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# Evaluation of Strength Characteristics of Black Cotton Soil Stabilized Using Waste Glass

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***Abstract:*** **Black Cotton (BC) soil is a clayey and highly plastic in nature. In dry state it is so hard that the clods cannot be easily pulverized and this poses serious problems as regards to subsequent performance of the road. The roads laid on BC soil bases develop undulations at the road surface due to loss of strength of the sub grade through softening during monsoon. These soils need to be stabilized before constructing the roads in order to have efficient and long lasting roads. Efforts are therefore required to strengthen the sub grade soil by mechanical stabilization of BC soil to improve its performance.The objective of this study is to evaluate the strength characteristics of black cotton soil stabilized with waste pulverized glass in varying proportions. The glass used in the present study is pulverized glass used in window glass panes. Two different size of glass were used in the study, passing through 20 mm sieve and retained on 4.75 mm, and passing through 4.75 mm sieve and retained on 75 micron sieve. Further the glass was mixed with the BC soil in proportions of 10% and 20% of the weight of soil. Laboratory investigations were performed on the above combinations and Atterberg's limit, Compaction test and California Bearing Ratio (CBR) test were performed for evaluation of strength characteristics of BC soil stabilized with waste glass.**

***Keywords:*** **Black Cotton Soil, Glass Cullet, California Bearing Ratio, Strength characteristics.**

## 1. INTRODUCTION

Black cotton soil is found in the central part of the country and is a rich producer for growth of cotton. The name is derived from its properties and appearance. It is a clayey soil and rich in mineral called montmorillonite which provide it the property of shrinking and swelling. Usually BC soil is categorized into three types namely light, medium and deep based on its texture. It has low strength and unsuitable for construction purpose, so need to be stabilized. A possible suggestion would be using glass as an additive.

Glass has been used since past for various purposes like to make containers, window panes, etc. But when these glasses are broken they become useless until recycled. These broken pieces of glass are known as cullet and can be reused as an additive in soil to be used as a sub grade for pavements. These pieces of glass are generally sent to glass factories for treatment for the purpose of recycling. This recycling not only involves its processing charge but also its transportation

charge, this overall makes the process quite expansive than the actual process, especially in the case when the location of factory is at far distance .This problem can be solved by suggesting alternate methods for consumption of cullet. One possible way is suggested in this research, which provides us with a way of complete consumption of this cullet.

In the present scenario more emphasis is laid over reusing materials rather than recycling. Recycling involves extra processing charge which is not the same with reusing materials. Reusing materials provide us with 100 % utilization of material which is not possible in recycling. This research suggest reusing these glass cullet as an admixture in soil to improve its characteristics .Since the use of glass in soil is not frequent in this period, engineers and contractors should be encouraged towards use of crushed glass as an additive. One major reason for which engineers and contractors hesitate to use glass is lack of information regarding properties of soil when glass added to it. This research provides all those

information regarding the properties of soil when glass mixed to it at various size and variable percentages .The study includes addition of fine and coarse size glass and at percentages of 10% and 20% of the mixture .The research covers standardized test that are useful in determining mixture properties and their corresponding results are also discussed.

**Brief Literature Review:**

This section briefly presents the past studies carried out worldwide for usage of glass with soil as an admixture, for stabilization of soil.

Disfani et al. (2011) suggested use of recycled glass in road applications. The study was conducted at Australia over different debris of glass, for their geotechnical properties. The study out how glass could be used as backfill in embankment of roads and concluded that lower density of recycled glass compared to natural aggregate decreased the pressure exerted on the back of retaining wall which lead to more economical design for the retaining walls. The study also suggested that usage of glass for drainage purpose behind the retaining wall reduced the risk of clogging of drainage media and higher permeability of glass improved the drainage time of water accumulation behind the wall.

Finkle et al. (2007) suggested recycled glass utilization in highway pavement at Laramie WYDOT Wyoming, US and pointed out the possible usage of broken pieces of glass bottle in highway pavement. The study suggested usage of glass at replacement rates of 10%, 20% and 30% at sizes of 3/4" and 3/8" and discussed its effects on highway pavements.

Nash et al. (1995) suggested the possible specifications for using glass cullet in roadway construction on the basis of their tests conducted at Texas Department of Transportation (TxDOT). The study discussed characteristics of glass cullet and limestone blend at 5% + 95%; 10% + 90%; 20% + 80%; 50% + 50% respectively and that to at variable sizes. The study discussed long term long term performance of glass cullet in construction field and developed procedures to improve its performance.

Blengini et al. (2012) laid emphasis over waste management and green product development by developing Recycled Foam Glass (RFG), a bi-product material of glass treatment process, at Italy. The study discussed the usage of waste leftover after glass treatment, as in the process of recycling only a few quantity was available for developing RFG and the rest was to be send for either re-processing or land filling. The RFG came out to be a good building material and thus its usage reduced load of land filling. The study also suggested need for further research on usage of RFG in road construction and other fields possible.

**Objectives of the Study:**

The main objective of the study was to evaluate the strength characteristics of stabilized BC soil using waste glass. The problematic BC soil was stabilized using varying proportion of pulverized window vane glass. Further experimental investigations are required to assess the strength characteristics of such problematic soil from pavement engineering point of view. To meet the above the following objectives were identified:

(i) To review the relevant literature on usage of glass in soil.

(ii) To evaluate the strength characteristics of BC soil using waste glass.

(iii) To investigate the effect of varying percentage and size of pulverized waste window vane glass on BC soil.

**Proposed Methodology:**

The main objective of the study was to analyze the strength characteristics of glass stabilized BC soil, to achieve the same experimental investigations were done on varying size and proportions of waste glass material. The waste glass was first divided into two categories by virtue of their size, fine glass, defined as passing through IS sieve of 4.75 micron and retained on 75 micron IS sieve, coarse glass, defined as passing through IS sieve of 20 mm IS sieve and retained on 4.75 mm IS sieve. Further, five types of combinations were studied to assess the strength characteristics of waste glass stabilized problematic BC soil, namely, virgin BC soil, BC soil mixed with 10% fine glass, BC soil mixed with 20% fine glass, BC soil mixed with 10% coarse glass and BC soil mixed with 20% coarse glass. The laboratory experimental investigations were conducted as per Indian Standards (IS) specifications. The following laboratory tests were performed, Atterberg's Limits, Free Swell Index (FSI), Modified Compaction Test and California Bearing Ratio (CBR) Test. The proposed methodology is presented in figure 1.

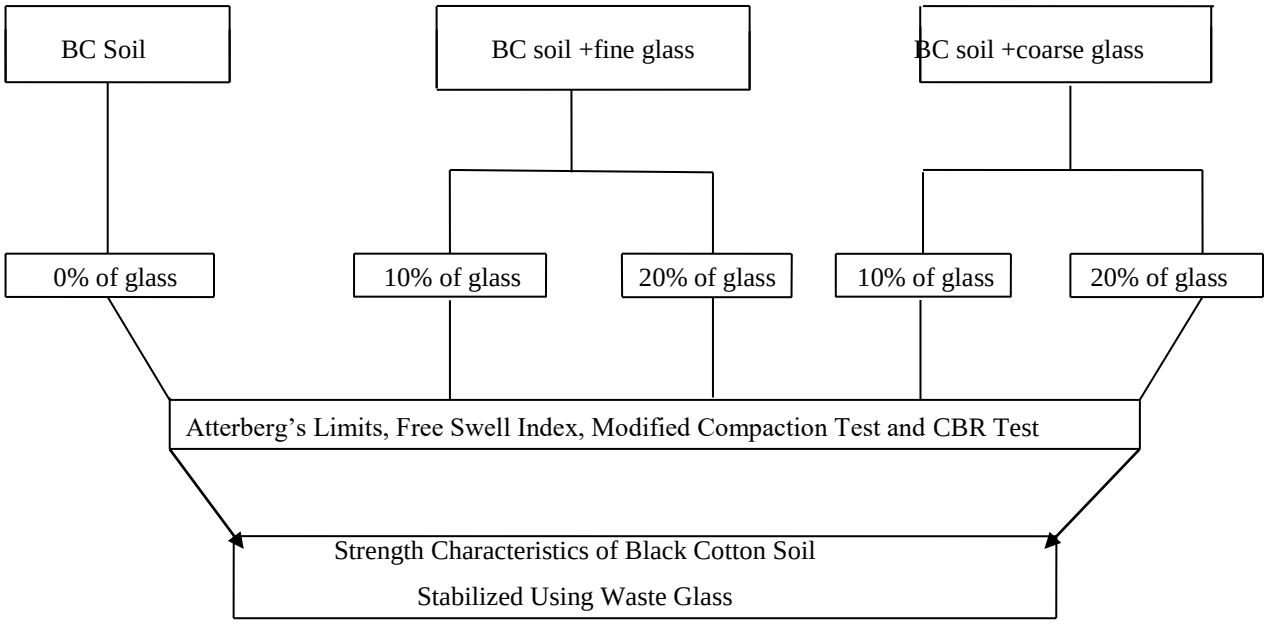


**Figure.1: Methodology for Evaluation of Strength Characteristics of Glass Stabilized BC Soil**

**Photograph.1: Modified Compaction Test being Performed**

**Photograph.2: Waste Glass used in the Study**

### A. Analysis and Results:

This section discusses the analysis and results of the experimental investigations carried out in the laboratory. The results of the tests performed on virgin BC soil are presented in table 1 below.

**Table.1: RESULTS OF VIRGIN BC SOIL**

| Name of Test | Unit | Relevant Specifications | Results Obtained |
|---|---|---|---|
| Liquid Limit | % | IS : 2720 ( Part 5) – 1985 | 62.32 |
| Plastic Limit | % | IS : 2720 ( Part 5) – 1985 | 39.05 |
| Plasticity Index | % | IS : 2720 ( Part 5) – 1985 | 21.41 |
| Maximum Dry Density | g/cc | IS;2720 (Part7)-1980 | 1.58 |
| CBR Value | % | IS:2720 (Part16)- 1987 | 3.25 |
| FSI | % | IS: 2720 (Part 40)-1985 | 28.5 |

The results show that the BC soil used in the present study is plastic soil with high degree of clay in the soil. Further, the soil has low CBR value which is a strength parameter in flexible highway pavements. This deems this soil problematic and unusable for embankment and sub grade construction of roads.

**B. Liquid Limit:**

The liquid limit (LL) corresponds to the moisture content at 25 blows on Casagrande's apparatus. The results show that the liquid limit of soil mix decreases gradually with increase in percentage of glass as presented in figure 2. The LL of virgin BC soil is 60.46%, this is reduced to 52.2% and 46.25% for soil with 10% waste glass mix and 20% waste glass mix respectively.

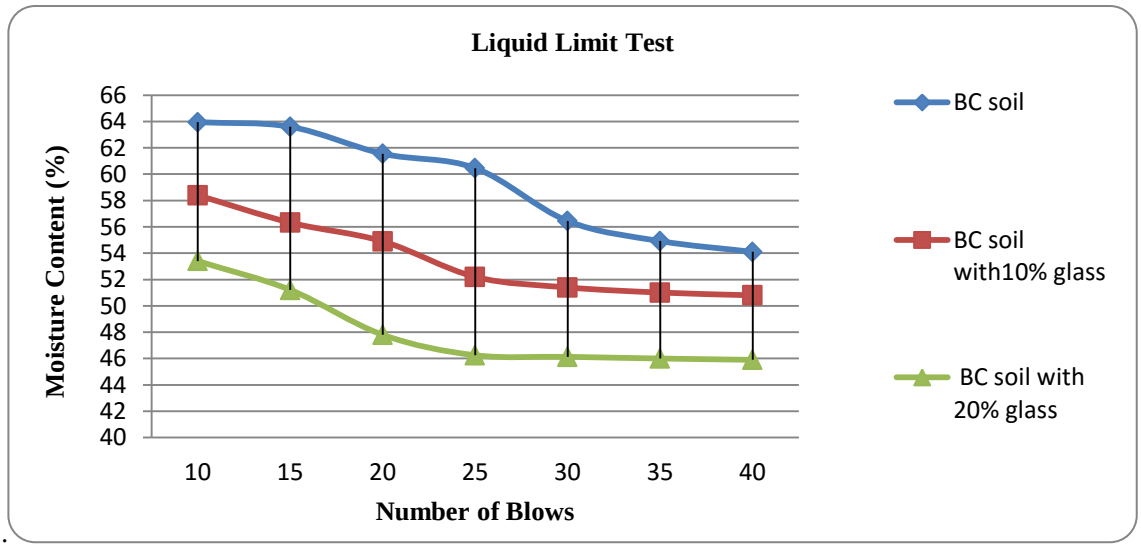


**Figure.2: Graph Presenting the Variation in Liquid Limit Values with Varying Glass Content**

**C. Plastic Limit:**

The results presented that with the increment in glass percentage the plastic limit first decreased and then increased. The results showed that the plastic limit value of 39.05% is obtained for virgin BC soil; it decreased to 35.45% when 10% glass was added to it. It further showed a variation by increasing to 34.4% when 20% glass was added to soil sample.

**D. Plasticity Index:**

The plasticity index is the difference between liquid limit and plastic limit. The results show that plasticity index of the sample reduces from 21.95% to 19.25% and then to 11.8% for virgin BC soil, BC soil with 10% glass and BC soil with 20% glass respectively. The decrease in plasticity index indicates the increment in shear strength; hence the soil will have reduced plasticity and the volumetric changes with change in moisture content will be reduced. This will further enhance the suitability of the material to be used in embankment and sub grade construction of the flexible highway pavement.

Test performed and results obtained by black cotton soil with 10% and 20% of waste glass are presented in table 2,

**Table.2: RESULTS OF TESTS ON WASTE GLASS STABILIZED BC SOIL**

| Name of Test | Unit | Relevant Specifications | Results Obtained for | |
|---|---|---|---|---|
| | | | 10% fine glass | 20% fine glass |
| Liquid limit | % | IS : 2720 (Part 5) – 1985 | 52.20 | 46.18 |
| Plastic limit | % | IS : 2720 (Part 5) – 1985 | 35.45 | 34.4 |
| Plasticity index | % | IS : 2720 (Part 5) – 1985 | 16.75 | 11.78 |

**E. Modified Compaction Test**

The modified compaction test was performed on BC soil mixed with 10% and 20% of fine and coarse glass. The compaction test were performed as per IS: 2720(Part7)-1980. The results obtained are presented in table 3 below:

**Table.3: Results of Compaction Test on BC Soil mixed with 10% & 20% of Fine Glass**

| Name of Test | Relevant Specifications | Results Obtained for | | | |
|---|---|---|---|---|---|
| | | fine glass | | coarse glass | |
| | | 10% | 20% | 10% | 20% |
| MDD (gm/cc) | IS;2720(Part7)-1980 | 1.70 | 1.75 | 1.80 | 1.83 |

The results of the compaction tests show that the MDD value of glass stabilized BC soil enhances on mixing with both the fine and coarse glass. The increment in MDD values is higher in case of coarse glass. Such modified MDD values makes this problematic soil eligible to be used as an embankment material. Also the minimum MDD value required for a material to be used in the sub grade is 1.75 gm/cc (as per MoRT&H, 2013 specifications). The glass stabilized BC soil at 10% coarse, 20% fine and coarse satisfied this requirement and can be effectively used as a sub grade material for highway pavements. The results of compaction tests are depicted in figure 3.

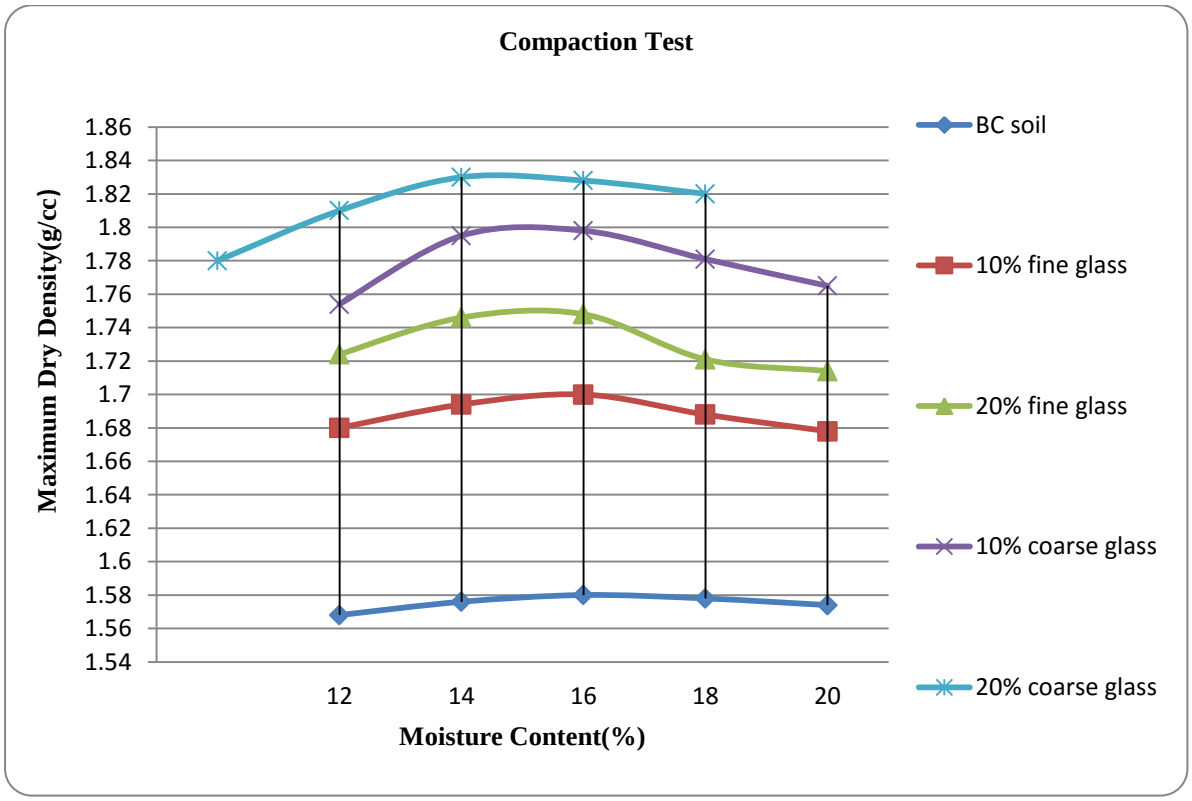


**Figure.3: Graph Presenting the Variation in MDD Values with Varying Glass Size and Content**

### F. California Bearing Ratio Test:

The CBR test is the most important test for the evaluation of strength characteristics of soil and granular materials used in the pavement construction. The four days soaked CBR tests were conducted on virgin BC soil and waste glass stabilized BC soil. The results of CBR test are presented in table 5 and table 6.

**Table.5: Results of CBR Test on BC Soil mixed with 10% & 20% of Fine Glass**

| Name of Test | Unit | Relevant Specifications | Results Obtained for | |
|---|---|---|---|---|
| | | | 10% fine glass | 20% fine glass |
| CBR value | % | IS:2720 (Part16)- 1987 | 4.55 | 5.25 |
| Swelling | % | IS: 2720 (Part 40)-1985 | 18.50 | 15.00 |

**Table.6: Results of CBR Test on BC Soil mixed with 10% & 20% of Coarse Glass**

| Name of Test | Unit | Relevant Specifications | Results Obtained for | |
|---|---|---|---|---|
| | | | 10% coarse glass | 20% coarse glass |
| CBR value | % | IS:2720 (Part16)- 1987 | 5.60 | 6.85 |
| Swelling | % | IS: 2720 (Part 40)-1985 | 17.25 | 13.20 |

The glass stabilized BC soil showed improvement in the strength parameter of CBR. The increment in CBR value was more in the case of glass stabilized BC soil with 20% fine and coarse glass. Such enhancement in CBR value of problematic BC soil which was unusable prior to stabilization with waste glass, can now be used in the construction of highway pavements. Further this would also reduce the total thickness of the pavement section making the whole construction operation more economical.

## 2. CONCLUSIONS

The following conclusions were drawn from the present study:

1. The Plasticity Index of BC soil reduces on mixing waste glass with BC soil. This reduction in Plasticity Index reduces the plastic nature of the problematic BC soil. Further the swelling characteristics of BC soil also reduced, making it less susceptible to variation in moisture conditions.
2. The addition of waste glass in BC soil has pronounced effect on compaction characteristics. The MDD value shows an increasing trend with a maximum percentage increase on 16.7 % with coarse glass stabilized BC soil. Further the stabilization of BC soil with waste glass makes the problematic soil eligible to be used in highway pavement construction.
3. The waste glass stabilized BC soil also enhances the strength characteristics of the problematic BC soil. The strength parameter of CBR also showed a maximum percentage increase of 110.8% with coarse glass stabilized BC soil. Also with addition of both fine and coarse glass the strength parameter enhances. This significant improvement in the strength characteristics of BC soil deems it to be more suitable to be used in pavement construction. This would further reduce the total thickness requirement of the flexible pavement, thereby making road construction economical.

Hence, it can be concluded that utilization of waste glass in problematic BC soil enhances the strength characteristics of such soils. The waste glass stabilized BC soil can be effectively used in the construction of highway embankments and sub grade, further it will also economize the highway construction activity.

**Future Scope:**

In the present study the scope of the work was limited to the utilization of problematic BC soil of low compressibility available in Bhopal city with waste glass. Studies may also be taken up on other soils types like silty clay etc. and varying glass type and contents, may be used to study the effect of glass on various properties of soils. Further investigations needs to be carried out to assess the performance of highway pavements constructed with glass stabilized soils.

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