Effects Of The Soil Properties On The Maximum Dry Density Obtained Fro

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EFFECTS OF THE SOIL PROPERTIES ON THE MAXIMUM DRY DENSITY OBTAINED FROM THE STANDARD PROCTOR TEST.

by

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ABSTRACT

In the construction of highways, airports, and other structures, the compaction of soils is needed to improve its strength. In 1933 Proctor developed a laboratory compaction test to determine the maximum dry density of compacted soils, which can be used for specifications of field compaction. The Compaction of soils is influenced by many factors, the most common are the moisture content, the soil type and the applied compaction energy.

The objective of this research is the analysis of the maximum dry density values based on the soil classification and characterization. The method of choice in the determination of the maximum dry density from different soils was the Standard Proctor Test following the procedure for the standard Proctor test as is explained in ASTM Test Designation D-698.

From this investigation, the maximum dry density of eight types of sands was obtained, the sands were classified by using the Unified Soil Classification System. The influence on the maximum dry density of the type of sands, type of fines, amount of fines and distribution of the grain size was determined, followed by a sensitivity analysis that measured the influence of these parameters on the obtained maximum dry density.

The research revealed some correlations between the maximum dry density of soils with the type of fines, the fines content and the Uniformity Coefficient. These correlations were measured and some particular behavioral trends were encountered and analyzed. It was found that well-graded sands have higher maximum dry density than poorly graded when the soils have the same fines content, also it was encountered that plastic fines tend to increase the maximum dry density.

I would like to dedicate this research

to God, Jesus, and the Virgin Mary who always show me the right path

to my parents and brothers who have educated and supported me

and to Natalie who makes everything possible and closes all the circles.

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CHAPTER ONE

INTRODUCTION

Compaction is the artificial improvement of the mechanical properties of the soil. This process increases the resistance, reduces the deformation capacity, and provides the soils with inalterability against external agents.

Soil compaction investigations started during the 20th century due to the automobile invention along with the paved roads. Then many efficient and economical methods were developed, and it was proved that there is no compaction method that is efficient for every type of soil. It was also found that the degree of compaction, for any compaction method, depends on the moisture content of the soil.

Soils comprise three phases: the solid, the liquid and the gaseous phase. The solid phase includes the mineral particles of gravel, sands, silts and clays. Particle-size properties are determined from the size distribution of individual particles in a soil sample. The solid phase usually includes organic material that is called humus content. The liquid phase usually consists of water that can move through the pores of the soil. Other liquids may be present, they may be miscible or immiscible in water and generally they are the result of agricultural and industrial activities or accidental spills. The principal component of the gaseous phase is air or other dissolved gases like water vapor and volatile components.

The compaction process consists in the rapid densification of soils without losing humidity. During compaction the volume of void containing air is diminished and the soil particles get closer due to the new arrangement. In soil compaction not only the voids are modified, but the mechanical resistance, deformability and permeability are affected. These characteristics are modified due to the diminution of the void ratio produced by the soil densification.

The objectives of the study is to evaluate the effect of fine content such as clay or silt on the compaction of well-graded and poorly graded sands. In order to achieve such accomplishment, the following scope of the activities were performed:

- Introduction: This chapter provides a preamble to the compaction process, including some definitions, and historical references.
- Literature Review: This chapter explains the definition of the saturation curve, different theories of compaction curve, the standard Proctor test method and its factors of influence.
- Methodology: This chapter shows the sample collection that were prepared and selected to perform the standard Proctor test.
- Result of Study: This chapter analyzes the effect of different soil characteristics on the standard Proctor test results. This effect is also quantified by using a sensitivity analysis.
- Summary and Conclusion: This chapter compiles the results obtained from the investigation; it also provides the observed limitations, and recommendations for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Saturation Curve

In the compaction process the air content in the soil is reduced, decreasing the soil porosity as result of the soil densification (increase in the unit weight of the soil). Figure 1 shows a representation of the increment in the soil unit weight or dry density of two points (A and B) as consequence of a compaction force.

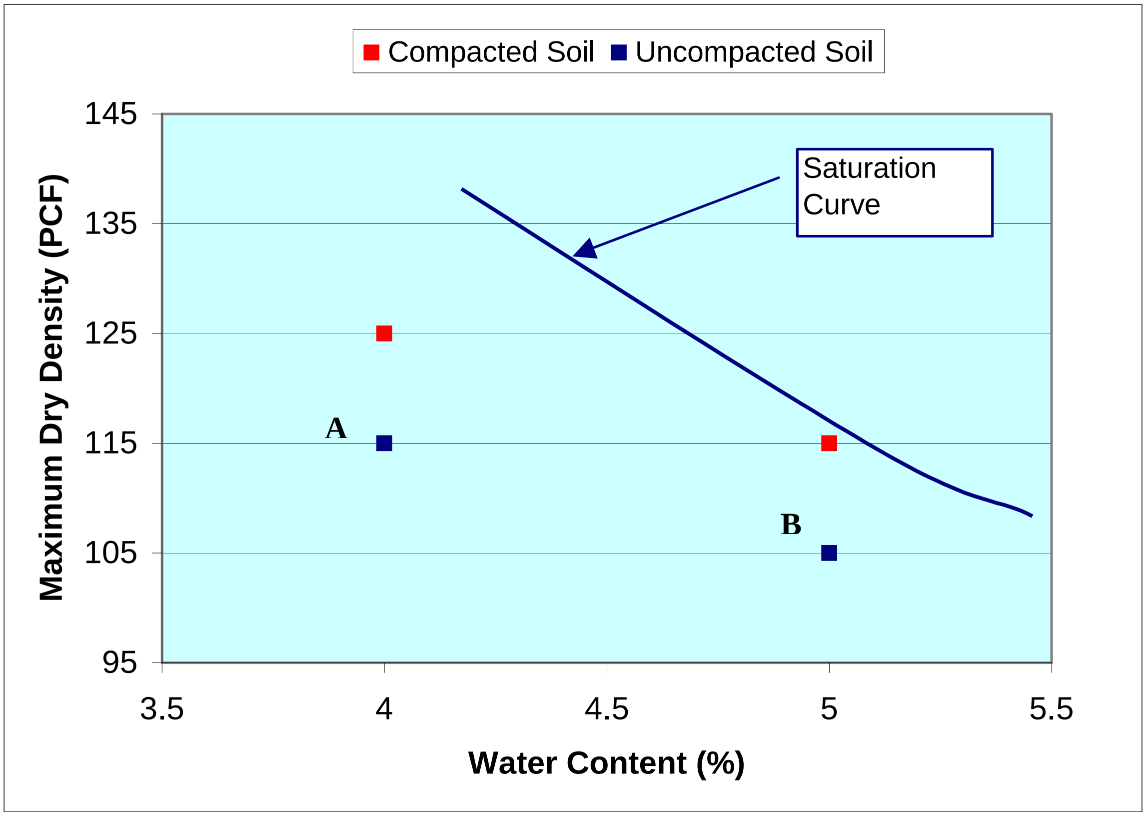

Figure 1. Saturation Curve of a Soil.

Note the “saturation curve” from Figure 1, this curve represents an ideal condition where the voids of a compacted soil are fulfilled with water. This state is never achieved in the practice because there is always air in the voids, therefore, it can be concluded that as result of the compaction process all the soils will be located on the left side of the “saturation curve”, regardless the water content and the energy applied to compact the soil.

2.2 Compaction Curve

The compaction curve is the representation of the dry densities versus the moisture contents obtained from a compaction test. The achieved dry density depends on the water content during the compaction process. When samples of the same material are compacted with the same energy but with different water contents, they present different densification stages, as shown on Figure 2.

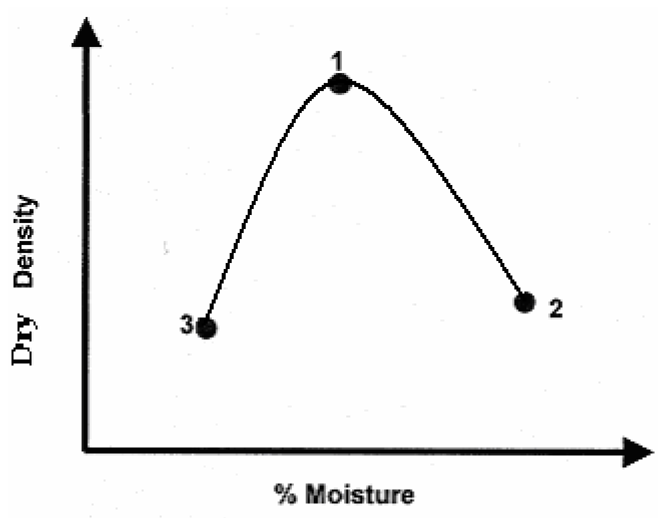

Figure 2. Typical Compaction Moisture/Density Curve.

This densification stages are represented in the compaction curve, which has a particular shape. Many theories have tried to explain the shape of this curve. The principal theories are presented following:

- Proctor (1933), believed that the humidity in soils relatively dry creates a capillarity effect that produces tension stress and grouping of the solid particles, that results in a high friction resistance that opposes the compaction stresses. For instance it is very difficult the compaction of soils with low water content. He obtained a better rearrangement of the soil particles by compacting it with higher water content, because of the increment of lubrication from the water. By compacting the soil while the water content is increased, the lubrication effect will continue until a point where the water combined with the remaining air is enough to fill the voids. At this stage the soil is at its maximum dry density $(\gamma_{d\,\max})$ and optimum water content $(w_{(\%)_{optimum}})$ as represented in point 1 in Figure 2. For any increment in the water content after the "optimum water content", the volume of voids tends to increase, and the soil will obtain a lower density and resistance.
- Hogentogler (1936) considered that the compaction curve shape reflects four stages of the soil humidity: hydration, lubrication, expansion and saturation. These stages are represented in Figure 3.

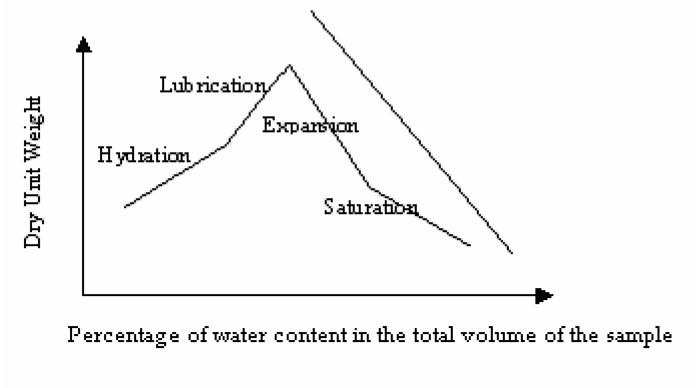

Figure 3. Compaction Curve.

As shown in Figure 3, Hogentogler's moisture-density curve differs from Proctor's curve in the abscise axe. Hogentogler used for this axe the percentage of water content in the total volume of the sample. Hogentogler believed that by using that chart the compaction curve becomes four straight lines that represent his humectation stages. "Hydration" is the stage where the water incorporation creates a surface coat in the solid particles providing viscosity. "Lubrication" is the stage where the coat is increased by the addition of water acting as a lubricant, and making possible the rearrangement of the soil particles without filling all the air voids. The maximum water content in this stage corresponds to the maximum dry density obtained from the compaction. Hogentogler (1936) believed that more water after the lubrication stage will create the "expansion" of the soil mass without affecting the volume of the air voids, so the additional water in this stage acts in the displacement of the soil particles. Addition of more water to the soil produces its "saturation", which is the stage where the air content is displaced.

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Hilf (1956), gave the first modern type of compaction theory by using the concept of pore water pressures and pore air pressures. He suggested that the compaction curve be presented in terms of void ratio (volume of water to volume of solids). A curve similar to the conventional compaction curve results, with the optimum moisture content corresponding to a minimum void ratio. In his chart the zero air voids curve is shown as a straight line and so are the saturation lines, all originating at zero void ratio and zero moisture content. Points representing soil samples with equal air void ratios (volume of air to volume of solids) plot on lines parallel to the zero air voids or 100% saturation line.

According to Hilf, dry soils are difficult to compact because of high friction due to capillary pressure. Air, however, is expelled quickly because of the larger air voids. By increasing the water content the tension in the pore water decreases, reducing friction and allowing better densification until a maximum density is reached. Less-effective compaction beyond the optimum moisture content is attributed to the trapping of air and the increment of pore air pressures and the added water taking space instead of the denser solid particles.

- Lambe (1960), explained the compaction curve based on theories that used the soils' surface chemical characteristics. In lower water contents, the particles flocculation is caused by the high electrolytic concentration. The flocculation causes lower compaction densities, but when the water content is increased the electrolytic concentration is reduced.

- Olson (1963), confirmed that the air permeability of a soil is dramatically reduced at or very close to the optimum moisture content. At this point, high pore air pressures and pore water pressures minimize effective stress allowing adjustments of the relative position of the soil particles to produce a maximum density. At water contents below optimum, Olson attributes resistance to repeated compaction forces to the high negative residual pore pressures, the relatively low shear-induced pore pressures, and the high residual lateral total stress. On the wet side of optimum, Olson explains the reduced densification effect by pointing out that the rammer or foot penetration during compaction is larger than in drier soil, which may cause temporary negative pore pressure known to be associated with large strains in over-consolidated soil; in addition the soil resists compaction by increasing bearing capacity due to the depth effect.
- Barden and Sides (1970), made experimental researches on the compaction of clays that were partially saturated, reporting the obtained microscopic observations of the modifications in the clay structure. The conclusions they obtained can be summarized as follows:
    1. The theories based on the effective tensions used to determine the curve shape are more reliable than the theories that used viscosity and lubrication.
    2. It is logical to suppose that soils with low humidity content remain conglomerated due to the effective tension caused by the capillarity. The dryer these soils are the bigger the tensions are. In the compaction process the soil remains conglomerated. By increasing the water content this tensions are reduced, and the compaction is more effective.

3. The blockage of the air in the soil mass provides a reasonable explanation of the effectiveness of a used compaction energy.
4. If by increasing the water content the blocked air is not expelled and the air pressure is increased, the soil will resist the compaction.

- Lee and Suedkamp (1972), studied compaction curves for 35 soil samples. They observed that four types compaction curves can be found. These curves are shown in Figure 4. Type A compaction curve is a single peak. This type of curve is generally found for soils that have a liquid limit between 30 and 70. Curve type B is a one-and-one-half-peak curve, and curve type C is a double-peak curve. Compaction curves of type B and C can be found for soils that have a liquid limit less than about 30. Compaction curve of type D does not have a definite peak. This is termed an “odd shape”. Soils with a liquid limit grater than 70 may exhibit compaction curves of type C or D, such soils are uncommon. (Das, 2002).

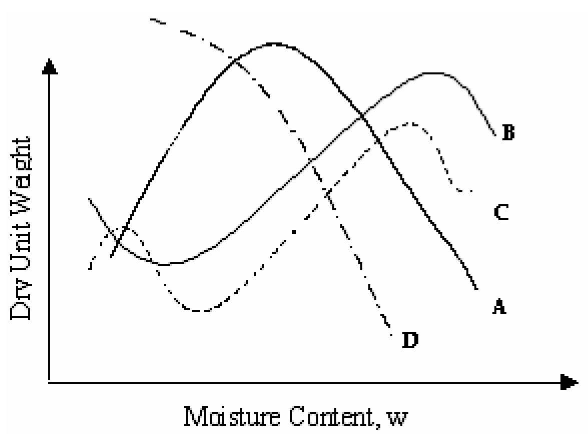

Figure 4: Types of Compaction Curves.

2.3 Standard Proctor Test

In the Proctor test the soil is compacted in a mold with a volume of 944 cm^3 ($\frac{1}{30}$ ft^3). The diameter of the mold is 101.6 mm (4 in.). During the laboratory test, the mold is attached to a base plate at the bottom and to an extension at the top. The soil is mixed with varying amounts of water and then compacted in three equal layers by a hammer that delivers 25 blows each layer. The hammer has a weight of 2.5 Kg (5.5 lb) and is dropped from 30.5 mm (12 in.) height. For each test, the moist unit weight of compacted soil, γ, can be calculated as:

$$\gamma = \frac{W_t}{V_{(m)}} \qquad (1)$$

where,

W_t = weight of the compacted soil in the mold.

$V_{(m)}$= volume of the mold [944 cm^3 ($\frac{1}{30}$ ft^3)]

And the dry unit weight is from:

$$\gamma_d = \frac{\gamma}{1 + \frac{w_{(\%)}}{100}} \qquad (2)$$

where $w_{(\%)}$ = percentage of moisture content.

The values γ_d determined from the previous equation can be plotted against the corresponding moisture contents to obtain the maximum dry unit weight and the optimum moisture content for the soil.

2.4 Factors Influencing the Compaction Test

As it was mentioned before the moisture content has a strong influence on the degree of compaction achieved by a given soil. Besides moisture content, other important factors that affect the compaction of a soil are soil type and compaction effort (energy per unit volume). These factors are described in the following section.

2.4.1 Effect of Soil Types

The soil type in terms of the grain-size distribution, shape of the soil grains, specific gravity of soil solids, percentage of the fine content and the type of fine, provides a great impact on the maximum dry unit weight and optimum moisture content. Figure 5 shows the typical compaction curves obtained from four soils.

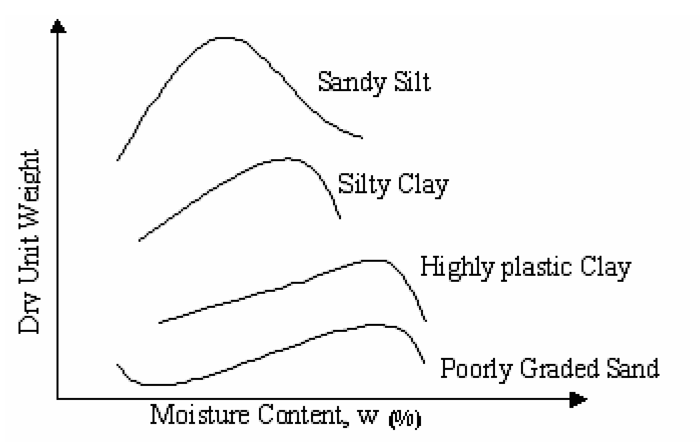

Figure 5: Typical Compaction Curves for four soils.

Note that the bell-shaped compaction curves shown in Figure 5 are typically of most soils containing fines. Figure 5 also shows that for sands, the dry unit weight has a general tendency first to decrease as moisture content increases, and then to increase to a maximum value with further increase of moisture. The initial decrease of dry unit weight with the increase of moisture content can be attributed to the capillary tension effect. At lower moisture contents, the capillary tension in the pore water inhibits the tendency of the soil particles to move around and be densely compacted. (Das, 2002)

2.4.2 Effect of the Compaction Energy

The applied energy in a soil compaction is measured by its specific energy value (E), which is the applied energy per unit volume. When the energy per unit is increased, the maximum dry unit weight is also increased, while the optimum water content is reduced as shown in Figure 6.

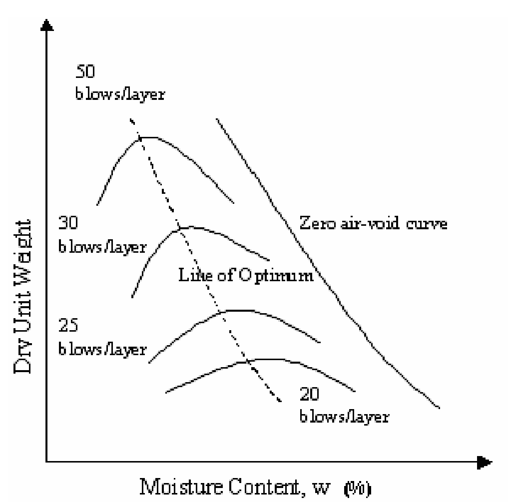

Figure 6: Effect of Compaction Energy on the Compaction of Sandy Clay.

It can be seen that when the energy is increased all the densities are higher between the moisture contents range. The process efficiency is better for lower water contents and becomes practically useless when the water content is too high. A common characteristic among the shown curves is that when the water content is very high, the compaction curves tend to come closer. Another detail is that after the maximum value in the compaction curves is reached, the curves tend to align parallel to the Zero-Air-Void curve.

The compaction energy per unit volume used for the standard Proctor test can be given by;

$$E = \frac{(Number\ of\ blows\ per\ layer)x(Number\ of\ layers)x(Weight\ of\ hammer)x(Height\ of\ drop\ of\ hammer)}{Volume\ of\ mold} \quad (3)$$

In SI units, E becomes

$$E = \frac{(25)x(3)x(\frac{2.5x9.81}{1000}kN)x(0.305m)}{944x10^{-6}} = 594\ kN-m/m^3 \approx 600\ kN-m/m^3$$

In English units, E is

$$E = \frac{(25)x(3)x(5.5)(1)}{\frac{1}{30}} = 12{,}375\ ft-lb/ft^3 \approx 12{,}400\ ft-lb/ft^3$$

2.4.3 Effect of other Factors

Other factors can also change the results of dry unit weight obtained from the compaction test. Some of these factors are described as follow:

- The uncertainty of the uniformly distributed moisture in all soil samples. This is the reason why it is very important to vary the moisture contents in samples, and carefully mix the water with the soil.
- Recycling the soil for the same test might produce a re-compaction effect that will produce higher dry densities than the one obtained using non-recycled soils for each point. This effect is neglected in sandy soils because the size of the particles remain about the same despite the number of tests, while for bigger particles the re-compaction might brake them increasing the final dry density.

2.5 Purpose of the Laboratory Tests

The purpose of the laboratory compaction tests of a soil is the determination of the mechanical properties that will be used as a reference for that particular soil. The laboratory compaction result of finding its maximum dry unit weight and optimum moisture content is to identify the better compaction equipment, thickness of the compacted lift, and the number of passes the equipment should perform in the field.

CHAPTER THREE

METHODOLOGY

3.1 Proctor Tests Method of Investigation for Different Soils

The method used to study and evaluate the effect of the soil type and the fine content type in the Proctor Compaction Test, will be described in two parts. The first part will discuss the method used to prepare and classify the soils, while the second part will describe the type and number of tests used for each type of soil.

3.1.1 Sample Preparation

The Unified Soil Classification System (USCS) was applied to divide the soils passing a 75 mm (3 in.) sieve in twenty-six different soils. The soils are grouped into two major categories:

a) Coarse-grained soils: these are soils that are gravelly and sandy in nature with less than 50% passing through the No. 200 sieve. The group symbols start with prefixes of either G or S. Where G stands for gravel or gravelly soil, and S for sand or sandy soil.

b) Fine-grained soils: these are soils with 50% or more passing through the No. 200 sieve. The group symbols start with prefixes of M, which stands for inorganic silt, C for inorganic clay, and O for organic clays and silts. The symbol Pt is used for peat, muck, and other highly organic soils.

Other symbols used for the soil classification are:

- W: for well-graded
- P: for poorly graded
- L: low plasticity (liquid limit less than 50)
- H: high plasticity (liquid limit more than 50)

The extent of this investigation is to find the values from the Proctor Compaction Test in common sands such as the presented in the Unified Soil Classification System.

This study was sampled using a total of 38,329.5 grams of sand. The sand was washed to remove any fines content or particles passing through the number 200 sieve. Subsequently the clean sand was sieved and separated by particle size in independent containers according to the USCS, the results are tabulated in Table 1.

Table 1: Weight of Soils used in the preparation of samples utilized in the experiments.

Number of Sieve	**Weight of soil in grams**
#10	**2,027.5**
#40	**18,573.0**
#60	**7,389.0**
#100	**7,664.0**
#200	**2,676.4**
>200	**0.0**
Total	**38,329.5**

In addition, two kilograms of clay and three kilograms of silt were obtained, tested and then classified using the Atterberg Limits. The results of these experiments are presented below in Table 2 and Figure 7.

Table 2: Atterberg limits.

	Clay	**Silt**
Liquid Limit	**61.9**	**28.4**
Plasticity Limit	**22.9**	**26.3**
Plasticity Index	**39**	**2.1**

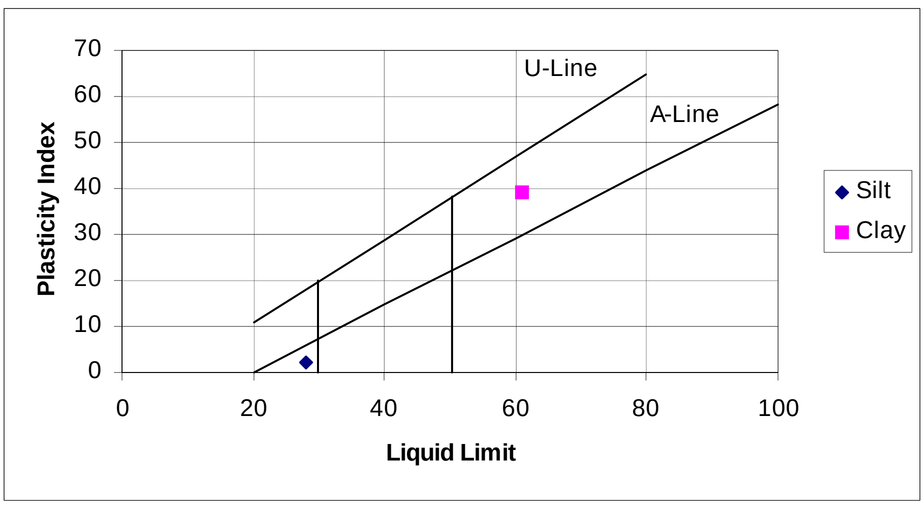

Figure 7: Plasticity Chart

Once the sand was divided in different sizes and the Clay and Silt material were defined, the preparation of the soils for the Proctor test proceeded. In order to prepare the soils, the amounts of each particle size were established as presented in table 4. The soils were classified using the USCS into eight types, each with different fines content as presented in Table 3.

Table 3: Studied Soils and Fine Contents.

Soil Type	**Fine Content**
SW	**0%, 2%, 3%, 4.5%**
SW-SM	**5.5%, 6.5%, 9%, 11.5%**
SW-SC	**5.5%, 6.5%, 9%, 11.5%**
SP	**0%, 2%, 3%, 4.5%**
SP-SM	**5.5%, 6.5%, 9%, 11.5%**
SP-SC	**5.5%, 6.5%, 9%, 11.5%**
SC	**15%, 20%, 25%**
SM	**15%, 20%, 25%, 30%**

Table 4: Weight and particle-size distribution in the formation of the soils to be tested.

Sample #	Soil Type	#10		#40		#60		#100		#200		>200	
		[grams]	%	[grams]	%	[grams]	%	[grams]	%	[grams]	%	[grams]	%
1	SP	0.0	0.0	2400.0	80.0	300.0	10.0	300.0	10.0	0.0	0.0	0.0	0.0
2	SP	0.0	0.0	2400.0	78.4	300.0	9.8	300.0	9.8	0.0	0.0	62.0	2.0
3	SP	0.0	0.0	2400.0	77.5	300.0	9.7	300.0	9.7	0.0	0.0	95.0	3.1
4	SP	0.0	0.0	2400.0	76.8	300.0	9.6	300.0	9.6	0.0	0.0	126.0	4.0
5	SP-SM	0.0	0.0	2400.0	75.6	300.0	9.4	300.0	9.4	0.0	0.0	175.0	5.5
6	SP-SM	0.0	0.0	2400.0	74.8	300.0	9.3	300.0	9.3	0.0	0.0	210.0	6.5
7	SP-SM	0.0	0.0	2400.0	72.7	300.0	9.1	300.0	9.1	0.0	0.0	300.0	9.1
8	SP-SM	0.0	0.0	2400.0	70.8	300.0	8.8	300.0	8.8	0.0	0.0	390.0	11.5
9	SP-SC	0.0	0.0	2400.0	75.6	300.0	9.4	300.0	9.4	0.0	0.0	175.0	5.5
10	SP-SC	0.0	0.0	2400.0	74.8	300.0	9.3	300.0	9.3	0.0	0.0	210.0	6.5
11	SP-SC	0.0	0.0	2400.0	72.7	300.0	9.1	300.0	9.1	0.0	0.0	300.0	9.1
12	SP-SC	0.0	0.0	2400.0	70.8	300.0	8.8	300.0	8.8	0.0	0.0	390.0	11.5
13	SM	0.0	0.0	2304.0	68.0	288.0	8.5	288.2	8.5	0.0	0.0	508.0	15.0
14	SM	0.0	0.0	2124.0	64.0	265.5	8.0	265.5	8.0	0.0	0.0	663.8	20.0
15	SM	0.0	0.0	2040.0	60.0	255.0	7.5	255.0	7.5	0.0	0.0	850.0	25.0
16	SM	0.0	0.0	1800.0	56.0	225.0	7.0	225.0	7.0	0.0	0.0	964.3	30.0
17	SW	150.0	5.0	1950.0	65.0	300.0	10.0	300.0	10.0	300.0	10.0	0.0	0.0
18	SW	150.0	4.9	1950.0	63.7	300.0	9.8	300.0	9.8	300.0	9.8	62.0	2.0
19	SW	150.0	4.8	1950.0	63.0	300.0	9.7	300.0	9.7	300.0	9.7	93.0	3.0
20	SW	150.0	4.8	1950.0	62.4	300.0	9.6	300.0	9.6	300.0	9.6	126.0	4.0
21	SW-SC	150.0	4.7	1950.0	61.4	300.0	9.4	300.0	9.4	300.0	9.4	175.0	5.5
22	SW-SC	150.0	4.7	1950.0	60.7	300.0	9.3	300.0	9.3	300.0	9.3	210.0	6.5
23	SW-SC	150.0	4.5	1950.0	59.1	300.0	9.1	300.0	9.1	300.0	9.1	300.0	9.1
24	SW-SC	150.0	4.4	1950.0	57.5	300.0	8.8	300.0	8.8	300.0	8.8	390.0	11.5
25	SW-SM	150.0	4.4	1950.0	57.5	300.0	8.8	300.0	8.8	300.0	8.8	390.0	11.5
26	SW-SM	150.0	4.4	1950.0	57.5	300.0	8.8	300.0	8.8	300.0	8.8	390.0	11.5
27	SW-SM	150.0	4.4	1950.0	57.5	300.0	8.8	300.0	8.8	300.0	8.8	390.0	11.5
28	SW-SM	150.0	4.4	1950.0	57.5	300.0	8.8	300.0	8.8	300.0	8.8	390.0	11.5
29	SC	144.0	4.2	1872.0	55.2	288.0	8.5	288.0	8.5	288.0	8.5	508.2	15.0
30	SC	132.8	4.0	1725.8	52.0	265.5	8.0	265.5	8.0	265.5	8.0	663.8	20.0
31	SC	127.5	3.8	1657.5	48.8	255.0	7.5	255.0	7.5	255.0	7.5	850.0	25.0

Size grain distribution charts were developed for every tested soil and are included in Appendix B. A sample chart is presented below in Figure 8, the chart compares the grain size distribution of a well-graded sand and a poorly graded sand with 0 % fines content.

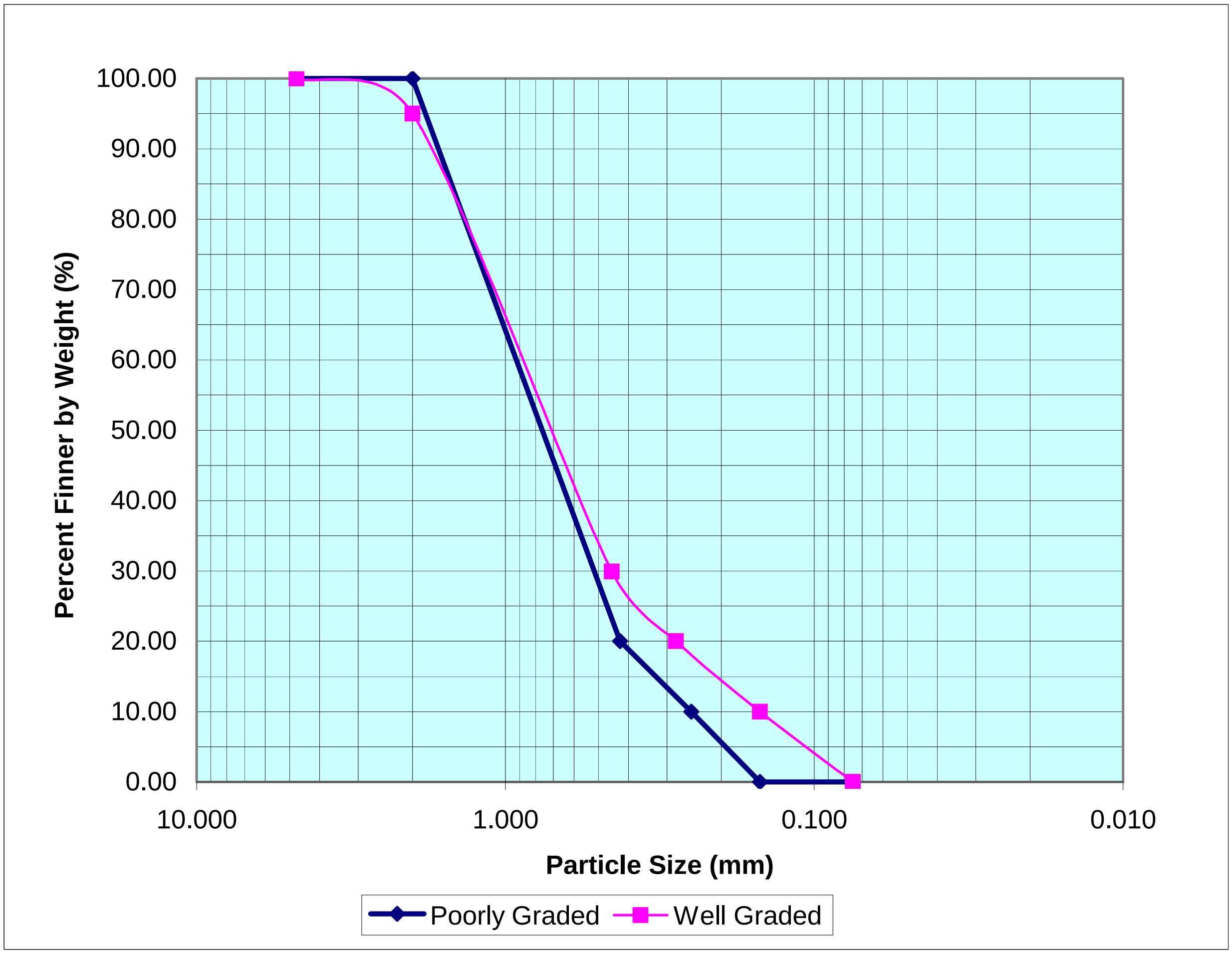

Figure 8: Particle Size distribution chart for the Poorly Graded Sand and the Well-graded Sand.

3.1.2 Proctor Test

Once the soils were prepared, the Standard Proctor Test was applied using the ASTM Test Designation D-698 (ASTM, 1999). Using different moisture contents $w_{(\%)}$, such as 5%, 7%, 9%, and 11%, the dry unit weight measured at the end of each Proctor Test were plotted, and subsequently the maximum dry density and optimum moisture content for each soil type were obtained. Once the experiments were finished, the data was analyzed in order to find correlations between the soils' characteristics and the obtained maximum dry densities. It is expected that soils with more fines content and higher Cu values have higher maximum dry density. In order to demonstrate this assumption, the obtained data was tabulated and plotted in charts similar to the one presented below in Figure 9.

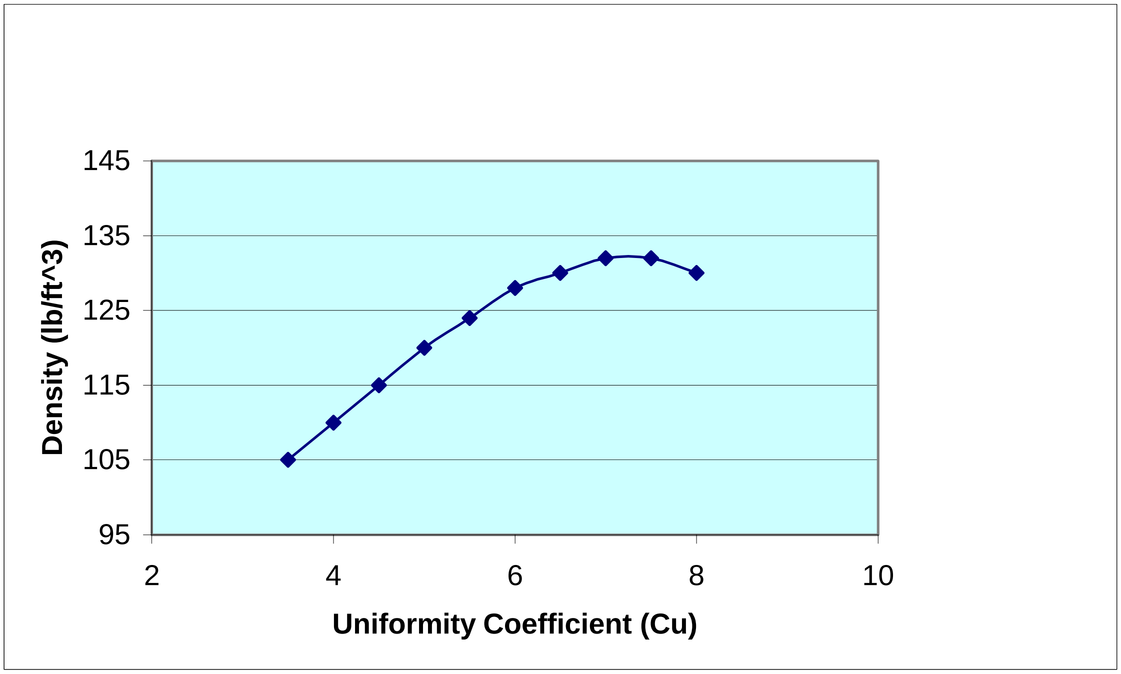

Figure 9: Variation of the Maximum Dry Density by the Increment in Uniformity Coefficient.

After the values were tabulated, the next steps were necessary to develop a curve that predicts reasonable maximum dry densities from the soils characteristics:

1. The carts option from Excel was used to graph the values obtained from the experiments, it was also applied a feature that is capable of adding a non-linear trend-line to a specified set of points. The trend-line is a curve defined from pre-determined functions such as: Polynomial, Logarithmic, Power and Exponential. Also, the R-squared, known as the coefficient of determination, can be calculated. The R-squared value is an indicator that ranges from 0 to 1 and reveals how closely the estimated values from the trend-line correspond to the actual data. The trend-line is more reliable when its R-squared value is at or near 1.
2. The selected trend-line was one with the highest R-squared value. The power function was the closest approximation to the set of points obtained from the tests, this equation has a R-squared value of 0.906
3. The power function, presented below in equation 4, can be used to find the maximum dry density of a soil when the independent value, uniformity coefficient, is substituted into the equation.

$$\gamma_d = 87.715 x Cu^{0.166} \qquad (4)$$

CHAPTER FOUR

RESULTS OF STUDY

After all the soils were tested, the values obtained from the experiments were tabulated and graphed in order to prove the relationships between the soils properties and the obtained maximum dry densities. The soil specifications, grain size distribution curve and Proctor curve for every studied soil are presented in detail in the Appendixes. A summary is presented below in Table 5, which includes sample number, soil type, percentage of fine content, uniformity coefficient, obtained maximum dry density and optimum moisture content for every studied soil.

Table 5: Summary of the Experimental Results.

Sample #	Soil Type (USCS)	Soil Type (AASHTO)	Fine Content (%)	Cu	Maximum Dry Density (lb/ft3)	Optimum Moisture Content (%)
1	SP	A-3	0	3.7	109.6	12
2	SP	A-3	2	4	110.2	9.8
3	SP	A-3	3.1	4.2	110.5	9.5
4	SP	A-3	4	4.3	110.5	9
5	SP-SM	A-3	5.5	4.6	110.6	10.4
6	SP-SM	A-3	6.5	4.8	112.5	7.5
7	SP-SM	A-3	9.1	5.4	116	10
8	SP-SM	A-2-4	11.5	6.4	118.3	8.8
9	SP-SC	A-3	5.5	4.6	113.8	7.8
10	SP-SC	A-3	6.5	4.8	116.8	7.4
11	SP-SC	A-3	9.1	5.4	119.3	8.5
12	SP-SC	A-2-7	11.5	6.4	122.4	9.2
13	SM	A-2-4	15	7.7	123.8	8.5
14	SM	A-2-4	20	8.8	130	8.5
15	SM	A-2-4	25	9.2	131.5	8
16	SM	A-2-4	30	9.2	131.5	8
17	SW	A-3	0	5.8	115.3	9.8
18	SW	A-3	2	6.5	117.8	6.8
19	SW	A-3	3	6.8	120.2	7.5
20	SW	A-3	4	7.2	120.8	6
21	SW-SC	A-3	5.5	7.9	124	8.1
22	SW-SC	A-3	6.5	8.4	124.2	6.5
23	SW-SC	A-3	9.1	9.8	126.5	7.5
24	SW-SC	A-2-7	11.5	10.8	129	7.5
25	SW-SM	A-3	5.5	7.9	120.2	7.4
26	SW-SM	A-3	6.5	8.4	123.5	7.5
27	SW-SM	A-3	9.1	9.8	124.4	6.9
28	SW-SM	A-2-4	11.5	10.8	127.8	7.3
29	SC	A-2-7	15	11.2	130.5	8
30	SC	A-2-7	20	11.2	131	7.5
31	SC	A-2-7	25	10.8	130.4	7.8

4.1 Soil Type Analysis

The first analysis was done considering the soil type. Figures 10 through 15 show the maximum dry density for soil type and fine content, and the increment of the initial maximum dry density by the addition of fines.

As seen in Figure 10, well-graded sands are better compacted than poorly graded sands, because the arrangement of the particles in the well-graded sands provides fewer voids than those encountered in poorly graded sands. Figure 10 also shows that the increase of fine content increases the maximum dry density in both types of soils, but the effect is greater for well-graded sands. In order to visualize how the maximum dry density is increased by the addition of fines Figure 11 was developed, showing the increments of the initial maximum dry density versus the fine content. It is interesting to note that with the addition of 2 to 4% of fines, the well-graded sand has increased from 2 to 5% of density. As for the poorly graded sand, the addition of fines has no impact on the density by compaction.

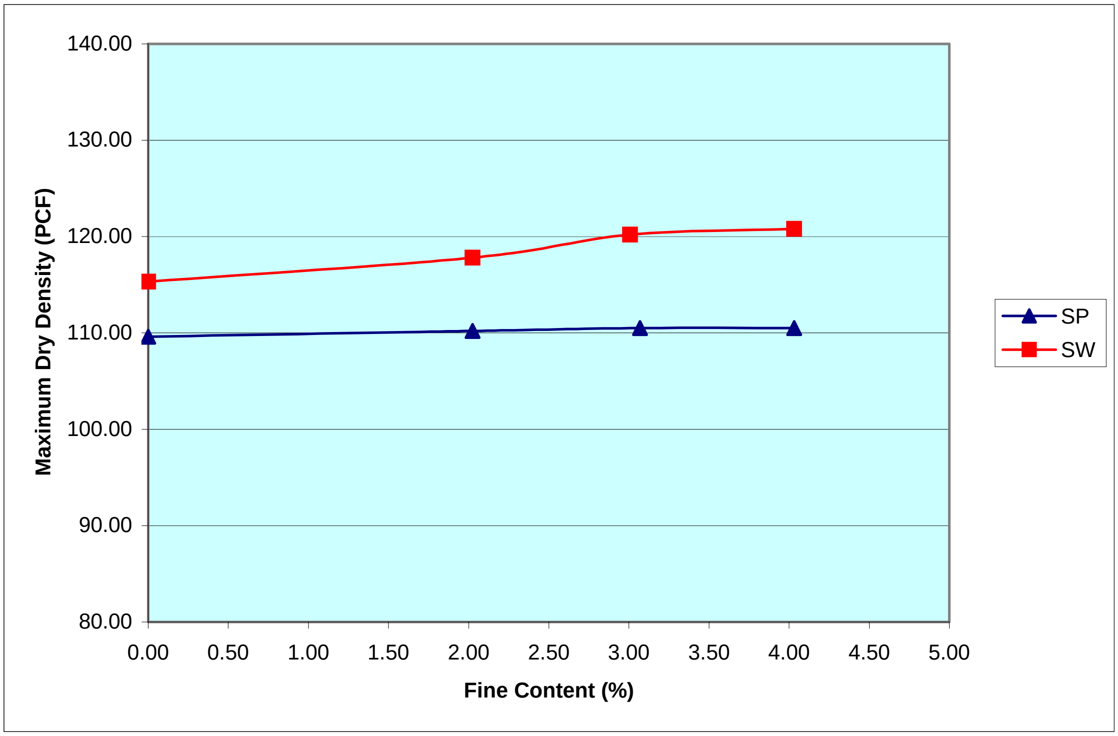

Figure 10: Variation of the Maximum Dry Density by the addition of fine.

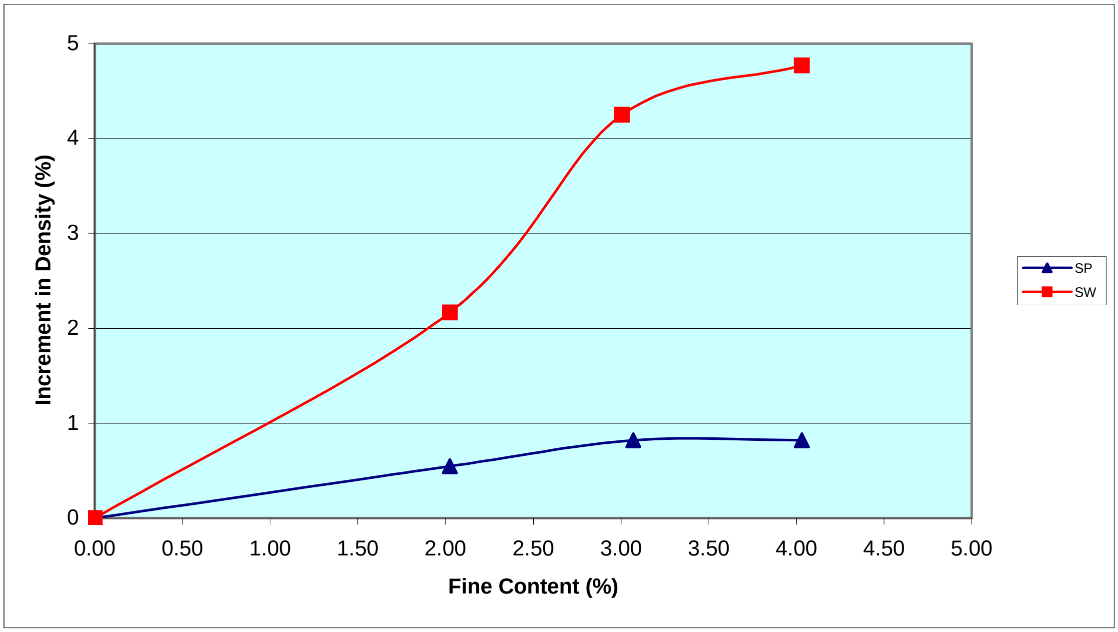

Figure 11: Increment in the Maximum Dry Density by the addition of fine.

The same procedure was applied to analyze the effect of the fine content in soils with more than 5 % fine content but less than 12 %. Those soils were divided into Poorly Graded Sand with Silt, Poorly Graded Sand with Clay, Well-Graded Sand with Silt and Well-Graded Sand with Clay. The effects of the fine content in those soils are shown in Figure 12 and Figure 13. The charts demonstrate that an addition of the fine content produces an increment in the maximum dry density in all of the soils. However, from Figure 13 it concludes that soils containing clay have a slightly higher increment of the initial maximum dry density than the silt. This effect may be attributed to the plastic characteristic of the clay that bonds the sand particles.

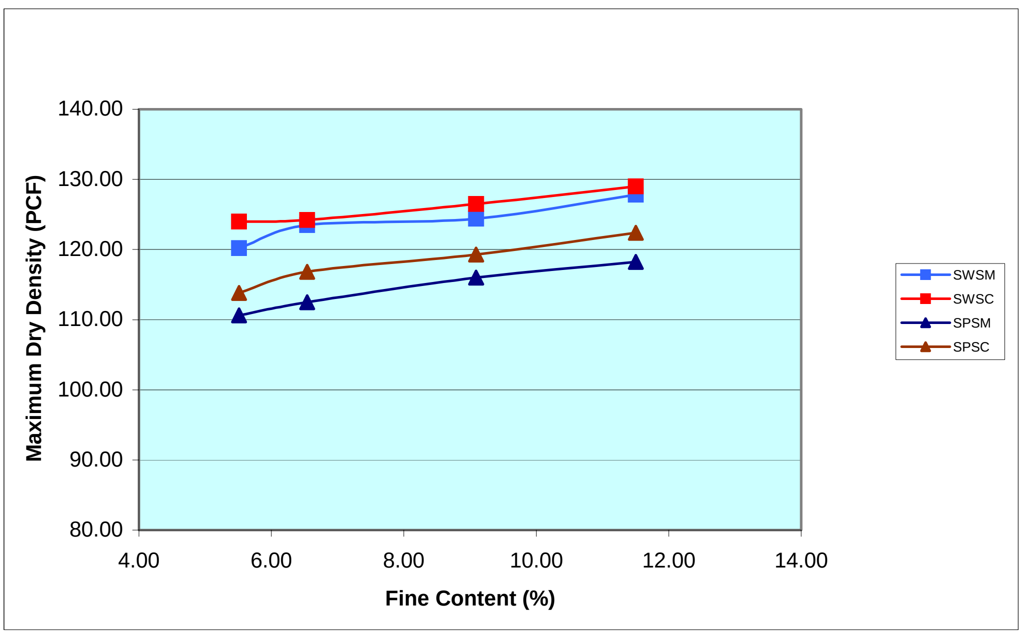

Figure 12: Variation of the Maximum Dry Density by the addition of fine.

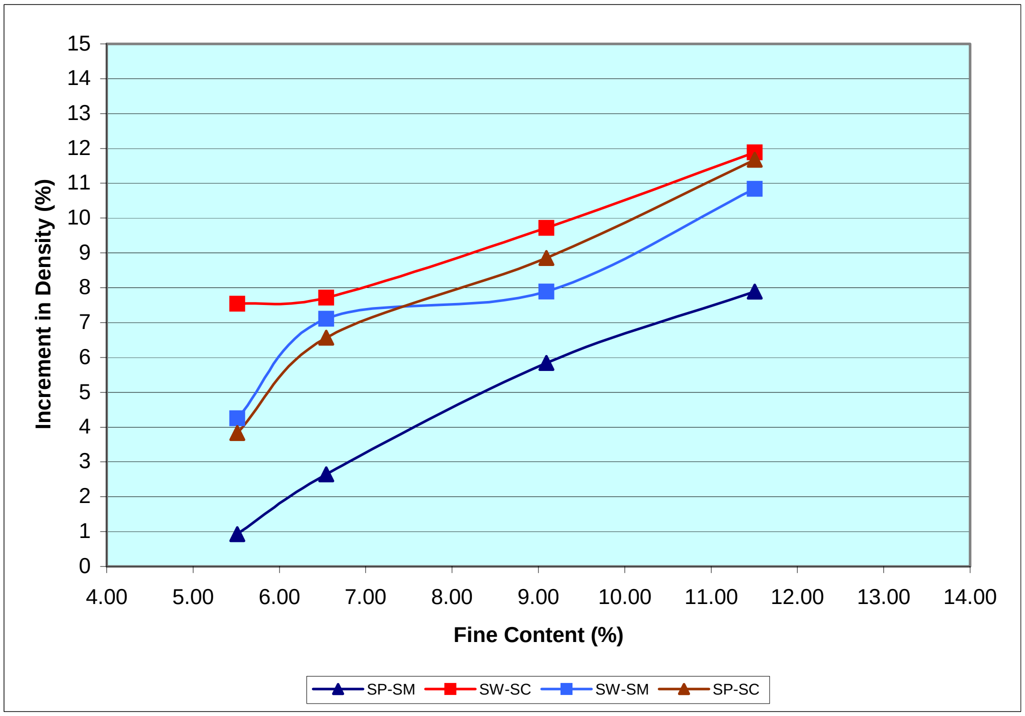

Figure 13: Increment in the Maximum Dry Density by the addition of fine.

The same analysis was done for soils having more than 12 % fine content, such as, Silty Sands and Clayey Sands. The results of the addition of fines in those soils are illustrated in Figures 14 and 15. The two figures demonstrate a different behavior in the soils having clay and silt fine contents. It was observed that by adding clay to the clayey sands the maximum dry density did not change significantly, and after 20 % fine content the maximum dry density started to decrease its value. When more silt was added to the silty sands, the maximum dry density of these soils kept growing considerably until a maximum value at 25 % fines content, after that point the maximum dry density remained about the same despite any increment in the fines content.

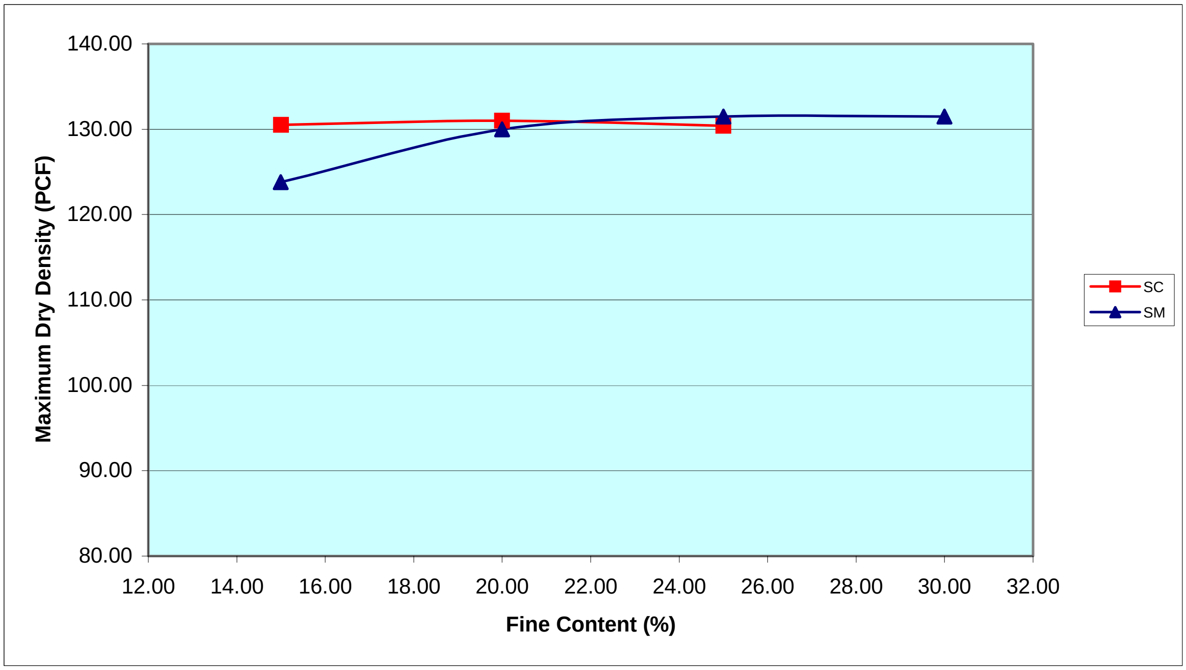

Figure 14: Variation of the Maximum Dry Density by the addition of fine.

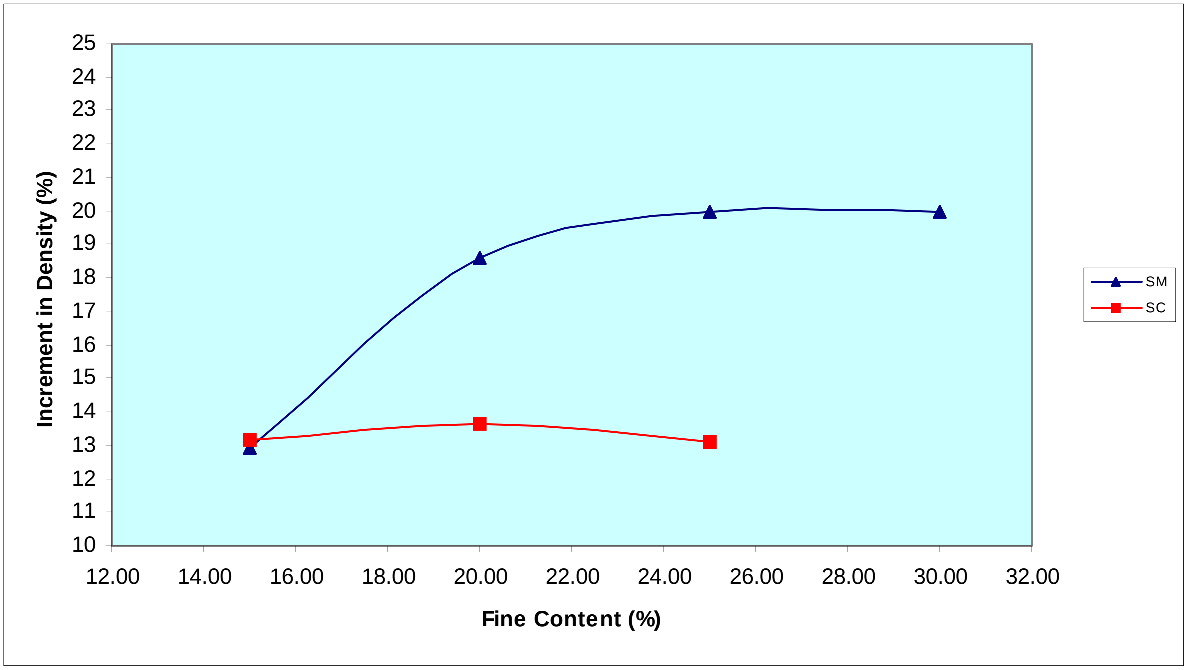

Figure 15: Increment in the Maximum Dry Density by the addition of fine.

4.2 Fine Type Analysis

From the investigation it is observed a general behavior of the soils' maximum dry density related to the type of fine that they contain. It is important to note on Figure 16 that in soils with 20 % fines the maximum dry density start to be about the same despite the type of fine.

It is observed from Figure 17 that the increment in the soils' clay content produces an augmentation in the initial maximum dry density. This increment is stronger in soils with less than 12% fine content and then weakens afterward, reaching a maximum at 20% fine content where the total increase of the initial maximum dry density is 13%.

Also from Figure 17 is noticed that the early increments in silt content do not contribute to important variations in the initial maximum dry density. This behavior changes when the fine content is more than 5%, it is seen that silt content augmentation represents important increments in the initial maximum dry density. A maximum value is reached when the silt content is 25%, providing a 20% increment of the initial maximum dry density. Increments beyond 25% silt content do not modify the soils' maximum dry density.

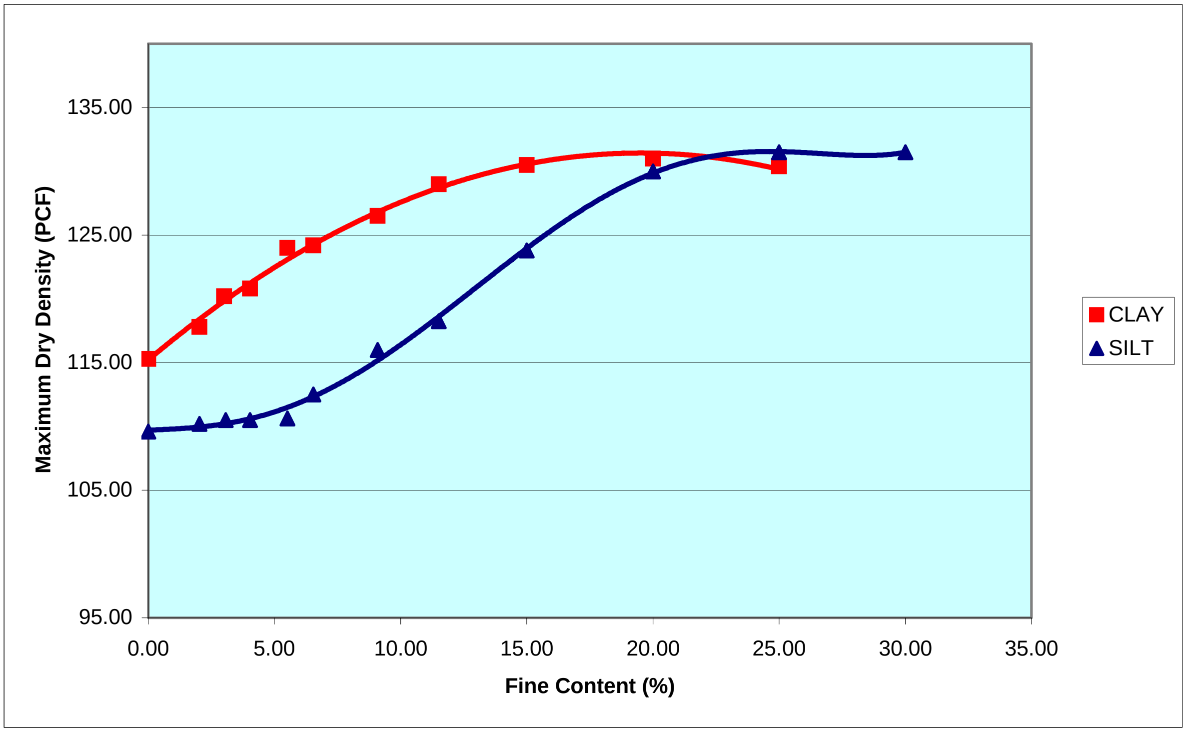

Figure 16: Variation of the Maximum Dry Density by the addition of fine.

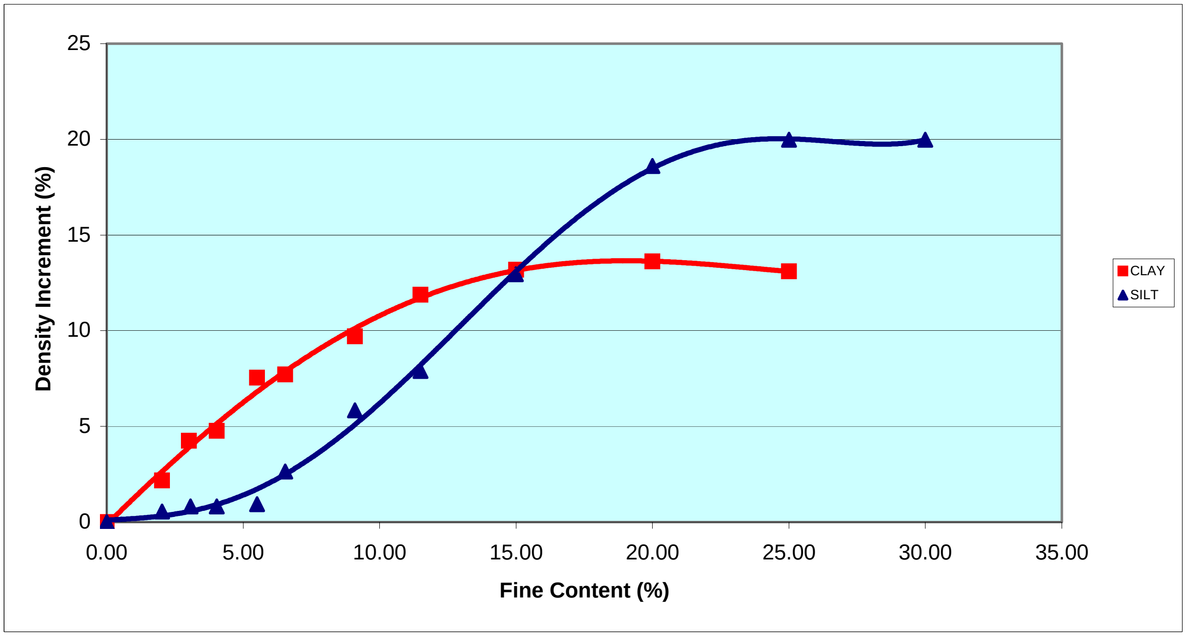

Figure 17: Increment in the Maximum Dry Density by the addition of fine.

4.3 Uniformity Coefficient Analyses

Subsequent to the analysis of compacted density based on soil type and fine content, the correlations between the Uniformity Coefficient, Cu, and the maximum dry density were studied. Figure 18, was plotted based on the data of the Uniformity Coefficient and the maximum dry density of soils. The data points show that the higher values of Cu, the higher values of soil density. The relationship for the Cu versus γ_d can be expressed by an equation as:

$$\gamma_d = 87.715xCu^{0.166} \qquad (4)$$

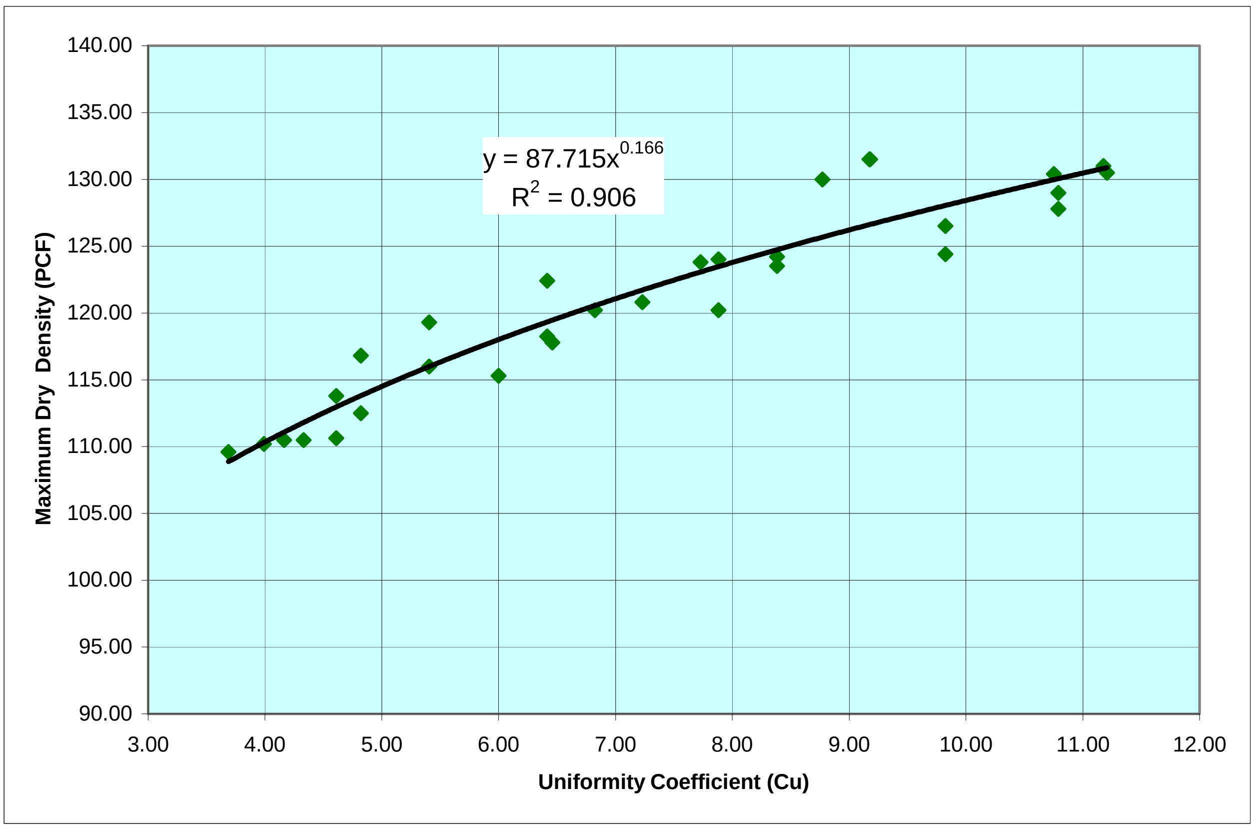

Figure 18: Increment in Maximum Dry Density by the Increment in Uniformity Coefficient.

Figure 19 displays that well-graded soils have a greater uniformity coefficient and higher maximum dry density, which is quite obvious from the most soil classification systems. It is also interesting to note that soils with a Cu between five and seven, poorly graded soils tend to reach higher maximum dry densities; this is because poorly graded soils between this range may have more fines (more than 9 %), thus, decreases the voids on soils, while well-graded soils with the same uniformity coefficient have less than 5 % of fines. Figure 19 also indicates that for the same uniformity coefficient and same soil grain size distribution, there are two different maximum dry densities, this is simply due to the type of fine; the higher value of γ_d corresponds to soils with plastic fines and the lower dry density to soils with non-plastic fines. This effect is shown in Figure 20, which was developed using data from soils with the same grain size distribution but different type of fine.

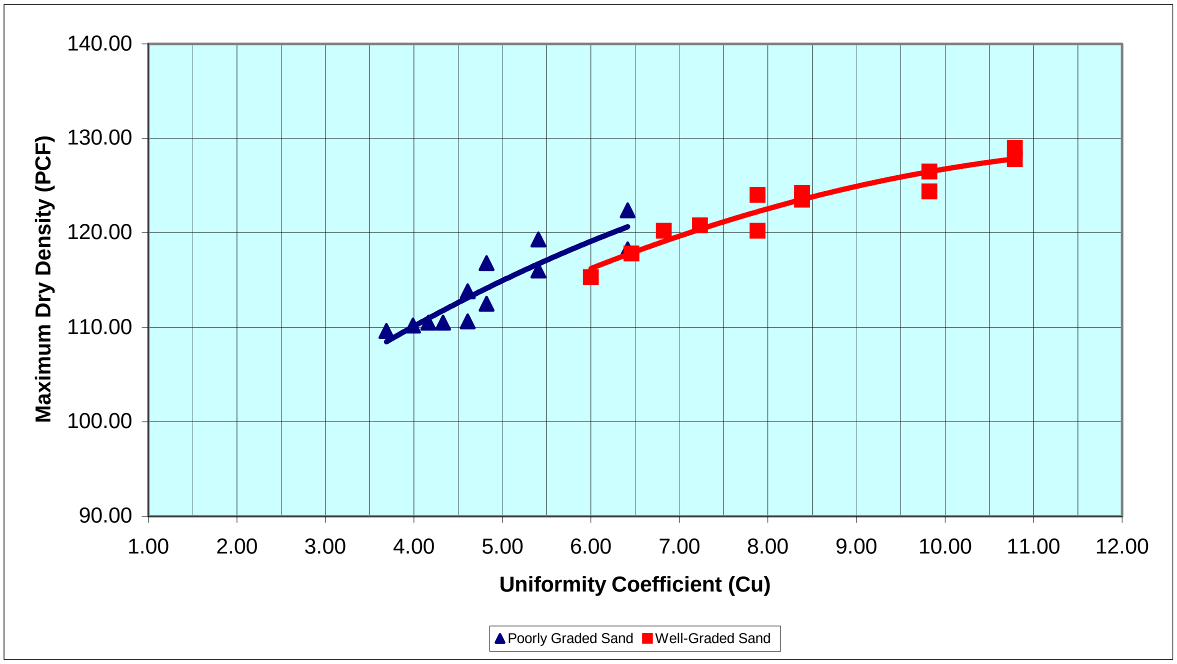

Figure 19: Variation of the Maximum Dry Density by the Increment in Uniformity Coefficient.

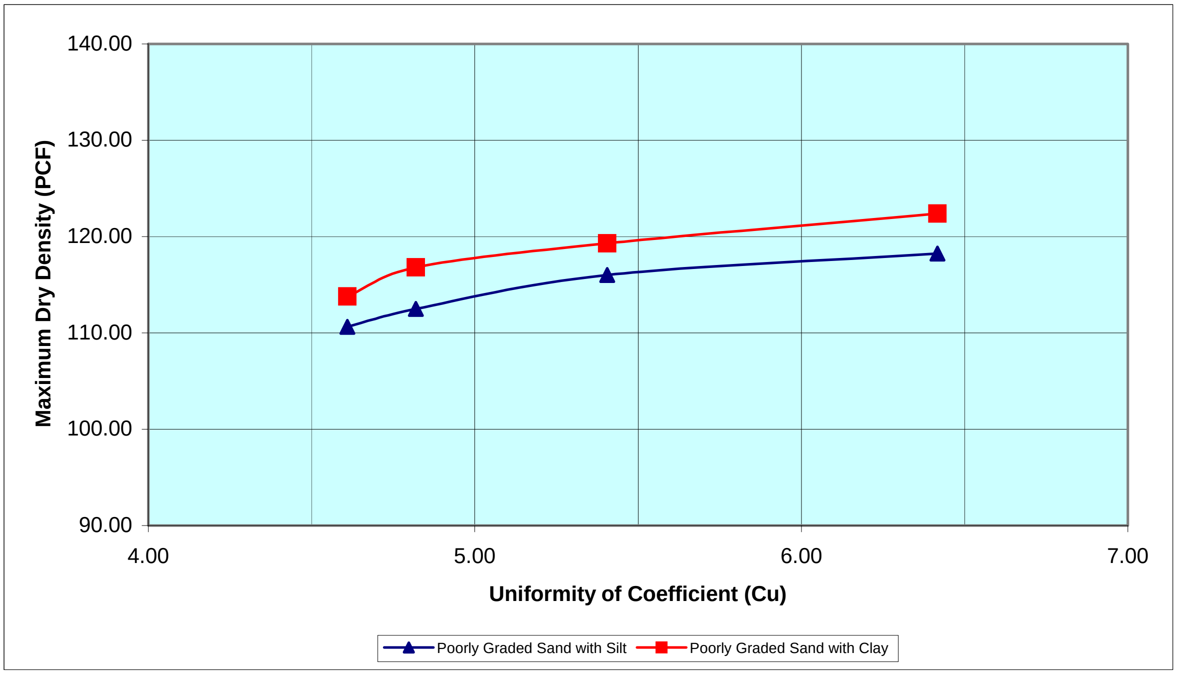

Figure 20: Increment in Maximum Dry Density by the Increment in Uniformity Coefficient.

4.4 Sensitivity Analysis

As earlier mentioned in this chapter, the maximum dry density is correlated to the fines type and the soils' gradation. In order to quantify the influence of these factors on the maximum dry density obtained from the standard Proctor test, a sensitivity analysis was performed based on the following tables and figures.

4.4.1 Fines Content

Table 6: Variation of the Maximum Dry Density by Fines Content.

Fine Content	Maximum Dry Density Well-Graded Sand with Clay (lb/ft^3)	Maximum Dry Density Poorly Graded Sand with Clay (lb/ft^3)	Maximum Dry Density Well-Graded Sand with Silt (lb/ft^3)	Maximum Dry Density Poorly Graded Sand with Silt (lb/ft^3)
5.5	124.0	113.8	120.2	113.8
6.5	124.2	116.8	123.5	117.8
9.1	126.5	119.3	124.4	120.2
11.5	129.0	122.4	127.8	120.8

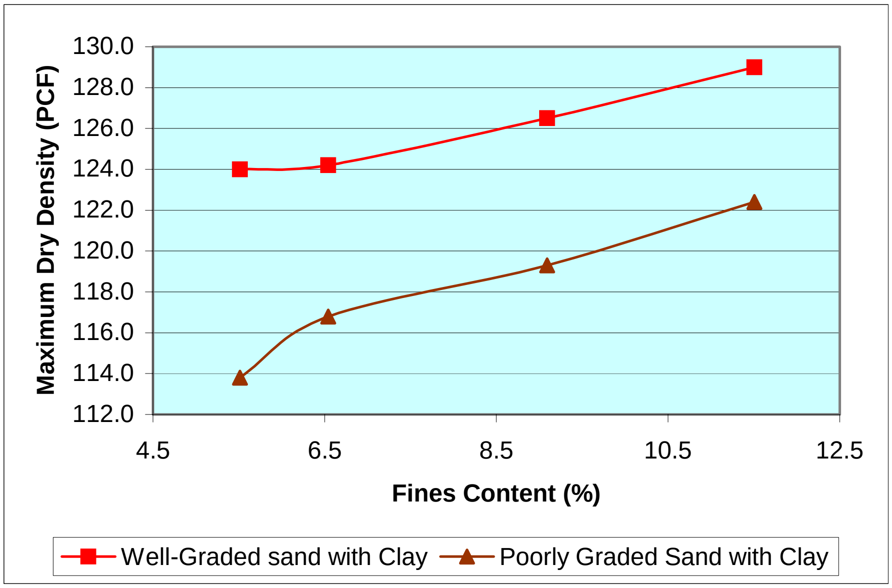

Figure 21: Maximum Dry Density versus Fine Content for Well-Graded and Poorly graded Sands with Clay.

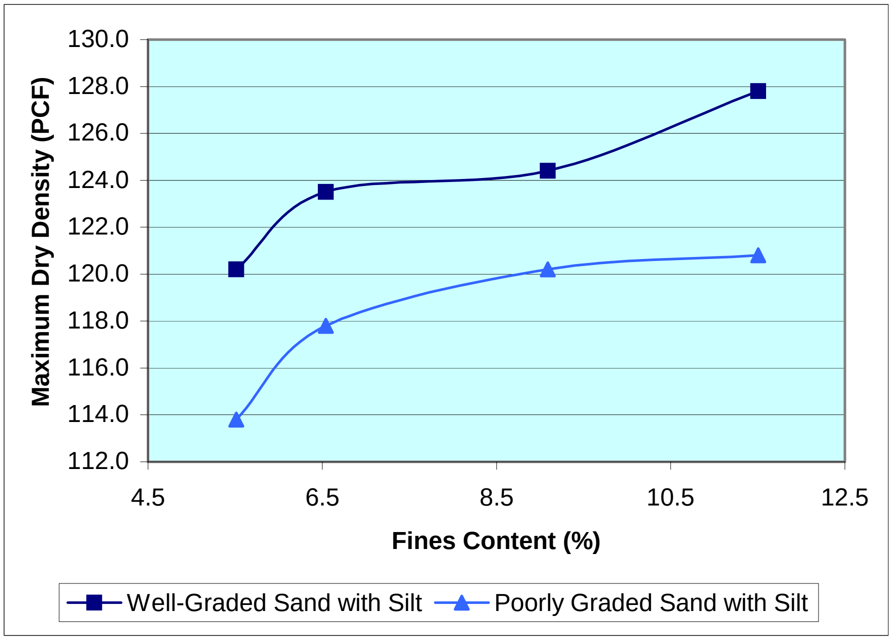

Figure 22: Maximum Dry Density versus Fine Content for Well-Graded and Poorly graded Sands with Silt.

Figures 21 and 22 compare the maximum dry densities of poorly graded and well-graded sands with the same amounts of fines. In Figure 21 the fines content consisted of Clay while in Figure 22 consisted of silt. It can be noticed from both figures that, despites the amount of fines, the maximum dry density of well-graded sands tends to be higher than that of poorly graded sands, this is because well-graded soils are more uniform in the grain size distribution, and for instance achieve higher maximum dry densities. It was encountered that for the soils presented in Table 5 this difference ranges from 5 to 9% and depends on the amount of fines.

4.4.2 Fines Type

Table 7: Variation of the Maximum Dry Density by Fines Type.

Cu	Clay fines	Silt fines
4.61	113.8	110.6
4.82	116.8	112.5
5.41	119.3	116.0
6.42	122.4	118.3
7.88	124.0	120.2
8.38	124.2	123.5
9.82	126.5	124.4
10.79	129.0	127.8

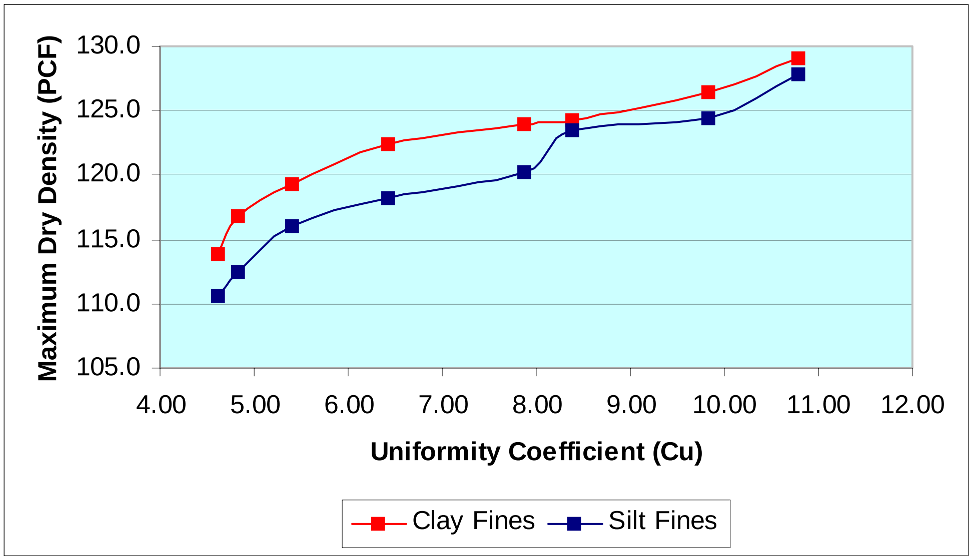

Figure 22: Maximum Dry Density versus Fines Type.

Figure 22 was developed from the values in Table 7 to evaluate how the type of fines affects the maximum dry density of common sands. It was developed using soils with the same size gradation but different type of fines. It is observed how different are the maximum dry densities due to the type of fines. It is seen that soils containing clay have higher maximum dry densities than those containing silt. This difference ranges from 1 to about 4%for the soils used in this research, and depends on the amount of fines.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

As discussed in the previous chapters the work performed in this thesis was aimed in addressing the influence of the soil characteristics in the maximum dry density obtained from the standard Proctor test. Particularly, the main interest was to evaluate the influence of the fines type and content in the maximum dry density.

The literature review mentions that the compaction of soils is affected by many factors, such as the moisture content, the compaction effort and the soil type among others. The review also includes a description of the graphical shapes for different types of soils and compaction efforts. This information was used in order to select the variables and measure their influence in the maximum dry density from the Proctor test.

Based on previous literature, it is concluded that the gradation of the soils plays an important role on its maximum dry density. It is known that for well-graded sands, the maximum dry density tends to be higher than for poorly graded sands. It is notorious that the increment in the fines content tends to increase the maximum dry density up to a maximum point, followed by a reduction in the maximum dry density thereafter.

Subsequent is a summary of the achievements of the study:

1) The maximum dry density presents a very interesting behavior from the cementation properties of the fines. It was observed that the soils containing clay tend to conglomerate more and achieve higher maximum dry densities than those having silt.

2) The Uniformity Coefficient is observed to have an important correlation with the maximum dry density. It is seen that variations in the Uniformity Coefficient represent proportional changes in the maximum dry density. This proportional relationship is expressed by the equation $\gamma_d = 87.715xCu^{0.166}$. It was observed that this relationship depends on the type of soil as described below:

- For sands with less than 5 % fines content, it was observed that the increment in the maximum dry density and the uniformity coefficient by the addition of fines was higher in well-graded sands than in poorly graded sands.
- For sands containing more than 5 % but less than 12 % fines content, the increment in the maximum dry density and the uniformity coefficient by the addition of fines was slightly higher in well-graded sands than in poorly graded sands. Also, it was observed an influence from the cementation properties of the clay.
- For soils with more than 12 % fines content, such as clayey sands and silty sands, it was observed that the uniformity coefficient and the maximum dry density of both types of soils are still affected by the addition of fines. It was found that the uniformity coefficient and the maximum dry density of these soils have a maximum value, which tends to decrease by the further increment of the fines content. From the studied soils it was observed that this maximum value was reached at 20% fines content for the clayey sands and at 25% fines content for the silty sands.

3) From the sensitivity analysis it was found that the maximum dry density tends to be higher for well-graded sands than for poorly graded sands. As it is detailed on section 4.4, this difference depends on the amount of fines, (i.e. for the sands used during this research this difference ranges from 5 to 9%). Also from the sensitivity analysis it was found that the cementation properties of the clay tends to provide higher maximum dry densities because the conglomeration of the soil's particles. It was noticed that this characteristic depends on the amount of fines, (i.e. for the studied soils this difference ranges from 1 to about 4%).

5.1 Limitations

Encountered limitation of this study include:

- Soil shape factor was not considered; therefore, it had to be estimated.
- Final behavior of the silty sand was not determined.
- Only the Standard Proctor Test was used during the investigation.

5.2 Recommendations for Future Research

The following recommendations may be useful for future studies:

- Evaluation of different soils from different sources will provide a more general behavior.
- Performance of different compaction energy for the same soil.
- Evaluation of fines with different plasticity index.

APPENDIX A

PROCTOR TEST AND SIEVE ANALYSIS RESULTS

Table A-1
SW (0% Fine Content): Proctor Test and Sieve Analysis

Sample			Fine content	0.00
SW			Content Tipe	CLAY
			Optimum Moisture Content	9.80
Visual Description of Soil:	Redish Gray Well Graded Sand		Maximum Dry Density	115.30
			Uniformity Coefficient	6.00

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

Mold Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
	4	4.6	0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	49.90	42.00	42.20	49.80
PAN and WET	250.10	250.60	250.30	250.50
PAN AND DRY	233.70	232.00	229.50	227.50
Wt. of water	16.40	18.60	20.80	23.00
Wt. of dry soil	183.80	190.00	187.30	177.70
Moisture Content	8.92	9.79	11.11	12.94

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	8.92	9.79	11.11	12.94
Wt. of soil + mold [lb]	13.44	13.52	13.52	13.54
Wt. of mold [lb]	9.30	9.30	9.30	9.30
Wt. soil in mold [lb]	4.14	4.22	4.22	4.24
Wet density [lb/cu. ft.]	124.14	126.54	126.54	127.14
Dry density [lb/cu. ft]	113.97	115.26	113.89	112.57

Gradation Analysis

PAN I.D.	1		D10	0.15
Wt. PAN	0.00		D30	0.425
PAN and WET	3000.00		D60	0.9
PAN AND DRY	3000.00			
PAN AND DRY2	3000.00		Cu	6.00
Wt. of water	0.00		Cz	1.34
Wt. of dry soil	3000.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D. 1

SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	5.00	95.00
40	0.425	2100.00	70.00	30.00
60	0.250	2400.00	80.00	20.00
100	0.150	2700.00	90.00	10.00
200	0.075	3000.00	100.00	0.00
>200	0.050	3000.00	100.00	0.00

Table A-2
SW (2% Fine Content): Proctor Test and Sieve Analysis

Sample		Fine content	2.02
SW		Content Tipe	CLAY
		Optimum Moisture Content	6.80
Visual Description of Soil:	Redish Gray Well Graded Sand	Maximum Dry Density	117.80
		Uniformity Coefficient	6.46

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
	4	4.6	0.033333333

Water Content Measurement

PAN I.D.	a	b	c	
Wt. PAN	39.15	40.40	50.30	
PAN and WET	225.10	231.80	260.00	
PAN AND DRY	216.70	218.80	242.10	
Wt. of water	8.40	13.00	17.90	
Wt. of dry soil	177.55	178.40	191.80	
Moisture Content	4.73	7.29	9.33	

Density Measurement

Assumed Moisture Content	8	10.5	13	
Moisture Content	4.73	7.29	9.33	
Wt. of soil + mold [lb]	13.39	13.52	13.46	
Wt. of mold [lb]	9.31	9.31	9.31	
Wt. soil in mold [lb]	4.08	4.21	4.15	
Wet density [lb/cu. ft.]	122.40	126.30	124.50	
Dry density [lb/cu. ft]	116.87	117.72	113.87	

Gradation Analysis

PAN I.D.	2		D10	0.131855934
Wt. PAN	0.00		D30	0.393595979
PAN and WET	3062.00		D60	0.851694883
PAN AND DRY	3062.00			
PAN AND DRY2	3000.00		Cu	6.46
Wt. of water	0.00		Cz	1.38
Wt. of dry soil	3062.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	2			
SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.90	95.10
40	0.425	2100.00	68.58	31.42
60	0.250	2400.00	78.38	21.62
100	0.150	2700.00	88.18	11.82
200	0.075	3000.00	97.98	2.02
>200	0.050	3062.00	100.00	0.00

Table A-3
SW (3% Fine Content): Proctor Test and Sieve Analysis

Sample		Fine content	3.01
SW		Content Tipe	CLAY
		Optimum Moisture Content	7.50
Visual Description of Soil:	Redish Gray Well Graded Sand	Maximum Dry Density	120.20
		Uniformity Coefficient	6.82

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
	4	4.6	0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	40.40	42.00	50.00	50.30
PAN and WET	234.50	256.40	262.00	238.40
PAN AND DRY	225.80	244.20	246.90	222.40
Wt. of water	8.70	12.20	15.10	16.00
Wt. of dry soil	185.40	202.20	196.90	172.10
Moisture Content	4.69	6.03	7.67	9.30

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.69	6.03	7.67	9.30
Wt. of soil + mold [lb]	13.44	13.52	13.62	13.53
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.13	4.21	4.31	4.22
Wet density [lb/cu. ft.]	123.90	126.30	129.30	126.60
Dry density [lb/cu. ft]	118.35	119.11	120.09	115.83

Gradation Analysis

PAN I.D.	3		D10	0.123624313
Wt. PAN	0.00		D30	0.378775181
PAN and WET	3093.00		D60	0.843347828
PAN AND DRY	3093.00			
PAN AND DRY2	3000.00		Cu	6.82
Wt. of water	0.00		Cz	1.38
Wt. of dry soil	3093.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	3			
SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.85	95.15
40	0.425	2100.00	67.90	32.10
60	0.250	2400.00	77.59	22.41
100	0.150	2700.00	87.29	12.71
200	0.075	3000.00	96.99	3.01
>200	0.050	3093.00	100.00	0.00

Table A-4

SW (4% Fine Content): Proctor Test and Sieve Analysis

Sample			Fine content	4.03
SW			Content Tipe	CLAY
			Optimum Moisture Content	6.00
Visual Description of Soil:	Redish Gray Well Graded Sand		Maximum Dry Density	120.80
			Uniformity Coefficient	7.23

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
	4	4.6	0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	41.80	42.20	41.80	50.50
PAN and WET	221.40	228.70	276.40	310.80
PAN AND DRY	215.80	219.70	260.50	289.90
Wt. of water	5.60	9.00	15.90	20.90
Wt. of dry soil	174.00	177.50	218.70	239.40
Moisture Content	3.22	5.07	7.27	8.73

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	3.22	5.07	7.27	8.73
Wt. of soil + mold [lb]	13.43	13.54	13.62	13.56
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.12	4.23	4.31	4.25
Wet density [lb/cu. ft.]	123.58	126.97	129.21	127.54
Dry density [lb/cu. ft]	119.73	120.84	120.45	117.30

Gradation Analysis

PAN I.D.	4		D10	0.115425542
Wt. PAN	0.00		D30	0.363610945
PAN and WET	3126.00		D60	0.834552127
PAN AND DRY	3126.00			
PAN AND DRY2	3000.00		Cu	7.23
Wt. of water	0.00		Cz	1.37
Wt. of dry soil	3126.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	4			
SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.80	95.20
40	0.425	2100.00	67.18	32.82
60	0.250	2400.00	76.78	23.22
100	0.150	2700.00	86.37	13.63
200	0.075	3000.00	95.97	4.03
>200	0.050	3126.00	100.00	0.00

Table A-5
SP (0% Fine Content): Proctor Test and Sieve Analysis

Sample		Fine content	0.00
SP		Content Tipe	Silt
		Optimum Moisture Content	12.00
Visual Description of Soil:	Gray Poorly Graded Sand	Maximum Dry Density	109.60
		Uniformity Coefficient	3.69

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	41.20	50.20	50.40	50.10
PAN and WET	250.70	250.00	250.10	252.80
PAN AND DRY	234.70	232.20	228.80	228.80
Wt. of water	16.00	17.80	21.30	24.00
Wt. of dry soil	193.50	182.00	178.40	178.70
Moisture Content	8.27	9.78	11.94	13.43

Density Measurement

	5949.3	6011.4	6093.5	6085.8
Moisture Content	8.27	9.78	11.94	13.43
Wt. of soil + mold [lb]	13.12	13.26	13.43	13.42
Wt. of mold [lb]	9.34	9.34	9.34	9.34
Wt. soil in mold [lb]	3.78	3.92	4.09	4.08
Wet density [lb/cu. ft.]	113.40	117.60	122.70	122.40
Dry density [lb/cu. ft]	104.74	107.12	109.61	107.91

Gradation Analysis

PAN I.D.	c-8		D10	0.25
Wt. PAN	0.00		D30	0.515785422
PAN and WET	3000.00		D60	0.921954446
PAN AND DRY	3000.00			
PAN AND DRY2	3000.00		Cu	3.69
Wt. of water	0.00		Cz	1.15
Wt. of dry soil	3000.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	80.00	20.00
60	0.250	2700.00	90.00	10.00
100	0.150	3000.00	100.00	0.00
200	0.075	3000.00	100.00	0.00
>200	0.050	3000.00	100.00	0.00

Table A-6
SP (2% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	2.02
SP		Content Tipe	Silt
		Optimum Moisture Content	9.75
Visual Description of Soil:	Gray Poorly Graded Sand	Maximum Dry Density	110.20
		Uniformity Coefficient	0.00

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.30	49.80	41.70	42.00
PAN and WET	243.80	237.80	241.00	239.30
PAN AND DRY	234.50	224.70	223.30	219.80
Wt. of water	9.30	13.10	17.70	19.50
Wt. of dry soil	184.20	174.90	181.60	177.80
Moisture Content	5.05	7.49	9.75	10.97

Density Measurement

Moisture Content	5.05	7.49	9.75	10.97
Wt. of soil + mold [lb]	13.13	13.24	13.33	13.36
Wt. of mold [lb]	9.30	9.30	9.30	9.30
Wt. soil in mold [lb]	3.83	3.94	4.03	4.06
Wet density [lb/cu. ft.]	114.90	118.20	120.90	121.80
Dry density [lb/cu. ft]	109.38	109.96	110.16	109.76

Gradation Analysis

PAN I.D.	c-8		D10	0.227340149
Wt. PAN	0.00		D30	0.501539879
PAN and WET	3062.00		D60	0.907316562
PAN AND DRY	3062.00			
PAN AND DRY2	3000.00		Cu	3.99
Wt. of water	0.00		Cz	1.22
Wt. of dry soil	3062.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	78.38	21.62
60	0.250	2700.00	88.18	11.82
100	0.150	3000.00	97.98	2.02
200	0.075	3000.00	97.98	2.02
>200	0.050	3062.00	100.00	0.00

Table A-7
SP (3% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	3.07
SP		Content Tipe	Silt
		Optimum Moisture Content	9.50
Visual Description of Soil:	Gray Poorly Graded Sand	Maximum Dry Density	110.50
		Uniformity Coefficient	4.16

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	42.00	50.40	50.30	42.00
PAN and WET	219.20	252.80	241.00	258.60
PAN AND DRY	211.10	241.20	227.30	238.40
Wt. of water	8.10	11.60	13.70	20.20
Wt. of dry soil	169.10	190.80	177.00	196.40
Moisture Content	4.79	6.08	7.74	10.29

Density Measurement

Moisture Content	4.79	6.08	7.74	10.29
Wt. of soil + mold [lb]	13.09	13.16	13.25	13.34
Wt. of mold [lb]	9.30	9.30	9.30	9.30
Wt. soil in mold [lb]	3.79	3.86	3.95	4.04
Wet density [lb/cu. ft.]	113.70	115.80	118.50	121.20
Dry density [lb/cu. ft]	108.50	109.16	109.99	109.90

Gradation Analysis

PAN I.D.	c-8	D10	0.216129035
Wt. PAN	0.00	D30	0.494118712
PAN and WET	3095.00	D60	0.899620436
PAN AND DRY	3095.00		
PAN AND DRY2	3000.00	Cu	4.16
Wt. of water	0.00	Cz	1.26
Wt. of dry soil	3095.00		
Moisture Content	0.00	Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	77.54	22.46
60	0.250	2700.00	87.24	12.76
100	0.150	3000.00	96.93	3.07
200	0.075	3000.00	96.93	3.07
>200	0.050	3095.00	100.00	0.00

Table A-8
SP (4% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	4.03
SP		Content Tipe	Silt
		Optimum Moisture Content	9.00
Visual Description of Soil:	Gray Poorly Graded Sand	Maximum Dry Density	110.50
		Uniformity Coefficient	4.33

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	39.30	41.90	42.10	41.90
PAN and WET	240.40	243.90	252.10	267.70
PAN AND DRY	231.20	230.10	234.70	247.20
Wt. of water	9.20	13.80	17.40	20.50
Wt. of dry soil	191.90	188.20	192.60	205.30
Moisture Content	4.79	7.33	9.03	9.99

Density Measurement

Assumed Moisture Content				
Moisture Content	4.79	7.33	9.03	9.99
Wt. of soil + mold [lb]	13.15	13.26	13.32	13.33
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	3.84	3.95	4.01	4.02
Wet density [lb/cu. ft.]	115.25	118.61	120.20	120.55
Dry density [lb/cu. ft]	109.98	110.51	110.24	109.61

Gradation Analysis

PAN I.D.	c-8		D10	0.206101514
Wt. PAN	0.00		D30	0.487247371
PAN and WET	3126.00		D60	0.892450219
PAN AND DRY	3126.00			
PAN AND DRY2	3000.00		Cu	4.33
Wt. of water	0.00		Cz	1.29
Wt. of dry soil	3126.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	76.78	23.22
60	0.250	2700.00	86.37	13.63
100	0.150	3000.00	95.97	4.03
200	0.075	3000.00	95.97	4.03
>200	0.050	3126.00	100.00	0.00

Table A-9
SW-SC (5.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	5.51
SW-SC		Content Tipe	Clay
		Optimum Moisture Content	8.10
Visual Description of Soil:	Redish Gray Sand with Clay	Maximum Dry Density	124.00
		Uniformity Coefficient	7.88

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	41.20	50.00	50.40	50.20
PAN and WET	223.60	260.50	242.10	282.50
PAN AND DRY	215.30	245.00	225.70	259.10
Wt. of water	8.30	15.50	16.40	23.40
Wt. of dry soil	174.10	195.00	175.30	208.90
Moisture Content	4.77	7.95	9.36	11.20

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.77	7.95	9.36	11.20
Wt. of soil + mold [lb]	13.58	13.74	13.44	13.24
Wt. of mold [lb]	9.30	9.30	9.30	9.30
Wt. soil in mold [lb]	4.28	4.44	4.14	3.94
Wet density [lb/cu. ft.]	128.40	133.20	124.20	118.20
Dry density [lb/cu. ft]	122.56	123.39	113.57	106.29

Gradation Analysis

PAN I.D.	1		D10	0.104243866
Wt. PAN	0.00		D30	0.342207051
PAN and WET	3175.00		D60	0.821660791
PAN AND DRY	3175.00			
PAN AND DRY2	3000.00		Cu	7.88
Wt. of water	0.00		Cz	1.37
Wt. of dry soil	3175.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	1			
SIEVE No.	Size. [mm]	Wt. Retained including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.72	95.28
40	0.425	2100.00	66.14	33.86
60	0.250	2400.00	75.59	24.41
100	0.150	2700.00	85.04	14.96
200	0.075	3000.00	94.49	5.51
>200	0.050	3175.00	100.00	0.00

Table A-10
SW-SC (6.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	6.54
SW-SC		Content Tipe	Clay
		Optimum Moisture Content	6.50
Visual Description of Soil:	Redish Gray Sand with Clay	Maximum Dry Density	124.20
		Uniformity Coefficient	8.38

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.40	50.30	41.20	50.50
PAN and WET	237.50	243.40	238.60	262.00
PAN AND DRY	229.40	230.90	221.80	241.30
Wt. of water	8.10	12.50	16.80	20.70
Wt. of dry soil	179.00	180.60	180.60	190.80
Moisture Content	4.53	6.92	9.30	10.85

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.53	6.92	9.30	10.85
Wt. of soil + mold [lb]	13.58	13.72	13.55	13.32
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.27	4.41	4.24	4.01
Wet density [lb/cu. ft.]	128.10	132.30	127.20	120.30
Dry density [lb/cu. ft]	122.55	123.74	116.37	108.53

Gradation Analysis

PAN I.D.	a		D10	0.096926462
Wt. PAN	0.00		D30	0.327694354
PAN and WET	3210.00		D60	0.812574792
PAN AND DRY	3210.00			
PAN AND DRY2	3000.00		Cu	8.38
Wt. of water	0.00		Cz	1.36
Wt. of dry soil	3210.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	a			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.67	95.33
40	0.425	2100.00	65.42	34.58
60	0.250	2400.00	74.77	25.23
100	0.150	2700.00	84.11	15.89
200	0.075	3000.00	93.46	6.54
>200	0.050	3210.00	100.00	0.00

Table A-11
SW-SC (9% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	9.09
SW-SC			Content Tipe	Clay
			Optimum Moisture Content	7.50
Visual Description of Soil:	Redish Gray Sand with Clay		Maximum Dry Density	126.50
			Uniformity Coefficient	9.82

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	42.20	50.30	50.40	50.50
PAN and WET	225.80	271.30	266.50	241.50
PAN AND DRY	217.30	256.70	249.30	223.60
Wt. of water	8.50	14.60	17.20	17.90
Wt. of dry soil	175.10	206.40	198.90	173.10
Moisture Content	4.85	7.07	8.65	10.34

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.85	7.07	8.65	10.34
Wt. of soil + mold [lb]	13.64	13.83	13.86	13.57
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.33	4.52	4.55	4.26
Wet density [lb/cu. ft.]	129.88	135.54	136.48	127.73
Dry density [lb/cu. ft]	123.86	126.58	125.62	115.76

Gradation Analysis

PAN I.D.	3		D10	0.08038301
Wt. PAN	0.00		D30	0.293139731
PAN and WET	3300.00		D60	0.789669486
PAN AND DRY	3300.00			
PAN AND DRY2	3000.00		Cu	9.82
Wt. of water	0.00		Cz	1.35
Wt. of dry soil	3300.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	3			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.55	95.45
40	0.425	2100.00	63.64	36.36
60	0.250	2400.00	72.73	27.27
100	0.150	2700.00	81.82	18.18
200	0.075	3000.00	90.91	9.09
>200	0.050	3300.00	100.00	0.00

Table A-12
SW-SC (11.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	11.50
SW-SC		Content Tipe	Clay
		Optimum Moisture Content	7.50
Visual Description of Soil:	Redish Gray Sand with Clay	Maximum Dry Density	129.00
		Uniformity Coefficient	10.79

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	42.20	42.00	50.40	41.20
PAN and WET	228.70	230.90	219.10	266.70
PAN AND DRY	219.70	217.80	205.10	244.90
Wt. of water	9.00	13.10	14.00	21.80
Wt. of dry soil	177.50	175.80	154.70	203.70
Moisture Content	5.07	7.45	9.05	10.70

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	5.07	7.45	9.05	10.70
Wt. of soil + mold [lb]	13.72	13.93	13.91	13.72
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.41	4.62	4.60	4.41
Wet density [lb/cu. ft.]	132.28	138.56	138.10	132.26
Dry density [lb/cu. ft]	125.90	128.95	126.64	119.47

Gradation Analysis

PAN I.D.	c-8		D10	0.07112691
Wt. PAN	0.00		D30	0.262228815
PAN and WET	3390.00		D60	0.767409847
PAN AND DRY	3390.00			
PAN AND DRY2	3000.00		Cu	10.79
Wt. of water	0.00		Cz	1.26
Wt. of dry soil	3390.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.42	95.58
40	0.425	2100.00	61.95	38.05
60	0.250	2400.00	70.80	29.20
100	0.150	2700.00	79.65	20.35
200	0.075	3000.00	88.50	11.50
>200	0.050	3390.00	100.00	0.00

Table A-13

SW-SM (5.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	5.51
SW-SM		Content Tipe	Silt
		Optimum Moisture Content	7.40
Visual Description of Soil:	Gray Sand with Silt	Maximum Dry Density	120.20
		Uniformity Coefficient	7.88

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	42.00	50.10	50.30	41.60
PAN and WET	258.00	248.60	245.30	265.30
PAN AND DRY	247.70	235.00	227.70	241.60
Wt. of water	10.30	13.60	17.60	23.70
Wt. of dry soil	205.70	184.90	177.40	200.00
Moisture Content	5.01	7.36	9.92	11.85

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	5.01	7.36	9.92	11.85
Wt. of soil + mold [lb]	13.51	13.64	13.71	13.76
Wt. of mold [lb]	9.34	9.34	9.34	9.34
Wt. soil in mold [lb]	4.17	4.30	4.37	4.42
Wet density [lb/cu. ft.]	125.10	129.00	131.10	132.60
Dry density [lb/cu. ft]	119.13	120.16	119.27	118.55

Gradation Analysis

PAN I.D.	1	D10	0.104243866
Wt. PAN	0.00	D30	0.342207051
PAN and WET	3175.00	D60	0.821660791
PAN AND DRY	3175.00		
PAN AND DRY2	3000.00	Cu	7.88
Wt. of water	0.00	Cz	1.37
Wt. of dry soil	3175.00		
Moisture Content	0.00	Gradation:	Well

PAN I.D.	1			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.72	95.28
40	0.425	2100.00	66.14	33.86
60	0.250	2400.00	75.59	24.41
100	0.150	2700.00	85.04	14.96
200	0.075	3000.00	94.49	5.51
>200	0.050	3175.00	100.00	0.00

Table A-14
SW-SM (6.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	6.54
SW-SM		Content Tipe	Silt
		Optimum Moisture Content	7.50
Visual Description of Soil:	Gray Sand with Silt	Maximum Dry Density	123.50
		Uniformity Coefficient	8.38

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	10	11	5	4
Wt. PAN	41.80	39.70	41.80	42.10
PAN and WET	227.80	225.70	241.50	245.70
PAN AND DRY	219.30	214.40	226.70	227.90
Wt. of water	8.50	11.30	14.80	17.80
Wt. of dry soil	177.50	174.70	184.90	185.80
Moisture Content	4.79	6.47	8.00	9.58

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.79	6.47	8.00	9.58
Wt. of soil + mold [lb]	13.62	13.71	13.79	13.71
Wt. of mold [lb]	9.35	9.35	9.35	9.35
Wt. soil in mold [lb]	4.27	4.36	4.44	4.36
Wet density [lb/cu. ft.]	128.10	130.80	133.20	130.80
Dry density [lb/cu. ft]	122.25	122.85	123.33	119.36

Gradation Analysis

PAN I.D.	2		D10	0.096926462
Wt. PAN	0.00		D30	0.327694354
PAN and WET	3210.00		D60	0.812574792
PAN AND DRY	3210.00			
PAN AND DRY2	3000.00		Cu	8.38
Wt. of water	0.00		Cz	1.36
Wt. of dry soil	3210.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	2			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.67	95.33
40	0.425	2100.00	65.42	34.58
60	0.250	2400.00	74.77	25.23
100	0.150	2700.00	84.11	15.89
200	0.075	3000.00	93.46	6.54
>200	0.050	3210.00	100.00	0.00

Table A-15
SW-SM (9% Fine Content): Proctor Test and Sieve Analysis

Sample No.	Fine content	9.09
SW-SM	Content Tipe	0.00
	Optimum Moisture Content	6.90
Visual Description of Soil: Gray Sand with Silt	Maximum Dry Density	124.40
	Uniformity Coefficient	9.82

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.00	50.40	42.10	39.40
PAN and WET	224.10	249.60	242.80	281.30
PAN AND DRY	214.50	236.80	227.20	259.40
Wt. of water	9.60	12.80	15.60	21.90
Wt. of dry soil	164.50	186.40	185.10	220.00
Moisture Content	5.84	6.87	8.43	9.95

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	5.84	6.87	8.43	9.95
Wt. of soil + mold [lb]	13.66	13.74	13.78	13.65
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.35	4.43	4.47	4.34
Wet density [lb/cu. ft.]	130.36	132.86	133.98	130.12
Dry density [lb/cu. ft]	123.17	124.33	123.56	118.34

Gradation Analysis

PAN I.D.	3	D10	0.08038301
Wt. PAN	0.00	D30	0.293139731
PAN and WET	3300.00	D60	0.789669486
PAN AND DRY	3300.00		
PAN AND DRY2	3000.00	Cu	9.82
Wt. of water	0.00	Cz	1.35
Wt. of dry soil	3300.00		
Moisture Content	0.00	Gradation:	Well

PAN I.D.	3			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.55	95.45
40	0.425	2100.00	63.64	36.36
60	0.250	2400.00	72.73	27.27
100	0.150	2700.00	81.82	18.18
200	0.075	3000.00	90.91	9.09
>200	0.050	3300.00	100.00	0.00

Table A-16
SW-SM (11.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	11.50
SW-SM			Content Tipe	Silt
			Optimum Moisture Content	7.30
Visual Description of Soil:	Gray Sand with Silt		Maximum Dry Density	127.80
			Uniformity Coefficient	10.79

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.00	42.00	50.30	41.80
PAN and WET	253.60	258.10	252.70	283.50
PAN AND DRY	244.10	243.50	236.00	260.10
Wt. of water	9.50	14.60	16.70	23.40
Wt. of dry soil	194.10	201.50	185.70	218.30
Moisture Content	4.89	7.25	8.99	10.72

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.89	7.25	8.99	10.72
Wt. of soil + mold [lb]	13.73	13.88	13.89	13.72
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.42	4.57	4.58	4.41
Wet density [lb/cu. ft.]	132.56	137.09	137.40	132.35
Dry density [lb/cu. ft]	126.38	127.83	126.06	119.54

Gradation Analysis

PAN I.D.	4		D10	0.07112691
Wt. PAN	0.00		D30	0.262228815
PAN and WET	3390.00		D60	0.767409847
PAN AND DRY	3390.00			
PAN AND DRY2	3000.00		Cu	10.79
Wt. of water	0.00		Cz	1.26
Wt. of dry soil	3390.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	4			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	150.00	4.42	95.58
40	0.425	2100.00	61.95	38.05
60	0.250	2400.00	70.80	29.20
100	0.150	2700.00	79.65	20.35
200	0.075	3000.00	88.50	11.50
>200	0.050	3390.00	100.00	0.00

Table A-17
SP-SC (5.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	5.51
SP-SC		Content Tipe	Clay
		Optimum Moisture Content	7.80
Visual Description of Soil:	Red Sand with Clay	Maximum Dry Density	113.80
		Uniformity Coefficient	4.61

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	B-4	B-1	B-2	B-3
Wt. PAN	49.90	50.00	42.00	42.20
PAN and WET	276.50	245.80	256.90	253.60
PAN AND DRY	272.60	231.90	238.20	233.00
Wt. of water	3.90	13.90	18.70	20.60
Wt. of dry soil	222.70	181.90	196.20	190.80
Moisture Content	1.75	7.64	9.53	10.80

Density Measurement

Assumed Moisture Content	15	8	10.5	13
Moisture Content	1.75	7.64	9.53	10.80
Wt. of soil + mold [lb]	13.04	13.38	13.25	13.07
Wt. of mold [lb]	9.30	9.30	9.30	9.30
Wt. soil in mold [lb]	3.74	4.08	3.95	3.77
Wet density [lb/cu. ft.]	112.20	122.40	118.50	113.10
Dry density [lb/cu. ft]	110.27	113.71	108.19	102.08

Gradation Analysis

PAN I.D.	c-8		D10	0.191191867
Wt. PAN	0.00		D30	0.476580581
PAN and WET	3175.00		D60	0.881233027
PAN AND DRY	3175.00			
PAN AND DRY2	3000.00		Cu	4.61
Wt. of water	0.00		Cz	1.35
Wt. of dry soil	3175.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	75.59	24.41
60	0.250	2700.00	85.04	14.96
100	0.150	3000.00	94.49	5.51
200	0.075	3000.00	94.49	5.51
>200	0.050	3175.00	100.00	0.00

Table A-18
SP-SC (6.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	6.54
SP-SC			Content Tipe	Clay
			Optimum Moisture Content	7.40
Visual Description of Soil:	Red Sand with Clay		Maximum Dry Density	116.80
			Uniformity Coefficient	4.82

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	B-1	B-2	B-3	B-4
Wt. PAN	50.00	42.00	42.20	49.90
PAN and WET	205.40	213.70	245.10	205.00
PAN AND DRY	198.20	201.90	227.40	189.40
Wt. of water	7.20	11.80	17.70	15.60
Wt. of dry soil	148.20	159.90	185.20	139.50
Moisture Content	4.86	7.38	9.56	11.18

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.86	7.38	9.56	11.18
Wt. of soil + mold [lb]	13.35	13.48	13.49	13.17
Wt. of mold [lb]	9.30	9.30	9.30	9.30
Wt. soil in mold [lb]	4.05	4.18	4.19	3.87
Wet density [lb/cu. ft.]	121.50	125.40	125.70	116.10
Dry density [lb/cu. ft]	115.87	116.78	114.73	104.42

Gradation Analysis

PAN I.D.	c-8		D10	0.181207136
Wt. PAN	0.00		D30	0.469104715
PAN and WET	3210.00		D60	0.87330717
PAN AND DRY	3210.00			
PAN AND DRY2	3000.00		Cu	4.82
Wt. of water	0.00		Cz	1.39
Wt. of dry soil	3210.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	74.77	25.23
60	0.250	2700.00	84.11	15.89
100	0.150	3000.00	93.46	6.54
200	0.075	3000.00	93.46	6.54
>200	0.050	3210.00	100.00	0.00

Table A-19
SP-SC (9% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	9.09
SP-SC		Content Tipe	Clay
		Optimum Moisture Content	8.50
Visual Description of Soil:	Red Sand with Clay	Maximum Dry Density	119.30
		Uniformity Coefficient	5.41

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.40	41.20	50.00	42.00
PAN and WET	235.60	244.90	269.00	266.40
PAN AND DRY	227.70	231.30	251.90	245.60
Wt. of water	7.90	13.60	17.10	20.80
Wt. of dry soil	177.30	190.10	201.90	203.60
Moisture Content	4.46	7.15	8.47	10.22

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.46	7.15	8.47	10.22
Wt. of soil + mold [lb]	13.37	13.53	13.62	13.54
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.06	4.22	4.31	4.23
Wet density [lb/cu. ft.]	121.89	126.60	129.36	126.89
Dry density [lb/cu. ft]	116.69	118.15	119.26	115.12

Gradation Analysis

PAN I.D.	c-8		D10	0.157861467
Wt. PAN	0.00		D30	0.450415129
PAN and WET	3300.00		D60	0.853252186
PAN AND DRY	3300.00			
PAN AND DRY2	3000.00		Cu	5.41
Wt. of water	0.00		Cz	1.51
Wt. of dry soil	3300.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	72.73	27.27
60	0.250	2700.00	81.82	18.18
100	0.150	3000.00	90.91	9.09
200	0.075	3000.00	90.91	9.09
>200	0.050	3300.00	100.00	0.00

Table A-20
SP-SC (11.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	11.50
SP-SC		Content Tipe	Clay
		Optimum Moisture Content	9.20
Visual Description of Soil:	Red Sand with Clay	Maximum Dry Density	122.40
		Uniformity Coefficient	6.42

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	c-7	bb-11	c	d
Wt. PAN	50.30	42.20	50.30	41.70
PAN and WET	236.80	270.60	248.40	259.00
PAN AND DRY	228.20	254.70	231.60	237.40
Wt. of water	8.60	15.90	16.80	21.60
Wt. of dry soil	177.90	212.50	181.30	195.70
Moisture Content	4.83	7.48	9.27	11.04

Density Measurement

Assumed Moisture Content	8	13	13	15
Moisture Content	4.83	7.48	9.27	11.04
Wt. of soil + mold [lb]	13.50	13.78	13.94	13.87
Wt. of mold [lb]	9.48	9.48	9.48	9.48
Wt. soil in mold [lb]	4.02	4.30	4.46	4.39
Wet density [lb/cu. ft.]	120.60	128.87	133.71	131.63
Dry density [lb/cu. ft]	115.04	119.90	122.37	118.55

Gradation Analysis

PAN I.D.	c-8		D10	0.129926721
Wt. PAN	0.00		D30	0.432470155
PAN and WET	3390.00		D60	0.833657753
PAN AND DRY	3390.00			
PAN AND DRY2	3000.00		Cu	6.42
Wt. of water	0.00		Cz	1.73
Wt. of dry soil	3390.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	70.80	29.20
60	0.250	2700.00	79.65	20.35
100	0.150	3000.00	88.50	11.50
200	0.075	3000.00	88.50	11.50
>200	0.050	3390.00	100.00	0.00

Table A-21
SP-SM (5.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	5.51
SP-SM		Content Tipe	Silt
		Optimum Moisture Content	10.40
Visual Description of Soil:	Brown Sand with Silt	Maximum Dry Density	110.62
		Uniformity Coefficient	4.61

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	b
Wt. PAN	39.40	39.60	39.50	42.10
PAN and WET	253.50	241.60	245.90	255.40
PAN AND DRY	243.60	227.90	226.50	232.50
Wt. of water	9.90	13.70	19.40	22.90
Wt. of dry soil	204.20	188.30	187.00	190.40
Moisture Content	4.85	7.28	10.37	12.03

Density Measurement

Moisture Content	4.85	7.28	10.37	12.03
Wt. of soil + mold [lb]	13.15	13.25	13.39	13.42
Wt. of mold [lb]	9.32	9.32	9.32	9.32
Wt. soil in mold [lb]	3.83	3.93	4.07	4.10
Wet density [lb/cu. ft.]	114.90	117.90	122.10	123.00
Dry density [lb/cu. ft]	109.59	109.90	110.62	109.79

Gradation Analysis

PAN I.D.	c-8		D10	0.191191867
Wt. PAN	0.00		D30	0.476580581
PAN and WET	3175.00		D60	0.881233027
PAN AND DRY	3175.00			
PAN AND DRY2	3000.00		Cu	4.61
Wt. of water	0.00		Cz	1.35
Wt. of dry soil	3175.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	75.59	24.41
60	0.250	2700.00	85.04	14.96
100	0.150	3000.00	94.49	5.51
200	0.075	3000.00	94.49	5.51
>200	0.050	3175.00	100.00	0.00

Table A-22
SP-SM (6.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	6.54
SP-SM			Content Tipe	Silt
			Optimum Moisture Content	7.50
Visual Description of Soil:	Brown Sand with Silt		Maximum Dry Density	112.50
			Uniformity Coefficient	4.82

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	39.50	49.90	39.40	50.10
PAN and WET	230.00	229.60	251.10	264.90
PAN AND DRY	221.80	218.50	235.40	244.90
Wt. of water	8.20	11.10	15.70	20.00
Wt. of dry soil	182.30	168.60	196.00	194.80
Moisture Content	4.50	6.58	8.01	10.27

Density Measurement

Moisture Content	4.50	6.58	8.01	10.27
Wt. of soil + mold [lb]	13.22	13.31	13.37	13.35
Wt. of mold [lb]	9.32	9.32	9.32	9.32
Wt. soil in mold [lb]	3.90	3.99	4.05	4.03
Wet density [lb/cu. ft.]	117.00	119.70	121.50	120.90
Dry density [lb/cu. ft]	111.96	112.31	112.49	109.64

Gradation Analysis

PAN I.D.	c-8		D10	0.181207136
Wt. PAN	0.00		D30	0.469104715
PAN and WET	3210.00		D60	0.87330717
PAN AND DRY	3210.00			
PAN AND DRY2	3000.00		Cu	4.82
Wt. of water	0.00		Cz	1.39
Wt. of dry soil	3210.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	74.77	25.23
60	0.250	2700.00	84.11	15.89
100	0.150	3000.00	93.46	6.54
200	0.075	3000.00	93.46	6.54
>200	0.050	3210.00	100.00	0.00

Table A-23
SP-SM (9% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content		9.09
SP-SM		Content Tipe		Silt
		Optimum Moisture Content		10.00
Visual Description of Soil:	Brown Sand with Silt	Maximum Dry Density		116.00
		Uniformity Coefficient		5.41

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	b	d
Wt. PAN	49.90	50.30	50.10	50.30	42.10
PAN and WET	251.20	263.10	236.80	239.00	225.20
PAN AND DRY	242.30	250.60	223.40	222.50	206.80
Wt. of water	8.90	12.50	13.40	16.50	18.40
Wt. of dry soil	192.40	200.30	173.30	172.20	164.70
Moisture Content	4.63	6.24	7.73	9.58	11.17

Density Measurement

Assumed Moisture Content	5	7	8	10	11
Moisture Content	4.63	6.24	7.73	9.58	11.17
Wt. of soil + mold [lb]	13.30	13.37	13.46	13.53	13.40
Wt. of mold [lb]	9.31	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	3.99	4.06	4.15	4.22	4.09
Wet density [lb/cu. ft.]	119.64	121.75	124.59	126.69	122.72
Dry density [lb/cu. ft]	114.35	114.60	115.65	115.61	110.39

Gradation Analysis

PAN I.D.	c-8		D10	0.157861467
Wt. PAN	0.00		D30	0.450415129
PAN and WET	3300.00		D60	0.853252186
PAN AND DRY	3300.00			
PAN AND DRY2	3000.00		Cu	5.41
Wt. of water	0.00		Cz	1.51
Wt. of dry soil	3300.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	72.73	27.27
60	0.250	2700.00	81.82	18.18
100	0.150	3000.00	90.91	9.09
200	0.075	3000.00	90.91	9.09
>200	0.050	3300.00	100.00	0.00

Table A-24
SP-SM (11.5% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	11.50
SP-SM			Content Tipe	Silt
			Optimum Moisture Content	8.80
			Maximum Dry Density	118.25
Visual Description of Soil:	Brown Sand with Silt		Uniformity Coefficient	6.42

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	b
Wt. PAN	39.50	41.90	42.00	40.40
PAN and WET	224.70	243.30	256.30	258.30
PAN AND DRY	216.30	229.80	238.80	237.20
Wt. of water	8.40	13.50	17.50	21.10
Wt. of dry soil	176.80	187.90	196.80	196.80
Moisture Content	4.75	7.18	8.89	10.72

Density Measurement

Assumed Moisture Content	8	13	13	15
Moisture Content	4.75	7.18	8.89	10.72
Wt. of soil + mold [lb]	13.43	13.63	13.77	13.62
Wt. of mold [lb]	9.48	9.48	9.48	9.48
Wt. soil in mold [lb]	3.95	4.15	4.29	4.14
Wet density [lb/cu. ft.]	118.63	124.52	128.75	124.22
Dry density [lb/cu. ft]	113.25	116.18	118.24	112.19

Gradation Analysis

PAN I.D.	c-8		D10	0.129926721
Wt. PAN	0.00		D30	0.432470155
PAN and WET	3390.00		D60	0.833657753
PAN AND DRY	3390.00			
PAN AND DRY2	3000.00		Cu	6.42
Wt. of water	0.00		Cz	1.73
Wt. of dry soil	3390.00			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	c-8			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2400.00	70.80	29.20
60	0.250	2700.00	79.65	20.35
100	0.150	3000.00	88.50	11.50
200	0.075	3000.00	88.50	11.50
>200	0.050	3390.00	100.00	0.00

Table A-25
SC (15% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	15.00
SC			Content Tipe	Clay
			Optimum Moisture Content	8.00
Visual Description of Soil:	Red Clayey Sand		Maximum Dry Density	130.50
			Uniformity Coefficient	11.21

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.40	49.90	50.50	50.10
PAN and WET	206.20	264.30	277.40	231.20
PAN AND DRY	199.10	250.40	259.80	214.40
Wt. of water	7.10	13.90	17.60	16.80
Wt. of dry soil	148.70	200.50	209.30	164.30
Moisture Content	4.77	6.93	8.41	10.23

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.77	6.93	8.41	10.23
Wt. of soil + mold [lb]	13.60	13.91	14.02	13.89
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.29	4.60	4.71	4.58
Wet density [lb/cu. ft.]	128.65	137.92	141.21	137.53
Dry density [lb/cu. ft]	122.79	128.98	130.26	124.77

Gradation Analysis

PAN I.D.	1		D10	0.065518395
Wt. PAN	0.00		D30	0.221685744
PAN and WET	3388.24		D60	0.734160446
PAN AND DRY	3388.24			
PAN AND DRY2	2880.00		Cu	11.21
Wt. of water	0.00		Cz	1.02
Wt. of dry soil	3388.24			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	1			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	144.00	4.25	95.75
40	0.425	2016.00	59.50	40.50
60	0.250	2304.00	68.00	32.00
100	0.150	2592.00	76.50	23.50
200	0.075	2880.00	85.00	15.00
>200	0.050	3388.24	100.00	0.00

Table A-26

SC (20% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	20.00
SC			Content Tipe	Clay
			Optimum Moisture Content	7.50
Visual Description of Soil:	Red Clayey Sand		Maximum Dry Density	131.00
			Uniformity Coefficient	11.18

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.30	50.50	50.30	41.70
PAN and WET	249.80	274.40	286.30	243.50
PAN AND DRY	241.10	259.70	267.70	224.30
Wt. of water	8.70	14.70	18.60	19.20
Wt. of dry soil	190.80	209.20	217.40	182.60
Moisture Content	4.56	7.03	8.56	10.51

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.56	7.03	8.56	10.51
Wt. of soil + mold [lb]	13.56	13.97	13.99	13.85
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.25	4.66	4.68	4.54
Wet density [lb/cu. ft.]	127.53	139.93	140.46	136.22
Dry density [lb/cu. ft]	121.97	130.74	129.39	123.26

Gradation Analysis

PAN I.D.	2		D10	0.061237244
Wt. PAN	0.00		D30	0.170432905
PAN and WET	3318.75		D60	0.684471566
PAN AND DRY	3318.75			
PAN AND DRY2	2655.00		Cu	11.18
Wt. of water	0.00		Cz	0.69
Wt. of dry soil	3318.75			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	2			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	132.75	4.00	96.00
40	0.425	1858.50	56.00	44.00
60	0.250	2124.00	64.00	36.00
100	0.150	2389.50	72.00	28.00
200	0.075	2655.00	80.00	20.00
>200	0.050	3318.75	100.00	0.00

Table A-27
SC (25% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	25.00
SC			Content Tipe	Clay
			Optimum Moisture Content	7.80
Visual Description of Soil:	Red Clayey Sand		Maximum Dry Density	130.40
			Uniformity Coefficient	10.75

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.60	50.30	50.40	41.80
PAN and WET	274.60	240.30	302.60	276.50
PAN AND DRY	264.20	227.20	281.60	253.20
Wt. of water	10.40	13.10	21.00	23.30
Wt. of dry soil	213.60	176.90	231.20	211.40
Moisture Content	4.87	7.41	9.08	11.02

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.87	7.41	9.08	11.02
Wt. of soil + mold [lb]	13.47	13.97	14.00	13.85
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.16	4.66	4.69	4.54
Wet density [lb/cu. ft.]	124.95	139.76	140.58	136.11
Dry density [lb/cu. ft]	119.15	130.13	128.87	122.60

Gradation Analysis

PAN I.D.	3		D10	0.058803951
Wt. PAN	0.00		D30	0.119055079
PAN and WET	3400.00		D60	0.632209472
PAN AND DRY	3400.00			
PAN AND DRY2	2550.00		Cu	10.75
Wt. of water	0.00		Cz	0.38
Wt. of dry soil	3400.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	3			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	127.50	3.75	96.25
40	0.425	1785.00	52.50	47.50
60	0.250	2040.00	60.00	40.00
100	0.150	2295.00	67.50	32.50
200	0.075	2550.00	75.00	25.00
>200	0.050	3400.00	100.00	0.00

Table A-28
SM (15% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	14.99
SM			Content Tipe	Silt
			Optimum Moisture Content	8.50
Visual Description of Soil:	Gray Silty Sand		Maximum Dry Density	123.80
			Uniformity Coefficient	7.73

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	39.40	42.10	41.80	50.30
PAN and WET	231.60	239.90	285.60	274.10
PAN AND DRY	223.40	227.30	265.10	252.40
Wt. of water	8.20	12.60	20.50	21.70
Wt. of dry soil	184.00	185.20	223.30	202.10
Moisture Content	4.46	6.80	9.18	10.74

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.46	6.80	9.18	10.74
Wt. of soil + mold [lb]	13.49	13.67	13.78	13.79
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.18	4.36	4.47	4.48
Wet density [lb/cu. ft.]	125.29	130.68	134.03	134.30
Dry density [lb/cu. ft]	119.95	122.36	122.76	121.28

Gradation Analysis

PAN I.D.	1		D10	0.104039585
Wt. PAN	0.00		D30	0.37511378
PAN and WET	3388.24		D60	0.80418919
PAN AND DRY	3388.24			
PAN AND DRY2	2880.00		Cu	7.73
Wt. of water	0.00		Cz	1.68
Wt. of dry soil	3388.24			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	1			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2304.00	68.00	32.00
60	0.250	2592.00	76.50	23.50
100	0.150	2880.24	85.01	14.99
200	0.075	2880.24	85.01	14.99
>200	0.050	3388.24	100.00	0.00

Table A-29
SM (20% Fine Content): Proctor Test and Sieve Analysis

Sample No.		Fine content	20.00
SM		Content Tipe	Silt
		Optimum Moisture Content	8.50
Visual Description of Soil:	Gray Silty Sand	Maximum Dry Density	130.00
		Uniformity Coefficient	8.77

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	42.00	39.30	50.40	50.00
PAN and WET	256.10	253.70	235.60	275.50
PAN AND DRY	246.50	239.50	220.90	254.50
Wt. of water	9.60	14.20	14.70	21.00
Wt. of dry soil	204.50	200.20	170.50	204.50
Moisture Content	4.69	7.09	8.62	10.27

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.69	7.09	8.62	10.27
Wt. of soil + mold [lb]	13.58	13.87	14.02	13.96
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.27	4.56	4.71	4.65
Wet density [lb/cu. ft.]	128.14	136.73	141.30	139.39
Dry density [lb/cu. ft]	122.39	127.67	130.08	126.41

Gradation Analysis

PAN I.D.	2		D10	0.08660254
Wt. PAN	0.00		D30	0.285464586
PAN and WET	3318.75		D60	0.759677615
PAN AND DRY	3318.75			
PAN AND DRY2	2655.00		Cu	8.77
Wt. of water	0.00		Cz	1.24
Wt. of dry soil	3318.75			
Moisture Content	0.00		Gradation:	Well

PAN I.D.	2			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2124.00	64.00	36.00
60	0.250	2389.50	72.00	28.00
100	0.150	2655.00	80.00	20.00
200	0.075	2655.00	80.00	20.00
>200	0.050	3318.75	100.00	0.00

Table A-30
SM (25% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	25.00
SM			Content Tipe	Silt
			Optimum Moisture Content	8.00
Visual Description of Soil:	Gray Silty Sand		Maximum Dry Density	131.50
			Uniformity Coefficient	9.18

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	41.80	42.00	41.80	39.50
PAN and WET	240.30	290.40	238.80	285.10
PAN AND DRY	231.40	274.60	223.50	262.80
Wt. of water	8.90	15.80	15.30	22.30
Wt. of dry soil	189.60	232.60	181.70	223.30
Moisture Content	4.69	6.79	8.42	9.99

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	4.69	6.79	8.42	9.99
Wt. of soil + mold [lb]	13.58	13.94	14.06	14.00
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.26	4.63	4.75	4.69
Wet density [lb/cu. ft.]	127.94	139.04	142.55	140.60
Dry density [lb/cu. ft]	122.21	130.20	131.48	127.83

Gradation Analysis

PAN I.D.	3		D10	0.077592279
Wt. PAN	0.00		D30	0.210858166
PAN and WET	3400.00		D60	0.712201065
PAN AND DRY	3400.00			
PAN AND DRY2	2550.00		Cu	9.18
Wt. of water	0.00		Cz	0.80
Wt. of dry soil	3400.00			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	3			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	2040.00	60.00	40.00
60	0.250	2295.00	67.50	32.50
100	0.150	2550.00	75.00	25.00
200	0.075	2550.00	75.00	25.00
>200	0.050	3400.00	100.00	0.00

Table A-31
SM (30% Fine Content): Proctor Test and Sieve Analysis

Sample No.			Fine content	30.00
SM			Content Tipe	Silt
			Optimum Moisture Content	8.00
Visual Description of Soil:	Gray Silty Sand		Maximum Dry Density	131.50
			Uniformity Coefficient	9.17

Method	ASTM/AASHTO	HAMMER WT	DROP	No. LAYERS	No. Blows
STANDARD PROCTOR	D 698/T-99	5.5 lb.	12 in.	3	25

MOLD Dimensions	Diameter [in]:	Height [in]:	Volume [cu. Ft.]
			0.033333333

Water Content Measurement

PAN I.D.	a	b	c	d
Wt. PAN	50.30	39.50	42.00	42.00
PAN and WET	241.20	262.30	277.50	273.70
PAN AND DRY	231.10	245.80	256.80	250.50
Wt. of water	10.10	16.50	20.70	23.20
Wt. of dry soil	180.80	206.30	214.80	208.50
Moisture Content	5.59	8.00	9.64	11.13

Density Measurement

Assumed Moisture Content	8	10.5	13	15
Moisture Content	5.59	8.00	9.64	11.13
Wt. of soil + mold [lb]	13.78	14.04	13.95	13.86
Wt. of mold [lb]	9.31	9.31	9.31	9.31
Wt. soil in mold [lb]	4.47	4.73	4.64	4.55
Wet density [lb/cu. ft.]	133.96	142.01	139.29	136.56
Dry density [lb/cu. ft]	126.87	131.49	127.04	122.89

Gradation Analysis

PAN I.D.	4		D10	0.072112396
Wt. PAN	0.00		D30	0.149999487
PAN and WET	3214.29		D60	0.66156337
PAN AND DRY	3214.29			
PAN AND DRY2	2250.00		Cu	9.17
Wt. of water	0.00		Cz	0.47
Wt. of dry soil	3214.29			
Moisture Content	0.00		Gradation:	Poor

PAN I.D.	4			
SIEVE No.	Size. [mm]	Weight including PAN	% Retained	% Passing
4	4.750	0.00	0.00	100.00
10	2.000	0.00	0.00	100.00
40	0.425	1800.00	56.00	44.00
60	0.250	2025.00	63.00	37.00
100	0.150	2250.00	70.00	30.00
200	0.075	2250.00	70.00	30.00
>200	0.050	3214.29	100.00	0.00

APPENDIX B

SIEVE ANALYSIS CHARTS

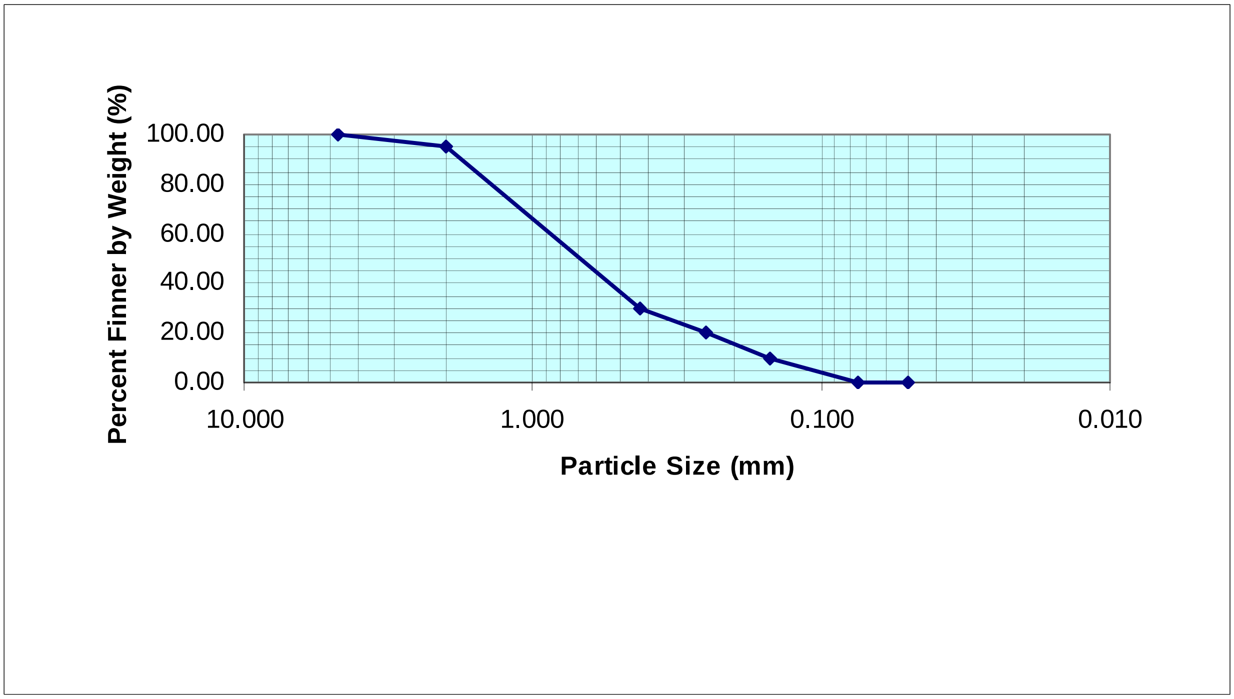

Figure B-1; SW (0% Fine Content): Sieve Analysis

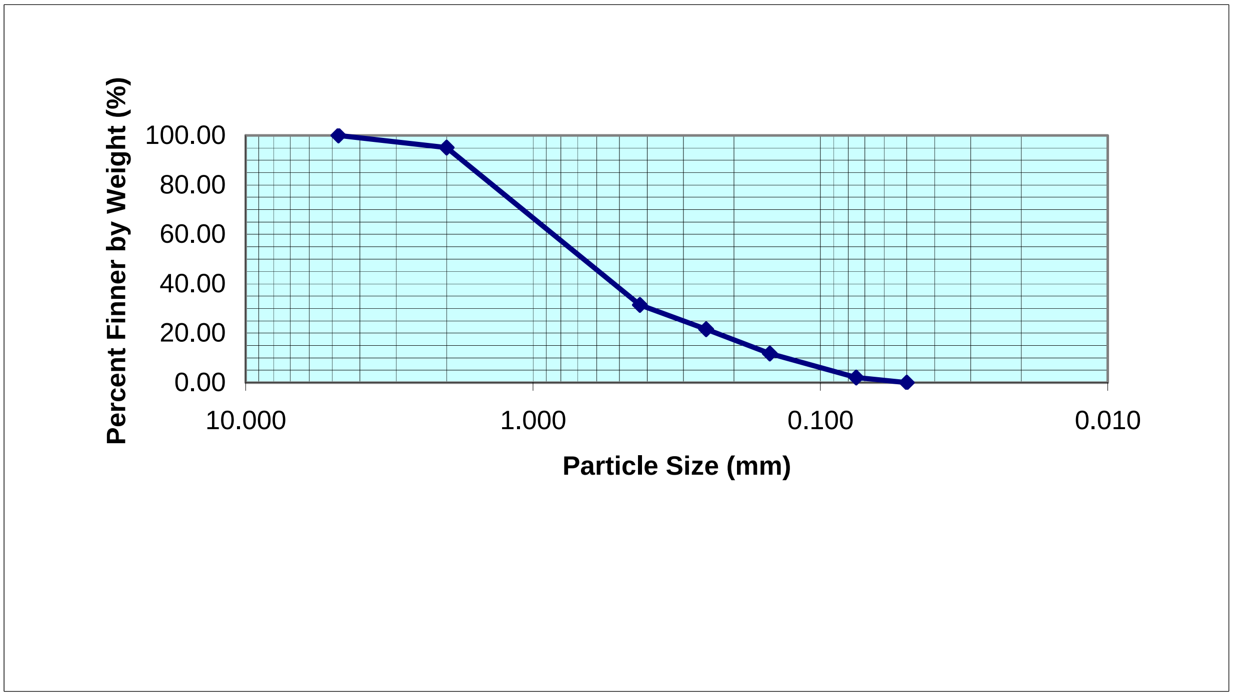

Figure B-2; SW (2% Fine Content): Sieve Analysis

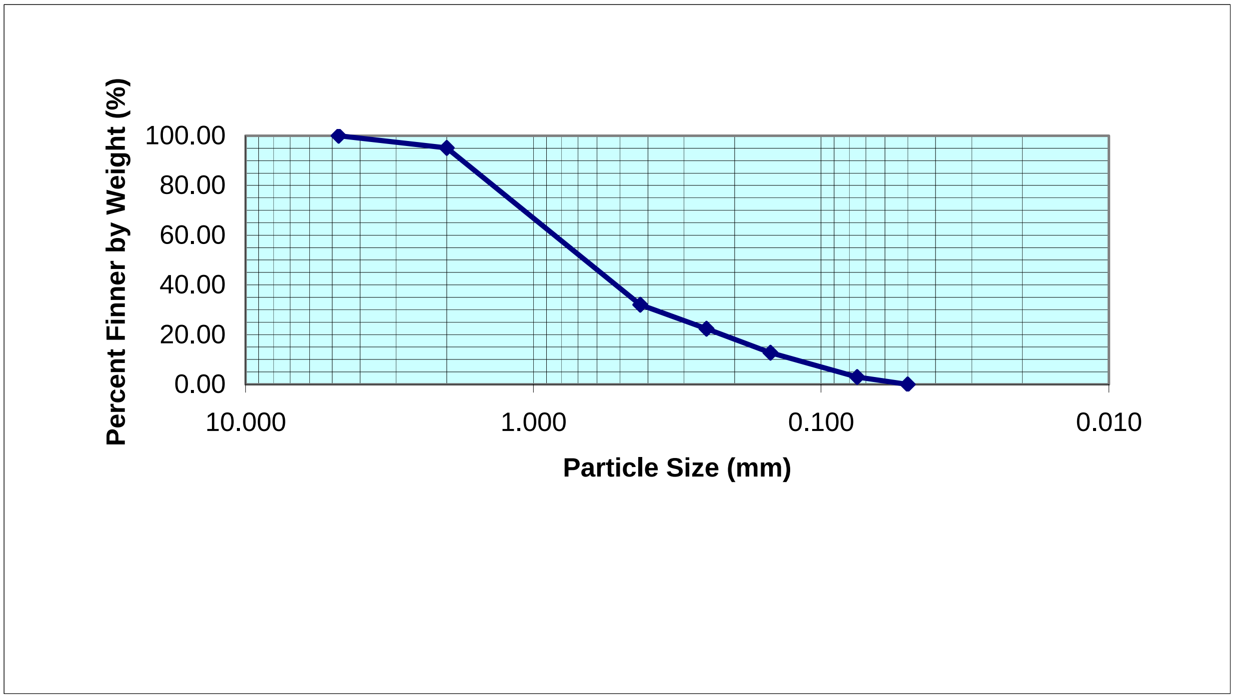

Figure B-3; SW (3% Fine Content): Sieve Analysis

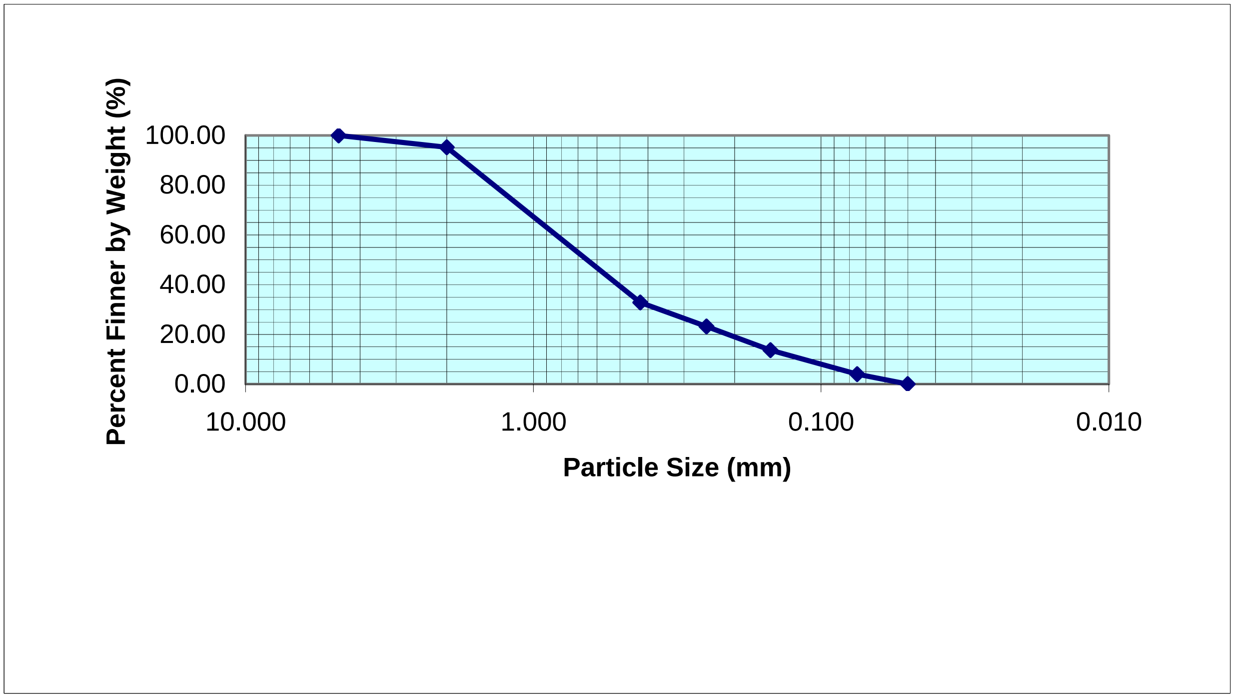

Figure B-4; SW (4% Fine Content): Sieve Analysis

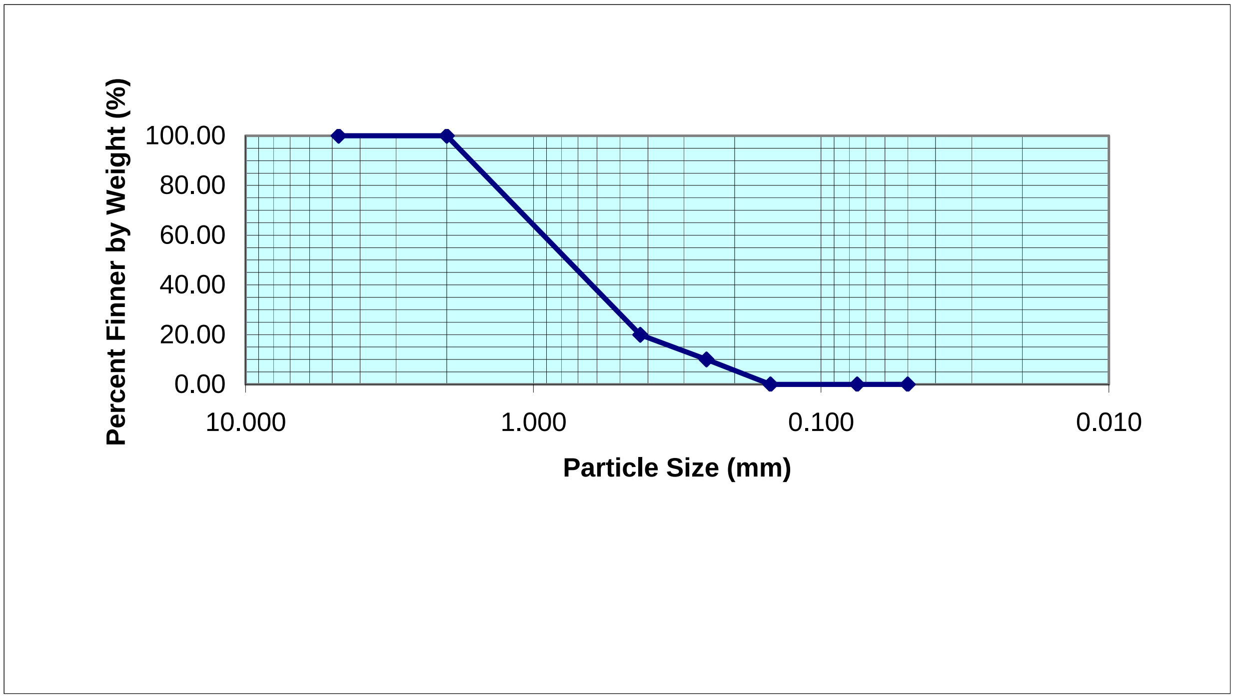

Figure B-5; SP (0% Fine Content): Sieve Analysis

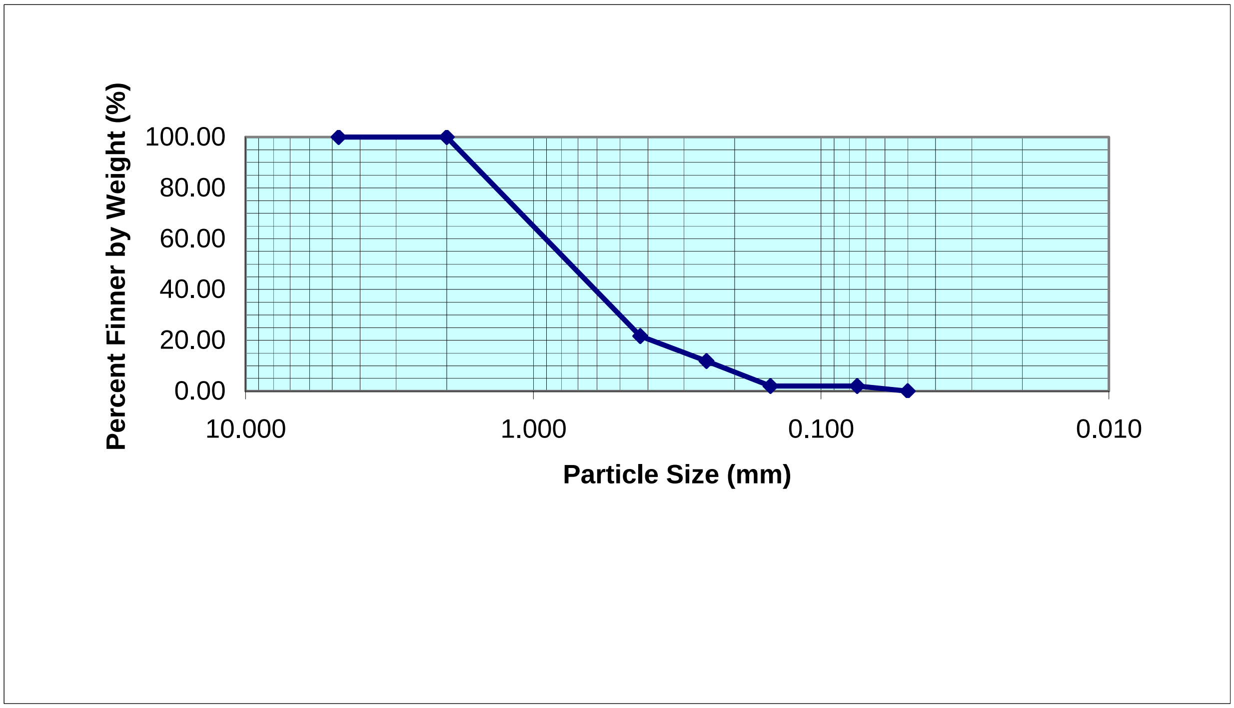

Figure B-6; SP (2% Fine Content): Sieve Analysis

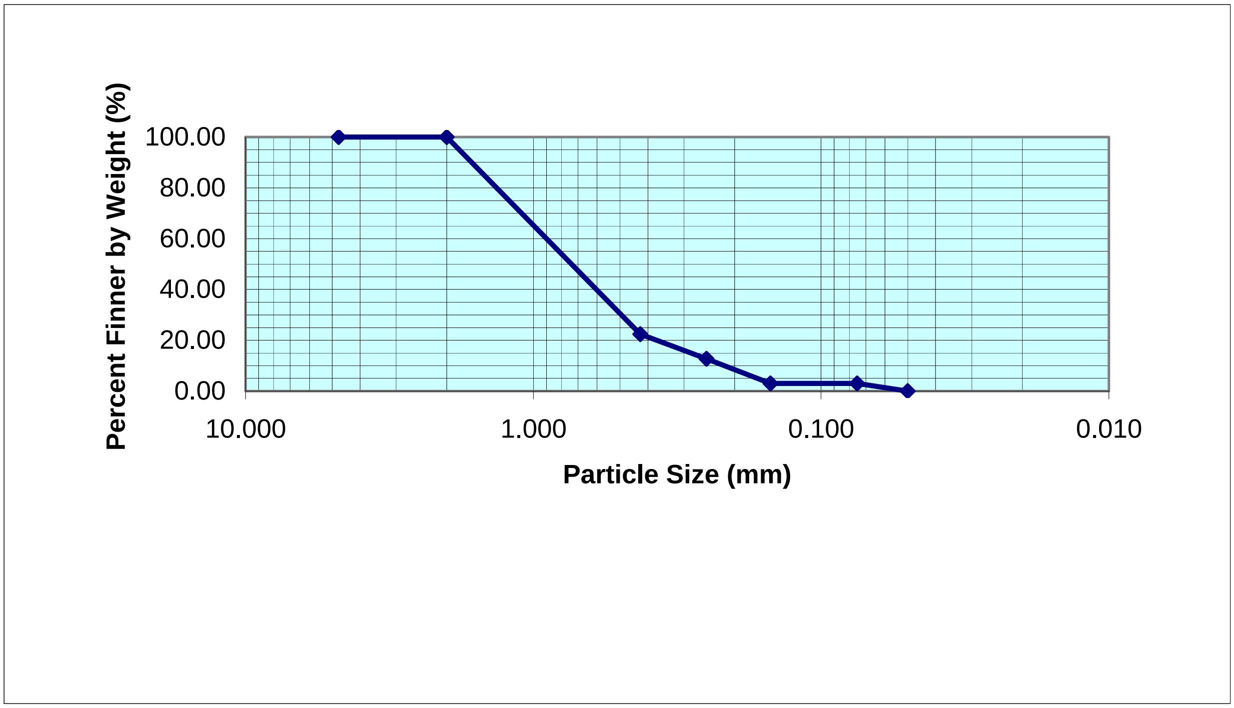

Figure B-7; SP (3% Fine Content): Sieve Analysis

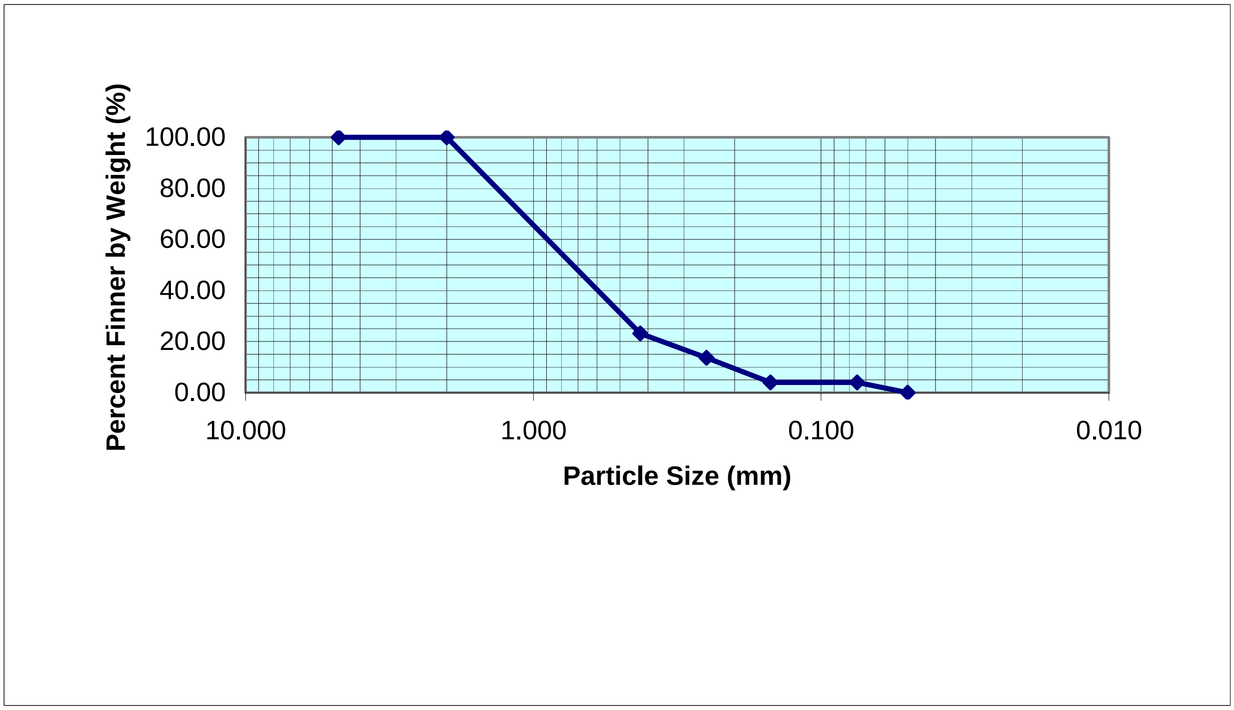

Figure B-8; SP (4% Fine Content): Sieve Analysis

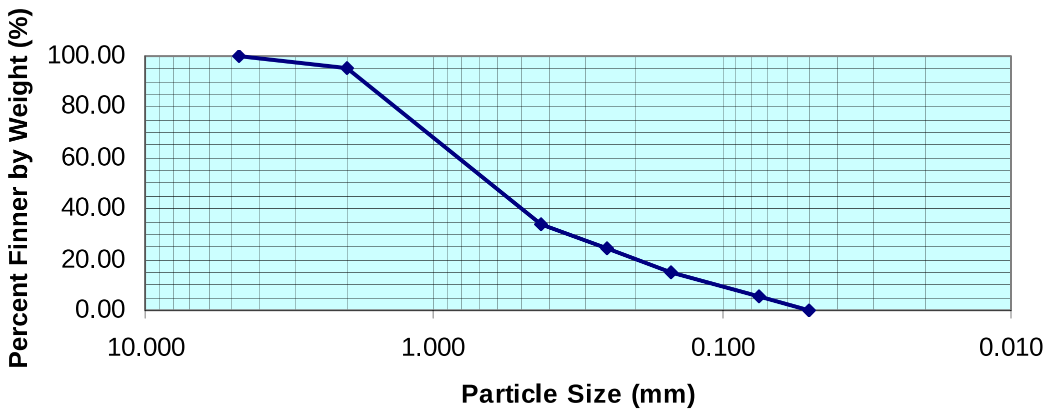

Figure B-9; SW-SC (5.5% Fine Content): Sieve Analysis

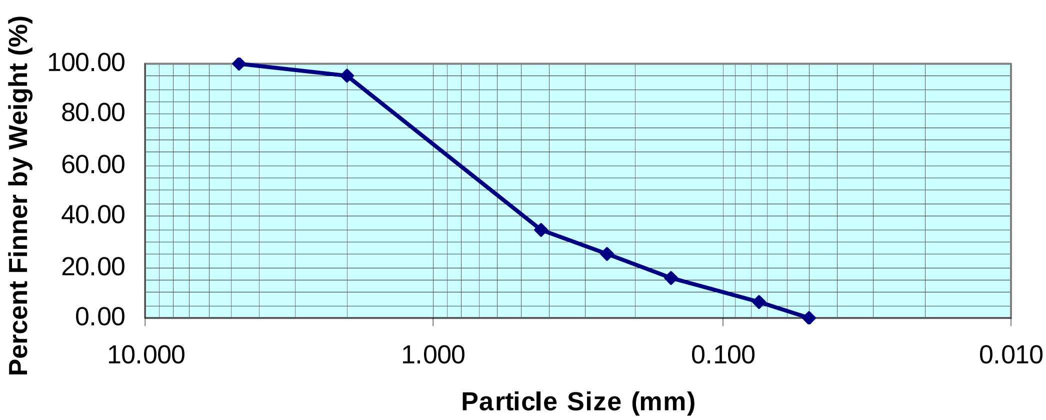

Figure B-10; SW-SC (6.5% Fine Content): Sieve Analysis

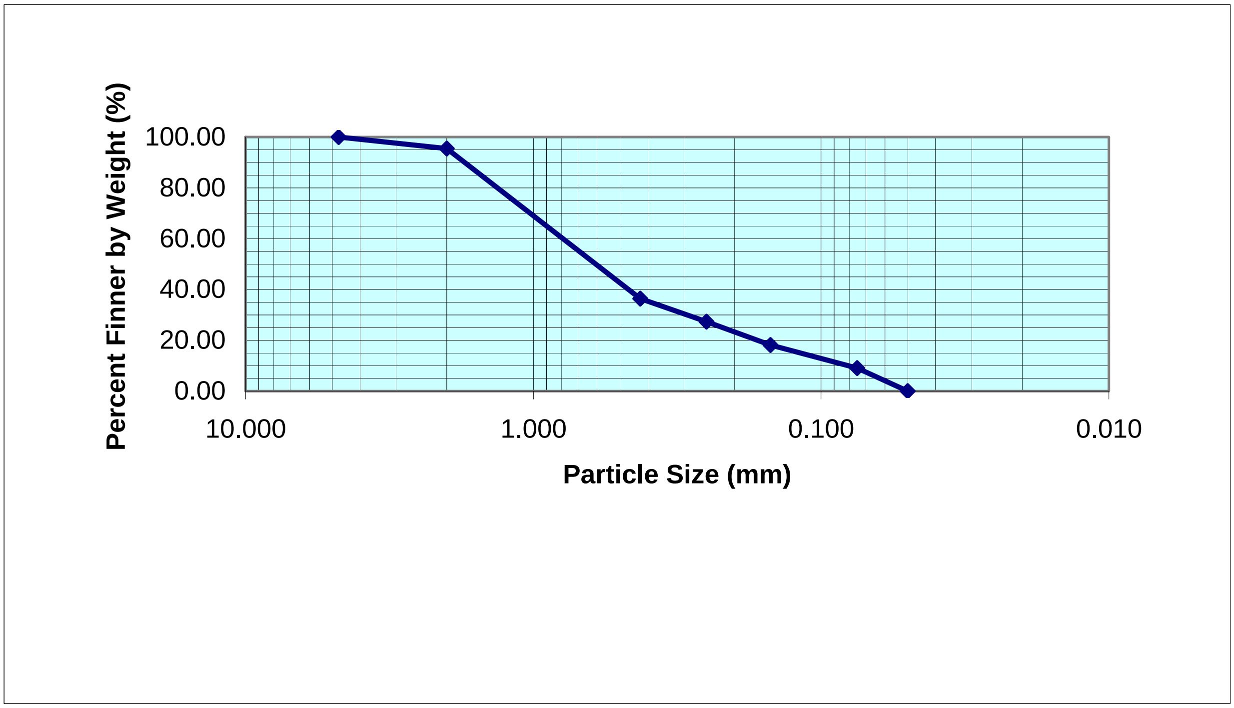

Figure B-11; SW-SC (9% Fine Content): Sieve Analysis

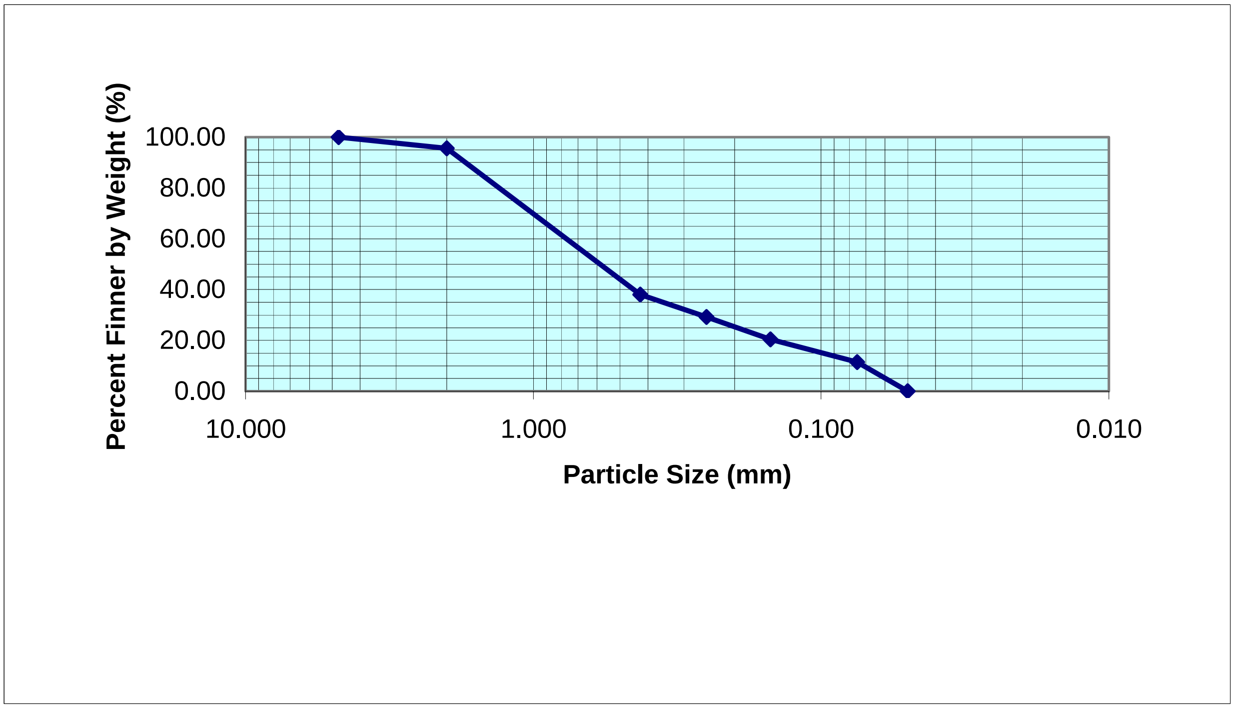

Figure B-12; SW-SC (11.5% Fine Content): Sieve Analysis

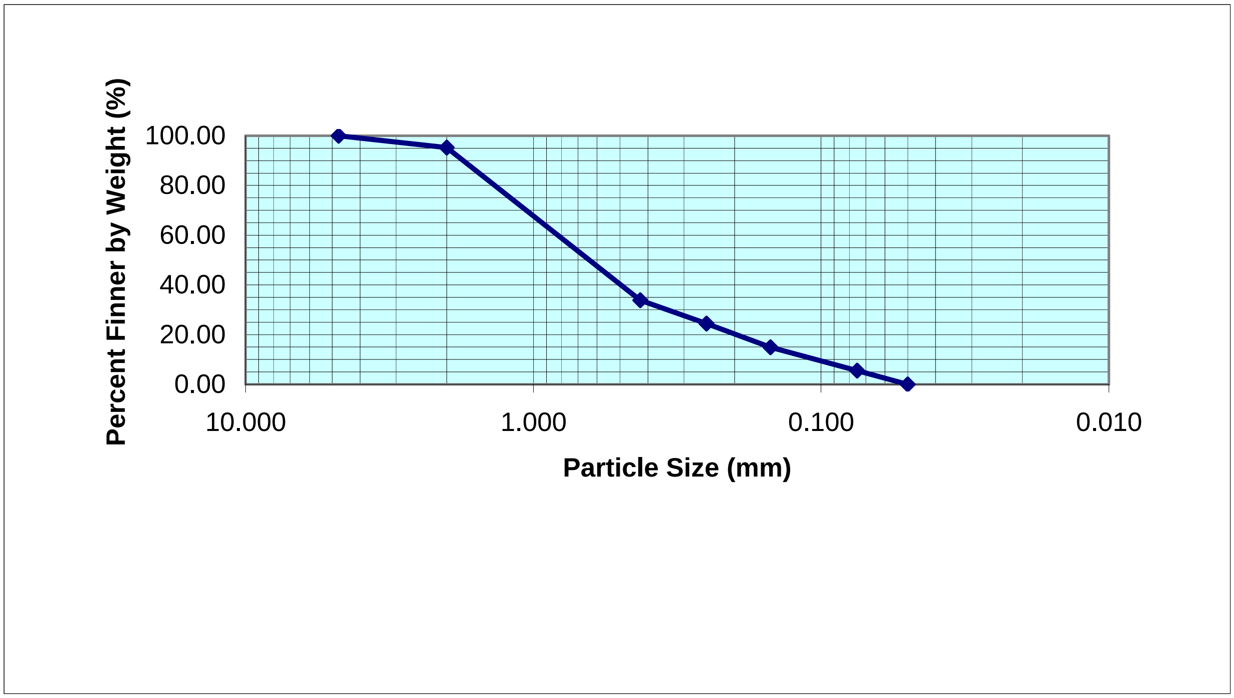

Figure B-13; SW-SM (5.5% Fine Content): Sieve Analysis

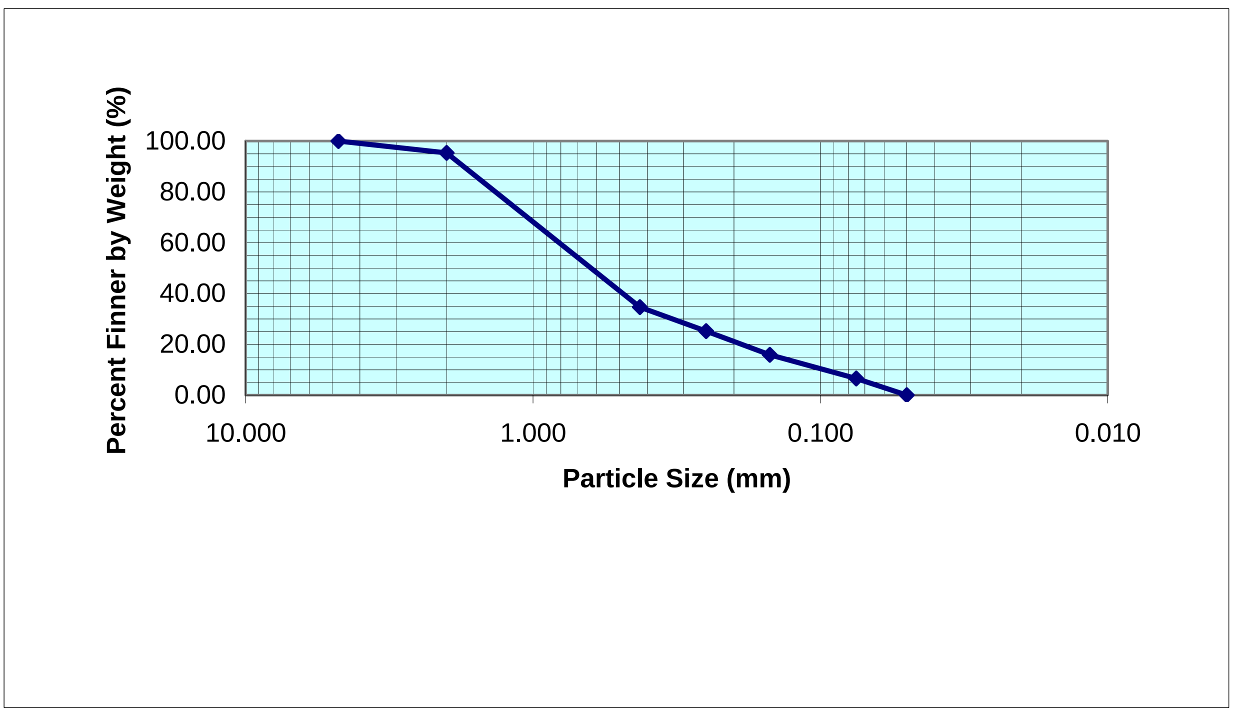

Figure B-14; SW-SM (6.5% Fine Content): Sieve Analysis

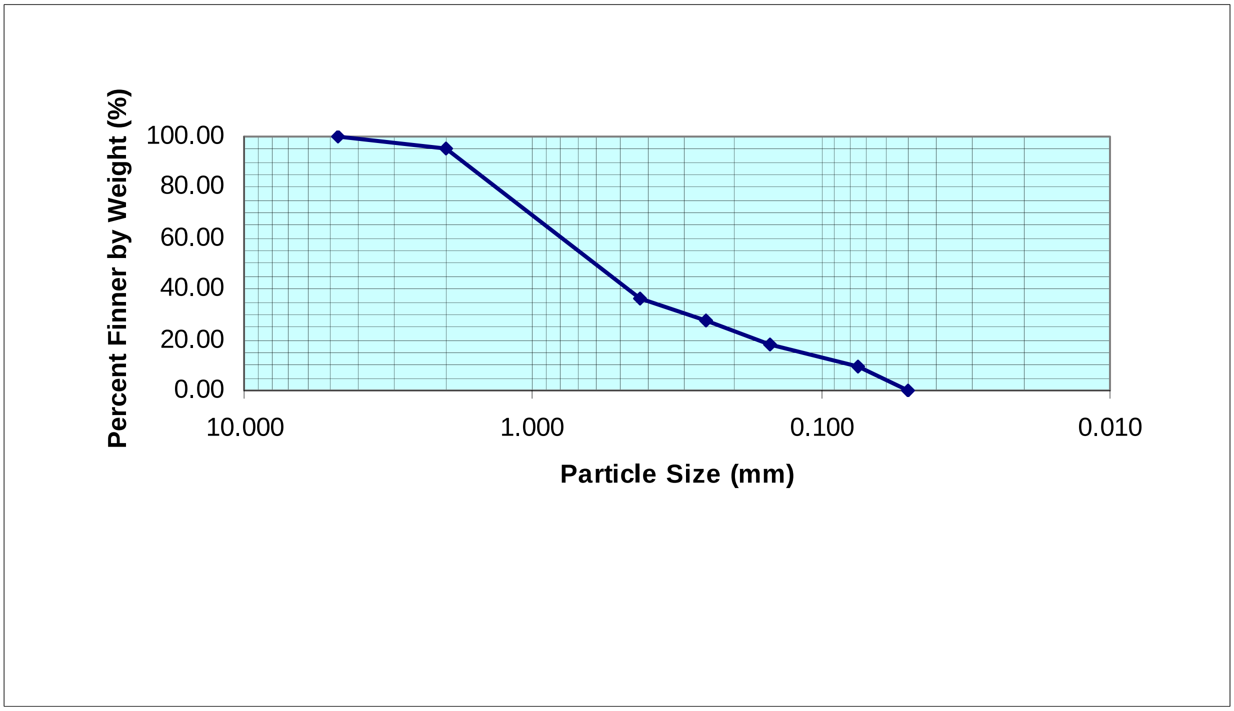

Figure B-15; SW-SM (9% Fine Content): Sieve Analysis

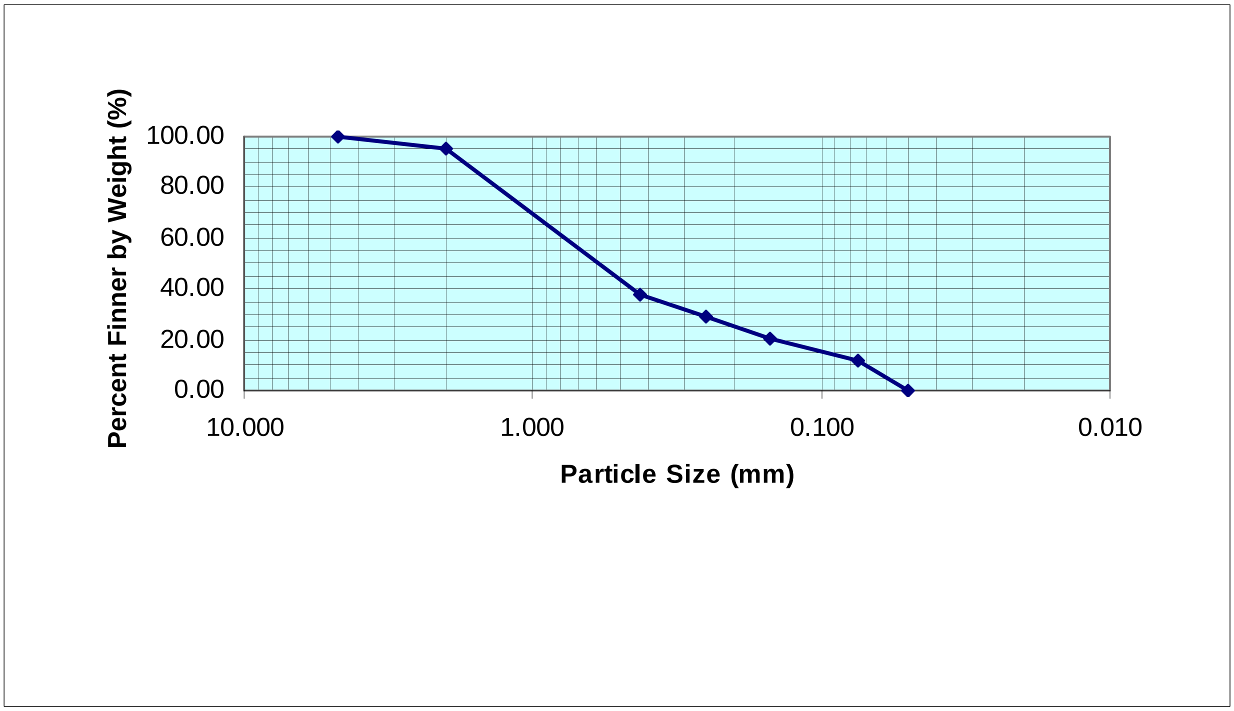

Figure B-16; SW-SM (11.5% Fine Content): Sieve Analysis

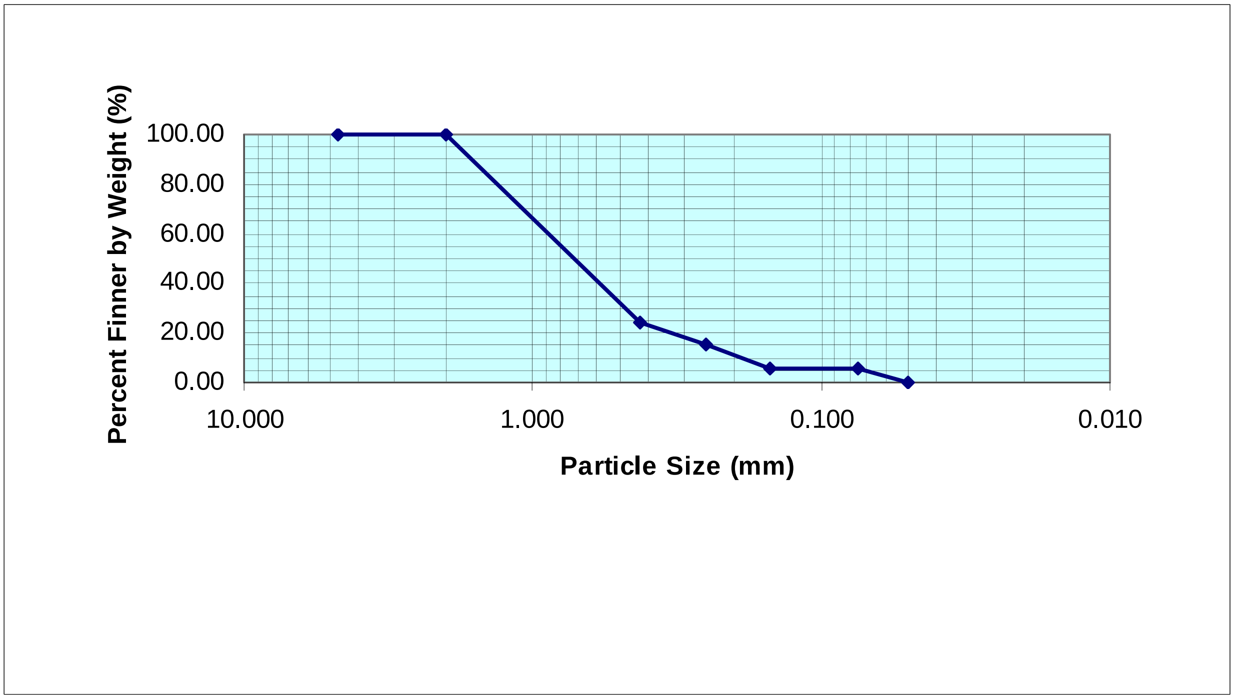

Figure B-17; SP-SC (5.5% Fine Content): Sieve Analysis

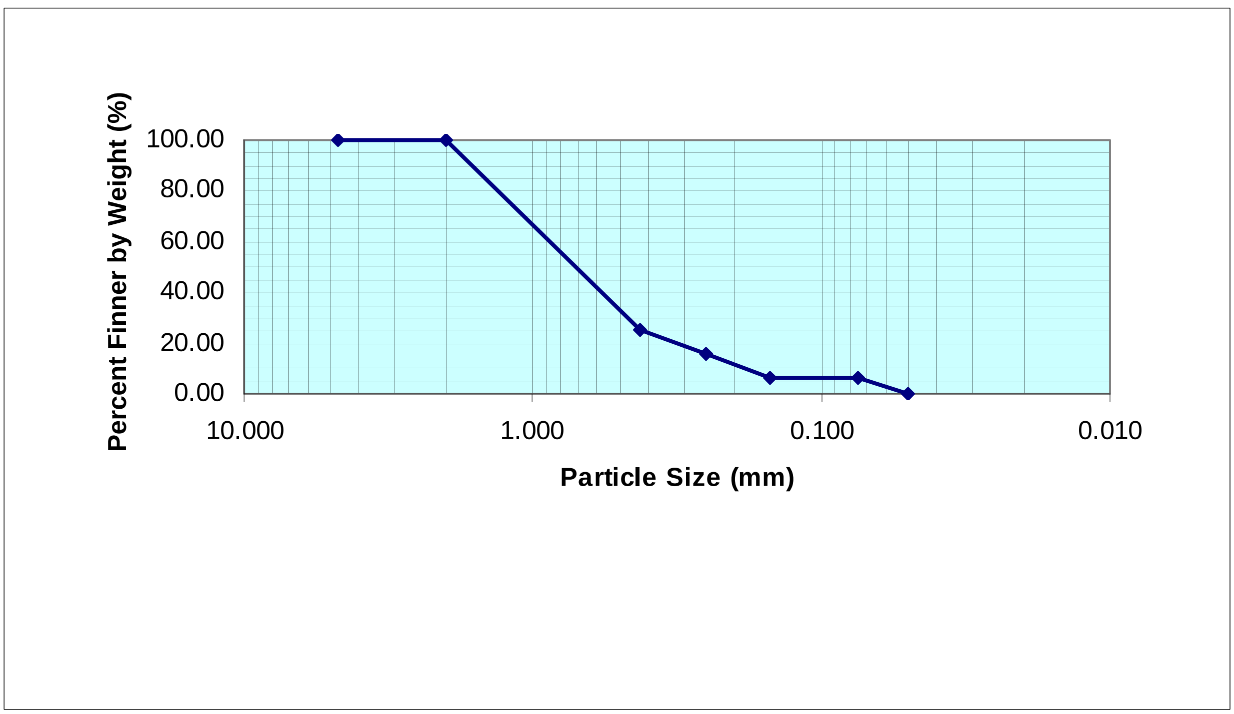

Figure B-18; SP-SC (6.5% Fine Content): Sieve Analysis

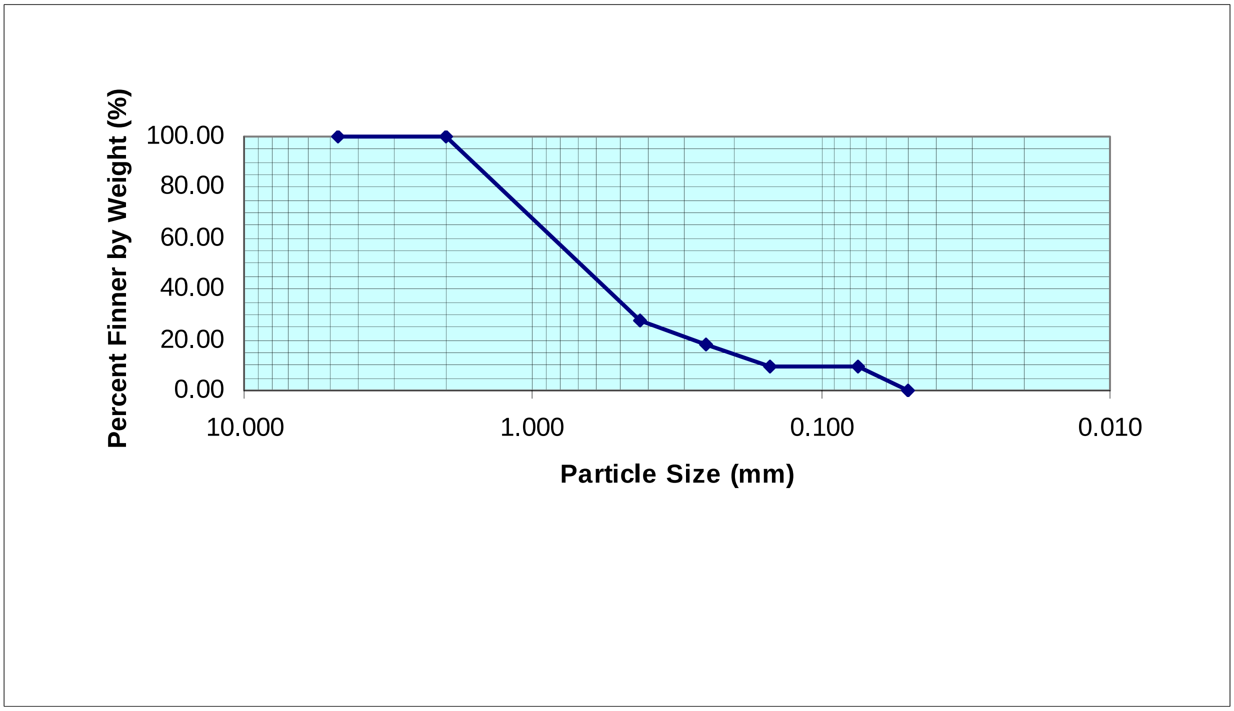

Figure B-19; SP-SC (9% Fine Content): Sieve Analysis

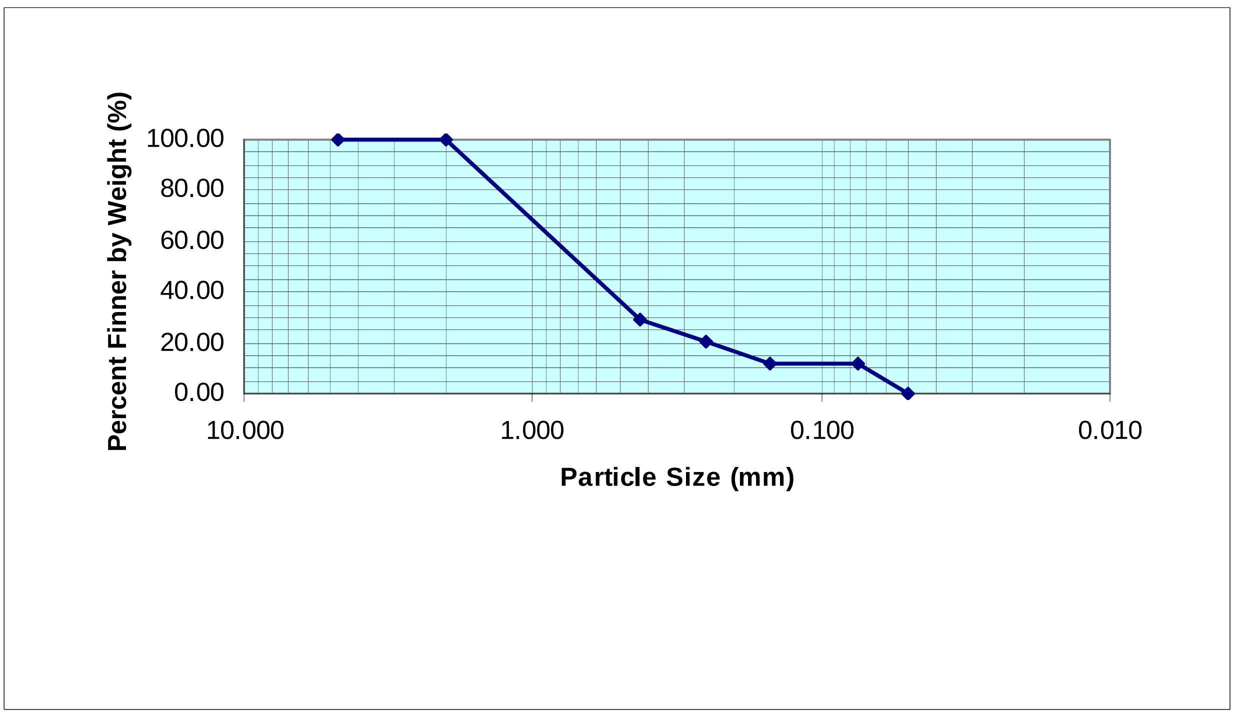

Figure B-20; SP-SC (11.5% Fine Content): Sieve Analysis

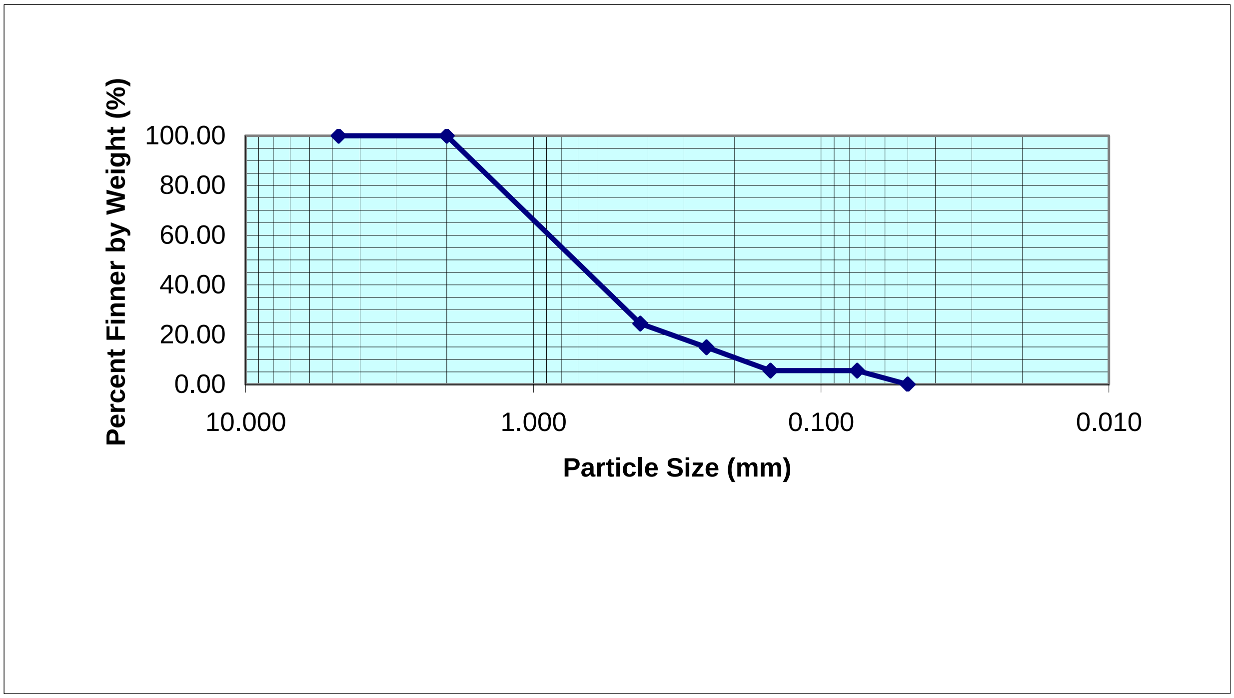

Figure B-21; SP-SM (5.5% Fine Content): Sieve Analysis

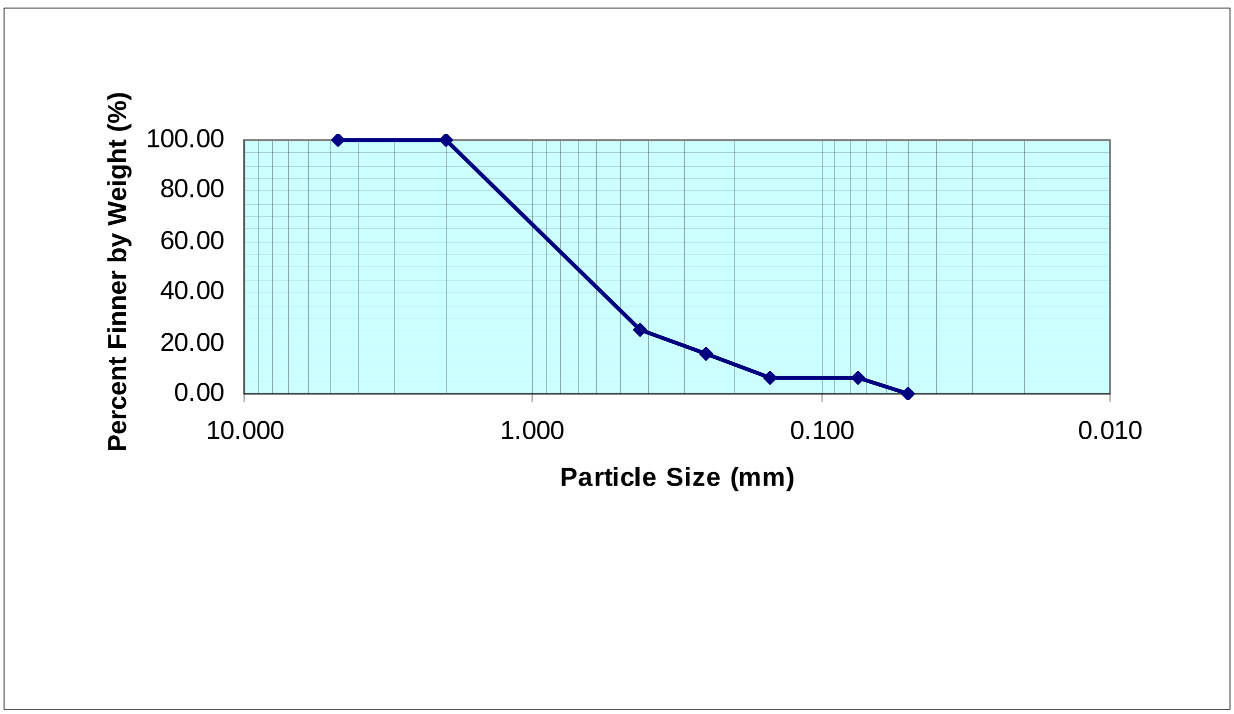

Figure B-22; SP-SM (6.5% Fine Content): Sieve Analysis

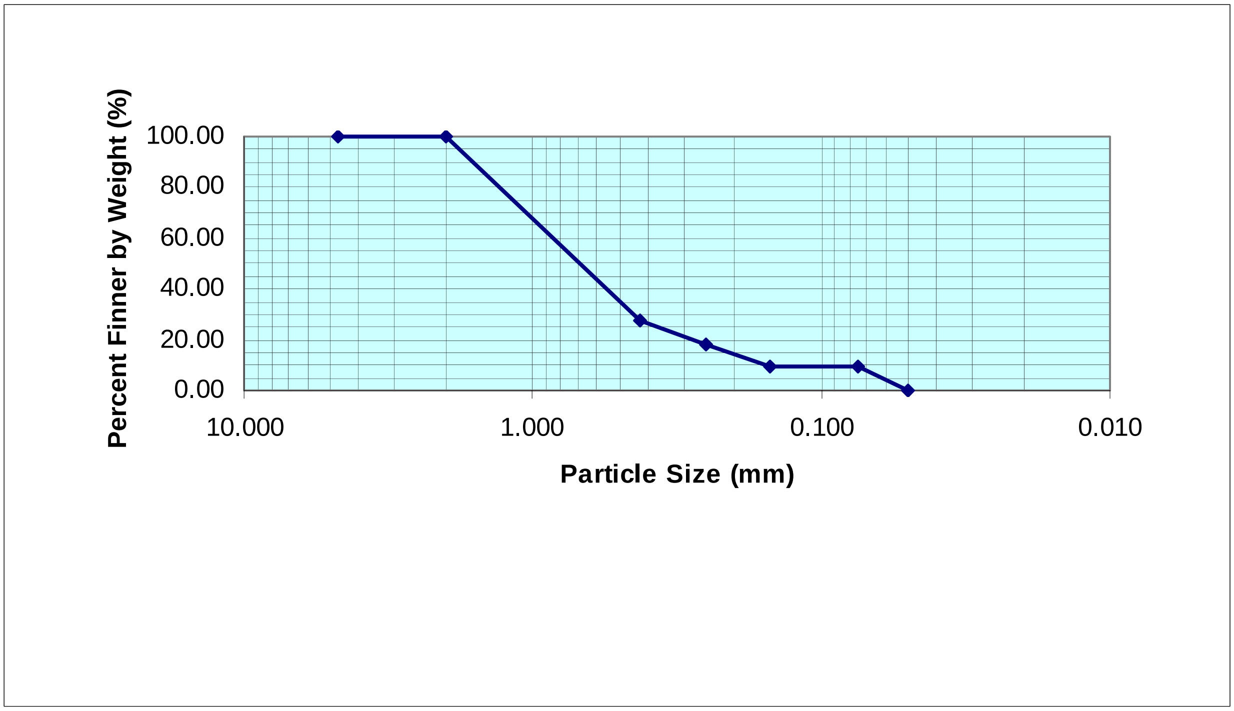

Figure B-23; SP-SM (9% Fine Content): Sieve Analysis

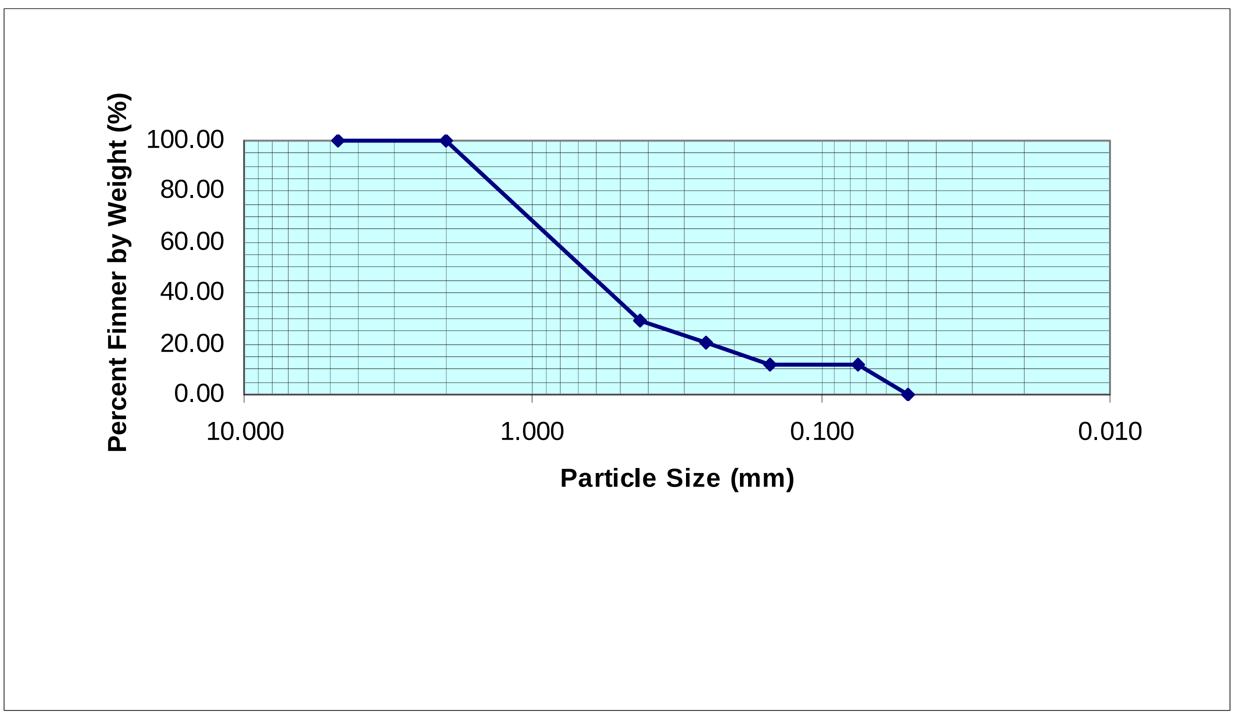

Figure B-24; SP-SM (11.5% Fine Content): Sieve Analysis

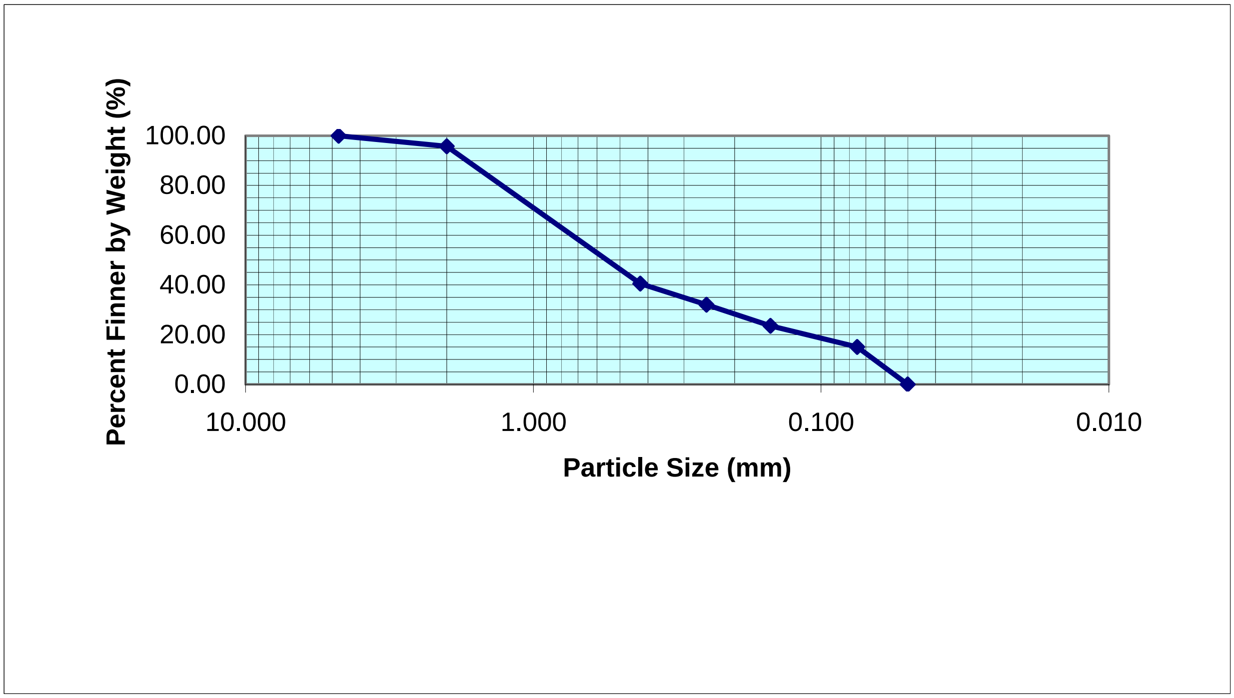

Figure B-25; SC (15% Fine Content): Sieve Analysis

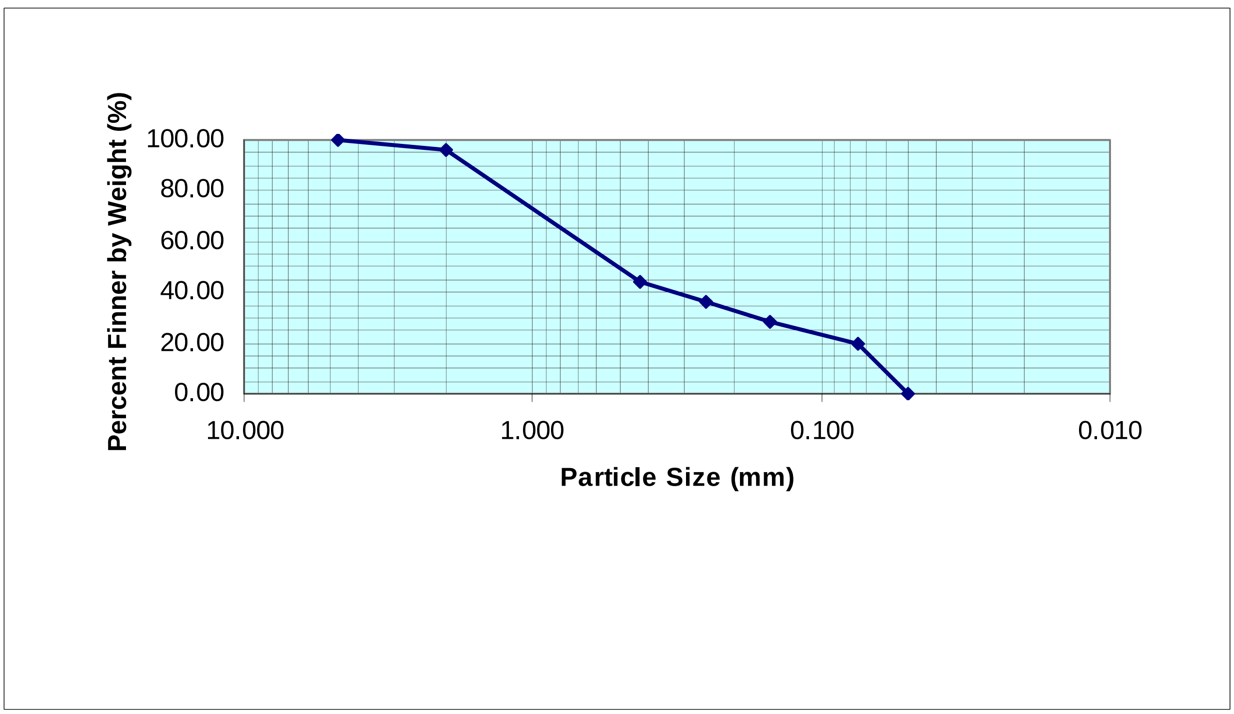

Figure B-26; SC (20% Fine Content): Sieve Analysis

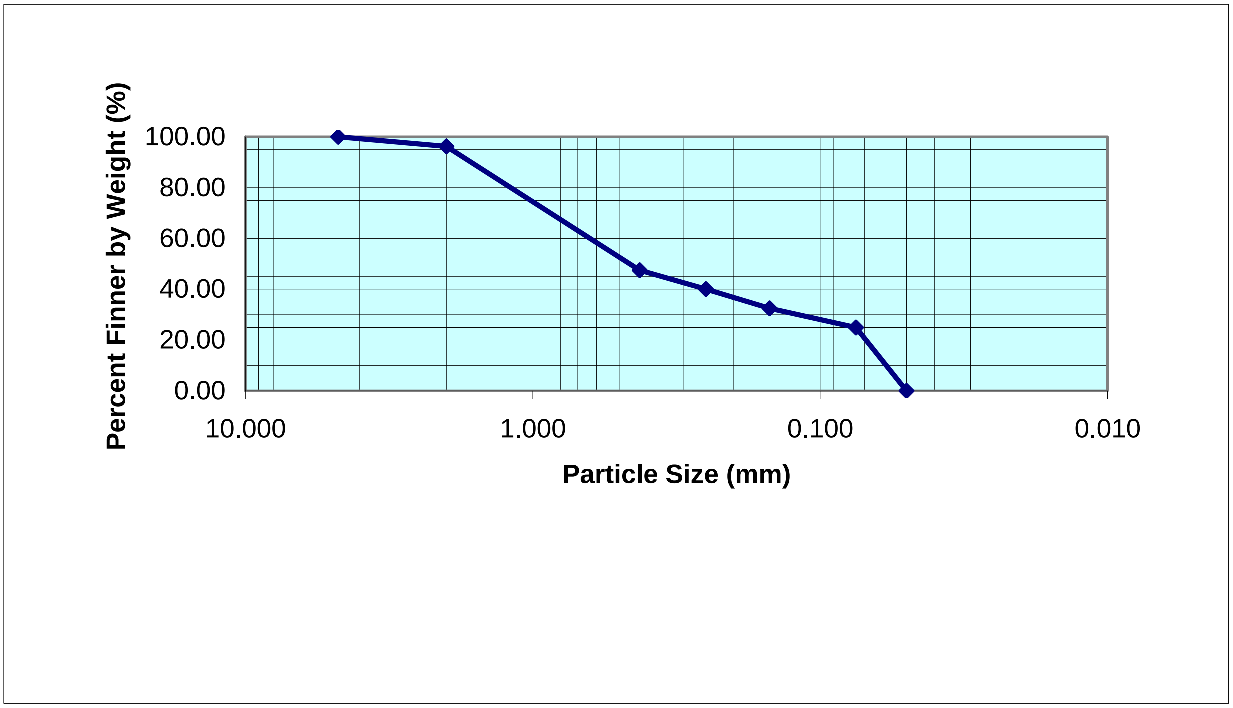

Figure B-27; SC (25% Fine Content): Sieve Analysis

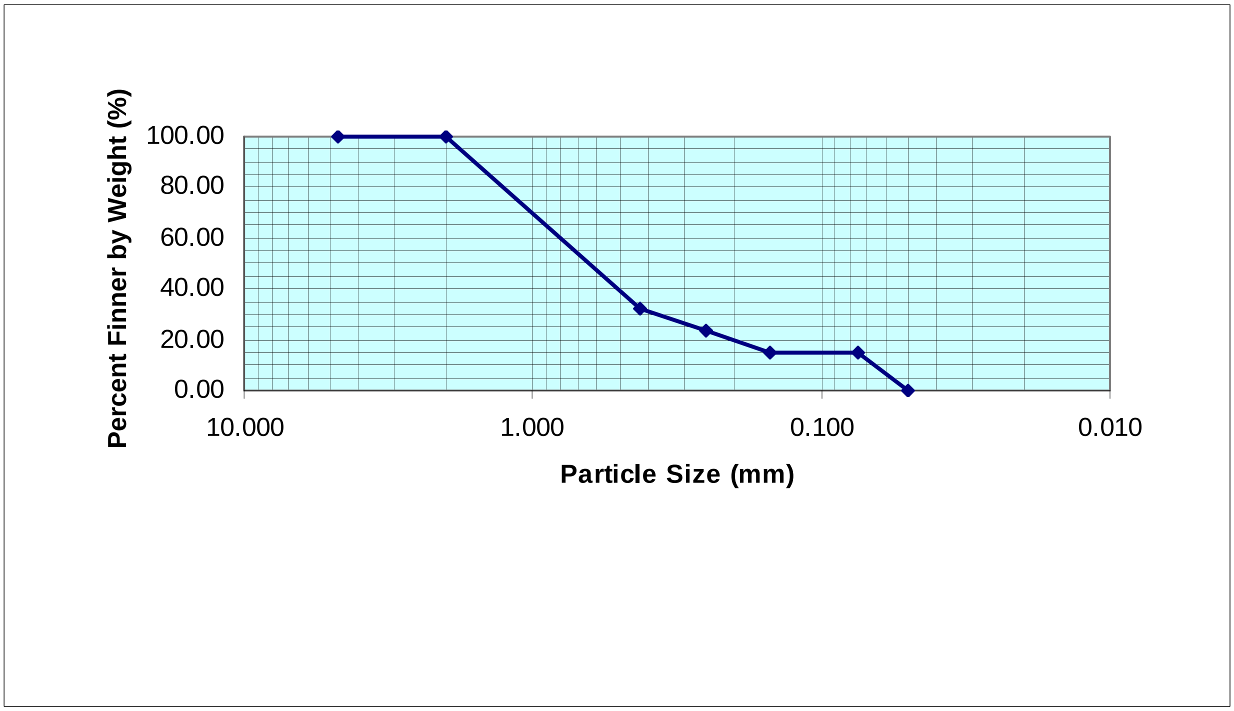

Figure B-28; SM (15% Fine Content): Sieve Analysis

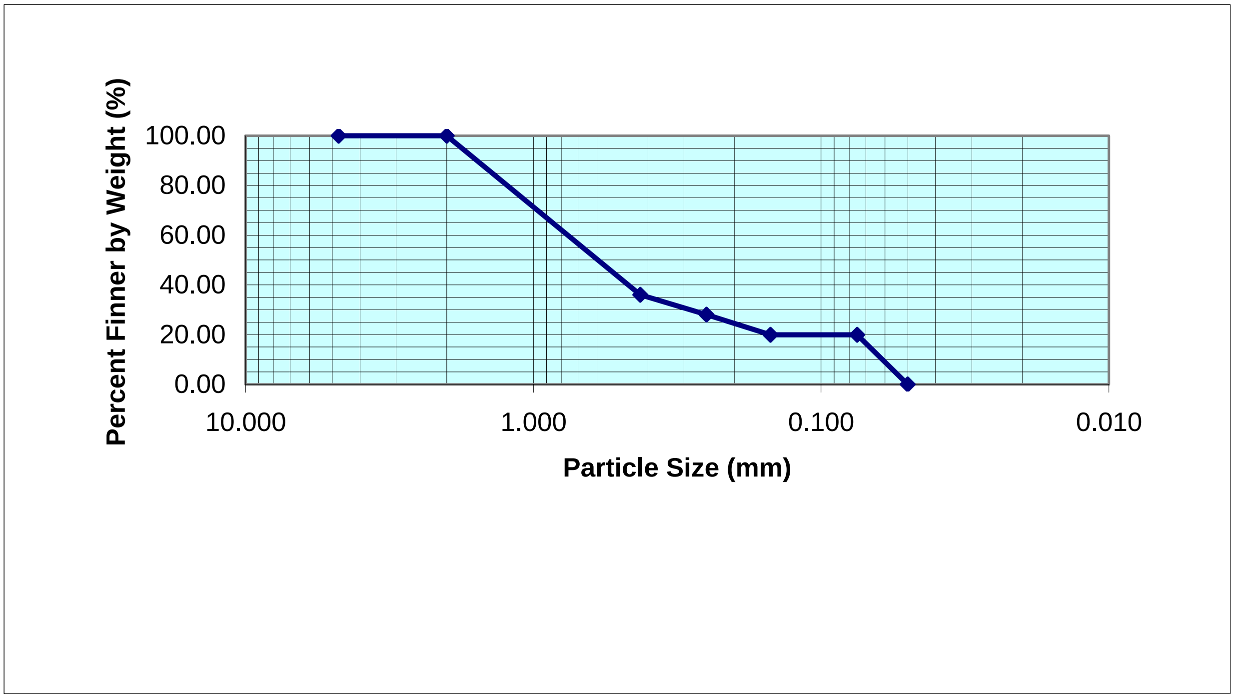

Figure B-29; SM (20% Fine Content): Sieve Analysis

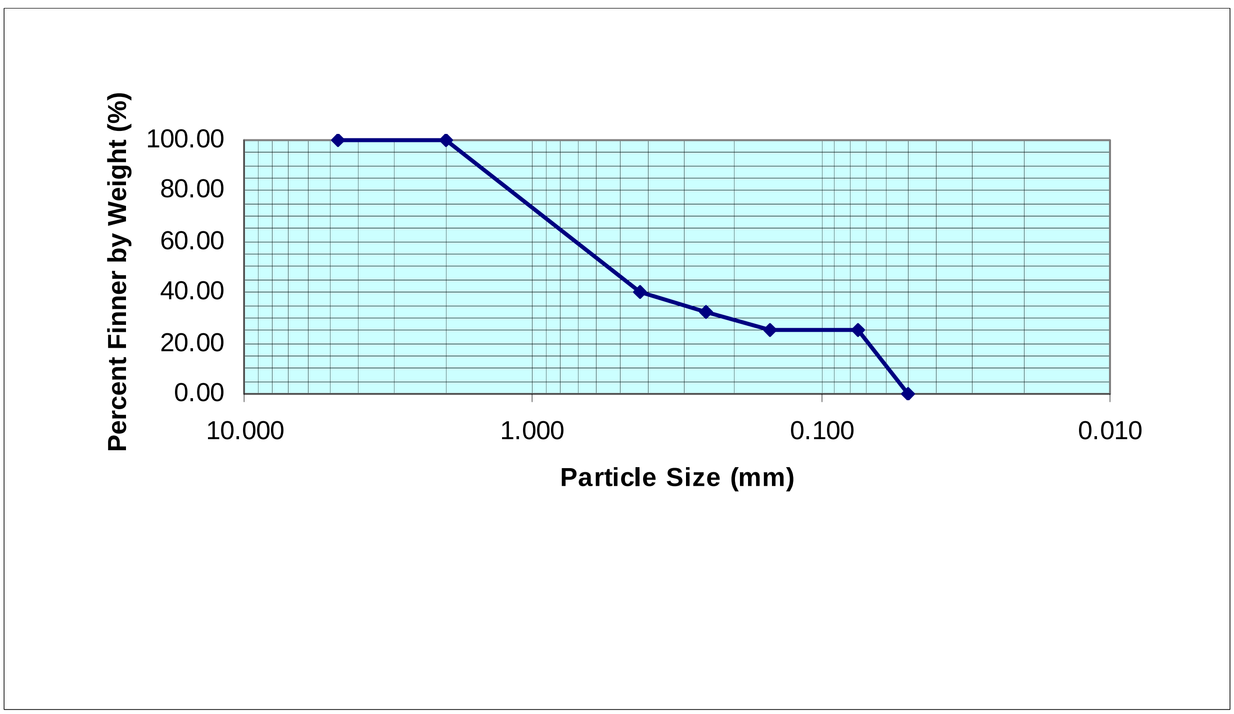

Figure B-30; SM (25% Fine Content): Sieve Analysis

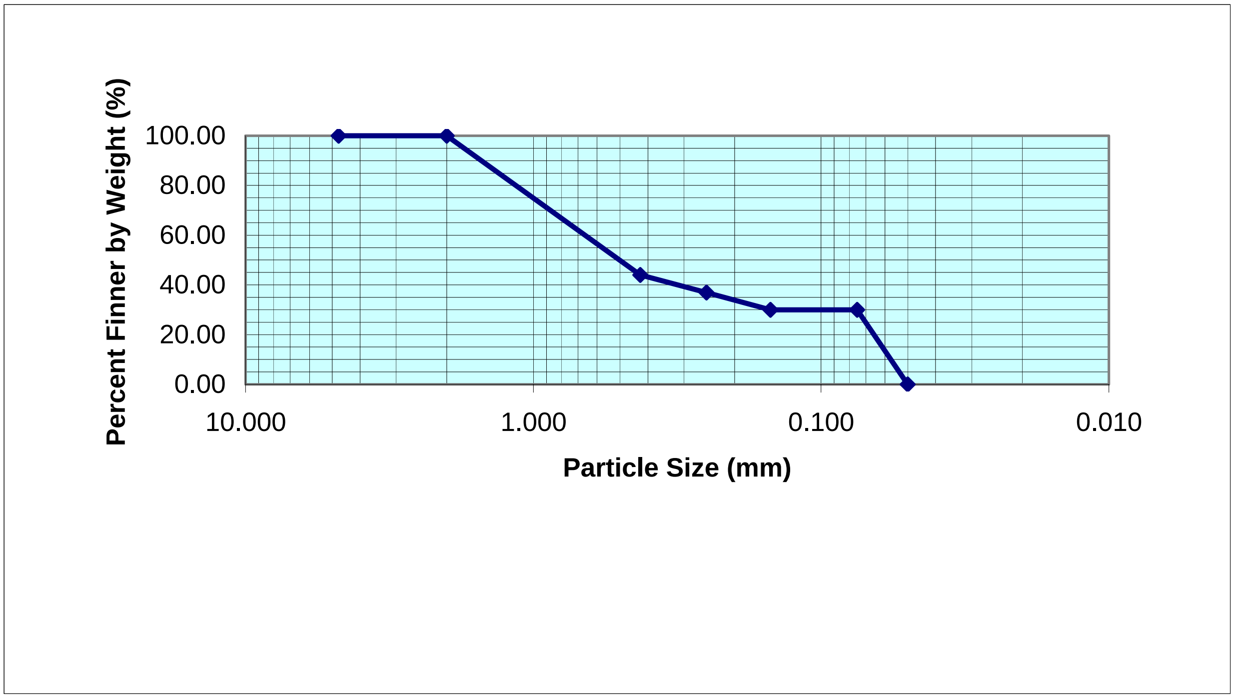

Figure B-31; SM (30% Fine Content): Sieve Analysis

APPENDIX C

COMPACTION CURVES

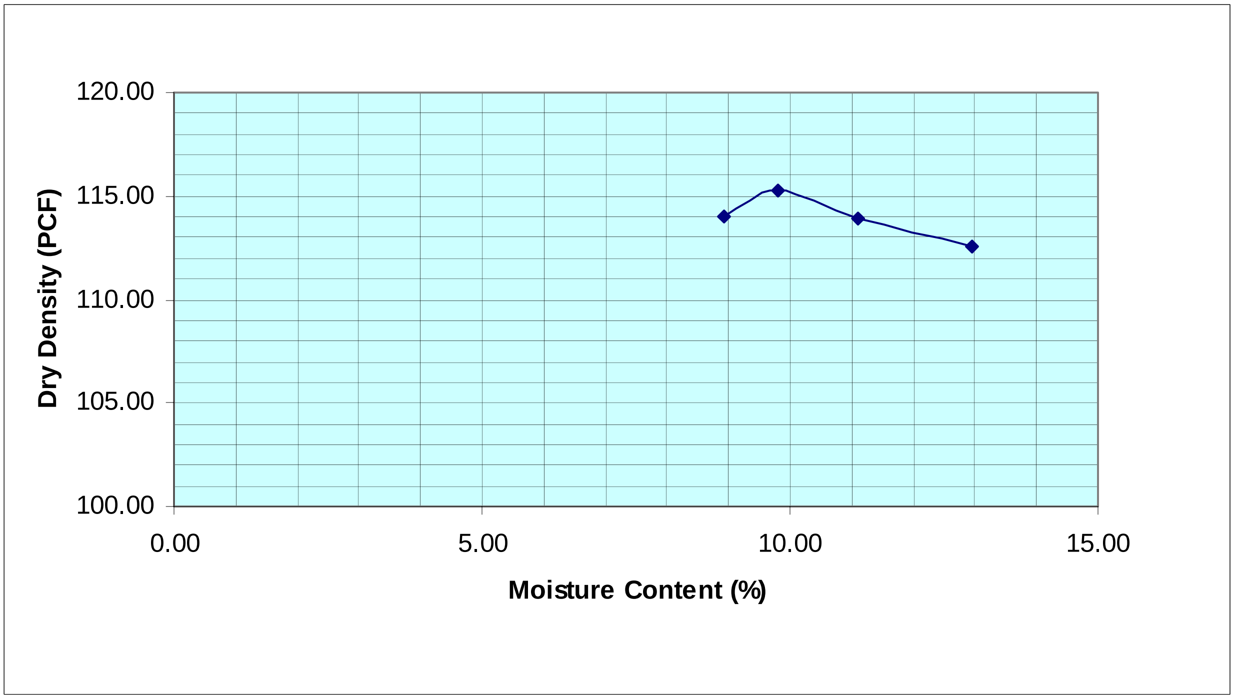

Figure C-1: SW (0% Fine Content): Proctor Test

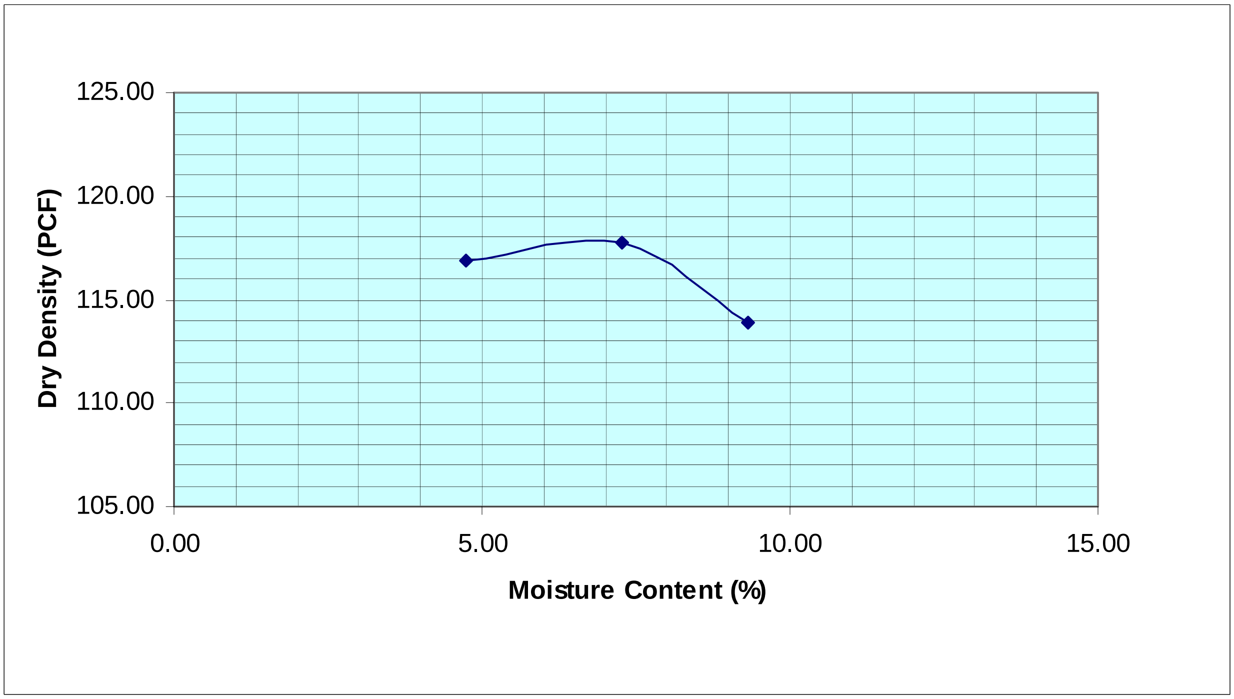

Figure C-2; SW (2% Fine Content): Proctor Test

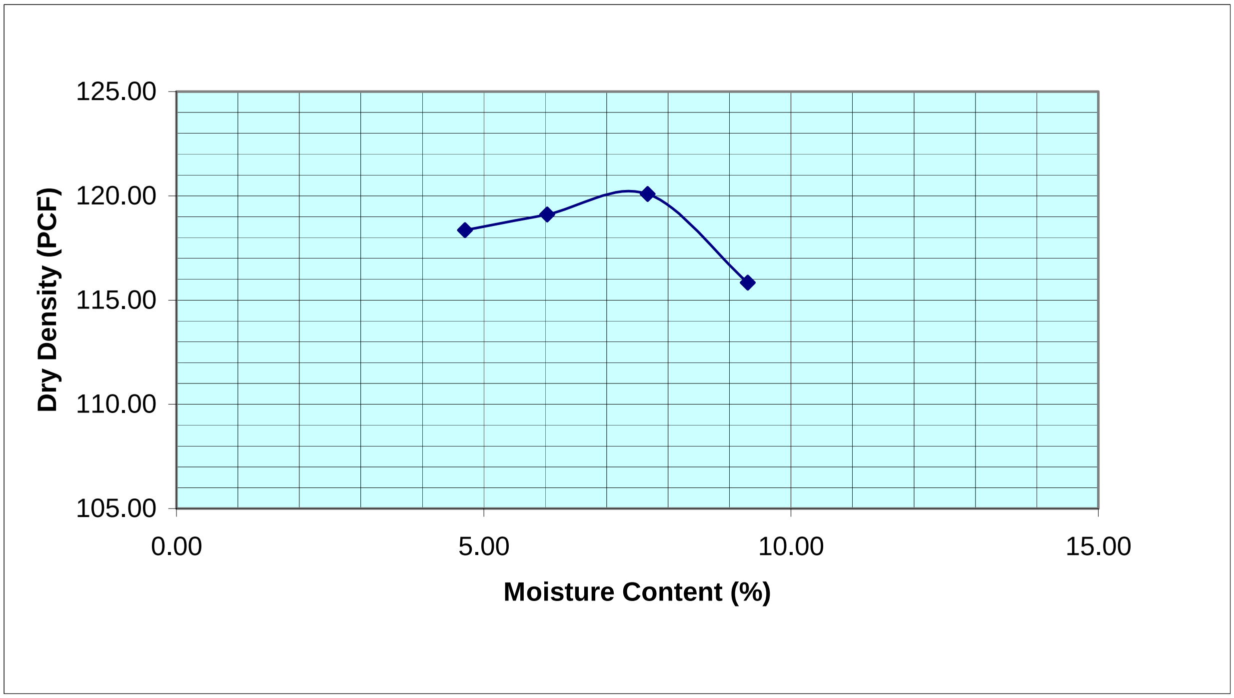

Figure C-3; SW (3% Fine Content): Proctor Test

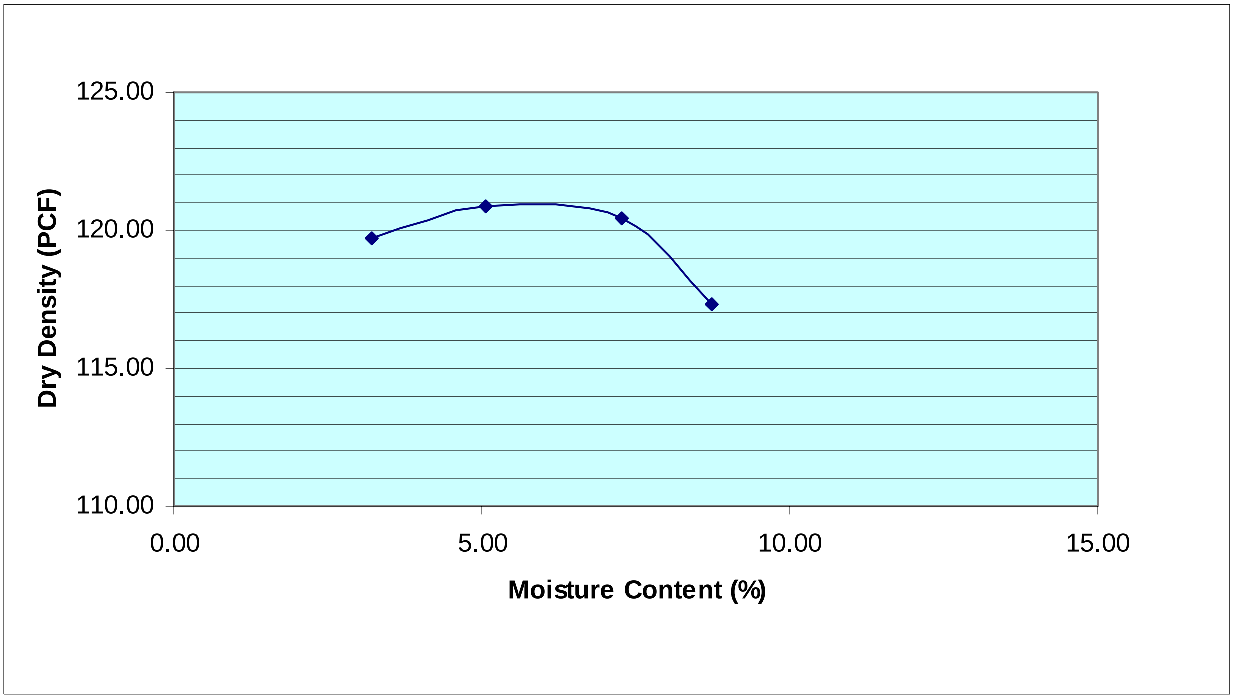

Figure C-4; SW (4% Fine Content): Proctor Test

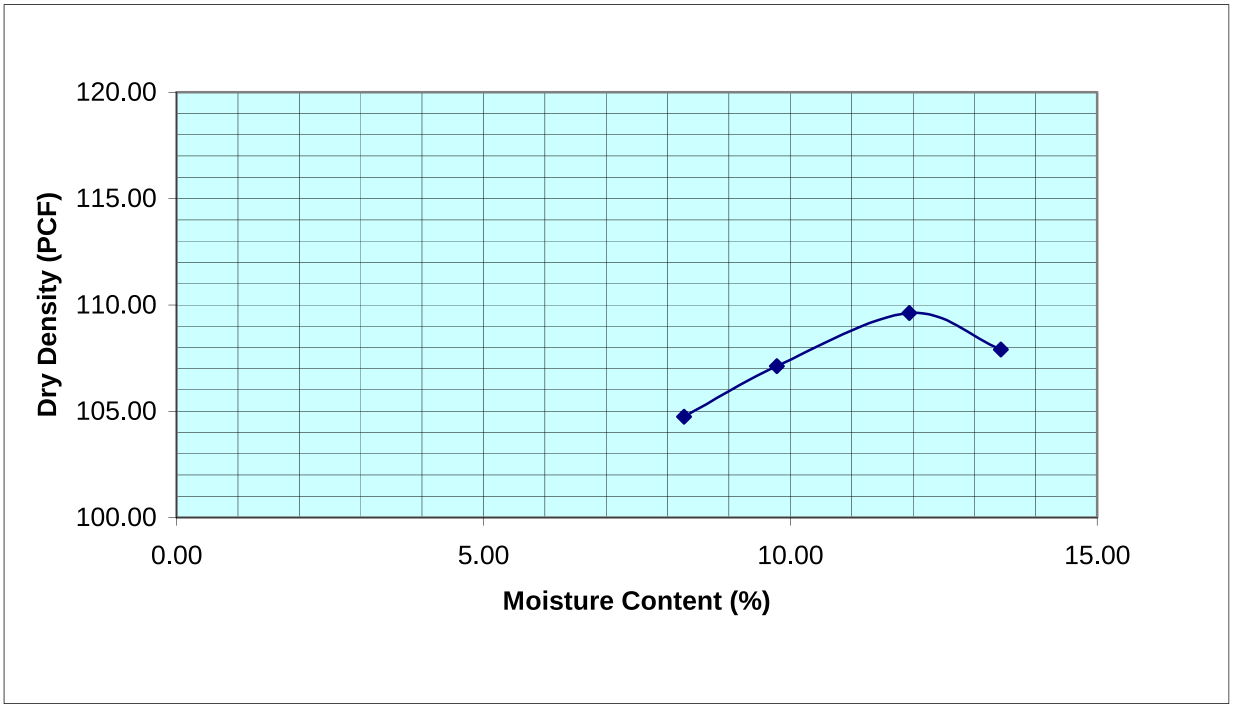

Figure C-5; SP (0% Fine Content): Proctor Test

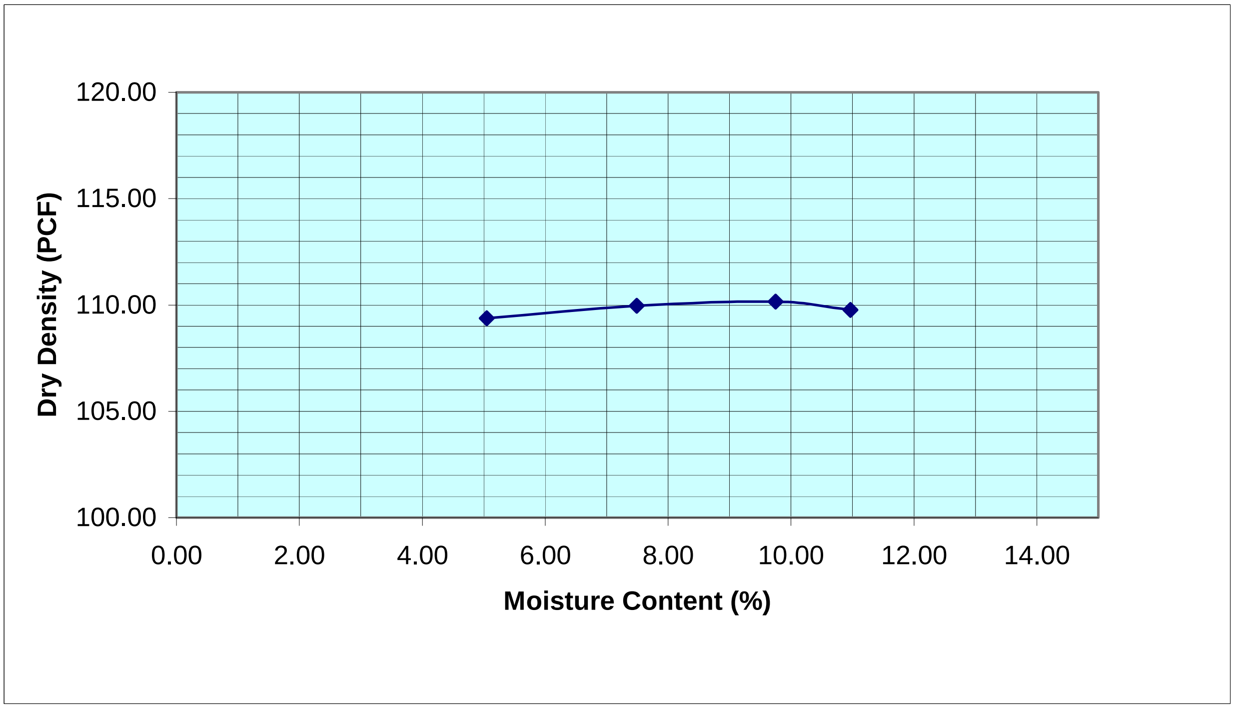

Figure C-6; SP (2% Fine Content): Proctor Test

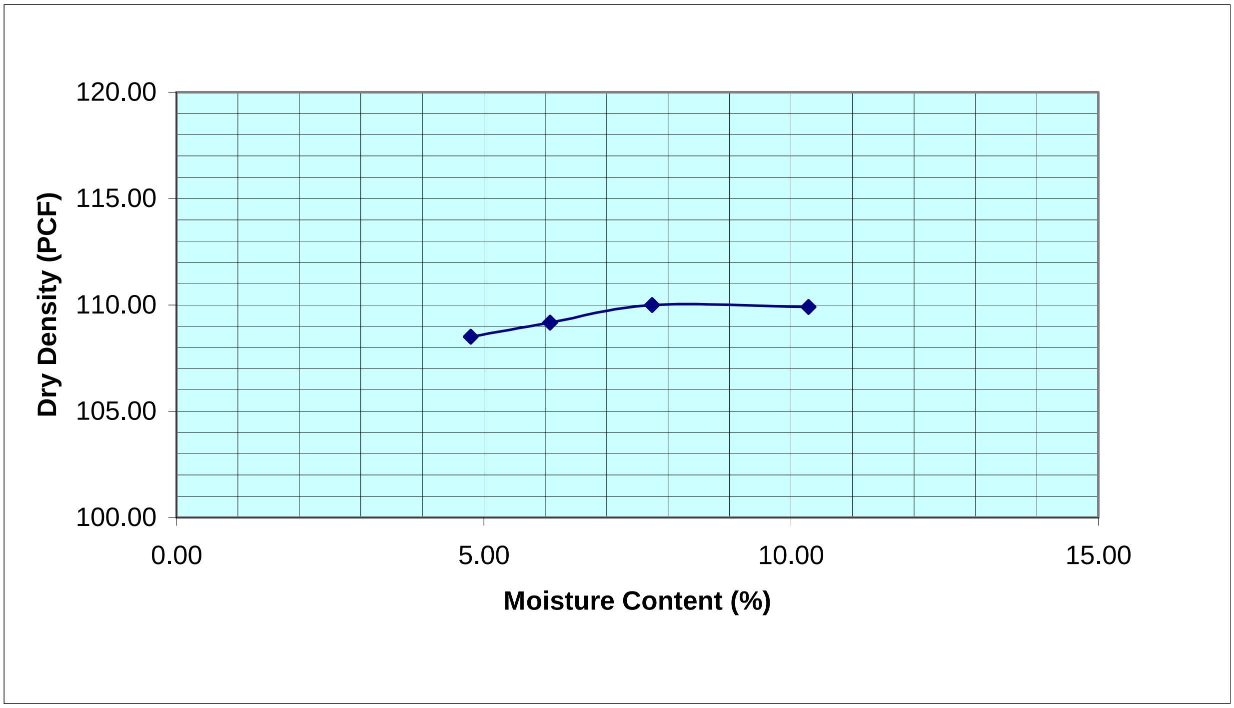

Figure C-7; SP (3% Fine Content): Proctor Test

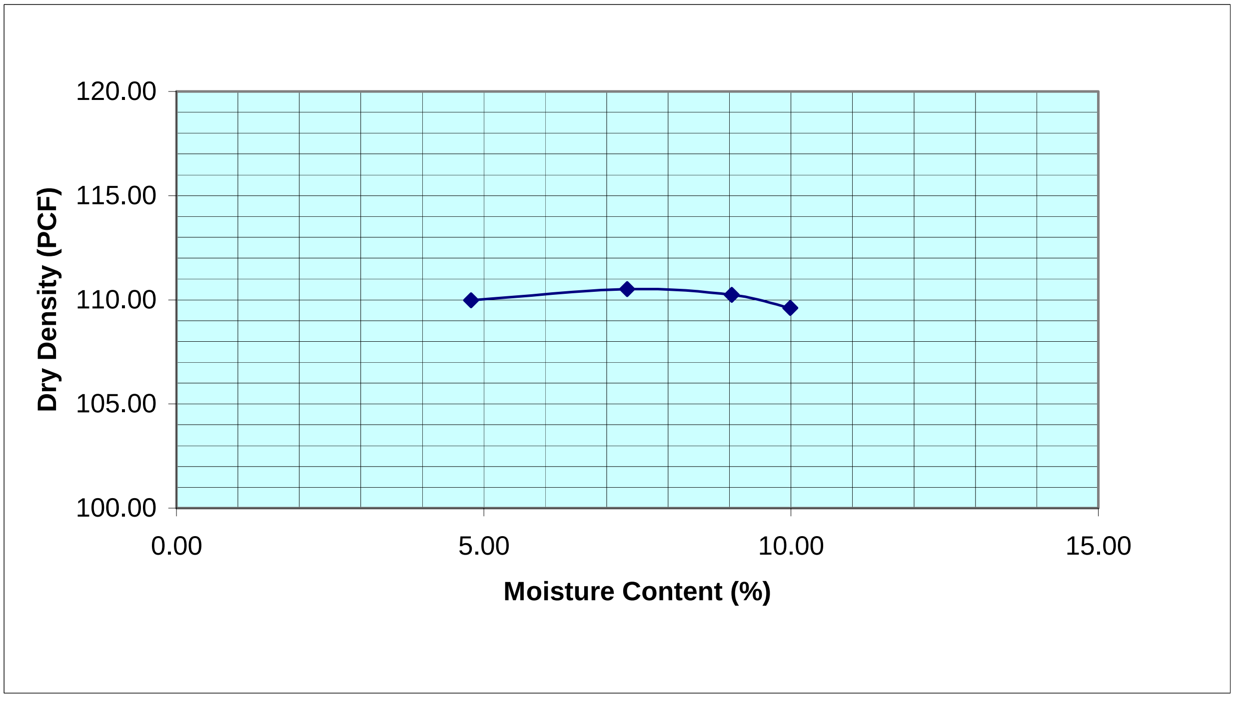

Figure C-8; SP (4% Fine Content): Proctor Test

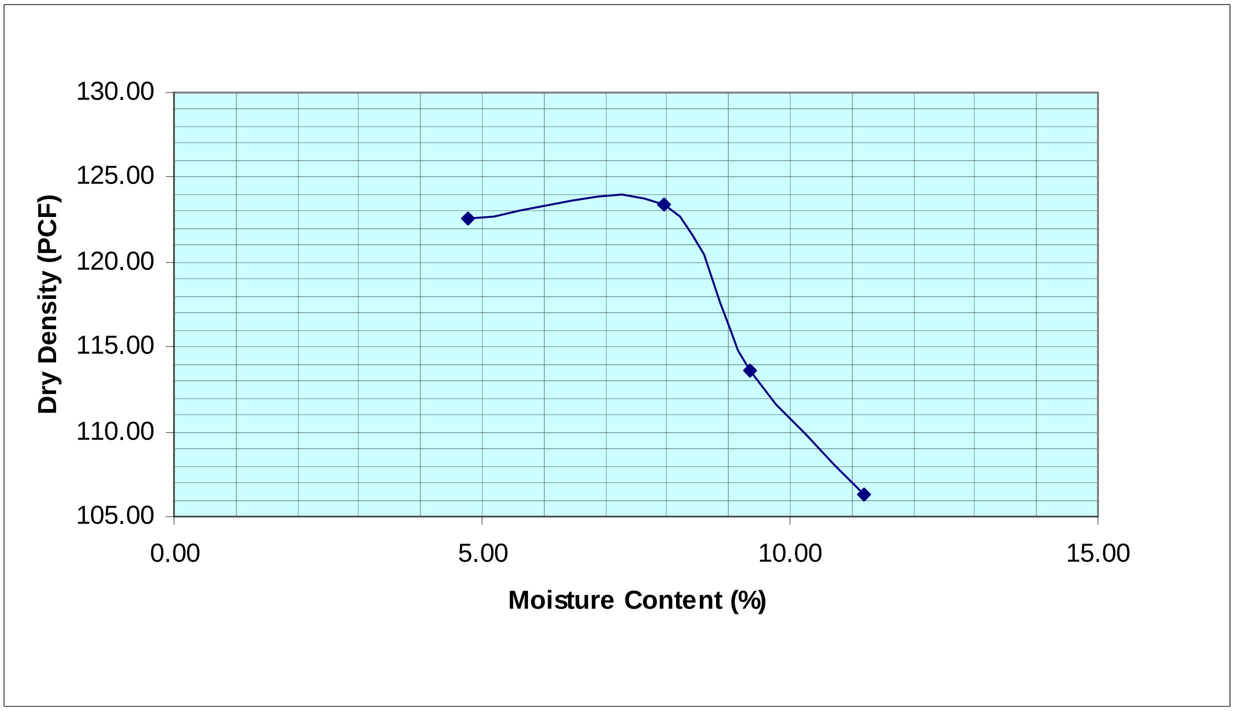

Figure C-9; SW-SC (5.5% Fine Content): Proctor Test

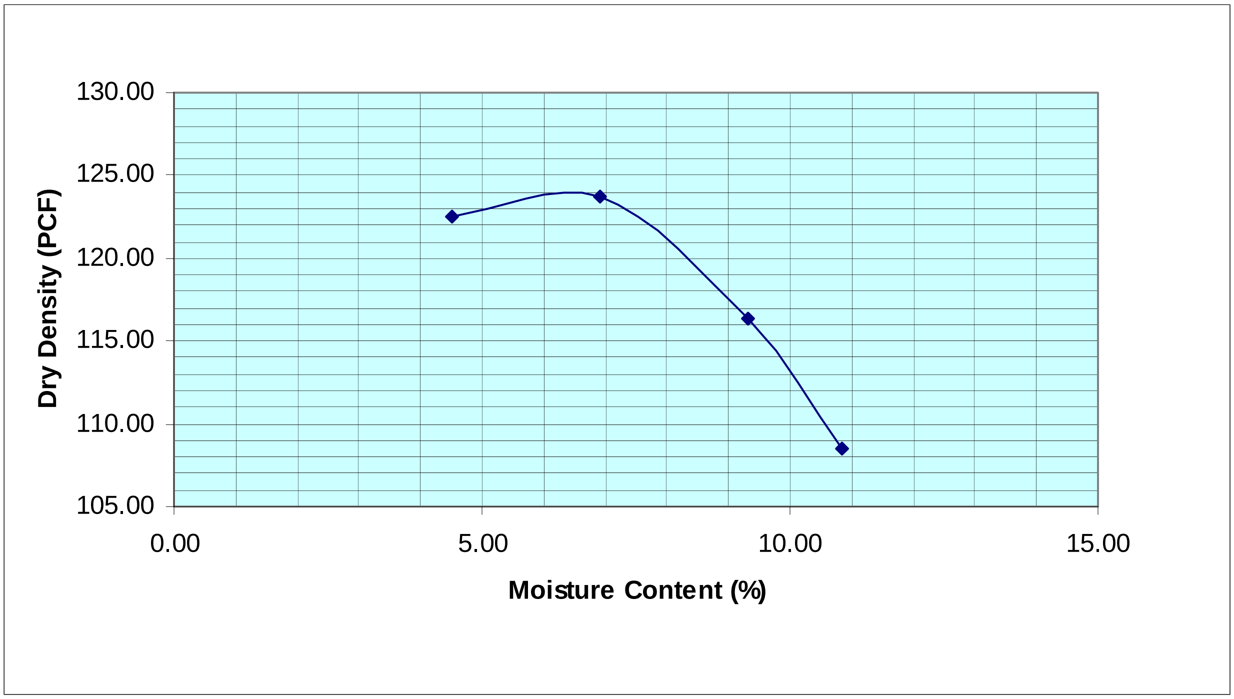

Figure C-10; SW-SC (6.5% Fine Content): Proctor Test

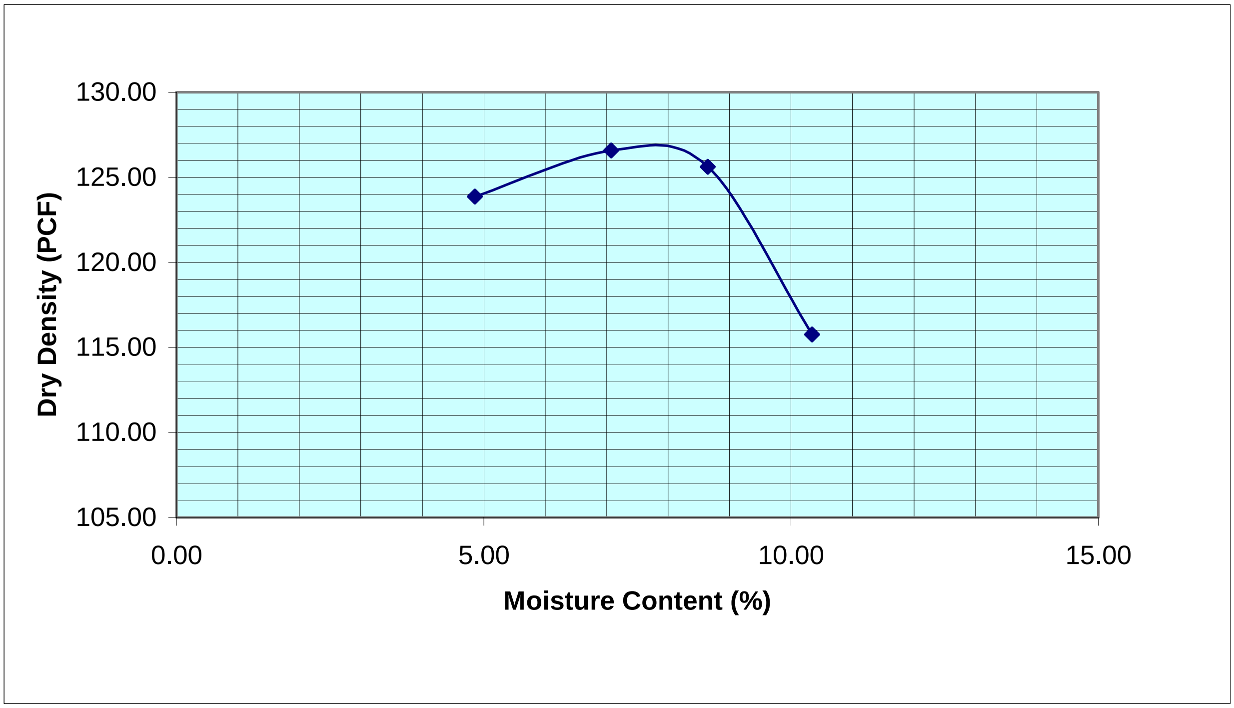

Figure C-11; SW-SC (9% Fine Content): Proctor Test

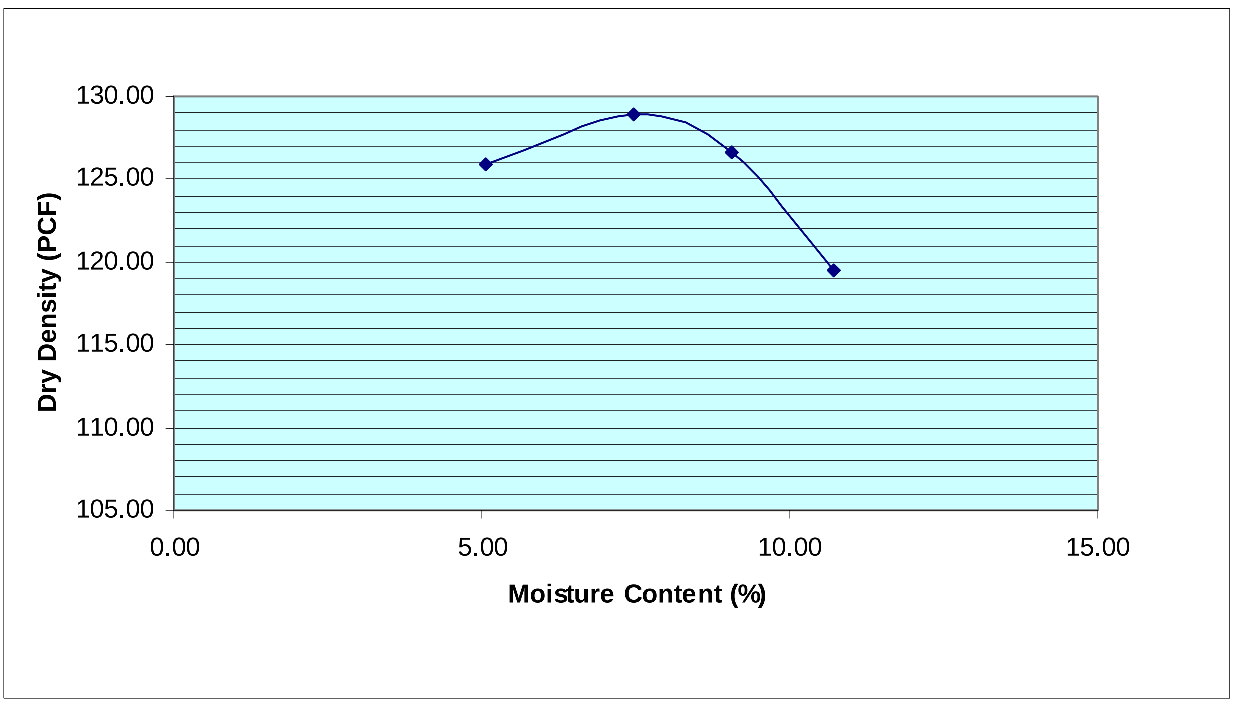

Figure C-12; SW-SC (11.5% Fine Content): Proctor Test

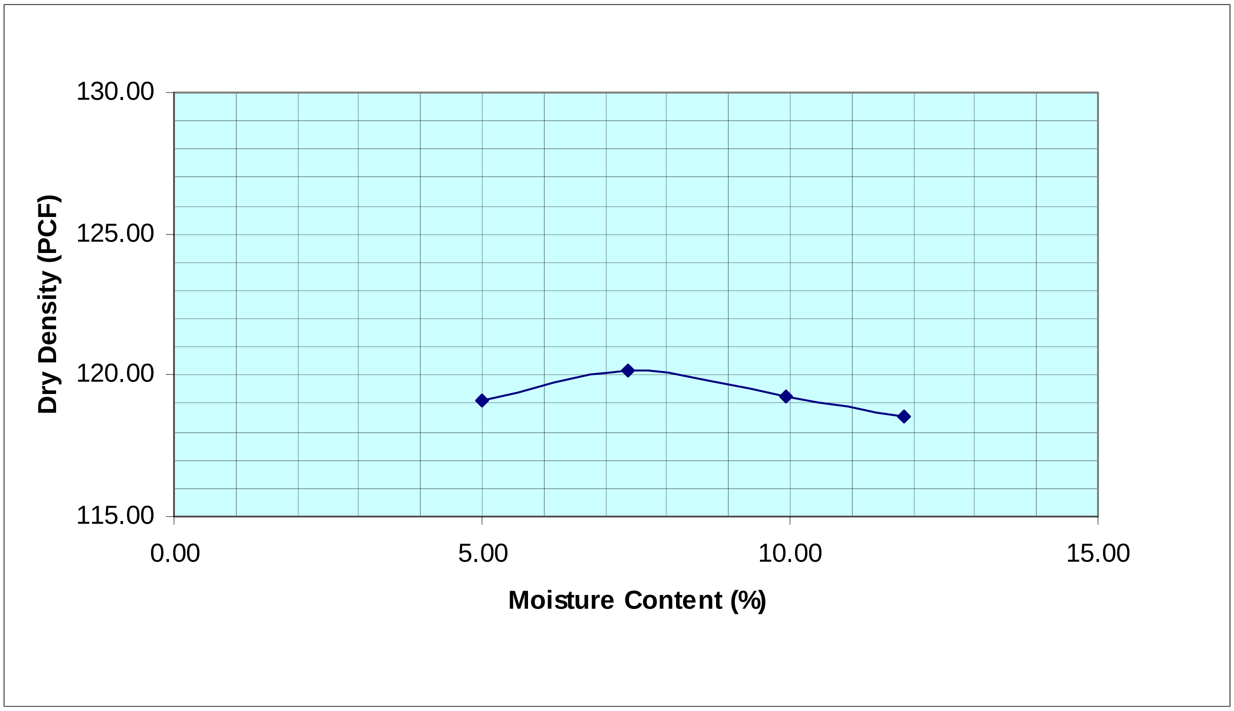

Figure C-13; SW-SM (5.5% Fine Content): Proctor Test

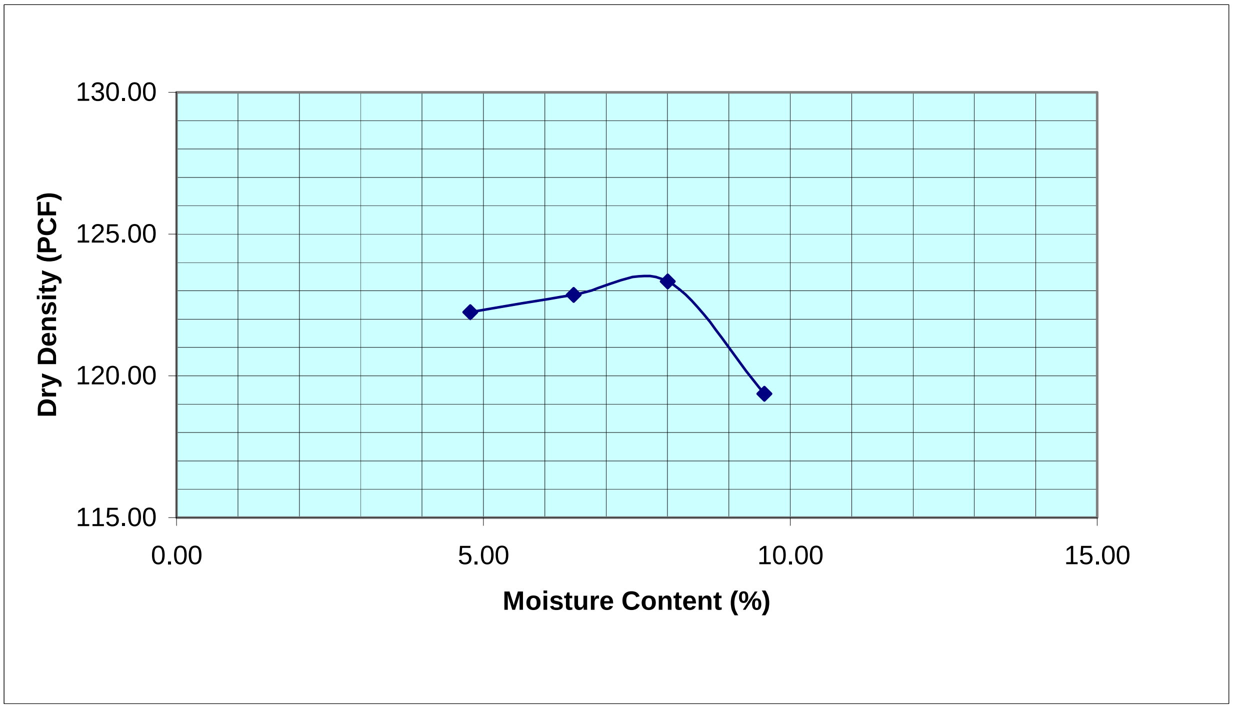

Figure C-14; SW-SM (6.5% Fine Content): Proctor Test

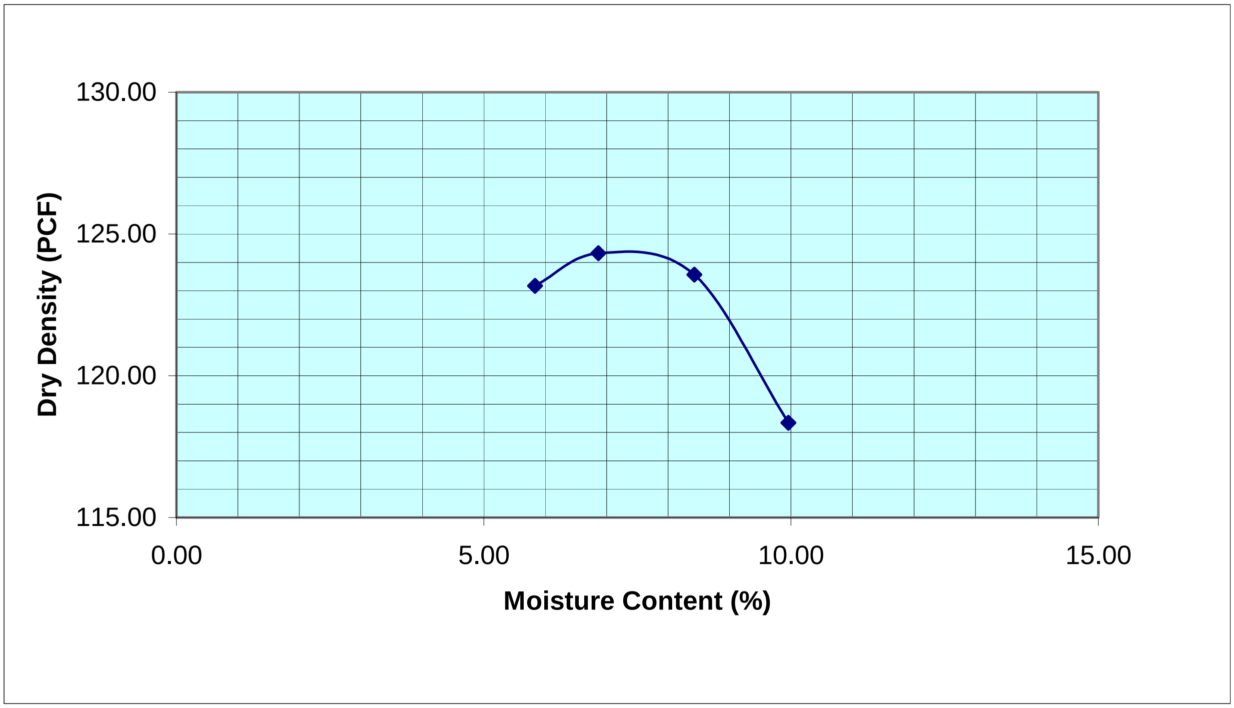

Figure C-15; SW-SM (9% Fine Content): Proctor Test

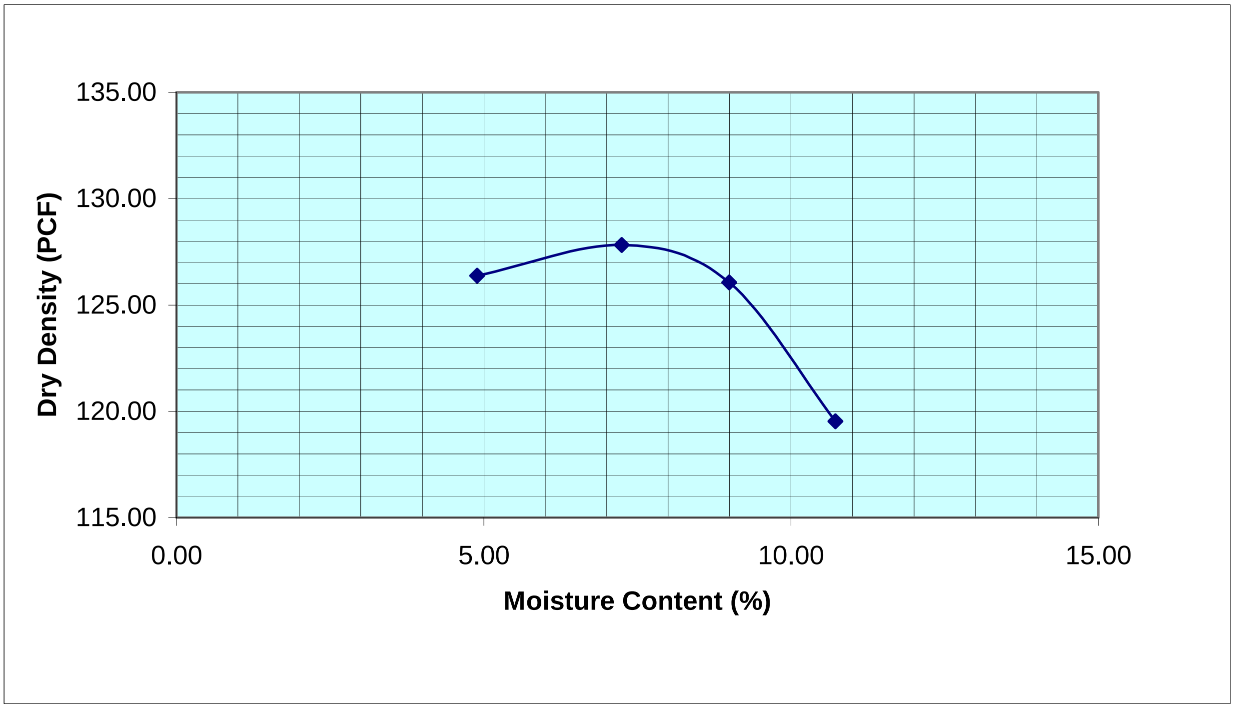

Figure C-16; SW-SM (11.5% Fine Content): Proctor Test

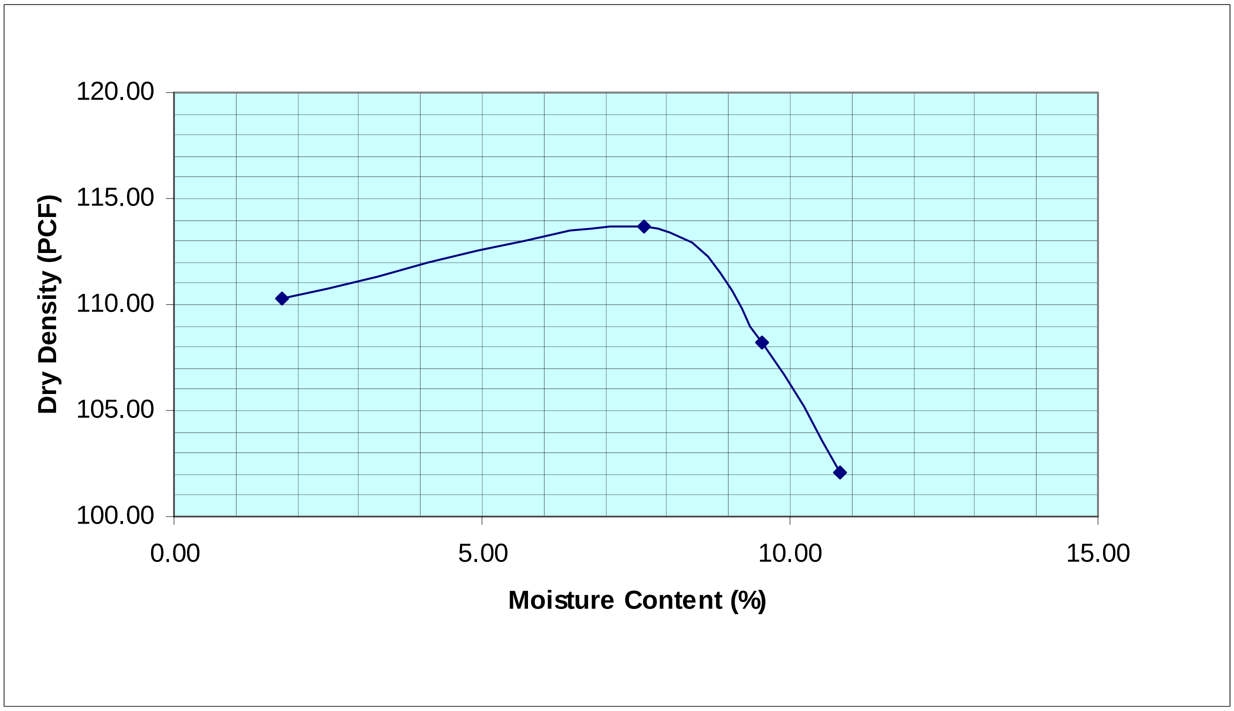

Figure C-17; SP-SC (5.5% Fine Content): Proctor Test

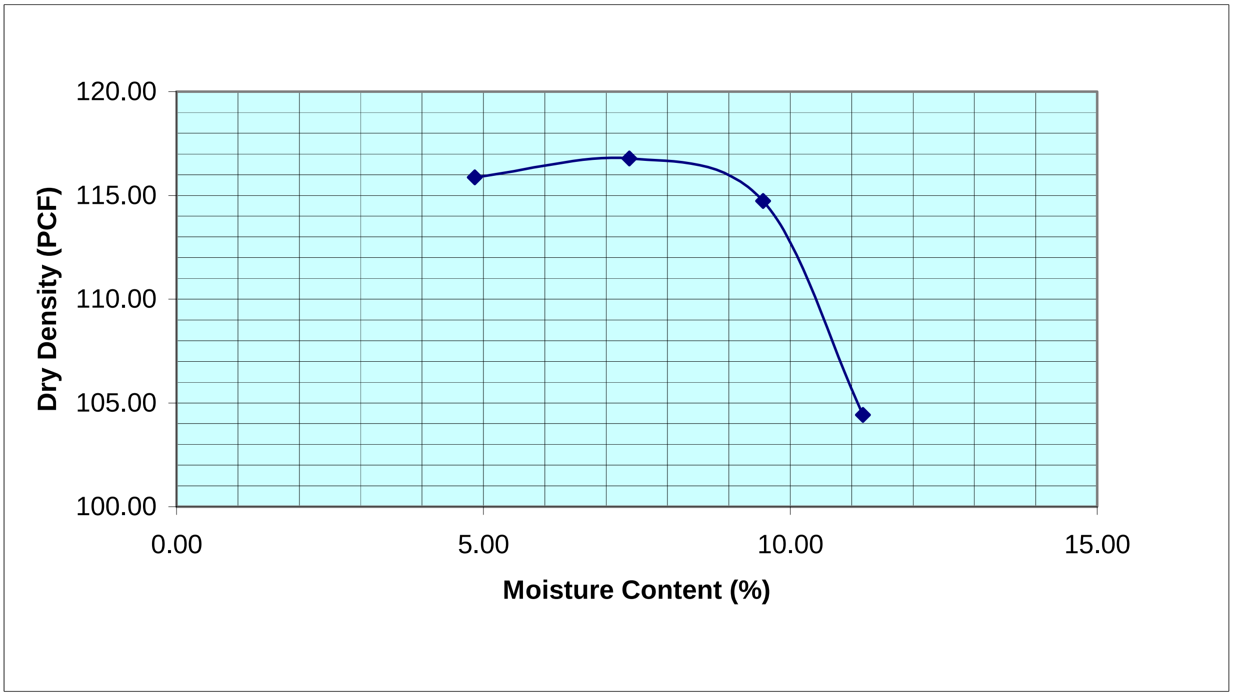

Figure C-18; SP-SC (6.5% Fine Content): Proctor Test

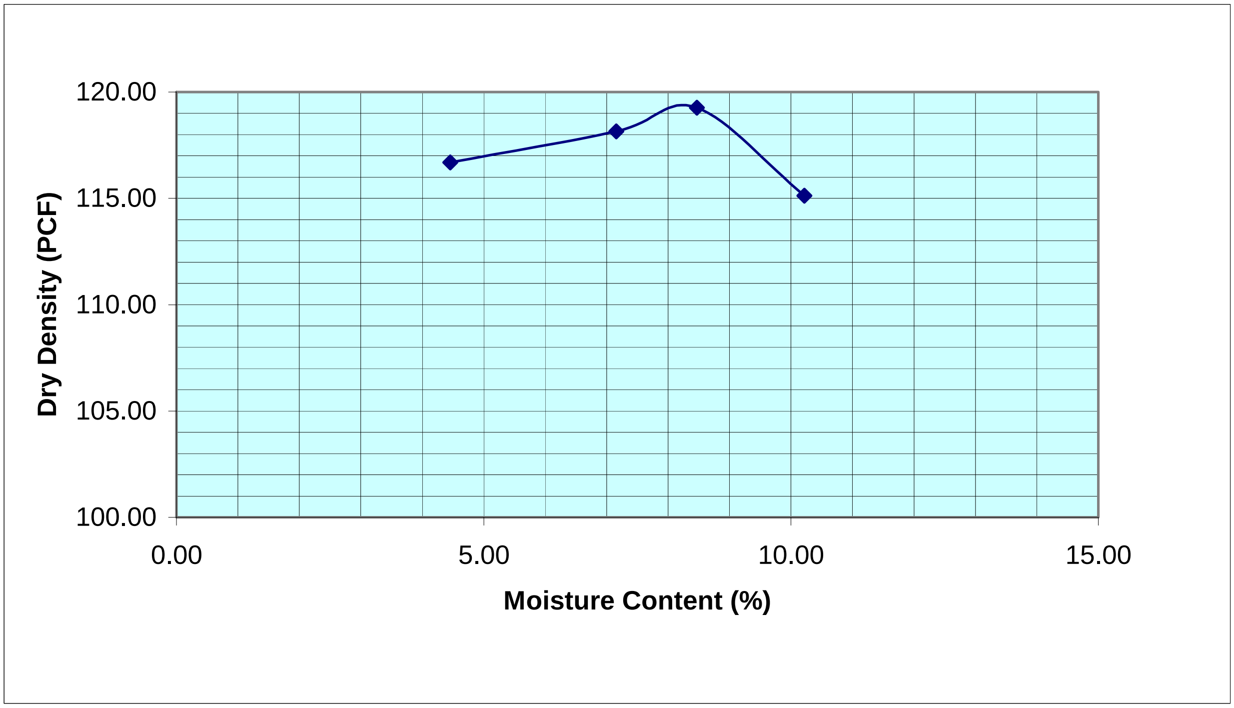

Figure C-19; SP-SC (9% Fine Content): Proctor Test

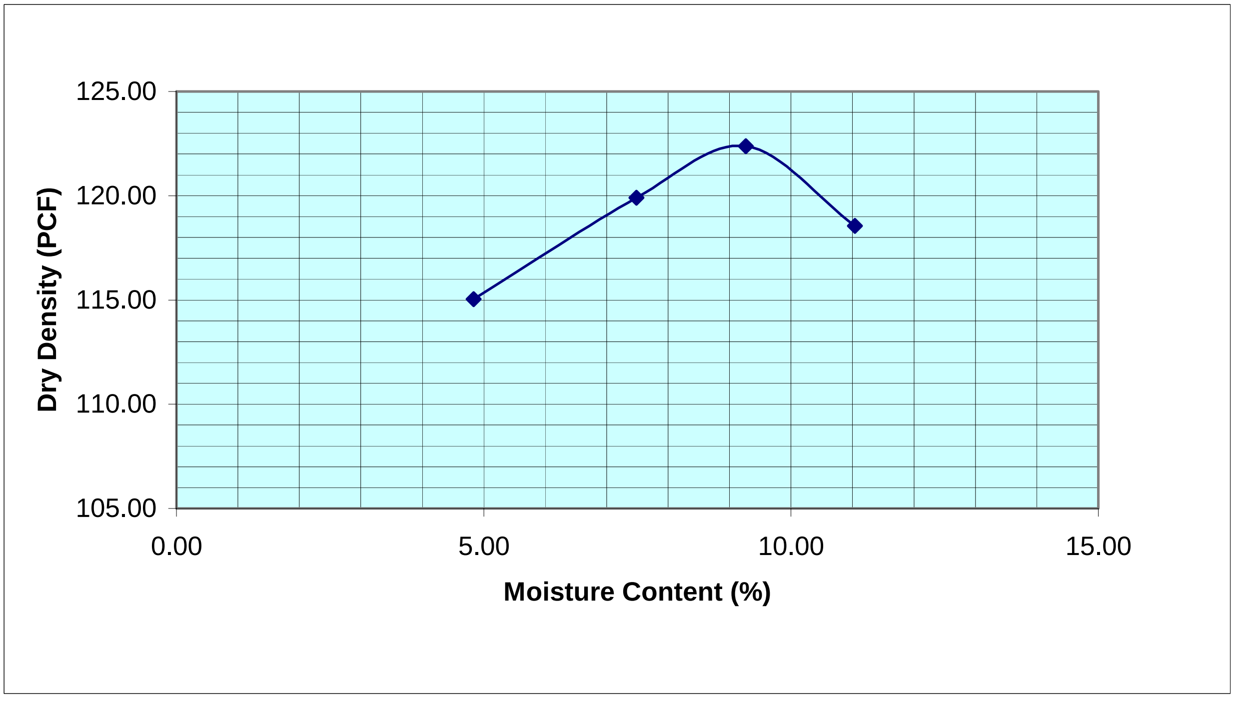

Figure C-20; SP-SC (11.5% Fine Content): Proctor Test

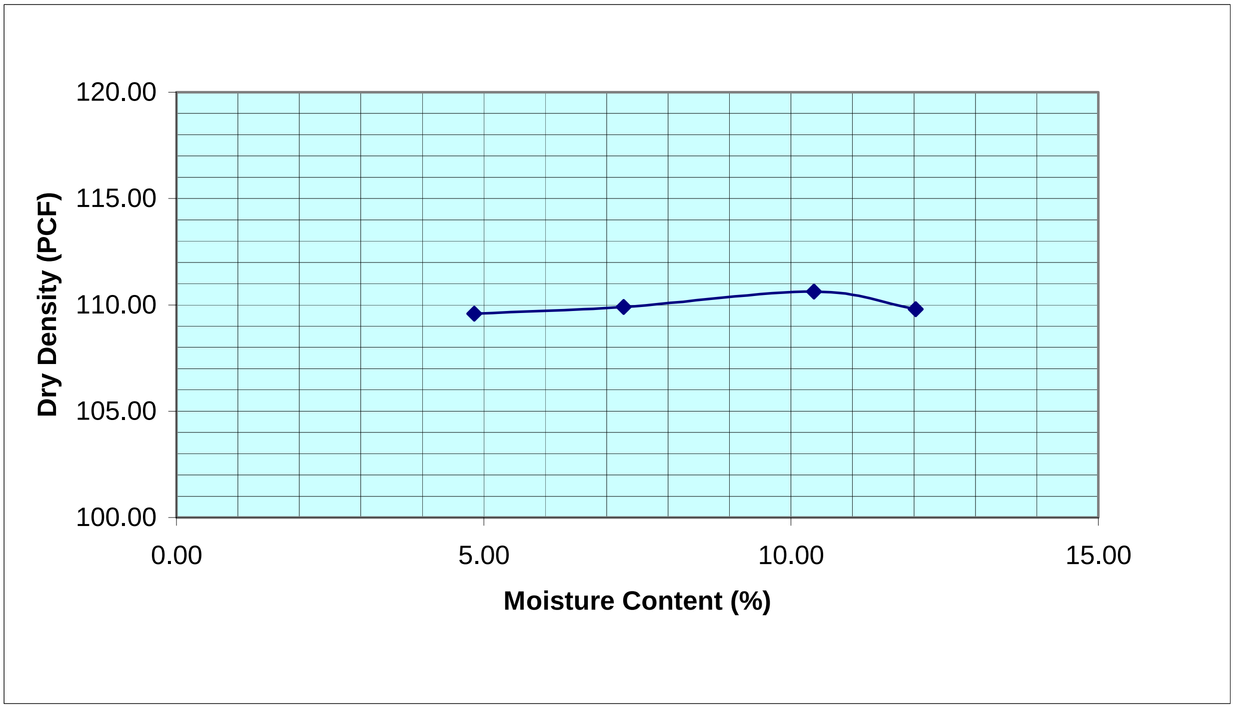

Figure C-21; SP-SM (5.5% Fine Content): Proctor Test

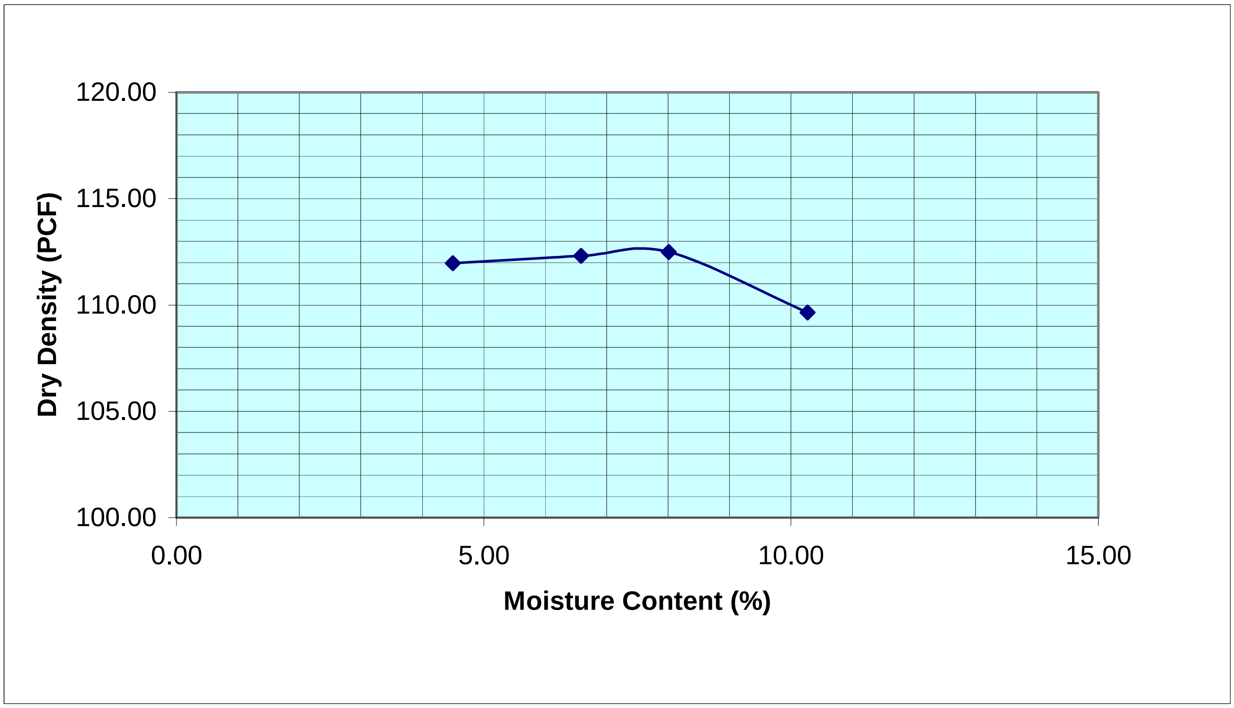

Figure C-22; SP-SM (6.5% Fine Content): Proctor Test

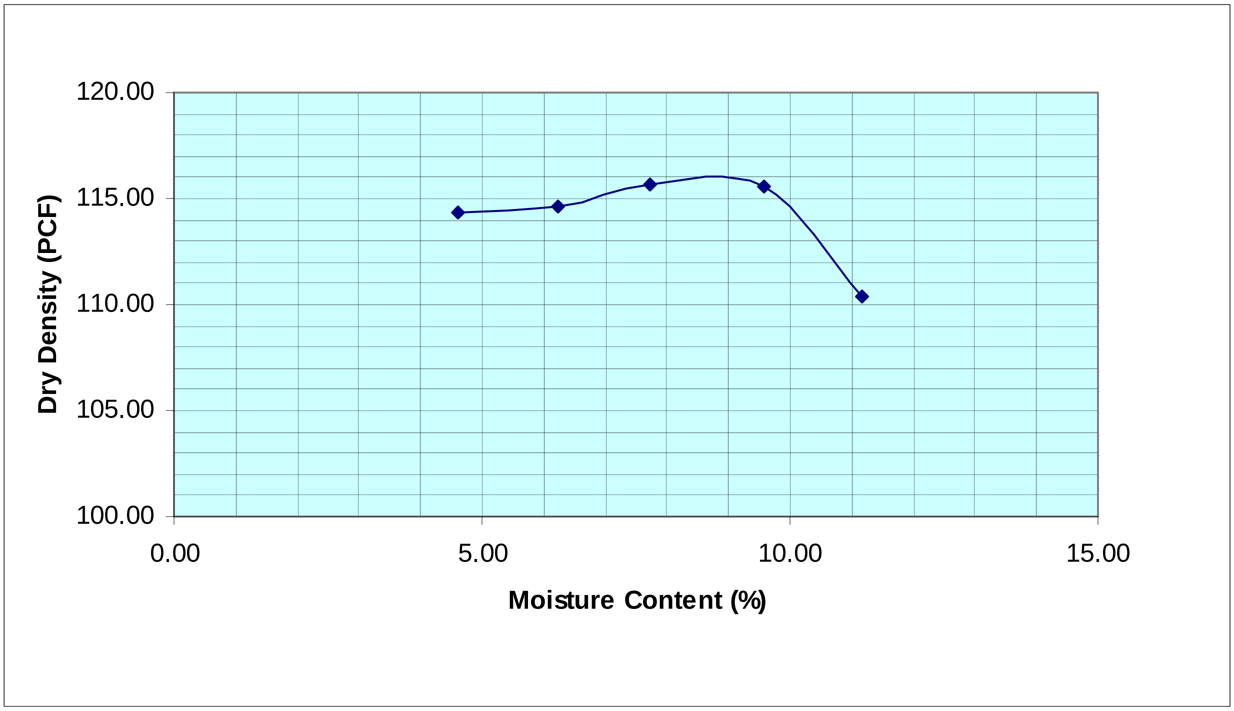

Figure C-23; SP-SM (9% Fine Content): Proctor Test

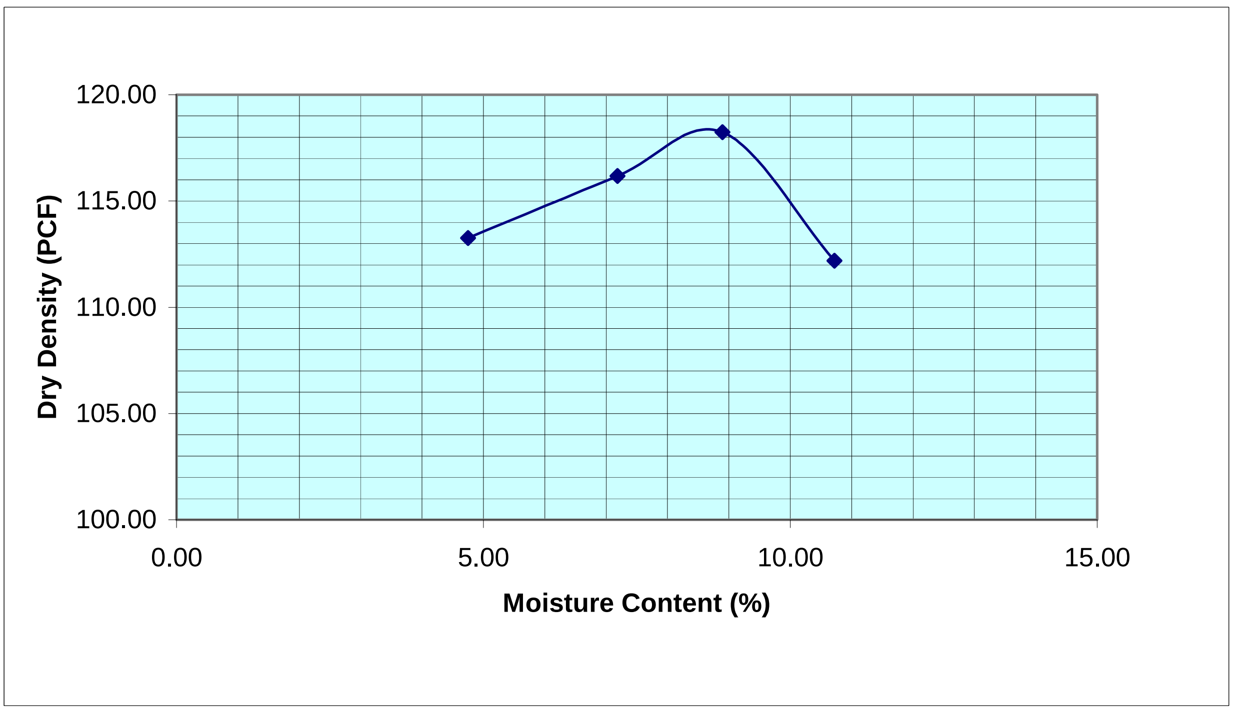

Figure C-24; SP-SM (11.5% Fine Content): Proctor Test

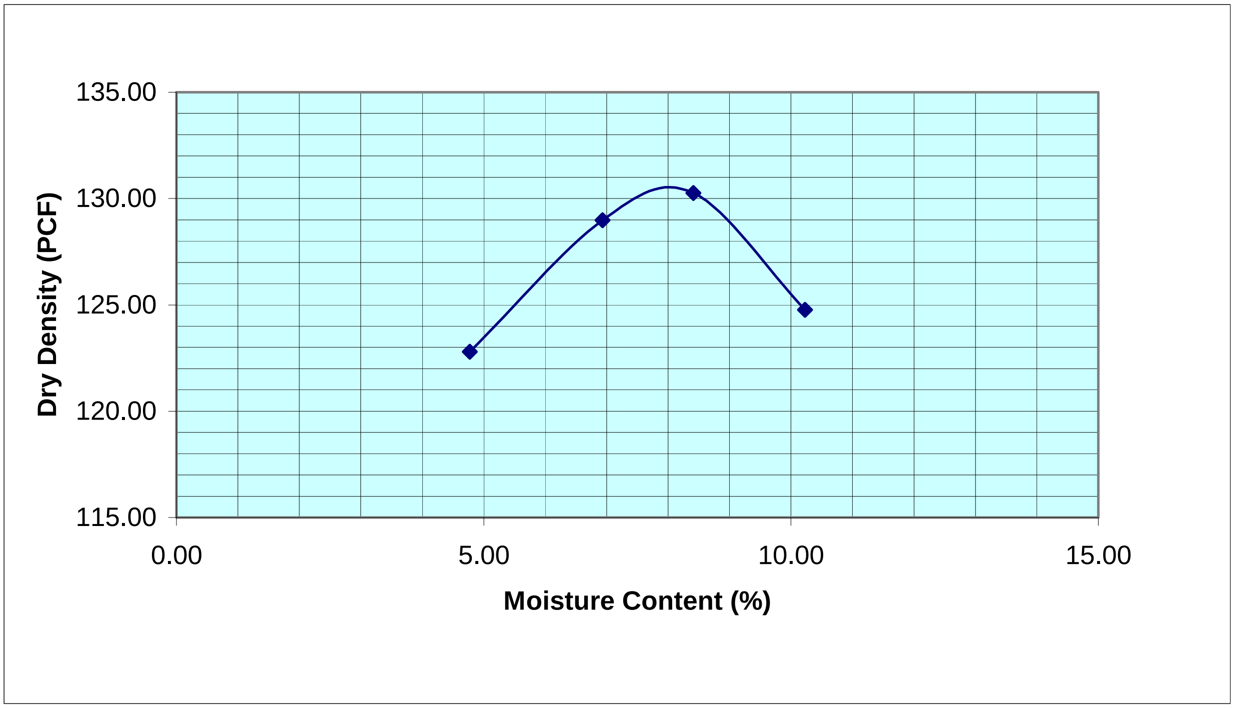

Figure C-25; SC (15% Fine Content): Proctor Test

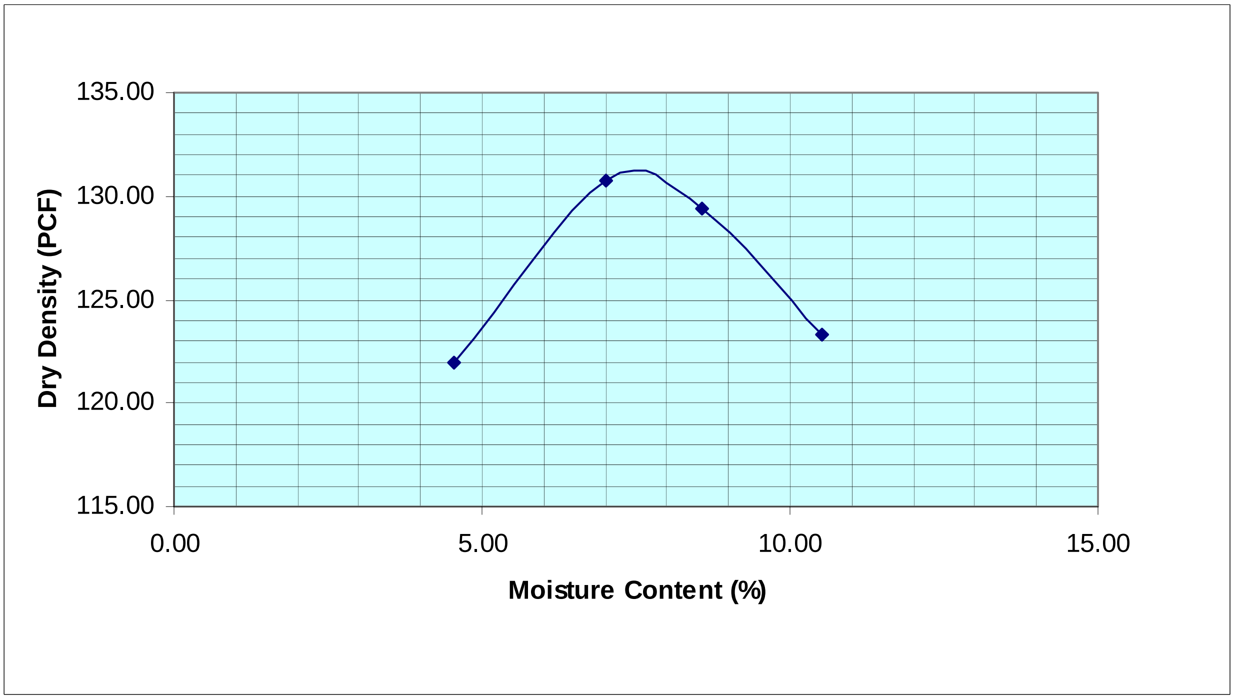

Figure C-26; SC (20% Fine Content): Proctor Test

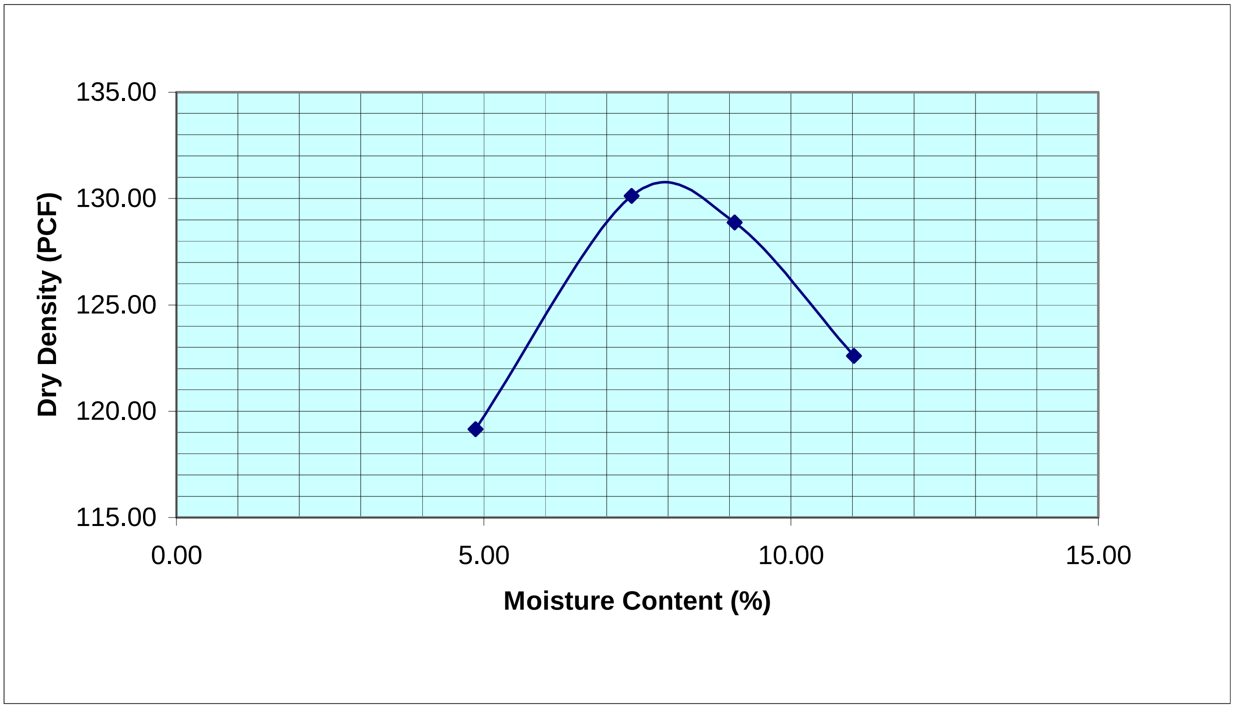

Figure C-27; SC (25% Fine Content): Proctor Test

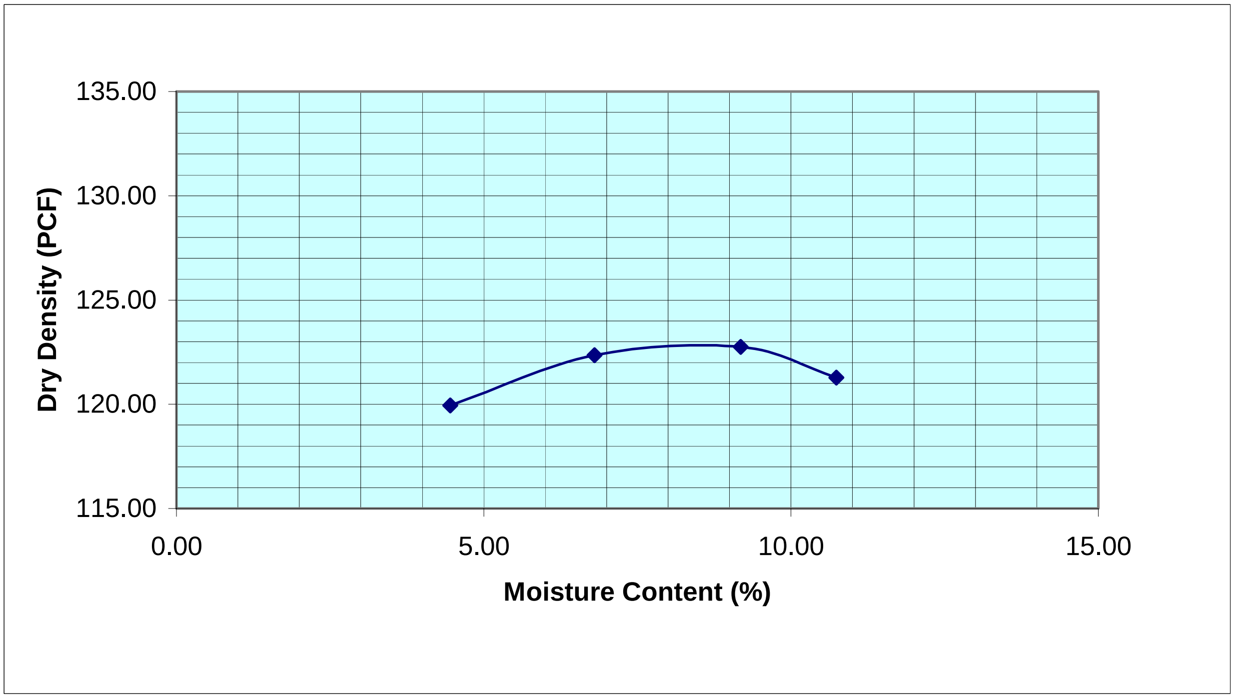

Figure C-28; SM (15% Fine Content): Proctor Test

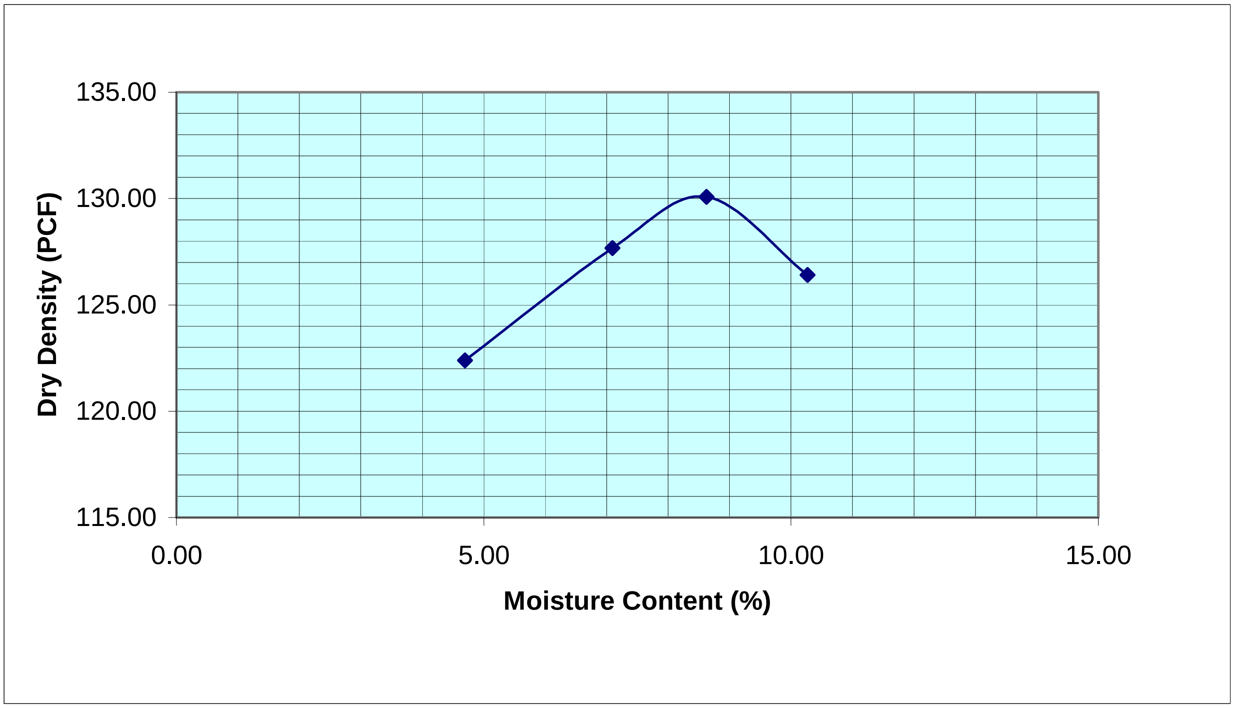

Figure C-29; SM (20% Fine Content): Proctor Test

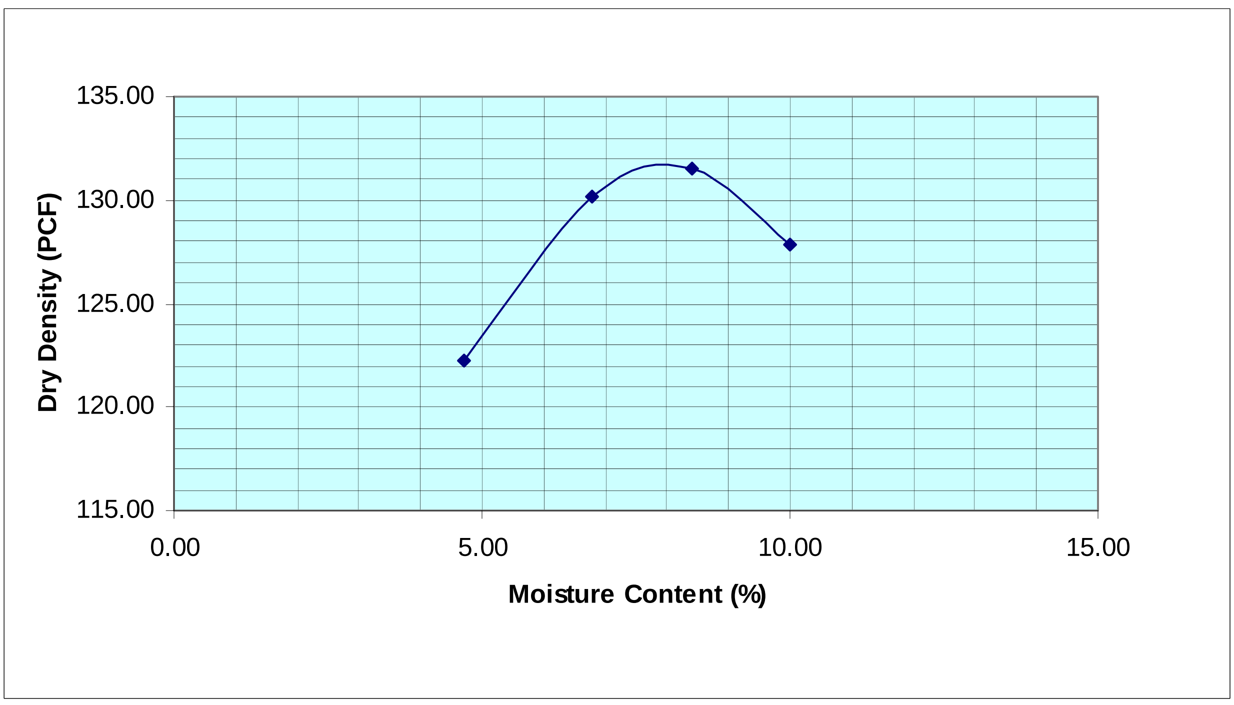

Figure C-30; SM (25% Fine Content): Proctor Test

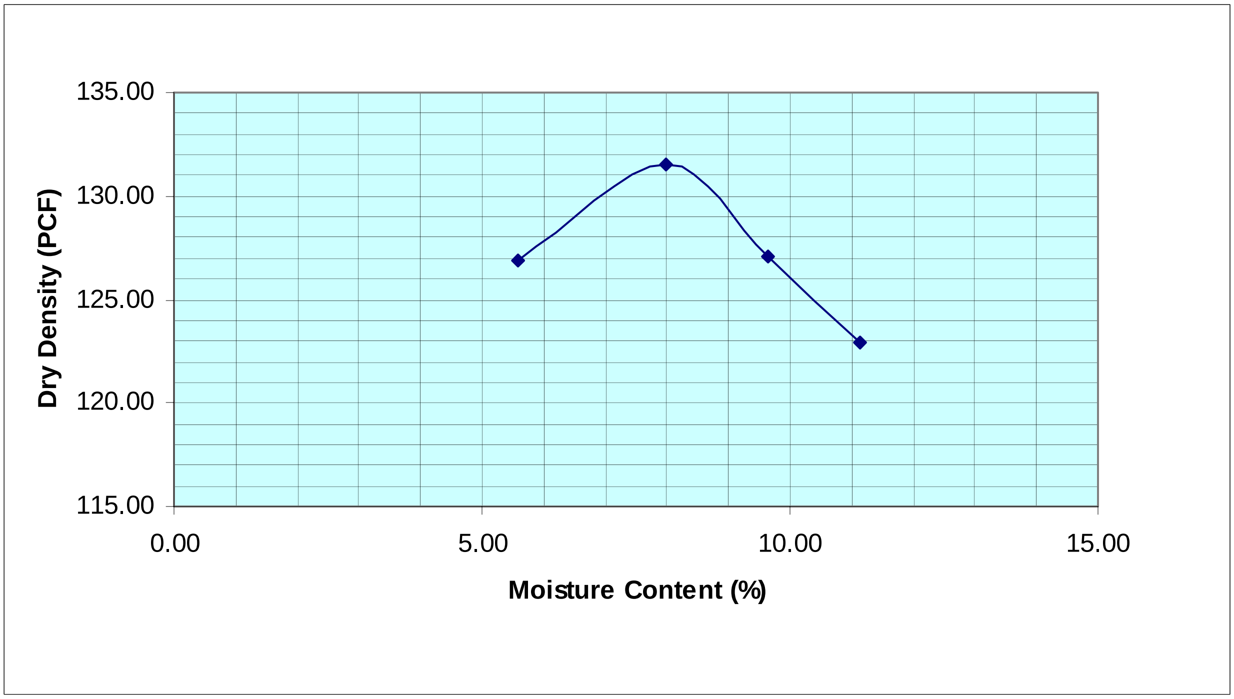

Figure C-31; SM (30% Fine Content): Proctor Test

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