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EXTENDED ABSTRACT

Improvement of Tabriz Green Marl Using Alkaline Activated Zeolite and Metaclay

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1. Introduction

Marl or marl clays are named for carbonated soils with the amount of carbonate in varying proportions from 20 to 55% (Elert et al., 2017). Marls are one of the most important problematic soils that not only the problem of volume changes but also their bearing capacity is lower than coarse-grained beds, so not meet the load-bearing goals of engineering structures. Different improvement methods are proposed to improve the engineering characteristics of problematic soils, the most common is using of lime for this purpose in clayey soils (Al-Mukhtar et al., 2012 and Obuzor et al., 2012) But this substance is less effective in marls (Ghobadi et al., 2014 and Ureña et al., 2015). According to the history of soil modification, the geopolymerization method can be introduced as the third generation of cementation methods after lime and cement (Li et al., 2010). Geopolymers are alkaline activated bonds with low calcium and medium to high aluminum produced by the reaction between alkaline hydroxide solution and materials containing alumina silicate (Provis et al., 2009 and Yung-Ming et al., 2016).

The purpose of this research is using the geopolymerization technique to stabilize Tabriz carbonate clay with the approach of controlling deformations and increasing strength. To achieve this outcome, laboratory studies have been carried out on Tabriz green marl with alkali activated zeolite and metaclay as sources of alumina silicate to form cemented bonds. The alkali activator used in this study is sodium hydroxide with different concentrations to achieve optimal results. For this purpose, multiple tests of uniaxial compressive strength have been used to evaluate the strength of stabilized soil. The effective parameters studied in the current research can be referred to the weight percentages of materials containing alumina silicate (zeolite and metaclay), curing time and molarity of the alkaline solution (NaOH)

2. Methodology

2.1. The soil studied

The clay soil (green marl) studied in present article 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 placed in the category of clay with high plasticity properties (CH). The natural zeolite and metaclay used were obtained from the zeolite mine of Amirabad and the process of self-calcination of carbonate clay (green marl), respectively. Also sodium hydroxide has been chosen as an alkali activator because of its cheapness and having a higher efficiency in separating silica and alumina monomers (Zhang, 2003). 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.

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2.2. Preparation of samples and tests

In this study, two series of experiments 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 green marl soil passed through sieve No. 40 with an additive containing silica alumina (zeolite or metaclay) in the desired percentage by weight is completely mixed in dry state for 5 minutes and then alkaline activator (L) in optimal moisture added to the ingredients and this mixture is stirred 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 weight. The manufactured samples are removed from the molds and placed inside the plastic covers and finally cured at the laboratory temperature (25 ± 2°C) until the desired time.

3. Results and discussion

3.1. Uniaxial strength of zeolite geopolymer samples

According to the results obtained from the tests for all concentrations of the alkaline solution, the augmentation of zeolite up to 15%, the strength of the samples increased and the amount of zeolite 15% can be introduced as the optimal percentage. Also, for all amaounts of zeolite, the concentration value of 12M is desirable. In this research, for the optimal geopolymeric sample (15Z, 12M and 28 days), the uniaxial strength was obtained 42kg/cm^2, which is about 12 times the uniaxial strength of the pure green marl. On the other hand, the experiments show that in all molarities of activator, the resistance enhanced with the growth of the curing time, but in 12M and 16M, the role of time in obtaining the resistance is more remarkable. The minimum failure strain value of the sample was observed in 20% zeolite, in other words, keeping the alkaline solution magnitude constant and increasing the zeolite percentage leads to more brittle samples, so that the failure strain of the green marl is about 0.5%, but in the optimal geopolymer sample (15Z, 12M, 28day) this value has been reduced to 0.4%.

3.2. Uniaxial strength of metaclay geopolymer samples

In geopolymers made on activated metaclay, with enhancement of this element, the resistance of the samples has increased for all magnitude of alkaline solution and at all curing times so it is not possible to introduce the optimal percentage for metaclay like zeolite. On the other hand, for all molarities of alkali activator and metaclay, curing time acted as a positive parameter so that the passage of time has positive affect on the resistance in all samples, but the rate of resistene change for all conditions is not constant. By comparing the results of all tests, it is concluded that the behavior of zeolitic and metaclayey geopolymeric improved soils in obtaining resistance to time is not completely similar. By referring to the previous studies, the reason for this difference can be stated that the time required for forming a continuous gel from the supersaturated aluminosilicate solution, significantly varies with the processing conditions of the raw materials (in this research, zeolite or metaclay), the solution composition and synthesis procedure (Duxson et al., 2007). For all values of metaclays, like the zeolitic geopolymers, the 12M of activator was considered as the optimal, but in metaclayey geopolymer samples, the unconfined compression strength went up slightly by increment of the alkaline molarity from 12M to 16 M.

Fig. 1 is presented to compare the uniaxial compressive strength of zeolite and metaclay geopolymer samples in different concentrations of alkaline solution during 28 days of curing. As it can be deduced from this graph, at the 12 M activator, the biggest difference between the ratio of compressive strength of zeolite geopolymer to metaclay is seen so that varies between 1.32 to 2.07. On the other hand, for the 4M alkaline solution, the compressive strength of the zeolite geopolymer samples is lower the metaclay ones due to the insufficiency of the hydroxide in the environment to dissolve the alumina silica of the zeolite.

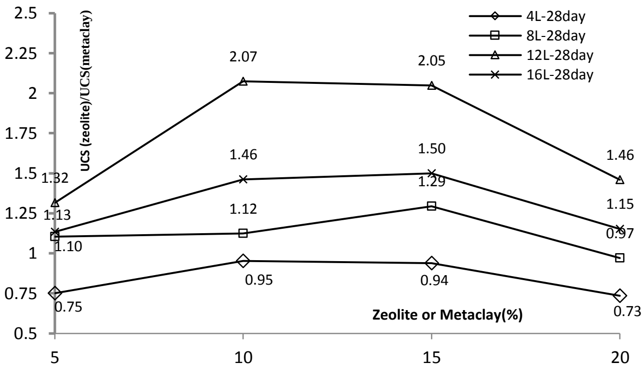

Fig. 1. Changes in the uniaxial strength ratio of 28-day geopolymer samples with different percentages of zeolite or metaclay

4. Conclusions

1) In zeolite geopolymeric samples, zeolite amount of 15%, alkaline solution concentration equal to 12 M can be introduced as optimal values.

2) In metaclayey geopolymeric samples, with the increment of additive, the strength of the samples increased and the optimal weight value was not obtained.

3) In the metaclayey geopolymeric samples for all magnitudes of this material, the activator concentration value of 12 M is considered as the optimal, and the resistance of the samples decrease with the growth of the alkaline solution molarity.

4) By enhancement of zeolite or metaclay, the failure strain of the samples reduces, in other words, keeping the alkaline solution magnitude constant and increasing the zeolite or metaclay leads to making more brittle geopolymeric samples.

5) In zeolite and metaclay geopolymeric sampels for all alkali activator molarities and in all amount of additive, the curing time acted as a positive parameter but resistance change rate for all conditions compared to time is not fixed.

6) At concentrations above 4M of alkaline solution for all weight percentages of zeolite or metaclay, the uniaxial strength of zeolite geopolymeric samples is higher than that of metaclay ones.

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