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Effects of Waste Glass Powder on the Geotechnical Properties of Loose Subsoils

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Abstract

Foundation soils are most affected by different problems when it comes to the loose soil having low shear strength and bearing capacity. Failure of the soil with settlement and shear arises when the shear stresses in the soil exceed the limit. This study is keen to observe the effects of utilization of waste broken glass in the enhancement of Geotechnical properties of soil by performing different laboratory tests. Collection of the soil sample from was concluded from Pabbi, Peshawar, KPK, and Pakistan, which is a low strength soil, are also being called soft soil having low bearing capacity. Furthermore, this particular soil was needed to be enhanced. The physical, chemical and engineering properties of virgin soil were contemplated and the soil was treated with added substances of Glass Powder to stabilize the local soil. Addition of Glass Powder was finished in different proportions that are 4%, 8% and 12% etc. Performance of different tests as Gradation, Specific Gravity, Standard Proctor compaction, Atterberg Limits, Direct Shear, CBR and so forth were done. The results were concluded, based on the Glass Dust stabilization analysis. It was obtained that pulverized glass can be effectively used as a soil stabilizer as mainly the strength characteristics were observed to be valeted. The Results showed that the gradation of soil is narrow from the particle size analysis. Plasticity index (P.I), Liquid limit (L.L) and plastic limit (P.L) were decreased with the addition of Glass powder. The reason behind decreasing P.I is maybe the fact that the Glass powder is cohesionless. Ideal percentage of Glass Powder as a stabilizer is 8%. Such improvements included an achievement of the highest CBR obtained at the 4%, 8% and 12% of powdered glass content. The reason is that the glass is pozzolanic material when blended with soil gives additional strength. The achievement of the increasing rate of the values of angle of internal friction on 4% and 8% and decreasing rate of values obtained at 12% powdered glass substances. Cohesion rate decreases up to 8% and starts increasing at 12%. Maximum dry density increasing as the density of glass is higher than such soil and Optimum moisture content (OMC) is decreasing because of low absorption capacity of glass. The study showed that the best stabilizer for the case study (Pabbi, Peshawar) is the Glass Powder and the optimum dose is 8 %.

Keywords: Glass Powder; Stabilization; CBR; Specific Gravity; LL; PL; PI.

1. Introduction

Soil stabilization is the alteration of soils to enhance their physical properties. It can increase the shear strength of a soil, control its shrink-swell properties and improve its load bearing capacity. Soil stabilization can be utilized on roadways, parking areas, site development projects, airports and many other situations where sub-soils are not suitable for construction. It can also be used to treat a wide range of subgrade materials varying from expansive clays to granular soils as well as improve other physical properties of soils such as increasing their resistance to erosion, dust formation or frost heaving. Clay soils exhibit generally undesirable engineering properties. They tend to have a low shear strength which reduces further upon wetting or other physical disturbances. They can be plastic and compressible; expand when wetted and shrink when dried. Some types expand and shrink greatly upon wetting and drying, thereby, exhibiting some very undesirable features. Cohesive soils can creep over time under constant load, especially when the shear stress is

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approaching its shear strength, making them prone to sliding. They develop large lateral pressures and tend to have low resilient modulus values. For these reasons, clays are generally poor materials for foundations. Their properties may need to be improved upon in some cases by soil stabilization.

Engineers have long been aware of the stabilizing effects of various materials in earth works. The first and by far, the most extensive and successful application of stabilization was developed by the French engineer, Henry Vidal, in the late 1950's. Vidal's system was known as 'Reinforced Earth', which consists of placing steel reinforcing strips at predetermined intervals within the fill mass for the purpose of providing tensile or cohesive strength in a relatively cohesion less material [1]. The possible specifications for using glass cullet in roadway construction on the basis of their tests conducted at the Texas Department of Transportation (TxDOT). The study discussed characteristics of glass cullet and limestone blend of 5% + 95%; 10% + 90%; 20% + 80%; 50% + 50% respectively and that to varying sizes. The study discussed long term long term performance of glass cullet in the construction field and developed procedures to improve its performance [2]. Glass as a product of man's ingenuity, maybe as old as bronze, even older is the use of natural glass used for arrow head and artifacts. However, glass vases and glazes dates back 4500 years showing humans manipulating their resources for aesthetic desires. Glass is also an inorganic polymer [3]. Compaction usually eliminates the larger soil pores. A large portion of the initial soil air is forced out of the upper plant root zone, and the channels of greatest continuous and least resistance to air movement, water movement and root penetration are destroyed. Under comparable conditions, soils with a range of soil particle sizes (such as fine sandy loam) are generally more compactable than the sandy soils of uniform particle size [4].

The Chemical stabilization method deals with improving the engineering properties of soil by adding chemicals or other such materials and it is generally cost effective. These additives react with the soil usually clay minerals, with subsequent precipitation of new and insoluble minerals, which bind the soil together [5]. Glass is totally inert and therefore non-biodegradable. 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 [6].

Emphasis was laid over waste management and green product development by developing Recycled Foam Glass (RFG), a bi-product materially of glass treatment process, at Italy. The study discussed the usage of waste left over after glass treatment, as in the process of recycling only a little 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 the need for further research on the usage of RFG in road construction and other fields possible [7]. Use 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 [8]. It is suggested to use recycled glass in road applications. The study was conducted in Australia over different debris of glass, for their Geotechnical properties. The study 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 [9].

Soil adjustment is the change of soils to improve their physical properties. It can build the shear quality of a soil, control its shrink-swell properties and enhance its load bearing limit. Soil adjustment can be used on roadways, stopping regions, site improvement ventures, air terminals and numerous different circumstances where sub-soils are not reasonable for development. It can likewise be utilized to treat an extensive variety of subgrade materials differing from far reaching clays to granular soils and also enhance other physical properties of soils, such as frost heaving. A lot of research work has been done in the past to improve the engineering properties of soil using additives [10]. Therefore, in spite of the clear straight forwardness of glass recuperation, its reusing rate is among the lowest, compared normal MSW recuperation level of 30.6% [11]. Hypothetically, glass is a 100 % recyclable material; it can be reused without any loss of quality. According to EPA official statistics, the municipal solid waste (MSW) stream in the USA contains around 5.3 % of waste glass or 12.5 million tons [12].

Following are the objectives of the study.

- To upgrade the Geotechnical parameters of soil by including the admixture.
- To audit uncommonly the quality attributes of soil to use of Glass.
- To research the impact of changing levels of Glass in soil.

2. Materials

2.1. Soil

The soil sample in this study was collected from Pabbi, Peshawar, Kpk, Pakistan.

Table 1. Geotechnical properties of soil sample

Moisture Content (%)	6.38%
Liquid Limit (%)	34.30
Plastic Limit (%)	30.158
Plasticity Index	4.142
Specific Gravity	2.56
Maximum Dry Density (gm/cc)	2.272
Optimum Moisture Content	8.9
USCS Classification	CL-ML
CBR Unsoaked (%)	45.1

2.2. Glass Powder

Squander Glass was taken from the neighbourhood Glass processing plant at Phase 3 indirect, Hayatabad, Peshawar, where glass is produced. The waste Glass was taken to the PCSIR labs during the time spent pounding. Ball Mill is a contraption utilized for squashing materials. Squander Glass was transformed into cinder with the assistance of Ball Mill Apparatus. Acquired Glass Powder was utilized as altogether blended in changing rates by weight of dry soil. As the Glass Powder was in the residue shape so its fineness of the particles was strainer #200 passing. The particular gravity was observed to be 2.56. Tests were directed on the examples blended with Glass Powder at various rates.

Figure 1. Glass powder

4. Research Methodology

The Following tasks are to be done for achieving the above mentioned objectives.

- A Collection of test from Pabbi, Peshawar, which is a low quality soil which should be moved forward.
- Addition of admixture in various extents following 4%, 8% and 12% and so forth.
- The Performance of various tests, i.e. Degree, Specific Gravity, Standard Proctor compaction, Atterberg Limits, Direct Shear and CBR and so forth.
- Measurement of various Geotechnical properties incorporates Maximum Dry Density and Strength of the soil example.
- Comparison of the outcomes between typical soil test and balanced out soil test.

5. Results and Discussions

Investigations were led on the examples blended with various rates of Glass dust, i.e. 4%, 8% and 12% so as to decide the building properties of the changed soils. The example parameters were resolved by ASTM principles.

5.1. Gradation Test

The Gradation curve of soil sample is shown in Figure 2. The soil sample is essentially a fine grained material.

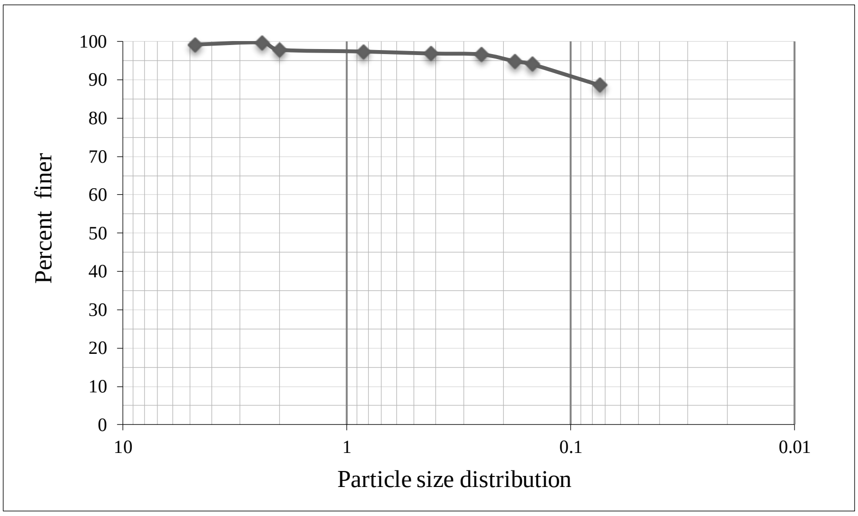

Figure 2. Gradation Curve for Soil Sample

5.2. Compaction Characteristics

The moisture content-dry density relationship of a given soil is determined by Modified proctor test.

Table 2. Variation of MDD and OMC with the percentage of Glass Powder

Soil + Glass Powder (%)	MDD (gm/cc)	OMC (%)
100 + 0	2.272	8.9
96 + 4	2.338	7.9
92 + 8	2.397	6.7
88 + 12	2.399	5.5

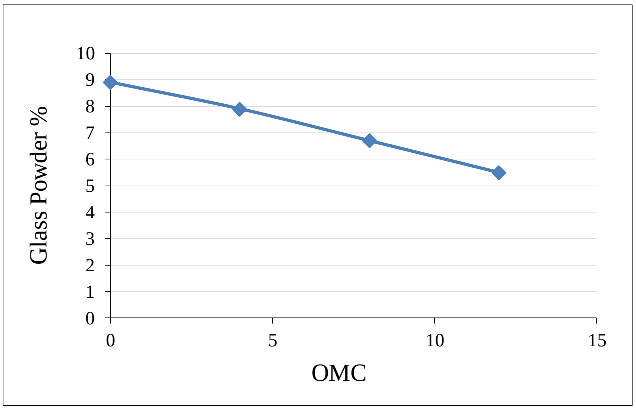

Figure 3. Variation of graph between OMC with different percentage of Glass Powder

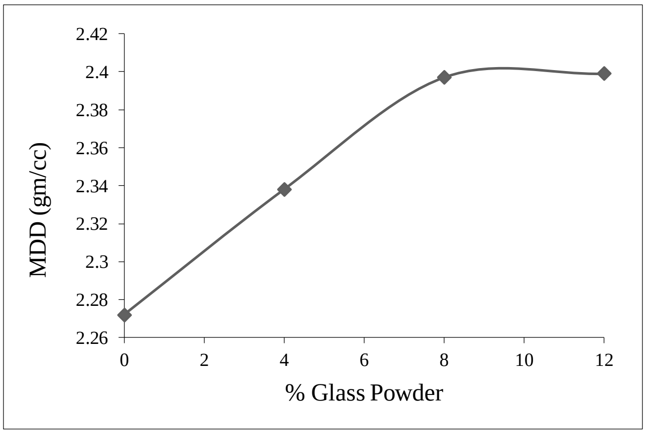

Figure 4. Variation of graph between MDD with different percentage of Glass Powder

The maximum dry density of soil was observed to be expanded from to 2.399gm/cc from 2.272gm/cc up to the expansion of 12% Glass Powder. While in the event of OMC, the diagram demonstrates varieties. The maximum OMC got at 0% Glass Powder and expanding Glass Powder diminishes the OMC as appeared in Figure 3 and 4.

5.3. Atterberg Limits Test

The Percentage of variety of liquid limit, plastic limit and Plasticity index to the admixture are appear in figures. It is watched that as the level of admixture (Glass Powder) expands, as far as possible, plastic limit and plasticity index continue diminishing and is delegated CL-ML as per the brought together soil grouping framework (USCS) by plotting the qualities on the plasticity chart.

Table 3. Variations of L.L, P.L and P.I for Soil and Glass Powder Mixes

Soil + Glass Powder (%)	Liquid Limit (LL) %	Plastic Limit (PL) %	Plasticity Index (PI) %
100 + 0	34.30	30.158	4.142
96 + 4	33.12	29.68	3.44
92 + 8	29.70	26.54	3.16
88 + 12	27.31	24.53	2.87

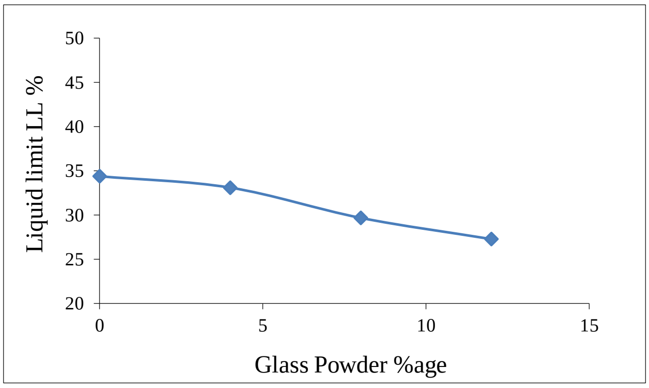

Figure 5. Plot of curve between Liquid Limit with different percentage of Glass Powder

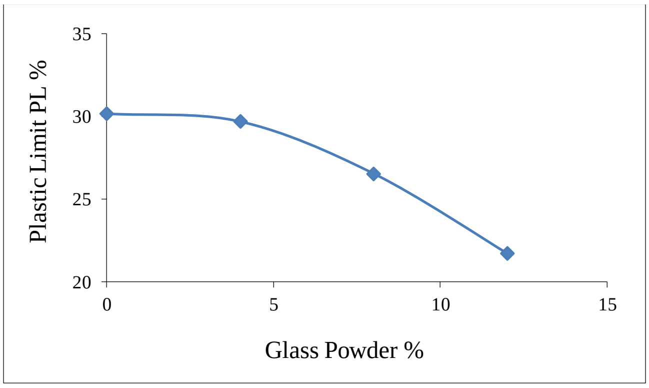

Figure 6. Plot of curve between Plastic Limit with different percentage of Glass Powder

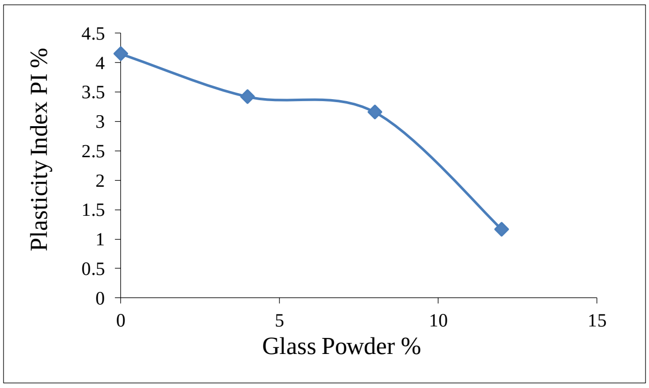

Figure 7. Plot of curve between Plasticity indexes with various percentages of Glass Powder

5.4. Specific Gravity

The Percentage of variation of specific gravity to the admixture is shown in Figure 8. It is observed that as the percentage of admixture (Glass Powder) increases, the specific gravity increases.

Table 4. Variations of Specific Gravity with different percentage of Soil + Glass Powder

Soil + Glass Powder (%)	Specific gravity Gs
100 + 0	2.56
96 + 4	2.60
92 + 8	2.63
88 + 12	2.67

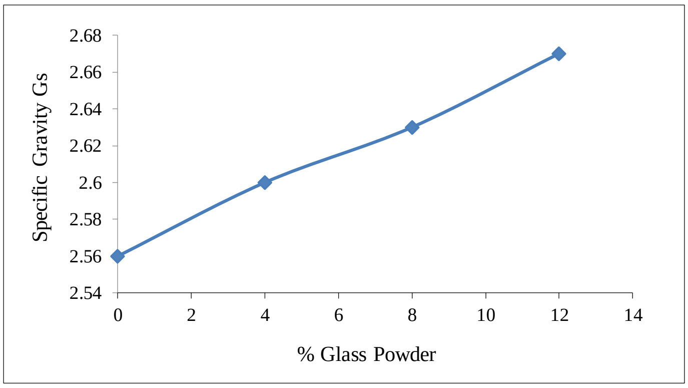

Figure 8. Plot of curve between specific gravity with different percentages of glass

5.5. Direct Shear Test

The variety of shear strength parameters is appeared in figure. With the expansion of admixture (Glass Powder), the cohesion of the soil reductions till 8% of added substance and increments of 12%, while the angle of internal friction increments till 8% of the added substance while decreases of 12%.

Table 5. Variations of Cohesion C and angle of internal friction φ with different percentage of Soil + Glass Powder

Soil + Glass Powder (%)	**Cohesion (N/cm^2)**	**Angle of internal Friction (φ)**
100 + 0	0.08	27.73
96 + 4	0.06	28.50
92 + 8	0.03	31.30
88 + 12	0.07	24.62

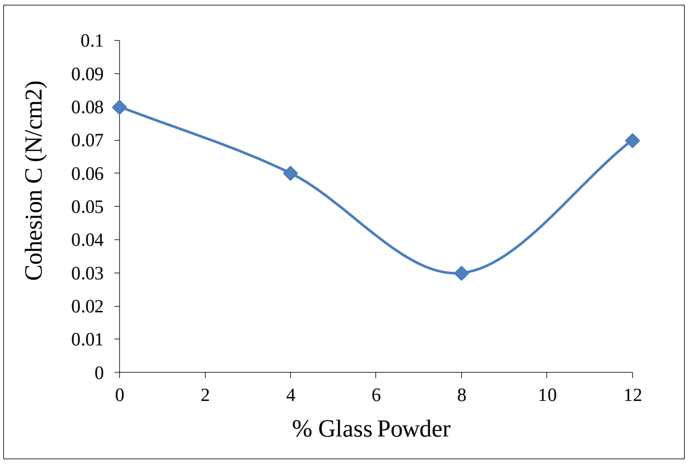

Figure 9. Plot of curve between cohesion C with different percentages of Glass Powder

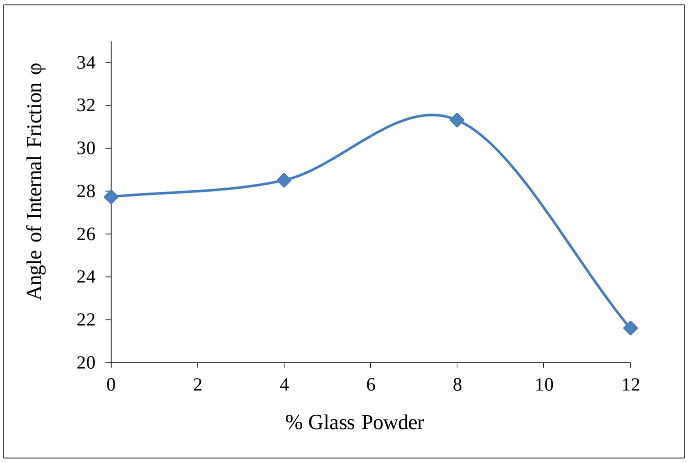

Figure 10. Plot of curve between Angle of internal friction with different percentage of Glass Powder

5.6. California Bearing Ratio

The California bearing ratio value was found to be increased with the increase with the percentage of Glass Powder as shown Figure 11. The improvement in CBR value can be attributed to significant improvement in the angle of shearing resistance.

Table 6. Variations of CBR with different percentage of Soil + Glass Powder

Soil + Glass Powder (%)	CBR (%)
100 + 0	45.10
96 + 4	51.01
92 + 8	56.03
88 + 12	59.61

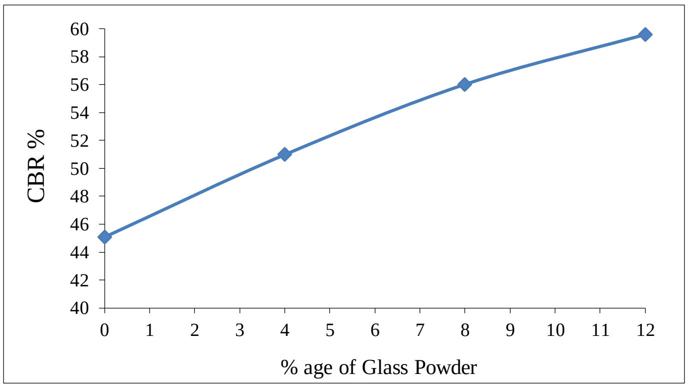

Figure 11. Plot of curve between CBR with different percentage of Glass Powder

6. Conclusion

This investigation has demonstrated that the enhancements in the properties of the subsoil acquired thus are more noteworthy with the expansion of the powdered glass. It appears that the rate amount of the powdered glass required to accomplish the best outcomes in the wording of the earth soil properties lies in the vicinity of 8% by mass of the soil. Moreover, it can be finished up in view of the outcomes acquired that powdered glass can be successfully utilized as a soil stabilizer since it could create impressive changes in the properties. Using waste glass to modify loose subsoil properties has technical, economic and environmental advantages.

- Specific gravity of soil expanded with expansion in glass content while Atterberg limits diminish.
- Angle of internal friction expanded up to 8% of glass powder, however past 8% Glass Powder, it began to diminish.
- For 4% and 8% Glass content, Cohesion began to diminish with increment in Glass content. For 4% and 8% glass content, the lessening in cohesion was 25% and 83.33% separately.

- The CBR expanded with increment in Glass content. The rate increment in CBR was 11.56%, 8.97% and 5.98% to 4%, 8% and 12% Glass content individually.

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