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Effect of Glass Powder on Engineering Properties of Clayey Soil

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***Abstract*— Clay soils exhibit generally undesirable engineering properties. They tend to have low shear strength which reduces further upon wetting or other physical disturbances. Hence, there exists a need of improving the engineering properties of soil before construction by soil stabilization techniques. The main objective of this study is to investigate the use of waste glass powder in geotechnical applications and to evaluate the effects of waste glass powder on shear strength, compressibility and CBR values of clayey soil by carrying out direct shear tests, unconfined compression tests, standard proctor test and CBR test. The powdered glass material is added to the soil in different proportions like 2%, 4%, 6%, 8%, and 10% and find the percentage at which the maximum soil strength is obtained. Also a comparative study on the properties of untreated clay soil and clay soil treated with glass powder was also done.**

Keywords—* *Clay soil, glass powder,CBR,UCC.direct shear test

I. INTRODUCTION

Soil has been used as a construction material from ancient times. Due to its poor mechanical properties, it is a challenge for the engineers to improve its properties depending upon the requirement. In case of silty and clayey soil, the settlement that can be caused due to the load is high compared to others. Clay soil will swell significantly when come in contact with water and shrink when the water squeezes out. Due to this alternative swell-shrink behavior of the soil, damages occur to different civil engineering structures founded on them. Hence stabilization is essential for such type of soil. Stabilization is the process of blending and mixing materials with a soil to improve the properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation and improve the engineering properties of soil, thus making it more stable. This study seeks to determine the geotechnical properties of silty clay soil stabilized with glass powder through laboratory tests.

The disposal of wastes produced from different industries has become a great problem. These materials pose a threat to the environment because they can result in pollution in the nearby locality since they are majorly non-biodegradable. One solution to this crisis lies in recycling and reusing wastes into useful products. In general the engineering properties of silty and clayey materials were improved by using waste material as stabilizer. Consequently, this study assesses the use of broken (waste) glass in powdered form as stabilizer for silty clay soil. The underlying objective is to assess its performance as a stabilizer by measuring its effects on silty clay soil (through a comparison of the properties of the soil with and without the addition of the broken glass powder) and determine appropriate quantities of the glass powder required for adequate stabilization of the soil.

II. METHODOLOGY

The materials used in carrying out this project are powdered glass and clayey soil. Glass is an amorphous non crystalline material which is typically brittle and optically transparent. The familiar type of waste glass materials found around are drinking vessels and window glasses, most of the readily available waste glass materials are soda-lime glass bottles, composed of about 75% silica plus, Na_2O, CaO and several additives. Glass factories are also source of waste glass powder. This material is added to soil in its powdered form for stabilization. Glass is totally inert and therefore non-biodegradable. Also the angle of friction of glass powder is high as compared to clayey soil which has very low angle of friction. It degrades in a manner similar to natural rock. As an inert construction material, it can increase the strength of various road building elements. Glass has been experimented on as a substitute aggregate in asphalt concrete. Crushed glass has also been used as an aggregate for sub-base. The size of the glass powder chosen was <0.075mm.

The clayey soil was collected from a construction site located at Kuttanadu after removing the top soil and excavating to a depth of about 7 m. The clay was collected and basic tests were conducted on it for obtaining the gradation and index properties of the soil. The Direct shear, UCC and CBR tests are the main tests done here. These tests were done on clayey soil with 0% glass powder and also on clayey soil added with different proportions of glass powder like 2%, 4%, 6%, 8%, 10%.

Fig 1: Glass powder

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Fig 2: Clayey soil

III. TEST PROCEDURE

1. Specific gravity (IS 2720 (part 3):1980)
2. Liquid Limit (IS 2720 (Part 5):1985)
3. Plastic Limit (IS 2720 (Part 5): 1985)
4. Shrinkage Limit (IS 2720 (Part 5): 1985)
5. Wet Sieve analysis (IS 2720 Part IV: 1985)
6. Hydrometer Analysis (IS 2720 Part IV: 1980)
7. Standard Proctor Test (IS 2720 Part VII -1980)
8. Direct Shear Test
9. Unconfined Compression Test (UCC)
10. California Bearing Ratio (CBR) Test

TABLE 1: INDEX AND ENGINEERING PROPERTIES OF CLAYEY SOIL SAMPLE

Soil property	***Value***
Natural water content	87%
Specific gravity	2.53
Percentage of clay	35%
Liquid limit	70%
Plastic limit	20%
Shrinkage limit	7%
Plasticity index	50%
Maximum dry density	1.464 g/cm^3
Optimum moisture content	34%
Cohesion	0.056 N/mm^2
Angle of internal friction	18^o
Undrained cohesion	0.058 N/mm^2
CBR	3%

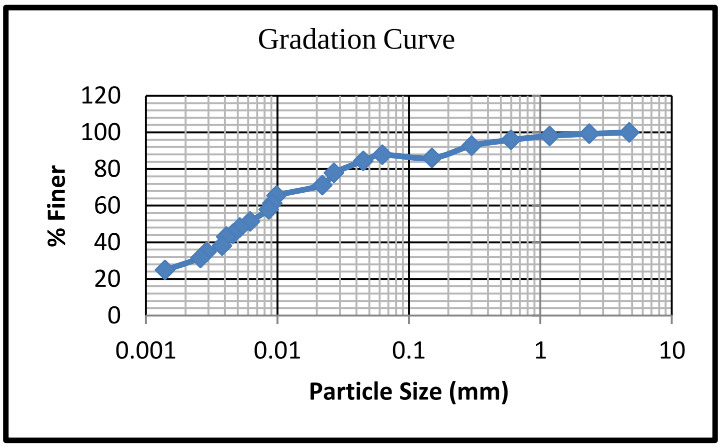

Fig 3: Gradation Curve for Combined Wet Sieve and Hydrometer Analysis

IV. STANDARD PROCTOR TEST

This experiment gives a clear relationship between the dry density of the soil and the moisture content of the soil. Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory used in the experiment is that for any compactive effort, the dry density depends upon the moisture content in the soil. The maximum dry density (MDD) is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC). After plotting the data from the experiment with water content as the abscissa and dry density as the ordinate, we can obtain the OMC and MDD. The equations (1) and (2) are used in this experiment.

$$\text{Moisture content } w\,(\%) = \frac{Weight\ of\ water\,(gms)}{Weight\ of\ dry\ soil\,(gms)} x100 \quad (1)$$

$$\text{Dry density } \rho d\ (gm/cc) = \frac{bulk\ density}{1+w} \quad (2)$$

V. DIRECT SHEAR TEST

This test is used to find out the cohesion (c) and the angle of internal friction (φ) of the soil, these are the soil shear strength parameters. The shear strength is one of the most important soil properties and it is required whenever any structure depends on the soil shearing resistance. The test is conducted by putting the soil inside the shear box which is made up of two independent parts. A constant normal load is applied to obtain one value of c and φ. Horizontal load (shearing load) is increased at a constant rate and is applied till the failure point is reached. This load when divided with the area gives the shear strength 'τ' for that particular normal load. The equation used in this experiment is equation (3).

$$\tau = c + \sigma * \tan(\varphi) \quad (3)$$

VI. UNCONFINED COMPRESSION TEST

The Unconfined Compressive Strength (UCC) is the compressive stress at which the unconfined cylindrical soil sample fails under simple compression test. For the UCC tests the mould of size 30mm diameter and 76mm height was prepared. The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. The water content used is the optimum water content obtained by laboratory Standard Proctor test.

VII. CALIFORNIA BEARING RATIO (CBR) TEST

The California Bearing Ratio (CBR) Test is a penetration test for evaluation of the mechanical strength of road subgrades and base courses. The test was conducted using CBR mould having 150mm diameter and 175mm high, provided with a detachable extension collar of 50mm height and detachable perforated base plate of 10mm thickness. The CBR value of the test sample was determined corresponding to plunger penetrations of 2.5mm and 5mm as per the standard procedure (IS 2720 (Part 16) – 1987).

The strength wise classification of the subgrade soil is shown in TABLE 2. From the obtained CBR value the strength of the soil can be classified.

TABLE 2: STRENGTH WISE CLASSIFICATION OF SOIL

Subgrade Classification	CBR (%)
Extremely weak	<1
Weak	1-2
Medium	2-5
Normal	5-10
Strong	10-30
Extremely strong	>30

TABLE 3: PROPERTIES OF GLASS POWDER

Soil property	Value
Cohesion	0.005 N/mm^2
Angle of friction	44^0

VII. RESULTS AND DISCUSSIONS

The results of all the experiments conducted are shown in TABLE 5 and TABLE 6.Cohesion, angle of friction, dry density, unconfined compressive strength and CBR values increases with increase in percentage of glass powder added due to increase in friction and reduction in settlement of the clayey soil. But after a certain limit the values decreases.

TABLE 5: RESULT SHEET

Percentage of glass powder added (% by weight of soil)	Angle of internal friction (φ)	Cohesion (N/ mm^2)	Dry density (g/cm^3)	Optimum Moisture Content (OMC) %	Shear strength, (UCS) N/mm^2
0	18	0.056	1.464	34	0.058
2	21	0.06	1.47	33	0.061
4	25	0.063	1.48	31.25	0.062
6	32	0.068	1.49	28	0.065
8	37	0.071	1.47	30	0.07
10	37	0.072	1.46	29	0.071

TABLE 6: RESULT SHEET FOR CBR TEST

Percentage of glass powder added (% by weight of soil	CBR (%)
0	3
2	4.38
4	7.29
6	12.8
8	7.2

VIII. CONCLUSION

Constructions over weak soil have been a real challenge even today. This study is done to stabilize the weak clayey soil using locally available waste materials and to arrive a cost effective methodology for construction in this type of weak soil. Based on the present investigations it is concluded that the cohesion, angle of internal friction and UCC values of soil increases with the addition of glass powder up to an optimum value of 8%. When the glass powder content is increased, the dry density value of soil is further increased. Since glass powder is an industrial waste, it can be obtained cheaply. Therefore stabilization of weak soil using glass powder is very economical. Waste management can also be done very efficiently by this project. Overall it can be concluded that stabilization of soil using glass powder is a good and economical ground improvement technique especially in engineering projects on weak soil.

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