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Feasibility Study of Sandy Soil Stabilization with Glass Powder and Natural Pozzolan Based Geopolymer

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ABSTRACT: Improvement of problematic soils using chemical additives has had a long history in the field of geotechnical engineering. One of the common materials used for soil stabilization is Portland cement that has had detrimental impacts on the environment thus engineers are looking for a green material with the same characteristics as an alternative. Geopolymer materials have recently drawn attentions of civil engineers since they have similar properties to cement. In current study, natural pozzolan based geopolymer has been used for improvement of sandy soil. Besides efforts have been made to use glass powder as a replacement for natural pozzolan. Two kinds of alkaline activators were used. The first type was a combination of sodium hydroxide and liquid sodium silicate and the second type had different concentrations of sodium hydroxide. Beside the unconfined compressive strength test which was the main comparison criteria, the microstructural characteristics of geopolymeric samples were investigated with X-ray diffraction (XRD) and scanning electron microscopy (SEM). Results indicated that with the increase of pozzolan and activators, the unconfined compressive strength of the samples were increased. In addition, increasing the concentration of type II activator will lead to the increase of unconfined compressive strength of the samples.

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1- Introduction

Stabilization of problematic soil with chemical additives has been considered for a long time in geotechnical engineering. There is a lack of sufficient research regards to soil stabilization with alkaline activation and geopolymer technology; therefore, it has been given more attention recently. Cement industries produce 5-8 % of total carbon dioxide (CO_2) in the world [1]. Geopolymer cement emit 62-90 % less CO_2 than Portland cement [2]. Furthermore, in 2007, around 89.4 million ton of waste glass have been produced in the world that 89 % of them includes Soda-Lime type [3]. Usage of waste in the construction industry could be more effective in the sustainability of environment.

Geopolymer is an inorganic polymer, formed through alkaline activation of aluminosilicate materials and polycondensation of silica (SiO_4) and alumina (AlO_4), which are shared all their oxygen atoms [4]. Zhang et al. [5] stabilized clay soil with metakaolin based geopolymer. Cristelo et al. [6] stabilized loose soil with fly ash class F and various concentrations of sodium hydroxide used as an activator and they reached to ideal results. Most of studies in recent years on the soil stabilization with geopolymer and alkaline activated additives have been done based on different types of fly ash and slag. This subject is not desirable in many countries due to lack of these types of additives. Physical and chemical characteristics of five types of pozzolans, in Iran, have been considered to produce geopolymer concrete. The results indicated that Taftan pozzolan have the highest reactivity as compared to other types [7]. Furthermore, Najafi and Allahverdi [8] investigated the possibility use of Taftan pozzolan to prepare geopolymer mortar and studied its basic engineering properties.

This research aims to improve the sandy soil properties by using natural pozzolan based geopolymer. Sodium hydroxide and sodium silicate have been used in alkaline activator preparation. Here, all types of specimens were tested under unconfined compressive strength. Moreover, X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used to analyze the chemical composition and microstructure of some specimens, respectively.

2- Materials

2- 1- Soil

The particle size distribution curve of the soil is shown in Figure 1 according to the unified system, the soil is poorly graded sand (SP). In addition, the optimum moisture content was determined 14 % after standard compaction test.

2- 2- Natural pozzolan

Natural pozzolan (NP) has been provided from Taftan volcano district in Sistan and Baluchestan province, Iran.

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2- 3- Glass powder

The glass powder (GP) used in this investigation has been provided by powdering the building waste glass. The particle size distribution curve of glass powder is shown in Figure 1.

2- 4- Alkaline activator

By the use of liquid sodium silicate (SS) (with 3.17 silica to sodium oxide ratio) and 6, 8, and 10 molar (M) sodium hydroxide (SH), tow type of alkaline activator were prepared. Activator Type I was made with the mix of SS and SH with the ratio of SS/SH = 1.43 by weight and molar ratio of Si/Na=1.25 and activator Type II, sodium hydroxide with the 6, 8, and 10 M concentrations.

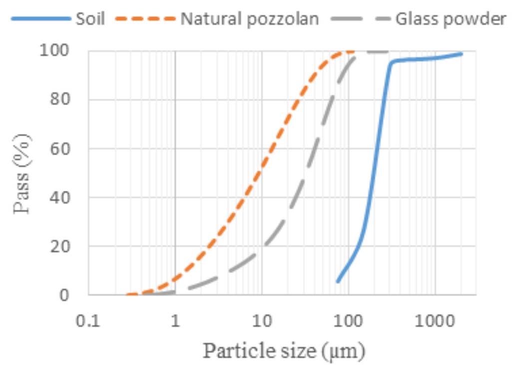

Figure 1. Particle size distribution of soil, natural pozzolan, and glass powder

3- Methodology

All specimens have been made in 14% moisture content and the same compacting energy. For each mixture, the amount of water in its activator was determined. After that, the required water to reach to the optimum moisture content was added as "Extra water". Cylindrical mold with the dimensions of 5 cm in diameter and 10 cm in height was used. Curing of all specimens except cement specimens occurred in room temperature. The specimens which include Portland cement cured in plastic mold for 3 days and after that remained in the room temperature.

Series 1 specimens includes pozzolan and activator Type I which has been denoted by "A" and two digits. The first digit (2, 3, and 4) represents 0.2, 0.3, and 0.45 ratios of pozzolan to the soil. The second digit (1, 2, and 3) represents ratio of activator to pozzolan (0.2, 0.3, and 0.45). In series 2, the type and concentration of activator and possibility replacement of glass powder instead of pozzolan have been considered. Therefore, B6, B8, and B10 have been made by the ratio of pozzolan to soil and activator to pozzolan equals to 0.3 and their activator was 6, 8, and 10 molar of sodium hydroxide (type II), respectively.

The GP10, GP20, and GP30 have been made by 10, 20 and 30 % pozzolan replacement by glass powder in B10 specimen, respectively. Furthermore, PC7, PC15, and PC30 have been made by 0.07, 0.15, and 0.3 ratio of cement to soil and NAP1 and NAP2 were similar to series A3 and A4, but without any activator (only water). After curing, UCS test was applied on each specimen and the reported results were the average of three specimens.

4- Results and discussion

4- 1- Mechanical properties

UCS of soil, within three periods curing of 7, 28 and 90 days are 0.385, 0.495 and 0.56 MPa, respectively as shown in Figure 2-a with specimens series 1. As the results of group A2 illustrate (Figure 2-a), by increasing the curing period, the UCS of specimens increased. Furthermore, by keeping the amount of pozzolan constant, increasing activator leads to an increase in the UCS of specimens. As the activator increases, the solution of alumina and silicate and production of alumina-silicate gel increases; therefore, the strength increases. Similar behavior in group of A3 specimens (Figure 2-b) and A4 (Figure 2-c) observed. A few increasing in strength of A21 specimen is the results of the less amount of activator and high percentage of water which leads to reduce pH [9].

Figure 3 shows the results of UCS for A32, B6, B8 and B10 specimens. By increasing the concentration of solutions 6M to 8M and 8M to 10M, the amount of UCS in each three periods of curing increase. Figure 4 shows the effect of glass powder on the compressive strength of B10 specimen. According to the results, it is observed that replacement of 10 % pozzolan with glass powder did not decrease the compressive strength. Replacement of 20% glass powder leads to a reduction in 7-day strength,

While 28 and 90 days strength increases (20% and 13% in 28 and 90 days respectively). Noted that in comparison with Portland cement, cement specimens had better behavior as compared to geopolymeric specimens. Cement specimens had 50 % higher strength than similar percentage of geopolymeric specimens (in 0.3 ratio of pozzolan to soil). More energy consumption and high CO_2 emission are the

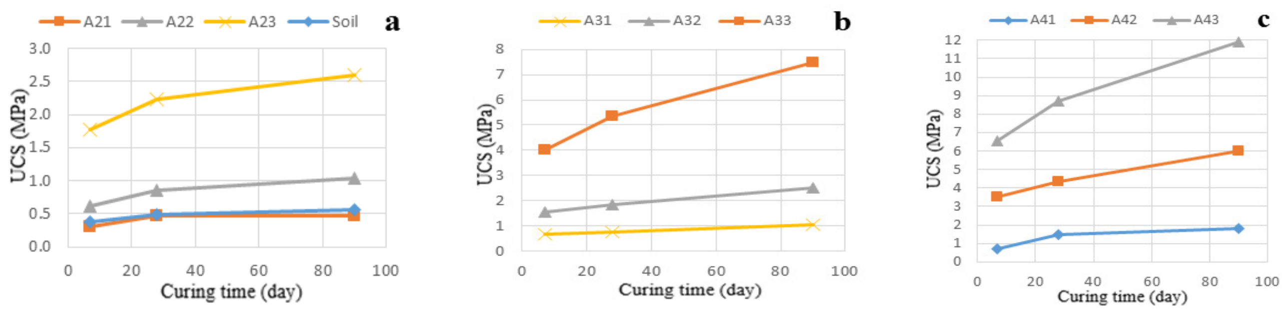

Figure 2. Compressive strength of series 1 specimens at 7, 28, and 90 day curing

disadvantages of Portland cement which must be considered in this comparison.

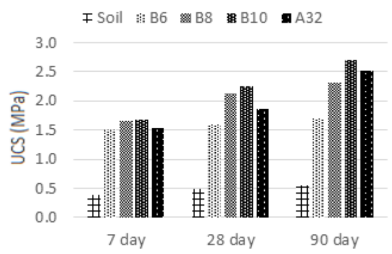

Figure 3. Effect of type and concentration of activator on compressive strength

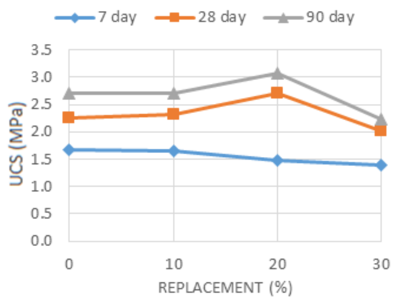

Figure 4. Effects of the replacement of natural pozzolan with glass powder on UCS

4- 2- Chemical analysis

The main parts of reaction products are the aluminosilicate gels based on Si-O-Si, Si-O-Al, Al-O-Al. Production of dominant C-S-H gel is not possible; however, regards to the presence of 10 % calcium in pozzolan, this production is possible, Also, due to the rapid composition, a part of strength is related to that [6, 10]. In addition, by determination of Si/Al and Na/Al molar ratios, it was observed that by increasing the ratio of Si/Al and Na/Al, the compressive strength increases.

4- 3- Microstructural analysis (XRD and SEM)

Regards to the XRD, it was observed that intense peaks of pozzolan has been completely disappeared, which indicates intense reaction of this material and the disruption of its crystalline structures. In addition, near to 2θ equal to 50˚ and 60˚, soil peaks has been reduced extremely. Regards to the SEM results, it was observed that the microstructure of A33 is much denser than A32, which responsible of more strength.

5- Conclusion

1. Increasing the amount of natural pozzolan and activator and its concentration causes an increase in unconfined compressive strength of stabilized soil with natural pozzolan based geopolymer.
2. Replacement of 10 % of glass powder instead of natural pozzolan causes no reduction in compressive strength. In addition, by replacement of 20 % of glass powder instead of pozzolan, the unconfined compressive strength of specimens in 28 and 90 days increased 20 and 13 %, respectively.
3. The results of XRD and SEM in geopolymeric specimens indicated that specimens included more percentage of activator, has more reaction product and denser microstructure.

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