Pressure Load Characteristics of Unsaturated Eggshell Powder Stabilized Black Cotton Soil on Basement Complex of Part of South-Western Nigeria

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Abstract: *Soil stabilization either by mechanical or chemical means is the remedy for shrinkage and swelling of black cotton soil to create an improved soil material possessing the desired engineering properties. Soils may be stabilized to increase strength and durability of the black cotton soil. Regardless of the purpose for stabilization, the desired result is the creation of a soil material or soil system that will remain in place under the design use conditions for the design life of the civil engineering project. The black cotton (expansive) soil was obtained from a borrow pit on the basement complex at Igbo-Ora in Oyo State, South-Western Nigeria. The borrow site lies within the coordinates Longitude 7^{0}24'45" and latitude 3^{0}18'34". The eggshell wastes were taken from Obasanjo Farms, Ota, Ogun State, Nigeria, Nigeria. The quantity of water which was used to obtain optimum moisture content and maximum dry density for black cotton soil (i. e. control, 0%) was determined. This water was then used to run consolidation tests. The eggshells were milled into powder and then substituted for black cotton soil from 0% to 30% at 10% intervals for consolidation and settlement parameters determination while 0% eggshell powder substitution served as control experiment. In line with BS 1377 (1990), 90% consolidation tests were conducted on unsaturated composite materials of black cotton soil mixed with varying degrees of eggshell powder to determine the compression and expansion characteristics for the 1-hour soaked samples. From the preliminary results, compression behavior is linear meaning; it is directly proportional to time for all the substitutions investigated while there is no reduction during expansion above 20% substitution while removing the load. The rate and magnitude of expansion is zero for the 30% substitutions investigated. At 30% eggshell powder substitution in black cotton soil, expansion problem would be significantly reduced if not completely eliminated.*

Keywords: *Black Cotton Soil, Expansion, Compression, Unsaturated, Eggshell Powder.*

Introduction

Black cotton soil is referred to as expansive soils, it is characterized by cracks in dry season and it heaves in rainy season for this reason, its geotechnical properties are important to be investigated before allowing any construction above it. The mineralogy of this soil is dominated by the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa. High percentage of montomorillonite in black cotton soil renders the soil poor for civil engineering project. The shrinking of the soil results in cracks in the soil without any warning. Use of soil that contains montomorillonite for civil engineering project may cause severe damage to the construction as a result of change in atmospheric conditions. Soil stabilization either by mechanical or chemical means is the remedy for shrinkage and swelling of black cotton soil to create an improved soil material possessing the desired engineering properties. Soils may be stabilized to increase strength and durability. Regardless of the purpose for stabilization, the desired result is the creation of a soil material or soil system that will remain in place under the design use conditions for the design life of the civil engineering project. Due to expansive characteristics of black cotton soil, it forms a very poor foundation material for road construction. Black cotton soils are found in the northern and southern parts of Nigeria, the soils are said to be inorganic clays which are expansive in nature. They are also known for their shrinkage and swelling nature. Black cotton soils have been a highly challenging material for the construction engineers due to its high swelling rate as well as its shrinkage characteristics. Although, black cotton soils tend to be strong in its dry state but when in a wet condition, it tends to lose its strength out rightly. The low strength and excessive volume changes of black cotton soil make their use in construction very difficult. The high volume of axle loads on our roads is currently a challenge in the design of road pavement. Important factors such as durability, strength and economic need have to be paramount in the design and construction of road pavement. To tackle these challenges head on at a reduced cost, investigation of potential use of various solid wastes in the production of construction materials should be put on high priority to reduce the cost of construction materials (Billman, 1976; BS1377, 1990; Chen, 1975; Elinwha and Mohmood, 1986; Egbuniwe, 1982; Faridi and Arabhosseini, 2018; Gundaliya and Oza, 2013; Kameswara, 1998; Kogbe, 1976; Kogbe and Obialo, 1976; Kosun, 1990; Lung et al. 2011; Okonkwo et al. 2012; Omatsola and Adegoke, 1981; Rahaman and Ocan, 1978; Sensale, 2009; Udoeyo et al. 2006).

Background Study

The properties of black cotton soil may be altered in many ways through mechanical, chemical and other means. Therefore, it becomes very important to investigate the physical and engineering properties associated with the black cotton soil especially as a construction material or for foundation purposes. Black cotton soil is clay-rich soil that mainly contains lime, iron, carbonate, magnesium, and a small amount of organic matter along with nitrogen, phosphorous, etc. in small quantities. It has a low bearing capacity, high moisture-absorbing power, low shear strength and a high plasticity value (Gidigasu and Gawu, 2013). Stabilization is mainly of three types physical, mechanical, and chemical. Mechanical stabilization is necessary after the adoption of either physical or chemical stabilization (Afrin, 2017). Reinforcement is meant to hold the soil particles by way of friction and cohesion with the admixtures. Mere physical stabilization cannot be relied on; hence, materials like eggshell powder and palm kernel shell etc. are mixed with soil, which performs both physical and chemical stabilization. Chicken egg is protiencious material which is consumed daily in India and all over the world. After consuming the edible part, the remaining non edible part say, eggshell is directly disposed on ground surface or to any landfills. Eggshells are non-biodegradable material and even it also attracts insects due to its constituent when it is directly disposed on ground surfaces as a waste material. It causes harmful infection and disturbs the natural environment which is not human friendly, and also effects human health as a secondary or tertiary reason for the cause of disease. The chicken eggshell mainly consists of calcium carbonate ($CaCO_3$) as constituent material, which is strengthening by a protein matrix. Due to its similar composition like limestone, the waste chicken eggsshells can also be effectively used as strengthening material, in the process of strengthening, the clayey soils which usually absorbs water by its nature and composition. This may increase the strength properties of clayey soils. (Billman, 1976; BS1377, 1990; Chen, 1975; Elinwha and Mohmood, 1986; Egbuniwe, 1982; Faridi and Arabhosseini, 2018; Gundaliya and Oza, 2013; Kameswara, 1998; Kogbe, 1976; Kogbe and Obialo, 1976; Kosun, 1990; Lung et al. 2011; Okonkwo et al. 2012; Omatsola and Adegoke, 1981; Rahaman and Ocan, 1978; Sensale, 2009; Udoeyo et al. 2006).

Methodology

The black cotton (expansive) soil (Figure 1a) was obtained from a borrow pit on the basement complex at Igbo-Ora in Oyo State, South-Western Nigeria. The borrow site lies within the coordinates Longitude $7^{0}24'45"$ and latitude $3^{0}18'34"$. The eggshell wastes in Figures 1 b and c were taken from Obasanjo Farms, Ota, Ogun State, Nigeria. The quantity of water which was used to obtain optimum moisture content and maximum dry density for black cotton soil (i. e. control, 0%) was determined and then used to run consolidation tests. The eggshells were milled into powder and then substituted for black cotton soil from 0% to 30% at 10% intervals for consolidation and settlement parameters determination while 0% eggshell powder substitution served as control experiment. In line with BS 1377 (1990), 90% consolidation tests were conducted on unsaturated composite materials of black cotton soil mixed with varying degrees of eggshell powder to determine the compression and expansion characteristics for the 1-hour soaked samples (Ola, (1983); Craig, 1987; BS 1377, 1990; Olarewaju and Tella, 2022).

Figure 1: (a) Black Cotton (Expansive) Soil (b) Eggshell (c) Eggshell Powder

Results and Discussion

The results of dial gauge readings (for maximum pressure of 313.92 kN/m^2) against time (minutes) for various eggshell powder substitutions in unsaturated black cotton soils ranging from 0% (control experiment) to 30% substitutions are graphically presented in Figures 2 to 9 respectively. From the preliminary results (Figures 2 to 9), similar to palm kernel shell substitutions, compression behavior is linear meaning, it is directly proportional to time for all the substitutions investigated while there is no reduction during expansion at 30% substitution when removing the pressure load. The rate and magnitude of expansion is minimal for all the substitutions investigated. The preliminary results in Figure 2 shows the difference in dial gauge readings equals 9.1mm while the results in Figure 3 shows the difference in dial gauge readings equals 0.2mm. In addition to this, the results in Figure 4 shows the difference in dial gauge readings equals 17.1mm while the results in Figure 5 shows the difference in dial gauge readings equals 0.9mm. Furthermore, the results in Figure 6 shows the difference in dial gauge readings equals 19.1mm while the results in Figure

7 shows the difference in dial gauge readings equals 1.7mm. Finally the results in Figure 8 shows the difference in dial gauge readings equals 12.7mm while the results in Figure 9 shows the difference in dial gauge readings equals 0mm.

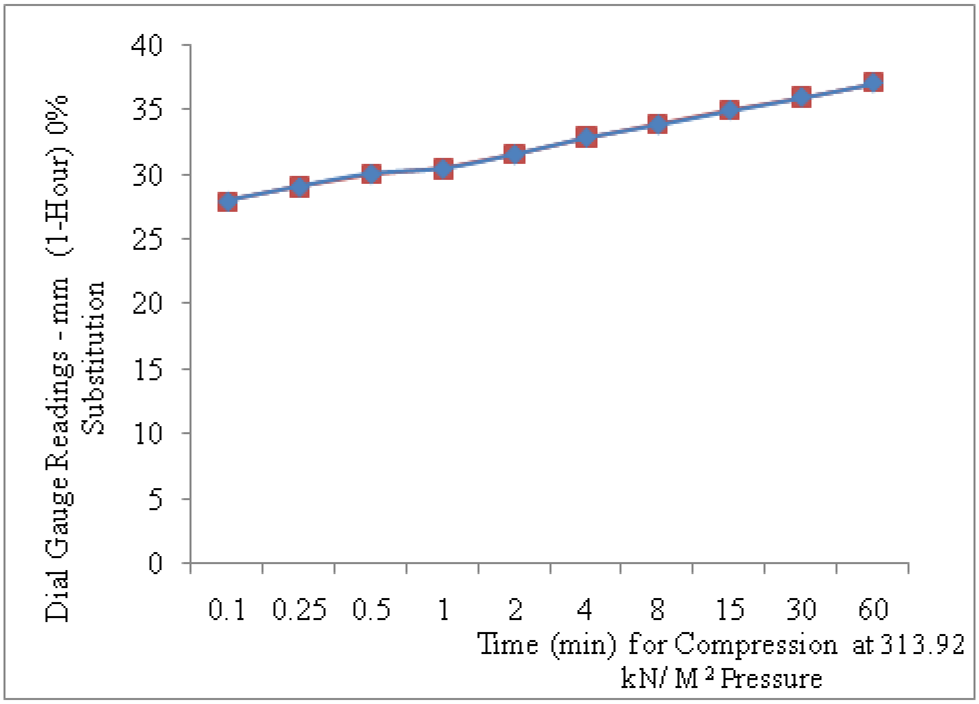

Figure 2: Results of dial gauge reading (mm) against time (min) for 1-hour soaked samples (0% eggshell powder substitution - compression): Difference in Dial Gauge Readings = 9.1mm

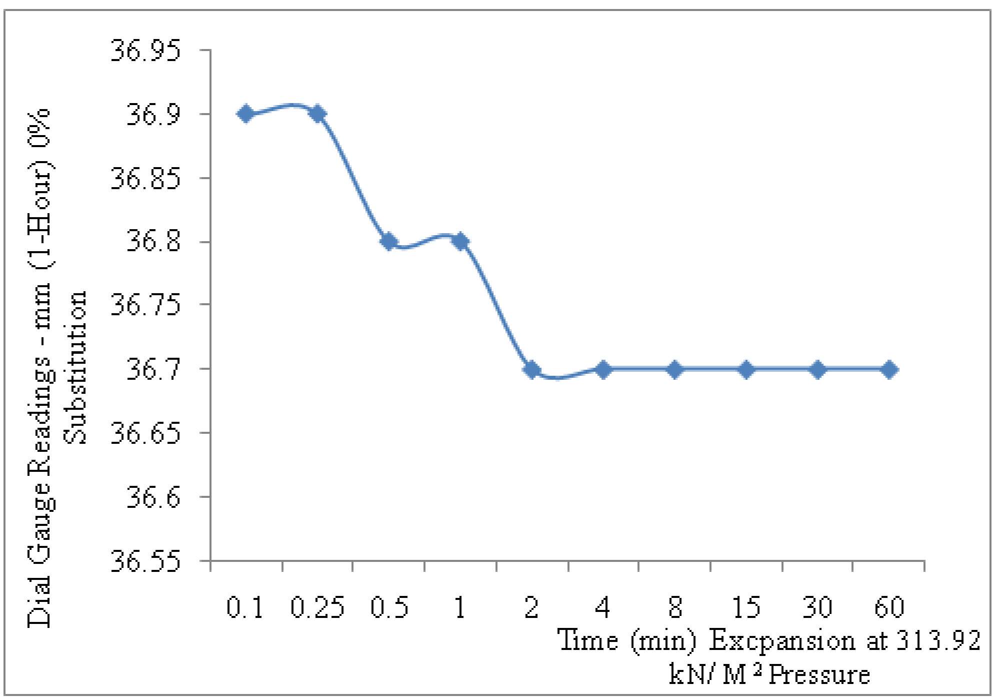

Figure 3: Results of dial gauge reading (mm) against time (min) for -hour soaked samples (0% eggshell powder substitution - expansion): Difference in Dial Gauge Readings = 0.2mm

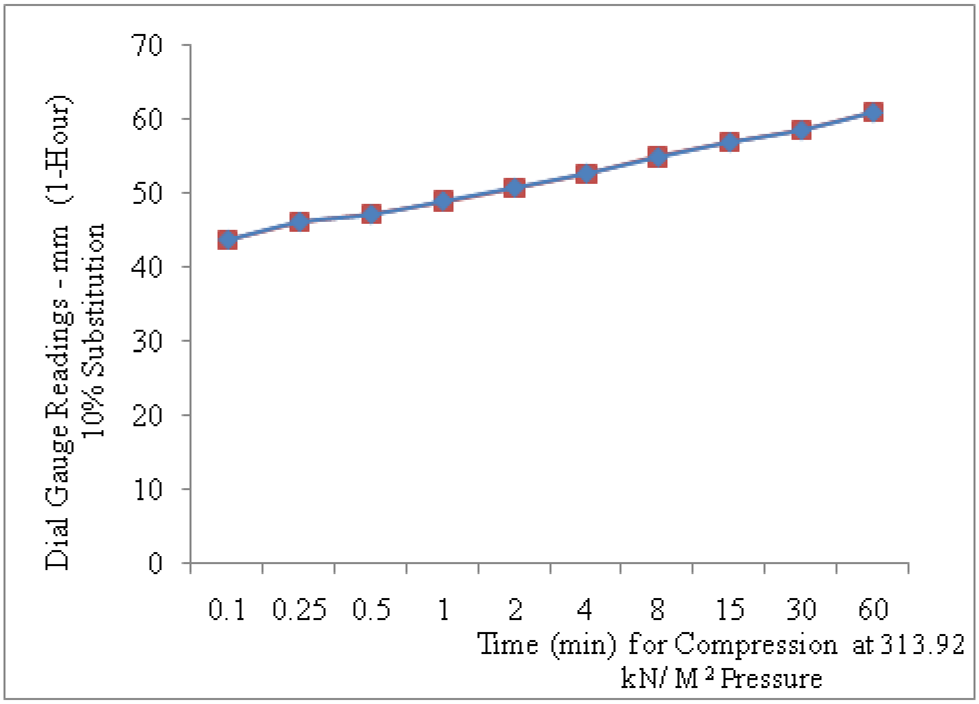

Figure 4: Results of dial gauge reading (mm) against time (min) for 1-hour soaked samples (10% eggshell powder substitution - compression): Difference in Dial Gauge Readings = 17.1mm

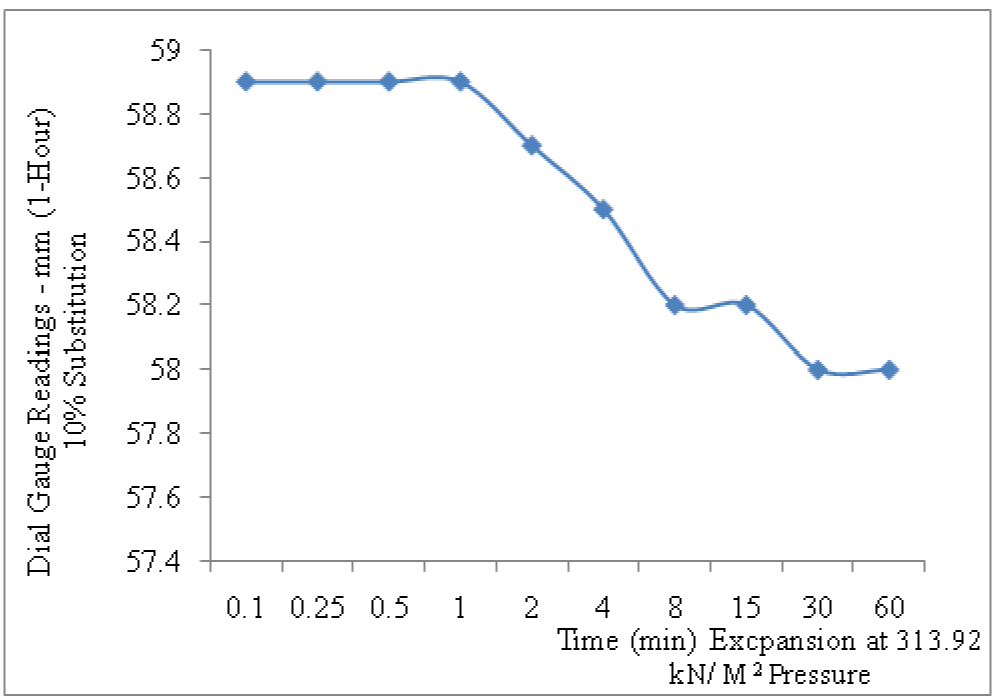

Figure 5: Results of dial gauge reading (mm) against time (min) for 1--hour soaked samples (10% eggshell powder substitution - expansion): Difference in Dial Gauge Readings = 0.9mm

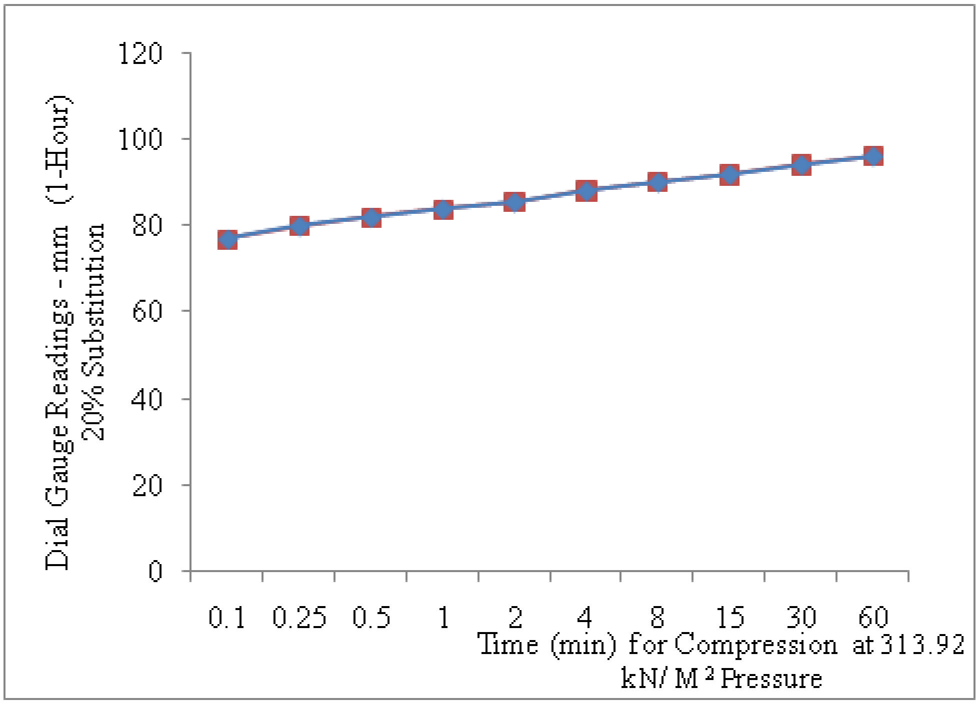

Figure 6: Results of dial gauge reading (mm) against time (min) for 1-hour soaked samples (20% eggshell powder substitution - compression): Difference in Dial Gauge Readings = 19.1mm

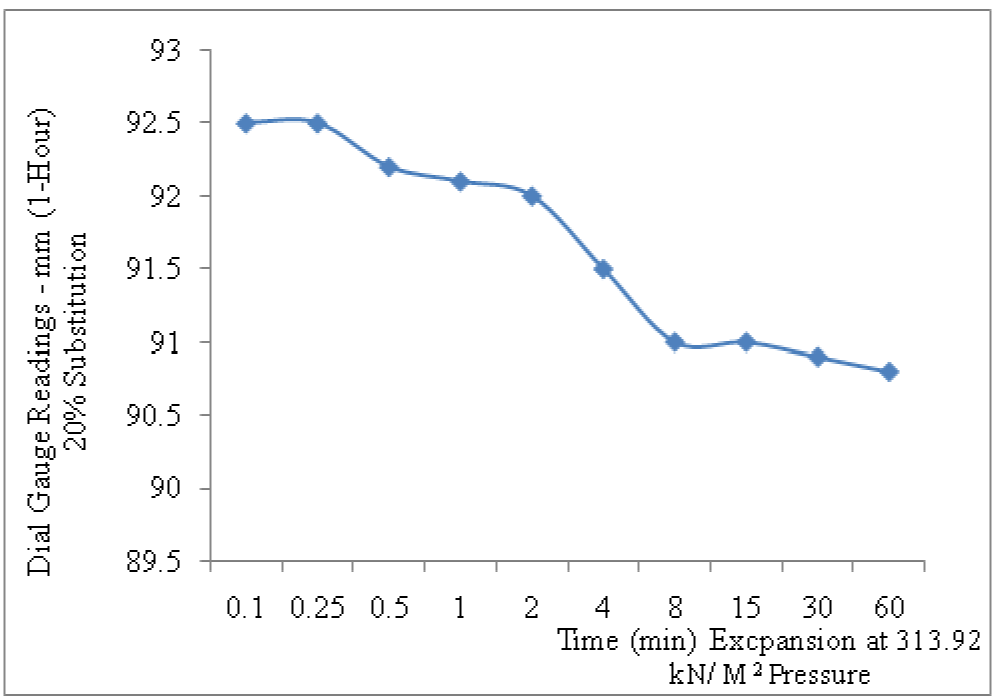

Figure 7: Results of dial gauge reading (mm) against time (min) for 1--hour soaked samples (20% eggshell powder substitution - expansion): Difference in Dial Gauge Readings = 1.7mm

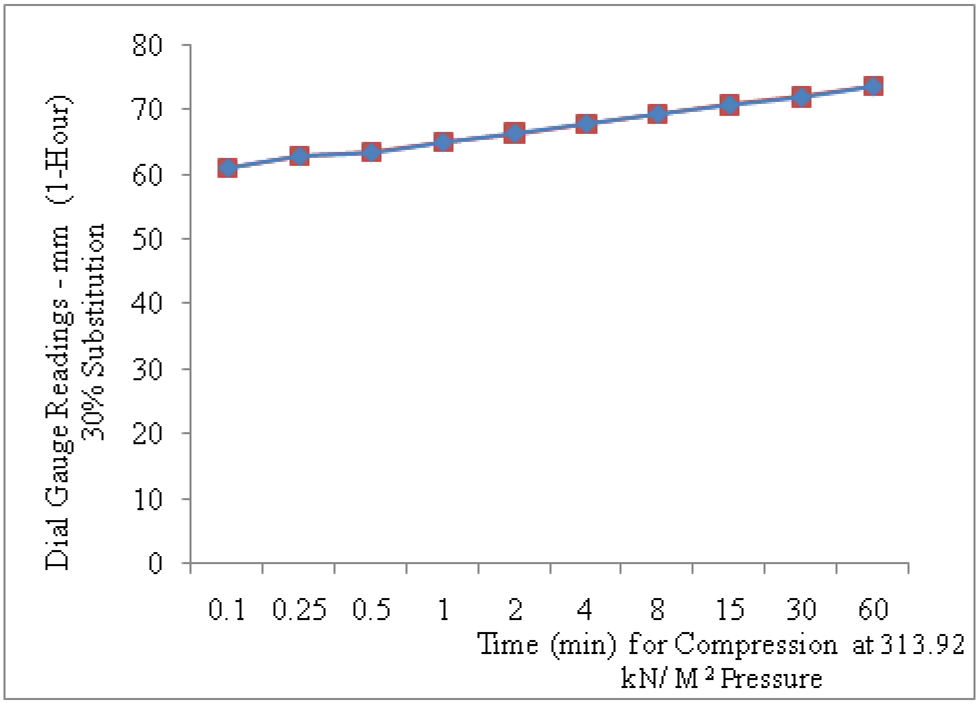

Figure 8: Results of dial gauge reading (mm) against time (min) for 1-hour soaked samples (30% eggshell powder substitution - compression): Difference in Dial Gauge Readings = 12.7mm

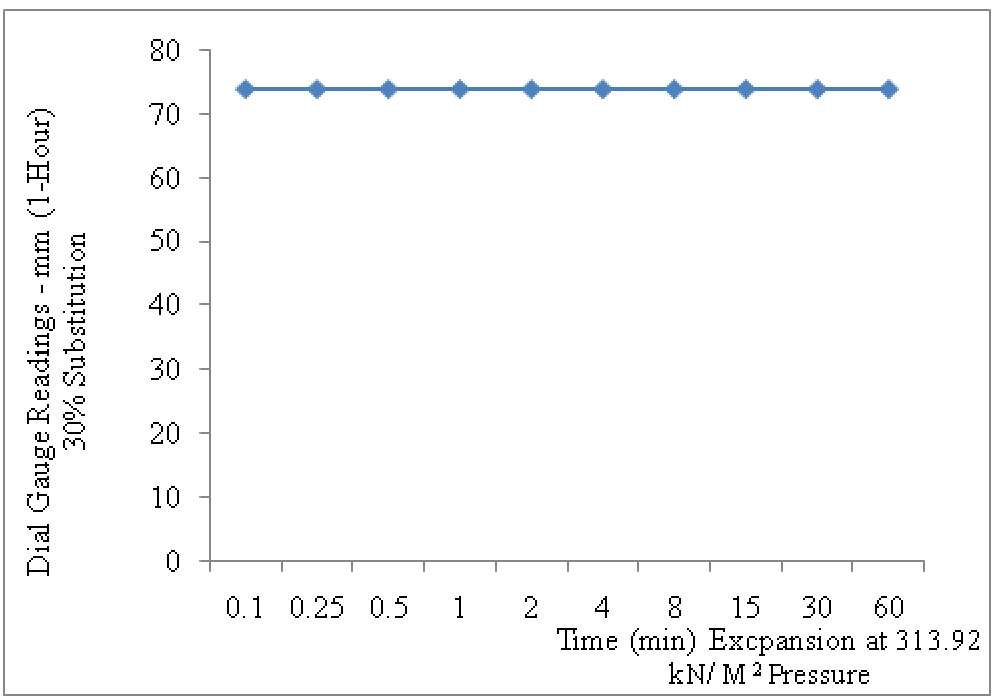

Figure 9: Results of dial gauge reading (mm) against time (min) for 1--hour soaked samples (30% eggshell powder substitution - expansion): Difference in Dial Gauge Readings = 0mm

From the these preliminary results, for 30% eggshell powder substitution in black cotton soil on basement complex, no expansion was observed after removing the pressure load while for the eggshell powder substitution less than 30%, the expansion is low compared to compression when pressure load is applied. This result is similar to that of 24-hour soaked samples of stabilized black cotton soil in the work of Olarewaju and Tella (2022). In a related development, the typically adopted constitutive relations of soils are elastic, elasto-plastic, or visco-plastic and in the case of accidental explosion, whether surface or underground accidental explosion, the initial response is the most important. It involve some plastic deformation that takes place within the vicinity of the explosion and as a result of this one could take the soil i.e. ground media to be an elasto-plastic material. Beyond this, the soil can be taken as an elastic material at certain distance from the explosion. Visco-elastic soils exhibit elastic behavior upon loading followed by a slow and continuous increase of strain at a decreasing rate. Most soils are homogenous, isotropic and anisotropic (i.e. soils with different hydraulic properties in different directions) and in most studies, it is considered as linear elastic, homogeneous, isotropic material. For such material, only two elastic constants are needed to study the geo mechanics/behavior of such body. These can be the usual elastic constants (the Young's modulus, E and Poisson's ratio,ν) or the Lame's constants λ and μ (Billman, 1976; BS1377, 1990; Chen, 1975; Elinwha and Mohmood, 1986; Egbuniwe, 1982; Faridi and Arabhosseini, 2018; Gundaliya and Oza, 2013; Kameswara, 1998; Kogbe, 1976; Kogbe and Obialo, 1976; Kosun, 1990; Lung et al. 2011; Okonkwo et al. 2012; Omatsola and Adegoke, 1981; Rahaman and Ocan, 1978; Sensale, 2009; Udoeyo et al. 2006).

Conclusion

Compression and expansion characteristics and behavior of unsaturated stabilized black cotton soil on basement complex has been investigated. From the preliminary results, compression behavior is directly proportional to time for all the substitutions of eggshell powder investigated but there is no remarkable and noticeable reduction during expansion while removing the load. The rate and magnitude of expansion is minimal for all the substitutions investigated but at 30% eggshell powder substitution, expansion is zero when removing the pressure load. Efforts are still on-going to determine the relevant consolidation parameters and settlement indices of stabilized black cotton soil on basemen complex as well as sedimentary formation. The materials used for stabilization of these black cotton soils are palm kernel shell and eggshell powder.

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