# Construction of recycled glass powder based geopolymer and its application in resistance parameters to stabilize the clay

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## ABSTRACT

**Glass powder is one of the increasing solid wastes in the world, and on the other hand, clay usually needs improvement to use in construction projects. In the present study, modification of clay soil strength parameters was studied by geopolymer based on recycled glass powder (RGP). For this purpose, uniaxial strength (UCS) and California load Bearing Ratio (CBR) tests were performed on the modified specimens. Processing time, weight percentage of used-RGP and activator concentration (M) were the studied variables in current study. For comparison, experiments were performed on samples modified with 10% Portland cement. Addition of the geopolymer to soil samples showed that 9% of RGP was the optimal amount. Also, despite of the 0day samples in the CBR experiment other UCS and CBR samples had the optimal amount of activator concentration (NAOH), which indicate the effect of processing conditions on the behavior of the modified soil. The assessed scanning electron imaging (SEM) images showed the effect of the corrective method on soil mass. Analytical comparison of UCS and CBR experiments indicated a mathematical relationship between the results of UCS and CBR-7day experiments associated by a good relative correlation that was predictable due to the same storage conditions of the samples in the first 7 days. Due to the different processing conditions of both tests in the first 7 days a slight correlation was observed in the results of UCS and CBR-0day tests.**

## KEYWORDS

**Geopolymer, Recycled Glass Powder, Clay Stabilization, California Bearing Ratio.**

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## 1. Introduction

Most problematic soils as the bedrock of development projects need to be improved. Portland cement and lime are traditional common options for stabilizing such soils in geotechnical engineering, however the use of mentioned materials has polluted the environment. For each ton of produced cement, is achieved one ton of carbon dioxide approximately; therefore, it has been considered as one of the most polluting industries [1]. Waste glass is also a challenge for waste management systems worldwide [2]. One of the best alternatives to Portland cement is geopolymers. Arulrajah et al., reported the positive effect of coal ash on UCS and CBR of soils with high organic matter [3]. An increased CBR was observed by Binal., through adding coal ash to fine-grained soil with high plasticity [4]. In other study, rice husk ash and cement kiln dust mixed by the clay improved the uniaxial strength and CBR quantity [5]. The uniaxial strength of glass powder-modified specimens was also measured and reported optimal values for both variables glass powder percentage and the activator concentration [6]. Dungca et al. illustrated that sludge soil modification by fly-ash was improved and both UCS and CBR parameters were increased using this geopolymer subsequently [7]. Sagathiya et al. Investigated the inflatable soils modified with cement kiln dust and observed the optimal amount of cement kiln dust consumption for CBR parameters [8]. Accordingly, present study aimed to investigate the effect of using RGP-based geopolymer on clay improvement. The experiments in this study included UCS, CBR, and some microstructural experiments.

## 2. Materials

### 2. 1. Soil

The used soil in this study was classified into clay with low pasty (CL) based on the soil classification system [9]. The results of standard compaction test showed that the optimal soil moisture and the maximum specific gravity was 14% and 1.368 gr/cm respectively.

### 2. 2. Glass powder

Recycled glass powder (RGP) was collected from the city then powdered and sieved in the laboratory.

### 2. 3. Activator substance

In this study, sodium hydroxide (NaOH) with 98% purity was used to make the activator. Since, sodium hydroxide dissolving in water raises the temperature, the alkaline solution was prepared the day before.

## 3. Methodology

All samples were made with the results of density test. To make the samples, specific amounts of dry soil and glass powder were mixed with different weight ratios of RGP to dry soil (1, 3, 9, 15 and 21 wt. %) for at least 2 min. The activator solution with different concentrations (1, 3, 5 and 7 M) was added to the soil and RGP mixture; then was kneaded for at least 10 min. The obtained mixture was concentrated in 3 layers inside the mold. Unmodified soil as a control sample (Soil) and 10% Portland cement modified samples (S-OPC10) were prepared by the same method. The compacted UCS specimens were placed at room temperature for 7, 28, and 90 days, afterwards tested for uniaxial compressive strength. For the CBR test, a series of samples were placed in a pond for 96 hours immediately after constructing and identified as 0 day; the second series were first placed at room temperature for 7 days then in a basin for 96 hours which identified as the 7day.

## 4. Results

Comparison of the uniaxial experiments results showed that, soil modification by geopolymer increased the resistance generally. According to Figure 1, the trend of increased resistance has an optimal value (RGP = 15%) by increasing the percentage of recycled glass powder in a constant molarity of the active ingredient. For example, M3G15 samples showed 34, 38 and 40 times higher resistance at 7, 28 and 90 days, respectively; as well as, they were 7, 5 and 4 times higher resistant compared to the S-OPC10 samples.

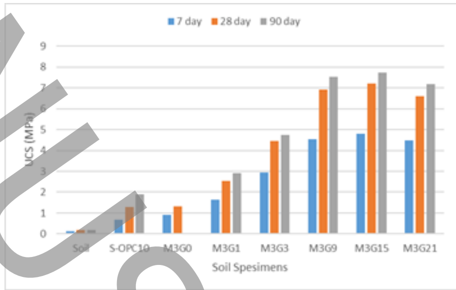


**Figure 1: Uniaxial strength of unstabilized soil, soil stabilized with 10% cement and soil stabilized with geopolymer (3 M caustic soda)**

As shown in Figure 2, the optimal molarity of the activating agent is 3% (M = M3). This trend was expected according to previous studies [6].

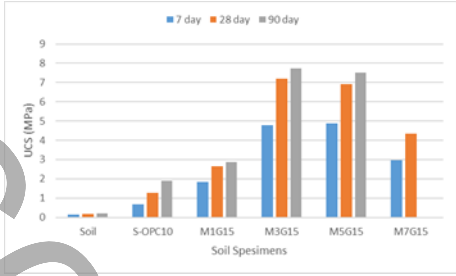


**Figure 2: Uniaxial strength of unstabilized soil, soil stabilized with 10% cement and soil stabilized with geopolymer (15% RGP)**

A CBR number equal to 3, was obtained in the laboratory for the studied soil. A 6.9-fold increase in CBR was observed for 0day samples compared to soil samples, which was greater than a 6.3-fold increase in 7day samples. Increased California load ratio of S-OPC10 models was 4.4 times compared to the Soil models. These values indicate that geopolymer is more effective in modifying soil CBR than Portland cement. Owing to that the CBR value equal to 5, is an important limit for using substrate materials in road pavement design [8]. According to Figures 3 and 4, the optimal value for the recycled glass powder was observed 15% in both series of 0day and 7day samples.

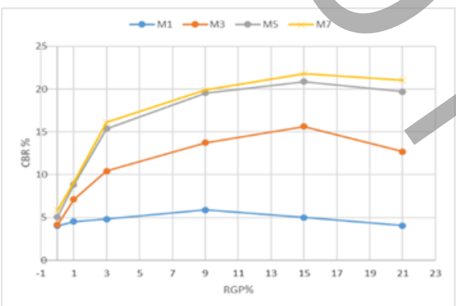


**Figure 3: Changes in CBR values versus changes in RGP percentage for 0day samples**

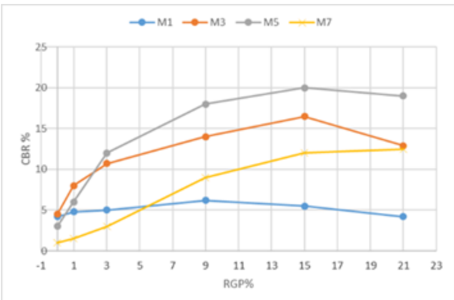


**Figure 4: Changes in CBR values versus changes in RGP percentage for 7day samples**

increasing the activator concentration for 0day samples resulted to the increased trend of CBR values with decreasing slope. However the optimal value rang for 7day samples was 3 (M = 3) to 5 (M = 5). While for UCS samples the optimal value of the activator concentration is 3 (M = 3).

## 5. Conclusions

Addition of RGP to soil, increased uniaxial compressive strength. The weight percentage of glass powder showed an optimal amount (15%).

Added RGP to the soil increased CBR in both 0day and 7day processing conditions. The highest increase in CBR occurred in the weight percentage of 15% of RGP.

The effect of activator concentration on increasing CBR showed two completely different trends for 0day and 7day samples.

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