Geotechnical Properties of Lateritic Soil Stabilized with Glass Fiber

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***Abstract*:- Laterites are rich in iron oxides, aluminum oxides and low silicates but may contain appreciable amount of kaolinite and due to the presence of iron oxides; lateritic soils are red in colour. This paper was aimed to investigate the effect of Glass Fiber on the properties of lateritic soil. Lateritic soil obtained from Ibadan in Oyo State, Nigeria. Preliminary tests were performed on the soil sample Ojoo (OJ) and Odinjo (OD) for classification purposes followed by the consistency limit tests, strength property tests (compaction, California bearing ratio (CBR), stabilized and unstabilized states by adding 0.2, 0.4, 0.6,0. 8 and 1.0% Glass Fiber by weight of sample to the soils.. Optimum moisture content decreased from 12.5% to 9.3% at 0.6% Glass fiber, the maximum dry density increased from1942kg/m3 to 1950kg/m3 at 0.8% Glass fiber for sample OJ. The unsoaked CBR values of samples increased from 38.62 to 52.26% at 0.6% Glass fiber stabilization for sample OJ, for sample OD, it increased from 46.12% to 53.01% at 1.0% Glass fiber. The results showed an improvement in the two soils maximum dry density and CBR on addition of the glass fibers. The glass fibers had optimum effect on the soils between 0.2% and 0.4% of soil samples. Therefore, incorporating glass fiber into the soils in the required quantity will enhance soils' CBR and density. The results showed that the addition of Glass Fiber improved the strengths of the samples. The geotechnical analysis results showed that the soils have high bearing capacity after addition of Glass Fiber and therefore can be used has a good potential for stabilizing lateritic soil.**

Keywords: Lateritic soil, Glass Fiber, Stabilization, compaction and California Bearing Ratio

INTRODUCTION

Lateritic soils are highly weathered and altered residual soils formed by the insitu weathering or decomposition of rocks in the tropical and sub-tropical regions with hot, humid climatic conditions. Laterites are rich in iron oxides, aluminum oxides and low silicates but may contain appreciable amounts of kaolinite and due to the presence of iron oxides; lateritic soils are red in colour (Amu et al, 2010).

Lateritic soil in its natural state generally have low bearing capacity and low strength due to high content of clay. When lateritic soil contains a large amount of clay materials its strength and stability cannot be guaranteed under load especially in the presence of moisture (Alhassan, 2008).

Hazirbaba and Gullu (2010) "addition of geofibers with synthetic fluid was noted to effectively increase the CBR performance of fine-grained soil under both soaked and unsoaked conditions and the optimum geofiber content was found to be between 0.2% and 0.5% depending on the sample condition and geofiber type.

Soil stability is one of the most important topics in geotechnical engineering practices. With frequent failures of soil mass, whether it is on a slope or level ground, have proved to be costly in terms of both life and property. Various soil stabilization techniques including fiber reinforcement have been in use for a while and the results in some of them has been quite satisfactory.

Application of synthetic materials like geotextiles, geogrids, and fibers have evoked considerable interest among geotechnical engineers and manufacturers for using these materials as reinforcing element to improve the bearing capacity of weak soils. Among several ground improvement techniques, reinforcing the subgrade soils with short fibers appears to have the greatest potential for successful application in the design of flexible pavements.

Fiber-reinforced soil has some advantages such as low cost, light weight, capability of maintaining strength isotropy within soil mass. Its application in construction is also not significantly affected by weather conditions (Suchit, 2016).

Soil stabilization is the process of improving the geotechnical properties of soils to satisfy the engineering requirements. Numerous kinds of stabilizers are being used as soil additives to improve soil engineering properties such as lime, cement and fly ash, depending on their chemical reactions with the soil elements in the presence of moisture.

Soil stabilization improves soil strength and increases its resistance to softening by water by bonding the soil particles together, water proofing the particles or combination of the two effects (Sherwood, 1995).

Several researchers have worked on the geotechnical investigation of fiber. Historically, engineers have long been aware of the stabilizing effects of various materials in earth works. Tingle et al. (2002) observed that fiber stabilization of medium sand improved the CBR by about sixfold, and the improvement was attributed to the confinement of sand particles by discrete fibers.

Chandra et al. (2002) reported that CBR values of clayey, silty and silty sand soils were found to be 1.16, 1.95, and 6.20%, respectively, which increased to 4.33, 6.42, and18.03%, respectively, with 1.5% fiber content of propylene fiber.

Kalantri et al. (2010) found that the 0.15% of polypropylene fiber reinforcement in cement stabilized peat soil caused maximum CBR increases by a factor of 22 for un-soaked condition and by a factor of 15 for the soaked condition.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

Zahran and Fatani (1999) reported that reinforcing asphalt paving mixture with glass fiber enhanced the overall performance of the pavement structure in terms of reducing the frequency of future rehabilitation costs and resulting in a more economical pavement.

The aim of the research was to ascertain glass fiber performance as a stabilizer by measuring its effects on lateritic soil (through a comparison of the properties of the soil with and without the addition of the glass fiber) and determine appropriate quantities of the glass fiber required for adequate stabilization of the lateritic soil. The glass fibers used in the study was locally sourced. The disposal of glass fiber produced from industries has become a great challenge.

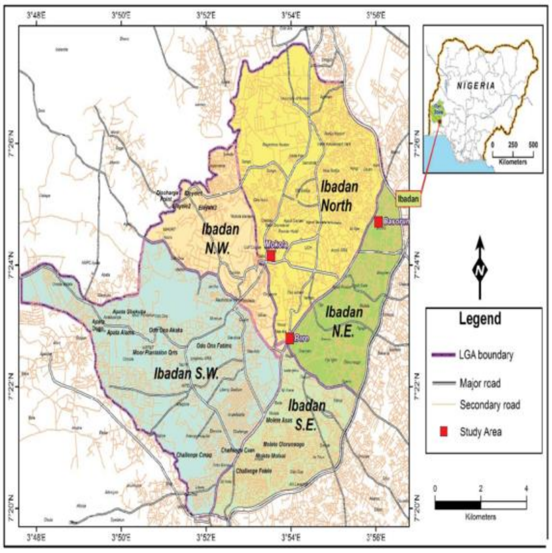

Figure 1: Map of Ibadan showing the study area

MATERIAL AND METHOD

Soils: Two lateritic soil samples were obtained from borrow pits. Sample 1 (OJ) was obtained from Ojoo while sample 2 (OD) was obtained from the Odinjo area of Ibadan metropolis, Nigeria. The borrow pits were situated in Ibadan, Nigeria. Enough quantities of subsoil samples were excavated from the two borrow pits and transported to the laboratory. During sample collection, at each location, the topsoil was removed manually to a depth of about 1.0m before subsoil samples were collected. At the laboratory, the subsoil samples were air-dried, stock pilled separately and covered with polythene materials to prevent moisture ingression.

Glass Fiber: Glass fiber was sourced locally as shown in Fig. 2. An appropriate quantity of glass fiber was obtained, transported to the laboratory and cut into pieces of lengths not longer than 25mm manually.

Each soil sample was subdivided into six portions. A portion served as control while the remaining five received single dosage of glass fiber proportions 0.2%, 0.4%, 0.6%, 0.8%, 1.0%, by weight. The mixing was carried out in dried state. The fiber and soil were mixed together to produced homogeneous mixture. The following geotechnical properties such as particle size analysis, Atterberg's limits (liquid limits and plastic limits), compaction test and California bearing ratio (CBR) of control samples were determined in the laboratory.

Fig2: Glass Fiber

The various geotechnical tests (natural moisture content, atterberg limits, grain size analysis, specific gravity and compaction test) were done according to the BS 1377 (1990); methods of test for soil for civil engineering purposes.

RESULT AND DISCUSSION

Properties of Glass Fiber

Fiberglass is a lightweight, extremely strong, and robust material. Glass fibers are among the most versatile industrial materials known today. The glass fibers used in this study was locally available, found in the form of mesh. The properties of the fibers are shown in Table 1.

Table 1: Properties of Glass Fiber

Properties	Values
Tensile Strength (ASTM D2256)	1.38GN/mm2
Young Modulus (ASTM D2256)	112.3GN/mm2
Specific gravity	2.38
Diameter	0.15mm
Length	25mm

Index properties of the Soil

The results of the preliminary tests (grain size analysis, natural moisture contents, specific gravity, and Atterberg's limits test) as well as the engineering tests (compaction, California bearing ratio test) carried out on both unstabilized and stabilized soils are presented in Table 2. The two samples were classified as well graded sand and A-2-7 (AASHTO). According to Unified Soil Classification System (USCS) soil sample OJ was lean clay with low plasticity (CL) while soil sample OD was silt of low plasticity (ML). The liquid limit and plastic limit of the control soils OJ and OD were 41.3, 25.5% and 45.5, 27.1%, respectively. Ojoo soil compaction test results indicated a maximum dry density (MDD) of 1.942g/m3 with corresponding optimum moisture content (OMC) of 12.5% for the control. Odinjo soil compaction test results indicated a maximum dry density (MDD) of 1.862g/m3 with corresponding optimum moisture content (OMC) of 14.8% for the control.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

Table 2: Properties of Natural Soil

Properties	Samples Location	
	Ojoo	Odinjo
% passing 200	8.98	8.21
Specific gravity	2.63	2.86
Liquid limit (%)	41.3	45.5
Plastic limit (%)	25.5	27.1
Plasticity Index (%)	15.8	18.4
MDD (g/cm3)	1.942	1.863
OMC (%)	12.5	14.8
CBR (%)	38.62	34.45
AASHTO classification	A-2-7	A-2-7
USCS classification	CL	ML

Atterberg Limit Test

The liquid limit and plastic limit was determined as Clause 4.5, Part 2 of BS 1 924 [1990]. The effect of reinforcement on the liquid limit and plastic limit of the soil has been shown in Table 3. It is observed that as the fiber content was increased from 0% to 1%, the liquid limit and plastic limit of the soil sample increased. This can attributed to the fact that glass fibers have a tendency to absorb water. Table 3 shows the variation of plasticity index. The plasticity index reduced as the fiber content increased. This indicated that the soil became less compressible when the fibers are added to the soil.

Table 3: Summary of Atterberg Limit for Glass Fiber

Soil+ GF	Liquid Limit (%)		Plastic Limit (%)		Plasticity Index (%)	
(%)	0J00	ODINJO	0J00	ODINJO	0J00	ODINJO
0	41.3	45.5	25.5	27.1	15.8	18.4
0.2	42.6	46.2	26.83	27.9	15.77	18.3
0.4	43.1	46.34	26.73	28.84	16.17	17.5
0.6	44.3	47.46	27.84	29.04	16.46	18.42
0.8	45.23	48.83	28.86	31.28	16.37	17.55
1	45.9	49.61	31.26	31.25	14.64	18.36

Compaction Test

The summary of the compaction test results for stabilized soil sample OJ and OD was displayed in Fig. 2 and Fig 3 respectively. The MDD values obtained from the test results without the addition of glass fiber is 1942Kg/m2 and for OD sample is 1862kg/m2, this indicates that natural soil sample for the two locations fair to use as subgrade material in accordance to AASHTO. The two soils MDD values increased as the percentage of glass fiber increased and reached the peak values at 0.6% glass fiber addition. Further increase in the glass fiber content led to decline in the MDD. The glass fiber has great affinity for water and excess fiber swell up leading to volume increase and reduction in density. The OMC of stabilized soils followed irregular pattern which is complex to interpret.

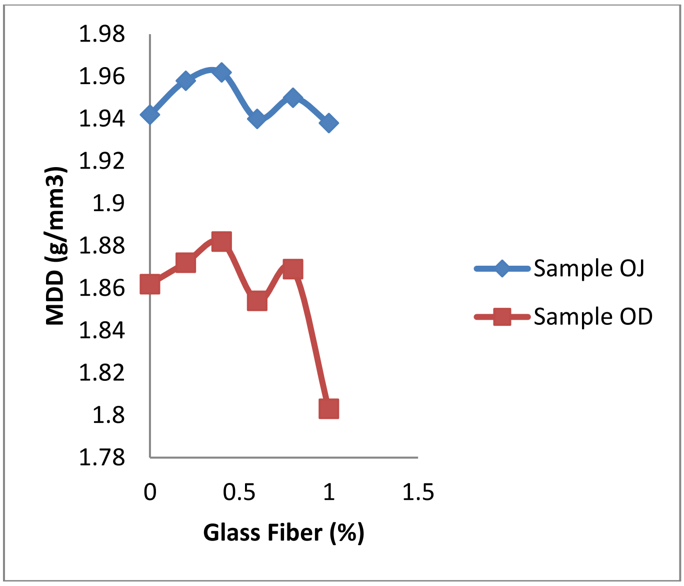

Figure 2: Maximum Dry Density at Different Percentages of Glass Fiber

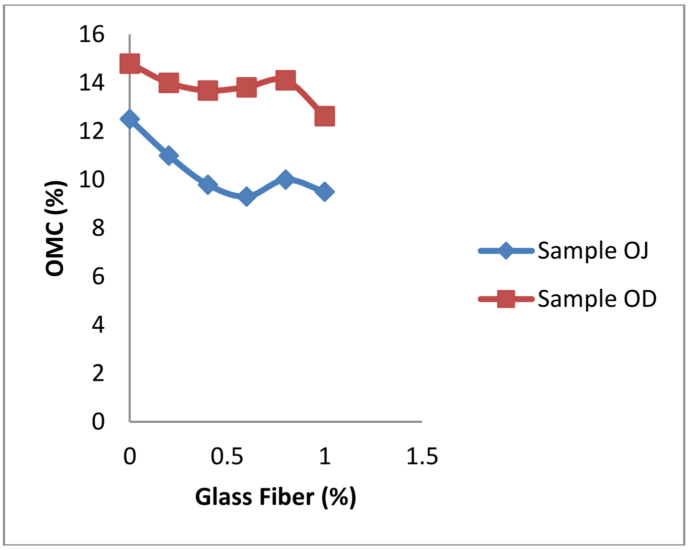

Figure 3: Optimum Moisture Content at Different Percentages of Glass Fiber

California Bearing Ratio (CBR)

The CBR value of soil sample OJ without the addition of glass fiber was 38.62%. A gradual nonlinear increment in the CBR with its peak value at 0.4% glass fiber content of value 55.2% was observed when the soil OJ was stabilized with glass fiber. This value is higher than the control value by 40%. Similar trend was observed when soil OD was stabilized with glass fiber. The control soil CBR was 46.12% and the peak CBR value at 0.4% stabilization was 51.88% equivalent to 27.1% increment. The improvement in the CBR value is as a result of the fact that glass fiber is strong in tension which enhances the bond strength among soil particles. The bond created hinder smooth passage of CBR machine plunger and therefore, required additional force for the required penetration to be reached. The presence of fibers provides mechanical interlocking among soil particles. When optimum value of glass fiber was exceeded, the excess formed spongy spot in the soil matrices that constituted a weak portion and hence the decrease in CBR obtained.

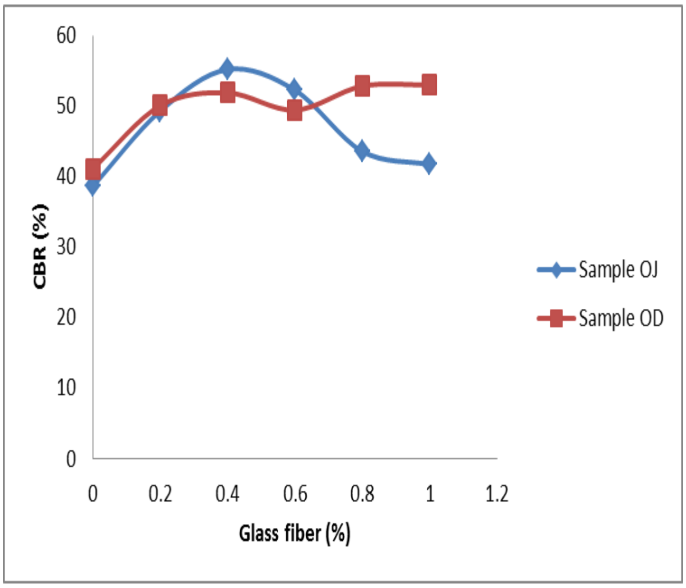

Figure 4: California Bearing Ratio at Different Percentages of Glass Fiber

CONCLUSION

The study revealed that glass fiber increases the cohesion between the soil particles and also increases the internal friction angles.also, addition of glass fiber into the two lateritic soils led to increase in soil California bearing ratio and maximum dry density with the peak influence recorded between 1.2 and 1.6% glass fiber. The glass fiber helped to hold the soil particle together and hence improved the bonding forces among the soil particles. The study therefore concluded that Glass Fiber has the potential to effectively stabilize lateritic soils for highway construction. Based on this study, it is therefore necessary to recommend Glass Fiber as a stabilizing agent for improving soils with low California bearing ratio.

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