PACE-2021
International Congress on the
Phenomenological Aspects of Civil Engineering
Research Article 20-23 June 2021

Effect of Thermal Properties on Strength in High Plastic Clay Soils Reinforced with Waste Glass Bottle Powder

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Keywords

Clay soil,
Glass bottle powder, Strength,
Thermal properties, Degrees.

Abstract

Today, waste/residual materials pose an extremely serious danger to the ecosystem. Such materials are widely used in a wide variety of engineering applications to reduce the negative effects of these waste/residual materials. In recent decades, researchers working on this issue, especially in geotechnical engineering, have started to use these waste/residual materials in soil improvement applications. In this study, the strength and thermal effect on cohesive soils reinforced with waste glass bottle powder (GP) were investigated. Clay soil (CS) mixed with GP at 5%, 10%, and 15% was compacted at optimum water content using standard proctor test. Mixture samples were cured for 7, 14, and 28 days. CS samples reinforced with GP were subjected to a series of unconfined compressive strengths after heating at three different temperatures (50, 80, and 110 degrees). From the experimental results obtained, the highest strength; was obtained in the CS+15 GP mixture for 28 days of curing and at 80 degrees heating temperature

1.Introduction

Soil improvement is defined as the improvement of the physical and mechanical properties (strength, bearing capacity, settlement, swelling, and deformations, etc.) of the soil by mixing various additives. The use of natural, synthetic, or various chemicals as additives in soil stabilization/reinforcement has increased significantly in the last decade. Clay soil, which are called common and problematic soil, are mixed with various waste or residual materials reinforcement works are continuing at an increasing pace. Today, many studies are ongoing on the effects of fine and coarse-grained soils on geotechnical properties reinforced with these waste or residual additives (Prabakar and Sridhar, 2002; Akbulut et al., 2007; Yarbaşı et al., 2007; Hejazi et al., 2012; Maliakal and Thiyyakkandi, 2012; Yarbasi, 2019; Kalkan, 2020; Kalkan et al., 2020; Yarbasi, 2020; Yarbasi and Kalkan, 2020). These wastes are now defined as raw materials.

Due to the increase in the world population and the change in consumption habits, our natural resources are decreasing day by day. Due to the rapid increase in consumption and the threat of running out of resources, the recycling system has been emphasized recently. The situation is not different in our country. Parallel to the population growth, the increase in the amount of waste and the use of packaged products has made recycling an economic value (CEVKO, 2021).

Since waste glass is not biodegradable, they occupy a large amount of space in landfills. It also causes serious environmental problems such as air, water and soil pollution. One of the best ways to reduce environmental impacts is to recycle and reuse waste glass. Recycling ensures the protection of natural resources, the reduction of storage areas, and the conservation of energy and resources (Asaga et al., 2006; Mahmutluoglu and Bagriacik, 2020). In addition to the recycling sector, waste glass is also used as construction material, decorative material, concrete raw material, asphalt material, filter material, ceramic and brick raw material, additive material in metal casting industry, filling material in paint and plastic (Yurtsever Kara, 2002).

Various studies have been carried out on the properties, modification, and thermal effects of waste glass bottle powder. Asaga et al. (2006) examined the effect of waste bottle glass powder on the hydration process, strength development and pore structure of the hardened cement. As a result; They determined that the waste bottle glass powder has a pozzolanic reactivity, the compressive strength increases with the pozzolanic reaction of the glass and the pore size of the mixture decreases (Asaga et al., 2006).

Ustunkol and Turabi (2009) investigated the usability of various industrial wastes and glass powders as filler materials in asphalt concrete pavement mixtures at values ranging from 7% to 0%. It has been shown that void ratio and stability values are increasing in all industrial wastes except glass powder waste, while yielding values are decreasing (Ustunkol and Turabi, 2009). Khmiri et al. (2012) found that the use of 20% waste glass in cement gave optimum values in terms of durability (permanence).

Mahmutluoglu and Bagrıacik (2020) investigated the effect of glass waste sludge and cement on the strength and consolidation parameters of clayey soil under freeze-thaw behavior. It was observed that the clayey soil became more stable, the strength parameters of the soil increased, and the consolidation behavior improved with the addition of glass waste sludge under the freeze-thaw effect. In addition, it was observed that these improvements increased with the addition of cement (Mahmutluoglu and Bagriacik, 2020).

Ahmadi et al. (2021) investigated the effect of simultaneous use of glass fiber and nano-SiO_2 on the strength properties of low plasticity clay (CL) under various thermal cycles. In the results obtained, they determined that the compressive strength (UCS) of 1.0% nano-SiO_2 and 2.5% glass fiber and clay mixture increased from 0.717 MPa to 1.381 MPa after 12 thermal cycles (Ahmadi et al., 2021).

In this study, the effect of glass bottle powder, which is used to strengthen the geotechnical properties of clayey soils and used as a waste material, on the strength and thermal properties was investigated.

2. Material

2.1. CS

The CS samples used in this study were obtained from the deposits of the Oltu Oligocene sedimentary basin, Erzurum, Northeast Turkey. This soil with green color and high plasticity ise over-consolidated and it has clayey-rock characteristics in natural conditions (Kalkan and Bayraktutan, 2008). The CS sample and its granulometry curve are shown in Fig. 1, and its physical and mechanical properties are shown in Table 1.

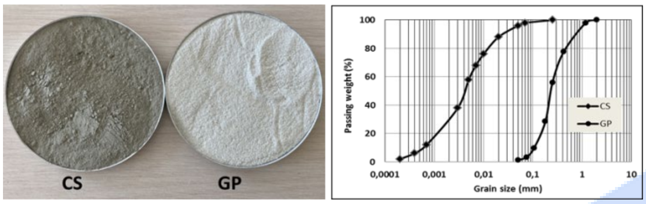

Figure 1. Photos and granulometry curves of CS and GP

2.2. GP

Waste glass bottles were obtained from waste material collection containers created in Erzurum (Turkey) center and its surroundings. After washing with pressurized water and drying in order to avoid any residual material in the glass bottles, it was ground in the etching device at 6000 revolutions. In the elemental analyzes of the waste glass bottles that were ground into powder, Oxygen 44.53%, Sodium 9.94%, Magnesium 1.61%, Aluminum 1.46%, Silicon 33.93%, and calcium 8.53%. Analyzes were made at Atatürk University Central Laboratories (DAYTAM). Waste glass bottle milled samples and granulometry curve are shown in Fig. 1.

Table 1. Physical and mechanical properties of CS (Kalkan and Bayraktutan, 2008)

Characteristics	CS
Specific weight, Gs	2.64
Sand (%)	10.0
Silty (%)	58.0
Clay (%)	32.0
LL, %	68
PL, %	28
PI, %	40
[1]Optimum water amount, %	25.8
[1]Max. dry weight, (kN/m^3)	14.1
[2]Soil category	CH

[1]Obtained from Standard Proctor Test.
[2]Soil class according to Unified Soil Classification System (USCS).

3. Experimental Procedure

In this study, the strength changes of GP reinforced CS as soil improvement methods under the thermal influence were investigated. GP was added at 5%, 10% and 15% based on the dry weight of the base material CS. Mixture samples were first compressed at optimum water content (ASTM D. 698-78, 2012) with the Standard Proctor Test, then cylindrical samples with a diameter of 3.5 cm and a height of 7.0 cm were formed with samplers. Mixing ratios are 100% CS (MIX0), 95% CS + 5% GP (MIX1), 90% CS + 10% GP (MIX2), and 85% CS + 15% GP (MIX3). After determining the optimum water content of the mixtures with the Standard Proctor Test, a work program was planned to determine the unconfined compressive strength (ASTM D 2166, 2006) under the influence of three different temperatures (50, 80 and 110 degrees). Mixtures of MIX0, MIX1, MIX2 and MIX3 were cured for 7, 14 and 28 days in a humid laboratory environment at 50 ± 5 °C. For the consistency of the results, 3 (three) samples were prepared for each mixture and the arithmetic average of the results was taken. Unconfined compressive strength values were determined at a constant loading speed of 0.5 mm/min.

4. Experimental results

The strength values of CS specimens equipped with GP at three different temperatures (50, 80 and 110 degrees) were determined with an unconfined pressure tester. The strength values of MIX1, MIX2 and MIX3 mixtures were determined after the mixture samples dried in the laboratory were heated at three different temperatures for 7, 14 and 28 days. The highest strength value was observed in the MIX3 mixture samples, which were heated at 80 degrees after curing for 28 days. When these values are compared with the reference material CS; increases were determined as 32.46%, 36.18% and 22.18%, respectively (Figure 2). Examples and fracture patterns of the examined specimens are shown in Figure 3.

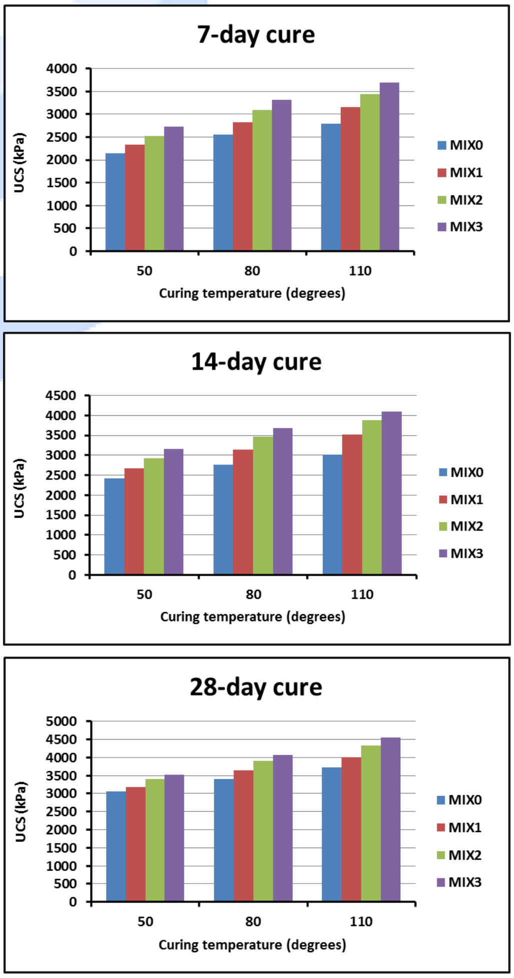

Figure 2. UCS distribution

Fig. 3. Examples of studied samples and fracture patterns

5. Conclusions

In this study, the effect of strength at three different temperatures (50, 80, 110 degrees) on CS reinforced with GP, which is a waste material, was investigated. As a result of experimental studies, it was determined that GP additive increased the strength of CS at three different temperatures. Curing time and increase in GP additive rate played an important role in this increase. The highest strength increase was seen in the CS+15 GP (MIX3) mixture at 80 degrees Celsius and 28 days of curing. The strength increase rate in this mixture was 36.18%. As a result, GP offers many advantages such as increased strength, lower cost, and environmental impact. Therefore, it is concluded that GP can be used as a sustainable and environmentally friendly material that reduces stabilization costs.

Acknowledgements

This experimental research was supported by the Scientific Research Project of Ataturk University with the ID number of 9229 code of FHD-2021-9229. So, the authors thank the authorities of the Ataturk University for the support.

Declaration of Conflict of Interests

There are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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