International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031(Online)
www.ijlret.com ‖ Volume 1 Issue 3‖ August 2015 ‖ PP.01-11

UNCONFINED COMPRESSIVE STRENGTH TEST OF A FLY ASH STABILIZED SANDY SOIL

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Abstract: This study deals with the stabilization of sandy soils through the application of fly ash. Soil stabilization simply means the permanent physical and chemical alteration of soils to enhance their physical and engineering properties.
The main aim of this study is to determine the percentage of fly ash that would be added to a sandy soil to obtain the optimum stability of the soil. In order to achieve these, the following tests were carried out: Sieve analysis, Compaction test, unconfined compressive strength test.
Sieve analysis is carried out purposely to determine the percentage of different grain sizes contained within a sandy soil. On the other hand, Compaction test was carried out in order to determine the maximum dry density and optimum moisture content of the sandy soil and lastly, unconfined compressive strength test was carried out to determine the compressive strength of the sandy soil sample with the addition of fly ash in percentages as a stabilizing agent.
After carrying out the above tests, observations were noted and considered and it was discovered that 40% fly ash has the highest impact in the increment of the compressive strength of the sandy soil and will be most suitable for the stabilization of sandy soil. So therefore, we recommend the addition of 40% fly ash to the sandy soil to be used on site for maximum stability

Key words: Unconfined Compressive Strength and Fly-Ash

Introduction

Soil stabilization is the permanent physical and chemical alteration of soils to enhance their physical properties and stabilization can also be the application of a chemical or mechanical treatment of a mass of soil to maintain its stability or improve its engineering properties (Coka, 2001). Stabilization increases the shear strength of soil thus, improving the load-bearing capacity of a sub-grade to support pavements and foundations. Stabilization can be used to treat a wide range of sub-grade materials from clay to granular materials. Stabilization can be achieved with a variety of chemical additives including lime, fly ash, and Portland cement, as well as by-products such as Lime-Kiln Dust (LKD) and Cement-Kiln Dust (CKD). It can also be achieved by injecting cementing materials or chemical solutions into the ground and also by applying electric currents to the ground. Proper design and testing is an important component of any stabilization project, this allows for the establishment of design criteria as well as the determination of the proper chemical additive and admixture rate to be used to achieve the desired engineering properties (Gantenbein, 2002).

Benefits of the stabilization process can include: Higher resistance (R) values of the soil, reduction in plasticity, lower permeability, reduction of pavement thickness, elimination of excavation – material hauling/handling – and base importation, aids compaction, provides “all-weather” access onto and within projects sites(White, 2002a&2002b).

On the other hand, one very important property of a soil is its compressive strength, which is the soil’s ability to withstand axial forces. The compressive strength of a soil is very important in nearly all geotechnical engineering designs because it is used in obtaining an estimate of the soil strength. The main aim of this study is to determine the percentage of fly ash that would be added to a sandy soil to obtain the optimum stability of the soil.

Sandy Soil

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz (Hunter, 1998).

Fly Ash

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal (Zia and Fox 2000).

Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants and together with bottom ash removed from the bottom of the furnace is in this case jointly known as ***coal ash***. Depending upon the source and makeup of the coal being burned, the component of fly ash vary considerably, but all fly ash includes substantial amount of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredient in many coal-bearing rock strata(Naibantoglu and Gucbilmez 2002).

Toxic constituent depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent: arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium and vanadium, along with dioxins and PAH compounds.

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used to supplement Portland cement in concrete production. Some have expressed health concerns about this.

In some cases, such as the burning of the solid waste to create electricity, the fly ash may contain higher levels of contaminants than the bottom ash and mixing the fly and bottom ash together brings the proportional levels of contaminants within the range to qualify as non-hazardous waste in a given state, whereas, unmixed, the fly ash would be within the range to qualify as hazardous waste (Rupnow 2002).

Chemical composition

Fly Ash is also a pozzolanic material, consisting of non – crystalline silicate and aluminates particles and rounded magnetic iron oxide (Fe_3O_4) grains, materials which when mixed with other chemicals like cement or lime containing calcium and in the presence of water can enhance cementation. Fly Ash possesses a wide quality range and this may be problematic.

Soil stabilization with fly ash

Soil stabilization is a technique aimed at increasing or maintaining the stability of soil mass and chemical alteration of soils to enhance their engineering properties. Stabilities can be used to treat a wide range of sub-grade materials from expansive clays to granular materials. This allows for the establishment of design criteria as well as the determination of the proper chemical additive and admixture rate to be used in order to achieve the desire engineering properties (Senol et al. 2002). Benefits of the stabilization process can include higher resistance values, reduction in plasticity, lower permeability, reduction of pavement thickness, elimination of excavation material hauling or handling. Stabilization of expansive soils with admixture controls the potential of soil for a change in volume, and improves the strength of soils. In the field of geotechnical engineering, it has long been known that swelling of expansive soils caused by moisture change result in significant distresses and hence in severe damage to overlying structures. Expansive soils are known as shrink swell or swelling soils. Different clays have different susceptibility to swelling. Such soils expand when they are wetted and shrink when dried. This movement exerts pressure to crack sidewalks, basement floors, pipelines and foundations (Kaniraj and Havanagi 1999).

The density of soil with coal ashes is an important parameter since it controls the strength, compressibility and permeability. The compacted unit weight of the material depends on the amount and method of energy application, grain size distribution, plasticity characteristics and moisture content at compaction. The variation of dry density with moisture content for fly ashes is less compared to that for a well-graded soil, both having the same grain size (Mahrt 2000). The tendency for fly ash to be less sensitive to variation in moisture content than for soil is due to higher air void content of fly ash. The higher void content could tend to limit the buildup of pores pressure during compaction, thus allowing the fly ash to be compacted over a larger range of water content.

Materials and Methods

Materials

These were the basic materials used for this study (i) sandy soil (ii) class C fly ash (iii) water

Laboratory tests employed

Sieve Analysis

Sieve analysis, also known as gradation test, is a practice used in civil engineering to assess the particles size distribution of a granular material. The dependence of the behaviour of a soil mass on the size of particles had led investigators to classify soils according to their particles size.

Compaction Test

The purpose of carryout this test is to determine the maximum dry density and optimum moisture content of each sample so as to enable us calculate the constant mass of sand and constant volume of water needed for compaction. The test is classified into viz-a-viz;

i. Dynamic compaction test.
ii. Static compaction test

Unconfined compressive strength (UCS) Test

The primary purpose of this test was to determine the unconfined compressive strength of a sandy soil sample with the addition of fly ash in percentage as a stabilizing agent. According to the ASTM standard, the unconfined compressive strength (q_u) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of test.

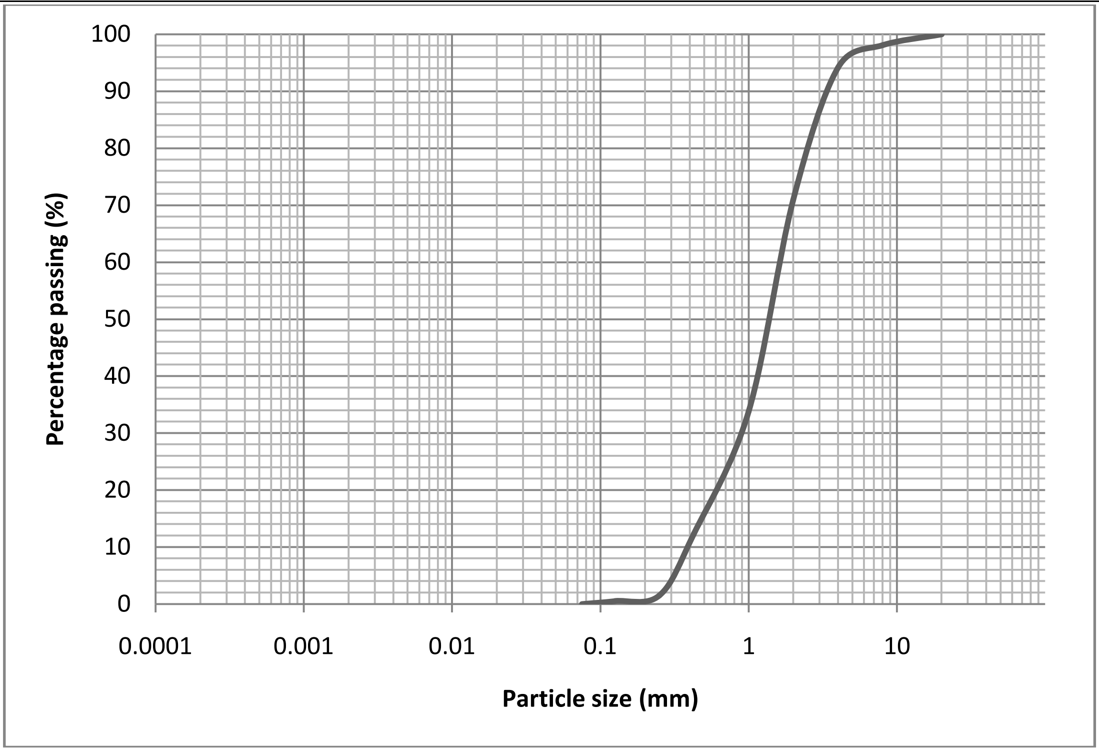
Results

Particle Size determination results

The particle size analysis was carried out majorly to classify the sample used for this study. The result shown clearly that the sample contains no clayey and silty content. Sample comprises of fine, medium and coarse sand and also fine and medium gravel.(Table 1and Figure 1)

Table 1 the sieve analysis of the sandy soil sample

Sieve Sizes (mm)	**Weight of Empty sieve (g)**	**Weight of sieve + sample (g)**	**Mass Retained (g)**	**Percentage Retained (%)**	**Cumm. Percentage Retained (%)**	**Percentage Passing (%)**
20.000	471.0	471.0				100
8.000	462.0	462.0				100
4.000	437.0	441.0	4	1.96	1.96	98.04
2.000	411.0	419.0	8	3.92	5.88	94.12
1.000	386.0	415.0	29	14.22	20.10	79.90
0.425	442.0	536.0	94	46.08	66.18	33.82
0.250	314.0	358.0	44	21.57	87.75	12.25
0.125	296.0	318.0	22	10.78	98.53	1.47
0.075	381.0	383.0	2	0.98	99.51	0.49
< 0.075			1	0.49	100	0.00



Fugure1 Graph of Sieve analysis of the sandy soil sample

Dynamic Compaction results

Figures 2-7 show the results for 0%, 10%, 20%, 30%, 40%, 50% addition of fly ash to the sandy soil sample under dynamic compaction. The dynamic compaction test was use to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) by adding water to the sample (i.e. sand mixed with fly ash) at percentage intervals. From Figures 2-7 OMC and MDD for each percentage of fly ash was determined.

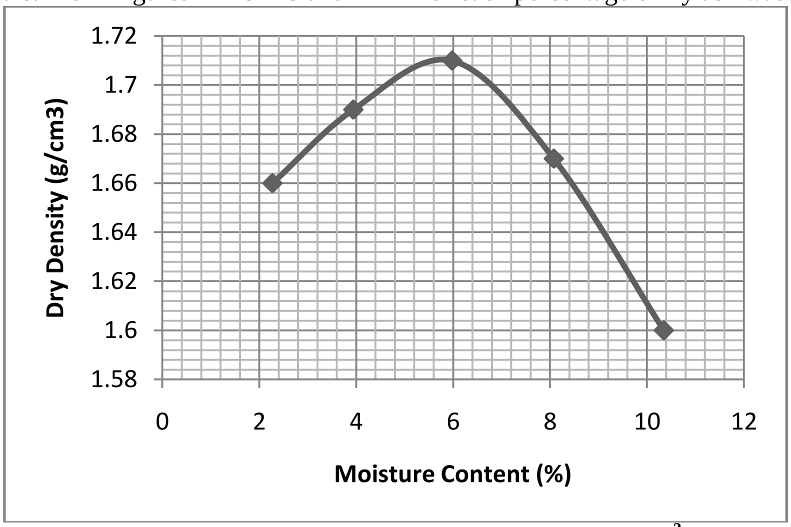


Figure 2 Graph of DD against MC for 0% fly ash ***MDD= 1.71g/cm^3 OMC= 5.98%***

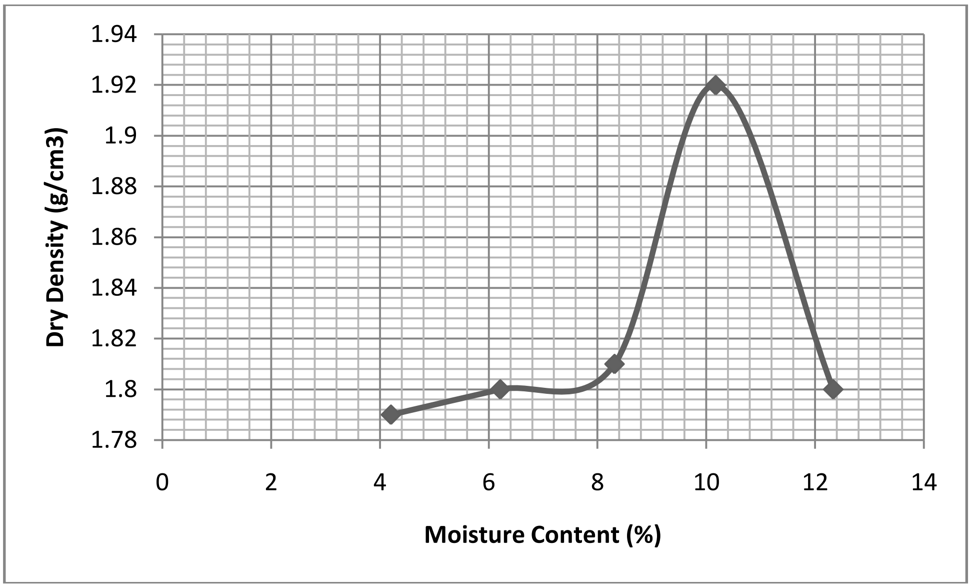


Figure 3 Graph of DD against MC for 10% fly ash
MDD= 1.92g/cm^3
OMC= 10.17%

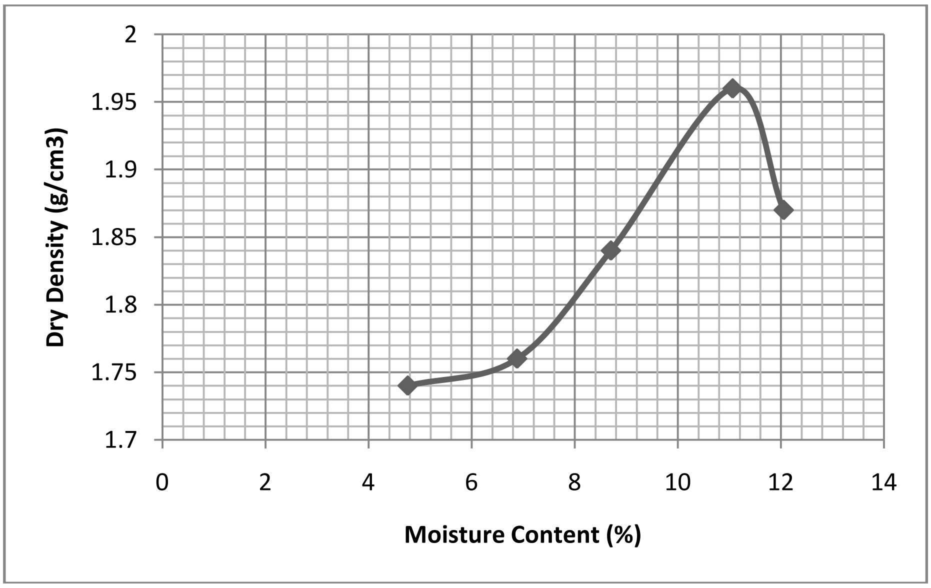


Figure 4 Graph of DD against MC for 20% fly ash
MDD= 1.96g/cm^3
OMC= 11.06%

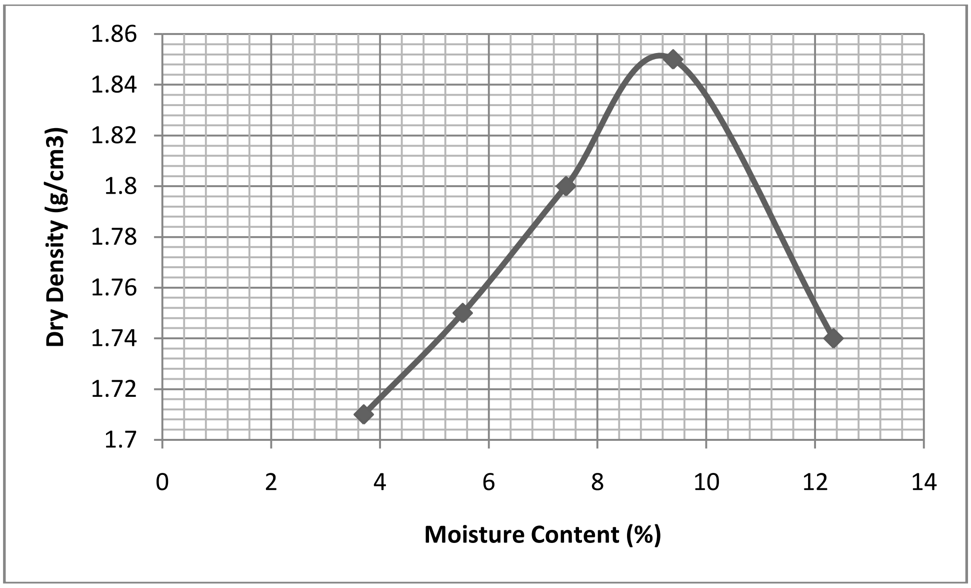


Figure 5 Graph of DD against MC for 30% fly ash
MDD= 1.85g/cm^3
OMC= 9.39%

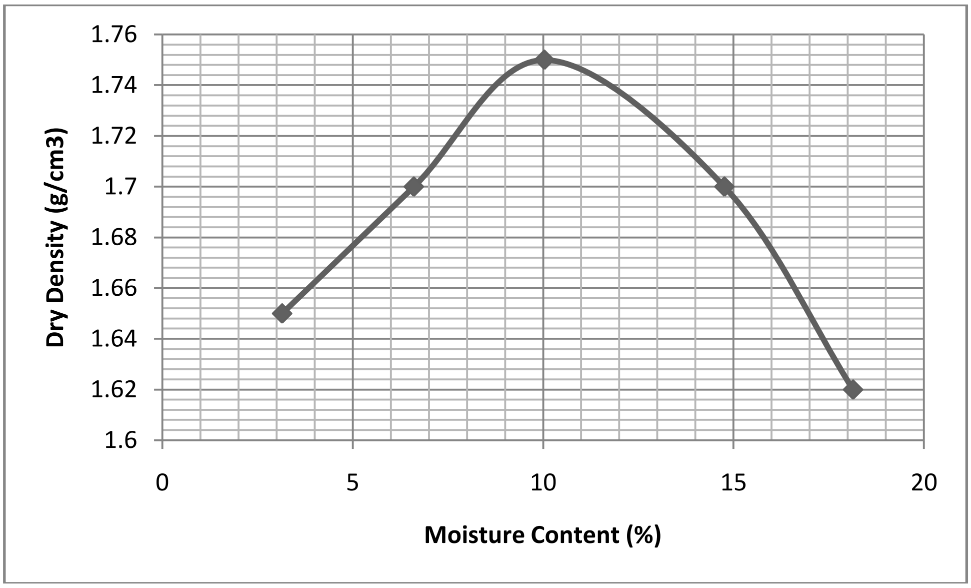


Figure 6 Graph of DD against MC for 40% fly ash
MDD= 1.75g/cm^3
OMC= 10.03%

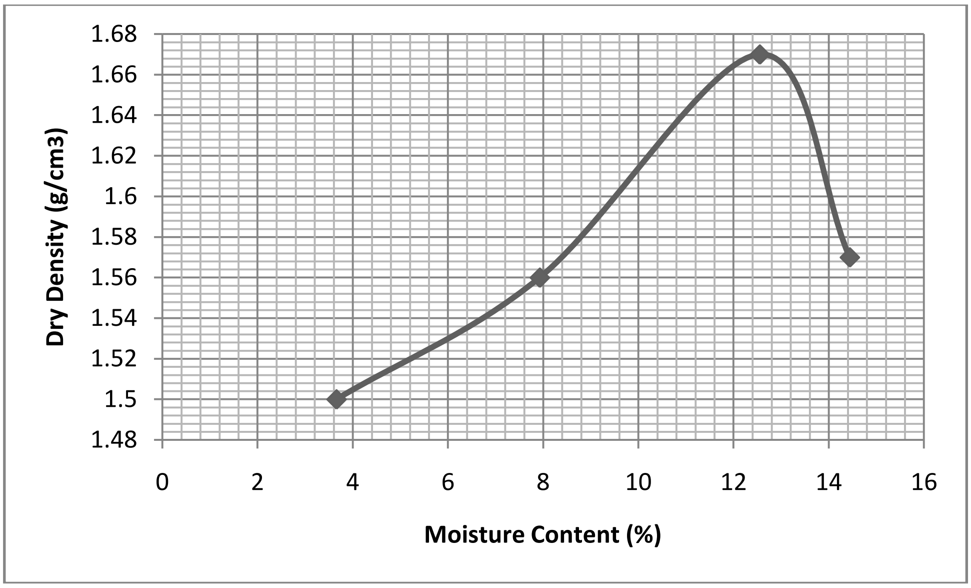


Figure 7 Graph of DD against MC for 50% fly ash

MDD= 1.67g/cm^3

OMC=12.55

Static Compaction results

i. For 0% addition of fly ash, the result obtained is:

Mass of Bulk soil for recompaction (M_b) = 1676.0g

Volume of water for the bulk soil (W_v) = 69ml

ii. For 10% addition of fly ash, the result obtained is:

Mass of Bulk soil for recompaction (M_b) = 1892g

Volume of water for the bulk soil (W_v) = 156ml

iii. For 20% addition of fly ash, the result obtained is:

Mass of Bulk soil for recompaction (M_b) = 1970g

Volume of water for the bulk soil (W_v) = 180ml

iv. For 30% addition of fly ash, the result obtained is:

Mass of Bulk soil for recompaction (M_b) = 1825g

Volume of water for the bulk soil (W_v) = 136ml

v. For 40% addition of fly ash, the result obtained is:

Mass of Bulk soil for recompaction (M_b) = 1725g

Volume of water for the bulk soil (W_v) = 140ml

vi. For 50% addition of fly ash, the result obtained is:

Mass of Bulk soil for recompaction (M_b) = 1646g

Volume of water for the bulk soil (W_v) = 175ml

The result from each dynamic compaction test (i.e. OMC and MDD) is used to calculate the constant mass of soil that is to be used in recompaction with a constant volume of water (i.e. static compaction). For instance, with 10% addition of fly ash, 10% will be removed from the mass of bulk sand and replaced with fly ash and then recompact. This however is the same for 20%, 30%, 40% and 50%.

Unconfined Compressive Strength results

From the static compaction results, recompaction of each percentage addition of fly ash to the sandy sample was done. While the recompacted sample was placed in UCS machine and firmly gripped, the dial-strain gauge was rotated at 5mm interval while corresponding reading was notably taken from the load gauge. The readings were taken until the sample began to fail. At the point of failure, readings were stopped being taken. Results were eventually obtained and graphs of axial load were plotted against axial strain, after which the compressive strength of each recompacted sample (i.e. 10%, 20% etc.) was determined. Figures 8-12 show for each percentage.

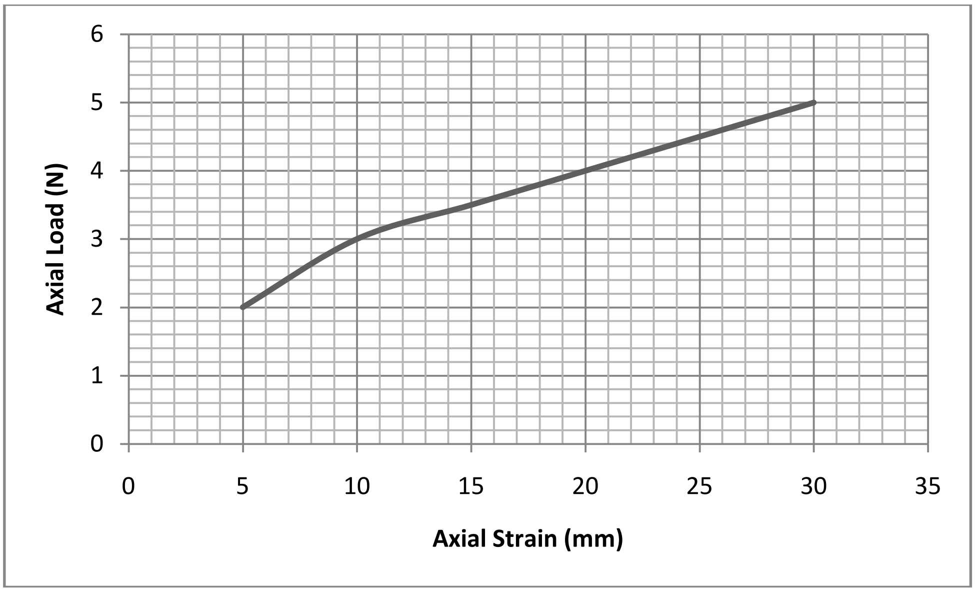


Figure 8 Graph of Axial Load against Axial Strain for 10% fly ash

Compressive Strength (q_u) = 8.80kN/m^2

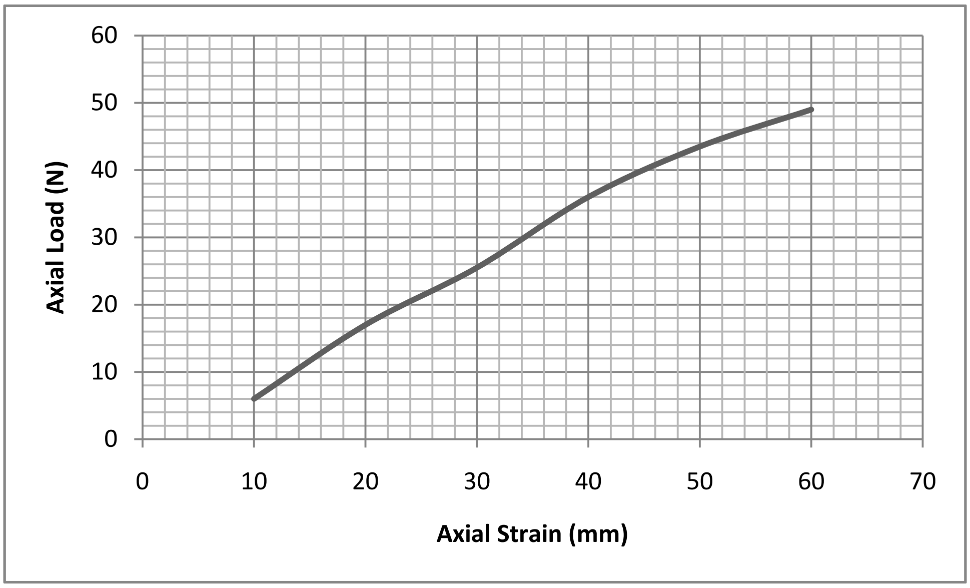


Figure 9 Graph of Axial Load against Axial Strain for 20% fly ash

Compressive Strength (q_u) = 86.1kN/m^2

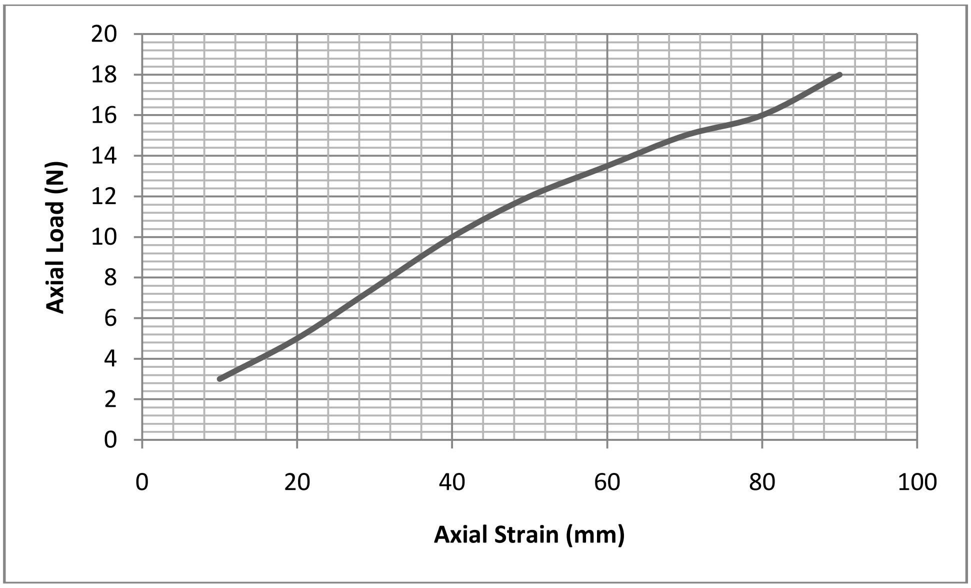


Figure 10 Graph of Axial Load against Axial Strain for 30% fly ash

Compressive Strength (q_u) = 31.51kN/m²

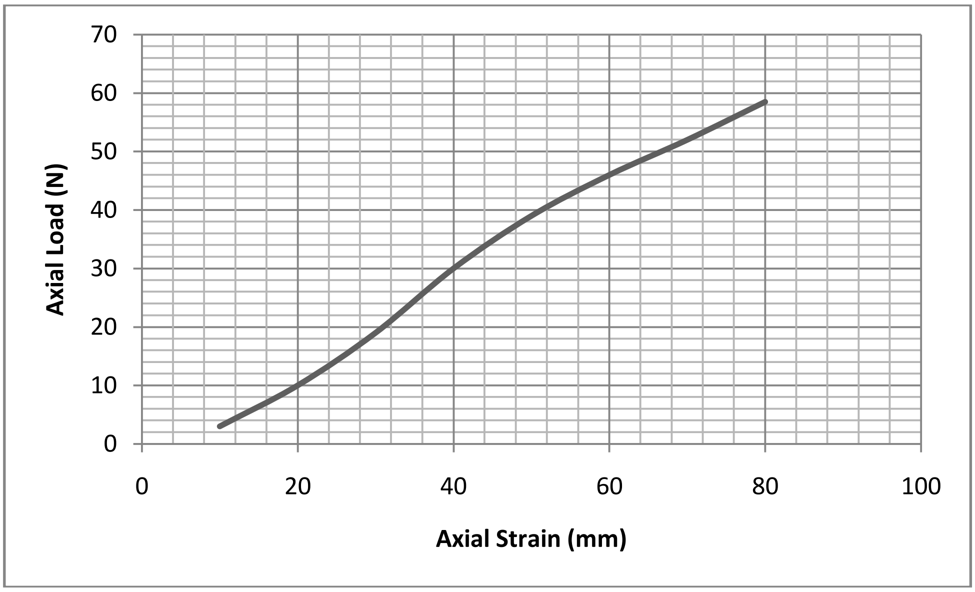


Figure 11 Graph of Axial Load against Axial Strain for 40% fly ash

Compressive Strength (q_u) = 102.51kN/m²

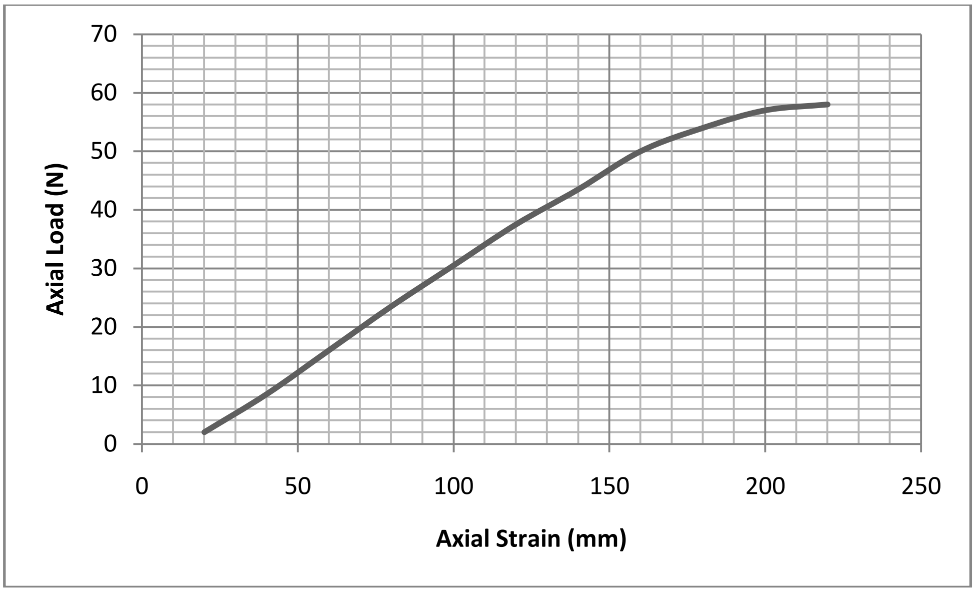


Figure 12 Graph of Axial Load against Axial Strain for 50% fly ash

Compressive Strength (q_u) = 100.35kN/m^2

The summary of compressive strength results from UCS for 0% fly ash is 0 kN/m^2 as shown in Figure 13 of which the effect of fly ash is clearly seen as it increases to 8.80 kN/m^2 with 10% addition to the sand. It increased further with 20% addition of fly ash to 86.1kN/m^2. For 30% addition of fly ash, the compressive strength reduced to 31.51kN/m^2. For 40% addition of fly ash, the compressive strength greatly increased to 102.51kN/m^2. For 50% addition of fly ash, the compressive strength slightly reduced to 100.35kN/m^2.

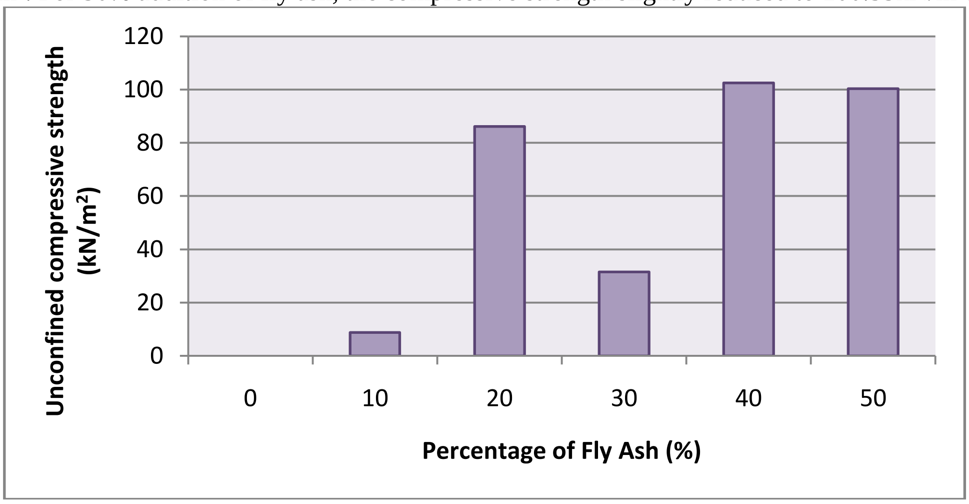


Figure 13 Bar chart reflecting the percentage of fly ash with corresponding compressive strength

Conclusion

In conclusion it was established that 40% of fly ash would perfectly stabilize sandy soil due to its highest compressive strength (i.e. 102.51kN/m^2).

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