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Stabilization of Clay with Waste Soda Lime Glass Powder

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Abstract

This study was carried out with an intention to observe any sign of improvement of clayey soil due to addition of waste soda lime glass powder (WSLGP). Waste soda lime glasses were crushed and sieved through #200 (75 µm) sieve and mixed with clay in 3, 6, 9, and 12% in dry weight of the clay. Strength and consistency test were carried out on mixed samples after curing. The test results indicated that the addition of WSLGP into clay has a significant effect on the strength and consistency properties of the clay.

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*Keywords:*clayey soil, waste soda lime glass powder,soil stabilization;

1. Introduction

Ecological or environmental benefits of alternative materials include (1) the diversion of non-recycled waste from landfills for useful applications, (2) the reduction in the negative effects of producing cement powder, namely the consumption of non-renewable natural resources, (3) the reduction in the use of energy for cement production and (4) the corresponding emission of greenhouse gasses. The economic benefits of using alternative materials were best realized in situations where the cost of the alternative material is less than that of cement powder while providing comparable performance. This cost must consider the source of the alternative material, its transportation, processing, and should consider savings through diversion, such as tipping fees and landfill management costs. The engineering or technical benefits of alternative materials are realized when a specialized use for such material may be developed, such that the use of the alternative material is more desirable than use of concrete made with OPC alone [1]. Hypothetically, glass is a 100 % recyclable material; it can be reused without any loss of quality. According to EPA official statistics [2-3], the municipal solid waste (MSW) stream in the USA contains around 5.3 % of waste glass or 12.5 million tons [2,4-5]. In 2003, just 18.8 % of this sum was reused [3]. 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% [3].

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A lot of research work has been done in the past to improve engineering properties of soil using additives. Fauzi et al. [6] studied the effects of crushed glass waste and plastic high density polyethylene (HDPE) waste as additives in stabilized soil. They concluded that the values of atterberg limit and optimum moisture content reduced, and maximum dry density increased when contents of HDPE waste and glass waste were increased. The values of California bearing ratio and friction angle (φ) increased and cohesion of soil decreased when content of HDPE waste and glass waste increased. Nuruzzaman and Hossain [7] used soda-lime glass dust that was passed through a sieve 300 μm to improve the clay soil. They concluded that the properties of the clay soil were improved by the addition of glass dust by comparing the behaviour of treated and untreated soil. They found that, the maximum dry density values increase with the addition of soda lime glass dust and the optimum moisture content values decrease with the addition of glass dust. The atterberg limits values decrease with the addition of glass dust. In the consolidation test, both values of compression index and swell index decrease with the addition of glass dust, and the UCS values for the soil decrease with the addition of glass dust without curing time. In this study, waste soda lime glass powder passing from sieve No. 200 (75 μm) was used to determine its effectiveness on the clay soil properties.

2. Materials and Methods

The materials used in carrying out this study were clay soil and waste soda lime glass powder. The soil sample was provided from the Bazian district in the city of Sulaymaneyah, in northern Iraq. In order to ensure no confusion with other particle materials, such as agricultural organic materials located on the surface of the soil, for the soil particles taken for the sample, the top surface of untreated soil was removed and the soil was excavated to 1 meter below ground level. The sample was then taken from the soil to be processed for the study. All properties of clay soil sample are shown in Table 2.

Table 1 Summarizes of various properties of soda lime glass [8].

Properites	Value
Silica ($Si0_2$)	74%
Sodium oxide (Na_20)	13%
Lime (CaO)	10.5 %
Alumina (Al_20_3)	1.3%
Another Components accumulate	1.2%
Density at 20°	2.52 g/cm^3
Young's modulus at 20°	72 GPa

Table 2. Some geotechnical properties of the clay used of this study.

Properites	Value
Maximum Dry Density	1.82 g/cm^3
Specific Gravity	2.72 g/cm^3
Optimum Moisture Content	15.25 %
Gravel	0.3 %
Sand	1.5 %
Silt	40.8 %
Clay	57.4 %
Liquid Limit	46.5%
Plastic Limit	28.68%
Plasticity Index	17.82%
CBR	2.5 %
Swelling index	5.5 %
Unconfined compressive strength	239.99 kPa

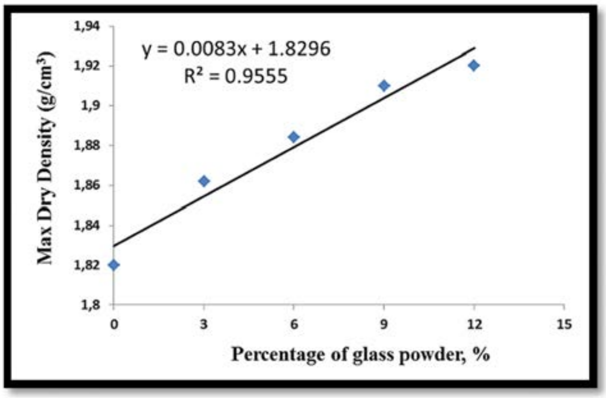
Water used in the experiments was clean and free of any impurities so that was safe to drink and, water temperature was about (25°±2). Glass metal water bottles with a green color available in most markets in Iraq was used for this study. Glass waste was passed through sieve number 200 # (75 μm) obtain glass powder. It was first washed then dried, and broken and crushed manually into powder sizes by use of hammer and mortar. The chemical composition and the physical properties of lime soda glass are shown in Tabe 1. Silica is the main composition of sand which is cohesion less so that the important property to improve the of clay soil. Soda lime glass consists of 10.5 % lime in it. This will supply some additional strength to the treated soil if hydrated. In this investigation, grain size distribution test, specific gravity test, atterberg limit test, compaction test, california bearing ratio test, unconfined compressive strength test and swelling test were performed for the untreated soil sample as well as for treated sample except grain size distribution test which was performed for various percentages of soda lime glass waste mixed with clay soil sample. To identify the maximum dry density and optimum moisture content, standart proctor test was performed. The clay soil mixed with addition of waste soda lime glass powder in varying proportions namely 3 %, 6 %, 9 %, and 12 % of dry weight of clay soil.

3. Test Results and Discussions

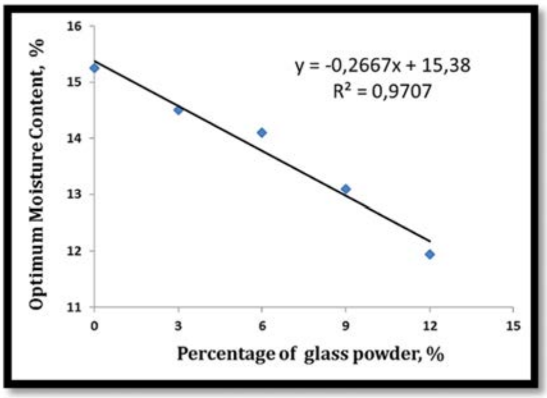
From the analysis of tests results, it was found that the type of the soil sample used was CL (clay of low plasticity) and A-7 according to the unified soil classification system and AASHTO classification, respectively. Table 2 presents the grain size analysis and all basic engineering properties for untreated soil that was used in this study.

3.1. Standart Proctor Tests

This experiment was performed to find the maximum dry density (MDD) and optimum moisture content (OMC) for untreated and treated clay soil. The relationship between maximum dry density and optimum moisture content are shown in Fig.1a-b.



(a)



(b)

Fig.1. (a) Relationship between MDD and percentage of WSLGP, (b) Relationship between OMC with percentage of WSLGP.

According to test results, it has been found that the maximum dry density of soil increased with increases in percentage of soda lime glass powder added. The largest percentage increase in maximum dry density was 5.49 % when 12 % soda lime glass powder was mixed with clay soil. The reason behind this result is that glass density higher than density of clay soil and also involves the fineness of glass powder [7]. In addition, it has been found that the optimum moisture content decreased with increases in percentage of soda lime glass powder added. The largest percentage decrease in optimum moisture content was 21.6 % when 12 % soda lime glass powder was mixed with clay soil. The reason behind this decrease may be that the absorption capability of glass is much less than that of clay soil.

3.2. Atterberg limits test

The atterberg limits tests were carried out in according to ASTM D 4318–93. The test results obtained from the study are show in Fig.2. It is clearly seen that the values of plasticity index for clay soil sample decreased due to increases in percentage of soda lime glass powder added. The largest percentage decrease of plasticity index was to 44.05 % when 12 % from soda lime glass powder was mixed with clay soil. The reason behind this result is that soda lime glass powder is cohesionless [7].

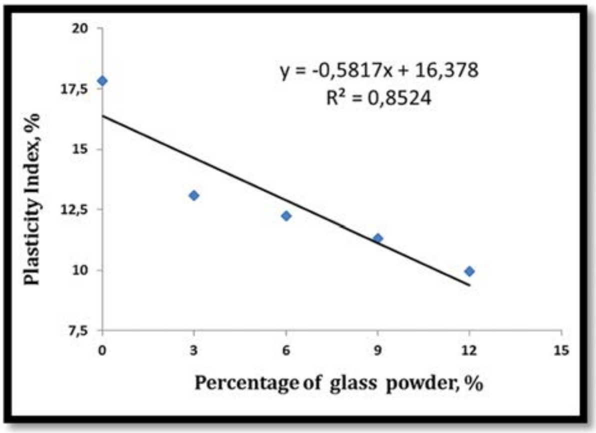


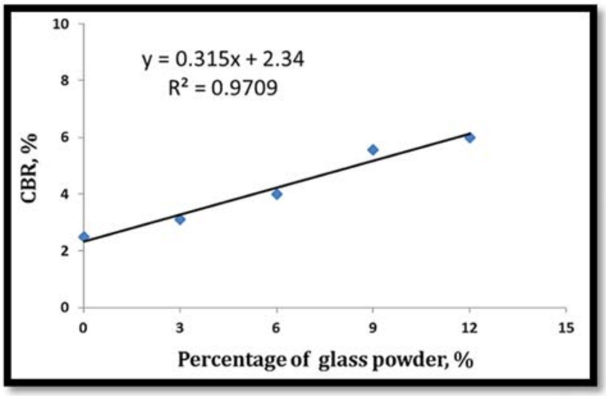
Fig.2. Relationship between plasticity index and percentage of WSLGP.

3.3. California bearing ratio (CBR) test

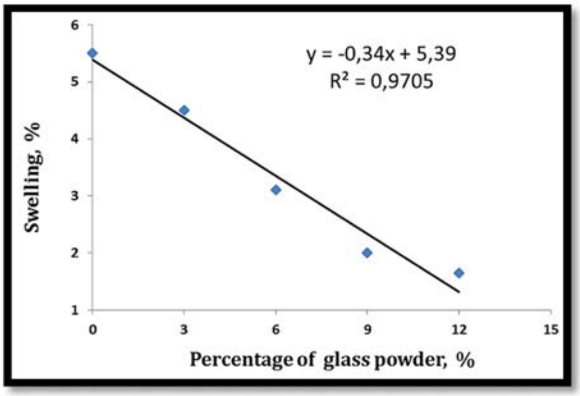
The CBR test was carried out in according to AASHTO T-193 and T-180, all samples were cured in the air for 4 days. From the results are shown in Fig.3a-b, it has been found that the CBR values increased due to increases in percentage of soda lime glass powder added. The largest percentage increases of CBR value was 140 % when clay soil was mixed with 12 % soda lime glass powder. The glass powder can be considered a pozzolanic-cementitious material [9], for this may be it was affected positive in the CBR property. Also from the results, it has been found that the swelling decreased due to increases in percentage of soda lime glass powder added, the non-cohesive property of glass powder reduce this Indicator [7].

3.4. Unconfined compressive strength test

The unconfined compressive strength were carried out in according to ASTM D2166. Three different curing times was used for the mechanical UCS tests. All samples were cured in the air at 3 and 7 days also 28 days curing was applied for the 6% addition. As it is clearly seen from Fig.4, for the 3-days curing time, the values of UCS increased at 3%, 6% and 9% compared with the untreated clay soil. The largest percentage increases of UCS value was 116 % when 6 % soda lime glass powder was mixed with clay soil, but in the 12 % addition, UCS started to decrease by 1.625 %. This decrease may be due to the decrease in adhesive strength between the surface of the waste glass and clay soil [10]. For curing time at 7 days, the values of UCS increased at all percentages of soda lime glass. The largest percentage increase of UCS value was 143 % when 6 % soda lime glass was mixed with clay soil. The test results also showed that curing time has a positive effect in compressive strength. Through a comparison between the curing times and UCS values at 6 %, it was found that the UCS values increases 519 kPa at 3 days, 583 kPa at 7 days and 723 kPa at 28 days.



(a)



(b)

Fig.3. (a) Relationship between CBR and percentage of WSLGP, (b) Relationship between swelling and percentage of WSLGP.

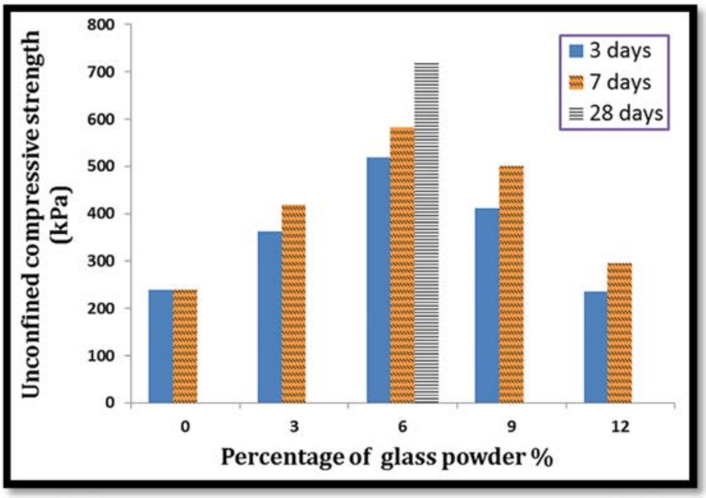


Fig.4. Effect of curing time on unconfined compressive strength of the samples used in this study.

4. Conclusions

According to test results, the conclusions that were extracted from the study were given as following. Soda lime glass powder has an ability to improve the engineering properties of clay soil, and also it has a positive effect on MDD, OMC and atterberg limits. California bearing ratio of clay soil increased when soda lime glass powder increased. The results show that the addition of soda glass powder to clay soil can be used efficiently to reduce the swell potential of soil. An improvement was observed for swelling potential of soil with respect to addition of 12% soda lime glass powder to clay. Swelling value of the clay decreased from 5.5% to 1.65% incorporating with 12% soda lime glass powder. With increasing curing time from 3 to 28 days, the hydration process is increasing between the soil clay particles and glass powder, that's lead to increase the values of unconfined compressive strength of clay.

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