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Soil Stabilization using glass-cement mixture

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Abstract This research investigates the use of waste glass and waste glass-cement mixture as an endeavor to improve the mechanical properties of soil. Crushed glass and glass-cement mixture were added to CH (high plasticity) clay soil at different percentages. The crushed glass was added to the soil at four different percentages (2.5, 5.0, 7.5 and 10.0%) by dry weight of the soil. Remolded specimens from the glass-soil mix were prepared at 95% relative compaction and optimum water content and tested for unconfined compressive strength (UCS). Thereafter, 2.5% of cement was added to all glass-soil mixes investigated and unconfined compressive strength tested. All tests were conducted at three different curing periods (24 hours, 72 hours and 7days). Test results showed that adding 5% of glass had increased the unconfined compressive strength by 48% and decrease thereafter. It was also noticed that the addition of 2.5% cement with 5% glass to the soil helps in increasing the unconfined compressive strength up to more than 100%. Additionally the test results concluded that with increase in curing period, an increment and decrement were noticed in unconfined compressive strength and failure strain of the soil respectively.

1. Introduction

In the recent times, human life have resulted in generation of gigantic quantities of wastes like industrial waste, agricultural waste, vehicular tires, hospital waste, and various wastes from residential homes such as glass, plastic, metallic wastes etc. These materials pose different problems to the environment and main challenges include finding enormous disposing sites to throw them particularly if they are non-biodegradable. Civil engineers have used different waste materials for various purposes like mixing in concrete, stabilizing soils, filling embankments etc. Different types of wastes like fly ash, silica fume, glass waste, shredded tire chips etc. were utilized by geotechnical engineers to improve various engineering properties of soil. The stabilization may be as mechanical stabilization (adding material to the soil) or chemical stabilization (reacts with soil and modifies the properties).

Researchers all around the world have used solid waste in soil stabilization of soil. A study on the use of waste glass with fired clay resulted in significant improvement in physical-mechanical properties [1]. Yadav and Tiwari [2] utilized waste rubber along with cement to reduce the swelling potential of clay soil. In another study, Mahasneh [3] tested the use of the aluminum residue and recycled asphalt in terms of increasing the bearing capacity, dry density, and unconfined shear strength of silty clay soil and found successful. A study by Bairage et al. [4] found that addition of jute fiber not only enhanced the California bearing ratio and unconfined compressive strength, but also reduced the expansion behavior of clay. In a recent research study, mixing clay with wheat husk was found to be successful in improving the shear strength and reducing the expansion of clay [5].

Waste glass is another challenging material that is challenging many scientists around the world in protecting the environment. By volume, glass is considered as one of the top five solid wastes in the world. According to calculations made in 2005, the global glass production was estimated to be around 130 million tons [6]. In one of the reports made in United State of America by Environmental

Protection Agency, the glass waste is around 12.5 million tons that comprises of 5.3% of total waste [7, 8, 9]. A study carried out by Islam et.al. [6] stated that using of waste glass powder in partially replacing the cement helped in increasing the compressive of concrete. Recently, a research indicated that use of soda lime glass powder waste has significant effect on the shear strength of the clayey soil [10]. The main aim of the current research is to investigate the use of waste glass as a sustainable material along with cement to stabilize the clay soil and verify through unconfined compressive strength tests.

2. Experimental program

2.1 Materials used

2.1.1 Clay

To accomplish the objective of current research, clay with highly plasticity (CH) was selected and tested for various physical properties such as specific gravity, gradation, Atterberg's limits, compaction characteristics (optimum moisture content and maximum dry density), and mineralogical composition were obtained in accordance with ASTM (American Standard for Testing and Materials) standard procedures. Soil was classified as CH in as per Unified classification system. For the ease of understanding all physical properties of soil used in this research were included in Table 1, whereas compaction curve can be seen in Figure 1.

Table1 Soil properties

Name of the property	**Value**
Liquid Limit (%)	79
Plastic Limit (%)	26
Plasticity Index (%)	53
$\gamma_{d\ max}$ [kN/m^3]	13.4
W_{op} (%)	35
Sand (%)	11
Silt (%)	25
Clay (%)	64
Activity	86
Specific Gravity (G_s)	2.7
Kaolinite (%)	18.2
Illite (%)	33.2
Montmorillonite (%)	14.1
Chlorite (%)	16.3
Classification (USCS)	CH

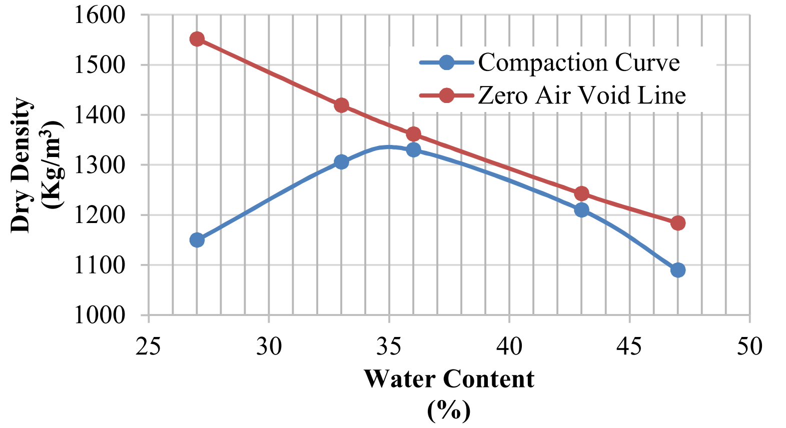

Fig 1 Compaction curve and zero-air void line of clay

2.1.2 Waste glass

Waste glass was crushed manually in the laboratory and the size passing through sieve # 4 was used in the study.

2.1.3 Cement

Ordinary Portland cement (OPC) of 53 grade was used in this study.

2.2 Experimental methodology

Unconfined compressive strength of the soil was used as a tool to measure the improvement in strength characteristics of soil. In each test, continuous readings were taken from start of the test till failure and stress strain curves plotted. Initially samples were prepared by mixing different percentage of waste glass (0, 2.5, 5, 7.5 and 10%) by dry weight of clay and tested at 24hours curing period. Once, the optimum percentage of waste glass is established, 2.5% cement by dry weight of soil was added to all percentages of waste glass mixed samples mentioned above and tested at three different curing periods i.e. 24 hours, 3 days and 7 days.

Irrespective of whether waste glass or waste glass along with cement is added in the soil, all remolded soil specimens of standard size (38mm dia. and 76mm height) were prepared and compacted to 95% of the maximum dry density at optimum moisture content.

3. Results and discussions

Based on the tests conducted, results were plotted and an effort is made to understand the influence of various parameters on unconfined compressive strength of clay.

3.1 Stress-strain characteristics of clay with addition of waste glass

Figure 2 shows stress strain plots at of UCS test conducted on clay samples mixed with different glass percentages (0, 2.5, 5.0, 7.5 and 10%). As seen from the plots, it is evident that the UCS of soil increase from 99.43 kN/m^2 (no glass) to147.38 kN.m^2 (5% glass). This could be attributed to inclusion of inert and stronger material than clay. However, the reduction in UCS with increase in glass beyond 5% is most likely due to more quantity of low friction glass-glass interfaces compared to glass-clay and clay-clay interfaces. Also, it is evident by comparing plots in figure 1 that with increase in glass up to 5%, the initial portion of graph was becoming steep (able to sustain higher stress at a particular strain) and turns to be flatter thereafter. To represent this behaviour clearly, modulus of elasticity was calculated at different percentages of glass tested at 24 hours curing period and shown in figure-3.

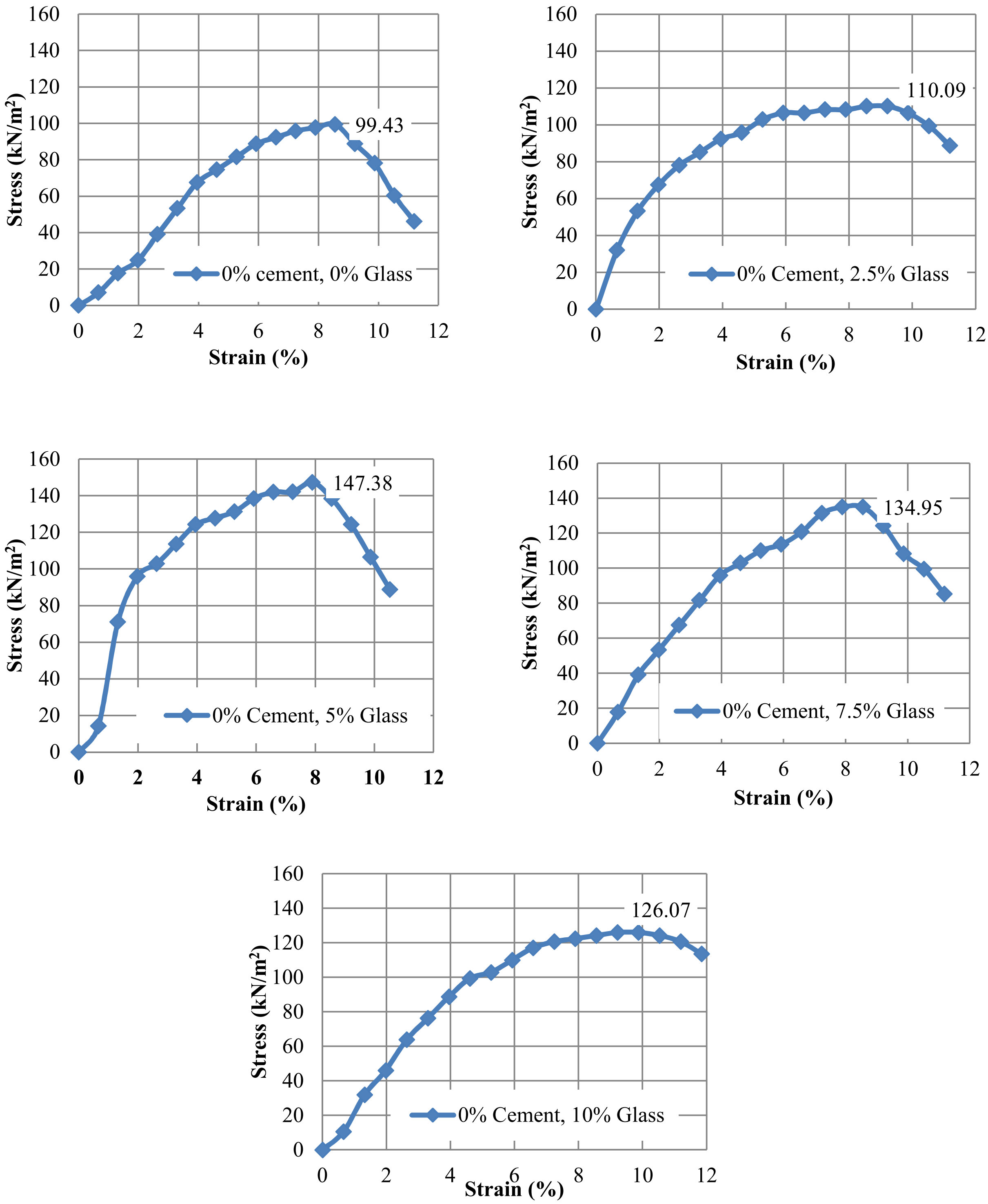

Fig 2 Stress-strain curves of UCS tests on clay with different percentages of glass at 24hours curing period

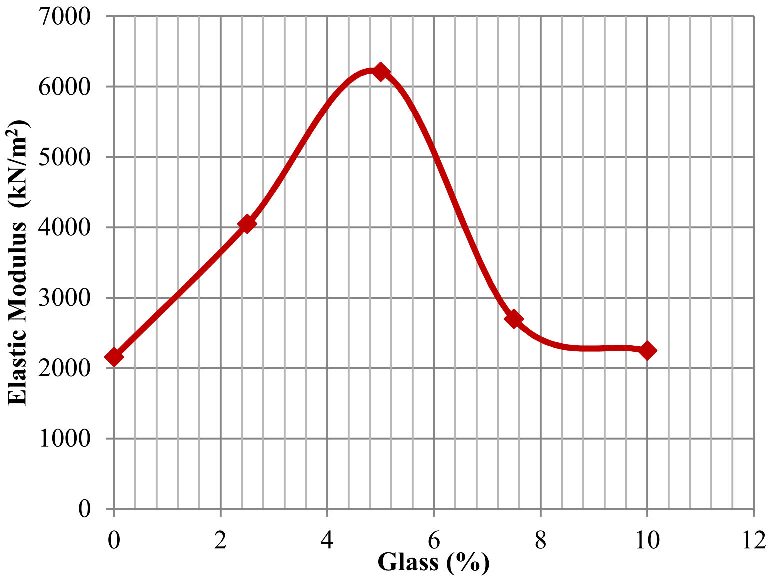

Fig 3 Variation of elastic modulus of clay at 24 hours curing period

3.2 Effect of waste glass addition on UCS of clay (24 hours of curing)

Figure 4 shows the variation of UCS with increase in glass percentage in clay with and without addition of cement. As stated earlier, UCS increased with increase in glass percentage up to 5% and decrease thereafter. Similar trend was noticed when 2.5% cement was added. This is due to the fact that cementitious bonds formed due to hydration process when reacted with water are undoubtedly stronger that inter-particle frictional forces of clay and hence resulted in exhibiting more resistance before the samples failed. Similar behaviour was noticed at all percentages of glass investigated as part of this research.

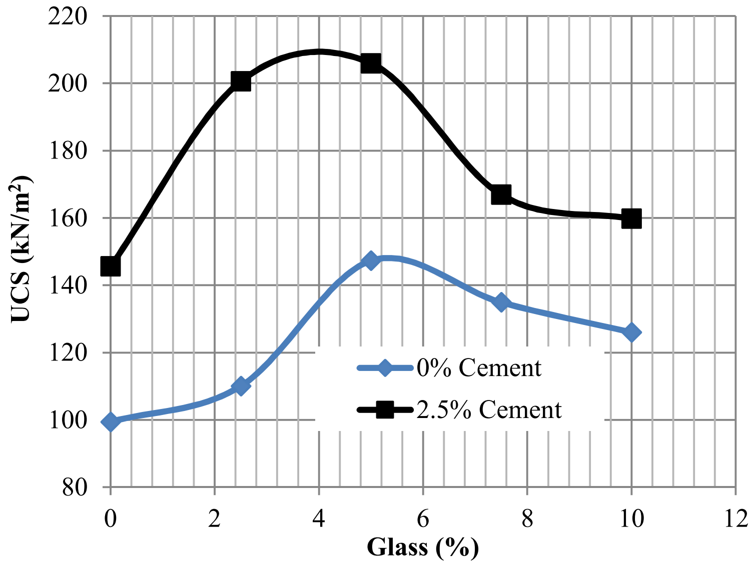

Fig 4 Variation of UCS of clay at 24 hours curing period (with and without addition of cement)

3.3 Effect of waste glass combined with cement on UCS at different curing periods

It can be seen from figure 5 that at 2.5% cement content, with increase in percentage of glass there is an increase in UCS at all curing periods tested. Also, at any percentage of glass, an increase in UCS was noticed with increase in curing period. However, within the curing periods at which samples were tested as part of this research, UCS was found to be increased only till addition of glass up to 5% and declined thereafter.

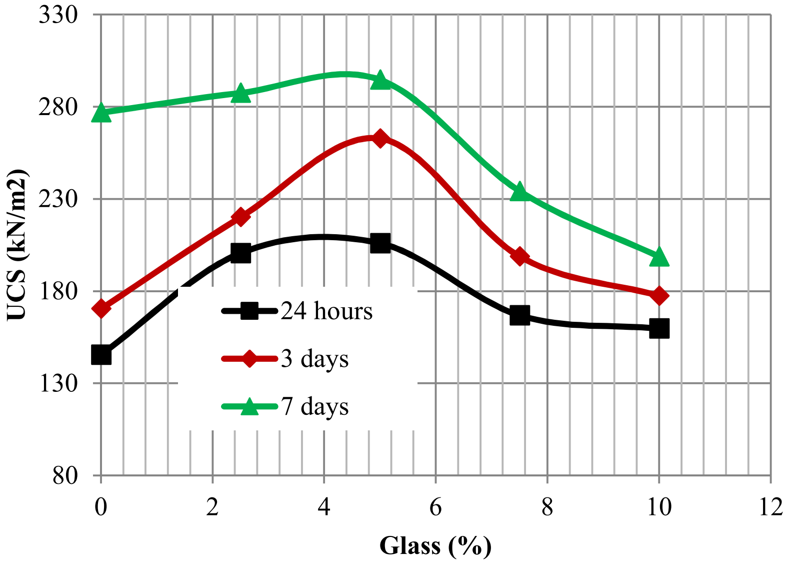

Fig 5 Variation of UCS of clay with 2.5% cement at different curing periods

4. Conclusions

1. UCS of the soil increased with increase in glass up to 5% and reduced thereafter.
2. An increase in elastic modulus was noticed till inclusion of glass up to 5% and reduced subsequently.
3. With the addition of cement, an improvement in UCS was noticed at all glass percentages.
4. Irrespective of percentage of glass added, with the addition of cement, UCS was found to be increased with increase in curing time.

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