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Final Report

Validation of DCP and LWD Moisture Specifications for Granular Materials

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16. Abstract (Limit: 200 words)

Advances in technology have produced a new generation of in situ soil testing devices. Implementation of quality assurance procedures that make use of these devices would improve test precision, increase inspector efficiency and safety, and allow for the direct verification of values used in mechanistic design procedures. During this study, the dynamic cone penetrometer (DCP) and light weight deflectometer (LWD) were used on laboratory prepared specimens. It was found that the Mn/DOT DCP specification accurately assessed compaction quality, although there were some suggestions for improvement. This study reached the following conclusions and recommendations. The DCP penetration should continue until the cone passes through the subbase lift of interest. The DCP seating requirement serves little purpose for a subbase lift that will be covered by subsequent lifts. The acceptable range of moisture contents during DCP testing of granular subbase should be capped at 10%. A sufficient amount of data exists to create an LWD trial specification for granular subbase. A mass of 10 kg, drop height of 50 cm, and plate diameter of 20 cm are recommended. It is also recommended that the LWD specification include three seating drops followed by three data drops at each new height.

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VALIDATION OF DCP AND LWD MOISTURE SPECIFICATIONS FOR GRANULAR MATERIALS

Final Report

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Executive Summary

The Minnesota Department of Transportation (Mn/DOT) has used the specified density method to control pavement foundation construction quality for many years. Inspectors and engineers have a high degree of comfort with the method, and the large amount of test data produced during state construction projects has provided confidence in the state's empirical design process. However, continued advances in technology have produced a new generation of in-situ soil test devices that are able to measure soil parameters, such as stiffness and strength, that more accurately reflect a pavement's suitability for traffic loadings. The implementation of quality control and quality assurance procedures that make use of these devices would improve test precision, reduce the amount of time inspectors spend testing, increase field personnel safety, and allow for the direct verification of values used in mechanistic design procedures.

To take advantage of these possibilities, Mn/DOT developed a specification in 1997 that utilized the dynamic cone penetrometer (DCP) to assess aggregate base strength. The specification became established as an alternative to the specified density method as construction offices realized its advantages. However, one drawback of the specification became clear as implementation proceeded: it did not account for soils' moisture content and gradation. Because these properties influence the cone penetration rate, inspectors were often required to rely on experience to determine whether the test was valid in particular situations. A report by Matthew Oman, *Advancement of Grading & Base Material Testing* (2004), concluded that up to 19% of inadequate aggregate bases were meeting the DCP specification due to these omissions. Therefore, a modified specification accounting for moisture content and gradation was created to decrease the number of false positives. A subsequent analysis of the modified specification by the Grading and Base Section determined that it was much more accurate.

In the summer of 2005, as part of LRRB Investigation 829, Mn/DOT's Office of Materials carried out a series of DCP tests on controlled laboratory specimens to further the implementation of the modified DCP specification as well as identify the correlation between the DCP results and measurements of stiffness. It was found that the modified specification accurately assessed compaction quality, although there were some suggestions for further improvement. In addition, other new generation in-situ test devices such as an LWD (light weight deflectometer), Percometer, and Trident moisture meter were used upon the specimens to evaluate their capabilities and performance in a controlled setting. Data from this and other studies will allow for the formulation of specifications for these devices.

Chapter 1
Introduction

The Minnesota Department of Transportation (Mn/DOT) has for many years verified the quality of roadway base construction by comparing lift densities to a “maximum” density identified for each soil. To calculate the maximum density, Mn/DOT’s *Standard Specifications for Construction* require that samples be compacted at different moisture contents using a standardized compactive effort. The densities of the resulting specimens are calculated and plotted versus moisture content. The peak of a curve fit through this data is located at the “optimum” moisture content and maximum density. This process is known as a standard Proctor test (ASTM D698, AASHTO T99).

A sand cone test (ASTM D 1556-00) is performed on a lift of material in the field to determine whether its density meets or exceeds a designated percentage of the standard Proctor maximum density. (Mn/DOT does not use the nuclear density gauge for quality assurance.) These tests are performed by scooping a small amount of compacted soil from the base layer and carefully filling the hole with a measured mass of sand. The sand used in these tests has a known density, and therefore the volume of the hole can be calculated. Lastly, the density of the layer is calculated using this volume and the weight of the material removed from the hole. The compaction is deemed acceptable if the density measured during the sand cone test meets or exceeds a particular percentage (usually 100%) of the standard Proctor maximum density. This process is known as the specified density method for quality control (Mn/DOT Standard Specification 2211.3).

While the specified density method is simple in theory and still widely practiced in the United States, it presents a number of challenges for state inspectors and designers. On a practical level, sand cone tests are time consuming, imprecise even when performed by skilled inspectors, difficult to perform on soils containing large aggregate, and responsible for placing inspectors in unsafe low visibility positions. The Proctor test is limited in that it sets the density standard of a variable material from a very small sample. Furthermore, the method is based on fitting a line through a set of density and moisture content values, which are difficult to measure precisely. More Proctor tests could be performed to increase statistical confidence, but this is impractical as the tests are time consuming.

Other problems with the specified density method arise on the theoretical level. A material’s density, while relatively easy to measure and understand, is a poor indicator of future performance compared to stress-based parameters such as stiffness and strength. Small variations in density can have relatively large effects on stiffness properties. Therefore, the small errors that accumulate during the specified density procedure have the potential to greatly influence the indicated load bearing capacity of the soil. Lastly, design engineers would be better equipped to adapt pavement designs to differing locations, soil classifications, construction methods, and other innovations if stiffness and strength parameters were used in place of density.

To take advantage of these possibilities, construction agencies throughout the world have developed in-situ test devices designed to measure the strength and stiffness values, particularly

Young's modulus, of compacted materials. These devices use several methods to calculate modulus values. Some, such as the light weight deflectometer (LWD) and the trailer-mounted falling weight deflectometer (FWD), use falling weights to generate a soil response. Others, such as the soil stiffness gauge, induce a vibration in the soil. Still others, such as the dynamic cone penetrometer (DCP) and rapid compaction control device (RCCD), drive a cone into the soil to produce a measure of shear strength.

Mn/DOT has used the DCP to assess aggregate base strength since the creation of a specification in 1997. While this specification has generally been given favorable reviews, areas of potential improvement were identified as its use became more widespread. In particular, the specification did not fully account for the effects of moisture content and gradation. A report by Matthew Oman (1), concluded that up to 19% of aggregate bases meeting the requirements of the 1997 DCP specification throughout the state were inadequate due in large part to these effects. (Inadequate bases were defined as those that had relative densities below 95% or were inadequate in the opinion of a Grading and Base Inspector.) To remedy this situation, Oman conducted a series of field DCP tests that included moisture and gradation measurements. An empirical formula that made use of the moisture content and grading number (GN) was derived from the results, which greatly reduced the percentage of poorly compacted bases being accepted. The grading number is a new parameter comprised of the sum of the percentages passing the seven most common sieves divided by one hundred.

Mn/DOT's Office of Materials carried out a series of DCP tests on controlled laboratory specimens over the summer of 2005, as part of LRRB Investigation 829, to validate Oman's 2004 modified specification for granular materials and provide the test data needed to draft a similar specification for LWD devices. The specimens were prepared using three select granular borrow samples at varying moisture contents and densities. Portable testing devices, which included an LWD, Percometer, and Trident moisture meter, were used upon the specimens to produce independent modulus or moisture measurements. As an added benefit, it was possible to evaluate the performance of each of these in-situ test devices in a controlled setting so that a specification for their use may be created. This report details the findings of this study.

Chapter 2
Test Procedure

The DCP, LWD, and moisture meter tests were carried out on carefully prepared select granular samples in a controlled laboratory setting. Specimens were prepared inside of an open-topped steel cylinder (half of a 55-gallon drum). The intent was to create a specimen that was as thick as a subbase layer and wide enough to avoid any "edge effects" caused by interaction with the specimen walls. The specimen was compacted using a procedure analogous to that used for a standard Proctor test in order to remain as consistent as possible with standard laboratory and field practice. Lastly, the test devices were used at various locations throughout the specimen to ascertain that the assumption of homogeneity was valid. This chapter will detail the equipment, soil, and test procedure used during this study.

2.1 Test Equipment

Several tools, in-situ test devices, and laboratory instruments were used during this testing. The specimens were formed and compacted using primarily standard laboratory equipment, including, among others, sealable containers, trowels, rulers, and scales. However, two new pieces of equipment were manufactured specifically for their use in this project. The first of these was an open-topped steel cylinder used to contain the select granular specimen. This was created by cutting horizontally through a standard 55-gallon drum 18 inches from its base. The resulting cylinder had a 16 ½ inch interior height and 22 ½ inch interior diameter. Its volume was found to be 3.15 ft^3 by filling it with water and recording the subsequent change in weight.

Figure 2.1 Specimen Barrel

Early in the test sequence, it was observed that the entire drum was prone to a rocking movement following the impact loading from the compaction hammer. To prevent this, the closed base of the drum was cast inside of a 2 ft by 2 ft form that was subsequently filled with concrete. No movement of the drum was detected following this correction. A second potential problem became apparent during the testing when the bottom surface and upper edges of the cylinder deformed under the impact loading. Fortunately, a second liquid volume measurement proved that there had been no substantial change to the drum's volume and testing was allowed to proceed as scheduled.

The second piece of equipment manufactured for this testing was a large scale version of a Proctor hammer. Laboratory soil specimen compaction is often standardized using a variable known as compactive effort (CE), which can be calculated using equation #1.

$$CE = \frac{h_d * w * reps * layers}{V} \qquad [\#1]$$

where:
h_d = drop height (ft)
w = hammer weight (lbf)
reps = number of hammer drops per layer
layers = number of compacted soil layers
V = specimen volume (ft^3)

ASTM D698 requires that a compactive effort of 12,400 lbf-ft/ft^3 be used to prepare soil specimens for standard Proctor testing. A standard Proctor hammer used for this purpose weighs 5.5-lbf and has a 1 ft drop height. The standard specimen diameter varies between 4 and 6 inches depending upon its gradation. A much larger specimen was used for this testing; therefore, a 51-lbf hammer with a 33 ¼ inch drop height was required in order to keep the total number of drops reasonable (93 drops on each of 3 lifts).

Figure 2.2 51-lbf Hammer

Several test devices were used on the soil specimens during and after the compaction of their lifts. The test devices were designed to measure three types of values: density, moisture content, and mechanistic properties (i.e., stiffness and strength). The density measurements were produced using sand cone tests in compliance with ASTM D1556-00. Two sand cones of different sizes were used to ascertain that the measurements were repeatable.

Specimen moisture measurements were taken using two methods. The first was the standard oven-dry process (ASTM D 2216-98) that is performed by measuring the weight of a soil sample before and after it is dried in an oven. Thirteen soil samples were taken from each specimen during the preparation and testing processes of this study to be used for oven-dry moisture content measurements.

The second moisture content measurement method made use of the Percometer, a device that estimates a soil's moisture content from dielectric permittivity and conductivity values. This instrument, which is manufactured in Estonia by ADEK, consists of a 6 cm diameter probe attached to a small computer. When the surface of this probe is pressed against the material, the device emits a small electric current. Dielectric permittivity and conductivity values are calculated as the current moves through the soil between electrodes on the probe. The measured values of dielectric permittivity are proportional to the soil's volumetric moisture content using established relationships that vary with soil type.

Figure 2.3 Percometer

The instruments used in this study to measure the mechanistic properties of the soil were the DCP and LWD. The DCP uses the impact force generated by a falling mass to drive a shaft with a conical point into a compacted soil surface. The conical point is sloped at 60°, the falling mass is 8 kg (17.64 lbs), and the drop height is 575 mm (22.64 in). The shaft's penetration into the soil is measured following every blow, and the resulting penetration per blow measurements can be related to modulus values using the method outlined in Section 3.3.

Figure 2.4 DCP

The final piece of equipment used during this study was the LWD. This device induces a soil response by dropping a weight onto a plate resting on the test layer. A load cell within the instrument measures the time history of the load pulse and a geophone suspended through the bottom plate measures the time history of the soil's displacement. These history files are automatically exported wirelessly to a data acquisition system, where the peak load and displacement values are used to calculate modulus values (2). These time history files can be used in a fast Fourier transform (FFT) dynamic analysis for a more accurate modulus calculation (3).

Figure 2.5 LWD

2.2 Soil Samples

One of the primary goals of this research was to validate Mn/DOT's modified DCP specification for select granular borrow. As such, it was important to make certain that many common select granular sources were used to create the test specimens. In 2001, Mn/DOT's Office of Materials obtained select granular samples from throughout the state by requesting each Mn/DOT district to collect samples from active construction projects.

These samples were assigned identifying letters from A to O. The soils were tested to determine their gradation, standard Proctor maximum density, standard Proctor optimum moisture content, and several other common parameters. As expected, many of the samples were found to have similar compositions. A study completed in 2004 made use of six of these samples after determining that they were representative of the entire set (4). A portion of this study involved measuring the resilient modulus of the soils using Mn/DOT's modified version of Long Term Pavement Performance Protocol 46 (LTPP P46). Therefore, the decision was made to use the same samples for this study so that the existing data could be utilized. The identification letters for the six samples were A, D, F, H, J, and N.

Figure 2.6 Select Granular Samples

These six select granular samples appeared to fall into two categories in the 2004 study. Samples A, D, and N were sandy and had high modulus values; samples F, H, and J had a higher percentage of fines and low modulus values. Unfortunately, sample A contained a significant amount of large aggregate, which is difficult to test accurately. Therefore, five of these soils were used to form two composite samples: DN and FHJ. In addition, a third sample was created using soils that had percent passing gradation values between those of DN and FHJ: sample KLO. Figure 2.8 contains the gradation data from these combined samples.

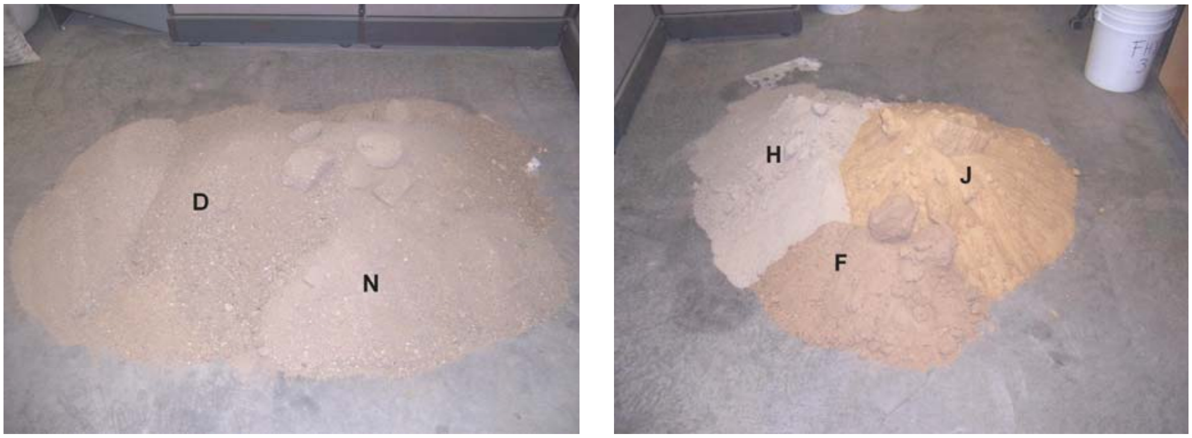
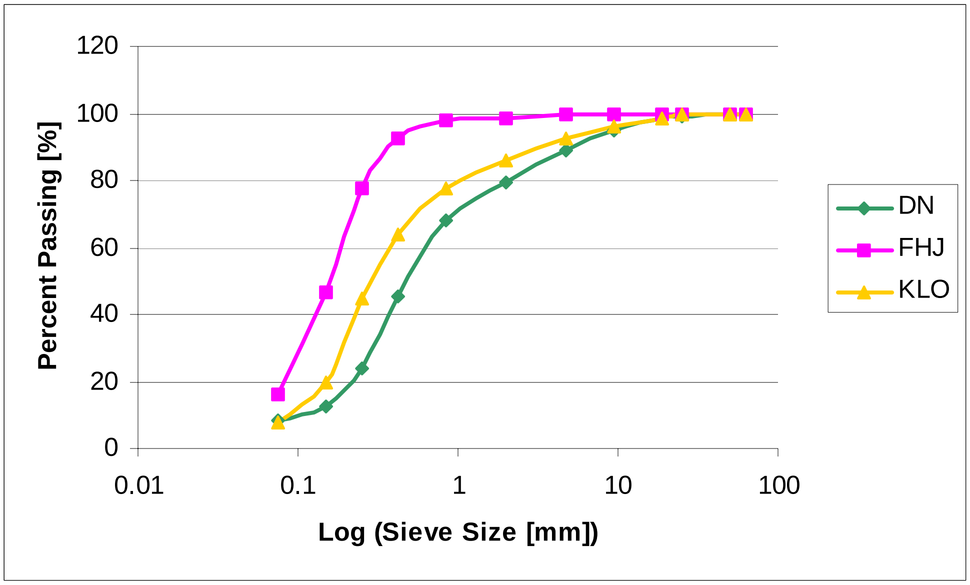


Figure 2.7 Combined Samples



Sieve Size	FHJ	DN	KLO
63 mm (2 1/2 in)	100	100	100
50 mm (2 in)	100	100	100
25.0 mm (1 in)	100	99.2	99.7
19.0 mm (3/4 in)	100	98.65	98.7
9.5 mm (3/8 in)	100	95.15	96.25
4.75 mm (#4)	99.9	88.75	92.6
2.00 mm (#10)	98.6	79.35	85.7
850 um (#20)	98	68.1	77.85
425 um (#40)	92.6	45.5	64.1
250 (#60)	77.9	24.1	44.5
150 um (#100)	46.3	12.8	19.7
75 um (#200)	16.0	8.2	7.8

Figure 2.8 Sample Gradations

2.3 Specimen Preparation

The specimen preparation procedure used for this study followed Mn/DOT's standard practices wherever possible. The first step in creating a test specimen was to bring the soil sample to the correct moisture content for a particular test. Eight soil containers (5-gallon buckets) containing samples of the correct gradation were poured evenly across a large (approximately 10 ft by 10 ft) mixing area such that its thickness did not exceed 4 inches. The amount of water was calculated using equation #2.

$$W_W = \frac{\omega_2 W_1}{\omega_1} - W_1 \qquad [\#2]$$

where:
W_W = required weight of water (lb)
W_1 = original weight of the soil sample (lb)
ω_1 = original moisture content (%)
ω_2 = desired moisture content (%)

The calculated weight of water was sprinkled on top of the soil as uniformly as possible using a regular garden sprinkling can. After adding the water, the soil was mixed thoroughly with shovels until the moisture was distributed evenly. At this point, the soil was scooped back into the buckets. Small amounts of soil (approximately ¼ to ½ of a pound) were taken from four random containers for overnight, oven-dry moisture content testing in compliance with ASTM D 2216-98. The lids were replaced on the buckets in order to make them airtight, and the entire sample was allowed to temper overnight.

The following day, the moisture samples were removed from the oven and the moisture content of each was calculated. If the average of the four moisture content values was within 0.5% of the intended moisture content, the test was allowed to proceed. If not, the sample preparation process was begun anew.

It was decided that the compacted specimens would be approximately 13 ½ inches in height so that the loose lifts would be confined within the specimen barrels. As a result, the desired volume of the specimen could be calculated by subtracting the volume of a cylinder 3 inches in height from the previously determined barrel volume. The maximum dry densities of the soil samples were also known from the previous laboratory Proctor test, allowing the weight of soil for each lift to be calculated using equation #3.

$$W_L = \rho V \qquad [\#3]$$

where:
W_L = weight of one lift (lb)
ρ = maximum dry density of the soil (lb/ft^3)
V = volume of the lift (ft^3)

Following this calculation, the calculated weight of soil needed for the first lift was poured into the drum and leveled. It was then compacted using 93 blows from the 51-lbf hammer. (See Section 2.1 for a description of the hammer.) This process was repeated for the second and third lifts. The loose material on the surface of the third lift was removed before the final leveling occurred and weighed so that the entire specimen mass could be calculated. In addition, the distance from the specimen surface to the top of the barrel was measured at 6 equidistant locations and averaged. Lastly, the barrel density was determined using equation #4.

$$\rho_B = \frac{nW_L - W_E}{V_B - h\pi r_B^2} \qquad \text{[\#4]}$$

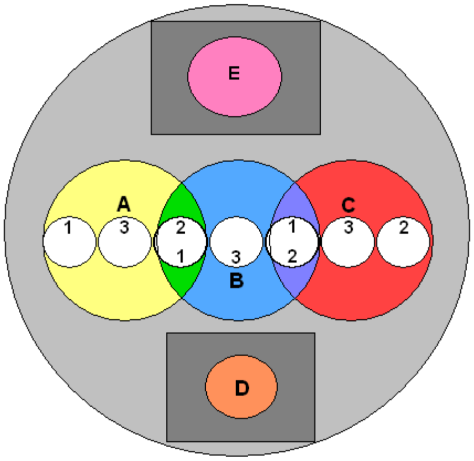
where:
ρ_B = barrel density (lb/ft^3)
n = number of lifts (3)
W_E = weight of the removed soil (lb)
V_B = calculated volume of the barrel (3.15 ft^3)
h = measured distance from the surface of the specimen to the top of the barrel (ft)
r_B = radius of the barrel (0.896 ft).

Figure 2.9 Surface of Smoothed Specimen

2.4 Data Acquisition

Five devices were used to measure properties of the compacted soil specimen: the DCP, the LWD, a Percometer moisture meter, and two sand cones. The operation of these devices is discussed in Section 2.1. The locations tested and devices used are shown in Figure 2.10.

The sequence of testing began with the least destructive devices and progressed to the most destructive. Therefore, the first device used on the specimen was the Percometer. Prior to each test, the Percometer's readings were calibrated against validation blocks of known dielectric properties. Following calibration, the surface of the probe was cleaned and placed at the first test location, “A1”. While the operator held the probe steady with the dead weight of his hand, the test was initiated by pressing a button on the instrument.



	Test Locations					
	Horizontal Position	A	B	C	D	E
Top	1	Percometer	Percometer	Percometer	Small Sandcone	Large Sandcone
	2	Percometer	Percometer	Percometer		
	3	Percometer, DCP, MC	Percometer, LWD, DCP, MC	Percometer, DCP, MC		
Middle	1	-	-	-	Small Sandcone	Large Sandcone
	2	-	-	-		
	3	MC	MC	MC		
Bottom	1	-	-	-	-	-
	2	-	-	-		
	3	MC	MC	MC		

Figure 2.10 Test Matrix

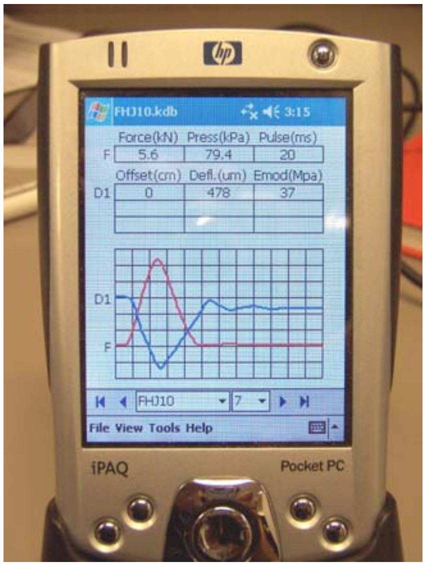
After a few seconds, the instrument output dielectric permittivity (E) and conductivity (J) values. These values were recorded and the test was repeated two additional times. If any of the dielectric readings at a given test location varied more than about 10% from the average value at that test location, additional readings were taken. This procedure was repeated at each of the locations identified in Figure 2.10.

Figure 2.11 Percometer Test

The second device used on the specimen was the LWD. Following the Percometer measurements, the LWD was carefully placed at location B and its initial drop height set at 25 cm. The data for the LWD tests was collected remotely by an iPAQ Pocket PC running the manufacturer's software "KP100". To prepare this system, the "Bluetooth Manager" was used to select the "KP100 Transmitter", a file was opened within the "KP100" program, and the program was instructed to connect to the LWD (2).

Figure 2.12 LWD Test

Once the transmitter on the data acquisition system was flashing green, the 10 kg falling weight was raised into position. The guide rod was held steady as the weight was released by pressing a lever and safety button on the LWD's handle. The weight was allowed to bounce until the computer beeped twice to signal that the data had been collected. Two seating drops were performed prior to data collection at the 25 cm drop height. The test procedure then called for three drops from each drop height (25 cm, 50 cm, and 75 cm) to produce the test data.



	Force(kN)	Press(kPa)	Pulse(ms)
F	5.6	79.4	20

	Offset(cm)	Defl.(um)	Emod(Mpa)
D1	0	478	37

Figure 2.13 iPAQ Pocket PC Data Acquisition

The third device used on the specimen was the DCP, which was used to take measurements at locations A, B, and C following the procedure outlined in ASTM 6951-03. After tightly assembling the DCP, it was placed upright at position A. An initial reading was taken and recorded from the measuring rod. The hammer was then raised to the top of the instrument, dropped, and a displacement measurement was recorded from the rod. This process was continued until the tip of the DCP contacted the bottom of the drum; the reading from this final blow is not used.

Figure 2.14 DCP Test

Lastly, small and large sand cones were used to determine the density at locations D and E, respectively. These tests were performed using the standard procedure outlined in ASTM D1556-00. Following these tests, three small samples of the specimen were placed in tins for an oven-dry moisture content analysis. The topmost lift of the specimen was subsequently removed and the surface re-leveled. Two more sand cone measurements were made at locations D and E, and three more samples were taken for moisture content testing. This process was repeated for the bottom lift with moisture measurements only.

Figure 2.15 Sand Cone Test

At this point, all of the soil was removed from the barrel and placed back into its containers. The containers were resealed so that the soil's moisture content would be known for future tests.

Chapter 3
Discussion of Results

The testing described in Chapter 2 was carried out at Mn/DOT's Maplewood Laboratory over the summer of 2005. This chapter summarizes the findings of the complete study.

3.1 Moisture and Density Data

The original test matrix included specimens prepared at only the standard Proctor compactive effort (12400 lbf-ft/ft^3) and three values of moisture content per soil type. However, it was understood that specimens with additional moisture-density combinations would be required to fully explore the moisture-density-strength-stiffness relationships. Therefore, the results of one test often influenced the moisture content and compactive effort used in a subsequent test. As a result, the overall test sequence did not proceed in a predetermined order. The results in Table 3.1 are sorted first by the target moisture content and second by the target compactive effort; the numbers in the "Test" column represent the true test sequence. For reference, the standard Proctor maximum density was 1942.4 kg/m^3 for sample DN, 1753.4 kg/m^3 for sample FHJ, and 1862.3 kg/m^3 for sample KLO. The optimum moisture contents were 8.1%, 10.3%, and 11.6%, respectively.

The measured moisture contents in Table 3.1 represent the average of 11 to 13 oven-dry samples taken from different compaction layers and locations following the DCP and LWD testing. (Two moisture samples were added to the test procedure in conjunction with additional sand cone tests after the data collection had begun.) The barrel density calculation is described in Section 2.3 of this report.

The moisture content of a sample was deemed acceptable prior to specimen compaction if the average value of the moisture samples taken the previous night was within 0.5% (as a fixed value, not a percentage) of the target value. A similar degree of variation was present in the compacted specimen moisture contents, with only two samples significantly deviating from the 0.5% target. This degree of fluctuation is difficult to avoid in soil testing. Therefore, the measured specimen moisture content values were deemed acceptable in comparison to the target values. Because of these fluctuations, it is important to emphasize the measured values when drawing conclusions from the data.

The barrel density values did not always vary as expected in response to modifications of the compactive effort. For example, a small number of specimens with identical target gradations and moisture contents were found to have smaller barrel densities following a greater compactive effort. Furthermore, in two cases the sand cone and barrel density measurements resulted in significantly different values for the same specimen.

Table 3.1 Final Test Matrix

Sample	Test	Target		Measured	
		Moisture Content (Percentage)	Compactive Effort (lbf-ft/ft^3)	Moisture Content (Percentage)	Barrel Density (kg/m^3)
DN	23	5	12400	5.05	1987
DN	1	5	12400	5.10	N/A
DN	24	7	12400	6.43	2043
DN	2	7	12400	7.19	1951
DN	3	10	12400	9.99	1999
DN	4	10	24800	9.95	1976
DN	5	10	12400-S	9.66	1985
DN	6	10	12400-C	9.16	2076*
FHJ	7	8	12400	7.76	1764
FHJ	21	8	13950	7.46	1820
FHJ	18	8	16533	7.98	1945*
FHJ	16	8	24800	8.05	1839
FHJ	8	10	12400	9.48	1791
FHJ	15	11	6200	11.38	1773
FHJ	9	11	12400	10.66	1802
FHJ	10	13	12400	12.75	1790
KLO	11	7	12400	7.05	1847
KLO	22	7	16533	6.99	1936
KLO	17	8	18600	8.06	1963
KLO	19	9	6200	8.86	1882
KLO	12	9	12400	8.94	1881
KLO	20	10	6200	10.30	1916
KLO	14	10	12400	10.51	1916
KLO	13	11	12400	12.04	1869

[*] denotes a barrel density value that differed from the average sand cone density by more than 50 kg/m^3
[-S] denotes a test in which sand was placed beneath the barrel to keep it from rocking (one test)
[-C] denotes the first test in which the barrel was cast in concrete (all tests following #5)

Table 3.2 displays the barrel density and average sand cone values recorded for each specimen. (Sand cone measurements of each size were taken on the surface and in the middle of each specimen.) The results show that the small sand cone usually measured a smaller density than the barrel density, while the large sand cone usually measured a larger density. On average, the small sand cone measurements were 13.7 kg/m^3 (0.7%) smaller than the barrel density. The large sand cone measurements were, on average, 13.8 kg/m^3 (0.7%) larger than the barrel density. The data from Test 22 was not used to calculate these percentages because of an outlying large sand cone measurement.

Table 3.2 Density Measurement Variation

Sample	Test	Target Variables		Density Measurements			
		Proctor Max Density (kg/m^3)	Compactive Effort (lbf-ft/ft^3)	Barrel (kg/m^3)	Small Sand Cone (kg/m^3)	Large Sand Cone (kg/m^3)	Barrel Relative to Proctor
DN	23	1942.4	12400	1987	2002	1976	102.3%
DN	1	1942.4	12400	N/A	1946	-	N/A
DN	24	1942.4	12400	2043	1971	2018	105.2%
DN	2	1942.4	12400	1951	1884	-	100.4%
DN	3	1942.4	12400	1999	2014	-	102.9%
DN	4	1942.4	24800	1976	2018	-	101.7%
DN	5	1942.4	12400-S	1985	2007	2026	102.2%
DN	6	1942.4	12400-C	2076	2002	1989	106.9%
FHJ	7	1753.4	12400	1764	1774	1795	100.6%
FHJ	21	1753.4	13950	1820	1793	1867	103.8%
FHJ	18	1753.4	16533	1945	1851	1872	110.9%
FHJ	16	1753.4	24800	1839	1811	1876	104.9%
FHJ	8	1753.4	12400	1791	1812	1868	102.1%
FHJ	15	1753.4	6200	1773	1792	1825	101.1%
FHJ	9	1753.4	12400	1802	1824	1873	102.8%
FHJ	10	1753.4	12400	1790	1782	1818	102.1%
KLO	11	1862.3	12400	1847	1812	1854	99.2%
KLO	22	1862.3	16533	1937	1945	2360	104.0%
KLO	17	1862.3	18600	1963	1946	2016	105.4%
KLO	19	1862.3	6200	1882	1936	1924	101.0%
KLO	12	1862.3	12400	1881	1836	1853	101.0%
KLO	20	1862.3	6200	1916	1906	1922	102.9%
KLO	14	1862.3	12400	1916	1890	1896	102.9%
KLO	13	1862.3	12400	1869	1881	1880	100.3%

[-S] denotes a test in which sand was placed beneath the barrel to keep it from rocking (one test)

[-C] denotes the first test in which the barrel was cast in concrete (all tests following #5)

These discrepancies were not entirely unexpected; indeed, they re-emphasize the need for better quality assurance tests and parameters. The barrel density values are used as the primary measurement of density in this report because they are representative of the entire specimen. This methodology is consistent with a 1966 study by Kersten and Skok that compared the sand cone test to the nuclear density gauge (5). In addition, the barrel density is close to the average of the sand cone measurements in most cases.

3.2 Sample DN Results

One difficulty encountered during this study was that the first six specimens prepared using sample DN appeared to have significantly less strength than specimens prepared at similar moisture contents using samples FHJ and KLO. As will be shown in Sections 3.3 and 3.4, the DCP and LWD measured particularly small values of Young's modulus for these sample DN specimens. The gradation data in Figure 2.8 makes it clear that sample DN is a relatively well-graded and coarse-grained material in comparison to samples FHJ and KLO, and therefore would be expected to have a larger modulus than the other samples.

There were two primary causes for this discrepancy. The first was that four of the six DN specimens were prepared at a 10% moisture content, which was well past the optimum moisture content for sample DN (8.1%). Soils lose much of their strength above their optimum moisture content due to the onset of local pore pressures and grain lubrication. The same phenomenon was observed in samples FHJ and KLO during Tests 10 and 13, respectively.

The second cause was a loss of compactive energy resulting from the barrel rocking and deforming under the impact loading from the compaction hammer. This problem was noticed early in the test sequence, but was not completely corrected until the bottom of the barrel was cast in concrete prior to Test 6. Test 5 was conducted with a layer of sand underneath the barrel in the hopes that it would reduce the deformation of the bottom of the barrel. Despite this effort, the sand was expelled during the compaction process. These solutions are detailed in Section 2.1 of this report.

Tests 1 and 2 were repeated as Tests 23 and 24 following the casting of the barrel with much more reasonable results. Table 3.2 makes it clear that a larger specimen density was achieved using the new procedure. For the remainder of this report the data from Tests 1 through 6 will be considered unreliable.

3.3 Mechanistic DCP Data Interpretation

The DCP uses the impact force from a falling mass to drive a shaft with a conical point into a soil. Because each blow drives the shaft further into the soil, the rate at which the shaft penetrates the soil layer is a relative measurement of the soil's shear strength. The penetration distance is known as the DCP Penetration Index (DPI). This section of the report describes the relationship between material strength (DPI) and stiffness (Young's modulus).

A number of research groups have proposed several relationships between DPI and Young's modulus. Unfortunately, none of the proposed relationships have been widely accepted as a standard in the United States. CSIR Transportek, a South African research organization that has been instrumental in the development of DCP technology, derived one of the more rigorously tested equations. In the early 1990s, CSIR engineers used a variety of devices to make static and dynamic modulus measurements of a highly instrumented pavement section. These modulus values were correlated to DPI values, and the following relationship derived (6):

$$E = 10^{3.04758 - [1.06166 \log(DPI)]} \qquad [\#5]$$

where:
E = Young’s modulus (MPa)
DPI = DCP Penetration Index (mm/blow)

Table 3.3 DCP Modulus Data

Sample	Test	Test Parameters		Young's Modulus			
		Moisture Content (Percentage)	Barrel Density (kg/m^3)	A (MPa)	B (MPa)	C (MPa)	Average (MPa)
DN	23	5.05	1987	55.8	50.5	42.4	**49.6**
DN	1	5.10	N/A	34.2	30.5	35.3	**33.3**
DN	24	6.43	2043	44.9	46.7	47.1	**46.2**
DN	2	7.19	1951	31.6	30.8	33.3	**31.9**
DN	3	9.99	1999	-	-	-	**-**
DN	4	9.95	1976	-	-	-	**-**
DN	5	9.66	1985	-	-	-	**-**
DN	6	9.16	2076*	-	-	-	**-**
FHJ	7	7.76	1764	34.4	32.6	33.1	**33.4**
FHJ	21	7.46	1820	41.1	43.7	45.4	**43.4**
FHJ	18	7.98	1945*	39.8	41.9	44.3	**42.0**
FHJ	16	8.05	1839	46.5	43.1	46.9	**45.5**
FHJ	8	9.48	1791	36.7	34.5	33.8	**35.0**
FHJ	15	11.38	1773	26.0	24.0	23.8	**24.6**
FHJ	9	10.66	1802	34.9	33.0	35.5	**34.5**
FHJ	10	12.75	1790	-	-	-	**-**
KLO	11	7.05	1847	35.5	36.1	37.3	**36.3**
KLO	22	7.11	1937	46.8	41.0	53.0	**46.9**
KLO	17	8.06	1963	49.9	47.3	51.8	**49.7**
KLO	19	8.86	1882	30.0	35.2	34.4	**33.2**
KLO	12	8.94	1881	37.4	30.2	36.2	**34.6**
KLO	20	10.30	1916	29.1	27.4	33.5	**30.0**
KLO	14	10.51	1916	28.4	28.8	30.6	**29.3**
KLO	13	12.04	1869	-	-	-	**-**

[*] denotes a value that differed from the average sand cone density by more than 50 kg/m^3
[-] denotes a specimen that had too little shear resistance to withstand three drops following seating

Equation #5 makes it possible to estimate the modulus of any soil layer knowing only its average DPI value. In this study, DPI values were collected over the full depth of each specimen at three locations. A weighted average of these values was calculated with equation #9 (presented in Section 4.1). This average value was used to estimate Young’s modulus in equation #5. The results of this analysis appear in Table 3.3.

Samples FHJ and KLO produced results that were consistent with expectations. The modulus values measured for these samples were lowest near saturation. Individual specimens with large density values tended to have large modulus values, although there were exceptions. The relationships between these three important parameters (modulus, moisture content, and density) are summarized graphically for samples KLO and FHJ in Figures 3.1 and 3.2, respectively.

Figures 3.1 and 3.2 were created by graphing the data listed in Table 3.3 in three-dimensional space and using a universal kriging method to create a surface through the points. It can be seen that, at any given density, the DCP-estimated modulus decreases as the moisture content rises above the optimum moisture content. A similar relationship can be identified between the modulus and density. The modulus rises as the density increases at any given moisture content.

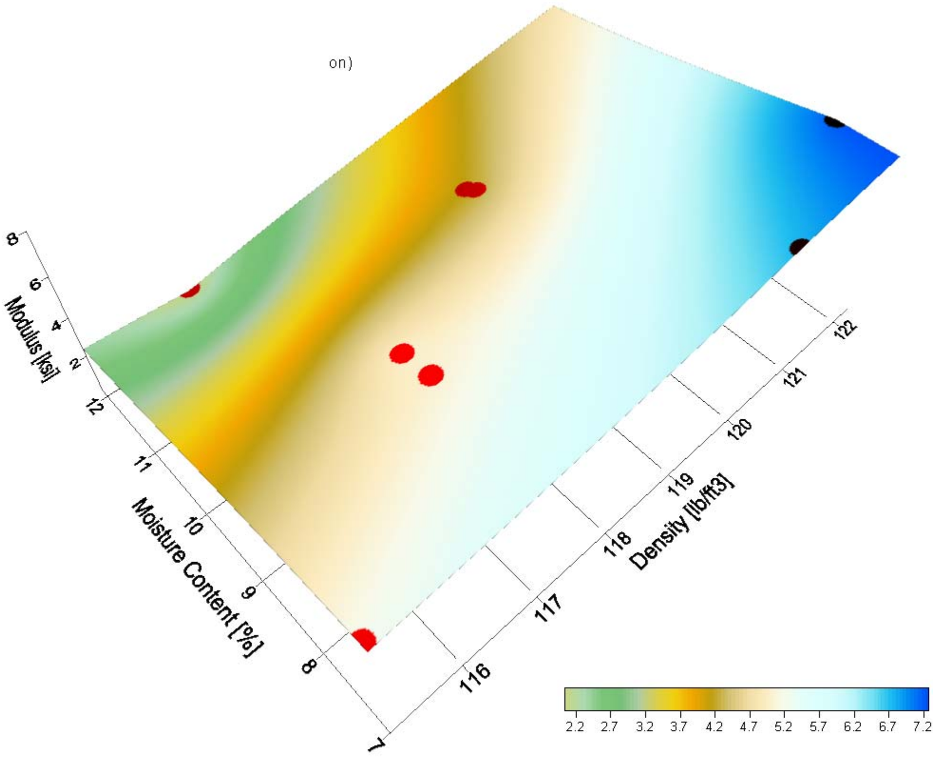


Figure 3.1 DCP-Estimated Modulus for Sample KLO

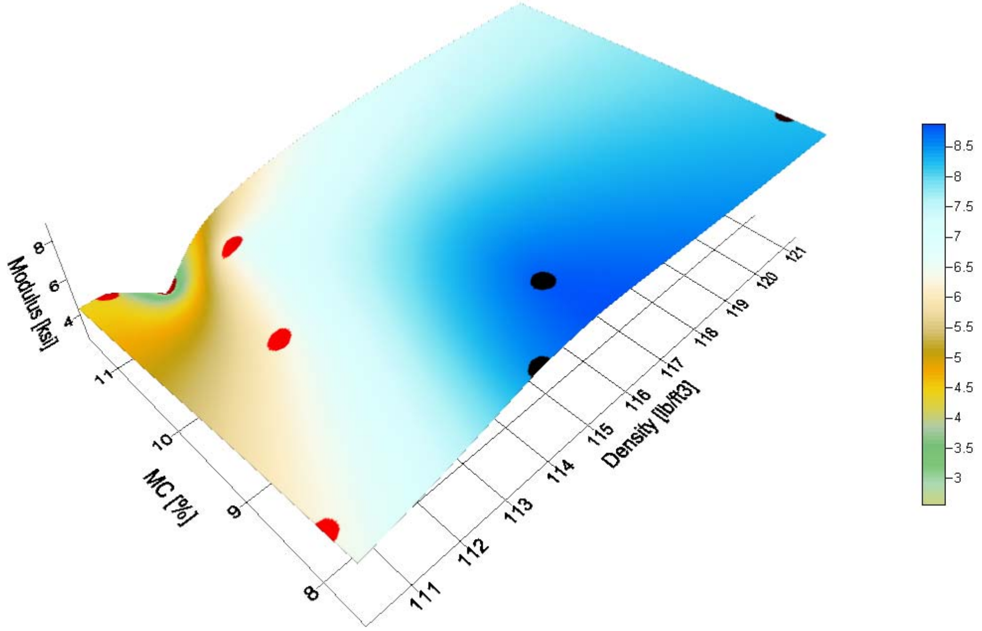


Figure 3.2 DCP-Estimated Modulus for Sample FHJ

One difficulty encountered during the DCP testing was that the DPI values reflected a significant increase in strength with depth. This is due to an increase in both compactive energy and confinement with increasing depth. Even though each lift was compacted using the same compactive effort, a portion of the energy produced when the compaction hammer fell on the upper lifts was transferred to the lower layers. Because this study made use of a larger than usual hammer, the hammer's area of influence extended deeper into the specimen. This resulted in a larger compactive effort for the lower layers and a smaller compactive effort for the upper layers.

To confirm that the specimen density increased with depth, sand cone tests were performed both at the surface and a point midway though the depth of each specimen following testing. These measurements confirmed that the bottom half of the specimen was denser than the surface by an average of 59 kg/m^3 (3.1%).

Lastly, it was possible that location or edge effects would be present within the DCP data due to non-uniform compaction, soil interaction with the specimen walls, and/or other factors. An observational analysis of the DCP data (Figure 3.3) shows what may be a small edge effect: the modulus values measured at locations A and C were, on average, 6.3% larger than the modulus values measured at location B. Fortunately, while this difference may represent a small edge effect, it is relatively negligible given the amount of variation inherent to soil testing.

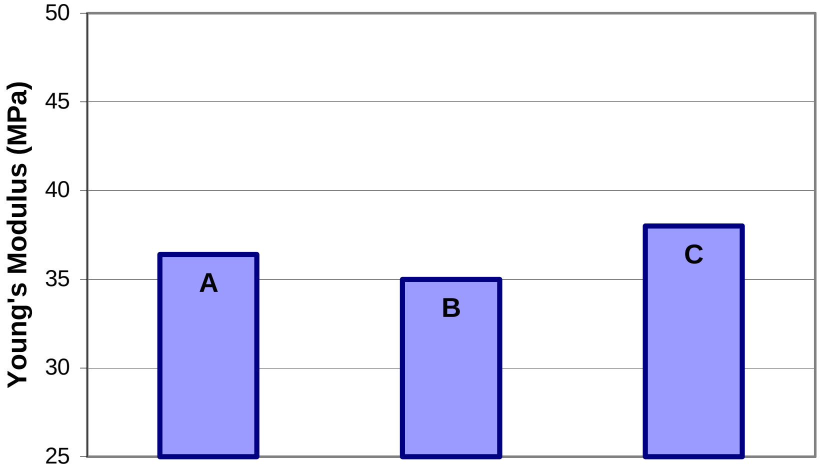


Figure 3.3 DCP Modulus Values versus Location

3.4 LWD Data Interpretation

As described in Chapter 2, the LWD uses the impact load of a falling mass to induce an elastic response from a compacted soil. A load cell mounted within the device's base measures the load beneath the rubber dampers, and a geophone resting on the soil underneath the device measures the soil displacement. These load and displacement quantities are transmitted to a hand-held data acquisition unit that saves their time-histories. The device's software identifies the peak displacement and force values from the time-histories and calculates a modulus value using the following equations:

$$\sigma = \frac{F}{1{,}000\pi r_p^2} \qquad [\#6]$$

where:
σ = peak stress applied to the soil (MPa)
F = peak force recorded by the load cell (kN)
r_p = radius of the plate in contact with the ground (0.1 m).

$$E = 2r_p\sigma(1-\upsilon^2)\frac{1{,}000{,}000D}{\Delta} \qquad [\#7]$$

where:
E = Young's modulus (MPa)
υ = Poisson's ratio for soil (0.35)
D = plate rigidity (0.79)
Δ = peak soil deflection (μm)

The test sequence for the LWD is modeled after the sequence used by Mn/DOT's trailer-mounted FWD unit, which is used to test pavement surfacing materials. This sequence consists of 11 drops: the mass is dropped twice from the lowest height for seating, and three tests are performed at each of three different drop heights. Unfortunately, this procedure may not be equally suited for both devices. The seating drops in the FWD's sequence are designed to make certain that its pad is in full contact with the pavement. The LWD's seating drops do the same, but they also compact loose surface soil to prevent it from interfering with the measurement. During this study it became clear that plastic compaction of the soil was occurring during the data drops, particularly following each increase in the drop height. As is shown in Figure 3.4, the measured modulus consistently increased from the first drop at a particular height to the last.

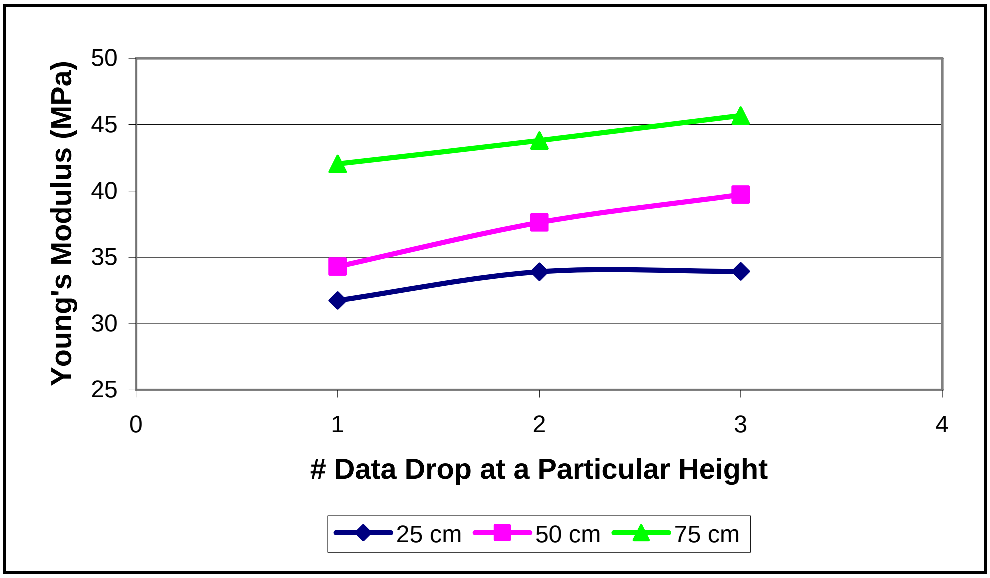


Figure 3.4 LWD Modulus Variation within Drop Sequence

The LWD data became increasingly repeatable as the soil surface beneath the instrument was compacted and the deformation became more elastic. Therefore, the data collected from the second and third drops was more significant than the data collected from the first drop. As a result, the LWD modulus values listed in this report are the average of the final two drops at each drop height. It is recommended that two or more seating drops be performed after each increase in drop height for future testing. Table 3.4 contains the LWD data collected during this study.

Table 3.4 LWD Data

Sample	Test	Test Parameters		Young's Modulus		
		Moisture Content (Percentage)	Barrel Density (kg/m^3)	25 cm (MPa)	50 cm (MPa)	75 cm (MPa)
DN	23	5.05	1987	39.6	45.1	51.7
DN	1	5.10	N/A	12.9	16.8	21.0
DN	24	6.43	2043	38.4	43.9	50.1
DN	2	7.19	1951	18.2	24.7	32.7
DN	3	9.99	1999	5.8	11.8	18.0
DN	4	9.95	1976	9.7	14.2	23.1
DN	5	9.66	1985	9.9	17.8	26.1
DN	6	9.16	2076*	8.0	13.6	19.1
FHJ	7	7.76	1764	58.6	57.7	60.2
FHJ	21	7.46	1820	46.0	48.7	55.9
FHJ	18	7.98	1945*	53.9	56.9	67.3
FHJ	16	8.05	1839	74.0	69.3	81.1
FHJ	8	9.48	1791	55.0	54.0	62.2
FHJ	15	11.38	1773	31.9	38.2	45.7
FHJ	9	10.66	1802	49.2	50.1	56.2
FHJ	10	12.75	1790	7.0	7.5	15.1
KLO	11	7.05	1847	37.6	44.3	49.8
KLO	22	7.11	1937	47.4	56.0	67.0
KLO	17	8.06	1963	58.6	64.3	68.9
KLO	19	8.86	1882	40.4	44.4	52.5
KLO	12	8.94	1881	44.0	51.3	58.2
KLO	20	10.30	1916	31.7	39.0	48.2
KLO	14	10.51	1916	26.0	32.2	42.2
KLO	13	12.04	1869	6.8	7.1	11.7

[*] denotes a value that differed from the average sand cone density by more than 50 kg/m^3

As shown in Figures 3.5 and 3.6, trends in the moduli calculated from the LWD data are similar to the trends in the DCP-estimated moduli. Samples FHJ and KLO saw declines in modulus above their optimum moisture contents. Both devices recorded an increase in modulus with density over the range being tested. Lastly, the calculated modulus values obtained from the lowest LWD drop height are similar to the estimated values obtained from the DCP.

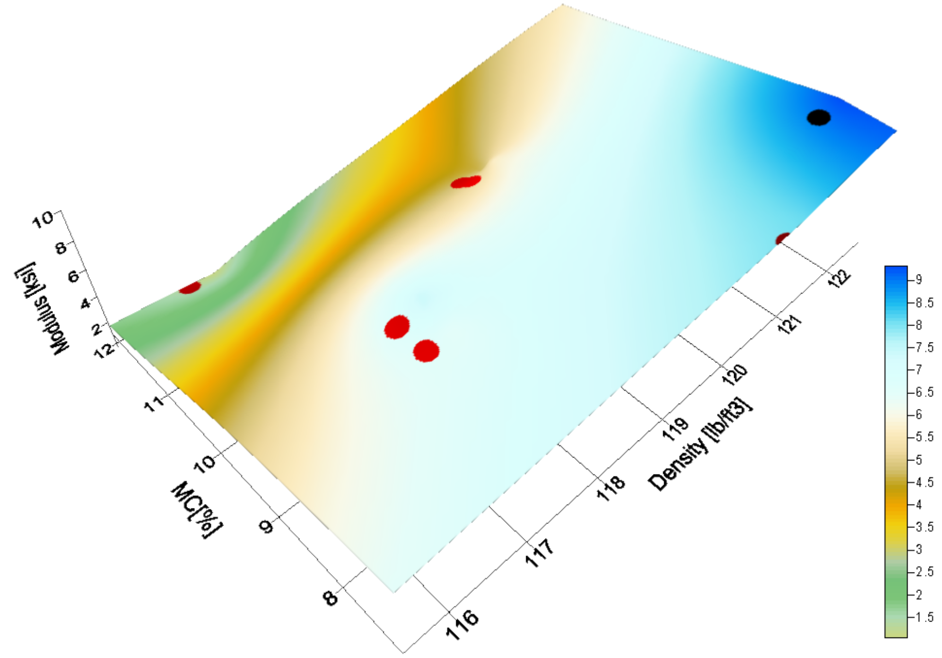


Figure 3.5 LWD Modulus for Sample KLO

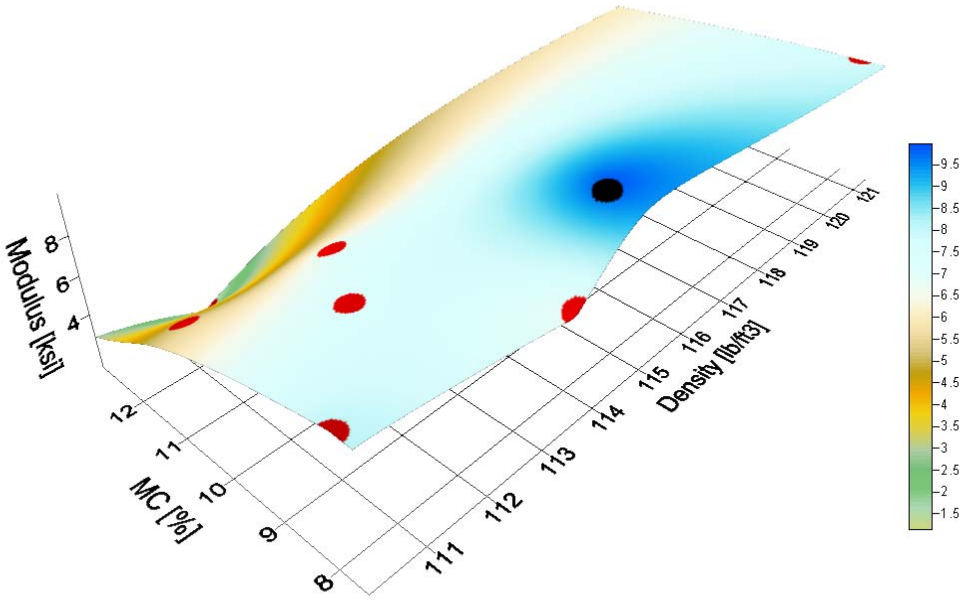


Figure 3.6 LWD Modulus for Sample FHJ

The data collected in this study enabled the creation of a trial quality assurance procedure for the LWD. The modulus data used in this procedure was taken from the 25 cm drop height. The target modulus values are based on the soil's moisture content and grading number (GN) in a manner similar to the 2004 modified DCP specification. Specimens with moisture contents larger than 10% were excluded from the procedure due to their unpredictability and rarity. Table 3.5 contains the results of this trial procedure.

Table 3.5 Trial LWD Quality Assurance Procedure

Sample	Test	Test Parameters			Target	LWD	P/F
		Barrel Density (kg/m^3)	Moisture Content (Percent)	Grading Number	Young's Modulus (MPa)	Young's Modulus (MPa)	
DN	23	1987	5.1	5.1	40	40	**PASS**
DN	1	N/A	5.1	5.1	40	13	**FAIL**
DN	24	2043	6.4	5.1	40	38	**FAIL**
DN	2	1951	7.2	5.1	40	18	**FAIL**
DN	3	2076*	9.2	5.1	36	6	**FAIL**
DN	4	1985	9.7	5.1	36	10	**FAIL**
DN	5	1976	10.0	5.1	High MC	10	**N/A**
DN	6	1999	10.0	5.1	High MC	8	**N/A**
FHJ	7	1820	7.5	6.1	35	59	**PASS**
FHJ	21	1764	7.8	6.1	35	46	**PASS**
FHJ	18	1945*	8.0	6.1	35	54	**PASS**
FHJ	16	1839	8.1	6.1	35	74	**PASS**
FHJ	8	1791	9.5	6.1	35	55	**PASS**
FHJ	15	1802	10.7	6.1	High MC	32	**N/A**
FHJ	9	1773	11.4	6.1	High MC	49	**N/A**
FHJ	10	1790	12.8	6.1	High MC	7	**N/A**
KLO	11	1847	7.1	5.4	40	38	**FAIL**
KLO	22	1937	7.1	5.4	40	47	**PASS**
KLO	17	1963	8.1	5.4	36	59	**PASS**
KLO	19	1881	8.9	5.4	36	40	**PASS**
KLO	12	1882	8.9	5.4	36	44	**PASS**
KLO	20	1916	10.3	5.4	High MC	32	**N/A**
KLO	14	1916	10.5	5.4	High MC	26	**N/A**
KLO	13	1869	12.0	5.4	High MC	7	**N/A**

[*] denotes a value that differed from the average sand cone density by more than 50 kg/m^3

3.5 Percometer Data Interpretation

The Percometer sends a small electric current through the surface of a soil layer (the uppermost 2 cm, approximately) to measure its conductivity and dielectric permittivity. The dielectric permittivity can be used to estimate a material's volumetric moisture content. Mn/DOT has found that these relationships provide a reasonable amount of accuracy so long as sufficient data exists for the soil type being tested.

In this study, the Percometer was used to estimate the moisture content of the specimens prior to the strength and stiffness measurements. In all, nine Percometer tests were performed on the surface of each specimen. These were aligned along the same diameter of the barrel as the DCP tests. Because two tests were replicates at locations between the DCP test points, there were seven unique test locations. (Figure 2.10 contains a chart of the test locations.) Table 3.6 contains averages of the dielectric permittivity values measured in this study.

Table 3.6 Percometer Results

Sample	Test	Test Parameters		Dielectric Permittivity			
		Moisture Content (Percentage)	Barrel Density (kg/m^3)	A (J)	B (J)	C (J)	Average (J)
DN	23	5.05	1987	6.2	6.2	6.0	**6.1**
DN	1	5.10	N/A	6.9	6.9	7.0	**6.9**
DN	24	6.43	2043	6.0	7.7	7.6	**7.1**
DN	2	7.19	1951	5.2	5.6	4.9	**5.2**
DN	3	9.16	2076*	10.9	10.2	10.2	**10.4**
DN	4	9.66	1985	12.0	11.0	11.3	**11.4**
DN	5	9.95	1976	8.5	8.7	7.8	**8.3**
DN	6	9.99	1999	9.5	8.6	10.6	**9.6**
FHJ	7	7.46	1820	9.9	9.5	9.5	**9.6**
FHJ	21	7.76	1764	8.2	6.8	8.7	**7.9**
FHJ	18	7.98	1945*	7.5	7.7	8.0	**7.7**
FHJ	16	8.05	1839	9.5	10.1	10.1	**9.9**
FHJ	8	9.48	1791	9.9	9.6	9.1	**9.5**
FHJ	15	10.66	1802	11.3	10.6	12.1	**11.3**
FHJ	9	11.38	1773	11.3	10.9	11.3	**11.2**
FHJ	10	12.75	1790	11.4	13.4	13.8	**12.9**
KLO	11	7.05	1847	8.5	8.3	8.9	**8.6**
KLO	22	7.11	1937	8.4	7.8	7.8	**8.0**
KLO	17	8.06	1963	9.1	9.2	9.5	**9.3**
KLO	19	8.86	1882	10.4	10.7	10.8	**10.6**
KLO	12	8.94	1881	9.9	9.5	10.1	**9.8**
KLO	20	10.30	1916	11.1	9.9	11.4	**10.8**
KLO	14	10.51	1916	9.2	9.7	9.8	**9.6**
KLO	13	12.04	1869	13.0	13.0	13.0	**13.0**

[*] denotes a value that differed from the average sand cone density by more than 50 kg/m^3

Using the mean of the three dielectric permittivity values at each test location, the following relationship between gravimetric moisture content and dielectric permittivity was derived:

$$\omega = 0.906\varepsilon - 0.247 \qquad [\#8]$$

where:
ω = gravimetric moisture content (%)
ε = dielectric permittivity (J)

It would have been possible for the metallic walls of the barrel to have an influence on the electrical measurements of the Percometer. If so, the effect was small: the dielectric values measured at locations A and C were, on average, 3% larger than the values measured at location B. This may represent a small edge effect, but when compared to the other sources of error in soil moisture testing (the coefficients of variation were approximately 20%) the edge effect is negligible.

Chapter 4
Modified DCP Specification Analysis

A primary goal of this study was to evaluate the DCP specification as written in the 2005 Mn/DOT Special Provision, which is included as Appendix E of this report. To accomplish this, the 2005 Mn/DOT DCP Special Provision was applied to the DCP data presented in Chapter 3. This chapter presents the specification results as well as an analysis of its performance.

4.1 Specification Data

The 2005 Special Provision calculates the target values based on moisture content and grading number (GN) values, where the grading number is defined as the sum of the percent passing values from the seven most common sieves divided by 100. In addition, the 2005 Special Provision requires the test layer to have at least a minimum thickness to ascertain that the cone does not pass through into other material.

As explained in Section 3.3, the specimens used in this study underwent an increase in density with depth. Therefore, the DCP-estimated modulus increased with depth as well. However, when the Special Provision is applied to the specimen, the results are applicable only to the upper lifts. In order to make the DCP results comparable to the compactive effort, density, and LWD measurements (all of which consider the specimen as a whole), a weighted DPI value that accounts for the measurement length was calculated using equation #9.

$$DPI_W = \frac{\sum_{2}^{n}\left(DPI_i * L_i\right)}{\sum_{2}^{n}\left(L_i\right)} \qquad [\#9]$$

where:
DPI_W = weighted average DPI value (mm/blow)
DPI_i = DPI value measured during the ith blow (mm/blow)
L_i = penetration distance recorded during the ith blow (mm)

In order to weight the top lift appropriately, only one seating DPI value was excluded from this calculation. DPI_W and the average DPI values from the Special Provision are presented in Tables 4.1 through 4.3 by location (A, B, and C).

Table 4.1 Special Provision Results from Point A

Sample	Test	Test Parameters			Target		Measured			P/F
		Barrel Density (kg/m^3)	Moisture Content (Percent)	Grading Number	2-blow SEAT (mm)	3-blow DPI (mm/blow)	2-blow SEAT (mm)	3-blow DPI (mm/blow)	Weighted DPI (mm/blow)	2005
DN	23	1987	5.1	5.1	85	17	91	19	17	**FAIL**
DN	1	N/A	5.1	5.1	95	21	114	25	27	**FAIL**
DN	24	2043	6.4	5.1	95	21	99	21	21	**FAIL**
DN	2	1951	7.2	5.1	95	21	114	26	29	**FAIL**
DN	3	2076*	9.2	5.1	105	25	165	-	-	**FAIL**
DN	4	1985	9.7	5.1	105	25	176	-	-	**FAIL**
DN	5	1976	10.0	5.1	105	25	184	-	-	**FAIL**
DN	6	1999	10.0	5.1	105	25	218	-	-	**FAIL**
FHJ	7	1820	7.5	6.1	115	24	121	23	22	**FAIL**
FHJ	21	1764	7.8	6.1	115	24	132	26	27	**FAIL**
FHJ	18	1945*	8.0	6.1	115	24	120	23	23	**FAIL**
FHJ	16	1839	8.1	6.1	115	24	98	19	20	**PASS**
FHJ	8	1791	9.5	6.1	125	28	114	25	25	**PASS**
FHJ	15	1802	10.7	6.1	125	28	125	27	26	**PASS**
FHJ	9	1773	11.4	6.1	125	28	133	33	35	**FAIL**
FHJ	10	1790	12.8	6.1	125	28	212	-	-	**FAIL**
KLO	11	1847	7.1	5.4	95	21	124	26	26	**FAIL**
KLO	22	1937	7.1	5.4	95	21	105	19	20	**FAIL**
KLO	17	1963	8.1	5.4	95	21	100	20	19	**FAIL**
KLO	19	1881	8.9	5.4	105	25	127	23	25	**FAIL**
KLO	12	1882	8.9	5.4	105	25	129	29	30	**FAIL**
KLO	20	1916	10.3	5.4	105	25	122	29	31	**FAIL**
KLO	14	1916	10.5	5.4	105	25	121	29	32	**FAIL**
KLO	13	1869	12.0	5.4	105	25	187	-	-	**FAIL**

[*] denotes a value that differed from the average sand cone density by more than 50 kg/m^3

[-] denotes a specimen that had too little shear resistance to withstand three drops following seating

Table 4.2 Special Provision Results from Point B

Sample	Test	Test Parameters			Target		Measured			P/F
		Barrel Density (kg/m^3)	Moisture Content (Percent)	Grading Number	2-blow SEAT (mm)	3-blow DPI (mm/blow)	2-blow SEAT (mm)	3-blow DPI (mm/blow)	Weighted DPI (mm/blow)	2005
DN	23	1987	5.1	5.1	95	21	101	20	18	**FAIL**
DN	1	N/A	5.1	5.1	95	21	123	29	30	**FAIL**
DN	24	2043	6.4	5.1	95	21	106	21	20	**FAIL**
DN	2	1951	7.2	5.1	95	21	111	28	29	**FAIL**
DN	3	2076*	9.2	5.1	105	25	174	-	-	**FAIL**
DN	4	1985	9.7	5.1	105	25	171	-	-	**FAIL**
DN	5	1976	10.0	5.1	105	25	184	-	-	**FAIL**
DN	6	1999	10.0	5.1	105	25	191	-	-	**FAIL**
FHJ	7	1820	7.5	6.1	115	24	120	23	21	**FAIL**
FHJ	21	1764	7.8	6.1	115	24	139	26	28	**FAIL**
FHJ	18	1945*	8.0	6.1	115	24	127	22	22	**FAIL**
FHJ	16	1839	8.1	6.1	125	28	121	21	21	**PASS**
FHJ	8	1791	9.5	6.1	125	28	121	27	26	**PASS**
FHJ	15	1802	10.7	6.1	125	28	125	25	28	**PASS**
FHJ	9	1773	11.4	6.1	125	28	139	33	37	**FAIL**
FHJ	10	1790	12.8	6.1	125	28	199	-	-	**FAIL**
KLO	11	1847	7.1	5.4	95	21	135	24	25	**FAIL**
KLO	22	1937	7.1	5.4	95	21	101	21	23	**FAIL**
KLO	17	1963	8.1	5.4	105	25	102	21	20	**PASS**
KLO	19	1881	8.9	5.4	105	25	130	23	30	**FAIL**
KLO	12	1882	8.9	5.4	105	25	124	25	26	**FAIL**
KLO	20	1916	10.3	5.4	105	25	127	30	33	**FAIL**
KLO	14	1916	10.5	5.4	105	25	121	29	31	**FAIL**
KLO	13	1869	12.0	5.4	105	25	154	-	-	**FAIL**

[*] denotes a value that differed from the average sand cone density by more than 50 kg/m^3

[-] denotes a specimen that had too little shear resistance to withstand three drops following seating

Table 4.3 Special Provision Results from Point C

Sample	Test	Test Parameters			Target		Measured			P/F
		Barrel Density (kg/m^3)	Moisture Content (Percent)	Grading Number	2-blow SEAT (mm)	3-blow DPI (mm/blow)	2-blow SEAT (mm)	3-blow DPI (mm/blow)	Weighted DPI (mm/blow)	2005
DN	23	1987	5.1	5.1	95	21	98	20	22	FAIL
DN	1	N/A	5.1	5.1	95	21	124	23	26	FAIL
DN	24	2043	6.4	5.1	95	21	106	20	20	FAIL
DN	2	1951	7.2	5.1	95	21	116	25	27	FAIL
DN	3	2076*	9.2	5.1	105	25	166	-	-	FAIL
DN	4	1985	9.7	5.1	105	25	178	-	-	FAIL
DN	5	1976	10.0	5.1	105	25	183	-	-	FAIL
DN	6	1999	10.0	5.1	105	25	193	-	-	FAIL
FHJ	7	1820	7.5	6.1	115	24	115	21	20	PASS
FHJ	21	1764	7.8	6.1	125	28	132	25	27	FAIL
FHJ	18	1945*	8.0	6.1	115	24	119	22	21	FAIL
FHJ	16	1839	8.1	6.1	115	24	115	21	20	PASS
FHJ	8	1791	9.5	6.1	125	28	121	26	27	PASS
FHJ	15	1802	10.7	6.1	125	28	113	25	26	PASS
FHJ	9	1773	11.4	6.1	125	28	138	33	38	FAIL
FHJ	10	1790	12.8	6.1	125	28	190	-	-	FAIL
KLO	11	1847	7.1	5.4	95	21	125	23	25	FAIL
KLO	22	1937	7.1	5.4	95	21	94	20	18	PASS
KLO	17	1963	8.1	5.4	95	21	100	19	18	FAIL
KLO	19	1881	8.9	5.4	105	25	128	23	25	FAIL
KLO	12	1882	8.9	5.4	105	25	137	25	27	FAIL
KLO	20	1916	10.3	5.4	105	25	117	27	27	FAIL
KLO	14	1916	10.5	5.4	105	25	109	27	30	FAIL
KLO	13	1869	12.0	5.4	105	25	153	-	-	FAIL

[*] denotes a value that differed from the average sand cone density by more than 50 kg/m^3

[-] denotes a specimen that had too little shear resistance to withstand three drops following seating

The results from each location are similar in most respects. The target SEAT and DPI values are almost identical from location to location, and the measured SEAT and DPI values have standard deviations of 6.1 and 1.2 (4.4% and 4.8%), respectively. However, several specimens that produced values near the acceptable limits wavered between passing and failing at the different locations. In what appears to be a random fluctuation, 5 of 24 specimens passed the Special Provision at location C, while only 3 and 4 passed at locations A and B, respectively.

It should be pointed out that the first six tests performed on sample DN occurred before the barrel was cast in concrete. As a result, the system appeared to lose a significant amount of compactive energy. Section 3.2 explains in detail the results from sample DN. Tables 4.1 through 4.3 make it clear that the final two tests on sample DN, Tests 23 and 24, produced reasonable results.

4.2 Grading Number Effects

The grading number (GN), as explained in earlier sections of this report, is a representation of a soil's gradation properties. Soils with large GN values have relatively large amounts of fine sand particles; soils with small GN values have larger amounts of aggregate and coarse sand. Soils composed primarily of gravel and coarse sand usually have larger strength and modulus values than soils with large amounts of fine sand. Therefore, strength and modulus values calculated from DCP and LWD data would be expected to increase as GN decreases.

A perfectly mechanistic design procedure would allow a pavement design engineer to specify an acceptable design soil modulus. In this idealized system, most soils would be acceptable so long as the contractor could compact them to the specified design modulus. During current construction practice, contractors and inspectors identify soil sources that are acceptable through gradation tests and experience. The specified density method is then used to make certain that the soil is compacted to a relative "maximum" value. To remain consistent with this pre-existing constructive standard, the DCP specification was modified to include GN as an input. In this way, a soil with a larger GN remains acceptable even though it may have a lower modulus.

The results presented in Section 4.1 indicate that the GN chart proposed by the Special Provision is too limiting for sandy soils. Samples DN, FHJ, and KLO were all prepared using the standard Proctor compactive effort. However, the specimens prepared using sample FHJ were much more likely to pass the Special Provision (10 of the 12 passing DCP tests were performed on sample FHJ specimens) despite similar DPI and modulus values. This discrepancy is partially explained by the fact that sample FHJ has a larger GN value. Therefore, the requirements placed upon it were less strict. This is particularly true of the seating value requirements. A discussion of these requirements is included in Section 4.4.

4.3 Moisture Content Effects

The stiffness properties of soils are highly affected by their moisture content. Soils with large moisture contents deform much more easily under loading than those with small moisture contents. In effect, the water molecules lubricate the soil grains so that they slide past each other more easily. As a result, soils with large moisture contents may appear to have poor stiffness characteristics even after being compacted with a sufficient amount of energy.

The Special Provision allows the SEAT and DPI targets to vary so that larger penetration values are acceptable at larger moisture contents. However, it appears that otherwise acceptable soils have trouble meeting the specification at high moisture contents. Moisture contents this large are relatively rare in the field and many soils (such as DN) lose significant amounts of strength and stiffness in this range. The specification should cover the largest range possible, but only up to a moisture content 1% to 2% below a soil's optimum standard Proctor moisture content.

In addition, it appeared that some specimens had trouble meeting the requirements of the specification at low moisture contents. However, Tests 1 and 2 were carried out without the concrete cast and, as mentioned in Section 4.1, Tests 23 and 24 prove that these low moisture content specimens should pass. The specimen in Test 11 was compacted to 99.1% of the standard Proctor maximum density, so its failure is reasonable. The specimen in Test 7 would have barely passed the specified density method at 100.6% of Proctor; however, it was close enough to the line that its failure was reasonable. With the exception of some seating failures, which will be covered in Section 4.4, the Special Provision appeared to treat the low moisture content specimens correctly.

4.4 Seating Drop Requirements

Seating drops are necessary for soil test devices that utilize falling weights to make certain that thin, loose, or irregular material on the surface does not unduly affect the measurements. In most cases, the seating data is discarded due to the unpredictable nature of soil surfaces. However, Mn/DOT's DCP Special Provision, require the measurement of the depth of penetration experienced during seating. The intention of this measurement is to determine whether the aggregate base layer has sufficient surface strength to allow construction equipment, such as a paver, to operate on its surface without significant rutting.

The 1997 DCP specification, which was only applicable to aggregate base layers, requires inspectors to abort the DCP test if the seating requirements are not met. In practice, the seating drop results can prevent the primary compaction quality control from occurring. This may be desirable when an aggregate base material is being placed because a base layer with a loose surface will require the addition of moisture or additional compaction regardless of the compaction quality results. However, subbase materials, such as those used in this study, are covered by an additional layer of compacted material and are not required to support paving equipment. Therefore, select granular materials should not be subjected to DCP seating requirements.

The report by Oman provides data that emphasizes the need to remove the seating requirement from subbase materials (1). The seating criteria resulted in a large number of failures for select granular materials with a GN greater than 5. Figure 3 of Oman's report displays the data and linear trendline used to establish the target seating penetration; it can be seen that the displayed trendline is a relatively poor fit for the data with a GN larger than 5.

During Investigation 829, it was found that the seating requirements were far more difficult to satisfy than the deeper DPI requirements. Thirty-two specimens met the DPI requirements, while only 12 of these passed the seating requirements. It is likely that some of the seating failures are attributable to the compaction method. As explained in Section 3.3, the soil specimens used in this study increased in strength and density with depth. Therefore, the surface of the specimen was compacted to a density less than the value in the test matrix (Table 3.1). In addition, the specimen experienced some natural surface looseness due to a lack of confinement. Lastly, hammer compaction over a large area has the capability to result in a more uneven surface density than other compaction methods.

4.5 DPI Value Requirements

Thirty-two of 72 DCP measurements met the DPI requirements for the select granular borrow samples used during this study. Of those that failed, 18 were on specimens prepared without the concrete cast and 15 others were prepared at or above a 10% moisture content. The remaining failures appeared to be the result of either large moisture contents or, in the cases of Tests 7 and 11, inadequate compaction. Therefore, the Special Provision DPI requirements appear to be adequate for the select granular materials used in this study with the exception of high moisture contents. As recommended in Section 4.3, the Special Provision should only be applied to select granular borrow materials at moisture contents 1% to 2% below their optimum moisture content.

4.6 Test Layer Thickness Requirements

The final components of the 2005 DCP Special Provisions are “test layer” requirements designed to make certain that the DCP cone does not pass through the layer being tested (the most recent lift) until after the fifth blow. The Special Provision requires that the test layer must be thicker than a “minimum test layer” that varies with GN.

The Special Provision worksheet, which is contained as Appendix E, contains an additional check to make certain that the test does not proceed past the desired test layer. The inspector enters the known test layer depth into the worksheet and a built-in equation makes certain that the five DCP penetration values are smaller than the layer depth.

In this study, the DCP tests that passed through the minimum test layer by the end of the fifth blow were failing tests without exception. Furthermore, the identified “minimum test layers” are set at such a level that a passing test cannot pass through them. Therefore, the 2005 Special Provision minimum test layer ranges are acceptable.

Chapter 5
Conclusions and Recommendations

Based on the findings presented, this study reaches the following conclusions and recommendations:

1) The DCP specification should not be limited to three DPI drops. One of the primary advantages of the DCP is its ability to monitor changes in soil strength with depth. The DCP has the ability to verify compaction quality from the top to the bottom of a lift if a sufficient number of blows are used. In fact, the Iowa Department of Transportation uses the DCP to ascertain that there is no significant change in strength from one lift to the next. To remain within the framework of the DCP Special Provision, it is recommended that the DPI blows continue until the cone passes through a layer equal to the "minimum test layer". The obtained DPI values could be entered directly into the "DPI" column on the spreadsheet. The small increase in inspector effort would be more than offset by the quality of the collected data. Furthermore, inspectors would gain a better understanding of the DPI values' relevance by viewing their variation through a lift. This, in turn, would allow them to quickly identify questionable results and give the inspectors a tool to pursue their own investigations when more information is needed.

2) The seating requirement serves no purpose for a subbase layer and should not be included in the specification for select granular materials. The requirement may be useful for determining the suitability of an aggregate base surface for paving equipment loading.

3) The acceptable range of moisture contents during DCP testing should be capped at 10%. It would be advisable to utilize three different ranges: less than 5%, between 5% and 7.5%, and between 7.5% and 10%. The current DPI targets are acceptable for these new ranges.

4) A sufficient amount of data exists to create a trial specification for LWD compaction quality control and assurance. The values of Young's modulus calculated by the device currently provide a level of accuracy similar to DCP testing. This accuracy is likely to improve as new FFT analysis software becomes available. One advantage of the LWD is that it directly measures quantities, such as force and displacement, that comprise pavement loading. Additionally, it is non-destructive and requires less inspector effort than DCP testing.

5) To obtain consistent and meaningful data from an LWD, it is necessary to standardize the falling mass drop height and plate size. Among the LWD devices used by Mn/DOT, the falling mass varies from 10 to 20 kg, the drop height varies from 0 to 90 cm, and the plate diameter varies from 10 to 30 cm. It would be desirable to choose a combination of dimensions that results in the test volume extending to the bottom of a common lift. To achieve this objective and remain consistent with existing LWD data, a mass of 10 kg, drop height of 50 cm, and plate diameter of 20 cm are recommended.

6) It was apparent that more seating drops were necessary to produce consistent LWD data. It is recommended that the LWD specification make use of three seating drops followed by three data drops at each new height.

References

1. Oman, M. 2004. *Advancement of Grading and Base Material Testing*. Office of Materials, Minnesota Department of Transportation, Maplewood.

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3. Hoffmann, O. et. al. 2003. *Enhancements and Verification Tests for Portable Deflectometers*. Mn/DOT Report 2003-10. Minnesota Department of Transportation, St. Paul.

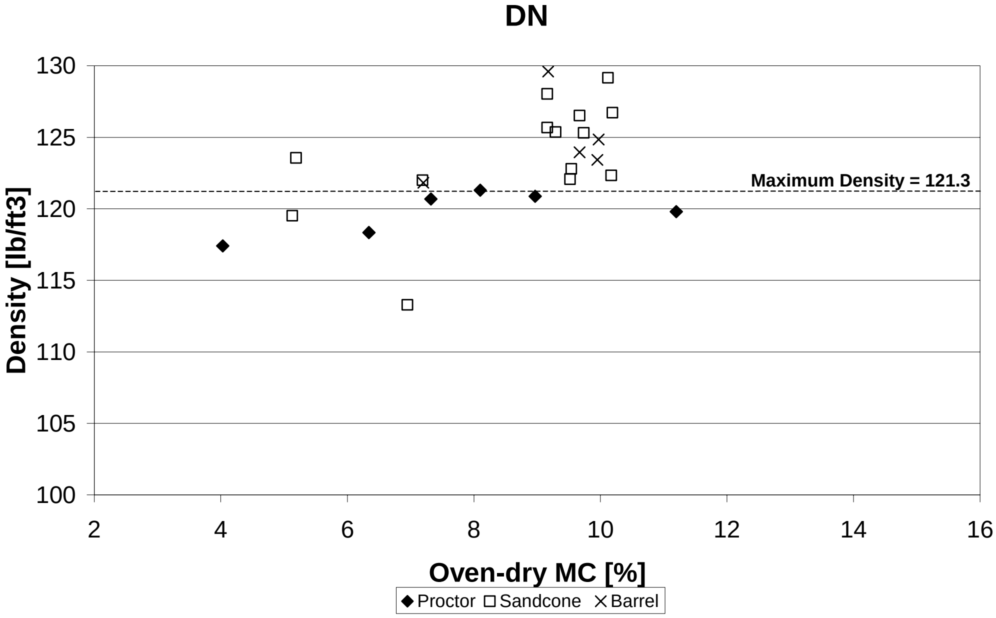
4. Davich, P. et. al. 2004. *Small Strain and Resilient Modulus Testing of Granular Soils*. Mn/DOT Report 2004-39. Minnesota Department of Transportation, St. Paul.

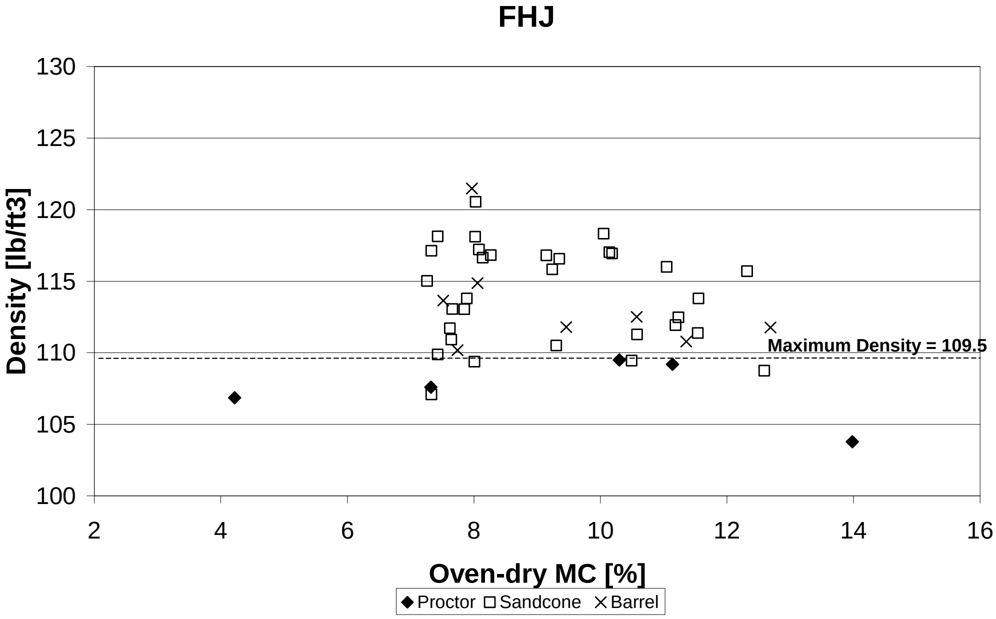
5. Kersten, M. and E. Skok, Jr. 1966. *Evaluation of Nuclear Moisture and Density Gages*. Investigation 622. Minnesota Department of Transportation, St. Paul.

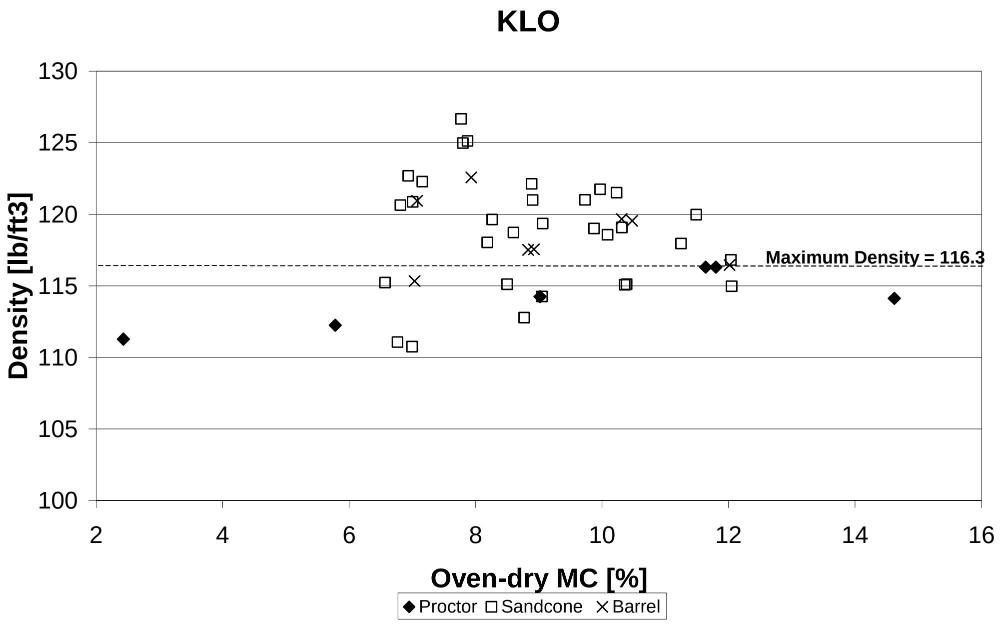
6. Lockwood, D. et. al. 2000. *Analysis and Classification of DCP Survey Data; Windows Version*. Technology & Information Management Programme, CSIR Transportek, Pretoria, South Africa.

Appendix A

Sample Proctors


DN
Density [lb/ft3]
130
125
120
115
110
105
100
2
4
6
8
10
12
14
16
Oven-dry MC [%]
Maximum Density = 121.3
◆ Proctor □ Sandcone × Barrel


FHJ
Density [lb/ft3]
130
125
120
115
110
105
100
2
4
6
8
10
12
14
16
Oven-dry MC [%]
Maximum Density = 109.5
◆ Proctor □ Sandcone × Barrel


KLO
Density [lb/ft3]
130
125
120
115
110
105
100
2
4
6
8
10
12
14
16
Oven-dry MC [%]
Maximum Density = 116.3
◆ Proctor
□ Sandcone
× Barrel

Appendix B

Drum Testing Procedure

Sample Preparation

Mixing

Materials:

- 450-500 lbs of soil
- Shovels
- Eight 5-gallon buckets with lids
- Scale
- Sample bag
- Oven
- 4 tin cups

Procedure:

1. Determine soil samples to be mixed in order to attain the desired gradation.

2. Combine the soils according to the Minnesota Grading and Base Manual procedures for mixing such that enough sample is attained (approximately 450-500 lbs).

3. Record the weight of the buckets, including their respective lids, in which the sample will be stored.

4. Place soil in the buckets and a bag. Send the bag to the Soils Lab for gradation and standard proctor testing.

5. Take 4 samples of soil from random buckets. Determine the oven-dry moisture content of each sample in compliance with ASTM D 2216-98.

6. Place lids on the buckets to prevent moisture loss.

7. Weigh the filled buckets and record.

Adding Water

Materials:

Same as above.

Procedure:

1. Calculate by weight the total amount of water needed to achieve the desired moisture content. Make sure initial average moisture content calculated previously is included in calculations.

2. Empty the buckets onto a clean concrete floor suitable for mixing.

3. Spread the soil out into a lift so that it is no greater then 4” in thickness.

4. Sprinkle one third of the water uniformly over the lift.

5. Use shovels to turn the soil.

6. Repeat steps 4-5 until no more water is left.

7. Turn soil as much as needed in order to ensure uniformity.

8. Place soil back in the buckets.

9. Take 4 samples of soil from random buckets. Determine the oven-dry moisture content of each sample in compliance with the ASTM D 2216-98 standard.

10. Place lids on the buckets to prevent moisture losses.

11. Weigh the filled buckets and record.

12. Allow soil to sit in the buckets overnight.

Volume Determination of Drum

Materials:

- Bottom half of a 55-gallon drum
- Water
- Tape measurer
- Heavy duty scale (approximately 200 lb capacity)

Procedure:

1. Measure 13.5” from the bottom of the container and mark the inside of the 55-gallon drum at three different locations.

2. Place the empty drum on a scale and zero the scale.

3. Fill the drum with water to the 13.5” marks and record the weight.

4. Determine the volume capacity of the drum assuming the density of water to be 62.4 lb/ft^3.

Preparing the Drum

Materials:

- Buckets containing prepared soil
- Drum
- 51-lbf hammer with a drop height of 33.25”
- Leveling tool (scraping blade)
- Tape measurer
- Scale

Procedure:

1. Check the previously collected moisture samples to see that the average moisture content is within half a percent of the targeted moisture content.

2. Estimate the weight of soil needed to fill the drum to a height of 13.5” from the maximum dry density.

3. Pour one third of soil in the drum and evenly distribute it across the area of the drum.

4. Compact the lift using the 51-lbf hammer dropped from a height of 33.25” producing a compactive effort of 4133.3 lbf-ft/ft^3 (200 kNm/m^3) according to ASTM D698.

5. Repeat steps 3-4 until all three lifts have been compacted.

6. Using a scraping blade remove the top 1-2” layer of the soil. Carefully remove the soil and place it in an empty bucket. This material MUST be weighed for barrel density determination.

7. With the soil surface now leveled, measure the height from the soil to the top of the barrel rim. Take six height readings and record the average height.

Barrel Testing

The locations of the tests are illustrated in Figure 1.

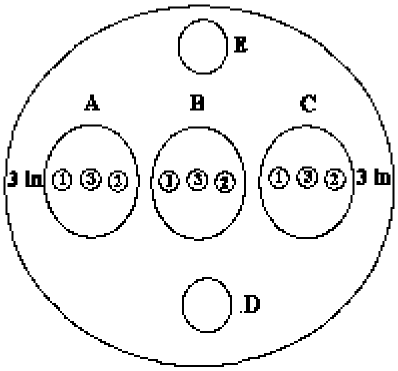


Figure 1. Barrel Testing Locations

Percometer Testing

1. Validate Percometer by taking readings on the validation blocks. It is important to note that the readings are affected when running the instrument on low battery.

2. Set Percometer to mode 4.

3. Mark locations A, B, and C as shown in figure 1.

4. Start testing at location A1. Place Percometer probe onto surface of soil. Press firmly on the probe with the approximate dead weight of one's hand.

5. Take two additional readings as shown by the pattern in Figure 1. Record both E and J values. It is possible that the locations will overlap slightly.

6. If dielectric (E) readings vary by more than 10% additional readings should be taken (i.e., an initial reading of 10.0 J with subsequent readings +/- 1.0 J).

7. Repeat steps 5-6 at locations B and C.

LWD Testing

1. Gently place the Prima 100 LWD at location B. Visually check that the metal guide rod is plumb.

2. On the iPAQ Pocket PC, go to the “Bluetooth Manager” and select the “KP100 Transmitter”.

3. Open the “KP100” program and create a file for the data set.

4. Connect to the Prima 100 in the menu of the “KP100” program. Make sure that the green light on the transmitter is flashing before beginning tests.

5. Set the drop mechanism to a height of 25 cm.

6. Slowly pull the 10 kg weight and lock it into the mechanism.

7. Drop the weight by pressing the lever and safety button. Wait for the Pocket PC to beep twice to verify that the data has been collected.

8. Complete four additional drops at the 25cm drop height. Record the first two as seating drops and the last three as actual readings.

9. Raise the drop height an additional 25cm and conduct three tests.

10. Repeat step 9.

11. Gently lift the Prima 100 from the barrel, taking care not to create a large dent on the surface.

DCP Testing

1. Remove the dynamic cone penetrometer (DCP) from the carrying case and assemble by screwing the two portions together.

2. Tighten the DCP tip to the lower half of the apparatus to maintain a strong connection during the test. This has been known to loosen as it is used. Hold the DCP vertically at location A3, shown in Figure 1.

3. Record the initial reading on the measuring stick following cone seating instructions in ASTM D 6951-03. Lift the hammer to the handle at the top of the DCP.

4. Drop and record the depth of the drive by reading the displacement from the measuring scale.

5. Repeat step 4 until the bottom of the drum has been reached. Disregard the final reading.

6. Remove the DCP from the location by pulling it upwards and repeat steps 2-4 at locations B3 and C3.

7. Clean the DCP and place it back into the case.

Sandcone Testing

1. Perform two sandcone tests in compliance with ASTM D1556-00 using a small cone for location D and a large cone for location E.

2. Remove a sufficient amount of soil from the drum, so that no holes from the top layer sandcone testing are present.

3. Level the surface.

4. Repeat step 1.

Appendix C

Percometer and Trident Testing Procedure

Sample Preparation

Materials:

- Concrete cylinder (approx. 6” in diameter and 12” tall), preferably clear, marked at half-inch increments so that material depth can be estimated accurately.
- Spoon or preferred mixing tool
- Large metal pan (approx. 24”x12”)
- Scale
- Measuring cup
- Tin cups for oven drying

Procedure:

1. Oven dry soil sample in accordance with ASTM D 2216-98.

2. Fill concrete cylinder with oven dried material. (Depending on the number of tests being run, additional material may be required as some material is lost from each oven-dry moisture test taken.)

3. Determine soil weight and calculate amount of water to achieve the lowest moisture content for the desired range of moistures. (Usually a range of +/- 5% optimum standard Proctor moisture works best, testing at 1% increments.)

4. Spread oven dried sample onto metal pan.

5. Sprinkle water over sample, mixing thoroughly until soil sample appears uniform.

6. Fill concrete cylinder to a depth of about 10”.

7. Weigh the cylinder and record for later determination of density.

8. Place lid on cylinder and roll the container on its side to loosen the material.

9. Drop container once from approximately 6” onto a level surface. It may be necessary to guide the container with your hands to ensure that the bottom impacts uniformly.

10. Gently smooth the surface of the soil being careful not to compact it. Record the height. If the height of the material is not at least 9” add more soil and repeat steps 7, 8, and 9.

11. Run Tests (explained below in greater detail)

12. Repeat steps 4-11 for the next moisture step.

Testing

Percometer Testing

Procedure:

1. Validate Percometer by taking readings on the validation blocks. It is important to note that the readings are affected when running the instrument on low battery.
2. Set Percometer to mode 4.
3. Place Percometer probe onto surface of soil. Press firmly on the probe with the approximate dead weight of one's hand.
4. Take three readings as shown by the pattern in Figure 1. Record both E and J values. It is possible that the locations will overlap slightly.

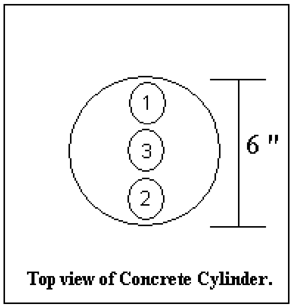


Figure 1. Percometer Test Locations

5. If dielectric (E) readings vary by more than 10% additional readings should be taken (i.e., an initial reading of 10.0 J with subsequent readings +/- 1.0 J).

Trident T90 Testing

Calibration:

1. Place probe into the sample. Make sure not to leave any air voids between the sample and probe. Press firmly on the probe with the approximate dead weight of one's hand.
2. Take five readings in succession at different locations. Avoid overlapping locations as much as possible.
3. Record the direct reading for each location.

4. Obtain oven-dry moisture content at each increment for later analysis.

5. Repeat steps 1-3 at each moisture content within the range of +/– 5% of optimum standard proctor moisture.

6. Plot the direct reading vs. oven-dry moisture and obtain the linear fit of the data.

7. Select desired user program, which ranges from 0-9, from the Ch. User. Mat. menu option.

8. Enter the y-intercept of fit equation into the Offset option by using the + or – keys.

9. Enter the slope of fit equation into the Gain option by using the + or – keys.

10. Press enter and the selected user program is ready for testing.

Testing:

1. Select the user program that was previously determined for the sample to be tested.

2. Place probe into the sample. Make sure not to leave any air voids between the sample and probe. Press firmly on the probe with the approximate dead weight of one’s hand.

3. Take five readings in succession at different locations. Avoid overlapping locations as much as possible.

4. Record moisture content reading at location.

Appendix D

Individual Specimen Results

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
DN5	3.82	1.32	5.14	A	Initial							90										
DN5	3.82	1.32	5.14	A	S1							169	79		10.8							
DN5	3.82	1.32	5.14	A	S2							204	35		25.6							
DN5	3.82	1.32	5.14	A	1	6.9	17					231	27	47.0	33.7							5.37
DN5	3.82	1.32	5.14	A	2	6.9	17					255	24	28.7	38.2							5.17
DN5	3.82	1.32	5.14	A	3	6.8	21					278	23	24.7	40.0							4.42
DN5	3.82	1.32	5.14	A	4							302	24	23.7	38.2							
DN5	3.82	1.32	5.14	A	5							324	22	23.0	41.9							
DN5	3.82	1.32	5.14	A	6							351	27	24.3	33.7							
DN5	3.82	1.32	5.14	A	7																	
DN5	3.82	1.32	5.14	A	8																	
DN5	3.82	1.32	5.14	A	Median A	6.9	17.0															
DN5	3.82	1.32	5.14	A	Mean A	6.9	18.3						24.5		37.6							4.99
DN5	3.82	1.32	5.14	A	CoeVar A	0.8%	12.6%						8.5%		8.8%							0.10
DN5	3.82	1.32	5.14	B	Initial							68										
DN5	3.82	1.32	5.14	B	S1			overload	na	na	na	155	87		9.7							
DN5	3.82	1.32	5.14	B	S2			3.3	0.105	1261	11.5	191	36		24.8							
DN5	3.82	1.32	5.14	B	1	6.3	13	3.2	0.102	1184	11.9	219	28	50.3	32.4							5.25
DN5	3.82	1.32	5.14	B	2	6.9	16	3.3	0.105	1147	12.7	248	29	31.0	31.3							4.98
DN5	3.82	1.32	5.14	B	3	7.2	17	3.3	0.105	1111	13.1	278	30	29.0	30.2							5.06
DN5	3.82	1.32	5.14	B	4			5.3	0.169	1539	15.2	307	29	29.3	31.3							
DN5	3.82	1.32	5.14	B	5			5.5	0.175	1462	16.6	330	23	27.3	40.0							
DN5	3.82	1.32	5.14	B	6			5.4	0.172	1402	17.0											
DN5	3.82	1.32	5.14	B	7			7.6	0.242	1676	20.0											
DN5	3.82	1.32	5.14	B	8			7.6	0.242	1626	20.6											
DN5	3.82	1.32	5.14	B	9			7.6	0.242	1568	21.4											
DN5	3.82	1.32	5.14	B	Mean H1			3.27	0.104	1147.33	12.58											
DN5	3.82	1.32	5.14	B	Mean H2			4.70	0.150	1370.67	14.97											
DN5	3.82	1.32	5.14	B	Mean H3			6.17	0.196	1513.33	17.87											
DN5	3.82	1.32	5.14	B	CoeVar H1			1.8%	1.8%	3.2%	4.8%											
DN5	3.82	1.32	5.14	B	CoeVar H2			25.9%	25.9%	16.6%	11.7%											
DN5	3.82	1.32	5.14	B	CoeVar H3			20.1%	20.1%	9.5%	10.4%											
DN5	3.82	1.32	5.14	B	Median B	6.9	16															
DN5	3.82	1.32	5.14	B	Mean B	6.8	15.3						27.8		33.0							5.10
DN5	3.82	1.32	5.14	B	CoeVar B	6.7%	13.6%						10.0%		12.0%							2.7%
DN5	3.82	1.32	5.14	C	Initial							79										
DN5	3.82	1.32	5.14	C	S1							166	87		9.7							
DN5	3.82	1.32	5.14	C	S2							203	37		24.1							
DN5	3.82	1.32	5.14	C	1	7.0	15					229	26	50.0	35.1							5.05
DN5	3.82	1.32	5.14	C	2	6.9	17					250	21	28.0	44.0							5.00
DN5	3.82	1.32	5.14	C	3	7.0	17					273	23	23.3	40.0							5.46
DN5	3.82	1.32	5.14	C	4							295	22	22.0	41.9							
DN5	3.82	1.32	5.14	C	5							311	16	20.3	58.8							
DN5	3.82	1.32	5.14	C	6																	
DN5	3.82	1.32	5.14	C	7																	
DN5	3.82	1.32	5.14	C	8																	
DN5	3.82	1.32	5.14	C	Median C	7.0	17.0															
DN5	3.82	1.32	5.14	C	Mean C	7.0	16.3						21.6		44.0							5.17
DN5	3.82	1.32	5.14	C	CoeVar C	0.8%	7.1%						16.9%		20.3%							4.9%
DN5	3.82	1.32	5.14	D	1												1978.5		1942.4	101.9%		5.19
DN5	3.82	1.32	5.14	E	1												1913.7		1942.4	98.5%		5.13
DN5	3.82	1.32	5.14	DE	Mean DE											#DIV/0!	1946.1	#DIV/0!	1942.4	100.2%		5.16
DN5	3.82	1.32	5.14	DE	CoeVar DE												2.4%			2.4%		0.9%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
DN7	3.82	1.32	5.14	A	Initial							82										
DN7	3.82	1.32	5.14	A	S1							161	79		10.8							
DN7	3.82	1.32	5.14	A	S2							196	35		25.6							
DN7	3.82	1.32	5.14	A	1	5.9	12					224	28	47.3	32.4							6.87
DN7	3.82	1.32	5.14	A	2	4.5	10					256	32	31.7	28.2							7.15
DN7	3.82	1.32	5.14	A	3	5.2	12					274	18	26.0	51.9							7.18
DN7	3.82	1.32	5.14	A	4							298	24	24.7	38.2							
DN7	3.82	1.32	5.14	A	5																	
DN7	3.82	1.32	5.14	A	6																	
DN7	3.82	1.32	5.14	A	7																	
DN7	3.82	1.32	5.14	A	8																	
DN7	3.82	1.32	5.14	A	Median A	5.2	12.0															
DN7	3.82	1.32	5.14	A	Mean A	5.2	11.3						25.5		37.7							7.07
DN7	3.82	1.32	5.14	A	CoeVar A	13.5%	10.2%						23.4%		27.4%							0.02
DN7	3.82	1.32	5.14	B	Initial							68										
DN7	3.82	1.32	5.14	B	S1			overload	na	na	na	144	76		11.2							
DN7	3.82	1.32	5.14	B	S2			3.3	0.105	1211	12.0	179	35		25.6							
DN7	3.82	1.32	5.14	B	1	5.6	11	3.3	0.105	936	15.6	208	29	46.7	31.3							7.41
DN7	3.82	1.32	5.14	B	2	5.7	12	3.3	0.105	831	17.5	234	26	30.0	35.1							7.16
DN7	3.82	1.32	5.14	B	3	5.6	12	3.3	0.105	774	18.8	262	28	27.7	32.4							7.34
DN7	3.82	1.32	5.14	B	4			5.5	0.175	1112	21.8	290	28	27.3	32.4							
DN7	3.82	1.32	5.14	B	5			5.5	0.175	1011	24.0	319	29	28.3	31.3							
DN7	3.82	1.32	5.14	B	6			5.5	0.175	954	25.4											
DN7	3.82	1.32	5.14	B	7			7.9	0.251	1175	29.7											
DN7	3.82	1.32	5.14	B	8			8.1	0.258	1117	32.0											
DN7	3.82	1.32	5.14	B	9			8.1	0.258	1071	33.4											
DN7	3.82	1.32	5.14	B	Mean H1			3.30	0.105	847.00	17.30											
DN7	3.82	1.32	5.14	B	Mean H2			5.50	0.175	1025.67	23.76											
DN7	3.82	1.32	5.14	B	Mean H3			8.03	0.256	1121.00	31.68											
DN7	3.82	1.32	5.14	B	CoeVar H1			0.0%	0.0%	9.7%	9.5%											
DN7	3.82	1.32	5.14	B	CoeVar H2			0.0%	0.0%	7.8%	7.7%											
DN7	3.82	1.32	5.14	B	CoeVar H3			1.4%	1.4%	4.6%	5.9%											
DN7	3.82	1.32	5.14	B	Median B	5.6	12															
DN7	3.82	1.32	5.14	B	Mean B	5.6	11.7						28.0		32.5							7.30
DN7	3.82	1.32	5.14	B	CoeVar B	1.0%	4.9%						4.4%		4.8%							1.7%
DN7	3.82	1.32	5.14	C	Initial							77										
DN7	3.82	1.32	5.14	C	S1							157	80		10.6							
DN7	3.82	1.32	5.14	C	S2							193	36		24.8							
DN7	3.82	1.32	5.14	C	1	4.9	14					220	27	47.7	33.7							7.46
DN7	3.82	1.32	5.14	C	2	6.3	13					246	26	29.7	35.1							7.12
DN7	3.82	1.32	5.14	C	3	4.2	9					269	23	25.3	40.0							7.40
DN7	3.82	1.32	5.14	C	4							291	22	23.7	41.9							
DN7	3.82	1.32	5.14	C	5							316	25	23.3	36.6							
DN7	3.82	1.32	5.14	C	6																	
DN7	3.82	1.32	5.14	C	7																	
DN7	3.82	1.32	5.14	C	8																	
DN7	3.82	1.32	5.14	C	Median C	4.9	13.0															
DN7	3.82	1.32	5.14	C	Mean C	5.1	12.0						24.6		37.5							7.33
DN7	3.82	1.32	5.14	C	CoeVar C	20.8%	22.0%						8.4%		9.1%							2.5%
DN7	3.82	1.32	5.14	D	1											1950.7	1814.1		1942.4	93.4%	100.4%	6.95
DN7	3.82	1.32	5.14	E	1											1950.7	1953.4		1942.4	100.6%	100.4%	7.19
DN7	3.82	1.32	5.14	DE	Mean DE											1950.7	1883.8	#DIV/0!	1942.4	97.0%		7.07
DN7	3.82	1.32	5.14	DE	CoeVar DE												5.2%			5.2%		2.4%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
DN10	3.82	1.32	5.14	A	Initial							80										
DN10	3.82	1.32	5.14	A	S1							208	128		6.5							
DN10	3.82	1.32	5.14	A	S2							298	90		9.4							
DN10	3.82	1.32	5.14	A	1	9.5	27					330	HIT									10.07
DN10	3.82	1.32	5.14	A	2	9.3	32															9.95
DN10	3.82	1.32	5.14	A	3	10.6	35															10.27
DN10	3.82	1.32	5.14	A	4																	
DN10	3.82	1.32	5.14	A	5																	
DN10	3.82	1.32	5.14	A	6																	
DN10	3.82	1.32	5.14	A	7																	
DN10	3.82	1.32	5.14	A	8																	
DN10	3.82	1.32	5.14	A	Median A	9.5	32.0															
DN10	3.82	1.32	5.14	A	Mean A	9.8	31.3															10.10
DN10	3.82	1.32	5.14	A	CoeVar A	7.1%	12.9%															0.02
DN10	3.82	1.32	5.14	B	Initial							88										
DN10	3.82	1.32	5.14	B	S1			overload	na	na	na	201	113		7.4							
DN10	3.82	1.32	5.14	B	S2			overload	na	na	na	279	78		10.9							
DN10	3.82	1.32	5.14	B	1	8.6	28	2.7	0.086	2114	5.6	316	HIT									10.08
DN10	3.82	1.32	5.14	B	2	8.3	28	3.2	0.102	2087	6.8											10.13
DN10	3.82	1.32	5.14	B	3	9.3	29	2.1	0.067	1913	4.8											9.70
DN10	3.82	1.32	5.14	B	4			5.3	0.169	1972	11.9											
DN10	3.82	1.32	5.14	B	5			5.2	0.166	1993	11.5											
DN10	3.82	1.32	5.14	B	6			5.2	0.166	1901	12.1											
DN10	3.82	1.32	5.14	B	7			7.3	0.232	2008	16.0											
DN10	3.82	1.32	5.14	B	8			7.5	0.239	1841	18.0											
DN10	3.82	1.32	5.14	B	9			7.4	0.236	1813	18.0											
DN10	3.82	1.32	5.14	B	Mean H1			2.67	0.085	2038.00	5.75											
DN10	3.82	1.32	5.14	B	Mean H2			5.23	0.167	1955.33	11.82											
DN10	3.82	1.32	5.14	B	Mean H3			7.40	0.236	1887.33	17.35											
DN10	3.82	1.32	5.14	B	CoeVar H1			20.7%	20.7%	5.4%	16.8%											
DN10	3.82	1.32	5.14	B	CoeVar H2			1.1%	1.1%	2.5%	2.4%											
DN10	3.82	1.32	5.14	B	CoeVar H3			1.4%	1.4%	5.6%	6.5%											
DN10	3.82	1.32	5.14	B	Median B	8.6	28															
DN10	3.82	1.32	5.14	B	Mean B	8.7	28.3															9.97
DN10	3.82	1.32	5.14	B	CoeVar B	5.9%	2.0%															2.4%
DN10	3.82	1.32	5.14	C	Initial							97										
DN10	3.82	1.32	5.14	C	S1							208	111		7.5							
DN10	3.82	1.32	5.14	C	S2							290	82		10.4							
DN10	3.82	1.32	5.14	C	1	8.6	26					333	HIT									10.25
DN10	3.82	1.32	5.14	C	2	11.1	42															9.23
DN10	3.82	1.32	5.14	C	3	10.6	42															9.64
DN10	3.82	1.32	5.14	C	4																	
DN10	3.82	1.32	5.14	C	5																	
DN10	3.82	1.32	5.14	C	6																	
DN10	3.82	1.32	5.14	C	7																	
DN10	3.82	1.32	5.14	C	8																	
DN10	3.82	1.32	5.14	C	Median C	10.6	42.0															
DN10	3.82	1.32	5.14	C	Mean C	10.1	36.7															9.71
DN10	3.82	1.32	5.14	C	CoeVar C	13.1%	25.2%															5.3%
DN10	3.82	1.32	5.14	D	1											1999.1	2068.2		1942.4	106.5%	102.9%	10.12
DN10	3.82	1.32	5.14	E	1											1999.1	1958.9		1942.4	100.8%	102.9%	10.27
DN10	3.82	1.32	5.14	DE	Mean DE											1999.1	2013.5	#DIV/0!	1942.4	103.7%		10.20
DN10	3.82	1.32	5.14	DE	CoeVar DE												3.8%			3.8%		1.1%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
DN10X2	3.82	1.32	5.14	A	Initial							108										
DN10X2	3.82	1.32	5.14	A	S1							211	103		8.1							
DN10X2	3.82	1.32	5.14	A	S2							292	81		10.5							
DN10X2	3.82	1.32	5.14	A	1	8.5	17					320	HIT									10.40
DN10X2	3.82	1.32	5.14	A	2	8.6	23															10.51
DN10X2	3.82	1.32	5.14	A	3	7.9	21															9.98
DN10X2	3.82	1.32	5.14	A	4																	
DN10X2	3.82	1.32	5.14	A	5																	
DN10X2	3.82	1.32	5.14	A	6																	
DN10X2	3.82	1.32	5.14	A	7																	
DN10X2	3.82	1.32	5.14	A	8																	
DN10X2	3.82	1.32	5.14	A	Median A	8.5	21.0															
DN10X2	3.82	1.32	5.14	A	Mean A	8.3	20.3															10.30
DN10X2	3.82	1.32	5.14	A	CoeVar A	4.5%	15.0%															0.03
DN10X2	3.82	1.32	5.14	B	Initial							86										
DN10X2	3.82	1.32	5.14	B	S1			overload	na	na	na	201	115		7.2							
DN10X2	3.82	1.32	5.14	B	S2			overload	na	na	na	270	69		12.5							
DN10X2	3.82	1.32	5.14	B	1	8.7	30	3.3	0.105	1944	7.5	299	HIT									10.56
DN10X2	3.82	1.32	5.14	B	2	7.4	17	3.4	0.108	1596	9.4											9.95
DN10X2	3.82	1.32	5.14	B	3	9.8	33	3.4	0.108	1495	10.0											10.16
DN10X2	3.82	1.32	5.14	B	4			5.3	0.169	1831	12.8											
DN10X2	3.82	1.32	5.14	B	5			5.1	0.162	1770	12.7											
DN10X2	3.82	1.32	5.14	B	6			5.2	0.166	1457	15.8											
DN10X2	3.82	1.32	5.14	B	7			7.7	0.245	1580	21.5											
DN10X2	3.82	1.32	5.14	B	8			7.8	0.248	1453	23.7											
DN10X2	3.82	1.32	5.14	B	9			7.6	0.242	1484	22.6											
DN10X2	3.82	1.32	5.14	B	Mean H1			3.37	0.107	1678.33	8.98											
DN10X2	3.82	1.32	5.14	B	Mean H2			5.20	0.166	1686.00	13.75											
DN10X2	3.82	1.32	5.14	B	Mean H3			7.70	0.245	1505.67	22.60											
DN10X2	3.82	1.32	5.14	B	CoeVar H1			1.7%	1.7%	14.0%	14.8%											
DN10X2	3.82	1.32	5.14	B	CoeVar H2			1.9%	1.9%	11.9%	12.6%											
DN10X2	3.82	1.32	5.14	B	CoeVar H3			1.3%	1.3%	4.4%	4.8%											
DN10X2	3.82	1.32	5.14	B	Median B	8.7	30															
DN10X2	3.82	1.32	5.14	B	Mean B	8.6	26.7															10.22
DN10X2	3.82	1.32	5.14	B	CoeVar B	13.9%	31.9%															3.0%
DN10X2	3.82	1.32	5.14	C	Initial							83										
DN10X2	3.82	1.32	5.14	C	S1							188	105		8.0							
DN10X2	3.82	1.32	5.14	C	S2							266	78		10.9							
DN10X2	3.82	1.32	5.14	C	1	7.4	32					315	HIT									9.41
DN10X2	3.82	1.32	5.14	C	2	9.3	30															9.32
DN10X2	3.82	1.32	5.14	C	3	7.8	18															9.24
DN10X2	3.82	1.32	5.14	C	4																	
DN10X2	3.82	1.32	5.14	C	5																	
DN10X2	3.82	1.32	5.14	C	6																	
DN10X2	3.82	1.32	5.14	C	7																	
DN10X2	3.82	1.32	5.14	C	8																	
DN10X2	3.82	1.32	5.14	C	Median C	7.8	30.0															
DN10X2	3.82	1.32	5.14	C	Mean C	8.2	26.7															9.32
DN10X2	3.82	1.32	5.14	C	CoeVar C	12.3%	28.4%															0.9%
DN10X2	3.82	1.32	5.14	D	1											1976.2	2006.6		1942.4	103.3%	101.7%	9.74
DN10X2	3.82	1.32	5.14	E	1											1976.2	2029.1		1942.4	104.5%	101.7%	10.19
DN10X2	3.82	1.32	5.14	DE	Mean DE											1976.2	2017.9	#DIV/0!	1942.4	103.9%		9.96
DN10X2	3.82	1.32	5.14	DE	CoeVar DE												0.8%			0.8%		3.2%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	$[kg/m^3]$	$[kg/m^3]$	$[kg/m^3]$	$[kg/m^3]$	$[kg/m^3]$	$[kg/m^3]$	%
DN10S	3.82	1.32	5.14	A	Initial							106	na		na							
DN10S	3.82	1.32	5.14	A	S1							212	106		7.9							
DN10S	3.82	1.32	5.14	A	S2							282	70		12.3							
DN10S	3.82	1.32	5.14	A	1	12.0	40					328	46		19.2							10.46
DN10S	3.82	1.32	5.14	A	2	10.7	36															9.64
DN10S	3.82	1.32	5.14	A	3	12.1	45															9.78
DN10S	3.82	1.32	5.14	A	4																	
DN10S	3.82	1.32	5.14	A	5																	
DN10S	3.82	1.32	5.14	A	6																	
DN10S	3.82	1.32	5.14	A	7																	
DN10S	3.82	1.32	5.14	A	8																	
DN10S	3.82	1.32	5.14	A	Median A	12.0	40.0															
DN10S	3.82	1.32	5.14	A	Mean A	11.6	40.3						46.0		19.2							9.96
DN10S	3.82	1.32	5.14	A	CoeVar A	6.7%	11.2%						#DIV/0!		#DIV/0!							0.04
DN10S	3.82	1.32	5.14	B	Initial							82										
DN10S	3.82	1.32	5.14	B	S1			overload	na	na	na	183	101		8.3							
DN10S	3.82	1.32	5.14	B	S2			overload	na	na	na	253	70		12.3							
DN10S	3.82	1.32	5.14	B	1	8.2	12	3.2	0.102	2097	6.7	300	47		18.7							9.82
DN10S	3.82	1.32	5.14	B	2	11	39	3.4	0.108	1669	9.0	314	HIT									9.74
DN10S	3.82	1.32	5.14	B	3	11.3	41	3.5	0.111	1436	10.8											9.56
DN10S	3.82	1.32	5.14	B	4			5.6	0.178	1723	14.3											
DN10S	3.82	1.32	5.14	B	5			5.7	0.181	1527	16.5											
DN10S	3.82	1.32	5.14	B	6			5.7	0.181	1318	19.1											
DN10S	3.82	1.32	5.14	B	7			8	0.255	1428	24.7											
DN10S	3.82	1.32	5.14	B	8			8	0.255	1412	25.0											
DN10S	3.82	1.32	5.14	B	9			8.1	0.258	1318	27.1											
DN10S	3.82	1.32	5.14	B	Mean H1			3.37	0.107	1734.00	8.83											
DN10S	3.82	1.32	5.14	B	Mean H2			5.67	0.180	1522.67	16.63											
DN10S	3.82	1.32	5.14	B	Mean H3			8.03	0.256	1386.00	25.62											
DN10S	3.82	1.32	5.14	B	CoeVar H1			4.5%	4.5%	19.3%	22.8%											
DN10S	3.82	1.32	5.14	B	CoeVar H2			1.0%	1.0%	13.3%	14.3%											
DN10S	3.82	1.32	5.14	B	CoeVar H3			0.7%	0.7%	4.3%	5.1%											
DN10S	3.82	1.32	5.14	B	Median B	11	39															
DN10S	3.82	1.32	5.14	B	Mean B	10.2	30.7						47.0		18.7							9.71
DN10S	3.82	1.32	5.14	B	CoeVar B	16.8%	52.8%						#DIV/0!		#DIV/0!							1.3%
DN10S	3.82	1.32	5.14	C	Initial							64										
DN10S	3.82	1.32	5.14	C	S1							168	104		8.1							
DN10S	3.82	1.32	5.14	C	S2							242	74		11.6							
DN10S	3.82	1.32	5.14	C	1	11.3	38					285	43		20.6							9.54
DN10S	3.82	1.32	5.14	C	2	10.6	36					316	HIT									9.25
DN10S	3.82	1.32	5.14	C	3	11.3	34															9.67
DN10S	3.82	1.32	5.14	C	4																	
DN10S	3.82	1.32	5.14	C	5																	
DN10S	3.82	1.32	5.14	C	6																	
DN10S	3.82	1.32	5.14	C	7																	
DN10S	3.82	1.32	5.14	C	8																	
DN10S	3.82	1.32	5.14	C	Median C	11.3	36.0															
DN10S	3.82	1.32	5.14	C	Mean C	11.1	36.0						43.0		20.6							9.49
DN10S	3.82	1.32	5.14	C	CoeVar C	3.7%	5.6%						#DIV/0!		#DIV/0!							2.2%
DN10S	3.82	1.32	5.14	D	1											1984.9	2007.3		1942.4	103.3%	102.2%	9.30
DN10S	3.82	1.32	5.14	E	1											1984.9		2026.0	1942.4	104.3%	102.2%	9.67
DN10S	3.82	1.32	5.14	DE	Mean DE											1984.9	2007.3	2026.0	1942.4	103.8%		9.49
DN10S	3.82	1.32	5.14	DE	CoeVar DE															0.7%		2.8%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
DN10C	3.82	1.32	5.14	A	Initial							37										
DN10C	3.82	1.32	5.14	A	S1							121	84		10.1							
DN10C	3.82	1.32	5.14	A	S2							202	81		10.5							
DN10C	3.82	1.32	5.14	A	1	10.9	27					229	27		33.7							9.38
DN10C	3.82	1.32	5.14	A	2	11.3	39					258	HIT									9.38
DN10C	3.82	1.32	5.14	A	3	10.8	39															8.65
DN10C	3.82	1.32	5.14	A	4																	
DN10C	3.82	1.32	5.14	A	5																	
DN10C	3.82	1.32	5.14	A	6																	
DN10C	3.82	1.32	5.14	A	7																	
DN10C	3.82	1.32	5.14	A	8																	
DN10C	3.82	1.32	5.14	A	Median A	10.9	39.0															
DN10C	3.82	1.32	5.14	A	Mean A	11.0	35.0						27.0		33.7							9.14
DN10C	3.82	1.32	5.14	A	CoeVar A	2.4%	19.8%						#DIV/0!		#DIV/0!							0.05
DN10C	3.82	1.32	5.14	B	Initial							18										
DN10C	3.82	1.32	5.14	B	S1			overload	na	na	na	119	101		8.3							
DN10C	3.82	1.32	5.14	B	S2			2.8	0.089	2219	5.6	192	73		11.7							
DN10C	3.82	1.32	5.14	B	1	10.3	36	3	0.095	1998	6.6	245	53		16.5							9.01
DN10C	3.82	1.32	5.14	B	2	8.9	30	3.2	0.102	1814	7.8	247	HIT									9.73
DN10C	3.82	1.32	5.14	B	3	10.2	35	3.2	0.102	1709	8.3											9.13
DN10C	3.82	1.32	5.14	B	4			5.4	0.172	1798	13.3											
DN10C	3.82	1.32	5.14	B	5			5.4	0.172	1754	13.6											
DN10C	3.82	1.32	5.14	B	6			5.4	0.172	1741	13.7											
DN10C	3.82	1.32	5.14	B	7			7.5	0.239	1830	18.1											
DN10C	3.82	1.32	5.14	B	8			7.8	0.248	1803	19.1											
DN10C	3.82	1.32	5.14	B	9			7.9	0.251	1819	19.2											
DN10C	3.82	1.32	5.14	B	Mean H1			3.13	0.100	1840.33	7.56											
DN10C	3.82	1.32	5.14	B	Mean H2			5.40	0.172	1764.33	13.51											
DN10C	3.82	1.32	5.14	B	Mean H3			7.73	0.246	1817.33	18.78											
DN10C	3.82	1.32	5.14	B	CoeVar H1			3.7%	3.7%	7.9%	11.1%											
DN10C	3.82	1.32	5.14	B	CoeVar H2			0.0%	0.0%	1.7%	1.7%											
DN10C	3.82	1.32	5.14	B	CoeVar H3			2.7%	2.7%	0.7%	3.2%											
DN10C	3.82	1.32	5.14	B	Median B	10.2	35															
DN10C	3.82	1.32	5.14	B	Mean B	9.8	33.7						53.0		16.5							9.29
DN10C	3.82	1.32	5.14	B	CoeVar B	8.0%	9.5%						#DIV/0!		#DIV/0!							4.1%
DN10C	3.82	1.32	5.14	C	Initial							29										
DN10C	3.82	1.32	5.14	C	S1							125	96		8.8							
DN10C	3.82	1.32	5.14	C	S2							195	70		12.3							
DN10C	3.82	1.32	5.14	C	1	10.3	35					240	HIT									9.03
DN10C	3.82	1.32	5.14	C	2	9.9	34															9.04
DN10C	3.82	1.32	5.14	C	3	10.2	30															8.54
DN10C	3.82	1.32	5.14	C	4																	
DN10C	3.82	1.32	5.14	C	5																	
DN10C	3.82	1.32	5.14	C	6																	
DN10C	3.82	1.32	5.14	C	7																	
DN10C	3.82	1.32	5.14	C	8																	
DN10C	3.82	1.32	5.14	C	Median C	10.2	34.0															
DN10C	3.82	1.32	5.14	C	Mean C	10.1	33.0															8.87
DN10C	3.82	1.32	5.14	C	CoeVar C	2.1%	8.0%															3.2%
DN10C	3.82	1.32	5.14	D	1											2076.0	1954.8		1942.4	100.6%	106.9%	9.52
DN10C	3.82	1.32	5.14	E	1											2076.0		1966.2	1942.4	101.2%	106.9%	9.54
DN10C	3.82	1.32	5.14	D	2											2076.0	2050.2		1942.4	105.5%	106.9%	9.16
DN10C	3.82	1.32	5.14	E	2											2076.0		2012.4	1942.4	103.6%	106.9%	9.16
DN10C	3.82	1.32	5.14	DE	Mean DE											2076.0	2002.5	1989.3	1942.4	102.8%		9.35
DN10C	3.82	1.32	5.14	DE	CoeVar DE												3.4%	1.6%		2.2%		2.3%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
FHJ8	4.00	2.07	6.07	A	Initial							5										
FHJ8	4.00	2.07	6.07	A	S1							95	90		9.4							
FHJ8	4.00	2.07	6.07	A	S2							137	42		21.1							
FHJ8	4.00	2.07	6.07	A	1	8.2	18					165	28	53.3	32.4							7.62
FHJ8	4.00	2.07	6.07	A	2	8.0	21					191	26	32.0	35.1							7.63
FHJ8	4.00	2.07	6.07	A	3	8.2	20					214	23	25.7	40.0							8.12
FHJ8	4.00	2.07	6.07	A	4							233	19	22.7	49.0							
FHJ8	4.00	2.07	6.07	A	5							252	19	20.3	49.0							
FHJ8	4.00	2.07	6.07	A	6							271	19	19.0	49.0							
FHJ8	4.00	2.07	6.07	A	7							285	14	17.3	67.7							
FHJ8	4.00	2.07	6.07	A	8							290	HIT									
FHJ8	4.00	2.07	6.07	A	Median A	8.2	20.0															
FHJ8	4.00	2.07	6.07	A	Mean A	8.1	19.7						22.3		42.4							7.79
FHJ8	4.00	2.07	6.07	A	CoeVar A	1.4%	7.8%						17.8%		17.9%							0.04
FHJ8	4.00	2.07	6.07	B	Initial							14										
FHJ8	4.00	2.07	6.07	B	S1			2.8	0.089	29	426.1	110	96		8.8							
FHJ8	4.00	2.07	6.07	B	S2			3.3	0.105	271	53.7	153	43		20.6							
FHJ8	4.00	2.07	6.07	B	1	6.4	17	3.4	0.108	263	57.1	185	32	57.0	28.2							8.07
FHJ8	4.00	2.07	6.07	B	2	6.8	15	3.4	0.108	258	58.2	209	24	33.0	38.2							7.58
FHJ8	4.00	2.07	6.07	B	3	7.2	19	3.4	0.108	254	59.1	230	21	25.7	44.0							7.59
FHJ8	4.00	2.07	6.07	B	4			5.4	0.172	455	52.4	249	19	21.3	49.0							
FHJ8	4.00	2.07	6.07	B	5			5.5	0.175	427	56.8	266	17	19.0	55.1							
FHJ8	4.00	2.07	6.07	B	6			5.5	0.175	414	58.6	283	17	17.7	55.1							
FHJ8	4.00	2.07	6.07	B	7			8	0.255	622	56.8	295	HIT									
FHJ8	4.00	2.07	6.07	B	8			8.1	0.258	597	59.9											
FHJ8	4.00	2.07	6.07	B	9			8.2	0.261	597	60.6											
FHJ8	4.00	2.07	6.07	B	Mean H1			3.40	0.108	258.33	58.10											
FHJ8	4.00	2.07	6.07	B	Mean H2			5.47	0.174	432.00	55.95											
FHJ8	4.00	2.07	6.07	B	Mean H3			8.10	0.258	605.33	59.09											
FHJ8	4.00	2.07	6.07	B	CoeVar H1			0.0%	0.0%	1.7%	1.7%											
FHJ8	4.00	2.07	6.07	B	CoeVar H2			1.1%	1.1%	4.9%	5.8%											
FHJ8	4.00	2.07	6.07	B	CoeVar H3			1.2%	1.2%	2.4%	3.5%											
FHJ8	4.00	2.07	6.07	B	Median B	6.8	17															
FHJ8	4.00	2.07	6.07	B	Mean B	6.8	17.0						21.7		44.9							7.75
FHJ8	4.00	2.07	6.07	B	CoeVar B	5.9%	11.8%						26.4%		23.4%							3.6%
FHJ8	4.00	2.07	6.07	C	Initial							20										
FHJ8	4.00	2.07	6.07	C	S1							110	90		9.4							
FHJ8	4.00	2.07	6.07	C	S2							152	42		21.1							
FHJ8	4.00	2.07	6.07	C	1	8.7	19					184	32	54.7	28.2							8.16
FHJ8	4.00	2.07	6.07	C	2	8.9	27					208	24	32.7	38.2							8.03
FHJ8	4.00	2.07	6.07	C	3	8.6	26					228	20	25.3	46.4							8.04
FHJ8	4.00	2.07	6.07	C	4							247	19	21.0	49.0							
FHJ8	4.00	2.07	6.07	C	5							264	17	18.7	55.1							
FHJ8	4.00	2.07	6.07	C	6							279	15	17.0	62.9							
FHJ8	4.00	2.07	6.07	C	7							294	HIT									
FHJ8	4.00	2.07	6.07	C	8																	
FHJ8	4.00	2.07	6.07	C	Median C	8.7	26.0															
FHJ8	4.00	2.07	6.07	C	Mean C	8.7	24.0						21.2		46.6							8.08
FHJ8	4.00	2.07	6.07	C	CoeVar C	1.7%	18.2%						28.9%		26.4%							0.9%
FHJ8	4.00	2.07	6.07	D	1											1763.9	1788.9		1753.4	102.0%	100.6%	7.62
FHJ8	4.00	2.07	6.07	E	1											1763.9		1714.6	1753.4	97.8%	100.6%	7.43
FHJ8	4.00	2.07	6.07	D	2											1763.9	1759.4		1753.4	100.3%	100.6%	7.33
FHJ8	4.00	2.07	6.07	E	2											1763.9		1875.4	1753.4	107.0%	100.6%	7.33
FHJ8	4.00	2.07	6.07	DE	Mean DE											1763.9	1774.2	1795.0	1753.4	101.8%		7.43
FHJ8	4.00	2.07	6.07	DE	CoeVar DE												1.2%	6.3%		3.8%		1.8%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
FHJ10	4.00	2.07	6.07	A	Initial							166										
FHJ10	4.00	2.07	6.07	A	S1							244	78		10.9							
FHJ10	4.00	2.07	6.07	A	S2							280	36		24.8							
FHJ10	4.00	2.07	6.07	A	1	10.1	39					309	29	47.7	31.3							9.62
FHJ10	4.00	2.07	6.07	A	2	9.4	36					334	25	30.0	36.6							9.56
FHJ10	4.00	2.07	6.07	A	3	9.9	38					356	22	25.3	41.9							9.42
FHJ10	4.00	2.07	6.07	A	4							378	22	23.0	41.9							
FHJ10	4.00	2.07	6.07	A	5							396	18	20.7	51.9							
FHJ10	4.00	2.07	6.07	A	6							414	18	19.3	51.9							
FHJ10	4.00	2.07	6.07	A	7							430	16	17.3	58.8							
FHJ10	4.00	2.07	6.07	A	8							444	HIT									
FHJ10	4.00	2.07	6.07	A	Median A	9.9	38.0															
FHJ10	4.00	2.07	6.07	A	Mean A	9.8	37.7						21.4		44.9							9.53
FHJ10	4.00	2.07	6.07	A	CoeVar A	3.7%	4.1%						21.2%		21.6%							0.01
FHJ10	4.00	2.07	6.07	B	Initial							169										
FHJ10	4.00	2.07	6.07	B	S1			3.1	0.099	1396	9.8	250	81		10.5							
FHJ10	4.00	2.07	6.07	B	S2			3.3	0.105	333	43.7	290	40		22.2							
FHJ10	4.00	2.07	6.07	B	1	8.2	24	3.3	0.105	296	49.2	321	31	50.7	29.1							10.07
FHJ10	4.00	2.07	6.07	B	2	9.6	38	3.4	0.108	282	53.2	346	25	32.0	36.6							9.44
FHJ10	4.00	2.07	6.07	B	3	9.9	40	3.5	0.111	272	56.8	370	24	26.7	38.2							9.44
FHJ10	4.00	2.07	6.07	B	4			5.6	0.178	569	43.4	391	21	23.3	44.0							
FHJ10	4.00	2.07	6.07	B	5			5.6	0.178	478	51.7	409	18	21.0	51.9							
FHJ10	4.00	2.07	6.07	B	6			5.7	0.181	447	56.3	426	17	18.7	55.1							
FHJ10	4.00	2.07	6.07	B	7			8.1	0.258	680	52.6	442	16	17.0	58.8							
FHJ10	4.00	2.07	6.07	B	8			8.1	0.258	604	59.2	455	HIT									
FHJ10	4.00	2.07	6.07	B	9			8.1	0.258	548	65.2											
FHJ10	4.00	2.07	6.07	B	Mean H1			3.40	0.108	283.33	53.07											
FHJ10	4.00	2.07	6.07	B	Mean H2			5.63	0.179	498.00	50.47											
FHJ10	4.00	2.07	6.07	B	Mean H3			8.10	0.258	610.67	58.99											
FHJ10	4.00	2.07	6.07	B	CoeVar H1			2.9%	2.9%	4.3%	7.2%											
FHJ10	4.00	2.07	6.07	B	CoeVar H2			1.0%	1.0%	12.7%	12.9%											
FHJ10	4.00	2.07	6.07	B	CoeVar H3			0.0%	0.0%	10.8%	10.7%											
FHJ10	4.00	2.07	6.07	B	Median B	9.6	38															
FHJ10	4.00	2.07	6.07	B	Mean B	9.2	34.0						21.7		44.8							9.65
FHJ10	4.00	2.07	6.07	B	CoeVar B	9.8%	25.6%						24.6%		24.2%							3.8%
FHJ10	4.00	2.07	6.07	C	Initial							167										
FHJ10	4.00	2.07	6.07	C	S1							245	78		10.9							
FHJ10	4.00	2.07	6.07	C	S2							288	43		20.6							
FHJ10	4.00	2.07	6.07	C	1	9.7	37					317	29	50.0	31.3							9.86
FHJ10	4.00	2.07	6.07	C	2	8.9	35					343	26	32.7	35.1							9.03
FHJ10	4.00	2.07	6.07	C	3	9.1	38					366	23	26.0	40.0							9.48
FHJ10	4.00	2.07	6.07	C	4							386	20	23.0	46.4							
FHJ10	4.00	2.07	6.07	C	5							405	19	20.7	49.0							
FHJ10	4.00	2.07	6.07	C	6							422	17	18.7	55.1							
FHJ10	4.00	2.07	6.07	C	7							439	17	17.7	55.1							
FHJ10	4.00	2.07	6.07	C	8							453	HIT									
FHJ10	4.00	2.07	6.07	C	Median C	9.1	37.0															
FHJ10	4.00	2.07	6.07	C	Mean C	9.2	36.7						21.6		44.6							9.45
FHJ10	4.00	2.07	6.07	C	CoeVar C	4.5%	4.2%						21.4%		21.1%							4.4%
FHJ10	4.00	2.07	6.07	D	1											1790.6	1769.5		1753.4	100.9%	102.1%	9.30
FHJ10	4.00	2.07	6.07	E	1											1790.6		1870.4	1753.4	106.7%	102.1%	9.15
FHJ10	4.00	2.07	6.07	D	2											1790.6	1854.7		1753.4	105.8%	102.1%	9.24
FHJ10	4.00	2.07	6.07	E	2											1790.6		1866.6	1753.4	106.5%	102.1%	9.35
FHJ10	4.00	2.07	6.07	DE	Mean DE											1790.6	1812.1	1868.5	1753.4	105.0%		9.26
FHJ10	4.00	2.07	6.07	DE	CoeVar DE												3.3%	0.1%		2.6%		1.0%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
FHJ11	4.00	2.07	6.07	A	Initial							166										
FHJ11	4.00	2.07	6.07	A	S1							250	84		10.1							
FHJ11	4.00	2.07	6.07	A	S2							290	40		22.2							
FHJ11	4.00	2.07	6.07	A	1	11.3	19					320	30	51.3	30.2							10.81
FHJ11	4.00	2.07	6.07	A	2	11.1	22					346	26	32.0	35.1							10.50
FHJ11	4.00	2.07	6.07	A	3	11.9	24					370	24	26.7	38.2							10.87
FHJ11	4.00	2.07	6.07	A	4							390	20	23.3	46.4							
FHJ11	4.00	2.07	6.07	A	5							405	15	19.7	62.9							
FHJ11	4.00	2.07	6.07	A	6							422	17	17.3	55.1							
FHJ11	4.00	2.07	6.07	A	7							436	14	15.3	67.7							
FHJ11	4.00	2.07	6.07	A	8																	
FHJ11	4.00	2.07	6.07	A	Median A	11.3	22.0															
FHJ11	4.00	2.07	6.07	A	Mean A	11.4	21.7						20.9		47.9							10.73
FHJ11	4.00	2.07	6.07	A	CoeVar A	3.6%	11.6%						28.8%		30.1%							0.02
FHJ11	4.00	2.07	6.07	B	Initial							165										
FHJ11	4.00	2.07	6.07	B	S1			3	0.095	1603	8.3	245	80		10.6							
FHJ11	4.00	2.07	6.07	B	S2			3.5	0.111	376	41.1	290	45		19.6							
FHJ11	4.00	2.07	6.07	B	1	10.6	22	3.5	0.111	338	45.7	320	30	51.7	30.2							10.68
FHJ11	4.00	2.07	6.07	B	2	10.4	21	3.5	0.111	321	48.1	345	25	33.3	36.6							10.74
FHJ11	4.00	2.07	6.07	B	3	11.2	21	3.5	0.111	307	50.3	366	21	25.3	44.0							10.74
FHJ11	4.00	2.07	6.07	B	4			5.6	0.178	577	42.8	388	22	22.7	41.9							
FHJ11	4.00	2.07	6.07	B	5			5.6	0.178	509	48.6	407	19	20.7	49.0							
FHJ11	4.00	2.07	6.07	B	6			5.6	0.178	479	51.6	422	15	18.7	62.9							
FHJ11	4.00	2.07	6.07	B	7			8	0.255	703	50.2	437	15	16.3	62.9							
FHJ11	4.00	2.07	6.07	B	8			8.1	0.258	653	54.7	449	HIT									
FHJ11	4.00	2.07	6.07	B	9			8.1	0.258	620	57.7											
FHJ11	4.00	2.07	6.07	B	Mean H1			3.50	0.111	322.00	48.04											
FHJ11	4.00	2.07	6.07	B	Mean H2			5.60	0.178	521.67	47.66											
FHJ11	4.00	2.07	6.07	B	Mean H3			8.07	0.257	658.67	54.21											
FHJ11	4.00	2.07	6.07	B	CoeVar H1			0.0%	0.0%	4.8%	4.8%											
FHJ11	4.00	2.07	6.07	B	CoeVar H2			0.0%	0.0%	9.6%	9.3%											
FHJ11	4.00	2.07	6.07	B	CoeVar H3			0.7%	0.7%	6.3%	6.9%											
FHJ11	4.00	2.07	6.07	B	Median B	10.6	21															
FHJ11	4.00	2.07	6.07	B	Mean B	10.7	21.3						21.0		46.8							10.72
FHJ11	4.00	2.07	6.07	B	CoeVar B	3.9%	2.7%						25.6%		26.7%							0.3%
FHJ11	4.00	2.07	6.07	C	Initial							167	na		na							
FHJ11	4.00	2.07	6.07	C	S1							236	69		12.5							
FHJ11	4.00	2.07	6.07	C	S2							280	44		20.1							
FHJ11	4.00	2.07	6.07	C	1	9.8	17					309	29	47.3	31.3							10.83
FHJ11	4.00	2.07	6.07	C	2	12.6	32					333	24	32.3	38.2							10.66
FHJ11	4.00	2.07	6.07	C	3	12.1	28					354	21	24.7	44.0							10.77
FHJ11	4.00	2.07	6.07	C	4							372	18	21.0	51.9							
FHJ11	4.00	2.07	6.07	C	5							391	19	19.3	49.0							
FHJ11	4.00	2.07	6.07	C	6							406	15	17.3	62.9							
FHJ11	4.00	2.07	6.07	C	7							421	15	16.3	62.9							
FHJ11	4.00	2.07	6.07	C	8							435	14	14.7	67.7							
FHJ11	4.00	2.07	6.07	C	Median C	12.1	28.0															
FHJ11	4.00	2.07	6.07	C	Mean C	11.5	25.7						19.4		51.0							10.75
FHJ11	4.00	2.07	6.07	C	CoeVar C	13.0%	30.3%						26.6%		25.4%							0.8%
FHJ11	4.00	2.07	6.07	D	1											1801.9	1752.6		1753.4	100.0%	102.8%	10.49
FHJ11	4.00	2.07	6.07	E	1											1801.9		1872.4	1753.4	106.8%	102.8%	10.19
FHJ11	4.00	2.07	6.07	D	2											1801.9	1894.7		1753.4	108.1%	102.8%	10.14
FHJ11	4.00	2.07	6.07	E	2											1801.9		1873.9	1753.4	106.9%	102.8%	10.05
FHJ11	4.00	2.07	6.07	DE	Mean DE											1801.9	1823.7	1873.1	1753.4	105.4%		10.22
FHJ11	4.00	2.07	6.07	DE	CoeVar DE												5.5%	0.1%		3.5%		1.9%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
FHJ13	4.00	2.07	6.07	A	Initial							188										
FHJ13	4.00	2.07	6.07	A	S1							318	130		6.4							
FHJ13	4.00	2.07	6.07	A	S2							400	82		10.4							
FHJ13	4.00	2.07	6.07	A	1	12.1	17					447	HIT									13.35
FHJ13	4.00	2.07	6.07	A	2	11.4	14															13.21
FHJ13	4.00	2.07	6.07	A	3	11.4	18															13.56
FHJ13	4.00	2.07	6.07	A	4																	
FHJ13	4.00	2.07	6.07	A	5																	
FHJ13	4.00	2.07	6.07	A	6																	
FHJ13	4.00	2.07	6.07	A	7																	
FHJ13	4.00	2.07	6.07	A	8																	
FHJ13	4.00	2.07	6.07	A	Median A	11.4	17.0															
FHJ13	4.00	2.07	6.07	A	Mean A	11.6	16.3															13.37
FHJ13	4.00	2.07	6.07	A	CoeVar A	3.5%	12.7%															0.01
FHJ13	4.00	2.07	6.07	B	Initial							174										
FHJ13	4.00	2.07	6.07	B	S1			overload	#VALUE!	na	#VALUE!	295	121		6.9							
FHJ13	4.00	2.07	6.07	B	S2			overload	#VALUE!	na	#VALUE!	373	78		10.9							
FHJ13	4.00	2.07	6.07	B	1	13.4	35	1.9	0.060	2195	3.8	426	53	84.0	16.5							13.54
FHJ13	4.00	2.07	6.07	B	2	12.8	35	3.2	0.102	2182	6.5	437	HIT									13.55
FHJ13	4.00	2.07	6.07	B	3	13.5	37	3.5	0.111	2043	7.6											12.62
FHJ13	4.00	2.07	6.07	B	4			overload	#VALUE!	na	#VALUE!											
FHJ13	4.00	2.07	6.07	B	5			overload	#VALUE!	na	#VALUE!											
FHJ13	4.00	2.07	6.07	B	6			3.6	0.115	2128	7.5											
FHJ13	4.00	2.07	6.07	B	7			7.8	0.248	2128	16.2											
FHJ13	4.00	2.07	6.07	B	8			7.8	0.248	2054	16.8											
FHJ13	4.00	2.07	6.07	B	9			8	0.255	2028	17.4											
FHJ13	4.00	2.07	6.07	B	Mean H1			2.87	0.091	2140.00	5.95											
FHJ13	4.00	2.07	6.07	B	Mean H2			3.60	0.115	2128.00	7.47											
FHJ13	4.00	2.07	6.07	B	Mean H3			7.87	0.250	2070.00	16.78											
FHJ13	4.00	2.07	6.07	B	CoeVar H1			29.7%	29.7%	3.9%	32.3%											
FHJ13	4.00	2.07	6.07	B	CoeVar H2			#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!											
FHJ13	4.00	2.07	6.07	B	CoeVar H3			1.5%	1.5%	2.5%	3.7%											
FHJ13	4.00	2.07	6.07	B	Median B	13.4	35															
FHJ13	4.00	2.07	6.07	B	Mean B	13.2	35.7						53.0		16.5							13.24
FHJ13	4.00	2.07	6.07	B	CoeVar B	2.9%	3.2%						#DIV/0!		#DIV/0!							4.0%
FHJ13	4.00	2.07	6.07	C	Initial							162										
FHJ13	4.00	2.07	6.07	C	S1							281	119		7.0							
FHJ13	4.00	2.07	6.07	C	S2							352	71		12.1							
FHJ13	4.00	2.07	6.07	C	1	13.8	35					401	49	79.7	17.9							11.97
FHJ13	4.00	2.07	6.07	C	2	14.2	37					433	HIT									12.33
FHJ13	4.00	2.07	6.07	C	3	13.8	41															12.81
FHJ13	4.00	2.07	6.07	C	4																	
FHJ13	4.00	2.07	6.07	C	5																	
FHJ13	4.00	2.07	6.07	C	6																	
FHJ13	4.00	2.07	6.07	C	7																	
FHJ13	4.00	2.07	6.07	C	8																	
FHJ13	4.00	2.07	6.07	C	Median C	13.8	37.0															
FHJ13	4.00	2.07	6.07	C	Mean C	13.9	37.7						49.0		17.9							12.37
FHJ13	4.00	2.07	6.07	C	CoeVar C	1.7%	8.1%						#DIV/0!		#DIV/0!							3.4%
FHJ13	4.00	2.07	6.07	D	1											1790.1	1741.3		1753.4	99.3%	102.1%	12.59
FHJ13	4.00	2.07	6.07	E	1											1790.1		1852.7	1753.4	105.7%	102.1%	12.32
FHJ13	4.00	2.07	6.07	D	2											1790.1	1822.1		1753.4	103.9%	102.1%	11.55
FHJ13	4.00	2.07	6.07	E	2											1790.1		1783.4	1753.4	101.7%	102.1%	11.54
FHJ13	4.00	2.07	6.07	DE	Mean DE											1790.1	1781.7	1818.1	1753.4	102.7%		12.00
FHJ13	4.00	2.07	6.07	DE	CoeVar DE												3.2%	2.7%		2.7%		4.5%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	**CGN**	**FGN**	**GN**	**Section**	**Trial**	**E**	**J**	**Force**	**Stress**	**Deflection**	**E**	**Reading**	**DPI**	**3 pt avg**	**E**	**Barrel**	**S cone**	**L cone**	**Proctor**	**Relative cone**	**Relative barrel**	**Oven-dry**
					#	**[J]**	**[mS/cm]**	**[kN]**	**[MPa]**	**[µm]**	**[MPa]**	**[mm]**	**[mm/blow]**	**[mm/blow]**	**[MPa]**	**[kg/m^3]**	**[kg/m^3]**	**[kg/m^3]**	**[kg/m^3]**	**[kg/m^3]**	**[kg/m^3]**	**%**
KLO7	3.85	1.57	5.42	A	Initial							178										
KLO7	3.85	1.57	5.42	A	S1							266	88		9.6							
KLO7	3.85	1.57	5.42	A	S2							302	36		24.8							
KLO7	3.85	1.57	5.42	A	1	8.5	14					332	30	51.3	30.2							7.09
KLO7	3.85	1.57	5.42	A	2	7.5	9					357	25	30.3	36.6							7.19
KLO7	3.85	1.57	5.42	A	3	8.7	14					380	23	26.0	40.0							7.46
KLO7	3.85	1.57	5.42	A	4							400	20	22.7	46.4							
KLO7	3.85	1.57	5.42	A	5							418	18	20.3	51.9							
KLO7	3.85	1.57	5.42	A	6							433	15	17.7	62.9							
KLO7	3.85	1.57	5.42	A	7							447	HIT									
KLO7	3.85	1.57	5.42	A	8																	
KLO7	3.85	1.57	5.42	A	Median A	8.5	14.0															
KLO7	3.85	1.57	5.42	A	Mean A	8.2	12.3						21.8		44.7							7.25
KLO7	3.85	1.57	5.42	A	CoeVar A	7.8%	23.4%						24.5%		26.2%							0.03
KLO7	3.85	1.57	5.42	B	Initial							186										
KLO7	3.85	1.57	5.42	B	S1			3.4	0.108	987	15.2	285	99		8.5							
KLO7	3.85	1.57	5.42	B	S2			3.4	0.108	457	32.8	321	36		24.8							
KLO7	3.85	1.57	5.42	B	1	8.3	13	3.3	0.105	419	34.8	347	26	53.7	35.1							7.34
KLO7	3.85	1.57	5.42	B	2	7.8	14	3.3	0.105	393	37.1	371	24	28.7	38.2							6.58
KLO7	3.85	1.57	5.42	B	3	8.5	16	3.3	0.105	382	38.1	392	21	23.7	44.0							7.48
KLO7	3.85	1.57	5.42	B	4			5.6	0.178	613	40.3	410	18	21.0	51.9							
KLO7	3.85	1.57	5.42	B	5			5.6	0.178	571	43.3	426	16	18.3	58.8							
KLO7	3.85	1.57	5.42	B	6			5.6	0.178	546	45.3	437	HIT									
KLO7	3.85	1.57	5.42	B	7			8	0.255	754	46.8											
KLO7	3.85	1.57	5.42	B	8			7.9	0.251	712	49.0											
KLO7	3.85	1.57	5.42	B	9			7.5	0.239	654	50.6											
KLO7	3.85	1.57	5.42	B	Mean H1			3.30	0.105	398.00	36.65											
KLO7	3.85	1.57	5.42	B	Mean H2			5.60	0.178	576.67	42.95											
KLO7	3.85	1.57	5.42	B	Mean H3			7.80	0.248	706.67	48.80											
KLO7	3.85	1.57	5.42	B	CoeVar H1			0.0%	0.0%	4.8%	4.7%											
KLO7	3.85	1.57	5.42	B	CoeVar H2			0.0%	0.0%	5.9%	5.8%											
KLO7	3.85	1.57	5.42	B	CoeVar H3			3.4%	3.4%	7.1%	3.9%											
KLO7	3.85	1.57	5.42	B	Median B	8.3	14															
KLO7	3.85	1.57	5.42	B	Mean B	8.2	14.3						21.0		45.6							7.13
KLO7	3.85	1.57	5.42	B	CoeVar B	4.4%	10.7%						19.6%		21.4%							6.8%
KLO7	3.85	1.57	5.42	C	Initial							202										
KLO7	3.85	1.57	5.42	C	S1							289	87		9.7							
KLO7	3.85	1.57	5.42	C	S2							327	38		23.5							
KLO7	3.85	1.57	5.42	C	1	7.3	10					353	26	50.3	35.1							7.10
KLO7	3.85	1.57	5.42	C	2	9.4	17					374	21	28.3	44.0							6.79
KLO7	3.85	1.57	5.42	C	3	8.9	17					396	22	23.0	41.9							7.09
KLO7	3.85	1.57	5.42	C	4							412	16	19.7	58.8							
KLO7	3.85	1.57	5.42	C	5							427	15	17.7	62.9							
KLO7	3.85	1.57	5.42	C	6							443	16	15.7	58.8							
KLO7	3.85	1.57	5.42	C	7							454	HIT									
KLO7	3.85	1.57	5.42	C	8																	
KLO7	3.85	1.57	5.42	C	Median C	8.9	17.0															
KLO7	3.85	1.57	5.42	C	Mean C	8.5	14.7						19.3		50.3							6.99
KLO7	3.85	1.57	5.42	C	CoeVar C	12.9%	27.6%						22.6%		22.6%							2.5%
KLO7	3.85	1.57	5.42	D	1											1847.3	1778.3		1862.3	95.5%	99.2%	6.77
KLO7	3.85	1.57	5.42	E	1											1847.3		1773.3	1862.3	95.2%	99.2%	7.00
KLO7	3.85	1.57	5.42	D	2											1847.3	1845.1		1862.3	99.1%	99.2%	6.57
KLO7	3.85	1.57	5.42	E	2											1847.3		1935.4	1862.3	103.9%	99.2%	7.01
KLO7	3.85	1.57	5.42	DE	Mean DE											1847.3	1811.7	1854.4	1862.3	98.4%		6.84
KLO7	3.85	1.57	5.42	DE	CoeVar DE												2.6%	6.2%		4.1%		3.1%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
KLO9	3.85	1.57	5.42	A	Initial							66										
KLO9	3.85	1.57	5.42	A	S1							157	91		9.3							
KLO9	3.85	1.57	5.42	A	S2							193	36		24.8							
KLO9	3.85	1.57	5.42	A	1	8.1	12					219	26	51.0	35.1							8.75
KLO9	3.85	1.57	5.42	A	2	9.9	18					244	25	29.0	36.6							8.53
KLO9	3.85	1.57	5.42	A	3	10.2	23					263	19	23.3	49.0							9.52
KLO9	3.85	1.57	5.42	A	4							282	19	21.0	49.0							
KLO9	3.85	1.57	5.42	A	5							299	17	18.3	55.1							
KLO9	3.85	1.57	5.42	A	6							316	17	17.7	55.1							
KLO9	3.85	1.57	5.42	A	7							329	HIT									
KLO9	3.85	1.57	5.42	A	8																	
KLO9	3.85	1.57	5.42	A	Median A	9.9	18.0															
KLO9	3.85	1.57	5.42	A	Mean A	9.4	17.7						20.5		46.6							8.93
KLO9	3.85	1.57	5.42	A	CoeVar A	12.1%	31.2%						19.5%		18.9%							0.06
KLO9	3.85	1.57	5.42	B	Initial							76										
KLO9	3.85	1.57	5.42	B	S1			3.5	0.111	689	22.4	162	86		9.9							
KLO9	3.85	1.57	5.42	B	S2			3.5	0.111	398	38.8	206	44		20.1							
KLO9	3.85	1.57	5.42	B	1	8.9	20	3.5	0.111	366	42.2	235	29	53.0	31.3							9.55
KLO9	3.85	1.57	5.42	B	2	9.5	25	3.5	0.111	356	43.4	257	22	31.7	41.9							8.72
KLO9	3.85	1.57	5.42	B	3	9.9	23	3.5	0.111	346	44.6	276	19	23.3	49.0							8.86
KLO9	3.85	1.57	5.42	B	4			5.8	0.185	553	46.3	287	11	17.3	87.5							
KLO9	3.85	1.57	5.42	B	5			5.8	0.185	508	50.4	294	HIT									
KLO9	3.85	1.57	5.42	B	6			5.7	0.181	482	52.2											
KLO9	3.85	1.57	5.42	B	7			8.4	0.267	662	56.0											
KLO9	3.85	1.57	5.42	B	8			8.3	0.264	637	57.5											
KLO9	3.85	1.57	5.42	B	9			8.3	0.264	621	59.0											
KLO9	3.85	1.57	5.42	B	Mean H1			3.50	0.111	356.00	43.41											
KLO9	3.85	1.57	5.42	B	Mean H2			5.77	0.184	514.33	49.62											
KLO9	3.85	1.57	5.42	B	Mean H3			8.33	0.265	640.00	57.50											
KLO9	3.85	1.57	5.42	B	CoeVar H1			0.0%	0.0%	2.8%	2.8%											
KLO9	3.85	1.57	5.42	B	CoeVar H2			1.0%	1.0%	7.0%	6.1%											
KLO9	3.85	1.57	5.42	B	CoeVar H3			0.7%	0.7%	3.2%	2.6%											
KLO9	3.85	1.57	5.42	B	Median B	9.5	23															
KLO9	3.85	1.57	5.42	B	Mean B	9.4	22.7						20.3		52.4							9.04
KLO9	3.85	1.57	5.42	B	CoeVar B	5.3%	11.1%						36.8%		46.7%							4.9%
KLO9	3.85	1.57	5.42	C	Initial							76										
KLO9	3.85	1.57	5.42	C	S1							164	88		9.6							
KLO9	3.85	1.57	5.42	C	S2							204	40		22.2							
KLO9	3.85	1.57	5.42	C	1	10.2	27					232	28	52.0	32.4							9.37
KLO9	3.85	1.57	5.42	C	2	10.1	25					253	21	29.7	44.0							8.52
KLO9	3.85	1.57	5.42	C	3	9.8	24					272	19	22.7	49.0							9.24
KLO9	3.85	1.57	5.42	C	4							287	15	18.3	62.9							
KLO9	3.85	1.57	5.42	C	5							303	16	16.7	58.8							
KLO9	3.85	1.57	5.42	C	6							318	15	15.3	62.9							
KLO9	3.85	1.57	5.42	C	7							329	HIT									
KLO9	3.85	1.57	5.42	C	8																	
KLO9	3.85	1.57	5.42	C	Median C	10.1	25.0															
KLO9	3.85	1.57	5.42	C	Mean C	10.0	25.3						19.0		51.7							9.04
KLO9	3.85	1.57	5.42	C	CoeVar C	2.1%	6.0%						26.4%		23.5%							5.1%
KLO9	3.85	1.57	5.42	D	1											1881.3	1829.5		1862.3	98.2%	101.0%	9.05
KLO9	3.85	1.57	5.42	E	1											1881.3		1805.9	1862.3	97.0%	101.0%	8.77
KLO9	3.85	1.57	5.42	D	2											1881.3	1843.1		1862.3	99.0%	101.0%	8.50
KLO9	3.85	1.57	5.42	E	2											1881.3		1901.1	1862.3	102.1%	101.0%	8.60
KLO9	3.85	1.57	5.42	DE	Mean DE											1881.3	1836.3	1853.5	1862.3	99.1%		8.73
KLO9	3.85	1.57	5.42	DE	CoeVar DE												0.5%	3.6%		2.2%		2.8%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
KLO11	3.85	1.57	5.42	A	Initial							205										
KLO11	3.85	1.57	5.42	A	S1							312	107		7.8							
KLO11	3.85	1.57	5.42	A	S2							392	80		10.6							
KLO11	3.85	1.57	5.42	A	1	12.4	27					441	HIT									13.09
KLO11	3.85	1.57	5.42	A	2	13.0	33															12.92
KLO11	3.85	1.57	5.42	A	3	13.5	34															12.60
KLO11	3.85	1.57	5.42	A	4																	
KLO11	3.85	1.57	5.42	A	5																	
KLO11	3.85	1.57	5.42	A	6																	
KLO11	3.85	1.57	5.42	A	7																	
KLO11	3.85	1.57	5.42	A	8																	
KLO11	3.85	1.57	5.42	A	Median A	13.0	33.0															
KLO11	3.85	1.57	5.42	A	Mean A	13.0	31.3															12.87
KLO11	3.85	1.57	5.42	A	CoeVar A	4.2%	12.1%															0.02
KLO11	3.85	1.57	5.42	B	Initial							190										
KLO11	3.85	1.57	5.42	B	S1			overload	na	na	na	283	93		9.1							
KLO11	3.85	1.57	5.42	B	S2			overload	na	na	na	344	61		14.2							
KLO11	3.85	1.57	5.42	B	1	12.6	26	overload	na	na	na	399	55	69.7	15.8							11.95
KLO11	3.85	1.57	5.42	B	2	13.5	36	no read	na	na	na	427	HIT									12.74
KLO11	3.85	1.57	5.42	B	3	13	37	3.2	0.102	2066	6.8											12.68
KLO11	3.85	1.57	5.42	B	4			3.1	0.099	2114	6.5											
KLO11	3.85	1.57	5.42	B	5			3.2	0.102	2001	7.1											
KLO11	3.85	1.57	5.42	B	6			overload	na	na	na											
KLO11	3.85	1.57	5.42	B	7			overload	na	na	na											
KLO11	3.85	1.57	5.42	B	8			5.4	0.172	2060	11.6											
KLO11	3.85	1.57	5.42	B	9			5.5	0.175	2050	11.8											
KLO11	3.85	1.57	5.42	B	Mean H1			3.20	0.101	2060.33	6.79											
KLO11	3.85	1.57	5.42	B	Mean H2			5.45	0.17	2055.00	11.70											
KLO11	3.85	1.57	5.42	B	Mean H3			na	na	na	na											
KLO11	3.85	1.57	5.42	B	CoeVar H1			1.8%	1.8%	2.8%	4.4%											
KLO11	3.85	1.57	5.42	B	CoeVar H2			1.3%	1.3%	0.3%	1.6%											
KLO11	3.85	1.57	5.42	B	CoeVar H3			na	na	na	na											
KLO11	3.85	1.57	5.42	B	Median B	13.0	36.0															
KLO11	3.85	1.57	5.42	B	Mean B	13.0	33.0						55.0		15.8							12.46
KLO11	3.85	1.57	5.42	B	CoeVar B	3.5%	18.4%						#DIV/0!		#DIV/0!							3.5%
KLO11	3.85	1.57	5.42	C	Initial							190										
KLO11	3.85	1.57	5.42	C	S1							282	92		9.2							
KLO11	3.85	1.57	5.42	C	S2							343	61		14.2							
KLO11	3.85	1.57	5.42	C	1	12.5	31					394	51	68.0	17.2							11.39
KLO11	3.85	1.57	5.42	C	2	14.1	37					432	HIT									10.86
KLO11	3.85	1.57	5.42	C	3	13.4	32															11.14
KLO11	3.85	1.57	5.42	C	4																	
KLO11	3.85	1.57	5.42	C	5																	
KLO11	3.85	1.57	5.42	C	6																	
KLO11	3.85	1.57	5.42	C	7																	
KLO11	3.85	1.57	5.42	C	8																	
KLO11	3.85	1.57	5.42	C	Median C	13.0	34.5															
KLO11	3.85	1.57	5.42	C	Mean C	13.0	34.5						51.0		17.2							11.13
KLO11	3.85	1.57	5.42	C	CoeVar C	0.2%	6.1%						#DIV/0!		#DIV/0!							2.4%
KLO11	3.85	1.57	5.42	D	1											1868.6	1841.0		1862.3	98.9%	100.3%	12.05
KLO11	3.85	1.57	5.42	E	1											1868.6		1870.4	1862.3	100.4%	100.3%	12.04
KLO11	3.85	1.57	5.42	D	2											1868.6	1921.1		1862.3	103.2%	100.3%	11.49
KLO11	3.85	1.57	5.42	E	2											1868.6		1888.8	1862.3	101.4%	100.3%	11.25
KLO11	3.85	1.57	5.42	DE	Mean DE											1868.6	1881.0	1879.6	1862.3	101.0%		11.71
KLO11	3.85	1.57	5.42	DE	CoeVar DE												3.0%	0.7%		1.8%		3.4%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
KLO10	3.85	1.57	5.42	A	Initial							62										
KLO10	3.85	1.57	5.42	A	S1							137	75		11.4							
KLO10	3.85	1.57	5.42	A	S2							183	46		19.2							
KLO10	3.85	1.57	5.42	A	1	9.1	19					218	35	52.0	25.6							11.00
KLO10	3.85	1.57	5.42	A	2	9.2	26					246	28	36.3	32.4							10.62
KLO10	3.85	1.57	5.42	A	3	9.6	31					270	24	29.0	38.2							10.39
KLO10	3.85	1.57	5.42	A	4							289	19	23.7	49.0							
KLO10	3.85	1.57	5.42	A	5							308	19	20.7	49.0							
KLO10	3.85	1.57	5.42	A	6							325	HIT									
KLO10	3.85	1.57	5.42	A	7																	
KLO10	3.85	1.57	5.42	A	8																	
KLO10	3.85	1.57	5.42	A	Median A	9.2	26.0															
KLO10	3.85	1.57	5.42	A	Mean A	9.3	25.3						25.0		38.8							10.67
KLO10	3.85	1.57	5.42	A	CoeVar A	2.8%	23.8%						27.0%		26.4%							0.03
KLO10	3.85	1.57	5.42	B	Initial							69										
KLO10	3.85	1.57	5.42	B	S1			2.8	0.089	961	12.9	145	76		11.2							
KLO10	3.85	1.57	5.42	B	S2			3.3	0.105	597	24.4	190	45		19.6							
KLO10	3.85	1.57	5.42	B	1	9.6	31	3.3	0.105	571	25.5	224	34	51.7	26.4							10.36
KLO10	3.85	1.57	5.42	B	2	9.9	26	3.3	0.105	572	25.5	253	29	36.0	31.3							10.83
KLO10	3.85	1.57	5.42	B	3	9.7	33	3.3	0.105	548	26.6	277	24	29.0	38.2							10.87
KLO10	3.85	1.57	5.42	B	4			5.4	0.172	653	36.5	298	21	24.7	44.0							
KLO10	3.85	1.57	5.42	B	5			5.3	0.169	743	31.5	315	17	20.7	55.1							
KLO10	3.85	1.57	5.42	B	6			5.4	0.172	725	32.9	329	HIT									
KLO10	3.85	1.57	5.42	B	7			7.9	0.251	871	40.0											
KLO10	3.85	1.57	5.42	B	8			7.9	0.251	844	41.3											
KLO10	3.85	1.57	5.42	B	9			8.1	0.258	829	43.1											
KLO10	3.85	1.57	5.42	B	Mean H1			3.30	0.105	563.67	25.85											
KLO10	3.85	1.57	5.42	B	Mean H2			5.37	0.171	707.00	33.62											
KLO10	3.85	1.57	5.42	B	Mean H3			7.97	0.254	848.00	41.49											
KLO10	3.85	1.57	5.42	B	CoeVar H1			0.0%	0.0%	2.4%	2.4%											
KLO10	3.85	1.57	5.42	B	CoeVar H2			1.1%	1.1%	6.7%	7.7%											
KLO10	3.85	1.57	5.42	B	CoeVar H3			1.4%	1.4%	2.5%	3.7%											
KLO10	3.85	1.57	5.42	B	Median B	9.7	31															
KLO10	3.85	1.57	5.42	B	Mean B	9.7	30.0						25.0		39.0							10.69
KLO10	3.85	1.57	5.42	B	CoeVar B	1.6%	12.0%						26.7%		28.8%							2.6%
KLO10	3.85	1.57	5.42	C	Initial							67										
KLO10	3.85	1.57	5.42	C	S1							130	63		13.7							
KLO10	3.85	1.57	5.42	C	S2							176	46		19.2							
KLO10	3.85	1.57	5.42	C	1	9.8	27					207	31	46.7	29.1							10.49
KLO10	3.85	1.57	5.42	C	2	9.4	26					235	28	35.0	32.4							10.26
KLO10	3.85	1.57	5.42	C	3	10.2	25					258	23	27.3	40.0							10.93
KLO10	3.85	1.57	5.42	C	4							279	21	24.0	44.0							
KLO10	3.85	1.57	5.42	C	5							297	18	20.7	51.9							
KLO10	3.85	1.57	5.42	C	6							313	16	18.3	58.8							
KLO10	3.85	1.57	5.42	C	7							326	HIT									
KLO10	3.85	1.57	5.42	C	8																	
KLO10	3.85	1.57	5.42	C	Median C	9.8	26.0															
KLO10	3.85	1.57	5.42	C	Mean C	9.8	26.0						22.8		42.7							10.56
KLO10	3.85	1.57	5.42	C	CoeVar C	4.1%	3.8%						25.3%		26.5%							3.2%
KLO10	3.85	1.57	5.42	D	1											1915.5	1843.12		1862.29	99.0%	102.9%	10.39
KLO10	3.85	1.57	5.42	E	1											1915.5		1842.6	1862.3	98.9%	102.9%	10.36
KLO10	3.85	1.57	5.42	D	2											1915.5	1937.59		1862.3	104.0%	102.9%	9.73
KLO10	3.85	1.57	5.42	E	2											1915.5		1949.6	1862.3	104.7%	102.9%	9.97
KLO10	3.85	1.57	5.42	DE	Mean DE											1915.5	1890.4	1896.1	1862.3	101.7%		10.11
KLO10	3.85	1.57	5.42	DE	CoeVar DE												3.5%	4.0%		3.1%		3.1%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
FHJ11X.5	4.00	2.07	6.07	A	Initial							177										
FHJ11X.5	4.00	2.07	6.07	A	S1							264	87		9.7							
FHJ11X.5	4.00	2.07	6.07	A	S2							310	46		19.2							
FHJ11X.5	4.00	2.07	6.07	A	1	11.3	27					352	42	58.3	21.1							11.49
FHJ11X.5	4.00	2.07	6.07	A	2	11.4	27					384	32	40.0	28.2							10.40
FHJ11X.5	4.00	2.07	6.07	A	3	10.9	28					410	26	33.3	35.1							10.79
FHJ11X.5	4.00	2.07	6.07	A	4							433	23	27.0	40.0							
FHJ11X.5	4.00	2.07	6.07	A	5							454	21	23.3	44.0							
FHJ11X.5	4.00	2.07	6.07	A	6							463	HIT									
FHJ11X.5	4.00	2.07	6.07	A	7																	
FHJ11X.5	4.00	2.07	6.07	A	8																	
FHJ11X.5	4.00	2.07	6.07	A	Median A	11.3	27.0															
FHJ11X.5	4.00	2.07	6.07	A	Mean A	11.2	27.3						28.8		33.7							10.89
FHJ11X.5	4.00	2.07	6.07	A	CoeVar A	2.4%	2.1%						29.4%		27.3%							0.05
FHJ11X.5	4.00	2.07	6.07	B	Initial							178										
FHJ11X.5	4.00	2.07	6.07	B	S1			overload	#VALUE!		#VALUE!	268	90		9.4							
FHJ11X.5	4.00	2.07	6.07	B	S2			3.4	0.108	704	21.3	317	49		17.9							
FHJ11X.5	4.00	2.07	6.07	B	1	10.7	27	3.4	0.108	541	27.7	357	40	59.7	22.2							11.62
FHJ11X.5	4.00	2.07	6.07	B	2	11.4	27	3.4	0.108	493	30.4	390	33	40.7	27.3							11.68
FHJ11X.5	4.00	2.07	6.07	B	3	10.9	25	3.4	0.108	451	33.3	417	27	33.3	33.7							12.86
FHJ11X.5	4.00	2.07	6.07	B	4			5.6	0.178	789	31.3	444	27	29.0	33.7							
FHJ11X.5	4.00	2.07	6.07	B	5			5.7	0.181	685	36.7	462	HIT									
FHJ11X.5	4.00	2.07	6.07	B	6			5.7	0.181	635	39.6											
FHJ11X.5	4.00	2.07	6.07	B	7			8.2	0.261	892	40.6											
FHJ11X.5	4.00	2.07	6.07	B	8			8.1	0.258	806	44.4											
FHJ11X.5	4.00	2.07	6.07	B	9			8.1	0.258	761	47.0											
FHJ11X.5	4.00	2.07	6.07	B	Mean H1			3.40	0.108	495.00	30.48											
FHJ11X.5	4.00	2.07	6.07	B	Mean H2			5.67	0.180	703.00	35.89											
FHJ11X.5	4.00	2.07	6.07	B	Mean H3			8.13	0.259	819.67	43.96											
FHJ11X.5	4.00	2.07	6.07	B	CoeVar H1			0.0%	0.0%	9.1%	9.1%											
FHJ11X.5	4.00	2.07	6.07	B	CoeVar H2			1.0%	1.0%	11.2%	11.7%											
FHJ11X.5	4.00	2.07	6.07	B	CoeVar H3			0.7%	0.7%	8.1%	7.3%											
FHJ11X.5	4.00	2.07	6.07	B	Median B	10.9	27															
FHJ11X.5	4.00	2.07	6.07	B	Mean B	11.0	26.3						31.8		29.2							12.06
FHJ11X.5	4.00	2.07	6.07	B	CoeVar B	3.3%	4.4%						19.5%		19.1%							5.8%
FHJ11X.5	4.00	2.07	6.07	C	Initial							180										
FHJ11X.5	4.00	2.07	6.07	C	S1							267	87		9.7							
FHJ11X.5	4.00	2.07	6.07	C	S2							318	51		17.2							
FHJ11X.5	4.00	2.07	6.07	C	1	11.7	35					358	40	59.3	22.2							11.54
FHJ11X.5	4.00	2.07	6.07	C	2	11.3	36					390	32	41.0	28.2							11.24
FHJ11X.5	4.00	2.07	6.07	C	3	11.0	32					417	27	33.0	33.7							11.93
FHJ11X.5	4.00	2.07	6.07	C	4							440	23	27.3	40.0							
FHJ11X.5	4.00	2.07	6.07	C	5							462	HIT									
FHJ11X.5	4.00	2.07	6.07	C	6																	
FHJ11X.5	4.00	2.07	6.07	C	7																	
FHJ11X.5	4.00	2.07	6.07	C	8																	
FHJ11X.5	4.00	2.07	6.07	C	Median C	11.3	35.0															
FHJ11X.5	4.00	2.07	6.07	C	Mean C	11.3	34.3						30.5		31.0							11.57
FHJ11X.5	4.00	2.07	6.07	C	CoeVar C	3.1%	6.1%						24.0%		24.5%							3.0%
FHJ11X.5	4.00	2.07	6.07	D	1											1772.5	1782.0		1753.4	101.6%	101.1%	10.58
FHJ11X.5	4.00	2.07	6.07	E	1											1772.5		1792.3	1753.4	102.2%	101.1%	11.19
FHJ11X.5	4.00	2.07	6.07	D	2											1772.5	1801.0		1753.4	102.7%	101.1%	11.23
FHJ11X.5	4.00	2.07	6.07	E	2											1772.5		1857.6	1753.4	105.9%	101.1%	11.05
FHJ11X.5	4.00	2.07	6.07	DE	Mean DE											1772.5	1791.5	1825.0	1753.4	103.1%		11.01
FHJ11X.5	4.00	2.07	6.07	DE	CoeVar DE												0.7%	2.5%		1.9%		2.7%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
FHJ8X2	4.00	2.07	6.07	A	Initial							69										
FHJ8X2	4.00	2.07	6.07	A	S1							131	62		14.0							
FHJ8X2	4.00	2.07	6.07	A	S2							167	36		24.8							
FHJ8X2	4.00	2.07	6.07	A	1	9.5	37					189	22	40.0	41.9							7.86
FHJ8X2	4.00	2.07	6.07	A	2	9.2	33					208	19	25.7	49.0							7.85
FHJ8X2	4.00	2.07	6.07	A	3	9.8	38					225	17	19.3	55.1							8.20
FHJ8X2	4.00	2.07	6.07	A	4							242	17	17.7	55.1							
FHJ8X2	4.00	2.07	6.07	A	5							258	16	16.7	58.8							
FHJ8X2	4.00	2.07	6.07	A	6							273	15	16.0	62.9							
FHJ8X2	4.00	2.07	6.07	A	7							288	15	15.3	62.9							
FHJ8X2	4.00	2.07	6.07	A	8							300	12	14.0	79.8							
FHJ8X2	4.00	2.07	6.07	A	9							311	11	12.7	87.5							
FHJ8X2	4.00	2.07	6.07	A	10							321	10	11.0	96.8							
FHJ8X2	4.00	2.07	6.07	A	11							330	HIT									
FHJ8X2	4.00	2.07	6.07	A	Median A	9.5	37.0															
FHJ8X2	4.00	2.07	6.07	A	Mean A	9.5	36.0						15.4		65.0							7.97
FHJ8X2	4.00	2.07	6.07	A	CoeVar A	3.2%	7.3%						23.9%		27.0%							0.02
FHJ8X2	4.00	2.07	6.07	B	Initial							58										
FHJ8X2	4.00	2.07	6.07	B	S1			3.5	0.111	142	108.8	143	85		10.0							
FHJ8X2	4.00	2.07	6.07	B	S2			3.6	0.115	238	66.8	179	36		24.8							
FHJ8X2	4.00	2.07	6.07	B	1	9.7	35	3.6	0.115	229	69.4	208	29	50.0	31.3							8.45
FHJ8X2	4.00	2.07	6.07	B	2	10.2	44	3.5	0.111	218	70.9	224	16	27.0	58.8							8.05
FHJ8X2	4.00	2.07	6.07	B	3	10.1	36	3.6	0.115	206	77.1	243	19	21.3	49.0							8.03
FHJ8X2	4.00	2.07	6.07	B	4			5.6	0.178	357	69.2	260	17	17.3	55.1							
FHJ8X2	4.00	2.07	6.07	B	5			5.5	0.175	353	68.8	275	15	17.0	62.9							
FHJ8X2	4.00	2.07	6.07	B	6			5.5	0.175	348	69.7	289	14	15.3	67.7							
FHJ8X2	4.00	2.07	6.07	B	7			8.4	0.267	468	79.2	301	12	13.7	79.8							
FHJ8X2	4.00	2.07	6.07	B	8			8.3	0.264	462	79.3	314	13	13.0	73.3							
FHJ8X2	4.00	2.07	6.07	B	9			8.3	0.264	442	82.9	325	11	12.0	87.5							
FHJ8X2	4.00	2.07	6.07	B	10							334	HIT									
FHJ8X2	4.00	2.07	6.07	B	Mean H1			3.57	0.114	217.67	72.45											
FHJ8X2	4.00	2.07	6.07	B	Mean H2			5.53	0.176	352.67	69.25											
FHJ8X2	4.00	2.07	6.07	B	Mean H3			8.33	0.265	457.33	80.46											
FHJ8X2	4.00	2.07	6.07	B	CoeVar H1			1.6%	1.6%	5.3%	5.7%											
FHJ8X2	4.00	2.07	6.07	B	CoeVar H2			1.0%	1.0%	1.3%	0.7%											
FHJ8X2	4.00	2.07	6.07	B	CoeVar H3			0.7%	0.7%	3.0%	2.6%											
FHJ8X2	4.00	2.07	6.07	B	Median B	10.1	36															
FHJ8X2	4.00	2.07	6.07	B	Mean B	10.0	38.3					271.0	16.2		62.8							8.18
FHJ8X2	4.00	2.07	6.07	B	CoeVar B	2.6%	12.9%					14.9%	33.3%		27.0%							2.9%
FHJ8X2	4.00	2.07	6.07	C	Initial							59										
FHJ8X2	4.00	2.07	6.07	C	S1							139	80		10.6							
FHJ8X2	4.00	2.07	6.07	C	S2							174	35		25.6							
FHJ8X2	4.00	2.07	6.07	C	1	10.1	41					199	25	46.7	36.6							8.26
FHJ8X2	4.00	2.07	6.07	C	2	10.3	44					218	19	26.3	49.0							7.86
FHJ8X2	4.00	2.07	6.07	C	3	9.9	38					236	18	20.7	51.9							8.00
FHJ8X2	4.00	2.07	6.07	C	4							251	15	17.3	62.9							
FHJ8X2	4.00	2.07	6.07	C	5							266	15	16.0	62.9							
FHJ8X2	4.00	2.07	6.07	C	6							279	13	14.3	73.3							
FHJ8X2	4.00	2.07	6.07	C	7							291	12	13.3	79.8							
FHJ8X2	4.00	2.07	6.07	C	8							302	11	12.0	87.5							
FHJ8X2	4.00	2.07	6.07	C	9							313	11	11.3	87.5							
FHJ8X2	4.00	2.07	6.07	C	10							323	10	10.7	96.8							
FHJ8X2	4.00	2.07	6.07	C	11							332	HIT									
FHJ8X2	4.00	2.07	6.07	C	Median C	10.1	41.0															
FHJ8X2	4.00	2.07	6.07	C	Mean C	10.1	41.0						14.9		68.8							8.04
FHJ8X2	4.00	2.07	6.07	C	CoeVar C	2.0%	7.3%						31.2%		28.3%							2.5%
FHJ8X2	4.00	2.07	6.07	D	1											1839.3	1751.48		1753.4	99.9%	104.9%	8.01
FHJ8X2	4.00	2.07	6.07	E	1											1839.3		1822.2	1753.4	103.9%	104.9%	7.89
FHJ8X2	4.00	2.07	6.07	D	2											1839.3	1870.60		1753.4	106.7%	104.9%	8.27
FHJ8X2	4.00	2.07	6.07	E	2											1839.3		1930.4	1753.4	110.1%	104.9%	8.03
FHJ8X2	4.00	2.07	6.07	DE	Mean DE											1839.3	1811.0	1876.3	1753.4	105.1%		8.05
FHJ8X2	4.00	2.07	6.07	DE	CoeVar DE												4.7%	4.1%		4.1%		2.0%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
KLO8X1.5	3.85	1.57	5.42	A	Initial							180										
KLO8X1.5	3.85	1.57	5.42	A	S1							249	69		12.5							
KLO8X1.5	3.85	1.57	5.42	A	S2							280	31		29.1							
KLO8X1.5	3.85	1.57	5.42	A	1	9.1	25					303	23	41.0	40.0							7.89
KLO8X1.5	3.85	1.57	5.42	A	2	8.7	24					323	20	24.7	46.4							7.79
KLO8X1.5	3.85	1.57	5.42	A	3	9.3	32					341	18	20.3	51.9							7.92
KLO8X1.5	3.85	1.57	5.42	A	4							356	15	17.7	62.9							
KLO8X1.5	3.85	1.57	5.42	A	5							371	15	16.0	62.9							
KLO8X1.5	3.85	1.57	5.42	A	6							386	15	15.0	62.9							
KLO8X1.5	3.85	1.57	5.42	A	7							398	12	14.0	79.8							
KLO8X1.5	3.85	1.57	5.42	A	8							410	12	13.0	79.8							
KLO8X1.5	3.85	1.57	5.42	A	9							420	10	11.3	96.8							
KLO8X1.5	3.85	1.57	5.42	A	10							430	10	10.7	96.8							
KLO8X1.5	3.85	1.57	5.42	A	11							440	HIT									
KLO8X1.5	3.85	1.57	5.42	A	Median A	9.1	25.0															
KLO8X1.5	3.85	1.57	5.42	A	Mean A	9.0	27.0						15.0		68.0							7.87
KLO8X1.5	3.85	1.57	5.42	A	CoeVar A	3.4%	16.1%						28.6%		29.1%							0.01
KLO8X1.5	3.85	1.57	5.42	B	Initial							179										
KLO8X1.5	3.85	1.57	5.42	B	S1			3.5	0.111	858	18.0	247	68		12.6							
KLO8X1.5	3.85	1.57	5.42	B	S2			3.6	0.115	307	51.8	281	34		26.4							
KLO8X1.5	3.85	1.57	5.42	B	1	9.1	27	3.6	0.115	281	56.5	306	25	42.3	36.6							8.39
KLO8X1.5	3.85	1.57	5.42	B	2	9.4	32	3.5	0.111	269	57.4	326	20	26.3	46.4							7.74
KLO8X1.5	3.85	1.57	5.42	B	3	9.2	30	3.5	0.111	258	59.9	343	17	20.7	55.1							8.05
KLO8X1.5	3.85	1.57	5.42	B	4			5.8	0.185	467	54.8	360	17	18.0	55.1							
KLO8X1.5	3.85	1.57	5.42	B	5			5.9	0.188	412	63.2	374	14	16.0	67.7							
KLO8X1.5	3.85	1.57	5.42	B	6			5.9	0.188	398	65.4	388	14	15.0	67.7							
KLO8X1.5	3.85	1.57	5.42	B	7			8.3	0.264	580	63.2	399	11	13.0	87.5							
KLO8X1.5	3.85	1.57	5.42	B	8			8.4	0.267	549	67.5	410	11	12.0	87.5							
KLO8X1.5	3.85	1.57	5.42	B	9			8.3	0.264	521	70.3	420	10	10.7	96.8							
KLO8X1.5	3.85	1.57	5.42	B	10							431	11	10.7	87.5							
KLO8X1.5	3.85	1.57	5.42	B	11							441	HIT									
KLO8X1.5	3.85	1.57	5.42	B	Mean H1			3.53	0.112	269.33	57.94											
KLO8X1.5	3.85	1.57	5.42	B	Mean H2			5.87	0.187	425.67	61.14											
KLO8X1.5	3.85	1.57	5.42	B	Mean H3			8.33	0.265	550.00	67.00											
KLO8X1.5	3.85	1.57	5.42	B	CoeVar H1			1.6%	1.6%	4.3%	3.0%											
KLO8X1.5	3.85	1.57	5.42	B	CoeVar H2			1.0%	1.0%	8.6%	9.2%											
KLO8X1.5	3.85	1.57	5.42	B	CoeVar H3			0.7%	0.7%	5.4%	5.4%											
KLO8X1.5	3.85	1.57	5.42	B	Median B	9.2	30															
KLO8X1.5	3.85	1.57	5.42	B	Mean B	9.2	29.7						15.0		68.8							8.06
KLO8X1.5	3.85	1.57	5.42	B	CoeVar B	1.7%	8.5%						32.0%		29.7%							4.0%
KLO8X1.5	3.85	1.57	5.42	C	Initial							180										
KLO8X1.5	3.85	1.57	5.42	C	S1							247	67		12.9							
KLO8X1.5	3.85	1.57	5.42	C	S2							280	33		27.3							
KLO8X1.5	3.85	1.57	5.42	C	1	9.2	30					302	22	40.7	41.9							8.10
KLO8X1.5	3.85	1.57	5.42	C	2	9.5	30					321	19	24.7	49.0							7.89
KLO8X1.5	3.85	1.57	5.42	C	3	9.9	34					336	15	18.7	62.9							7.71
KLO8X1.5	3.85	1.57	5.42	C	4							351	15	16.3	62.9							
KLO8X1.5	3.85	1.57	5.42	C	5							365	14	14.7	67.7							
KLO8X1.5	3.85	1.57	5.42	C	6							379	14	14.3	67.7							
KLO8X1.5	3.85	1.57	5.42	C	7							390	11	13.0	87.5							
KLO8X1.5	3.85	1.57	5.42	C	8							400	10	11.7	96.8							
KLO8X1.5	3.85	1.57	5.42	C	9							410	10	10.3	96.8							
KLO8X1.5	3.85	1.57	5.42	C	10							420	10	10.0	96.8							
KLO8X1.5	3.85	1.57	5.42	C	11							430	10	10.0	96.8							
KLO8X1.5	3.85	1.57	5.42	C	Median C	9.5	30.0															
KLO8X1.5	3.85	1.57	5.42	C	Mean C	9.5	31.3						13.6		75.2							7.90
KLO8X1.5	3.85	1.57	5.42	C	CoeVar C	3.7%	7.4%						29.6%		27.3%							2.5%
KLO8X1.5	3.85	1.57	5.42	D	1											1962.8	1890.1		1862.3	101.5%	105.4%	8.19
KLO8X1.5	3.85	1.57	5.42	E	1											1962.8		2003.6	1862.3	107.6%	105.4%	7.87
KLO8X1.5	3.85	1.57	5.42	D	2											1962.8	2001.1		1862.3	107.5%	105.4%	7.80
KLO8X1.5	3.85	1.57	5.42	E	2											1962.8		2028.2	1862.3	108.9%	105.4%	7.77
KLO8X1.5	3.85	1.57	5.42	DE	Mean DE											1962.8	1945.6	2015.9	1862.3	106.4%		7.91
KLO8X1.5	3.85	1.57	5.42	DE	CoeVar DE												4.0%	0.9%		3.1%		2.4%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	**CGN**	**FGN**	**GN**	**Section**	**Trial**	**E**	**J**	**Force**	**Stress**	**Deflection**	**E**	**Reading**	**DPI**	**3 pt avg**	**E**	**Barrel**	**S cone**	**L cone**	**Proctor**	**Relative cone**	**Relative barrel**	**Oven-dry**
					#	**[J]**	**[mS/cm]**	**[kN]**	**[MPa]**	**[μm]**	**[MPa]**	**[mm]**	**[mm/blow]**	**[mm/blow]**	**[MPa]**	**[kg/m^3]**	**[kg/m^3]**	**[kg/m^3]**	**[kg/m^3]**	**[kg/m^3]**	**[kg/m^3]**	**%**
FHJ8X4/3	4.00	2.07	6.07	A	Initial							61										
FHJ8X4/3	4.00	2.07	6.07	A	S1							143	82		10.4							
FHJ8X4/3	4.00	2.07	6.07	A	S2							181	38		23.5							
FHJ8X4/3	4.00	2.07	6.07	A	1	7.5	24					208	27	49.0	33.7							7.88
FHJ8X4/3	4.00	2.07	6.07	A	2	7.5	20					231	23	29.3	40.0							8.09
FHJ8X4/3	4.00	2.07	6.07	A	3	7.7	21					250	19	23.0	49.0							7.68
FHJ8X4/3	4.00	2.07	6.07	A	4							268	18	20.0	51.9							
FHJ8X4/3	4.00	2.07	6.07	A	5							284	16	17.7	58.8							
FHJ8X4/3	4.00	2.07	6.07	A	6							298	14	16.0	67.7							
FHJ8X4/3	4.00	2.07	6.07	A	7							311	13	14.3	73.3							
FHJ8X4/3	4.00	2.07	6.07	A	8							325	14	13.7	67.7							
FHJ8X4/3	4.00	2.07	6.07	A	Median A	7.5	21.0															
FHJ8X4/3	4.00	2.07	6.07	A	Mean A	7.6	21.7						18.0		55.3							7.88
FHJ8X4/3	4.00	2.07	6.07	A	CoeVar A	1.5%	9.6%						27.2%		25.6%							0.03
FHJ8X4/3	4.00	2.07	6.07	B	Initial							56										
FHJ8X4/3	4.00	2.07	6.07	B	S1			3.5	0.111	1266	12.2	145	89		9.5							
FHJ8X4/3	4.00	2.07	6.07	B	S2			3.6	0.115	333	47.7	183	38		23.5							
FHJ8X4/3	4.00	2.07	6.07	B	1	8	24	3.6	0.115	320	49.6	210	27	51.3	33.7							7.99
FHJ8X4/3	4.00	2.07	6.07	B	2	7.5	28	3.6	0.115	294	54.0	230	20	28.3	46.4							8.06
FHJ8X4/3	4.00	2.07	6.07	B	3	7.7	28	3.6	0.115	295	53.9	250	20	22.3	46.4							8.02
FHJ8X4/3	4.00	2.07	6.07	B	4			5.7	0.181	540	46.6	266	16	18.7	58.8							
FHJ8X4/3	4.00	2.07	6.07	B	5			5.8	0.185	468	54.7	281	15	17.0	62.9							
FHJ8X4/3	4.00	2.07	6.07	B	6			5.9	0.188	441	59.0	296	15	15.3	62.9							
FHJ8X4/3	4.00	2.07	6.07	B	7			8.2	0.261	637	56.8	309	13	14.3	73.3							
FHJ8X4/3	4.00	2.07	6.07	B	8			8.5	0.271	574	65.4	320	11	13.0	87.5							
FHJ8X4/3	4.00	2.07	6.07	B	9			8.6	0.274	548	69.3	330	10	11.3	96.8							
FHJ8X4/3	4.00	2.07	6.07	B	Mean H1			3.60	0.115	303.00	52.51											
FHJ8X4/3	4.00	2.07	6.07	B	Mean H2			5.80	0.185	483.00	53.44											
FHJ8X4/3	4.00	2.07	6.07	B	Mean H3			8.43	0.268	586.33	63.81											
FHJ8X4/3	4.00	2.07	6.07	B	CoeVar H1			0.0%	0.0%	4.9%	4.7%											
FHJ8X4/3	4.00	2.07	6.07	B	CoeVar H2			1.7%	1.7%	10.6%	11.8%											
FHJ8X4/3	4.00	2.07	6.07	B	CoeVar H3			2.5%	2.5%	7.8%	10.0%											
FHJ8X4/3	4.00	2.07	6.07	B	Median B	7.7	28															
FHJ8X4/3	4.00	2.07	6.07	B	Mean B	7.7	26.7						16.3		63.2							8.02
FHJ8X4/3	4.00	2.07	6.07	B	CoeVar B	3.3%	8.7%						32.4%		32.0%							0.4%
FHJ8X4/3	4.00	2.07	6.07	C	Initial							55										
FHJ8X4/3	4.00	2.07	6.07	C	S1							137	82		10.4							
FHJ8X4/3	4.00	2.07	6.07	C	S2							174	37		24.1							
FHJ8X4/3	4.00	2.07	6.07	C	1	8.0	23					200	26	48.3	35.1							8.00
FHJ8X4/3	4.00	2.07	6.07	C	2	7.3	19					220	20	27.7	46.4							7.92
FHJ8X4/3	4.00	2.07	6.07	C	3	8.2	30					239	19	21.7	49.0							8.05
FHJ8X4/3	4.00	2.07	6.07	C	4							256	17	18.7	55.1							
FHJ8X4/3	4.00	2.07	6.07	C	5							271	15	17.0	62.9							
FHJ8X4/3	4.00	2.07	6.07	C	6							285	14	15.3	67.7							
FHJ8X4/3	4.00	2.07	6.07	C	7							298	13	14.0	73.3							
FHJ8X4/3	4.00	2.07	6.07	C	8							310	12	13.0	79.8							
FHJ8X4/3	4.00	2.07	6.07	C	9							321	11	12.0	87.5							
FHJ8X4/3	4.00	2.07	6.07	C	10							330	9	10.7	108.3							
FHJ8X4/3	4.00	2.07	6.07	C	11							336	HIT									
FHJ8X4/3	4.00	2.07	6.07	C	Median C	8.0	23.0															
FHJ8X4/3	4.00	2.07	6.07	C	Mean C	7.8	24.0						15.6		66.5							7.99
FHJ8X4/3	4.00	2.07	6.07	C	CoeVar C	6.0%	23.2%						32.3%		32.7%							0.8%
FHJ8X4/3	4.00	2.07	6.07	D	1											1945.3	1810.2		1753.4	103.2%	110.9%	7.66
FHJ8X4/3	4.00	2.07	6.07	E	1											1945.3		1867.8	1753.4	106.5%	110.9%	8.14
FHJ8X4/3	4.00	2.07	6.07	D	2											1945.3	1891.1		1753.4	107.9%	110.9%	8.02
FHJ8X4/3	4.00	2.07	6.07	E	2											1945.3		1876.9	1753.4	107.0%	110.9%	8.08
FHJ8X4/3	4.00	2.07	6.07	DE	Mean DE											1945.3	1850.7	1872.3	1753.4	106.2%		7.97
FHJ8X4/3	4.00	2.07	6.07	DE	CoeVar DE												3.1%	0.3%		1.9%		2.7%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
KLO9X.5	3.85	1.57	5.42	A	Initial							185										
KLO9X.5	3.85	1.57	5.42	A	S1							272	87		9.7							
KLO9X.5	3.85	1.57	5.42	A	S2							314	42		21.1							
KLO9X.5	3.85	1.57	5.42	A	1	10.4	27					348	34	54.3	26.4							9.10
KLO9X.5	3.85	1.57	5.42	A	2	9.7	28					376	28	34.7	32.4							8.29
KLO9X.5	3.85	1.57	5.42	A	3	10.8	32					401	25	29.0	36.6							8.80
KLO9X.5	3.85	1.57	5.42	A	4							416	15	22.7	62.9							
KLO9X.5	3.85	1.57	5.42	A	5							434	18	19.3	51.9							
KLO9X.5	3.85	1.57	5.42	A	6							449	HIT									
KLO9X.5	3.85	1.57	5.42	A	7																	
KLO9X.5	3.85	1.57	5.42	A	8																	
KLO9X.5	3.85	1.57	5.42	A	9																	
KLO9X.5	3.85	1.57	5.42	A	10																	
KLO9X.5	3.85	1.57	5.42	A	11																	
KLO9X.5	3.85	1.57	5.42	A	Median A	10.4	28.0															
KLO9X.5	3.85	1.57	5.42	A	Mean A	10.3	29.0						24.0		42.1							8.73
KLO9X.5	3.85	1.57	5.42	A	CoeVar A	5.4%	9.1%						31.9%		35.7%							0.05
KLO9X.5	3.85	1.57	5.42	B	Initial							180										
KLO9X.5	3.85	1.57	5.42	B	S1			3.1	0.099	2198	6.2	266	86		9.9							
KLO9X.5	3.85	1.57	5.42	B	S2			3.5	0.111	521	29.6	304	38		23.5							
KLO9X.5	3.85	1.57	5.42	B	1	9.5	27	3.5	0.111	425	36.3	333	29	51.0	31.3							8.81
KLO9X.5	3.85	1.57	5.42	B	2	11.2	37	3.5	0.111	393	39.3	359	26	31.0	35.1							8.82
KLO9X.5	3.85	1.57	5.42	B	3	10.7	30	3.5	0.111	370	41.7	380	21	25.3	44.0							8.94
KLO9X.5	3.85	1.57	5.42	B	4			5.6	0.178	682	36.2	400	20	22.3	46.4							
KLO9X.5	3.85	1.57	5.42	B	5			5.7	0.181	585	43.0	415	15	18.7	62.9							
KLO9X.5	3.85	1.57	5.42	B	6			5.6	0.178	540	45.8	430	15	16.7	62.9							
KLO9X.5	3.85	1.57	5.42	B	7			8.1	0.258	787	45.4	442	HIT									
KLO9X.5	3.85	1.57	5.42	B	8			8.2	0.261	710	51.0											
KLO9X.5	3.85	1.57	5.42	B	9			8.2	0.261	671	53.9											
KLO9X.5	3.85	1.57	5.42	B	10																	
KLO9X.5	3.85	1.57	5.42	B	11																	
KLO9X.5	3.85	1.57	5.42	B	Mean H1			3.50	0.111	396.00	39.13											
KLO9X.5	3.85	1.57	5.42	B	Mean H2			5.63	0.179	602.33	41.67											
KLO9X.5	3.85	1.57	5.42	B	Mean H3			8.17	0.260	722.67	50.11											
KLO9X.5	3.85	1.57	5.42	B	CoeVar H1			0.0%	0.0%	7.0%	6.9%											
KLO9X.5	3.85	1.57	5.42	B	CoeVar H2			1.0%	1.0%	12.0%	11.8%											
KLO9X.5	3.85	1.57	5.42	B	CoeVar H3			0.7%	0.7%	8.2%	8.6%											
KLO9X.5	3.85	1.57	5.42	B	Median B	10.7	30															
KLO9X.5	3.85	1.57	5.42	B	Mean B	10.5	31.3						21.0		47.1							8.86
KLO9X.5	3.85	1.57	5.42	B	CoeVar B	8.3%	16.4%						27.1%		28.6%							0.8%
KLO9X.5	3.85	1.57	5.42	C	Initial							169										
KLO9X.5	3.85	1.57	5.42	C	S1							266	97		8.7							
KLO9X.5	3.85	1.57	5.42	C	S2							306	40		22.2							
KLO9X.5	3.85	1.57	5.42	C	1	10.8	31					335	29	55.3	31.3							9.09
KLO9X.5	3.85	1.57	5.42	C	2	11.0	33					359	24	31.0	38.2							9.06
KLO9X.5	3.85	1.57	5.42	C	3	10.8	24					382	23	25.3	40.0							8.78
KLO9X.5	3.85	1.57	5.42	C	4							400	18	21.7	51.9							
KLO9X.5	3.85	1.57	5.42	C	5							418	18	19.7	51.9							
KLO9X.5	3.85	1.57	5.42	C	6							435	17	17.7	55.1							
KLO9X.5	3.85	1.57	5.42	C	7							443	HIT									
KLO9X.5	3.85	1.57	5.42	C	8																	
KLO9X.5	3.85	1.57	5.42	C	9																	
KLO9X.5	3.85	1.57	5.42	C	10																	
KLO9X.5	3.85	1.57	5.42	C	11																	
KLO9X.5	3.85	1.57	5.42	C	Median C	10.8	31.0															
KLO9X.5	3.85	1.57	5.42	C	Mean C	10.9	29.3						21.5		44.7							8.98
KLO9X.5	3.85	1.57	5.42	C	CoeVar C	1.1%	16.1%						21.8%		21.4%							1.9%
KLO9X.5	3.85	1.57	5.42	D	1											1881.8	1915.6		1862.3	102.9%	101.0%	8.26
KLO9X.5	3.85	1.57	5.42	E	1											1881.8		1911.2	1862.3	102.6%	101.0%	8.89
KLO9X.5	3.85	1.57	5.42	D	2											1881.8	1955.6		1862.3	105.0%	101.0%	9.06
KLO9X.5	3.85	1.57	5.42	E	2											1881.8		1937.5	1862.3	104.0%	101.0%	8.90
KLO9X.5	3.85	1.57	5.42	DE	Mean DE											1881.8	1935.6	1924.3	1862.3	103.6%		8.78
KLO9X.5	3.85	1.57	5.42	DE	CoeVar DE												1.5%	1.0%		1.1%		4.0%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
KLO10X.5	3.85	1.57	5.42	A	Initial							61										
KLO10X.5	3.85	1.57	5.42	A	S1							140	79		10.8							
KLO10X.5	3.85	1.57	5.42	A	S2							183	43		20.6							
KLO10X.5	3.85	1.57	5.42	A	1	11.1	26					217	34	52.0	26.4							9.79
KLO10X.5	3.85	1.57	5.42	A	2	10.0	32					245	28	35.0	32.4							10.21
KLO10X.5	3.85	1.57	5.42	A	3	11.5	36					271	26	29.3	35.1							10.12
KLO10X.5	3.85	1.57	5.42	A	4							294	23	25.7	40.0							
KLO10X.5	3.85	1.57	5.42	A	5							314	20	23.0	46.4							
KLO10X.5	3.85	1.57	5.42	A	6							330	HIT									
KLO10X.5	3.85	1.57	5.42	A	7																	
KLO10X.5	3.85	1.57	5.42	A	8																	
KLO10X.5	3.85	1.57	5.42	A	9																	
KLO10X.5	3.85	1.57	5.42	A	10																	
KLO10X.5	3.85	1.57	5.42	A	11																	
KLO10X.5	3.85	1.57	5.42	A	Median A	11.1	32.0															
KLO10X.5	3.85	1.57	5.42	A	Mean A	10.9	31.3						26.2		36.1							10.04
KLO10X.5	3.85	1.57	5.42	A	CoeVar A	7.1%	16.1%						20.3%		21.0%							0.02
KLO10X.5	3.85	1.57	5.42	B	Initial							69										
KLO10X.5	3.85	1.57	5.42	B	S1			3.2	0.102	1697	8.3	148	79		10.8							
KLO10X.5	3.85	1.57	5.42	B	S2			3.5	0.111	619	25.0	196	48		18.3							
KLO10X.5	3.85	1.57	5.42	B	1	10.1	27	3.5	0.111	553	27.9	231	35	54.0	25.6							10.29
KLO10X.5	3.85	1.57	5.42	B	2	9.9	31	3.5	0.111	485	31.8	260	29	37.3	31.3							11.05
KLO10X.5	3.85	1.57	5.42	B	3	9.5	28	3.4	0.108	477	31.5	287	27	30.3	33.7							10.61
KLO10X.5	3.85	1.57	5.42	B	4			5.8	0.185	686	37.3	305	18	24.7	51.9							
KLO10X.5	3.85	1.57	5.42	B	5			5.6	0.178	635	38.9	324	19	21.3	49.0							
KLO10X.5	3.85	1.57	5.42	B	6			5.6	0.178	634	39.0	333	HIT									
KLO10X.5	3.85	1.57	5.42	B	7			8.1	0.258	842	42.5											
KLO10X.5	3.85	1.57	5.42	B	8			8.1	0.258	762	46.9											
KLO10X.5	3.85	1.57	5.42	B	9			8.2	0.261	732	49.4											
KLO10X.5	3.85	1.57	5.42	B	10																	
KLO10X.5	3.85	1.57	5.42	B	11																	
KLO10X.5	3.85	1.57	5.42	B	Mean H1			3.47	0.110	505.00	30.41											
KLO10X.5	3.85	1.57	5.42	B	Mean H2			5.67	0.180	651.67	38.40											
KLO10X.5	3.85	1.57	5.42	B	Mean H3			8.13	0.259	778.67	46.27											
KLO10X.5	3.85	1.57	5.42	B	CoeVar H1			1.7%	1.7%	8.3%	7.1%											
KLO10X.5	3.85	1.57	5.42	B	CoeVar H2			2.0%	2.0%	4.6%	2.5%											
KLO10X.5	3.85	1.57	5.42	B	CoeVar H3			0.7%	0.7%	7.3%	7.6%											
KLO10X.5	3.85	1.57	5.42	B	Median B	9.9	28															
KLO10X.5	3.85	1.57	5.42	B	Mean B	9.8	28.7						25.6		38.3							10.65
KLO10X.5	3.85	1.57	5.42	B	CoeVar B	3.1%	7.3%						27.8%		30.1%							3.6%
KLO10X.5	3.85	1.57	5.42	C	Initial							68										
KLO10X.5	3.85	1.57	5.42	C	S1							145	77		11.1							
KLO10X.5	3.85	1.57	5.42	C	S2							185	40		22.2							
KLO10X.5	3.85	1.57	5.42	C	1	10.0	36					214	29	48.7	31.3							9.63
KLO10X.5	3.85	1.57	5.42	C	2	11.6	50					242	28	32.3	32.4							11.04
KLO10X.5	3.85	1.57	5.42	C	3	11.4	40					266	24	27.0	38.2							10.81
KLO10X.5	3.85	1.57	5.42	C	4							282	16	22.7	58.8							
KLO10X.5	3.85	1.57	5.42	C	5							297	15	18.3	62.9							
KLO10X.5	3.85	1.57	5.42	C	6							316	19	16.7	49.0							
KLO10X.5	3.85	1.57	5.42	C	7							330	HIT									
KLO10X.5	3.85	1.57	5.42	C	8																	
KLO10X.5	3.85	1.57	5.42	C	9																	
KLO10X.5	3.85	1.57	5.42	C	10																	
KLO10X.5	3.85	1.57	5.42	C	11																	
KLO10X.5	3.85	1.57	5.42	C	Median C	11.4	40.0															
KLO10X.5	3.85	1.57	5.42	C	Mean C	11.0	42.0						21.8		45.4							10.49
KLO10X.5	3.85	1.57	5.42	C	CoeVar C	7.9%	17.2%						27.7%		29.8%							7.2%
KLO10X.5	3.85	1.57	5.42	D	1											1916.3	1906.8		1862.3	102.4%	102.9%	10.31
KLO10X.5	3.85	1.57	5.42	E	1											1916.3		1898.7	1862.3	102.0%	102.9%	10.09
KLO10X.5	3.85	1.57	5.42	D	2											1916.3	1905.6		1862.3	102.3%	102.9%	9.87
KLO10X.5	3.85	1.57	5.42	E	2											1916.3		1945.6	1862.3	104.5%	102.9%	10.23
KLO10X.5	3.85	1.57	5.42	DE	Mean DE											1916.3	1906.2	1922.2	1862.3	102.8%		10.13
KLO10X.5	3.85	1.57	5.42	DE	CoeVar DE												0.0%	1.7%		1.1%		1.9%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
FHJ8X1.125	4.00	2.07	6.07	A	Initial							175										
FHJ8X1.125	4.00	2.07	6.07	A	S1							256	81		10.5							
FHJ8X1.125	4.00	2.07	6.07	A	S2							296	40		22.2							
FHJ8X1.125	4.00	2.07	6.07	A	1	9.9	35					323	27	49.3	33.7							7.57
FHJ8X1.125	4.00	2.07	6.07	A	2	9.2	27					346	23	30.0	40.0							7.32
FHJ8X1.125	4.00	2.07	6.07	A	3	10.0	37					366	20	23.3	46.4							7.53
FHJ8X1.125	4.00	2.07	6.07	A	4							384	18	20.3	51.9							
FHJ8X1.125	4.00	2.07	6.07	A	5							400	16	18.0	58.8							
FHJ8X1.125	4.00	2.07	6.07	A	6							414	14	16.0	67.7							
FHJ8X1.125	4.00	2.07	6.07	A	7							427	13	14.3	73.3							
FHJ8X1.125	4.00	2.07	6.07	A	8							440	13	13.3	73.3							
FHJ8X1.125	4.00	2.07	6.07	A	9							451	11	12.3	87.5							
FHJ8X1.125	4.00	2.07	6.07	A	10							461	10	11.3	96.8							
FHJ8X1.125	4.00	2.07	6.07	A	Median A	9.9	35.0															
FHJ8X1.125	4.00	2.07	6.07	A	Mean A	9.7	33.0						16.5		62.9							7.47
FHJ8X1.125	4.00	2.07	6.07	A	CoeVar A	4.5%	16.0%						33.2%		32.6%							0.02
FHJ8X1.125	4.00	2.07	6.07	B	Initial							171										
FHJ8X1.125	4.00	2.07	6.07	B	S1			3.2	0.102	1444	9.8	252	81		10.5							
FHJ8X1.125	4.00	2.07	6.07	B	S2			3.4	0.108	430	34.9	291	39		22.8							
FHJ8X1.125	4.00	2.07	6.07	B	1	8.9	35	3.4	0.108	367	40.9	316	25	48.3	36.6							7.40
FHJ8X1.125	4.00	2.07	6.07	B	2	9.5	43	3.5	0.111	342	45.2	338	22	28.7	41.9							7.62
FHJ8X1.125	4.00	2.07	6.07	B	3	9.6	42	3.5	0.111	330	46.8	359	21	22.7	44.0							7.93
FHJ8X1.125	4.00	2.07	6.07	B	4			5.7	0.181	630	39.9	376	17	20.0	55.1							
FHJ8X1.125	4.00	2.07	6.07	B	5			5.7	0.181	539	46.7	391	15	17.7	62.9							
FHJ8X1.125	4.00	2.07	6.07	B	6			5.8	0.185	504	50.8	406	15	15.7	62.9							
FHJ8X1.125	4.00	2.07	6.07	B	7			8.1	0.258	758	47.2	418	12	14.0	79.8							
FHJ8X1.125	4.00	2.07	6.07	B	8			8.2	0.261	663	54.6	430	12	13.0	79.8							
FHJ8X1.125	4.00	2.07	6.07	B	9			8.1	0.258	624	57.3	441	11	11.7	87.5							
FHJ8X1.125	4.00	2.07	6.07	B	Mean H1			3.47	0.110	346.33	44.29	452	11	11.3	87.5							
FHJ8X1.125	4.00	2.07	6.07	B	Mean H2			5.73	0.182	557.67	45.80	463	11	11.0	87.5							
FHJ8X1.125	4.00	2.07	6.07	B	Mean H3			8.13	0.259	681.67	53.01	469	HIT									
FHJ8X1.125	4.00	2.07	6.07	B	CoeVar H1			1.7%	1.7%	5.5%	6.9%											
FHJ8X1.125	4.00	2.07	6.07	B	CoeVar H2			1.0%	1.0%	11.7%	12.0%											
FHJ8X1.125	4.00	2.07	6.07	B	CoeVar H3			0.7%	0.7%	10.1%	9.9%											
FHJ8X1.125	4.00	2.07	6.07	B	Median B	9.5	42															
FHJ8X1.125	4.00	2.07	6.07	B	Mean B	9.3	40.0						15.6		66.0							7.65
FHJ8X1.125	4.00	2.07	6.07	B	CoeVar B	4.1%	10.9%						32.0%		29.7%							3.5%
FHJ8X1.125	4.00	2.07	6.07	C	Initial							174										
FHJ8X1.125	4.00	2.07	6.07	C	S1							252	78		10.9							
FHJ8X1.125	4.00	2.07	6.07	C	S2							289	37		24.1							
FHJ8X1.125	4.00	2.07	6.07	C	1	9.5	35					313	24	46.3	38.2							7.25
FHJ8X1.125	4.00	2.07	6.07	C	2	9.0	25					334	21	27.3	44.0							7.41
FHJ8X1.125	4.00	2.07	6.07	C	3	10.2	35					353	19	21.3	49.0							7.49
FHJ8X1.125	4.00	2.07	6.07	C	4							371	18	19.3	51.9							
FHJ8X1.125	4.00	2.07	6.07	C	5							388	17	18.0	55.1							
FHJ8X1.125	4.00	2.07	6.07	C	6							402	14	16.3	67.7							
FHJ8X1.125	4.00	2.07	6.07	C	7							416	14	15.0	67.7							
FHJ8X1.125	4.00	2.07	6.07	C	8							429	13	13.7	73.3							
FHJ8X1.125	4.00	2.07	6.07	C	9							440	11	12.7	87.5							
FHJ8X1.125	4.00	2.07	6.07	C	10							451	11	11.7	87.5							
FHJ8X1.125	4.00	2.07	6.07	C	11							462	11	11.0	87.5							
FHJ8X1.125	4.00	2.07	6.07	C	Median C	9.5	35.0															
FHJ8X1.125	4.00	2.07	6.07	C	Mean C	9.6	31.7						15.7		64.5							7.38
FHJ8X1.125	4.00	2.07	6.07	C	CoeVar C	6.3%	18.2%						28.0%		28.1%							1.6%
FHJ8X1.125	4.00	2.07	6.07	D	1											1819.8	1776.2		1753.4	101.3%	103.8%	7.64
FHJ8X1.125	4.00	2.07	6.07	E	1											1819.8		1841.8	1753.4	105.0%	103.8%	7.26
FHJ8X1.125	4.00	2.07	6.07	D	2											1819.8	1810.0		1753.4	103.2%	103.8%	7.85
FHJ8X1.125	4.00	2.07	6.07	E	2											1819.8		1891.5	1753.4	107.9%	103.8%	7.43
FHJ8X1.125	4.00	2.07	6.07	DE	Mean DE											1819.8	1793.1	1866.7	1753.4	104.4%		7.55
FHJ8X1.125	4.00	2.07	6.07	DE	CoeVar DE												1.3%	1.9%		2.7%		3.4%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
KLO7X1.33	3.85	1.57	5.42	A	Initial							59										
KLO7X1.33	3.85	1.57	5.42	A	S1							129	70		12.3							
KLO7X1.33	3.85	1.57	5.42	A	S2							164	35		25.6							
KLO7X1.33	3.85	1.57	5.42	A	1	9.2	14					184	20	41.7	46.4							6.88
KLO7X1.33	3.85	1.57	5.42	A	2	8.0	27					209	25	26.7	36.6							6.95
KLO7X1.33	3.85	1.57	5.42	A	3	8.4	39					221	12	19.0	79.8							7.05
KLO7X1.33	3.85	1.57	5.42	A	4							238	17	18.0	55.1							
KLO7X1.33	3.85	1.57	5.42	A	5							253	15	14.7	62.9							
KLO7X1.33	3.85	1.57	5.42	A	6							265	12	14.7	79.8							
KLO7X1.33	3.85	1.57	5.42	A	7							279	14	13.7	67.7							
KLO7X1.33	3.85	1.57	5.42	A	8							289	10	12.0	96.8							
KLO7X1.33	3.85	1.57	5.42	A	9							299	10	11.3	96.8							
KLO7X1.33	3.85	1.57	5.42	A	10							304	5	8.3	202.1							
KLO7X1.33	3.85	1.57	5.42	A	11							313	HIT									
KLO7X1.33	3.85	1.57	5.42	A	Median A	8.4	27.0															
KLO7X1.33	3.85	1.57	5.42	A	Mean A	8.5	26.7						14.0		82.4							6.96
KLO7X1.33	3.85	1.57	5.42	A	CoeVar A	7.2%	46.9%						40.4%		56.5%							0.01
KLO7X1.33	3.85	1.57	5.42	B	Initial							58										
KLO7X1.33	3.85	1.57	5.42	B	S1			3.5	0.111	1072	14.4	122	64		13.5							
KLO7X1.33	3.85	1.57	5.42	B	S2			3.5	0.111	372	41.5	159	37		24.1							
KLO7X1.33	3.85	1.57	5.42	B	1	7.6	33	3.4	0.108	325	46.2	184	25	42.0	36.6							6.79
KLO7X1.33	3.85	1.57	5.42	B	2	7.8	38	3.3	0.105	303	48.1	204	20	27.3	46.4							7.50
KLO7X1.33	3.85	1.57	5.42	B	3	8.1	26	3.3	0.105	312	46.7	222	18	21.0	51.9							7.11
KLO7X1.33	3.85	1.57	5.42	B	4			5.7	0.181	530	47.5	238	16	18.0	58.8							
KLO7X1.33	3.85	1.57	5.42	B	5			5.7	0.181	464	54.2	252	14	16.0	67.7							
KLO7X1.33	3.85	1.57	5.42	B	6			5.7	0.181	435	57.8	265	13	14.3	73.3							
KLO7X1.33	3.85	1.57	5.42	B	7			8.4	0.267	622	59.6	277	12	13.0	79.8							
KLO7X1.33	3.85	1.57	5.42	B	8			8.4	0.267	559	66.3	288	HIT									
KLO7X1.33	3.85	1.57	5.42	B	9			8.4	0.267	548	67.6											
KLO7X1.33	3.85	1.57	5.42	B	10																	
KLO7X1.33	3.85	1.57	5.42	B	11																	
KLO7X1.33	3.85	1.57	5.42	B	Mean H1			3.33	0.106	313.33	46.97											
KLO7X1.33	3.85	1.57	5.42	B	Mean H2			5.70	0.181	476.33	53.17											
KLO7X1.33	3.85	1.57	5.42	B	Mean H3			8.40	0.267	576.33	64.52											
KLO7X1.33	3.85	1.57	5.42	B	CoeVar H1			1.7%	1.7%	3.5%	2.1%											
KLO7X1.33	3.85	1.57	5.42	B	CoeVar H2			0.0%	0.0%	10.2%	9.9%											
KLO7X1.33	3.85	1.57	5.42	B	CoeVar H3			0.0%	0.0%	6.9%	6.7%											
KLO7X1.33	3.85	1.57	5.42	B	Median B	7.8	33															
KLO7X1.33	3.85	1.57	5.42	B	Mean B	7.8	32.3						16.9		59.2							7.13
KLO7X1.33	3.85	1.57	5.42	B	CoeVar B	3.2%	18.6%						27.1%		26.0%							5.0%
KLO7X1.33	3.85	1.57	5.42	C	Initial							57										
KLO7X1.33	3.85	1.57	5.42	C	S1							117	60		14.4							
KLO7X1.33	3.85	1.57	5.42	C	S2							151	34		26.4							
KLO7X1.33	3.85	1.57	5.42	C	1	7.8	24					175	24	39.3	38.2							7.28
KLO7X1.33	3.85	1.57	5.42	C	2	7.2	15					195	20	26.0	46.4							7.18
KLO7X1.33	3.85	1.57	5.42	C	3	8.6	35					212	17	20.3	55.1							7.27
KLO7X1.33	3.85	1.57	5.42	C	4							226	14	17.0	67.7							
KLO7X1.33	3.85	1.57	5.42	C	5							240	14	15.0	67.7							
KLO7X1.33	3.85	1.57	5.42	C	6							255	15	14.3	62.9							
KLO7X1.33	3.85	1.57	5.42	C	7							267	12	13.7	79.8							
KLO7X1.33	3.85	1.57	5.42	C	8							277	10	12.3	96.8							
KLO7X1.33	3.85	1.57	5.42	C	9							287	10	10.7	96.8							
KLO7X1.33	3.85	1.57	5.42	C	10							296	9	9.7	108.3							
KLO7X1.33	3.85	1.57	5.42	C	11							304	8	9.0	122.7							
KLO7X1.33	3.85	1.57	5.42	C	12							313	9	8.7	108.3							
KLO7X1.33	3.85	1.57	5.42	C	13							321	8	8.3	122.7							
KLO7X1.33	3.85	1.57	5.42	C	14							328	7	8.0	141.4							
KLO7X1.33	3.85	1.57	5.42	C	Median C	7.8	24.0															
KLO7X1.33	3.85	1.57	5.42	C	Mean C	7.9	24.7						12.6		86.8							7.24
KLO7X1.33	3.85	1.57	5.42	C	CoeVar C	8.9%	40.6%						39.7%		36.5%							0.8%
KLO7X1.33	3.85	1.57	5.42	D	1											1936.6	1931.8		1862.3	103.7%	104.0%	6.81
KLO7X1.33	3.85	1.57	5.42	E	1											1936.6		1964.4	1862.3	105.5%	104.0%	6.93
KLO7X1.33	3.85	1.57	5.42	D	2											1936.6	1958.0		1862.3	105.1%	104.0%	7.16
KLO7X1.33	3.85	1.57	5.42	E	2											1936.6		2754.9	1862.3	147.9%	104.0%	7.06
KLO7X1.33	3.85	1.57	5.42	DE	Mean DE											1936.6	1944.9	2359.7	1862.3	115.6%		6.99
KLO7X1.33	3.85	1.57	5.42	DE	CoeVar DE												1.0%	23.7%		18.7%		2.2%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[μm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
DN05	3.82	1.32	5.14	A	Initial							170										
DN05	3.82	1.32	5.14	A	S1							230	60		14.4							
DN05	3.82	1.32	5.14	A	S2							261	31		29.1							
DN05	3.82	1.32	5.14	A	1	6.8	11					282	21	37.3	44.0							4.86
DN05	3.82	1.32	5.14	A	2	6.2	10					301	19	23.7	49.0							4.79
DN05	3.82	1.32	5.14	A	3	5.9	9					317	16	18.7	58.8							4.78
DN05	3.82	1.32	5.14	A	4							332	15	16.7	62.9							
DN05	3.82	1.32	5.14	A	5							347	15	15.3	62.9							
DN05	3.82	1.32	5.14	A	6							360	13	14.3	73.3							
DN05	3.82	1.32	5.14	A	7							372	12	13.3	79.8							
DN05	3.82	1.32	5.14	A	8							383	11	12.0	87.5							
DN05	3.82	1.32	5.14	A	9							393	10	11.0	96.8							
DN05	3.82	1.32	5.14	A	10							404	11	10.7	87.5							
DN05	3.82	1.32	5.14	A	11							415	11	10.7	87.5							
DN05	3.82	1.32	5.14	A	12							425	10	10.7	96.8							
DN05	3.82	1.32	5.14	A	13							435.0	10	10.3	96.8							
DN05	3.82	1.32	5.14	A	Median A	6.2	10.0															
DN05	3.82	1.32	5.14	A	Mean A	6.3	10.0						13.4		75.7							4.81
DN05	3.82	1.32	5.14	A	CoeVar A	7.3%	10.0%						26.9%		24.4%							4.3%
DN05	3.82	1.32	5.14	B	Initial							164										
DN05	3.82	1.32	5.14	B	S1			3.3	0.105	1610	9.0	229	65		13.3							
DN05	3.82	1.32	5.14	B	S2			3.5	0.111	449	34.4	265	36		24.8							
DN05	3.82	1.32	5.14	B	1	6.2	12	3.5	0.111	409	37.8	289	24	41.7	38.2							5.11
DN05	3.82	1.32	5.14	B	2	6.6	11	3.5	0.111	387	39.9	307	18	26.0	51.9							5.14
DN05	3.82	1.32	5.14	B	3	6.2	12	3.5	0.111	375	41.2	325	18	20.0	51.9							5.41
DN05	3.82	1.32	5.14	B	4			5.7	0.181	600	41.9	341	16	17.3	58.8							
DN05	3.82	1.32	5.14	B	5			5.8	0.185	557	46.0	355	14	16.0	67.7							
DN05	3.82	1.32	5.14	B	6			5.8	0.185	540	47.4	370	15	15.0	62.9							
DN05	3.82	1.32	5.14	B	7			8.2	0.261	718	50.4	381	11	13.3	87.5							
DN05	3.82	1.32	5.14	B	8			8.2	0.261	672	53.9	391	10	12.0	96.8							
DN05	3.82	1.32	5.14	B	9			7.9	0.251	687	50.7	401	10	10.3	96.8							
DN05	3.82	1.32	5.14	B	10							411	10	10.0	96.8							
DN05	3.82	1.32	5.14	B	11							420	9	9.7	108.3							
DN05	3.82	1.32	5.14	B	12							429	9	9.3	108.3							
DN05	3.82	1.32	5.14	B	13							439	10	9.3	96.8							
DN05	3.82	1.32	5.14	B	Mean H1			3.50	0.11	390.33	39.62											
DN05	3.82	1.32	5.14	B	Mean H2			5.77	0.18	565.67	45.09											
DN05	3.82	1.32	5.14	B	Mean H3			8.10	0.26	692.33	51.67											
DN05	3.82	1.32	5.14	B	CoeVar H1			0.0%	0.0%	4.4%	4.4%											
DN05	3.82	1.32	5.14	B	CoeVar H2			1.0%	1.0%	5.5%	6.3%											
DN05	3.82	1.32	5.14	B	CoeVar H3			2.1%	2.1%	3.4%	3.7%											
DN05	3.82	1.32	5.14	B	Median B	6.2	12															
DN05	3.82	1.32	5.14	B	Mean B	6.3	11.7						13.4		78.7							5.22
DN05	3.82	1.32	5.14	B	CoeVar B	3.6%	4.9%						34.4%		30.7%							16.4%
DN05	3.82	1.32	5.14	C	Initial							174										
DN05	3.82	1.32	5.14	C	S1							238	64		13.5							
DN05	3.82	1.32	5.14	C	S2							272	34		26.4							
DN05	3.82	1.32	5.14	C	1	5.7	5					294	22	40.0	41.9							5.51
DN05	3.82	1.32	5.14	C	2	6.0	8					313	19	25.0	49.0							5.15
DN05	3.82	1.32	5.14	C	3	6.3	8					331	18	19.7	51.9							5.19
DN05	3.82	1.32	5.14	C	4							347	16	17.7	58.8							
DN05	3.82	1.32	5.14	C	5							363	16	16.7	58.8							
DN05	3.82	1.32	5.14	C	6							374	11	14.3	87.5							
DN05	3.82	1.32	5.14	C	7							380	*Rock									
DN05	3.82	1.32	5.14	C	8																	
DN05	3.82	1.32	5.14	C	9																	
DN05	3.82	1.32	5.14	C	10																	
DN05	3.82	1.32	5.14	C	11																	
DN05	3.82	1.32	5.14	C	Median C	6.0	8.0															
DN05	3.82	1.32	5.14	C	Mean C	6.0	7.0						17.0		58.0							5.28
DN05	3.82	1.32	5.14	C	CoeVar C	5.0%	24.7%						21.7%		38.6%							19.5%
DN05	3.82	1.32	5.14	D	1											1988.6	1958.9		1942.4	100.8%	102.4%	4.66
DN05	3.82	1.32	5.14	E	1											1988.6		1885.9	1942.4	97.1%	102.4%	5.30
DN05	3.82	1.32	5.14	D	2											1988.6	2046.0		1942.4	105.3%	102.4%	4.62
DN05	3.82	1.32	5.14	E	2											1988.6		2066.3	1942.4	106.4%	102.4%	5.13
DN05	3.82	1.32	5.14	DE	Mean DE											1988.6	2002.4	1976.1	1942.4	102.4%		4.93
DN05	3.82	1.32	5.14	DE	CoeVar DE												3.1%	6.5%		4.2%		33.9%

Sample ID	Gradation			Location		Percometer		LWD				DCP				Density						Moisture Content
Sample	CGN	FGN	GN	Section	Trial	E	J	Force	Stress	Deflection	E	Reading	DPI	3 pt avg	E	Barrel	S cone	L cone	Proctor	Relative cone	Relative barrel	Oven-dry
					#	[J]	[mS/cm]	[kN]	[MPa]	[µm]	[MPa]	[mm]	[mm/blow]	[mm/blow]	[MPa]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]	%
DN07	3.82	1.32	5.14	A	Initial							63										
DN07	3.82	1.32	5.14	A	S1							129	66		13.1							
DN07	3.82	1.32	5.14	A	S2							162	33		27.3							
DN07	3.82	1.32	5.14	A	1	7.7	20					187	25	41.3	36.6							6.33
DN07	3.82	1.32	5.14	A	2	8.1	26					207	20	26.0	46.4							6.71
DN07	3.82	1.32	5.14	A	3	7.3	24					225	18	21.0	51.9							6.37
DN07	3.82	1.32	5.14	A	4							243	18	18.7	51.9							
DN07	3.82	1.32	5.14	A	5							260	17	17.7	55.1							
DN07	3.82	1.32	5.14	A	6							275	15	16.7	62.9							
DN07	3.82	1.32	5.14	A	7							290	15	15.7	62.9							
DN07	3.82	1.32	5.14	A	8							305	15	15.0	62.9							
DN07	3.82	1.32	5.14	A	9							318	13	14.3	73.3							
DN07	3.82	1.32	5.14	A	10							327	HIT									
DN07	3.82	1.32	5.14	A	11																	
DN07	3.82	1.32	5.14	A	12																	
DN07	3.82	1.32	5.14	A	13																	
DN07	3.82	1.32	5.14	A	Median A	7.7	24.0															
DN07	3.82	1.32	5.14	A	Mean A	7.7	23.3						17.3		56.0							6.47
DN07	3.82	1.32	5.14	A	CoeVar A	5.2%	13.1%						20.6%		19.4%							20.6%
DN07	3.82	1.32	5.14	B	Initial							58										
DN07	3.82	1.32	5.14	B	S1			3.2	0.102	963	14.7	128	70		12.3							
DN07	3.82	1.32	5.14	B	S2			3.5	0.111	453	34.1	164	36		24.8							
DN07	3.82	1.32	5.14	B	1	7.9	30	3.6	0.115	426	37.3	189	25	43.7	36.6							6.59
DN07	3.82	1.32	5.14	B	2	7.6	30	3.4	0.108	397	37.8	209	20	27.0	46.4							6.25
DN07	3.82	1.32	5.14	B	3	7.3	23	3.6	0.115	395	40.2	228	19	21.3	49.0							6.45
DN07	3.82	1.32	5.14	B	4			3.6	0.115	386	41.2	245	17	18.7	55.1							
DN07	3.82	1.32	5.14	B	5			5.9	0.188	606	43.0	260	15	17.0	62.9							
DN07	3.82	1.32	5.14	B	6			5.9	0.188	594	43.8	273	13	15.0	73.3							
DN07	3.82	1.32	5.14	B	7			5.9	0.188	579	45.0	285	12	13.3	79.8							
DN07	3.82	1.32	5.14	B	8			8.5	0.271	768	48.8	296	11	12.0	87.5							
DN07	3.82	1.32	5.14	B	9			8.5	0.271	748	50.2	308	12	11.7	79.8							
DN07	3.82	1.32	5.14	B	10			8.5	0.271	733	51.2	318	10	11.0	96.8							
DN07	3.82	1.32	5.14	B	11			3.4	0.108	389	38.6	324	HIT									
DN07	3.82	1.32	5.14	B	12			3.5	0.111	383	40.3											
DN07	3.82	1.32	5.14	B	13			3.5	0.111	383	40.3											
DN07	3.82	1.32	5.14	B	14			3.4	0.108	166	90.4											
DN07	3.82	1.32	5.14	B	15			3	0.095	164	80.7											
DN07	3.82	1.32	5.14	B	Mean H1			3.53	0.11	406.00	38.44											
DN07	3.82	1.32	5.14	B	Mean H2			5.13	0.16	528.67	42.65											
DN07	3.82	1.32	5.14	B	Mean H3			7.63	0.24	698.33	47.99											
DN07	3.82	1.32	5.14	B	CoeVar H1			3.3%	3.3%	4.3%	4.1%											
DN07	3.82	1.32	5.14	B	CoeVar H2			25.9%	25.9%	23.4%	3.2%											
DN07	3.82	1.32	5.14	B	CoeVar H3			19.7%	19.7%	14.9%	5.6%											
DN07	3.82	1.32	5.14	B	Median B	7.6	30															
DN07	3.82	1.32	5.14	B	Mean B	7.6	27.7						15.4		66.7							6.43
DN07	3.82	1.32	5.14	B	CoeVar B	3.9%	14.6%						31.1%		29.6%							17.1%
DN07	3.82	1.32	5.14	C	Initial							59										
DN07	3.82	1.32	5.14	C	S1							131	72		11.9							
DN07	3.82	1.32	5.14	C	S2							165	34		26.4							
DN07	3.82	1.32	5.14	C	1	7.9	29					188	23	43.0	40.0							6.42
DN07	3.82	1.32	5.14	C	2	8.4	31					207	19	25.3	49.0							6.33
DN07	3.82	1.32	5.14	C	3	7.8	26					225	18	20.0	51.9							6.29
DN07	3.82	1.32	5.14	C	4							239	14	17.0	67.7							
DN07	3.82	1.32	5.14	C	5							253	14	15.3	67.7							
DN07	3.82	1.32	5.14	C	6							266	13	13.7	73.3							
DN07	3.82	1.32	5.14	C	7							273	7	11.3	141.4							
DN07	3.82	1.32	5.14	C	8							280	7	9.0	141.4							
DN07	3.82	1.32	5.14	C	9							288	8	7.3	122.7							
DN07	3.82	1.32	5.14	C	10							295	*Rock									
DN07	3.82	1.32	5.14	C	11																	
DN07	3.82	1.32	5.14	C	Median C	7.9	29.0															
DN07	3.82	1.32	5.14	C	Mean C	8.0	28.7						16.8		58.3							6.35
DN07	3.82	1.32	5.14	C	CoeVar C	4.0%	8.8%						23.0%		74.8%							6.5%
DN07	3.82	1.32	5.14	D	1											2042.8	2013.4		1942.4	103.7%	105.2%	6.50
DN07	3.82	1.32	5.14	E	1											2042.8		2056.2	1942.4	105.9%	105.2%	6.18
DN07	3.82	1.32	5.14	D	2											2042.8	1929.1		1942.4	99.3%	105.2%	6.61
DN07	3.82	1.32	5.14	E	2											2042.8		1978.7	1942.4	101.9%	105.2%	6.50
DN07	3.82	1.32	5.14	DE	Mean DE											2042.8	1971.2	2017.4	1942.4	102.7%		6.45
DN07	3.82	1.32	5.14	DE	CoeVar DE												3.0%	2.7%		2.7%		18.3%

Appendix E

2005 Mn/DOT DCP Special Provision

Pilot 2005-06

5-692.255 mod MODIFIED DYNAMIC CONE PENETROMETER (DCP)

A. History and Development

The Dynamic Cone Penetrometer was first introduced to the Minnesota Department of Transportation (Mn/DOT) at the Minnesota Road Research Project (Mn/ROAD). Since 1993 the DCP has been used by Mn/DOT as an acceptance tool for the compaction of pavement edge drain trenches. In 1999, the Penetration Index Method for compaction acceptance of base aggregate Classes 5, 6, and 7 was adapted by Mn/DOT, which requires the use of the DCP as the testing device.

B. Description of Device

The Dynamic Cone Penetrometer consists of two 16 mm (5/8-inch) diameter shafts coupled near the midpoint. The lower shaft contains an anvil and a pointed tip, which is driven into unbound materials by dropping a sliding hammer contained on the upper shaft onto the lower anvil. The strength is determined by measuring the penetration of the lower shaft into the unbound materials. This value is recorded in millimeters (inches) per blow and is know as the Penetration Index (PI).

C. Equipment

The DCP is comprised of the following elements. (See Fig. 1 5-692.255 mod)

1. Handle: The handle is located at the top of the device. It is used to hold the DCP shafts plumb and to limit the upward movement of the hammer.

2. Hammer: The 8 kg (17.61 lb.) Hammer is manually raised to the bottom of the handle and then dropped (allowed to free fall) to transfer energy through the lower shaft to the cone tip. The upper shaft guides the hammer.

3. Upper Shaft: The upper shaft is a 16 mm (5/8-inch) diameter steel shaft on which the hammer moves. The length of the upper shaft allows the hammer to drop a distance 575 mm (22.6 inches).

4. Anvil: The anvil serves as the lower stopping mechanism for the hammer. It also serves as a connector between the upper and lower shaft. This allows for disassembly, which reduces the size of the instrument for transport.

5. Lower Shaft: The lower shaft is a 16 mm (5/8-inch) diameter steel shaft, of variable length up to 1 m (39.4 inches) in length, marked in 5mm (0.2-inch) increments for recording the penetration after each hammer drop.

6. Cone: The cone measures 20 mm (0.787-inch) in diameter. The cone tip has a 60-degree angle. (See Fig. 2 5-692.255 mod)

D. Operation Points of Caution

1. Always use caution to avoid pinching fingers between the hammer and the anvil during testing, use the handle to hold shafts plumb. **Do not hold the DCP near the anvil area**.

2. It is important to lift the hammer slowly and drop it cleanly, allowing it to rest on the anvil for at least one second before raising it for another drop. Lifting and dropping too rapidly may affect results because the hammer’s full energy may not be allowed to transfer to the lower shaft. This will cause incorrect test results.

E. Test Procedure - Base Aggregate (2211.3C3)

1. Record the gradation % passing values that represent the area to be tested by the DCP, on the attached Modified DCP Procedure 2005-06 form or spreadsheet. If using the form, calculate the Grading Number (GN) by using the formula on the form. If using the spreadsheet, the computer calculates this information. (See Fig. 3 5-692.255 mod)

2. Locate a level and undisturbed area (test site) that is representative of the material to be tested.

3. Record the Test #, Date, Station, Offset, and Test Layer Depth on the Modified DCP Procedure 2005-06 form or spreadsheet, in the DCP Data table. (See Fig. 3 5-692.255 mod)

4. Place the DCP device on the base aggregate test site. Record the initial reading using the graduated rule on the DCP. The measurement is taken to the nearest 2.5 mm (0.1 inch). (Place this information on the attached Modified DCP Procedure 2005-06 form or spreadsheet, in the DCP Data table, under **Initial Reading** column.)

5. To properly seat the DCP (cone tip), two hammer blows are required. Therefore, carefully raise the sliding weighted hammer until it meets the handle, and then release the hammer under its own weight. Repeat this process one more time for a total of two complete blows.

6. Record the penetration measurement after seating using the graduated rule on the DCP. The measurement is taken to the nearest 2.5 mm (0.1 inch). (Place this information on the attached Modified DCP Procedure 2005-06 form or spreadsheet, in the DCP Data table, under **Reading after seating (2 blows)** column.) (See Fig. 3 5-692.255 mod)

7. Carefully raise the hammer until it meets the handle, and then release the hammer under its own weight. Repeat this process two more times for a total of three times.

8. Record the final penetration measurement using the graduated rule on the DCP. The measurement is taken to the nearest 2.5 mm (0.1 inches). (Place this information on the attached Modified DCP Procedure 2005-06 form or spreadsheet, in the DCP Data table, under **Reading after test (3 blows)** column.) (See Fig. 3 5-692.255 mod)

9. After using the DCP, obtain a sample of material and determine the moisture content of the aggregate base by using the pan drying method or a Super Speedy. Record the moisture content on the Modified DCP Procedure 2005-06 form or spread sheet, in the DCP Data table, under **MC (%)** column. (See Fig. 3 5-692.255 mod)

10. If using the Modified DCP Procedure 2005-06 form, fill in the **Maximum Allowable SEAT** & **Maximum Allowable DPI** columns; this information is in the Penetration Requirements table by using the recorded **GN** & **MC**. Next calculate the **SEAT** by using the following formula:

    SEAT = **Reading after seating (2 blows) - Initial Reading**

    Compare the calculated **SEAT** and compare it the **Maximum Allowable SEAT column**, if **SEAT** is larger than the **Maximum Allowable SEAT**, the **SEAT** fails. If the **SEAT** is smaller than the **Maximum Allowable SEAT**, the **SEAT** passes.

    Next calculate the **DPI** by using the following formula:

$$\textbf{DPI} = \frac{\{\textbf{Reading after test (3 blows) - Reading after seating (2 blows)}\}}{3}$$

    Compare the calculated **DPI** and compare it the **Maximum Allowable DPI** column, if the **DPI** is larger than the **Maximum Allowable DPI**, the **Ave. DPI** fails. If the **DPI** is smaller than the **Maximum Allowable DPI**, the **DPI** passes.

    Next determine the **Adequate Layer?** by using the following formula:

Adequate Layer? = {Reading after test (3 blows) – Initial Reading} < Test Layer Depth

    If the **{Reading after test (3 blows) – Initial Reading}** is larger than the **Test Layer Depth,** the answer is No. If the **{Reading after test (3 blows) – Initial Reading}** is less than the **Test Layer Depth,** the answer is Yes.

To determine whether the **Test Pass or Fail**, check the **Seat Pass or Fail**, **DPI Pass or Fail**, and **Adequate Layer?** columns, if any of the three columns has Fail or No, the **Test** Fails. If all three columns have Pass or Yes, the **Test** Passes.

If using the Modified DCP Procedure 2005-06 spreadsheet, all the above information is calculated by the computer and to determine if the test passes or fails look in the **Test Pass or Fail** column for the answer. (See Fig. 3 5-692.255 mod)

11. For test purposes, the approximate test layer in compacted thickness is located in the Penetration Index chart on Fig. 3 5-692.255 mod.

F. Test Procedure - Granular Subgrade Material (2105.3F3)

1. Record the gradation % passing values that represent the area to be tested by the DCP, on the attached Modified DCP Procedure 2005-06 form or spreadsheet. If using the form, calculate the Grading Number (GN) by using the formula on the form. If using the spreadsheet, the computer calculates this information. (See Fig. 3 5-692.255 mod)

2. Locate a level and undisturbed area (test site) that is representative of the material to be tested.

3. Record the Test #, Date, Station, Offset, and Test Layer Depth on the Modified DCP Procedure 2005-06 form or spreadsheet, in the DCP Data table. (See Fig. 3 5-692.255 mod)

4. Place the DCP device on the granular material test site. Record the initial reading using the graduated rule on the DCP. The measurement is taken to the nearest 2.5 mm (0.1 inch). (Place this information on the attached Modified DCP Procedure 2005-06 form or spreadsheet, in the DCP Data table, under **Initial Reading** column.) (See Fig. 3 5-692.255 mod)

5. To properly seat the DCP (cone tip), two hammer blows are required. Therefore, carefully raise the sliding weighted hammer until it meets the handle, and then release the hammer under its own weight. Repeat this process one more time for a total of two complete blows.

6. Record the penetration measurement after seating using the graduated rule on the DCP. The measurement is taken to the nearest 2.5 mm (0.1 inch). (Place this information on the attached Modified DCP Procedure 2005-06 form or spreadsheet, in the DCP Data table, under **Reading after seating (2 blows)** column.) (See Fig. 3 5-692.255 mod)

7. Carefully raise the hammer until it meets the handle, and then release the hammer under its own weight. Repeat this process two more times for a total of three times.

8. Record the final penetration measurement using the graduated rule on the DCP. The measurement is taken to the nearest 2.5 mm (0.1 inches). (Place this information on the attached Modified DCP Procedure 2005-06 form or spreadsheet, in the DCP Data table, under **Reading after test (3 blows)** column.) (See Fig. 3 5-692.255mod)

9. After using the DCP, obtain a sample of material and determine the moisture content of the granular material by using the pan drying method or a Super Speedy. Record the moisture content on the Modified DCP Procedure 2005-06 form or spread sheet, in the DCP Data table, under **MC (%)** column. (See Fig. 3 5-692.255 mod)

10. If using the Modified DCP Procedure 2005-06 form, fill in the **Maximum Allowable SEAT** & **Maximum Allowable DPI** columns; this information is in the Penetration Requirements table by using the recorded **GN** & **MC**. Next calculate the **SEAT** by using the following formula:

    SEAT = Reading after seating (2 blows) - Initial Reading

    Compare the calculated **SEAT** and compare it the **Maximum Allowable SEAT column**, if **SEAT** is larger than the **Maximum Allowable SEAT**, the **SEAT** fails. If the **SEAT** is smaller than the **Maximum Allowable SEAT**, the **SEAT** passes.

    Next calculate the **DPI** by using the following formula:

$$\textbf{DPI} = \frac{\{\textbf{Reading after test (3 blows) - Reading after seating (2 blows)}\}}{3}$$

    Compare the calculated **DPI** and compare it the **Maximum Allowable DPI** column, if the **DPI** is larger than the **Maximum Allowable DPI**, the **Ave. DPI** fails. If the **DPI** is smaller than the **Maximum Allowable DPI**, the **DPI** passes.

    Next determine the **Adequate Layer?** by using the following formula:

Adequate Layer? = {Reading after test (3 blows) – Initial Reading} < Test Layer Depth

    If the **{Reading after test (3 blows) – Initial Reading}** is larger than the **Test Layer Depth,** the answer is No. If the **{Reading after test (3 blows) – Initial Reading}** is less than the **Test Layer Depth,** the answer is Yes.

To determine whether the **Test Pass or Fail**, check the **Seat Pass or Fail**, **DPI Pass or Fail**, and **Adequate Layer?** columns, if any of the three columns has Fail or No, the **Test** Fails. If all three columns have Pass or Yes, the **Test** Passes.

If using the Modified DCP Procedure 2005-06 spreadsheet, all the above information is calculated by the computer and to determine if the test passes or fails look in the **Test Pass or Fail** column for the answer. (See Fig. 3 5-692.255 mod)

12. For test purposes, a layer will be considered 300 mm (1-foot) in compacted thickness.

G. Test Procedure - Edge Drain Trench Filter Aggregate (2502)

1. After the compaction of the first 15 m (50 feet) of filter aggregate within the edge drain trench has been completed, determine the location of three test sites that are 3 m (10 feet) apart within that first 15 m (50 feet).

2. Calculate the number of hammer drops (blows) necessary to ‘properly test the trench filter aggregate but not damage the edge drain pipe by subtracting 150 mm (6-inches) from the depth of the trench to be tested and dividing that total by 75 for metric measurements or 3 for English measurements. If necessary, round this number down to the next whole number. (See Fig. 4 5-692.225 mod)

   Example: If the trench depth equals 650 mm (26-inches).
   Then 650 mm (26-inches) minus 150mm (6 inches) equals 500 mm (20 inches).
   Then 500 mm (20 inches) divided by 75 (for Metric) or 3 (for English) equals 6.7 or 6.

3. Place the DCP on test site #1 and seat the coned tip of the device by slightly tapping the lower anvil with the hammer until the coned tip is just out of sight.

4. After seating, record the penetration measurement using the graduated rule on the DCP. The measurement is taken to the nearest 2.5 mm (0.1 inch). [Use form TP-2170 –02(rev 11/05)] (See Fig. 5 5-692.255 mod)

5. Carefully raise the hammer until it meets the handle, and then release the hammer under its own weight. Repeat this process until the total number of hammer drops equals the required number of blows as calculated in step 2. Also, beware and avoid the chance of penetrating the edge drain pipe at the bottom of the trench when the compaction of the trench is less than passing.

6. Record the final penetration measurement from the graduated rule on the DCP. The measurement is taken to the nearest 2.5 mm (0.1 inch).

7. Subtract the measurement in step 4 from the measurement in, step 6 and then divide the difference of the measurements by the number of blows required for testing. The result is the penetration index. If necessary, follow the formula on the test form to convert from mm to inches.

8. Use the same procedures as outlined above for testing sites #2 and #3.

9. Add the three penetration index results from test site #1, #2, and #3 and divide that total by 3 in order to calculate the average of all three tests. Round off the average of the tests to the nearest 1 mm (0.1-inch). (See Grading and Base Manual 5-692.805)

H. Maintenance and Handling

Because the Dynamic Cone Penetrometer is driven into the ground, sometimes into very hard soil layers, regular maintenance and care are required. To ensure that the DCP operates properly, the following guidelines must be followed.

1. Monitor the condition of the connections to the anvil and handle. When the connections uses bolts, pins, or set screws, extra bolts, pins, or set screws should be kept in the DCP carrying cases because they frequently become stripped or broken and may need to be replaced during testing.

2. Keep the upper shaft clean. Lubricate very lightly with oil if binding develops. Frequently wipe both shafts clean with a soft cloth during use.

3. Monitor the DCP for excessive wear on any of the components and make repairs as needed. Because the DCP is a standardized testing device, its overall weight and dimensions must not change from specifications.

4. The cone tip should be replaced when the diameter of its widest section is reduced by more than 10 percent (2 mm [0.08 inch]) or rocks gouge the cone’s surface. Inspect the cone tip before and after each test. Nevertheless, the cone tip should be replaced at least once a year.

5. Never extract the DCP from the test hole by forcefully striking the hammer against the handle. Striking the handle causes accelerated wear and may lead to broken welds and connections. At least once a year, all welds on the DCP should be critically inspected for hairline or larger cracks.

6. Do not lay the device on the ground when not in use. The DCP should be kept in its carrying case to avoid bending the shafts. Straightness of the shafts is extremely important. The hammer cannot free fall if the shafts are bent. The

straightness of the shafts should be critically measured and reviewed each year prior to the start of construction season.

Modified DCP Procedure: 2005-06 (English)

SP ______ Highway ______ Engineer ______ Inspector ______

Material ______ Date ______ Notes ______

Procedure

- Enter Project info and Gradation Data. Calculate the Grading Number **(GN)** (electronic version calculated automatically)

$$SEAT = Pen_{2\,blows} - Pen_{0\,blows} \qquad DPI = \frac{Pen_{5\,blows} - Pen_{2\,blows}}{3\,blows}$$

Electronic Version

- Determine the test location and conduct the DCP test.
- Measure the moisture content (***MC***) at the DCP test location.
- Enter the Test Information and DCP Data in table.
- The test results will be determined automatically.

Hard Copy

- Determine the test location and conduct the DCP test.
- Measure the moisture content (***MC***) at the DCP test location.
- Enter the Test Information and DCP Data in table.
- Establish the allowable values for ***SEAT*** and ***DPI*** based on ***GN*** and ***MC***.
- Compute ***SEAT*** and ***DPI*** test results.
- Compare ***SEAT*** and ***DPI*** to Maximum Requirements. *Both must pass to accept test*.

Gradation Data (use **% passing** in formulas)

$$GN = \frac{1'' + 3/4'' + 3/8'' + \#4 + \#10 + \#40 + \#200}{100}$$

Sieve	% Passing
1"	
3/4"	
3/8"	
#4	
#10	
#40	
#200	
GN =	

Penetration Requirements

GN	MC (% dry)	Maximum Allowable SEAT (in)	Maximum Allowable DPI (in/blow)	Approximate Test Layer (in)
3.1-3.5	< 5.0	1.6	0.4	4.0 - 6.0
	5.0-8.0	1.6	0.5	
	> 8.0	1.6	0.6	
3.6-4.0	< 5.0	1.6	0.4	4.0 - 6.0
	5.0-8.0	1.7	0.6	
	> 8.0	2.1	0.7	
4.1-4.5	< 5.0	2.0	0.5	4.0 - 6.0
	5.0-8.0	2.4	0.7	
	> 8.0	2.8	0.8	

GN	MC (% dry)	Maximum Allowable SEAT (in)	Maximum Allowable DPI (in/blow)	Approximate Test Layer (in)
4.6-5.0	< 5.0	2.6	0.6	5.0 - 7.0
	5.0-8.0	3.0	0.7	
	> 8.0	3.4	0.9	
5.1-5.5	< 5.0	3.3	0.7	6.0 - 12.0
	5.0-8.0	3.7	0.8	
	> 8.0	4.1	1.0	
5.6-6.0	< 5.0	4.0	0.8	7.0 - 12.0
	5.0-8.0	4.5	0.9	
	> 8.0	4.9	1.1	

DCP Data

☐ Metric DCP Measurements (check if Metric, un-check to return to English)

Test Information							Requirements		DCP Data (**in**)			Test Results					
Test #	Date	Station	Offset	Test Layer Depth (in)	GN	MC (%)	Maximum Allowable SEAT (in)	Maximum Allowable DPI (in/blow)	Initial Reading	Reading after seating (2 Blows)	Reading after test (3 Blows)	SEAT (in)	SEAT: Pass or Fail	DPI (in/blow)	DPI: Pass or Fail	Adequate Layer? (1)	**TEST:** Pass or Fail

(1) [Reading after test (3 Blows) - Initial Reading] < Test Layer Depth = Adequate Layer

Fig. 3 5-692.255 mod