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Black Cotton Soil Stabilization using Glass Powder

Babatunde O.A¹, Sani J.E¹, Sambo A.H

Department of Civil Engineering, Nigerian Defence Academy, Kaduna State, Nigeria. ¹

ABSTRACT: Non-biodegradable materials are not environment friendly. Glass, which belongs to the non-biodegradable group, are produced in significant quantities globally. The waste produced from glass can be used in the stabilization of Black Cotton Soils (BCS), as BCS are generally known to have weak engineering properties and the need for stabilization often arises before BCS can be used. In this paper, an experimental study has been carried out to assess the effect of glass powder on BCS with respect to its engineering properties. Powdered glass was used as partial replacement of BCS by weight. Different percentage by weight of 0%, 2%, 4%, 6% and 8% were used to replace BCS with powdered glass. The BCS without glass powder content recorded an axial compressive stress of 40 kN/m² as against the maximum value of 140 kN/m² at 4 per cent glass powder replacement. This shows over 350 per cent increment. The lowest liquid limit was recorded to be 75.9 % for 6 % glass powder replacement by weight. A constant drop in Plastic Limit was recorded, with the lowest Plastic Limit at 14.5% for 8 % glass powder replacement. The Maximum Dry Density (MDD) of the black contain soil of 1.57 mg/m³ was obtain at 4 % glass powder replacement. The highest Optimum Moisture Content (OMC) was recorded at 2 % glass powder to be 22.2 %.

KEYWORDS: Black Cotton Soil, OMC, MDD, Stabilization, Glass powder, California Bearing Ratio, Unconfined Compressive Stress.

I. INTRODUCTION

BCS is a heavy clay soil, varying from clay to loam with clay contents of 40 to 50% (Mishra, 2017). It exhibits low bearing capacity, low permeability and high-volume change due to presence of montmorillonite in its mineralogical content and these properties makes it unfit for construction of embankment and other engineering structures.

Soil stabilization enhances the engineering properties of soils by alteration of its physical properties of the soil. It also increases the shear strength of a soil, control its shrink swell properties and improve the load bearing capacity of soils.

In applying sustainability to the process of soil stabilization, the utilization of waste products such as glass, plastics, rubber much more becomes paramount. Successful soil stabilization techniques are necessary to ensure adequate stability, especially for weak soils.

II. RELATED WORK

Glass is an amorphous non-crystalline material which is typically brittle and optically transparent. Most of the readily available waste glass materials are soda-lime glass bottles, composed of about 75% silica plus, CaO and several additives. Glass degrades in a manner similar to natural rock. As an inert material, it be used to increase the strength of BCS.

The use of glass as partial replacements for engineering materials such as in concrete tiles by Ayeniet *et al.*, (2019) or as stabilizing agent in Subash et al (2016) are on the increase. BCSs are known to have very low bearing capacity but high swelling and shrinkage characteristics, thus making it a poor foundation material for road construction and many other engineering projects. Due to very low CBR values of BCS excessive pavement thickness is required for designing for flexible pavement. This study intends to stabilize BCS with grounded waste glass, at various percentage replacement by weight.

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The stabilization of BCS with various waste products can then be checked for reliability estimation to ensure that the given stabilized BCS can perform under its specified mission satisfactorily within the speculated time and conditions. Ingles and Metcalf (1972) gave the requirement of 687 – 1373 kN/m² for sub base materials. Similar works on reliability estimate of BCS with various stabilizing agents, can be seen in Yisa and Sani (2014); Hamiduet al., (2015); Sani et al., (2017); Sani et al., (2018); Yohanna et al., (2019) and Babatunde et al., (2019).

III. METHODOLOGY AND MATERIALS

Black Cotton Soil:The soil used in this study is dark grey in Colour and is known as BCS, it was obtained along Gombe—Biu road in YamatuDeba local government Area of Gombe state using the method of disturbed sampling. The location lies along (latitude 10degrees 19’N and longitude11degrees 30’E).

Glass Powder:This material is added to soil in its powdered form for stabilization.Glass powder is an extremely fine powder made from ground glass. Glass was gotten from Coca Cola bottles and crushed because crushed glass is effectively used as an aggregate for sub-base. The glass powder was crushed till a size <0.075mm was attained.

Test Procedure:The BCS was collected from a construction site located at Gombe after removing the top soil and excavating to a depth of about 7 m. The BCS was collected and preliminary tests were conducted on it to obtain the gradation and index properties of the soil. Tests such as Liquid Limit, Plastic Limit, Optimum Moisture Content, Maximum Dry Density, Unconfined Compression Test, California Bearing Ratio (CBR) Tests were all carried out in accordance to the British standard. These tests were done on BCS with 0% 2%, 4%, 6%, 8% glass powder replacement by weight.

IV. RESULTS

Liquid Limit:The Liquid limit test results as various glass powder replacement are shown in Fig.1. The lowest liquid limit value of 75.9 %, was recorded at 6 percent glass powder replacement. Although, a constant decrease of liquid limit values was recorded with increase in glass powder replacement, the liquid limit began to increase after 6 percent glass powder replacement. This shows that glass powder as a positive effect in decreasing liquid limit of BCSs, when BCSs are replaced with powdered glass. By weight, the result indicates that 6 percent replacement BCS (BCS) with glass powder, produces approximately 4 percent reduction of liquid limit content of the BCS.

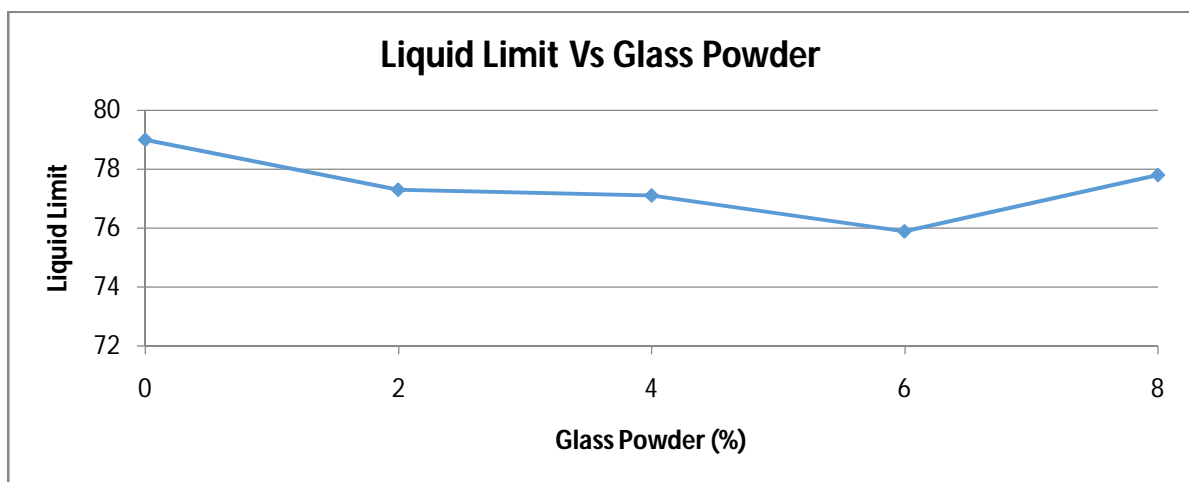


Fig.1: Liquid Limit with increased Glass Powder (%)

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Plastic Limit: The control laboratory results indicated a plastic limit of 22 percent for the BCS sample collected without glass powder inclusion. However, with steady increase in the glass powder content of BCS, the plastic limit decreases steadily as shown in Fig.2. The lowest plastic limit of 14.5 % was recorded for 8 percent glass replacement value.

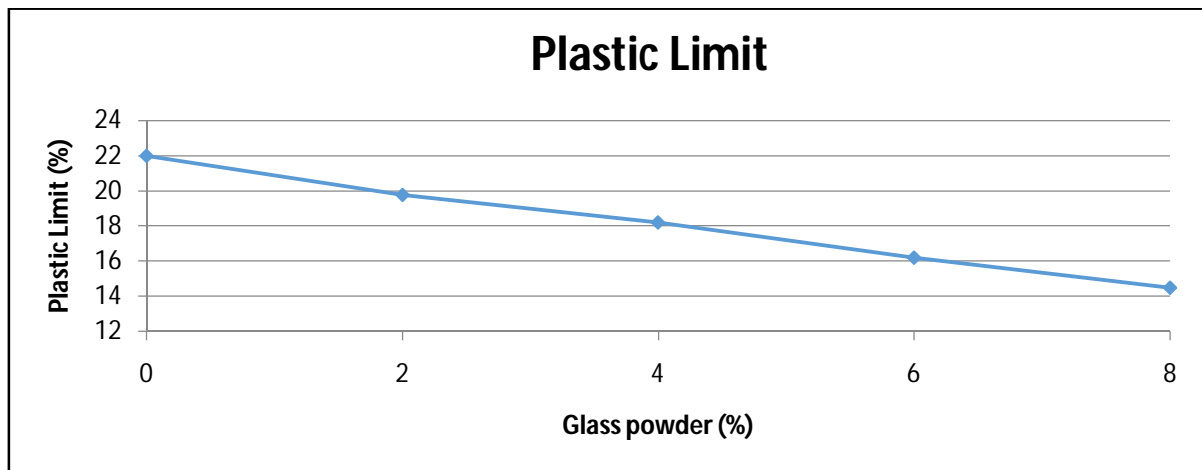


Fig.2: Plastic limit with increased glass powder (%)

Plasticity Index: The plasticity index of BCS without glass powder was calculated to be 55.8 percent. The introduction of glass powder produces a corresponding increase in Plasticity index. Fig.3 shows steady increase from 0% to 8% glass powder content which means as glass powder increases, so also the PI of the soil.

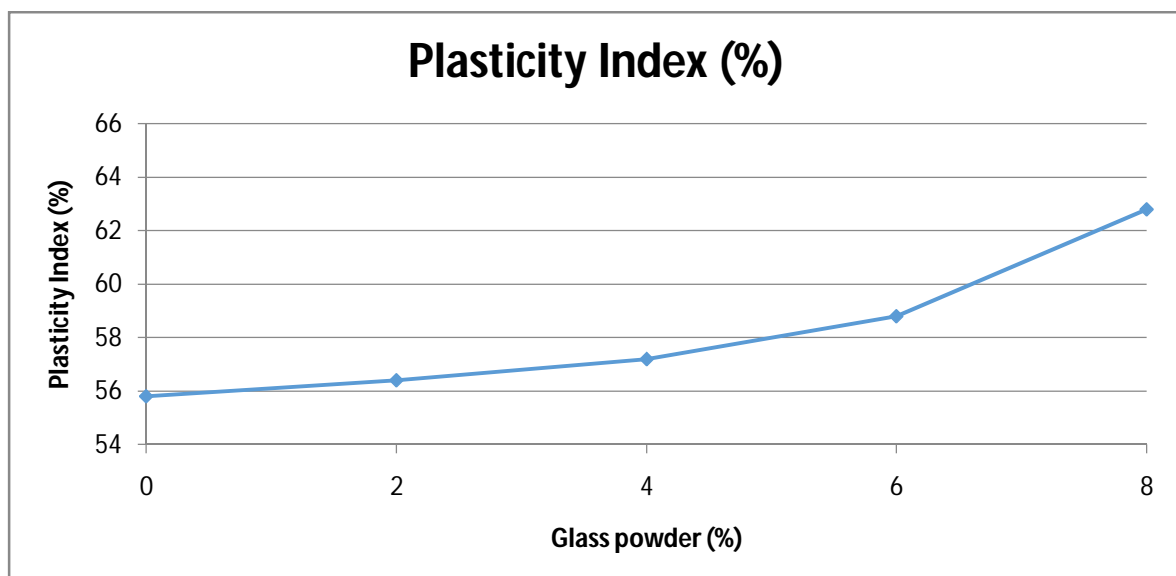


Fig.3: Plasticity index with increased Glass powder (%)

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Maximum Dry Density: In Fig. 4, the Maximum Dry Density shows a gradual increase from 1.5 mg/m³ to 1.52 for 0 to 2% glass powder content. The maximum dry density was recorded at 1.57 mg/m³ for 4 percent glass powder replacement. The least maximum dry density (1.48 mg/m³) was recorded at 6 percent glass powder replacement.

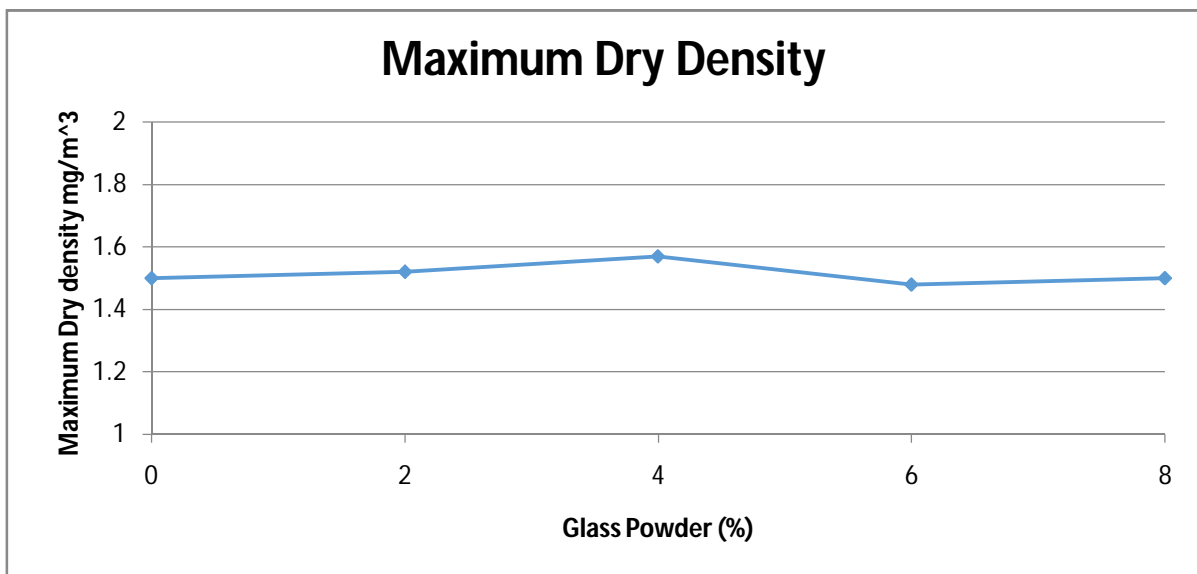


Fig.4:Maximum Dry Density with increased Glass Powder content

Optimum Moisture Content (OMC): Fig.5 shows steady increase of optimum moisture content of BCS at 0 to 2% glass powder and shows rapid decrease from 2% to 4% glass powder content. The highest Optimum moisture content was recorded at 2 % glass powder to be 22.2 %.

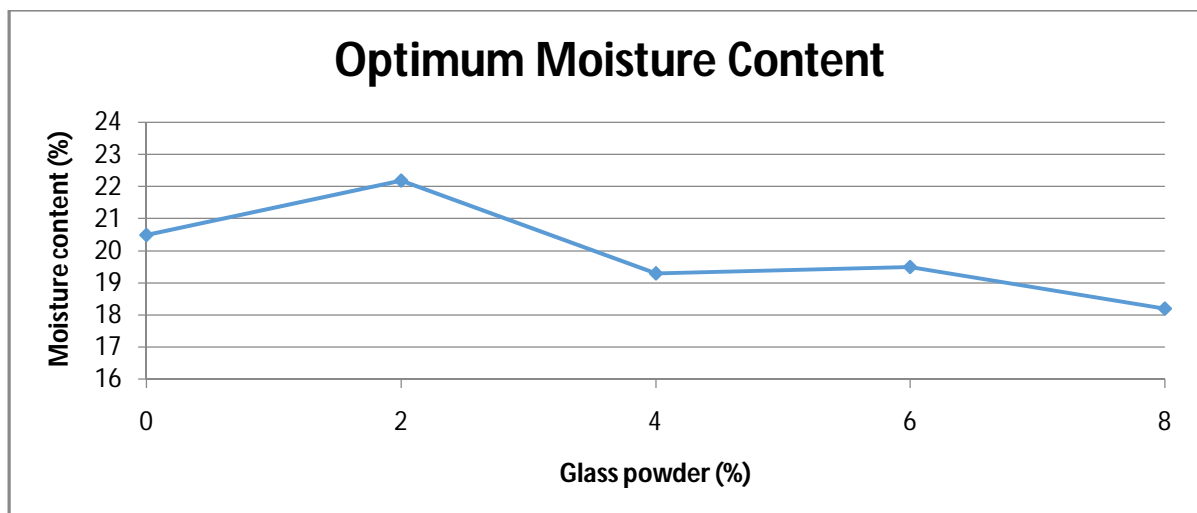


Fig.5: Optimum moisture content with Glass powder (%)

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Unconfined Compressive Strength (UCS): The UCS result of the BCS treated with glass powder is shown in Fig. 6 for 7 days. The highest UCS value was recorded at 4 percent glass powder replacement. For this maximum UCS value, a corresponding axial strain of 0.6 mm was recorded.

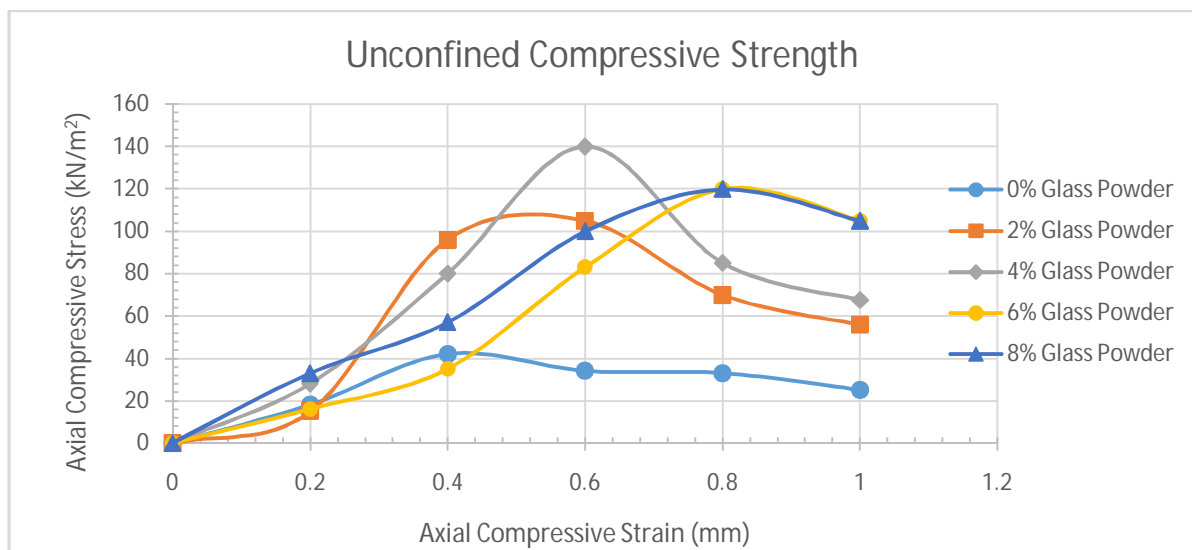


Fig.6: Unconfined Compressive Strength

Fig. 7 shows result of the maximum Unconfined Compressive strength of BCS for various glass powder percentage replacement. The unconfined compressive strength of BCS increases as glass powder increases from 0 percent to 4 percent, with 4 percent glass powder replacement recording the highest UCS 140 kN/m³. This shows over 350 per cent increment. Further increase of glass powder, produces a constant UCS value of 120 kN/m³.

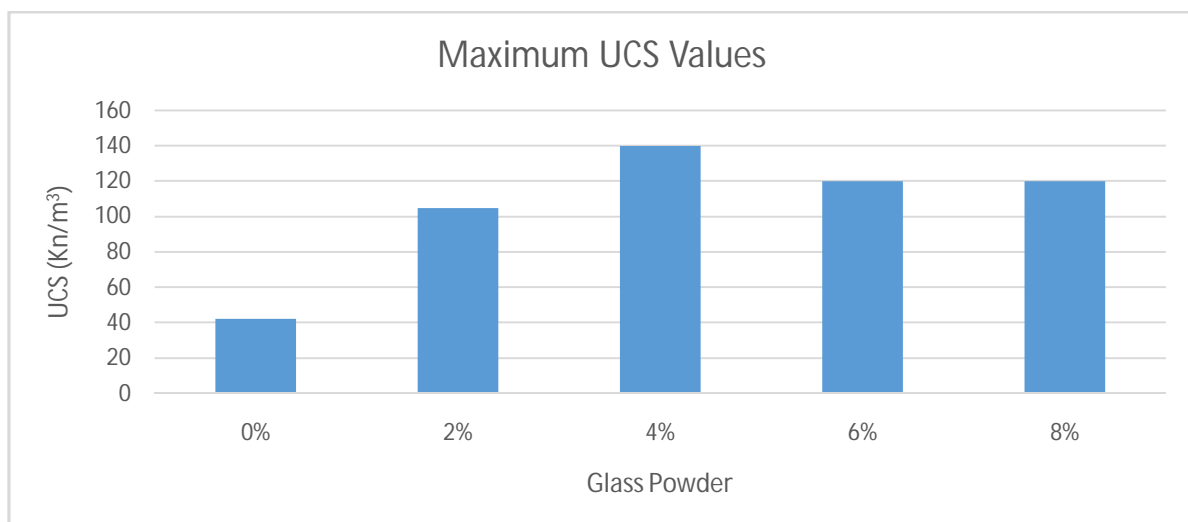


Fig 7: Maximum UCS value for various Glass Powder Content.

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California Bearing Ratio: The result presented in Fig. 8 shows that, the peak CBR value of 3.9 % was obtained at 6 % glass powder treated BCS for Standard proctor test. The CBR value of 2 % for untreated BCS, that is, 0 percent glass powder content, when compared with the peak value of CBR value recorded at 3.9 % for 6 % treated BCS. This shows approximately 95 percent increase is recorded for 6 percent glass content.

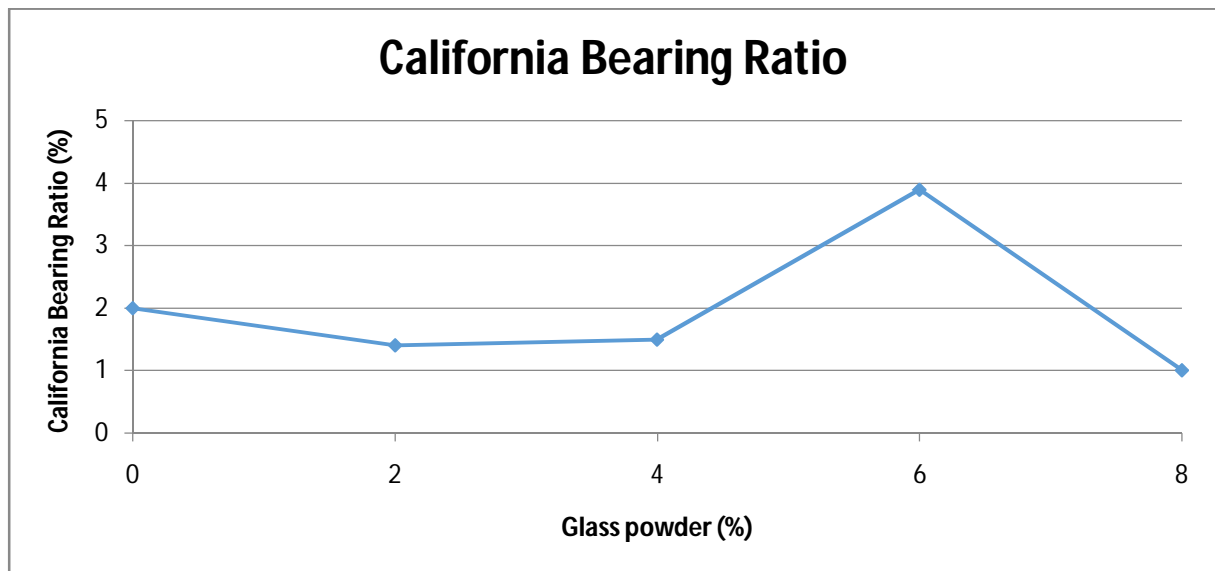


Fig. 8: CBR values for various Glass powder percentage replacement in BCS

IV. CONCLUSIONS

From the investigation carried out, the following conclusions are made:

1. At 0 percent glass powder replacement, the highest Plastic Limit and Liquid Limit of 22% and 79% was recorded respectively. The result for Plastic limit shows that with increase in glass powder treatment, the plastic limit of the treated BCS drops. While, the liquid limit initially shows similar trend, an increase in liquid limit was observed at 8 % glass powder replacement.
2. At 2 percent glass powder treatment of BCS, the highest Optimum moisture content was recorded. This indicated an overall increase by 8 percent, when compared with untreated BCS, that is, BCS with 0% glass powder content.
3. At 4 percent glass powder treatment of BCS, the highest Maximum Dry Density and Unconfined Compressive Strength of 1.57 mg/m^3 and 140 kN/m^2 were recorded respectively.
4. At 6 percent glass powder content in BCS, the lowest Liquid limit of 75.9 % was recorded. Similarly, the Maximum Dry Density was also recorded to be at 1.48 mg/m^3 for 6 % glass powder content. However, the highest CBR value of 3.9 % was recorded for the same glass powder content. This indicated approximately 95% increase in CBR value when compared to untreated BCS.
5. At 8 percent glass powder replacement, the lowest Plastic Limit, Optimum Moisture Content and CBR value were recorded. But, the Plasticity Index recorded the highest value when 8% glass powder content were introduced into the BCS.

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V. RECOMMENDATION

It is recommended that the UCS should be carried for more days. Additionally, other binding agents such as lime can be used with glass powder to stabilize the BCS.

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