The application of geopolymerization method to modify the yellow marl soil of Tabriz

Afshin Dibamehr [1], Fariba Behrooz Sarand [2*], Ramin Vafaipour Sorkhabi [3]

[1,2,3] Department of Civil Engineering, Islamic Azad University, Tabriz branch, Tabriz, Iran

ABSTRACT

Geopolymers produced by the reaction between solid aluminosilicate and an alkaline metal solution have been classified as the third generation binders after lime and portland cement. In the present study, the application of the above method to modify the behavior of the yellow marl soil of Tabriz has been evaluated by unconfined compression tests. For this purpose, zeolite and metaclay have been used as sources of silica alumina, and sodium hydroxide solution has been used as an alkaline activator. The most important variables studied in this research include the weight percentages of main materials containing alumina silicate (zeolite and metaclay), the molarity of alkaline solution (NaOH) and the curing time. The results of the tests have shown the very appropriate effect of the geopolymerization mechanism in treatment the resistance structure of carbonated clay soil. Meanwhile the zeolite geopolymer samples have higher resistance than the metaclay ones in all combinations and curing times. The effect of alkaline solution concentration on the strength of zeolite and metaclay geopolymer samples was not the same, so that in the metaclay samples, increasing the molarity of alkali had a negative effect on the results. Also, the results show that the rate of change of resistance with respect to time depends on the concentration of alkaline solution so that the treatment effect reduces with inhancement of alkali content. In the optimal sample of zeolite geopolymer (15% zeolite, 12 M alkaline), the uniaxial resistance is about 90.2 kg/cm^2, which is about 26 times yellow marl one wherease the optimal metaclay geopolymeric matrix (15% metaclay, 4 M alkaline solution) has obtained an unconfined compression strength of about 17.86 kg/cm^2. Also in the geopolymer samples, the failure strain has declined by 50% compared to the pure soil.

KEYWORDS

Stabilization, yellow marl, geopolymerization, zeolite, metaclay.

* Corresponding Author: Email: sarand@iaut.ac.ir

1. Introduction

For many years, soil stabilization has been used as a common technique in engineering to modify the characteristics of problematic soils. In clay soils the addition of natural stabilizing substances is especially advantageous [1]. It is very common to use lime or cement for modifying weaknesses of clays for many years [2,3]. Currently, besides lime or Portland cement, various industrial byproducts and waste products containing the oxides involved in pozzolanic reactions are being used as soil stabilizers.

In addition to the above methods, the use of alkali-activated cements is a new type of binder that can be classified as the third generation of cements after lime and Portland cement. In recent years, alkali-activated binders are considered as a suitable alternative to OPC (ordinary portland cement) due to their quality, high durability and also compatibility with the environment [4]. Indeed, from the reaction between solid aluminosilicate powder (usually metakaolin, fly ash, furnace slag or natural pozzolans) with an alkali metal source (including hydroxide or silicate solutions), a synthetic aluminosilicate product is obtained which Davidovits called geopolymer [5].

The purpose of this research is using the geopolymerization technique to stabilize Tabriz yellow marl. Therefore, multiple uniaxial compressive strength tests have been done to evaluate the strength of stabilized soil. The effective parameters studied in the current paper can be referred to the weight percentages of materials containing alumina silicate (zeolite and metaclay), curing time and molarity of the alkaline activator (NaOH).

2. Methodology

The yellow marl studied in this paper was taken from a depth of 1-2 meters in Nasr region, located in the northeast of Tabriz city. According to the unified classification, this soil is named clay with low plasticity (CL). The natural zeolite and metaclay used were obtained from the zeolite mine of Amirabad and the process of calcination of carbonate clay (yellow marl), respectively. Also sodium hydroxide has been chosen as an alkali activator because of its cheapness and having a higher efficiency in dissolution silica and alumina monomers [6]. The initial form of NaOH is prepared in the form of flakes and by dissolving in distilled water with different weight percentages based on the required molarity (M), it becomes a base activator solution.

In this study, two series of tests for determining uniaxial compressive strength have been carried out to investigate the effect of factors such as additives types, percentage of additive, molarity of alkali activator and curing time according to Table 1.

Table 1. Summary of the test program

Equation	Unit	First series	Second series
Zeolit (Z)	%	5,10,15,20	0
Metaclay(M)	%	0	5,10,15,20
Alkali activator (L)	M	4,8,12,16	4,8,12,16
Curing time	day	3,7,14,28	3,7,14,28

To make geopolymer samples, the yellow marl passed through sieve No. 40 and with an additive containing silica alumina (zeolite or metaclay) in the specific weight percentage is completely mixed for 5 minutes and then alkaline activator (L) in optimal moisture content added to the ingredients and this mixture is blended by a mixer for 5 minutes until a homogeneous texture is obtained. The composition is compacted inside a cylindrical mold in three layers until reaching the maximum dry density. The samples are removed from the molds and placed inside the plastic covers and finally cured at the laboratory temperature (25 ± 2°C) until the curing time.

3. Results and discussion

3.1. Uniaxial strength of zeolite geopolymer samples

The results of tests show that in all the geopolymeric samples, for all concentrations of alkaline solution, with the increase in the weight percentage of zeolite up to 15%, the strength of the samples inhanced and the amount of 15% can be introduced as the optimal percentage of zeolite. However, in the molarity of 4 M and 8 M, with an increment in the amount of zeolite from 15% to 20%, a growth of less than 5% in resistance is also observed. It can be said that the amount of alumina silicate in the additive (zeolite) has a major impact on obtaining the strength of geopolymeric stabilized soil. On the other hand, it can be seen that in high concentrations of alkaline solution, the resistance reduces with the increase of zeolite percentage from 15% to 20%. In other words, to obtain higher resistance at low molarity of alkali activator, a high weight percentage of zeolite is suitable and as the molarity increases, an appropriate resistance is obtained at a lesser weight percentage. Fig. 1 shows the changes in compressive strength of zeolite geopolymeric samples for different molarity of alkali activator for a 28-day curing time.

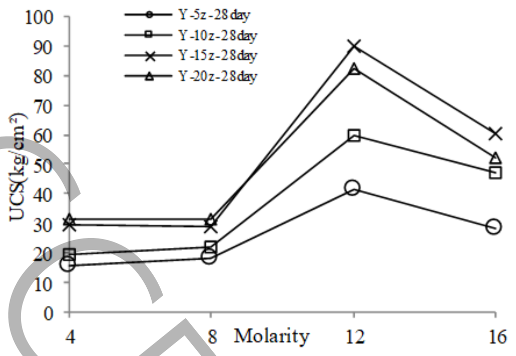

Figure1. Variations of compressive strength of zeolite geopolymeric samples against alkaline solution concentration for different percentages of zeolite

3.2. Uniaxial strength of metaclay geopolymer samples

Based on the obtained results, the weight value of 15% metaclay can be introduced as the optimal amount, but the rate of change of resistance against the percentage is not as high as the role of zeolite.

Also, the resistance obtained in all conditions in metaclayey geopolymers is much lower than zeolite geopolymers. It means that the type of aluminosilicate material used in geopolymer plays an important role in the strength of geopolymer modified, which is due to the different chemical composition of zeolite and metaclay. This problem can be attributed to the high amount of silica and alumina in zeolite compared to metaclay, that leads to the generation of more cement products.

In Fig.2, the effect of alkali activator molarity on the compressive strength of geopolymeric metaclayey samples during 28 days of curing time is presented as a graph. As it can be seen, for all metaclay magnitudes in yellow marl geopolymeric samples, the concentration value of 4 M is considered as the optimal amount.

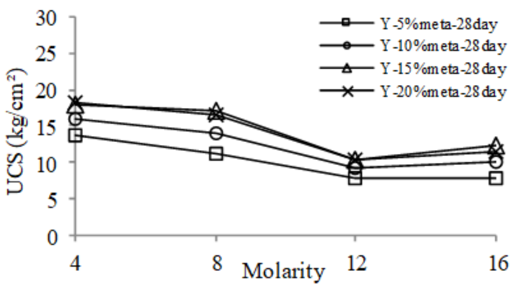

Figure2. Variations of compressive strength of geopolymer samples against alkali solution concentration for different percentages of metaclay

4. Conclusions

In zeolite geopolymer samples for all concentrations of alkaline solution, the strength of the samples increased by growing the magnitude of zeolite up to 15%, and the amount of zeolite 15% can be introduced as the optimal percentage. In geopolymeric samples of metaclay the weight value of 15% was obtained as the optimal amount.

In zeolite geopolymeric samples, the concentration value of 12 M has been obtained as the optimal concentration of the alkali activator for all percentages of zeolite. This is the case that in the geopolymeric samples with all percentages of metaclay, the activator concentration value of 4 M is considered as the optimal concentration in the composition.

In yellow marl soil, in all magnitudes of zeolite or metaclay and for all alkaline solution concentrations, the uniaxial strength of zeolite geopolymer samples is higher than that of metaclay geopolymer samples.

5. References

[1] A. Seco, F. Ramírez, L. Miqueleiz, B. García, E. Prieto, The use of non-conventional additives in Marls stabilization, Applied Clay Science, 51 (2011) 419–423.
[2] D. F. Lin, K. L. Lin, M. J. Hung, H. L. Luo, Sludge ash/hydrated lime on the geotechnical properties of soft soil, Journal of Hazardous Materials 145 (2007) 58–64.
[3] N. Degirmenci, A. Okucu, A. Turabi, Application of phosphogypsum in soil stabilization, Building and Environment ,42 (2007) 3393–3398.
[4] C. L. Henghu Sun, L. Li, A review: The comparison between alkali-activated slag (Si+Ca) and metakaolin (Si+Al) cements, Cement and Concrete Research, 40(2010) 1341–1349.
[5] J. Davidovits, Geopolymers: inorganic polymeric new materials, J Therm Anal, 37(1991) 1633–56.
[6] Y.S. Zhang, Research on structure formation mechanism and properties of high-performance geopolymer concrete, PhD Thesis, Southeast University, Nanjing (2003).
[7] I. Phummiphan, S. Horpibulsuk, P. Sukmak, A. Chinkulkijniwat, A. Arulrajah, S. Shen, Stabilisation of marginal lateritic soil using high calcium fly ash-based geopolymer, Road Mater. Pavement Des 17(2016) 877–891.
[8] N. Cristelo, A. Teixeira Pinto, A. Glendinning, Deep soft soil improvement by alkaline activation. Proc. Inst. Civ. Eng. – Ground Improv. 164 (2011) 73–82.