Comparing the Effects of two alkaline activators of Sodium Hydroxide and Calcium Carbide Residue on geopolymeric stabilization of clay soils

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ABSTRACT

Nowadays, the ordinary Portland cement (OPC) industry causes to extensive environmental consequences due to consuming huge amounts of fossil fuels. This necessitated researchers to introduce a novel group of binders called "Geopolymer cements" or "Green cements" with higher performance and lower pollution compared to the OPC. Thus, in this research, the effect of using two types of alkaline activators such as sodium hydroxide (NaOH) and calcium carbide residue (CCR), for stabilization of clay soil (CL) has been investigated. Initially, the chemical compositions of soil, recycled glass powder, calcium carbide residue, and sodium hydroxide were obtained via X-ray fluorescence (XRF) test. Then, the mechanical behavior of different unstabilized, geopolymer-stabilized, and OPC-stabilized samples has studied using unconfined compressive strength (UCS) test. The effects of several parameters such as the type and concentration of alkaline activators and the curing times (7, 28, and 91 days on the UCS and failure strain of samples have been assessed. Moreover, in order to studying the microstructure of samples, the scanning electron microscope (SEM) images and energy dispersive X-ray (EDX) analysis of selected samples have been used. Results showed the effective stabilization of soil geopolymer, using both alkaline activators. However, the CCR will be more appropriate if environmental and economic problems considered.

KEYWORDS

Alkaline activator, Calcium carbide residue, Sodium hydroxide, Recycled glass powder, geopolymer.

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Introduction

Production of cement products is more than 10 billion tons a year globally [1]. Energy consumption for production of OPC is too high which causes rising of production costs and increases the pollution of this industry too much. Several researches showed that production of one tone cement leads to a production of about one ton of CO_2. Therefore, the cement industry owns 7% of CO_2 produced by human [2]. Notice that CO_2 has the most effect on production of greenhouse gases. One of the best alternatives for OPC is using geopolymers. Geopolymeric cement or green cement is a combination of natural geologic materials, silicate and alumina that addition of alkaline activators to them results in geopolymerization and hence it is called geopolymer. These materials have been introduced by a French researcher Davidovits for the first time in 1972 [3]. Many researches have been conducted in recent years about applicability of geopolymeric cements for improving soils; the results showed high efficiency of these materials to improve strength behaviors of problematic soils [4-5]

Notice that the type and amount of precursor are highly effective on strength, physical and chemical properties of geopolymeric products [6-7]. Another factor effective on behavior of geopolymers is the type of alkaline activator. Commonly, materials such as SH, SH-Na_2SiO_3, KOH and in some cases CCR are used to provide alkaline activator. These materials have high pH and they can provide an appropriate alkaline environment for dissolving aluminosilicate particles when dissolved in water [8]. The SH and CCR alkaline solvents have been used in the present research to provide SH-RGP and CCR-RGP geopolymers respectively. The UCS test was conducted to measure compressive strength of specimens. Moreover, the effect of parameters such as alkaline activator, curing times (7, 28 & 91 days) on UCS and failure strain of the specimens was studied. In addition, the images of SEM and analysis of EDX were used for infrastructural study of the specimens.

Test materials and methods

Main materials used in this study are as follow:

- Clay soil with low-Plasticity (CL)
- Calcium carbide residue (CCR)
- Sodium hydroxide (SH)
- Recycled glass powder (RGP)

Two types of alkaline solutions used in the present research to make geopolymeric specimens: A: NaOH and B: CCR. The evaluation criterion of mechanic properties of the stabilized soil in the present paper is the UCS test. Cylindrical specimens of 76mm height and 37mm diameter made by separable metal molds were used in this research. At first, the soil specimens were prepared using specific ratios of soil-RGP or soil-OPC according to table 3. Then, alkaline solutions A and B, prepared by specific concentration, added to the specimens. Percentages of RGP and OPC in addition to concentration of alkaline solvents with naming conditions for each specimen are presented in table 1. Three different times (7, 28 & 91 days) were selected for curing the specimens.

Table 1. Name and specification of the specimens

Specimens	CCR (%)	SH (Molar)	RGP (%)	OPC (%)	Curing Time(day)
Soil(control1)	0	0	0	0	7, 28, 91
S-OPC5(control2)	0	0	0	5	7, 28, 91
M1G9	0	1	9	0	7, 28, 91
M2G9	0	2	9	0	7, 28, 91
M3G9	0	3	9	0	7, 28, 91
M4G9	0	4	9	0	7, 28, 91
M5G9	0	5	9	0	7, 28, 91
M6G9	0	6	9	0	7, 28, 91
M7G9	0	7	9	0	7, 28, 91
M8G9	0	8	9	0	7, 28, 91
C0G9	0	0	9	0	7, 28, 91
C4G9	4	0	9	0	7, 28, 91
C7G9	7	0	9	0	7, 28, 91
C10G9	10	0	9	0	7, 28, 91
C13G9	13	0	9	0	7, 28, 91

After curing time, the UCS test was conducted on all control and stabilized specimens according to ASTM D2166-87 standards and the UCS and failure strain (ε_f) of the specimens were measured [9].

Results and discussion

The effect of increasing NaOH concentration on UCS and failure strain of the specimens stabilized by SH-RGP are shown in Figures 1 and 2 respectively.

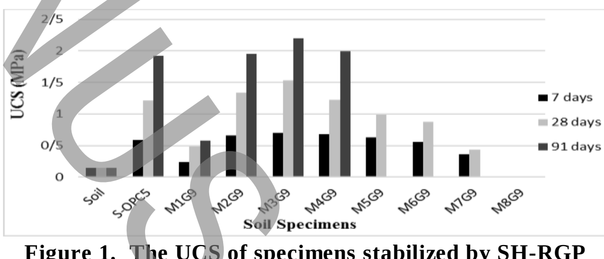

Figure 1. The UCS of specimens stabilized by SH-RGP

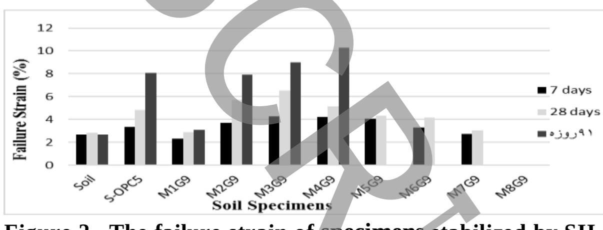

Figure 2. The failure strain of specimens stabilized by SH-RGP

The studied unstabilized clay soil (control1) has low UCS (0.147MPa) while the UCS of all stabilized geopolymeric specimens has been increased significantly. Figures (1) and (2) show that with increasing the NaOH concentration from 1M to 3M, the compressive strength and failure strain of the specimens has increased and for higher NaOH concentrations (5M to 8M), these values Have decreased. Therefore, 3 M NaOH concentration is required to obtain optimal mechanical properties.

Furthermore, the effect of increasing CCR concentration on UCS and failure strain of the specimens stabilized by CCR-RGP is shown in Figure 3 and Figure 4 respectively.

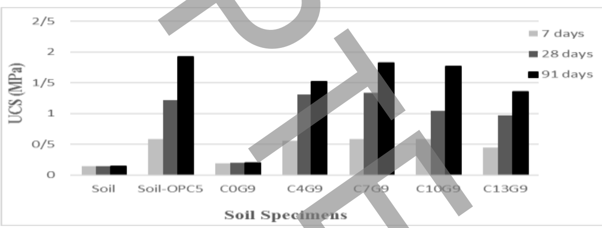

Figure 3. The UCS of specimens stabilized by CCR-RGP

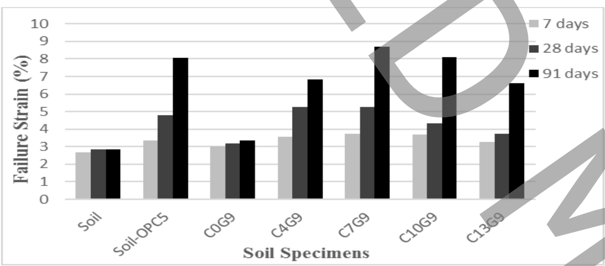

Figure 4. The failure strain of specimens stabilized by CCR-RGP

Based on Figures (3) and (4), it is observed that with increasing the CCR value from 0% to 7%, the compressive strength of the samples has increased and for higher CCR concentrations (10% and 13%), these values have decreased. The highest compressive strength and failure strain were obtained for 7% CCR.

For both types studied geopolymers, increase in curing time increases the UCS of the specimens. Furthermore, the results show that, increase rate of UCS in stabilized specimens within 7 to 28 days was significant while the UCS increased slowly afterward (28 to 91 days).

Studying the appearance of the specimens stabilized by SH-RGP geopolymer showed some traces efflorescence and surface cracks especially in specimens containing high concentrations of NaOH.

The SEM images show that the stabilized specimens have more compacted space and more homogenous structure with less porosity in surface in comparison with unstabilized specimens.

Conclusions

- The geopoloymeric stabilized specimens (for both geopolymers) had higher UCS, more deformability and failure strain than unstabilized specimens. Such performance is very useful when the joint effect of high UCS and deformability in soil is needed.
- In order to form more complete geopolymer gels, the optimal concentrations of alkali activator are required (3M for NaOH and 7% for CCR).
- Increase rate of UCS was significant during the first 28 days but the rate in 91-day specimens was less than 28-day specimens.
- Traces efflorescence and surface cracks on the specimens stabilized by SH-RGP was observed more than that of CCR-RGP significantly.
- Studying SEM images and EDX analysis verified the formation of geopolymer gels in the stabilized specimens qualitatively.
- Results showed the effective stabilization of soil geopolymer, using both alkaline activators. However, the CCR will be more appropriate if environmental and economic problems considered.

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