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Comparative Assessment of Using Glass Powder and Aluminum Waste to Improve Unconfined Strength of Clay Soil

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Abstract: ***The soil strength is one of the essential mechanical soil properties that should be studied before constructing any project. This paper compares two clay soil samples, where one was improved by adding glass powder and another by aluminum waste. Each waste material was mixed with soil in varying percentages of 0%, 5%, 10%, and 15%, by the soil's weight, which was added as medium sand aggregate. Therefore, physical and mechanical tests are carried out on the samples. The physical tests showed that the soil classification changes from height plasticity CH to low plasticity CL for both materials at some percentage. The results of compaction tests showed that the addition of glass powder increases the dry densities (γ_d) of the samples, but the increasing rate of added aluminum waste decreases it. The higher amount of dry densities was at the 15% of additive of both materials. Adding glass powder increases the density of standard soil by 8.51%, while aluminum waste decreases it by 0.7%. However, the improvement in the value of the optimal water content (O.M.C) stopped at 10% and 15% of additive materials, respectively. The unconfined compression test showed that the values of unconfined strength U.C. decreased in the case of glass powder additive and increased when aluminum waste additive.***

Keywords: unconfined strength, glass powder, aluminum waste, clay, soil properties

1. Introduction

Clay soil is one of the most available construction materials where found in the green mountain in Libya. However, this soil has many problems after construction, such as low hydraulic conductivity, high consolidation, low shear strength, and subsidence settlement. Therefore, geotechnical engineers have improved this soil to change its behavior by many methods. Adding waste materials is one of these methods that have low costs and reduce its environmental risks. This paper compares the unconfined compression strength of two clay samples, which improves by adding glass powder [1] and non-recyclable aluminum waste

2. Literature Review

Many waste materials have been used and proven effective in soil stabilization, such as fly ash, cement, wood powder, rice straw, glass powder, and other materials ingested on research studies. However, limited studies deal with using aluminum waste as a soil conditioner. (Hanifi Canakcia, 2016) [2] Waste aluminum beverage cans were used to improve the density properties and resistance of swollen soil, while (Matty, 2014) [3] studied using aluminum aslant to improve the resistance properties for paving soil. (Zuheir Karabash, 2015)[4] Studied swell clay soil reinforced with aluminum (Omar Adnan IBRAHIM, 2018) [5] studied the improvement of the equilibrium soils using aluminum slag. On the other hand, many people studied the improvement of soil properties by using glass powder as an additive. (Amrutha Mathew, 2015)[6] Worked to evaluate the effect of sisal fiber bagasse and glass powder on soil's physical and mechanical properties. [7] Improved unconfined compressive strength of soft soil by mixing with lime, cement, fly ash, and glass powder. (Navdeep Singh Sodhi1, 2017) [8] Studied engineering properties of expansive samples which improved by mixing with crushed glass waste. (Achmad Fauzi, 2016)[9] Also studied the effect addition of crushed glass on expansive soil engineering properties. The results were varied in all these research papers and others, between positive results at specific percentages of adding materials and negative or non-appearance improvement at other percentages. Since the soil is a single case for each type separately, the response of the soil to improve or not depends on the kind of waste materials used and the target properties which need to improve.

3. Materials Used

Clayey soil

Two disturbed clay samples were collected from a building site north of Al-Bayda, the central city on the green mountain. Both samples were brought to 30cm from the surface level. Various laboratory tests were done in clay for getting the engineering soil properties according to the specifications (USCS-ASTM.). The results obtained for clay (sample2) that was collected for this study and (sample1) [1] are shown in Table 1.

Glass powder

Glass has been used as an improved alternative material in many engineering fields. Waste glass bottles were collected and used after washing, drying, and grinding those using Los Angeles Abrasion apparatus. A gradient similar to medium and fine sand gradation, which passed through a 2 mm sieve, was used [1].

Aluminum waste

Waste of inert aluminum workshops for recycling (locally) was used as an additive .Waste aluminum was collected from the Bouhadi workshop in Benghazi. After that, the sample was washed and immersed in water to separate the impurities from them and dry it airily. Figure 1 shows the sample used and the stages of its preparation. Various laboratory tests were done on aluminum waste; the results obtained are shown in Table 2**:** Additive materials properties.

Table 1: Soil Properties

	Test	Sample 1	Sample 2
Physical properties	Natural water content	28%	28%
	Total density	1.23g/cm3	1.22g/cm3
	Specific gravity	2.64	2.73
	Liquid limit	54	59
	Plastic limit	32	31
	Plasticity index	22	28
	Soil classification	CH	CH
	Permeability	2.271E-04 cm/min	1.921E-03 cm/min
	Activity	0.48	0.62
Mechanical properties	Maximum dry density	1.41 g/cm3	1.4%
	Optimum water content	26.2%	30%
	Unconfined compression strength	28g/cm2	20.3g/cm2

Table 2: Additive materials properties

Test	Value
Total density	0.33g/cm3
Specific gravity	1.77
Permeability	4.16E-02 cm/sec

Figure 1: Stages of preparation aluminum waste

4. Methodology

The experimental studies were carried in two-phase. The first phase determined typical soil's physical and mechanical properties such as particle size distribution, specific gravity, consistency limits, permeability, compaction, and unconfined pressure strength. In the second phase, various tests were performed on clay soil using different proportions of glass powder [1] and aluminum waste. The selected contents of aluminum waste were (5%, 10%, and 15%) by dry weight of the sample, which was as additive of glass powder. All the tests were conducted as (ASTM) classification.

Experimental and Results

All the samples of clay soil used in the laboratory tests were dried airily and then mixed with dry glass powder and aluminum waste.

Consistency Limits Tests ASTM (D2487, D3148, D217)

To determine the liquid limit of mixed soil with aluminum waste, the fall cone test was used; due to the inability of the Casagrande device to find it. The results were illustrated in Table **3:** Results of consistency limit for both additives.

Table 3: Results of consistency limit

Material used	% of additive	LL%	PL %	PI %	Classification
Glass Powder	0	54	32	22	CH
	5	53.5	31.54	21.96	CH
	10	47	31	16	CL
	15	48	30	18	CL
Aluminium waste	0	59	31	28	CH

Material used	% of additive	LL%	PL %	PI %	Classification
Glass Powder	0	54	32	22	CH
	5	53.5	31.54	21.96	CH
	10	47	31	16	CL
	5	58.4	31	27.4	CH
	10	58	32	26	CH
	15	54	30	24	CL

Compaction Test (ASTM-D698, ASTM-D1557)

The standard Proctor's test has been conducted for the determination of the maximum dry density (ϒd) and optimum moisture content (O.M.C %) of standard clay samples and mixed soil with glass powder [9] and aluminum waste. The results are shown in Figure 2 and Figure 3.

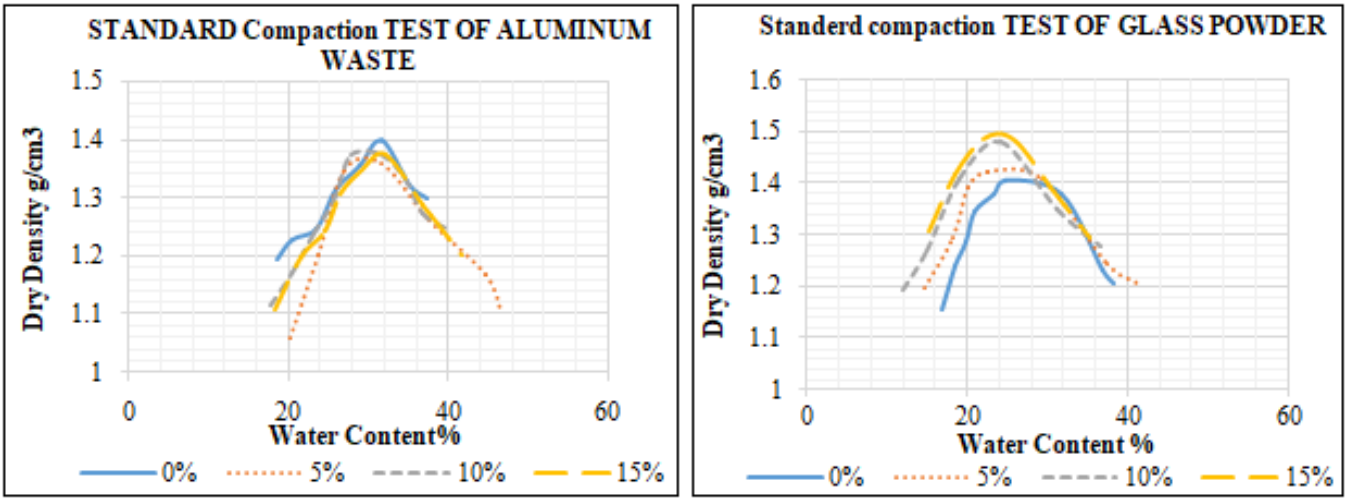

Figure 2: The properties of compaction curve

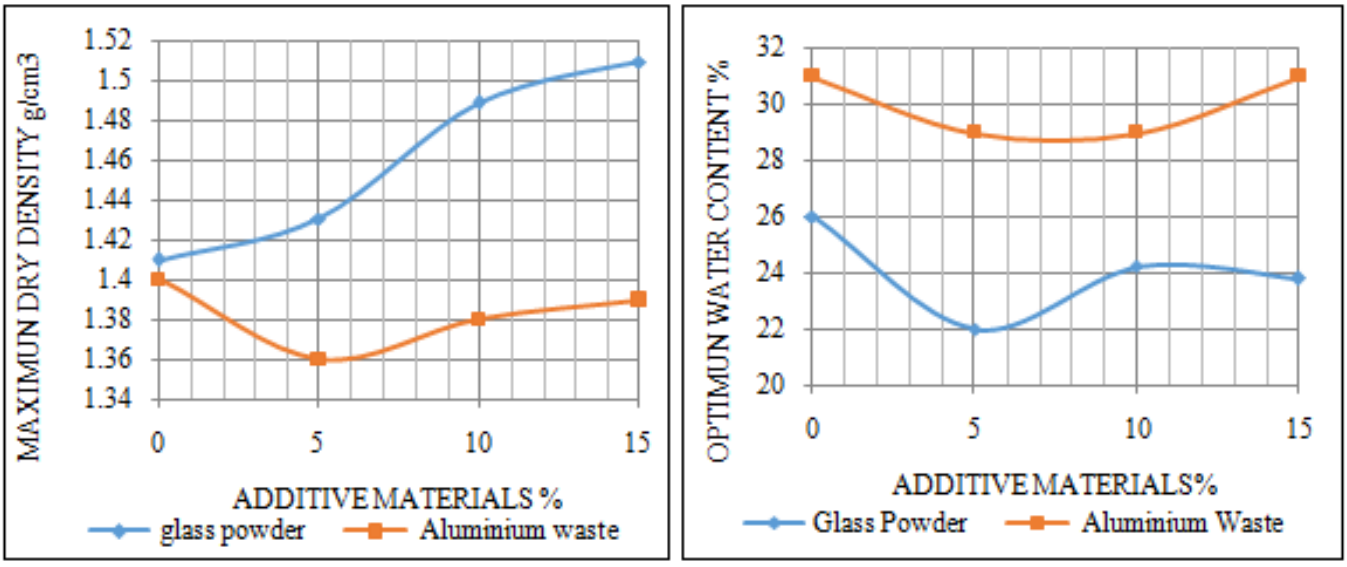

Figure 3: The relation between compaction properties and additive materials

The results of compaction tests showed that glass powder gradually increased the values of the dry density of the soil with the percentages of addition [1], while the aluminum residues led to a decrease. The maximum dry density was at 15% for both materials, which increased by 8.51% of glass powder and decreased by 0.7 of aluminum waste. On the other hand, the best results of O.M.C were at 10% of additive of glass powder and at 15% of the addition of aluminum waste, which remained the same as the natural soil.

Unconfined Compression Test (ASTM-D2435)

Strength is an essential engineering property based on the design of the foundation. Samples of standard and improved soil are prepared by taking clay soil which passes through a sieve 4.7 5mm, then water is added [10]. The water content used is the optimum water content obtained by laboratory standard protect test [11]. Then, the samples are tested after sixty days in two different cases: the wet case where samples are kept in an airtight bag and the dry case where samples

are dried in the air. The results of various tests are shown in Figure 4.

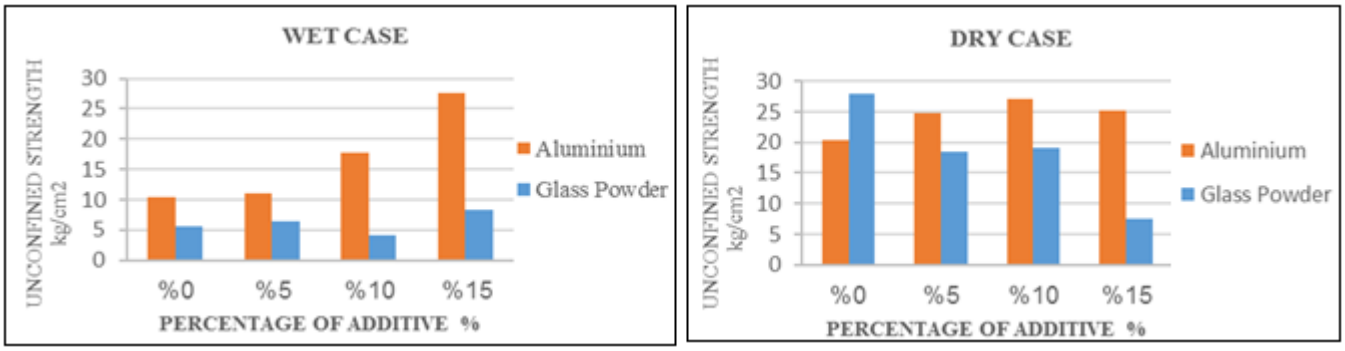

Figure 4: The results of unconfined compression test in both cases

Data presented in figure 4 bring out that the UC strength of soil increase in glass powder and as well as, in aluminum waste in wet case. The strength of 15% presented the best results, which is increased by 50% of glass powder and 164% of aluminum waste of normal soil. However, it can be observed that, dry case is not much positive effective in improving the strength of glass powder when compared to aluminum waste. Hence, increase in glass powder showed decrease in strength while increase in aluminum waste showed increase in strength. The strength of 10% illustrated high percentage of improving which decreased by 31%of glass powder and increased by 33% of aluminum waste of normal strength.

5. Discussion

The additive materials improved the consistency of the soil and changed its classification. The classification changed from (CH) to (CL) due to additive materials decreased liquid limit. Therefore, glass powder decreased void ratio and chancing of water penetrating into the improved soil particles decreases with an increase in additive of aluminum Waste. The maximum dry density increased of glass powder, because it consists of sand (sica) by up to 80%that remains in the soil for long periods and decomposes similarly to natural rocks .Glass powder helps to fill the void and increase the cohesion between the soil particles, on the other hand, it reduced friction between the particles, which affected negatively at unconfined compression strength. Aluminum is a lightweight material that decreases density and specific gravity of the soil, so it affected negatively the properties of compaction. At the same time, aluminum increased the percentage of friction between the grains, which had a positive effect on the unconfined compression strength in dry case. In wet case, aluminum decreased water adsorption and increasing water resistance, which lead to increase of unconfined compression [3].

6. Conclusion

This study presents the characteristics of clayey soil improved with randomly distributed glass powder and Aluminum waste as waste materials in improving soil. Unconfined strength of stabilized soil in two different conditions was investigated in this study. Based on the lab experimental results, the following conclusion can be drawn:

1) Both materials enhance competences properties of clayey soil which changed it of CH to CL.
2) The maximum dry density increased and O.W.C decreased with glass powder, on the other hand, the maximum dry density decreased and O.W.C increased with aluminum waste .Both materials had affected on the weight of mixed soil and absorption of water.
3) The increase in glass powder lead to decrease on compression strength in dry case, but it increased in wet case .The optimum values were at 15% of dry and wet case. By adding aluminum waste, unconfined compressive strength increases in both cases. The best results were at 10% and 15% of additive aluminum in dry and wet case respectively. This improving because both materials had affected on friction strength and water resistance.
4) This study improve that the glass powder and aluminum waste had positively and negatively influence on soil properties, so both materials need to add chemical materials which treatment negative affected.

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