

Effect of Glass Powder on The Geotechnical Properties of Soil A Sustainable Approach to Soil Stabilization

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Abstract: Soil stabilization is an essential process in improving the engineering behavior of sub grade soil for construction activities. This study investigates the potential of using glass powder, an industrial waste product, as a sustainable soil stabilizer. Various percentages of glass powder (2%, 4%, 6%, 8%, and 10%) were added to the native soil collected from a site. Laboratory tests including Atterberg's limits, Standard Proctor test, and California Bearing Ratio (CBR) were performed to evaluate the impact of glass powder in addition on soil properties. The results demonstrate significant improvement in CBR values and density, indicating enhanced strength and suitability for use in subgrade applications. The study concludes that glass powder can be effectively utilized in soil stabilization, promoting both engineering performance and environmental sustainability.

Keywords: Soil Stabilization, Glass Powder, CBR, Sustainable Construction.

I. Introduction:

Infrastructure development in rapidly growing nations such as India requires innovative and cost-effective solutions to manage weak sub grade soils. Traditionally, stabilizers such as lime, cement, and bitumen are used, but these can be environmentally burdensome and expensive. Glass powder, derived from recycled waste glass, has shown promise due to its pozzolanic activity and fine particle structure, which enhance soil binding and strength.

Stabilization of soil is the process of upgrading the engineering properties of the soil which potentially makes it flexible. It is most useful when soil is used for the construction which is not acceptable for the calculated grounds in its wide perception sense. It involves compaction, pre-consolidation and many other such processes. However, the term stabilization is generally not allowed in such processes where the alteration of the soil minerals is made for the upgrading of the soil properties.

Generally, stabilization is preferred to minimize the permeability and compressibility of mass soil in earth structure and it also increases the shear strength of the soil. To improve the bearing capacity of foundation the soil stabilization is preferred for the constructions of highway and airfields. The stabilization is mainly used to upgrade the natural soil. The grading and controlling of the soil for the construction is based on the soil stabilization and preferred as the base and sub base for the highway and airfields construction.

Objectives:

In this study the stabilizers chosen is glass powder and is merged with the soil sample separately with different proportions of 2 to 10 percentage to the weight of the dry soil. Numerous tests are conducted in the laboratory to study the effects of glass powder in soil.

Glass Powder:

Glass powder is a versatile material with numerous industrial and manufacturing applications, serving as filler, additive, abrasive, and even a pozzolan in concrete. Glass is principally composed of silica. Use of milled (ground) waste glass as partial replacement of cement could be an important step toward development of sustainable (environmentally friendly, energy-efficient and economical) infrastructure systems. When waste glass is milled down to micro size particles, it is expected to undergo pozzolanic reactions. The physical properties of glass powder include a specific gravity of 2.58 and density of 900 kg/m³. The glass powder was white in color and passed through a 90 µm sieve.



Experiments:

To find the index properties of soil many tests were conducted that includes liquid limit, plasticity index and moisture content. The following laboratory tests were performed:

- Atterberg's Limits (Liquid Limit and Plastic Limit)
- California Bearing Ratio (CBR)
- Standard Proctor Compaction Test

The soil was mixed with glass powder in varying percentages (2%, 4%, 6%, 8%, and 10%) by weight for testing.

Atterberg Limits:

The Atterberg limits help in determining the plasticity index and characteristics of soil. With increasing glass powder content, both the liquid limit and plasticity index decrease, indicating reduced plasticity and improved soil behavior for engineering applications. The figure below illustrates the variation in Atterberg limits with glass powder content.

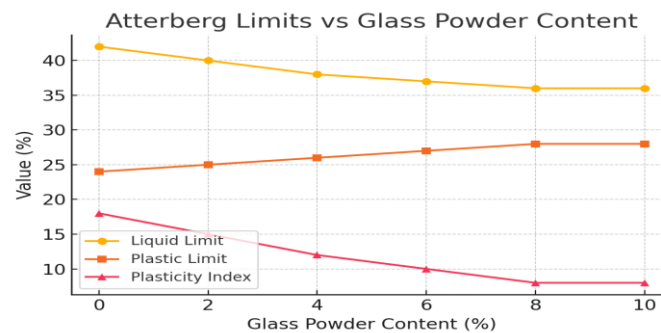


Table1: Atterberg Limits for Various Glass Powder Percentages

Glass Powder (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	42	24	18
2	40	25	15
4	38	26	12
6	37	27	10
8	36	28	8
10	36	28	8

The reduction in plasticity index indicates a decrease in the potential for volume changes due to moisture, making the soil more stable and suitable for sub grade use.

California Bearing Ratio (CBR):

The CBR test results show an increase in strength with the addition of glass powder up to 8%. The figure below illustrates this trend.

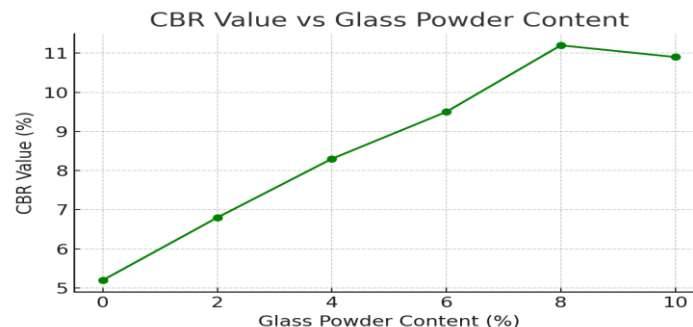


Table 2: CBR Values for Various Glass Powder Percentages

Glass Powder (%)	CBR Value (%)
0	5.2
2	6.8
4	8.3
6	9.5
8	11.2
10	10.9

A statistical analysis was conducted to evaluate the trend. The coefficient of determination ($R^2 \approx 0.97$) indicates a strong positive correlation between glass powder content and CBR values up to 8%. After 8%, the CBR improvement starts to plateau, suggesting that 8% is the optimal glass powder content for maximum benefit.

Compaction Characteristics

The Standard Proctor Test was conducted to determine the compaction characteristics of the soil - glass powder mixtures. The addition of glass powder resulted in an increase in Maximum Dry Density (MDD) and a corresponding decrease in Optimum Moisture Content (OMC). This indicates better packing of particles and lower water demand, which is favorable for construction. The graph below shows the trends observed.

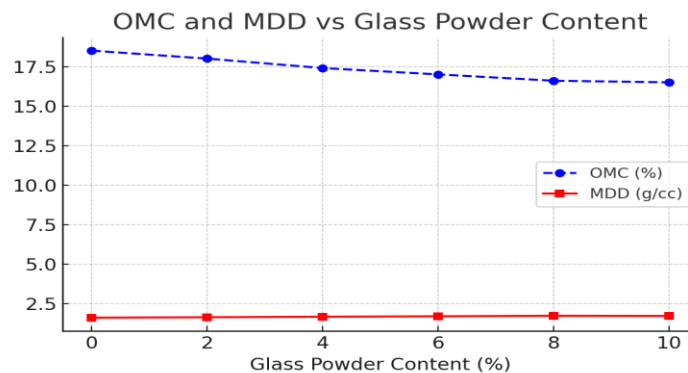


Table 3: OMC and MDD for Various Glass Powder Percentages

Glass Powder (%)	OMC (%)	MDD (g/cc)
0	18.5	1.62
2	18.0	1.65
4	17.4	1.68
6	17.0	1.71
8	16.6	1.74
10	16.5	1.73

The maximum dry density was observed at 8% glass powder content, after which a marginal reduction was noted. This suggests that 8% is the optimal content for maximum compaction efficiency.

II. Results and Discussion:

- The moisture content of the soil collected from the site was found to be 16.8%.
- The liquid limit and plastic limit of the soil were found to be 35% and 18% respectively.
- The inclusion of glass powder led to a decrease in the plasticity index, implying lower shrink-swell potential.
- Compaction tests showed increased dry density and reduced optimum moisture content.
- The dry density changes from 2.52 g/cc to 2.067 g/cc with optimum Glass powder addition at 8%.
- The CBR value for soil alone is 2.79% at 2.5mm penetration and 4.99% at 5mm penetration.
- The CBR value of the soil with addition of glass powder is 1.16% at 2.5mm penetration and 2.05% at 5mm penetration
- CBR values increased with higher glass powder content, peaking at 8% before slightly plateauing.

The glass powder acts as filler and reacts pozzolanically with soil moisture, contributing to matrix densification. This improves the load-bearing capacity and durability of the soil. The findings are aligned with previous studies using industrial waste like fly ash and GGBS.

III. Conclusion:

This study confirms that waste glass powder can be an effective stabilizer for improving sub grade soil properties. The optimal performance was observed at an 8% replacement level. The use of glass powder not only enhances soil strength but also offers a sustainable solution for waste glass management in construction.

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