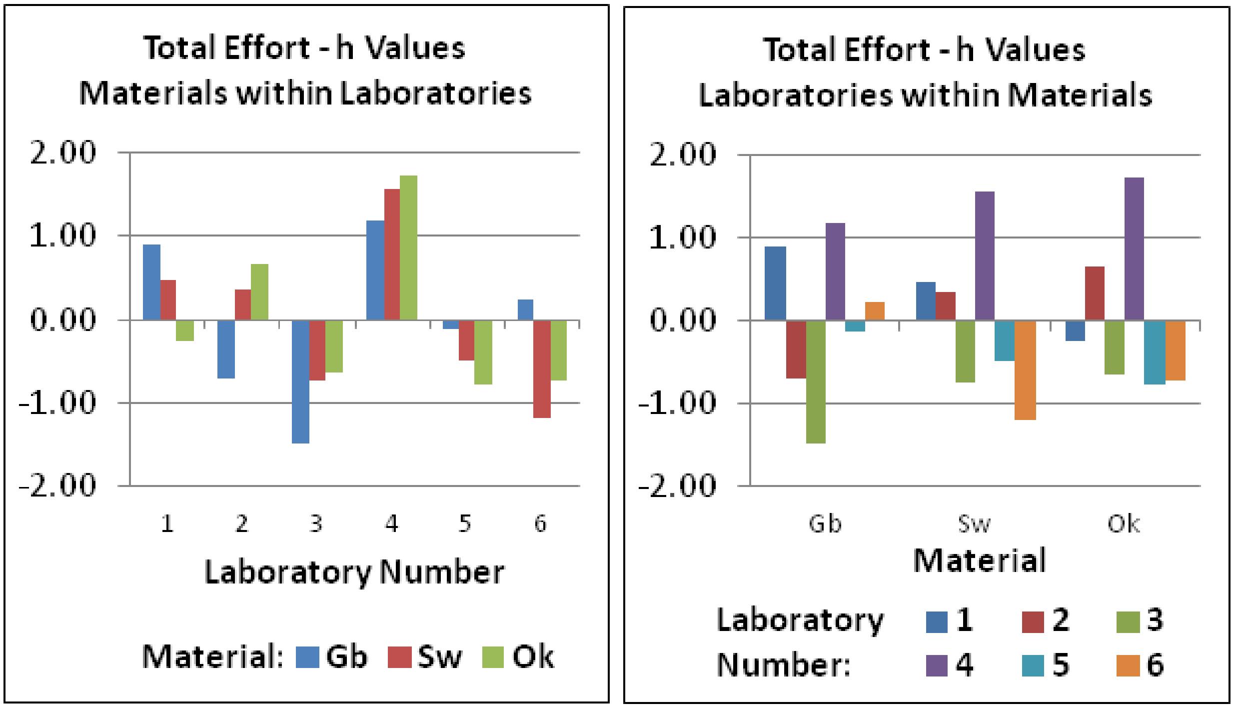


Figure 2.3. Between-Lab Consistency Statistics for Total Compaction Effort.

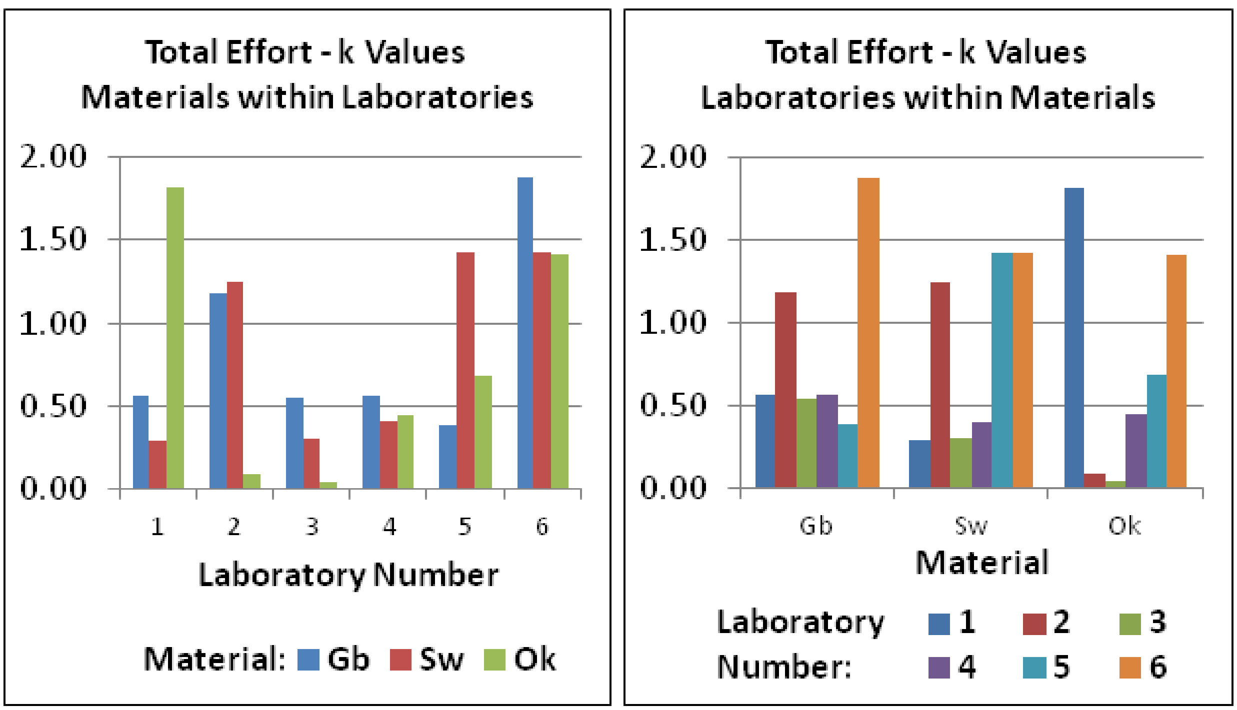


Figure 2.4. Within-Lab Consistency Statistics for Total Compaction Effort.

Calculation and Display of Statistics—Sample Dry Density

Tables 2.8–2.10 present each lab's data and the ILS worksheet for molded sample dry density. Figures 2.5 and 2.6 present the between-lab consistency statistic, *h*, and the within-lab consistency statistic, *k*, for these data. While no problematic patterns were observed in the consistency statistics, the *k* within-lab consistency statistic for lab 6 exceeded the critical value. The data were examined, and no procedural or tabulation errors were discovered, so the data were retained for use in the tabulation of the precision statistics.

Table 2.8. ILS Worksheet for Dry Density (pcf)—Groesbeck.

	Sample							
Lab	1	2	3	x_{bar}	s	d	h	k
1	137.00	136.30	*	136.65	0.49	0.79	1.21	0.50
2	136.90	136.90	136.00	136.60	0.52	0.74	1.13	0.52
3	135.60	135.50	134.10	135.07	0.84	-0.80	-1.22	0.84
4	135.30	135.60	135.20	135.37	0.21	-0.50	-0.76	0.21
5	135.59	135.60	*	135.60	0.01	-0.27	-0.41	0.01
6	135.81	133.78	138.12	135.90	2.17	0.04	0.06	2.18
*not tested due to sample damage			x_{barbar}	135.864				
			s_{xbar}	0.65061				
			s_r	0.99809				
			(s_r)*	1.0428				

Table 2.9. ILS Worksheet for Dry Density (pcf)—Spicewood.

	Sample							
Lab #	1	2	3	x_{bar}	s	d	h	k
1	149.50	149.70	149.20	149.47	0.25	0.92	0.70	0.39
2	150.10	150.50	149.90	150.17	0.31	1.62	1.24	0.47
3	149.00	148.70	*	148.85	0.21	0.30	0.23	0.33
4	149.00	148.50	147.50	148.33	0.76	-0.22	-0.17	1.19
5	148.90	148.20	147.20	148.10	0.85	-0.45	-0.35	1.33
6	146.38	145.40	147.37	146.38	0.99	-2.17	-1.66	1.53
*Not tested due to sample prep error			x_{barbar}	148.55				
			s_{xbar}	1.302903				
			s_r	0.643588				
			(s_r)*	1.404882				

Table 2.10. ILS Worksheet for Dry Density (pcf)—Oklahoma.

	Sample							
Lab	1	2	3	x_{bar}	s	d	h	k
1	136.10	136.20	136.20	136.17	0.06	0.06	0.09	0.06
2	136.30	136.40	135.00	135.90	0.78	-0.21	-0.30	0.82
3	135.50	136.20	136.70	136.13	0.60	0.03	0.04	0.63
4	137.30	138.00	136.80	137.37	0.60	1.26	1.84	0.63
5	133.70	136.70	136.70	135.70	1.73	-0.41	-0.59	1.81
6	134.14	135.99	135.99	135.37	1.07	-0.73	-1.07	1.12
			x_{barbar}	136.11				
			s_{xbar}	0.6838				
			s_r	0.9558				
			(s_r)*	1.0376				

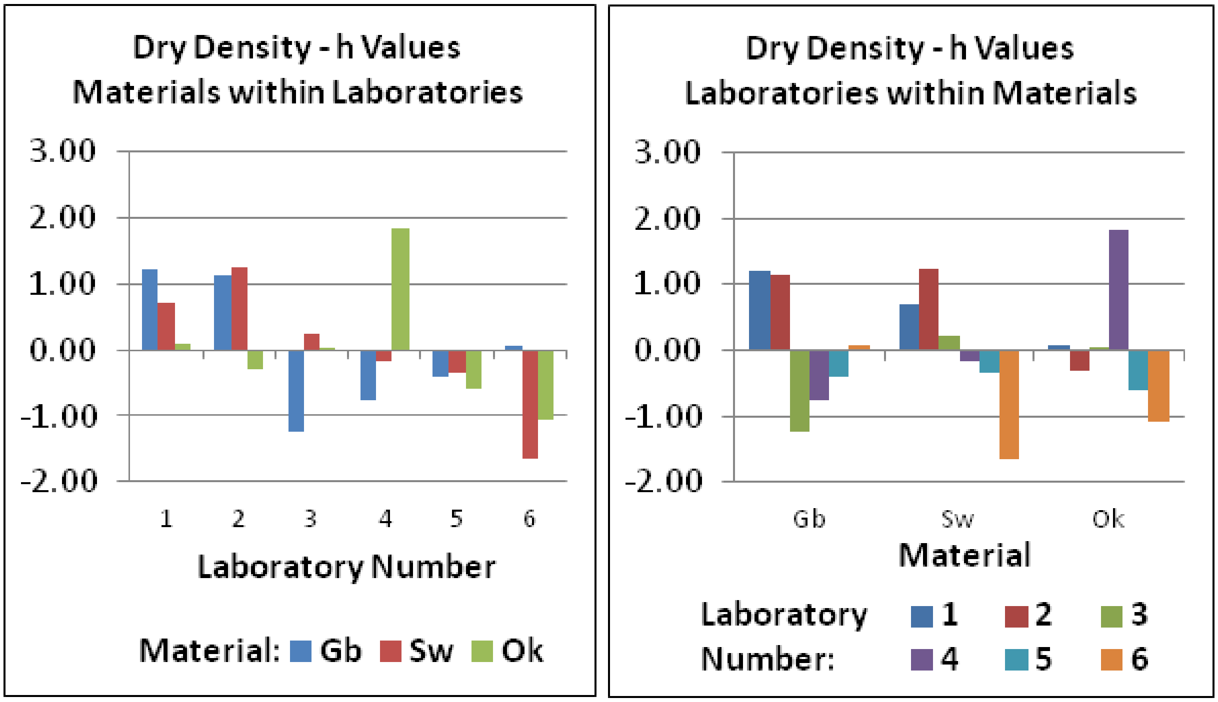


Figure 2.5. Between-Lab Consistency Statistics for Dry Density.

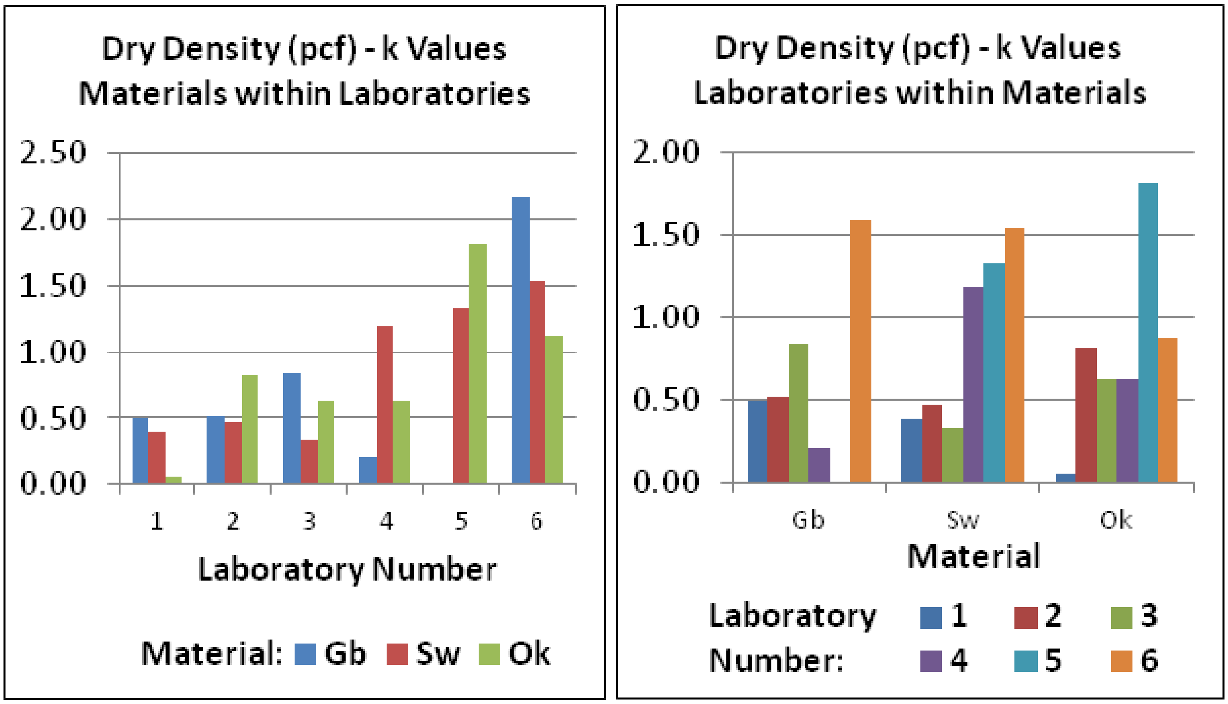


Figure 2.6. Within-Lab Consistency Statistics for Dry Density.

PRESENTATION OF PRECISION STATISTICS

Based upon the ILS worksheets in Tables 2.2–2.10, the precision statistics for total compaction energy, total compaction effort, and sample dry density are presented in Tables 2.11 through 2.13. The results suggest:

- Total compaction energy applied in Tex-113-E with the SCA exhibits excellent precision. The specification total compaction energy is 3000 ft-lbf. Both the repeatability and reproducibility limit are around 30 ft-lbf, or about 1 percent of the specification value.
- Total compaction effort exhibits good precision, with repeatability and reproducibility limits typically between 0.3 and 0.5 ft-lbf/in^3, or approximately 5 percent of the specification value.
- Density should be repeatable within 2 to 3 pcf and reproducible within 3 to 4 pcf.

Table 2.11. Precision Statistics for Total Compaction Energy (ft-lbf) in Tex-113-E.

Material	X bar	S_{xbar}	Sr	S_R	r	R
Groesbeck	3024.8	6.30	10.39	10.57	29.10	29.58
Spicewood	3024.5	5.04	8.98	8.89	25.14	25.14
Oklahoma	3026.6	6.12	9.28	9.74	25.98	27.23

Table 2.12. Precision Statistics for Total Compaction Effort (ft-lbf/in^3) in Tex-113-E.

Material	X bar	S_{xbar}	Sr	S_R	r	R
Groesbeck	13.20	0.125	0.107	0.153	0.299	0.427
Spicewood	13.53	0.129	0.130	0.167	0.364	0.468
Oklahoma	13.38	0.223	0.154	0.256	0.431	0.716

Table 2.13. Precision Statistics for Sample Dry Density (pcf) after Tex-117-E Part II.

Material	X bar	S_{xbar}	Sr	S_R	r	R
Groesbeck	135.9	0.65	1.00	1.04	2.79	2.91
Spicewood	148.6	1.30	0.64	1.40	1.80	3.93
Oklahoma	136.1	0.68	0.96	1.04	2.68	2.90

While ASTM E 691 does not call for pooling data from different materials to determine globally-applicable precision estimates, for purposes of provided a single numeric precision estimate to TxDOT the research team determined the pooled repeatibility and reproducibilty standard deviations. These pooled standard deviations allow for estimating a single repeatiblity and reproducibility limit as Table 2.14 presents.

Table 2.14. Precision Estimates from Pooled Data.

	Energy (ft-lbf)	Effort (ft-lbf/in^3)	Dry Density (pcf)
Repeatability Limit	26.80	0.368	2.46
Reproducibility Limit	27.32	0.552	3.29

CONCLUSIONS

The SCA addresses equipment variability during the sample fabrication process, and this interlaboratory study demonstrated that the SCA provides excellent precision in the application of compaction energy during that process. With the implementation of the SCA, TxDOT should generally expect the total compaction energy among samples to differ by no more than 27 ft-lbf. Additionally, the compacted dry density of samples constructed with Tex-113-E compaction should generally be repeatable within about 2.5 pcf and reproducible within about 3.3 pcf.

CHAPTER 3. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS ON MACHINE OPERATIONAL TOLERANCES

Many factors in the stages of sample fabrication, conditioning, and testing can impact the precision of strength results in Tex-117-E Part II. Since this test method is a specification requirement in Item 247, achieving the most homogenous compaction is in the best interest of producers, contractors, and the state. This project focused on homogenizing the application of compaction energy during the sample fabrication process. The impact of varying hammer weights and drop heights, while the Soil Compactor Analyzer controlled compaction to apply between 740 to 760 ft-lbf total energy per lift, was evaluated with a particular focus on:

- Moisture-density relationship.
- Molded specimen dry density when molded at Tex-113-E optimum.
- Specimen dielectric constant immediately after molding and after Tex-117-E Part II conditioning.
- Seismic modulus immediately after molding and after Tex-117-E Part II conditioning.
- Unconfined compressive strength after Tex-117-E Part II.
- Percent moisture after Tex-117-E Part II.

The results showed that while using the current TxDOT-approved SCA to control total energy per lift between 740 and 765 ft-lbf, the number of blows per lift may vary between 45 and 60 with no impact on important test results. TxDOT should require the prescribed amount of energy to be obtained within this number of blows per lift.

CONCLUSIONS AND RECOMMENDATIONS FROM INTERLABORATORY STUDY

As a final stage in this project, an interlaboratory study was conducted to develop precision statistics for total compaction energy, total compaction effort, and specimen dry density when molded at Tex-113-E optimum. These results showed that the SCA enables excellent precision of total compaction energy and good precision of total compaction effort. TxDOT should generally expect the total compaction energy among samples constructed with Tex-113-E to differ by no more than 27 ft-lbf and incorporate that precision information into the test procedure.

The dry density of replicate samples constructed at optimum water content within a single lab should generally not vary by more than 2 to 3 pcf, with 2.5 pcf representing the pooled repeatability limit. The dry density of replicate samples compacted at different labs should generally not vary by more than 3 to 4 pcf, with 3.3 pcf representing the pooled reproducibility limit. The precision statement for dry density should be added to the Tex-113-E test procedure.

APPENDIX A: TEST REPORT FROM FLEX BASE USED IN IMPACT HAMMER ADJUSTMENTS

TEXAS DEPARTMENT OF TRANSPORTATION

ATTERBERG LIMITS
Tex-104-E, Tex-105-E, Tex-106-E

Refresh Workbook

File Version: 08/17/09 11:35:13

SAMPLE ID:		SAMPLED DATE:	03/04/2010
TEST NUMBER:	10-074	LETTING DATE:	
SAMPLE STATUS:		CONTROLLING CSJ:	0456-03-015
COUNTY:	FREESTONE	SPEC YEAR:	2004
SAMPLED BY:	BA	SPEC ITEM:	247
SAMPLE LOCATION:	STKPL#01-10	SPECIAL PROVISION:	
MATERIAL CODE:		GRADE:	2
MATERIAL NAME:			
PRODUCER:	VULCAN		
AREA ENGINEER:		PROJECT MANAGER:	

COURSE\LIFT:		STATION:		DIST. FROM CL:	

Liquid Limit - Tex-104-E

	Dish No.	Mass of Wet Sample + Tare (g)	Mass of Dry Sample + Tare (g)	Tare Mass (g)	Moisture Content (%)	Number of Blows	Liquid Limit (%)
1							
						Liquid Limit	

Plastic Limit - Tex-105-E

	Dish No.	Mass of Wet Sample + Tare (g)	Mass of Dry Sample + Tare (g)	Tare Mass (g)	Mass of Water (g)	Plastic Limit (%)
1	101	34.13	31.94	16.65	2.19	14
2						
3						
					Plastic Limit	14

Plasticity Index - Tex-106-E

Plasticity Index Calculated from Linear Shrinkage:	*See Note
Use Bar Linear Shrinkage to Calculate Plasticity Index?	Yes
Test Tx107 Test Number Reference:	10-074

*See Test Tx107 Test Nbr (10-074) - Bar Linear Shrinkage Associated to this Sample for Plasticity Index.

Remarks:

Test Method:	Tested By:	Tested Date:
TX104		
TX105	TERRY GREEN	03/18/10
TX106	TERRY GREEN	03/18/10

Test Stamp Code:	Omit Test:	Completed Date:	Reviewed By:

Locked By:	TxDOT:	District:	Area:

Authorized By:	Authorized Date:

stockpile 01-10 FM80 Freestone Co.10-074 Tx117-2.xls 1 of 1 3/23/2010

TEXAS DEPARTMENT OF TRANSPORTATION

BAR LINEAR SHRINKAGE

TEX-107-E

Refresh Workbook

File Version: 08/26/09 23:36:38

SAMPLE ID:		SAMPLED DATE:	03/04/2010
TEST NUMBER:	10-074	LETTING DATE:	
SAMPLE STATUS:		CONTROLLING CSJ:	0456-03-015
COUNTY:	FREESTONE	SPEC YEAR:	2004
SAMPLED BY:	BA	SPEC ITEM:	247
SAMPLE LOCATION:	STKPL#01-10	SPECIAL PROVISION:	
MATERIAL CODE:		MIX TYPE / GRADE:	2
MATERIAL NAME:			
PRODUCER:	VULCAN		
AREA ENGINEER:		PROJECT MANAGER:	

COURSE\LIFT:		STATION:		DIST. FROM CL:	

Bar Linear Shrinkage - Tex-107-E

Unit	Initial Length (percent)	Final Length (percent)	Linear Shrinkage
percent	100	99	1.0

Calculate Plasticity Index from Bar Linear Shrinkage?	Yes
Plasticity Index Calculated from Linear Shrinkage:	1.6

Remarks:

ROUNDS UP TO A 2.0 PI

Test Method:	Tested By:	Tested Date:
TX107	TERRY GREEN	03/18/10

Test Stamp Code:	Omit Test:	Completed Date:	Reviewed By:

Locked By:	TxDOT:	District:	Area:

Authorized By:	Authorized Date:

stockpile 01-10 FM80 Freestone Co.10-074 Tx117-3.xlsof 1 3/23/2010

TEXAS DEPARTMENT OF TRANSPORTATION

PARTICLE SIZE ANALYSIS
Tex-110-E

Refresh Workbook

File Version: 10/06/09 11:04:06

SAMPLE ID:		SAMPLED DATE:	03/04/2010
TEST NUMBER:	10-074	LETTING DATE:	
SAMPLE STATUS:		CONTROLLING CSJ:	0456-03-015
COUNTY:	FREESTONE	SPEC YEAR:	2004
SAMPLED BY:	BA	SPEC ITEM:	247
SAMPLE LOCATION:	STKPL#01-10	SPECIAL PROVISION:	
MATERIAL CODE:		GRADE:	2
MATERIAL NAME:			
PRODUCER:	VULCAN		
AREA ENGINEER:		PROJECT MANAGER:	

COURSE\LIFT:		STATION:		DIST. FROM CL:	

Particle Size Analysis - Tex-110-E

Sieve Size	Cumulative Cumulative Weight Retained (g) (g)	Individual Weight Retained	Cumulative Percent Retained	Lower Spec Limit %	Upper Spec Limit %	Within Master Grading
2-1/2"	0	0	0.0	0	0	Yes
1-3/4"	0	0	0.0	0	10	Yes
No. 4	3233.8	3233.8	64.7	45	75	Yes
No. 40	3780.8	547	75.6	60	85	Yes
Total:	5000.00					

Remarks:

Test Method:	Tested By:	Tested Date:
TX110	TERRY GREEN	03/16/10

Test Stamp Code: | Omit Test: | Completed Date: | Reviewed By:

Locked By: | TxDOT: | District: | Area:

Authorized By: | Authorized Date:

stockpile 01-10 FM80 Freestone Co.10-074 Tx117-4.xls
for Tex-110-E Flexbase 1 of 1 3/23/2010

APPENDIX B: RESULTS FROM SPECIMENS TESTED FOR IMPACT HAMMER ADJUSTMENTS

Table B.1. Results from Samples Targeting 12.5 ft-lbf per Blow.

Section	Lift	Sample ID	Group 4 (113-E Moisture-Density Samples)				Group 5 (113-E Moisture-Density Samples)				Group 6 (113-E Moisture-Density Samples)				Test samples at 113-E Optimum		
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
		Hammer Weight	10.089	10.089	10.089	10.089	10.089	10.089	10.089	10.089	10.089	10.089	10.089	10.089	10.31	10.31	10.31
Molding Data	Lift 1	AVG drop ht (in)	15.28	15.03	16.25	16.88		16.69	14.84	15.92	14.21	16.37	15.45	16.23	16.48	17.32	17.49
Molding Data	Lift 1	# drops	60	60	61	61	60*	61	62	62	65	62	62	64	58	59	60
Molding Data	Lift 1	Total Energy (ft-lbf)	746.63	750.35	742.85	744.74		745.95	750.5	748.7	749.01	747.85	751.34	751.1	751.41	759.32	756.36
Molding Data	Lift 2	AVG drop ht (in)		15.63	16.07	16.1	16.91	15.23		14.86	16.31	16.17	16.56	16.72	17.35	17.49	16.79
Molding Data	Lift 2	# drops	65*	62	61	61	60	63	60*	57	64	57	62	61	58	58	60
Molding Data	Lift 2	Total Energy (ft-lbf)		749.7	749.93	752.97	745.66	756.18		750.07	751.81	747.76	754.87	747.25	757.39	750.8	757.82
Molding Data	Lift 3	AVG drop ht (in)	16.74	14.45	14.05	14.22	16.38	16.22	16.37	16.76	16.67		14.65	15.95	17.3	17.49	17.5
Molding Data	Lift 3	# drops	61	61	62	54	60	62	60	63	63	65*	63	62	58	58	58
Molding Data	Lift 3	Total Energy (ft-lbf)	745.1	743.3	752.81	748.58	745.75	754.72	746.41	761.82	743.06		751.54	751.19	754.76	762.43	757.61
Molding Data	Lift 4	AVG drop ht (in)	15.15	16.25	16.6	14.07	16.15	16.67	16.99	17.17	15.39		14.79		17.5	17.49	16.91
Molding Data	Lift 4	# drops	61	60	60	64	61	58	61	61	63	65*	62	60*	58	58	58
Molding Data	Lift 4	Total Energy (ft-lbf)	743.8	743.58	744.97	748.91	747.69	750.49	753.91	750.8	748.17		750.92		753.41	761.36	752.93
Molding Data		Total Energy Measured (ft-lbf)	2235.53	2986.93	2990.56	2995.2	2239.1	3007.34	2250.82	3011.39	2992.05	1495.61	3008.67	2249.54	3016.97	3033.91	3024.72
Molding Data		Sample Ht (in)	8.2	8	8	8	8.4	8.1	8	8	8	8.1	7.9	7.8	7.9	8.05	8
Molding Data		Sample Volume (ft^3)	0.134172	0.1309	0.1309	0.1309	0.137445	0.132536	0.1309	0.1309	0.1309	0.132536	0.129263	0.127627	0.1292634	0.1317178	0.1308997
Molding Data		Effort Measured [(ft-lbf/ft^3)]	16661.65	22818.46	22846.2	22881.64	16290.92	22690.75	17195	23005.32	22857.58	11284.56	23275.49	17625.87	23339.699	23033.406	23107.159
Molding Data		Molded water content (%)	5	6	7	8	5	6	7	8	5	6	7	8	6.9	6.9	6.9
Molding Data		Sample dry density (pcf)	133.2	137.1	137.1	137.26	130.93	135.02	137.17	136.8	135.22	135.85	139.2	137.17	139.21	136.7	137.63
Molding Data		Max dry density (pcf)	137.6				137.1				138				Not Applicable		
Molding Data		Optimum Water Content (%)	6.8				7.1				6.8				Not Applicable		
Dielectric at Molding		Reading 1	12.2	17.1	16.3	17	13	16.3	18.9	21.9	13.9	17.2	17.9	18.1	19.2	18.8	16
Dielectric at Molding		Reading 2	12.9	16.7	17.5	19.6	15.1	16.3	17	16.7	13.7	14	18.2	19.7	18.9	17.6	16
Dielectric at Molding		Reading 3	13.6	15.6	19.1	20.9	14.7	14	19.9	18.5	13.9	12.7	17.7	19.5	17.9	17.4	17.9
Dielectric at Molding		Reading 4	13	16.6	17.9	21.2	14.7	17.2	19	20	12	16.9	18.6	17.2	18.4	19.2	16
Dielectric at Molding		Reading 5	14.1	15.8	17.1	22	14.7	17.7	17.1	19.2	11.8	14.7	19.2	17.3	19.9	17.4	17.5
		AVG Dielectric at Molding	13.16	16.36	17.58	20.14	14.44	16.3	18.38	19.26	13.06	15.1	18.32	18.36	18.86	18.08	16.68
Seismic E at Molding		Reading 1	9	26.7	22.6	9.2	53.1	47.3	9.2	15.2	14.7	22.4	9.2	9	9.3	15	22.7
Seismic E at Molding		Reading 2	24.2	22.4	13.5	10.6	38.7	31.2	7.9	7.9	10.2	22.4	7.9	5.5	8	15	16.9
Seismic E at Molding		Reading 3	19.5	17.3	11.9	10.1	32.7	36.2	7.5	10.1	8.9	28.2	6.7	7.4	9.3	14	16.3
Seismic E at Molding		AVG Seismic E at Molding	17.56667	22.13333	16	9.966667	41.5	38.23333	8.2	11.06667	11.26667	24.33333	7.933333	7.3	8.8666667	14.666667	18.633333
Data after Tex-117-E part II Conditioning		Water content (%) after conditioning	4.73	5.82	6.59	7.48	4.67	5.78	6.7	7.56	4.72	5.69	6.65	7.5	6.6	6.61	6.62
Data after Tex-117-E part II Conditioning: Dielectric Values		Reading 1	12.4	15.6	17.4	16.7	13.1	15.5	18.4	15.1	12.7	16.4	18.1	17.4	18	17	16
Data after Tex-117-E part II Conditioning: Dielectric Values		Reading 2	11.2	15.5	14	16.8	11.4	16	17.5	14.6	11.3	12.5	16.2	18.5	17.3	18.6	16.2
Data after Tex-117-E part II Conditioning: Dielectric Values		Reading 3	11.9	15	15.5	19.7	9.8	13	17.2	18.4	12.2	13.2	16.4	18.5	18.1	16.1	15.4
Data after Tex-117-E part II Conditioning: Dielectric Values		Reading 4	12.4	15.9	16.5	16.6	13.8	16.7	18.3	16.9	11.9	13.9	19.9	13.8	18.8	16.7	17.5
Data after Tex-117-E part II Conditioning: Dielectric Values		Reading 5	12.7	14.3	16.4	17.9	13.3	17.8	17.7	19.9	11.6	15	17.5	17	18.6	15.2	16.5
Data after Tex-117-E part II Conditioning: Dielectric Values		AVG Dielectric after conditioning	12.12	15.26	15.96	17.54	12.28	15.8	17.82	16.98	11.94	14.2	17.62	17.04	18.16	16.72	16.32
Data after Tex-117-E part II Conditioning: Seismic E Values		Reading 1	59.2	47.4	60.5	9.2	41.5	47.3	15.1	22.7	18.1	67	36.7	26.4	26.9	31.2	41.8
Data after Tex-117-E part II Conditioning: Seismic E Values		Reading 2	38.4	36.3	42	29.4	36.1	44.4	15.1	20.7	18.1	53.6	24.8	16.6	24.7	31.2	39.1
Data after Tex-117-E part II Conditioning: Seismic E Values		Reading 3	41.1	36.3	36.5	21.4	36.1	43.4	16.3	17.6	18.1	51.5	21.3	18.4	24	45.4	38.2
Data after Tex-117-E part II Conditioning: Seismic E Values		AVG Seismic E after conditioning	46.23333	40	46.33333	20	37.9	45.03333	15.5	20.33333	18.1	57.36667	27.6	20.46667	25.2	35.933333	39.7
Data after Tex-117-E part II Conditioning		Unconfined Compressive Strength (psi)	42.4	56.4	51.1	35.1	55.3	55.1	44.0	24.8	44.4	83.8	55.9	26.6	42.6	64.4	46.7
		Water content (%) after compression test	4.73	5.82	6.59	7.48	4.67	5.78	6.7	7.56	4.72	5.69	6.65	7.5	6.6	6.61	6.62

*Drop count estimated due to SCA software lockup

Table B.2. Results from Samples Targeting 15 ft-lbf per Blow.

			113-E Moisture-Density Samples												Test samples at 113-E Optimum		
		Sample ID	Group 1				Group 2				Group 3						
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
		Hammer Weight	11.041	11.041	11.041	11.041	11.041	11.041	11.041	11.041	11.041	11.041	11.041	11.041	11.041	11.041	11.041
Molding Data	Lift 1	AVG drop ht (in)	17.83	17.05	16.96	17.57	18.41		17.79	17.8	18.41	18.41	18.41	17.49	18.23	18.22	18.24
		# drops	58	52	53	54	49	55*	50	50	50	50	50	50	52	52	52
		Total Energy (ft-lbf)	746.66	744.36	749.77	746.09	745.1		753.95	742.51	755.72	753.37	750.39	757.81	758.53	752.24	759.26
	Lift 2	AVG drop ht (in)	17.49	17.55	17.6		18.16		17.37	18.4		17.79	18.17	17.27	18.23	18.23	18.22
		# drops	56	48	49	60*	49		50	50	50*	50	50	50	52	52	52
		Total Energy (ft-lbf)	748.19	750.8	751.38		744		750.21	747.13		743.68	755.01	750.49	764.72	750.61	758.71
	Lift 3	AVG drop ht (in)	17.79	18.3	17.83	18.31	18.39		18.16	17.98	17.38	17.84	18.39	17.21	18.22	18.22	18.22
		# drops	55	50	56	64	49		50	50	52	51	50	50	52	52	52
		Total Energy (ft-lbf)	744.31	748.01	753.05	752.3	747.32		752.18	744.99	756.73	756.88	751.74	743.69	760.68	757.89	752.5
	Lift 4	AVG drop ht (in)	17.51	18.31	18.35	18.33	17.66		17.96	17.5	18.42	17.47		17.83	18.22	18.23	18.21
		# drops	55	51	54	58	50		50	50	50	50	55*	51	52	52	52
		Total Energy (ft-lbf)	749.03	749.11	751.75	750.93	749.47		752.08	743.75	744.71	748.7		754.47	755.15	755.7	761.66
	Total Energy Measured (ft-lbf)		2988.19	2992.28	3005.95	2249.32	2985.89	0	3008.42	2978.38	2257.16	3002.63	2257.14	3006.46	3039.08	3016.44	3032.13
	Sample Ht (in)		7.9	7.8	7.8	7.6	7.6	7.8	8	8.2	8	8	7.8	7.9	8	8	7.9
	Sample Volume (ft^3)		0.129263	0.127627	0.127627	0.124355	0.124355	0.127627	0.1309	0.134172	0.1309	0.1309	0.127627	0.129263	0.1308997	0.1308997	0.1292634
	Effort Measured [(ft-lbf/ft^3)]		23117.05	23445.47	23552.58	18087.94	24011.07	0	22982.64	22198.19	17243.43	22938.4	17685.41	23258.39	23216.861	23043.904	23456.979
	Molded water content (%)		5	6	7	8	5	6	7	8	5	6	7	8	6.9	6.9	6.9
	Sample dry density (pcf)		132.64	136.91	138.93	138.34	131.93	134.99	136.71	135.78	130.82	134.58	138.24	135.21	137.38	137.38	137.81
	Max dry density (pcf)		138.7				136.4				139				Not Applicable		
	Optimum Water Content (%)		7				6.8				6.9				Not Applicable		
	Dielectric at Molding	Reading 1	13	17.9	19.2	21	16	17.5	12.6	14.1	15.6	15.1	15.8	6.5	16.4	17.5	18.3
		Reading 2	13.2	12.7	19.7	20	19	18.3	12.7	12.9	20.4	17.3	15.7	9.9	16.2	19	16.8
		Reading 3	13.8	11.1	19.3	20.4	18.5	17.9	16.1	12.9	19.7	15.2	17.1	9.6	19.2	19	18.9
		Reading 4	12.3	16.9	19	21.4	18.2	16.8	15	13	18.7	158	15.7	12.1	16.7	16.5	19.9
		Reading 5	12.5	14.2	20.2	20.1	17.6	17.2	14.6	12.2	19.2	14.9	13.3	9.5	17.7	17.5	18
	AVG Dielectric at Molding		12.96	14.56	19.48	20.58	17.86	17.54	14.2	13.02	18.72	44.1	15.52	9.52	17.24	17.9	18.38
	Seismic E at Molding	Reading 1	91	30.9	30.4	6.1	4.2	21.5	15.1	4.8	45.1	26.2	9	6.6	6.7	22.6	11.9
		Reading 2	96	31.7	24.4	7.2	8.2	19.6	16.8	3.9	32.1	24	10.3	7.8	12	16.9	13.4
		Reading 3	88.3	32.5	25.8	7.1	6.7	20.3	16.2	4.2	31.3	23.4	9.9	7.4	11	16.3	10.9
	AVG Seismic E at Molding		91.76667	31.7	26.86667	6.8	6.366667	20.46667	16.03333	4.3	36.16667	24.53333	9.733333	7.266667	9.9	18.6	12.066667
Data after Tex-117-E part II Conditioning	Water content (%) after conditioning		4.37	5.71	6.66	7.63	4.72	5.84	6.6	7.53	5.49	5.76	6.52	7.86	6.66	6.67	6.6
	Dielectric Values	Reading 1	12.3	14.2	17.7	20	12.7	14.7	16	17	13.7	13.3	15.3	15.1	16	17.1	18.2
		Reading 2	11.5	16	16.7	17.5	6.3	15.5	17.3	17.2	12.5	13.8	17.3	18	16.8	16.9	14.4
		Reading 3	11.1	11.4	18.3	15.9	9.2	15.9	15	21	11.8	15.5	16.8	17.5	17.2	17.9	17.2
		Reading 4	11.7	9.2	16.7	16.3	9.7	14.7	14.9	17.5	13.5	13.8	16.2	18	14	15.4	18
		Reading 5	12	10.9	16.9	16.6	9.7	11.3	12	17.5	12.7	14.4	16.7	17.5	17	16.8	16.9
	AVG Dielectric after conditioning		11.72	12.34	17.26	17.26	9.52	14.42	15.04	18.04	12.84	14.16	16.46	17.22	16.2	16.82	16.94
	Seismic E Values	Reading 1	49	42.8	61.2	14.3	6	40	41.9	15.5	34.6	52.5	35.9	14.9	36.7	36.7	22.4
		Reading 2	47	47.5	59	16	9.4	40	41.9	19.1	34.6	49.5	26.4	13.3	31.6	39.4	31.3
		Reading 3	45.8	49.2	55.3	18.1	10.7	36.6	34.8	16.7	41.5	48.5	31	13.8	30	40.3	29.7
	AVG Seismic E after conditioning		47.26667	46.5	58.5	16.13333	8.7	38.86667	39.53333	17.1	36.9	50.16667	31.1	14	32.766667	38.8	27.8
	Unconfined Compressive Strength (psi)		60.0	56.7	39.4	31.0	24.8	41.3	43.5	26.0	55.4	57.9	47.3	28.9	50.8	46.5	56.0
	Water content (%) after compression test		4.37	5.71	6.66	7.63	4.72	5.84	6.6	7.53	5.49	5.76	6.52	7.86	6.66	6.67	6.6
	*Drop count estimated due to SCA software lockup																

Table B.3. Results from Samples Targeting 16.7 ft-lbf per Blow.

				113-E Moisture-Density Samples														
			Sample ID	Group 7				Group 8				Group 9				Test samples at 113-E Optimum		
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
			Hammer Weight	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675	12.20675
	Molding Data	Lift 1	AVG drop ht (in)	18.73	18.72	18.69	18.73	18.7	18.72	18.71	18.73	18.75	18.72	18.68	18.75	18.77	18.76	18.76
			# drops	44	45	45	45	45	45	45	46	46	45	45	46	45	45	45
			Total Energy (ft-lbf)	751.54	762	760.84	754.61	753.67	761.05	757.27	765.63	765.25	753.36	765.71	766.23	765.37	762.78	760.97
		Lift 2	AVG drop ht (in)	18.73	18.7	18.53	18.73	18.67	18.5	18.74	18.69	18.71	18.72	18.52	18.74	18.05	18.51	18.74
			# drops	45	45	44	45	45	45	45	45	45	45	45	45	37	45	45
			Total Energy (ft-lbf)	767.12	761.93	751.13	755.39	756.86	752.79	766.18	759.5	755.51	757.46	762.09	758	763.69	754.59	761.99
		Lift 3	AVG drop ht (in)	18.05	18.34	18.72	18.72	18.36	18.7	18.73	18.68	18.73	18.71	18.69	18.75	18.75	18.32	18.73
			# drops	45	46	45	45	46	46	45	45	45	46	45	46	46	45	46
			Total Energy (ft-lbf)	751.72	770.15	758.1	752.97	764.08	764.16	752.81	755.23	751.36	763.37	751.52	755.54	755.17	750.2	763.7
		Lift 4	AVG drop ht (in)	18.74	18.69	18.71	18.72	18.06	18.68	18.66	18.49	18.72	18.75	18.69	18.74	18.75	18.69	18.75
			# drops	45	45	45	46	44	46	45	45	45	46	46	46	45	46	45
			Total Energy (ft-lbf)	760.94	759.22	756.57	763.77	753.32	765.49	750.38	765.6	753.84	763.37	764.85	756.46	766.36	762.07	757.43
			Total Energy Measured (ft-lbf)	3031.32	3053.3	3026.64	3026.74	3027.93	3043.49	3026.64	3045.96	3025.96	3037.56	3044.17	3036.23	3050.59	3029.64	3044.09
			Sample Ht (in)	8.25	8.1	8.05	8.1	8.1	8.1	8.05	7.95	8.25	8.2	8.05	8	8.1	8	7.9
			Sample Volume (ft^3)	0.13499	0.132536	0.131718	0.132536	0.132536	0.132536	0.131718	0.130082	0.13499	0.134172	0.131718	0.1309	0.1325359	0.1308997	0.1292634
			Effort Measured [(ft-lbf/ft^3)]	22455.83	23037.52	22978.21	22837.13	22846.1	22963.51	22978.21	23415.77	22416.13	22639.27	23111.3	23195.09	23017.077	23144.745	23549.503
			Molded water content (%)	5	6	7	8	5	6	7	8	5	6	7	8	6.8	6.8	6.8
			Sample dry density (pcf)	133.21	135.43	137.08	134.62	134.49	135.69	136.92	136.01	132.08	135.28	136.52	136.06	136.09	136.37	137.63
			Max dry density (pcf)	136.5				136.5				136.3				Not Applicable		
			Optimum Water Content (%)	6.6				6.8				6.9				Not Applicable		
	Dielectric at Molding		Reading 1	No percometer available 9/16/10							18.4	No percometer available			17.4	16.8	17.9	18.8
			Reading 2								19.6				20.9	14.6	18	18.5
			Reading 3								20.7				22.9	18.1	16.7	17.7
			Reading 4								21.2				21.9	17.3	18.5	19.8
			Reading 5								22.7					16	16.3	18.7
			AVG Dielectric at Molding								20.52				20.775	16.56	17.48	18.7
	Seismic E at Molding		*Reading 1*	36.1	36.4	15.2	6.8	14.8	47.6	15.2	6.8	46.8	15	12	6.8	18.7	9.1	22.2
			Reading 2	28.8	36.4	13.5	5.7	10.3	44.7	9.2	7.9	43.9	11.9	6.8	15.2	18.7	10.4	13.3
			Reading 3	28	38.2	14.1	4.7	11.7	34.7	9.2	8.3	46.8	11.9	6.8	11	15.2	16.1	11.8
			AVG Seismic E at Molding	30.96667	37	14.26667	5.733333	12.26667	42.33333	11.2	7.666667	45.83333	12.93333	8.533333	11	17.533333	11.866667	15.766667
Data after Tex-117-E part II Conditioning			Water content (%) after conditioning	5	6.01	6.88	7.78	5	5.93	6.98	7.35	5.01	6.04	6.85	7.27	6.48	6.38	6.45
	Dielectric Values		Reading 1	12.8	14.3	18.3	20.2	12.8	14.2	15.9	19.9	13	15.6	17.8	15.8	16.9	17.7	18
			Reading 2	13.3	13.6	16.8	17.9	12.1	12.5	13	20.1	13	13.5	14.2	18.8	16.6	16.8	18.1
			Reading 3	11.9	14.4	17	19.1	12	12.1	16.9	19.1	13.3	12.9	12.9	17.4	14.9	16	17.6
			Reading 4	10.9	13.5	15.1	18.4	11.6	11.3	13.3	17.5	11.5	12.3	13.5	20.1	13.5	15.9	16.7
			Reading 5	12.3	14.6	16.7	18.3	11.6	13.5	17.3	20	12.9	14.6	16.9	19	16.5	16	17.1
			AVG Dielectric after conditioning	12.24	14.08	16.78	18.78	12.02	12.72	15.28	19.32	12.74	13.78	15.06	18.22	15.68	16.48	17.5
	Seismic E Values		*Reading 1*	skip due to dryness	46.9	53.3	17.3	skip due to dryness	48.9	36.4	18.8	came apart in weighing - no test	26	49.6	22.7	33.5	26.4	36.4
			Reading 2		46.9	34.5	15.5		48.9	36.4	24.8		26	49.6	31.7	34.5	26.4	50.4
			Reading 3		47.9	30.7	13.5		49.9	43	25.5		26	55.1	30.1	34.5	25	55.8
			AVG Seismic E after conditioning		47.23333	39.5	15.43333		49.23333	38.6	23.03333		26	51.43333	28.16667	34.166667	25.933333	47.533333
			Unconfined Compressive Strength (psi)	32.3	77.5	48.7	37.7	65.9	81.6	49.6	26.8	38.5	41.5	46.4	26.4	40.9	58.9	53.7
			Water content (%) after compression test	5	6.01	6.88	7.78	5	5.93	6.98	7.35	5.01	6.04	6.85	7.27	6.48	6.38	6.45

APPENDIX C: INDIVIDUAL LAB RESULTS FROM ILS

Table C.1. ILS Results from Laboratory 1.

Triaxial Test Data Sheet									
Specimen Data									
Specimen Number:	GB-1	GB-2	GB-3	SW-1	SW-2	SW-3	OK-1	OK-2	OK-3
Cell No.:									
Wet Mass Spec. & Mold, (lb):	38.649	38.505	No Sample	39.638	39.637	39.638	38.390	38.960	38.161
Wet Mass Specimen, (lb):	19.361	19.218		20.351	20.350	20.351	19.102	19.672	18.874
Initial Height of Specimen, in.:	8.056	8.029		7.890	7.871	7.899	7.976	8.211	7.865
New Height of Specimen, in.:	8.000	8.000		8.000	8.000	8.000	8.000	8.000	8.000
Average Diameter, in.:	6.00	6.00		6.00	6.00	6.00	6.00	6.00	6.00
Circumference, in. (manual):	19.100	19.100		19.000	19.000	19.000	18.900	18.900	18.900
Circumference, in. (auto):	19.100	19.100		19.000	19.000	19.000	18.900	18.900	18.900
Area, in.^2:	28.65	28.65		28.50	28.50	28.50	28.35	28.35	28.35
Avg. Cross Sectional Area, in^2:	29.84	29.56		29.35	29.44	29.62	28.99	29.01	28.81
Dry-Back Data									
Wet Mass of Pan & Specimen, (lb)	22.271	22.401		23.482	23.519	23.453	22.161	22.787	23.007
Dry Mass of Pan & Specimen, (lb):	21.031	21.138		22.485	22.494	22.436	20.875	21.466	21.644
Mass of Pan, (lb):	3.210	3.239		3.210	3.239	3.231	3.210	3.239	3.231
Dry Mass of Material, (lb):	17.821	17.899		19.275	19.255	19.205	17.665	18.227	18.413
Mass of Water, (lb):	1.240	1.263		0.997	1.025	1.017	1.286	1.321	1.363
Moisture Content, (%):	7.0	7.1		5.2	5.3	5.3	7.3	7.2	7.4
Wet Density, (pcf).:	146.5	145.9		157.3	157.6	157.1	146.0	146.1	146.3
Dry Density, (pcf):	137.0	136.3		149.5	149.7	149.2	136.1	136.2	136.2
SCA Data									
Total Energy (lb-ft) Lift 1:	759.620	759.710		758.000	755.000	760.760	757.170	754.610	750.470
Total Energy (lb-ft) Lift 2:	759.640	752.220		759.560	751.690	763.130	753.000	753.450	750.600
Total Energy (lb-ft) Lift 3:	751.140	758.860		757.430	762.460	761.400	761.670	752.910	759.470
Total Energy (lb-ft) Lift 4:	752.760	761.650		753.220	750.010	760.340	755.120	759.170	751.260
Energy/Lift (lb-ft) Lift 1:	13.330	12.880		12.850	13.260	13.350	13.050	13.240	12.940
Energy/Lift (lb-ft) Lift 2:	13.330	12.970		13.330	13.670	13.390	12.980	12.150	12.720
Energy/Lift (lb-ft) Lift 3:	13.180	13.080		13.530	13.620	13.840	13.360	12.980	12.870
Energy/Lift (lb-ft) Lift 4:	13.210	13.360		13.450	13.640	13.580	13.360	12.650	12.520
Avg. Drop Ht. (lb-ft) Lift 1:	18.300	15.990		18.470	18.480	18.400	17.180	17.810	16.520
Avg. Drop Ht. (lb-ft) Lift 2:	17.550	18.290		18.490	18.490	18.400	18.010	17.120	17.370
Avg. Drop Ht. (lb-ft) Lift 3:	17.960	18.000		18.490	18.500	17.420	17.960	18.470	18.040
Avg. Drop Ht. (lb-ft) Lift 4:	17.260	18.490		18.490	18.490	17.970	17.050	17.660	17.050
No. of Blows (lb-ft) Lift 1:	57.000	59.000		59.000	57.000	57.000	58.000	57.000	58.000
No. of Blows (lb-ft) Lift 2:	57.000	58.000		57.000	55.000	57.000	58.000	62.000	59.000
No. of Blows (lb-ft) Lift 3:	57.000	58.000		56.000	56.000	55.000	57.000	58.000	59.000
No. of Blows (lb-ft) Lift 4:	57.000	57.000		56.000	55.000	56.000	59.000	60.000	60.000

Table C.2. ILS Results from Laboratory 2.

Triaxial Test Data Sheet									
Specimen Data									
Specimen Number:	GB-1	GB-2	GB-3	OK-1	OK-2	OK-3	SW-1	SW-2	SW-3
Cell No.:	57	60	72	94	103	105	34	36	56
Wet Mass Spec. & Mold, (lb):	37.840	37.874	37.880	37.553	37.548	37.330	38.646	39.213	38.745
Wet Mass Specimen, (lb):	19.454	19.488	19.494	19.167	19.162	18.944	20.260	20.827	20.359
Initial Height of Specimen, in.:	8.105	8.127	8.168	7.940	7.933	7.925	7.793	7.999	7.847
New Height of Specimen, in.:	8.105	8.127	8.198	7.940	7.933	7.925	7.793	7.999	7.847
Average Diameter, in.:	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Circumference, in. (manual):									
Circumference, in. (auto):	18.850	18.850	18.850	18.850	18.850	18.850	18.850	18.850	18.850
Area, in.^2:	28.27	28.27	28.27	28.27	28.27	28.27	28.27	28.27	28.27
Avg. Cross Sectional Area, in^2:	28.99	28.90	29.00	28.72	28.81	28.84	28.87	28.96	29.09
Dry-Back Data									
Wet Mass of Pan & Specimen, (lb)	24.424	24.031	22.891	25.662	25.560	25.623	26.373	26.815	25.404
Dry Mass of Pan & Specimen, (lb):	23.297	22.936	21.749	24.328	24.231	24.287	25.415	25.851	24.454
Mass of Pan, (lb):	5.285	5.143	3.762	6.188	6.054	6.106	6.107	6.066	5.087
Dry Mass of Material, (lb):	18.012	17.794	17.987	18.140	18.177	18.182	19.308	19.785	19.368
Mass of Water, (lb):	1.127	1.095	1.143	1.334	1.330	1.336	0.959	0.964	0.950
Moisture Content, (%):	6.3	6.2	6.4	7.4	7.3	7.3	5.0	4.9	4.9
Wet Density, (pcf).:	145.5	145.3	144.6	146.3	146.4	144.9	157.6	157.8	157.2
Dry Density, (pcf):	136.9	136.9	136.0	136.3	136.4	135.0	150.1	150.5	149.9
SCA Data									
Total Energy (lb-ft) Lift 1:	753.520	758.040	753.130	759.620	761.420	761.750	760.070	761.310	750.620
Total Energy (lb-ft) Lift 2:	750.540	758.930	761.340	752.770	757.180	751.160	757.690	756.300	758.760
Total Energy (lb-ft) Lift 3:	762.010	762.700	750.430	759.540	756.960	759.760	754.020	760.590	752.050
Total Energy (lb-ft) Lift 4:	751.360	754.600	750.460	762.780	762.440	758.000	753.580	753.860	755.060
Energy/Lift (lb-ft) Lift 1:	13.220	13.300	13.210	13.100	13.130	13.130	13.570	13.130	13.170
Energy/Lift (lb-ft) Lift 2:	13.170	13.080	13.130	12.950	13.050	12.950	13.060	13.040	13.080
Energy/Lift (lb-ft) Lift 3:	13.140	13.150	13.170	13.100	13.050	13.100	13.000	13.110	13.190
Energy/Lift (lb-ft) Lift 4:	13.180	13.240	13.170	13.150	13.150	13.070	13.220	13.230	13.250
Avg. Drop Ht. (lb-ft) Lift 1:	18.400	18.380	18.390	18.380	18.360	18.330	18.380	18.410	18.390
Avg. Drop Ht. (lb-ft) Lift 2:	18.400	18.410	18.380	18.390	18.390	18.310	18.360	18.380	18.360
Avg. Drop Ht. (lb-ft) Lift 3:	18.390	18.370	18.390	18.370	18.380	18.390	18.340	18.360	18.360
Avg. Drop Ht. (lb-ft) Lift 4:	18.390	18.400	18.400	18.400	18.390	18.380	18.390	18.380	18.390
No. of Blows (lb-ft) Lift 1:	57.000	57.000	57.000	58.000	58.000	58.000	56.000	58.000	57.000
No. of Blows (lb-ft) Lift 2:	57.000	58.000	58.000	58.000	58.000	58.000	58.000	58.000	58.000
No. of Blows (lb-ft) Lift 3:	58.000	58.000	57.000	58.000	58.000	58.000	58.000	58.000	57.000
No. of Blows (lb-ft) Lift 4:	57.000	57.000	57.000	58.000	58.000	58.000	57.000	57.000	57.000

Table C.3. ILS Results from Laboratory 3.

Triaxial Test Data Sheet									
Specimen Data									
Specimen Number:	1	2	3	4	5	6	7	8	9
Cell No.:	G-1	G-2	G-3	O-5	O-6	O-7	S-A	S-B	
Wet Mass Spec. & Mold, (lb):	38.866	38.756	38.776	38.514	38.664	38.667	39.776	39.738	
Wet Mass Specimen, (lb):	19.549	19.439	19.459	19.197	19.347	19.350	20.459	20.421	
Initial Height of Specimen, in.:	8.235	8.202	8.291	8.096	8.120	8.094	7.969	7.973	
New Height of Specimen, in.:	8.235	8.202	8.291	8.096	8.120	8.094	7.969	7.973	
Average Diameter, in.:	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
Circumference, in. (manual):									
Circumference, in. (auto):	18.850	18.850	18.850	18.850	18.850	18.850	18.850	18.850	18.850
Area, in.^2:	28.27	28.27	28.27	28.27	28.27	28.27	28.27	28.27	
Avg. Cross Sectional Area, in^2:	28.96	28.99	28.78	28.78	28.69	29.05	28.84	28.72	
Dry-Back Data									
Wet Mass of Pan & Specimen, (lb)	25.650	25.222	25.543	24.474	25.445	24.999	25.349	26.396	
Dry Mass of Pan & Specimen, (lb):	24.421	24.011	24.321	23.278	24.247	23.807	24.371	25.427	
Mass of Pan, (lb):	6.141	5.833	6.116	5.409	6.246	5.793	4.939	6.031	
Dry Mass of Material, (lb):	18.280	18.178	18.205	17.869	18.001	18.014	19.432	19.396	
Mass of Water, (lb):	1.229	1.211	1.222	1.196	1.198	1.192	0.978	0.969	
Moisture Content, (%):	6.7	6.7	6.7	6.7	6.7	6.6	5.0	5.0	
Wet Density, (pcf).:	144.7	144.5	143.1	144.6	145.3	145.8	156.5	156.2	
Dry Density, (pcf):	135.6	135.5	134.1	135.5	136.2	136.7	149.0	148.7	
SCA Data									
Total Energy (lb-ft) Lift 1:	751.500	763.990	761.530	759.200	757.720	760.230	762.180	759.710	
Total Energy (lb-ft) Lift 2:	760.510	750.180	761.340	758.000	762.650	758.990	764.060	757.220	
Total Energy (lb-ft) Lift 3:	758.790	761.270	760.340	760.150	761.030	759.100	754.840	753.520	
Total Energy (lb-ft) Lift 4:	760.480	756.170	753.840	751.890	757.060	752.990	752.770	752.060	
Energy/Lift (lb-ft) Lift 1:	14.180	14.150	14.100	14.060	14.030	14.080	13.860	14.070	
Energy/Lift (lb-ft) Lift 2:	18.080	14.150	14.100	14.040	14.120	14.060	13.890	14.020	
Energy/Lift (lb-ft) Lift 3:	18.050	14.100	14.080	14.080	14.090	14.060	13.980	13.950	
Energy/Lift (lb-ft) Lift 4:	18.080	14.000	13.960	13.920	14.020	13.940	13.940	13.930	
Avg. Drop Ht. (lb-ft) Lift 1:	18.530	18.530	18.510	18.520	18.540	18.530	18.490	18.530	
Avg. Drop Ht. (lb-ft) Lift 2:	18.520	18.510	18.520	18.510	18.540	18.540	18.490	18.510	
Avg. Drop Ht. (lb-ft) Lift 3:	18.520	18.520	18.520	18.520	18.530	18.530	18.510	18.510	
Avg. Drop Ht. (lb-ft) Lift 4:	18.510	18.500	18.500	18.520	18.510	18.500	18.510	18.510	
No. of Blows (lb-ft) Lift 1:	53.000	54.000	54.000	54.000	54.000	54.000	55.000	54.000	
No. of Blows (lb-ft) Lift 2:	54.000	53.000	54.000	54.000	54.000	54.000	55.000	54.000	
No. of Blows (lb-ft) Lift 3:	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	
No. of Blows (lb-ft) Lift 4:	54.000	54.000	54.000	54.000	54.000	54.000	54.000	54.000	

Table C.4. ILS Results from Laboratory 4.

Triaxial Test Data Sheet									
Specimen Data									
Specimen Number:	GB-1	GB-2	GB-3	SW-1	SW-2	SW-3	OK-1	OK-2	OK-3
Cell No.:	4	5	6	7	8	9	1	2	3
Wet Mass Spec. & Mold, (lb):	29.382	29.347	29.273	30.250	30.274	30.262	28.995	29.122	29.113
Wet Mass Specimen, (lb):	19.421	19.386	19.312	20.289	20.313	20.301	19.034	19.161	19.152
Initial Height of Specimen, in.:	8.028	7.985	7.989	7.733	7.765	7.818	7.737	7.746	7.820
New Height of Specimen, in.:	8.028	7.985	7.989	7.733	7.765	7.818	7.737	7.746	7.820
Average Diameter, in.:	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Circumference, in. (manual):									
Circumference, in. (auto):	18.850	18.850	18.850	18.850	18.850	18.850	18.850	18.850	18.850
Area, in.^2:	28.27	28.27	28.27	28.27	28.27	28.27	28.27	28.27	28.27
Avg. Cross Sectional Area, in^2:	28.65	28.68	28.66	28.60	28.69	28.64	28.71	28.69	28.66
Dry-Back Data									
Wet Mass of Pan & Specimen, (lb)	22.955	23.161	23.158	24.056	23.852	24.124	22.532	23.016	22.806
Dry Mass of Pan & Specimen, (lb):	21.778	21.970	21.993	23.125	22.912	23.200	21.342	21.819	21.635
Mass of Pan, (lb):	3.534	3.774	3.836	3.777	3.546	3.836	3.558	3.895	3.794
Dry Mass of Material, (lb):	18.244	18.196	18.157	19.348	19.366	19.364	17.784	17.924	17.841
Mass of Water, (lb):	1.177	1.191	1.165	0.931	0.940	0.924	1.190	1.197	1.171
Moisture Content, (%):	6.5	6.5	6.4	4.8	4.9	4.8	6.7	6.7	6.6
Wet Density, (pcf).:	144.0	144.5	143.9	156.2	155.7	154.6	146.4	147.2	145.8
Dry Density, (pcf):	135.3	135.6	135.2	149.0	148.5	147.5	137.3	138.0	136.8
SCA Data									
Total Energy (lb-ft) Lift 1:	752.570	761.310	753.370	751.030	755.450	755.560	750.510	753.260	752.060
Total Energy (lb-ft) Lift 2:	754.140	758.790	758.700	750.480	756.570	755.040	751.130	758.880	762.160
Total Energy (lb-ft) Lift 3:	756.110	752.000	751.350	754.730	758.060	758.190	761.690	751.560	760.410
Total Energy (lb-ft) Lift 4:	751.570	750.650	759.380	750.640	754.060	753.800	762.410	751.320	753.280
Energy/Lift (lb-ft) Lift 1:	12.760	12.480	12.560	12.520	12.380	12.190	12.940	12.770	12.750
Energy/Lift (lb-ft) Lift 2:	12.570	12.440	12.440	12.510	12.200	11.980	12.950	12.650	12.490
Energy/Lift (lb-ft) Lift 3:	12.600	12.330	12.320	12.370	12.230	12.230	12.690	12.530	12.670
Energy/Lift (lb-ft) Lift 4:	12.530	12.310	12.050	12.110	12.160	11.970	12.500	12.320	12.350
Avg. Drop Ht. (lb-ft) Lift 1:	18.010	17.120	17.990	17.990	17.510	17.980	18.000	18.000	17.870
Avg. Drop Ht. (lb-ft) Lift 2:	17.980	17.170	17.330	17.490	17.080	17.320	17.510	17.280	17.620
Avg. Drop Ht. (lb-ft) Lift 3:	18.000	17.310	17.200	17.980	16.700	17.980	17.990	17.290	17.120
Avg. Drop Ht. (lb-ft) Lift 4:	17.510	18.000	17.250	17.390	17.610	16.790	18.000	18.000	18.000
No. of Blows (lb-ft) Lift 1:	59.000	61.000	60.000	60.000	61.000	62.000	58.000	59.000	59.000
No. of Blows (lb-ft) Lift 2:	60.000	61.000	61.000	60.000	62.000	63.000	58.000	60.000	61.000
No. of Blows (lb-ft) Lift 3:	60.000	61.000	61.000	61.000	62.000	62.000	60.000	60.000	60.000
No. of Blows (lb-ft) Lift 4:	60.000	61.000	63.000	62.000	62.000	63.000	61.000	61.000	61.000

Table C.5. ILS Results from Laboratory 5.

Triaxial Test Data Sheet

Specimen Data									
Specimen Number:	GB-1	GB-2	GB-3	SW-1	SW-2	SW-3	OK-1	OK-2	OK-3
Cell No.:	8	9		8	9	28	8	9	28
Wet Mass Spec. & Mold, (lb):	38.678	38.694		39.456	39.799	39.804	38.591	38.687	38.693
Wet Mass Specimen, (lb):	19.208	19.224		19.986	20.329	20.334	19.121	19.217	19.223
Initial Height of Specimen, in.:	8.120	8.121		7.827	7.991	8.052	8.192	8.035	8.050
New Height of Specimen, in.:	7.991	8.052		7.827	7.991	8.052	8.192	8.035	8.050
Average Diameter, in.:	6.00	6.00		6.00	6.00	6.00	6.00	6.00	6.00
Circumference, in. (manual):	18.850	18.850		18.900	18.850	18.900	18.900	18.850	19.000
Circumference, in. (auto):	18.850	18.850		18.900	18.850	18.900	18.900	18.850	19.000
Area, in.^2:	28.28	28.28		28.35	28.28	28.35	28.35	28.28	28.50
Avg. Cross Sectional Area, in^2:	28.95	28.84		29.04	28.95	28.92	30.64	29.65	29.04
Dry-Back Data									
Wet Mass of Pan & Specimen, (lb)	22.932	22.953		23.679	24.068	24.068	22.745	22.869	22.856
Dry Mass of Pan & Specimen, (lb):	21.782	21.791		22.806	23.158	23.172	21.592	21.672	21.689
Mass of Pan, (lb):	3.763	3.765		3.763	3.773	3.782	3.765	3.789	3.769
Dry Mass of Material, (lb):	18.019	18.026		19.043	19.385	19.390	17.827	17.883	17.920
Mass of Water, (lb):	1.150	1.162		0.873	0.910	0.896	1.153	1.197	1.167
Moisture Content, (%):	6.4	6.4		4.6	4.7	4.6	6.5	6.7	6.5
Wet Density, (pcf).:	144.2	144.3		155.7	155.1	154.0	142.3	145.8	145.6
Dry Density, (pcf):	135.6	135.6		148.9	148.2	147.2	133.7	136.7	136.7
SCA Data									
Total Energy (lb-ft) Lift 1:	759.190	753.740		754.540	753.110	755.120	761.850	758.560	761.920
Total Energy (lb-ft) Lift 2:	751.150	753.610		750.790	750.720	756.350	760.300	751.370	752.030
Total Energy (lb-ft) Lift 3:	763.600	754.370			753.690	756.040	753.100	751.000	755.270
Total Energy (lb-ft) Lift 4:	760.395	759.680		761.760	752.640	757.780		754.520	750.150
Energy/Lift (lb-ft) Lift 1:	13.319	13.460		13.010	12.980	12.590	13.850	13.080	13.140
Energy/Lift (lb-ft) Lift 2:	13.180	13.460		12.940	12.940	12.200	13.340	13.420	13.190
Energy/Lift (lb-ft) Lift 3:	13.640	13.720			12.990	11.120	13.210	13.180	12.380
Energy/Lift (lb-ft) Lift 4:	13.840	13.570		13.360	12.760	8.880		13.010	12.930
Avg. Drop Ht. (lb-ft) Lift 1:	17.450	18.410		17.630	17.650	17.600	18.420	17.880	18.340
Avg. Drop Ht. (lb-ft) Lift 2:	17.690	18.390		17.410	17.380	16.770	18.290	18.360	18.430
Avg. Drop Ht. (lb-ft) Lift 3:	18.210	18.430			18.200	15.190	18.070	18.380	18.190
Avg. Drop Ht. (lb-ft) Lift 4:	18.340	18.420		17.800	16.970	13.290		18.410	18.400
No. of Blows (lb-ft) Lift 1:	57.000	56.000		58.000	58.000	60.000	55.000	58.000	58.000
No. of Blows (lb-ft) Lift 2:	57.000	56.000		58.000	58.000	62.000	55.000	56.000	57.000
No. of Blows (lb-ft) Lift 3:	56.000	55.000			58.000	68.000	57.000	57.000	61.000
No. of Blows (lb-ft) Lift 4:	55.000	56.000		57.000	59.000	78.000		58.000	58.000

Table C.6. ILS Results from Laboratory 6.

Triaxial Test Data Sheet									
Specimen Data									
Specimen Number:	GB-1	GB-2	GB-3	SW-1	SW-2	SW-3	OK-1	OK-2	OK-3
Cell No.:									
Wet Mass Spec. & Mold, (lb):	30.354	30.347	30.348	31.330	31.446	31.182	30.383	30.414	30.315
Wet Mass Specimen, (lb):	19.089	19.081	19.083	20.065	20.181	19.917	19.118	19.148	19.050
Initial Height of Specimen, in.:	8.100	8.200	7.950	8.000	8.100	7.900	8.200	8.100	8.050
New Height of Specimen, in.:	8.105	8.127	8.198	7.940	7.933	7.925	7.793	7.999	7.847
Average Diameter, in.:	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Circumference, in. (manual):									
Circumference, in. (auto):	18.850	18.850	18.850	18.850	18.850	18.850	18.850	18.850	18.850
Area, in.^2:	28.27	28.27	28.27	28.27	28.27	28.27	28.27	28.27	28.27
Avg. Cross Sectional Area, in^2:	28.74	28.84	28.95	28.89	28.75	28.93	28.60	28.74	28.68
Dry-Back Data									
Wet Mass of Pan & Specimen, (lb)	20.199	20.359	19.940	20.737	20.979	21.288	20.343	20.405	20.065
Dry Mass of Pan & Specimen, (lb):	19.156	19.271	18.871	19.887	20.116	20.463	19.273	19.328	18.975
Mass of Pan, (lb):	1.177	1.321	0.947	0.888	0.864	1.321	1.373	1.384	1.113
Dry Mass of Material, (lb):	17.978	17.950	17.924	18.998	19.252	19.142	17.900	17.944	17.862
Mass of Water, (lb):	1.044	1.088	1.069	0.850	0.863	0.825	1.070	1.077	1.091
Moisture Content, (%):	5.8	6.1	6.0	4.5	4.5	4.3	6.0	6.0	6.1
Wet Density, (pcf).:	143.7	141.9	146.4	152.9	151.9	153.7	142.2	144.1	144.3
Dry Density, (pcf):	135.8	133.8	138.1	146.4	145.4	147.4	134.1	136.0	136.0
SCA Data									
Total Energy (lb-ft) Lift 1:	762.500	754.070	753.410	751.030	762.150	760.810	756.550	753.500	769.770
Total Energy (lb-ft) Lift 2:	758.360	755.990	755.530	762.190	757.990	757.970	756.120	751.180	759.410
Total Energy (lb-ft) Lift 3:	754.720	756.920	753.890	756.880	751.720	757.080	756.830	752.770	758.170
Total Energy (lb-ft) Lift 4:	760.110	752.370	753.830	753.470	750.730	755.020	756.080	753.260	758.400
Energy/Lift (lb-ft) Lift 1:	12.924	12.568	12.557	12.517	12.918	12.895	12.823	12.771	13.272
Energy/Lift (lb-ft) Lift 2:	13.075	13.034	13.026	12.918	13.069	13.068	13.037	12.951	12.871
Energy/Lift (lb-ft) Lift 3:	13.012	12.829	13.226	13.050	13.188	13.053	13.049	12.979	13.072
Energy/Lift (lb-ft) Lift 4:	13.105	12.540	13.225	13.219	13.171	12.797	13.036	12.987	13.076
Avg. Drop Ht. (lb-ft) Lift 1:	17.880	18.290	18.310	18.320	18.290	18.070	18.130	18.110	18.230
Avg. Drop Ht. (lb-ft) Lift 2:	17.830	17.780	18.320	18.280	18.300	18.180	18.280	18.290	18.100
Avg. Drop Ht. (lb-ft) Lift 3:	18.240	18.090	18.310	18.260	18.290	18.130	18.280	18.270	18.280
Avg. Drop Ht. (lb-ft) Lift 4:	18.240	17.960	18.240	18.290	18.240	18.020	18.250	18.240	18.250
No. of Blows (lb-ft) Lift 1:	59	60	60	60	59	59	59	59	58
No. of Blows (lb-ft) Lift 2:	58	58	58	59	58	58	58	58	59
No. of Blows (lb-ft) Lift 3:	58	59	57	58	57	58	58	58	58
No. of Blows (lb-ft) Lift 4:	58	60	57	57	57	59	58	58	58