Clayey Soil Stabilization using Fine Sand for Sub-grade Improvement

By

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Abstract

Clayey soil is one of the problematic soils, as it is vulnerable to high volumetric change (swelling and shrinkage), high plasticity properties, and other engineering related problems. Problem soils might be cart away as a spoilt and borrow materials supplied which is very expensive. Different percentages of fine sandy soils (0, 25, 50, 75, and 100%) were used to stabilize clay soil. The samples of sandy soil were obtained from the Federal Polytechnic Damaturu after removing the topsoil and that of clay soil were collected by Waziri Ibrahim Housing estate Damaturu. Fine sand was used to stabilize the clay soil. Engineering properties of clay and sandy soils were determined. The tests carried out include: Atterberg's limits, compaction, sieve analysis and CBR. It was deduced that 50% replacement of clayey soil with fine sand is the optimum as it produced the highest maximum dry density, CBR value and minimum optimum moisture content.

Keywords: Problematic soil, Stabilization, Fine sand, Compaction, CBR

1.0 Introduction

Suitable sub-grade materials are vital in cost effectiveness of pavement construction (Kollaros & Athanasopoulou, 2016; Roy, 2013) and maintenance (Geiman, 2005). Normally, clayey soils exhibit undesirable engineering behaviors such as low strength, and high swelling and shrinkage characteristics etc., which require improvement through soil stabilization, that is, improvement of both the plasticity and bearing capacity of local soils (Kollaros & Athanasopoulou, 2016). When unsuitable sub-grade is encountered, carting the spoilt soil away is very expensive. Hence the alternative way of treating the soil is soil stabilization.

Soil stabilization is a common term used for improvement of geotechnical properties of soils through physical, chemical, or biological methods, or a combination of these (Rahimi., Abbasi, & Shantia, 2011); there are many methods of soil stabilization, and the choice amongst them depends on several parameters which include economy, practicability and environmental factors (Kollaros & Athanasopoulou, 2016). It is inevitable to improve the engineering properties of problematic soil so as to effectively found structures on it (Abbasi & Mahdieh, 2018) as the durability of a constructed road principally depends on the quality of the materials used and the traffic volume on the road (Roy, 2013).

Some of the most serious problematic soils are expansive, collapsible, liquefiable, soluble, dispersive, silty fine sands, and highly organic weak soils (Afsharian, Abbasi, Khosrojerdi, & Sedghi, 2016; Abbasi & Nazifi, 2013; Abbasi, 2011). Kollaros & Athanasopoulou, (2016) reported that, soils that change their volume in response to change in their moisture content are characterized as expansive. They further observed that, such soils show swelling shrinkage and often cause damage to civil engineering structures like the transportation infrastructure.

The soils' volumetric change are highly dependent on both the mineralogy of materials composing the soils and their proportions in the soil mass (Kollaros & Athanasopoulou, 2016). Compaction of soil improves soil densification, reduces volume of air voids in the soil, and may lead to increase in the shear strength, decrease in the consolidation and the permeability characteristics of soils. Compaction parameters such as (maximum dry density (MDD) and optimum moisture content (OMC)) are significant in most of the constructions that need densified soils, such as embankments, highway and railway sub grades and foundation soils (Chetia, Baruah, & Sridharan, 2018).

Sand is a natural granular material and has a high load bearing capacity in confined condition, as such could be used as a filler material (Kollaros & Athanasopoulou, 2016). However, sand could be used in different proportions as stabilizing agents to cohesive soils in altering properties such as plasticity, compaction and strength of the mixtures (Khemissa, Mahamedi, & Mekki, 2015; Louafi & Bahar, 2012). Furthermore, sand is a non-plastic granular with high bearing capacity in a confined condition. In order to improve the characteristics of the weak soil, different types of sand may be used, which changes the grain size configuration of such soils (Roy, 2013).

Chavali & Sharma, (2014) reported that, the maximum dry density of clay-sand mix improved with the increase of sand up to 30% then decreased; conversely, the optimum moisture content decreased up to 30% sand content thereafter it increased slightly. Jjuuko, Kalumba, & Bagampadde, (2011) stabilzed clay with different percentages of sand and found out that maximum dry density (MDD) increased from 1867 to 2357 kg/m^3 and optimum moisture content (OMC) decreased from 16.5 to 8.5%, at sand blends of 20 to 100%.

The behavior of compacted clay-sand mixes depends on the quantity of the constituents, compaction characteristics, and test conditions. Shafiee, Tavakoli, & Jafari, (2008) reported that the undrained shear strength increases with increasing sand content. Similarly, Vallejo & Mawby, (2000) observed that the shear strength is governed by the granular phase when the sand content is greater than 75% and by the cohesive phase when the clay content is greater than 40%. The predominance of clay matrix occurs when the clay content is more than 40% as confirmed by Kumar & Wood, (2000) and Chandrasekaran & Pakassha, (2005).

Most of the stabilization works focused on cement, lime and other industrial by-products and agricultural wastes. This work is aimed at investigating the possibility of using fine sand to improve the engineering properties of clay soils.

2.0 Materials and Methods

2.1 Clayey Soil

Clayey soil samples were obtained behind Waziri Ibrahim Housing Estate Damaturu. Five Hundred (500 mm) from the soil surface was removed at the sampling points. Afterward, disturbed soil samples were collected by digging and packing into bags. The soil samples were then sun-dried to for use the experiments.

2.2 Stabilizing Sand

Fine sand was obtained from the Federal Polytechnic Damaturu, behind Civil Engineering Laboratories. The sandy soil was obtained after removing 500mm as the topsoil, then disturbed soil samples were collected. The samples were then air-dried to remove moisture.

2.3 Sample Preparation and Tests Methods

The soil stabilization was carried by the addition of fine sand to the clay which was proposed to bind and increase the strength of the soil. In this research work, sand was added as an inert material to stabilize the clay soil grains. The assessment of engineering properties of clay soil when blended with varying percentages of 0%, 25%, 50 %, 75%, and 100%, by weight of sandy soil were used in the investigation. Clay soil was mixed thoroughly with the above-mentioned percentages of sandy soil.

2.4 Experimental Procedures

2.4.1 Particle Size Distribution Test

Sieved analysis of the samples of clay and that of sandy soils were carried out. For the clay after weighing 500gm of the soil, it was washed through sieve No. 200 (75 μm) before conducting the test on it. As for the sandy soil 1000gm was weighed and used for the test. The test procedure was carried out in accordance with BS 1377.

2.4.2 Atterberg Limits Test

Cone penetrometer method was used to determine the liquid limit of the clay/sand mixtures. The soil samples were sieved through 425 μm sieve and carried out in accordance with BS 1377. Four to five different moisture contents were used, and penetrations of the cone was noted and plotted against the respective moisture content. From the same soil sample, a specimen was mixed with water and then molded into a ball and rolled between the palms of the hand and glass plate to threads of nearly 3mm in diameter, and then the moisture content determined, which was recorded as plastic limit moisture content of the soil.

2.4.3 Compaction Test

BS light and BS heavy compaction were used in this study in accordance with BS1377. For the BS light compaction, soil was compacted in three layers of equal thickness, into a metal mould of 105mm diameter and of 1000 cm^3 capacity for light compaction. Each layer received 27 blows from a 3kg mass rammer falling freely through a height of 300mm. As for the heavy compaction, the soil received 27 blows of 4.5kg rammer with a free-falling height of 450mm in five (5) layers. The moisture content of the soil was increased steadily by 3% of the total weight of the soil. It increased up to the point where the weight of the compacted soil start reducing. The dry density of the soil was calculated and plotted versus moisture content. The test was conducted on each of the percentage replacement.

2.4.4 California Bearing Ratio Test

Soaked and un-soaked CBR tests were conducted on the samples with different percentage (0, 25, 50, 75, and 100%) replacements in accordance with BS1377. The CBR values were compared in order to select the optimum result amongst the samples. The method followed in this piece of work is by, compacting the soil in five (5) layers at optimum moisture content of the soil. Each layer received sixty-five (65) blows of 4.5 kg rammer with a free fall of 450mm. For the soaked samples, four days soaking was carried out in the accordance with BS1377.

3.0 Results and Discussion

3.1.1 Particle Size Distribution

The results of sieve analysis for the samples (Figure 1) show that, the clay soil has 88% fines (that is, passing BS No. 200 sieve). The sandy soil was fine sand and poorly grade with coefficient of curvature of 3 and coefficient of uniformity of 1.8.

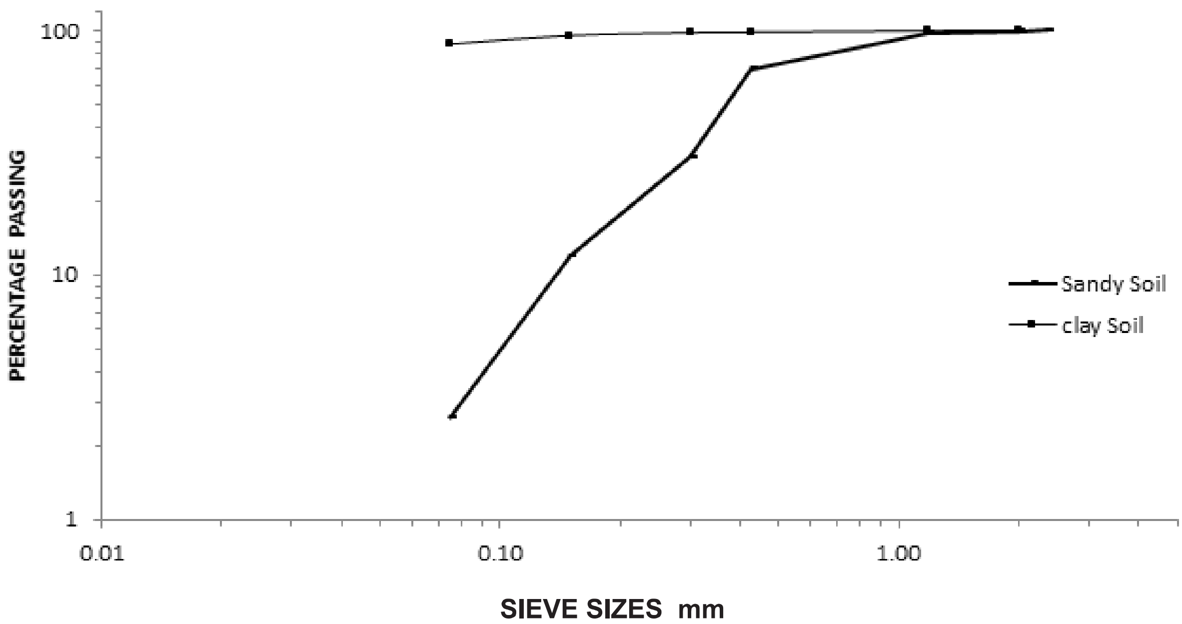

Figure 1: Particles Size Distribution of Clay and Sandy Soils

3.1.2 Compaction Characteristics Figure 2, and 3 show the relationship between maximum dry density and percentage replacement of sand in clayey soil. The maximum dry densities increase with increase in sand content up to 50% replacement for both compactive efforts and then declined. That shows that 50% replacement is the optimum. However, the optimum moisture content decreased and attaining the minimum value at 50% replacement (Figure 4) for both heavy and light compaction, then increased. Relatively similar finding has been reported in the literature (Chavali & Sharma, 2014; Jjuuko, Kalumba, & Bagampadde, 2011). This might be as a result of reduction of plasticity of the soil when sand content increases in the soil mixture. The soil mixture might have reduced surface area, thereby makes it more densified.

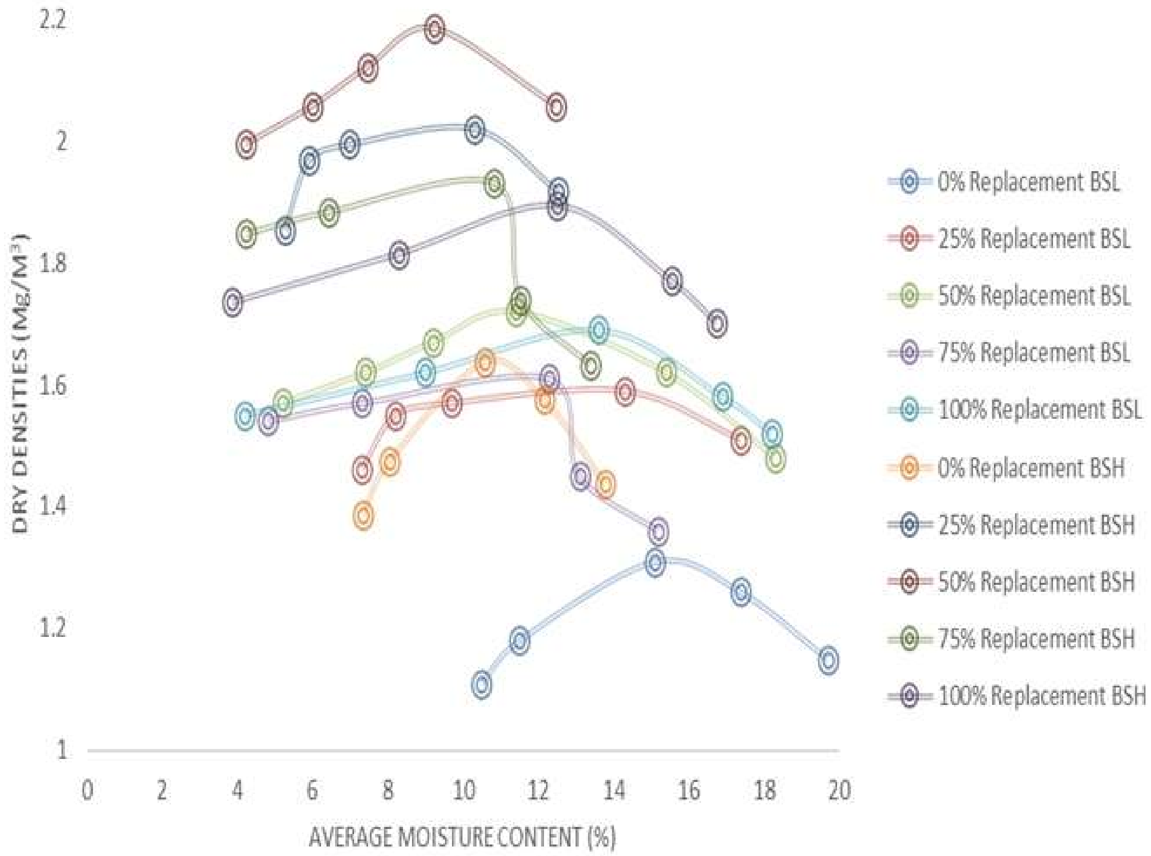

Figure 2: BS Light and Heavy Compaction results of different Percentage replacements

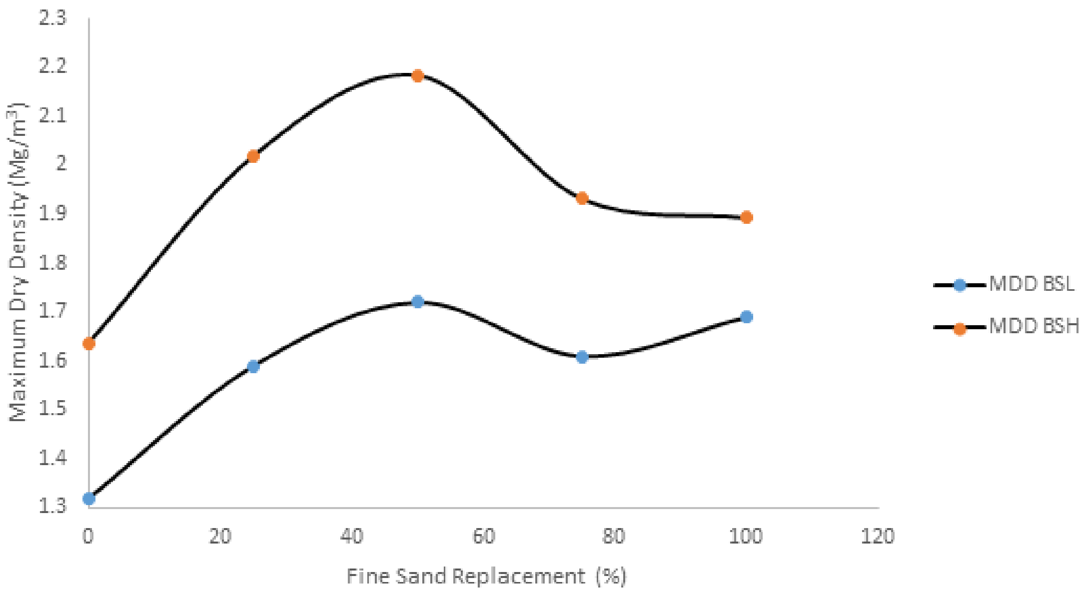

Figure 3: Relationship between Maximum Dry Density and Percentage sand replacement

Table 1: Relationship between Atterberg's Limits and Percentage of Sand replacement

% Replacement of Sand (%)	Liquid Limits (%)	Plastic Limit (%)	Plasticity Index (%)	USCS Classification
0	37.8	15.5	22.3	CL
25	30.2	14.7	15.5	CL
50	23.7	13.1	10.6	CL
75	10.2	8.8	1.4	ML
100	7.1			ML

3.1.4 California Bearing Ratio

The California Bearing Ratio (CBR) of the mixture of sand and clay increases as the sand content increase up to 50%, then declined. The optimum value of CBR for both soaked and un-soaked was obtained at 50%. This might be as a result of reduction in surface area of the soil up to 50% sand content, then the voids in the soil mixture become to large to be well compacted.

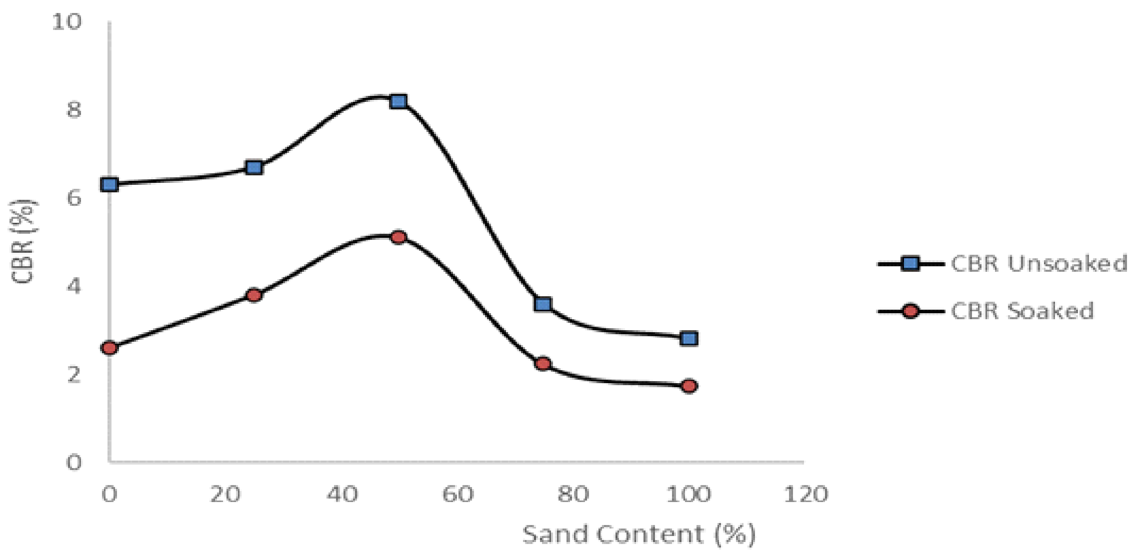

Figure 6: Relationship between California Bearing Ratio (CBR) and Percentage sand replacement

4.0 Conclusion

Based on the results of the work carried out, it was observed that the highest maximum dry density and minimum optimum moisture content of the clay-sand mix were obtained at 50% sand replacement. However, the maximum CBR value was equally reached at 50% sand replacement. The replacement level of 50% improves the quality of both the clayey and fine sandy soils tremendously. It however, reduced the plasticity of the soils. Unusual volumetric change has reduced to the bearable level.

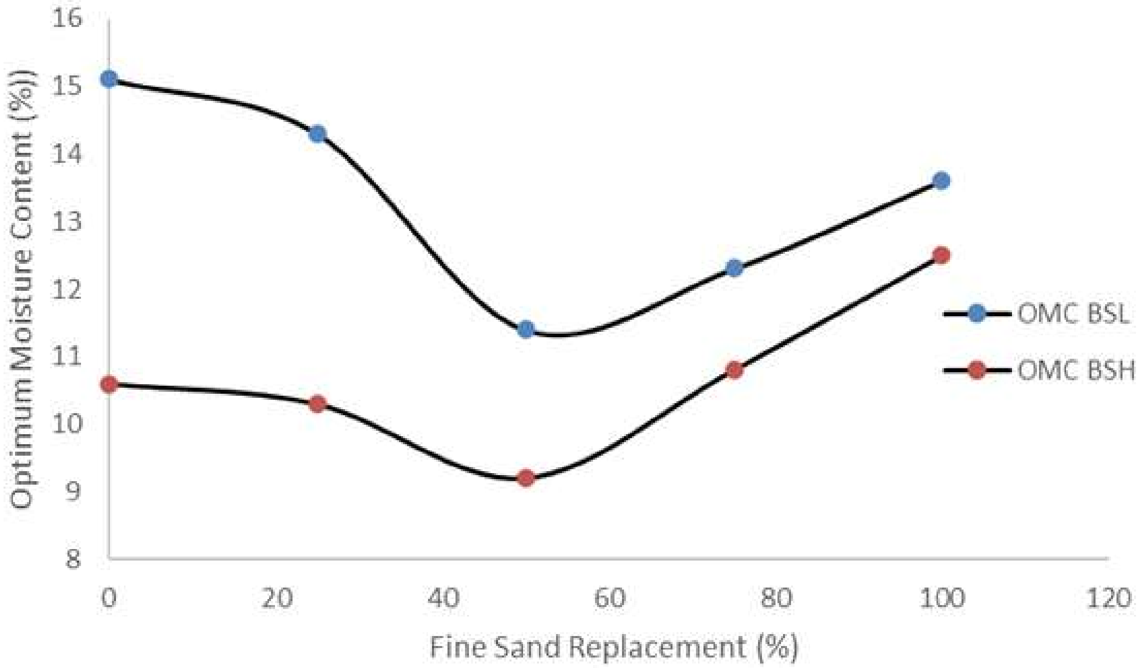

Figure 4:Relationship between Optimum Moisture Content and Percentage sand replacement

3.1.3 Plasticity Behaviors and Soil Classification

The relationship between sand content and atterberg's limits has been presented in Figure 5 and Table 1. The clay soils experienced reduction in plasticity properties to nonentity as the sand content increased. This finding is like that of Khemissa, Mahamedi, & Mekki, (2015) and Louafi & Bahar, (2012). The reason might be that, clay soil is plasticin nature and sandy soil is non-plastic in nature; thereby mixture of plastic and non-plastic soils reduces the plasticity of the mixture. However, the soil classification shows that clayey soil used was classified as low plastic (CL) and the same characteristic was observed for 25% and 50% sand contents. As the sand content increased to 75%, the classification of the soil has changed to sandy

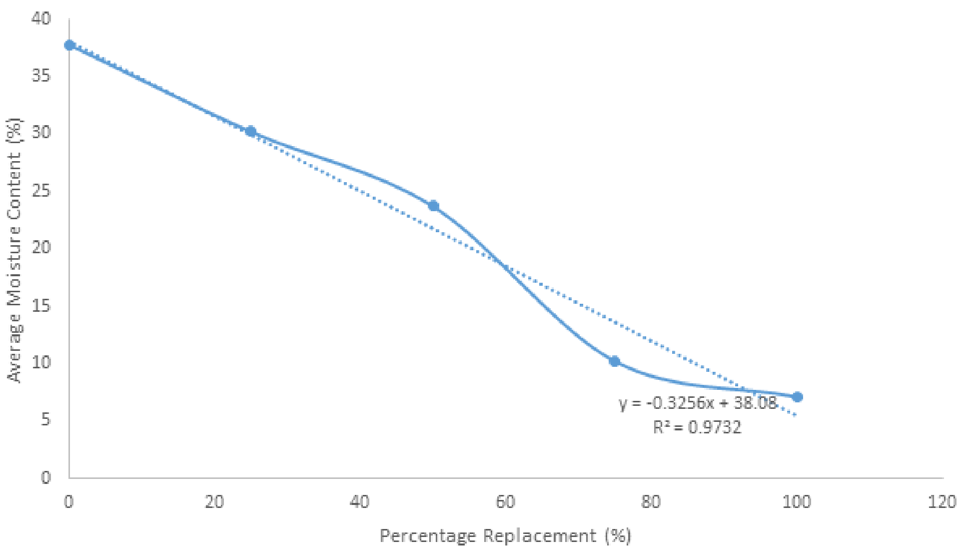

Figure 5: Liquid Limits versus Percentage Replacements

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