

The Assessment of Zeolite and Sepiolite Effect on Elastic Modulus and Hydraulic Conductivity of Clayey Soils with the Emphasize on Microstructure

Ali M. Rajabi^{1*}, Shima Bakhshi Ardakani²

1. Assistant Professor, Department of Engineering Geology, University of Tehran, Tehran, Iran,
2. Department of Civil Engineering, University of Qom, Qom, Iran

Extended Abstract

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Introduction

Improving the geotechnical characteristics of soils including superficial or deep soils has always been a challenge to geotechnical engineers. Therefore, various physical and chemical methods are used to improve different types of soils. In general, any physical, chemical, biological or combination of methods are used to change the characteristics of natural soil mass in order to achieve engineering goals which is defined in the "soil stabilization." Among different types of additives for soil stabilization, the use of pozzolans has been investigated by researchers because of their chemical compatibility with the environment and the cementation products due to chemical reactions. Today, a lot of researches has been done on the use of natural or artificial zeolites as pozzolanic materials for the production of cement mixtures. This material, as a pozzolan, increases the speed of the pozzolanic reactions and reduces the density of cement products. However, many studies have been done to investigate the effect of zeolite and sepiolite on the resistance of cement products such as concrete, but so far, the use of these additives has been less considered for soil improvement. On the other hand, because of the compatibility of zeolite and sepiolite with the environment and their unique physiochemical properties, it is necessary to pay attention to these additives in order to improve the soil. Therefore, in this research, the effect of zeolite and

sepiolite additives with different percentages at different treatment times have been investigated to determine the elasticity modulus and hydraulic conductivity with focus on soil microstructure behavior.

Materials and methods

1. The properties of the soils

In this research, two types of soil including clayey sand (with 20% clay) and sandy clay (with 51% of clay) were used. The studied soils were a mixture of clay and sand of Firoozkhouh (a typical type of sand located in north of Iran). Some physiochemical properties of zeolite and sepiolite are presented in Table 1.

Table 1. Physiochemical properties of zeolite and sepiolite used in this study

Chemical component	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	L.O.I.
Sepiolite (%)S	55.3	0.3	0.61	0.01	15.73	0.01	0.02	25.11
Zeolite (%)	69.74	13.54	1.26	2.45	0.87	-	0.13	11.94

2. Experiments

The uniaxial compressive strength tests were performed at 0.1 mm/min according to ASTM D2166 standard. The stabilized soil samples were compacted at percentages of 0, 5, 10, 15, 20 and 25 in cylindrical molds (38mm × 76mm) in five layers to achieve the desired density. In order to investigate the effect of curing time, the samples were placed inside sealed containers and underwent the test at instantaneous, 7, 14, and 28 days and at the desired additive percentages. To investigate the effect of additives on the soil hydraulic conductivity, clayey sand soil with additives 5, 10, 15, 20, and 25% was prepared using dry mixing method. Then, the prepared mixture was poured from a specific height into the permeability mold with a height of 8.65 cm and diameter of 5 cm. In this way, the specific dry unit weight of all samples was obtained as 1.47 g/cm³, close to the minimum specific dry unit weight. In this research, concerning the considerable effect of fine-grained soils on hydraulic conductivity, falling head test was used to determine the permeability coefficient.

In order to the morphology of the clayey sand soil without additives and stabilized with additives 15% was examined through SEM test.

Discussion and results

1. Modulus of elasticity

In this study, after uniaxial tests in different percentages and ages, the stress-strain graphs were plotted and then the elasticity modulus was calculated. The results showed that, with increasing zeolite content, the modulus of elasticity has been increased and, with increasing curing time, except for a slight decrease, after 7 days, the modulus of elasticity increased. During the initial treatment (7 days), the hardness of the sandy clay soil decreased and then increased with increasing time. In general, hardness in both soils in the high percentages of zeolite is significantly increased.

Also, the effect of sepiolite on the modulus of elasticity has been studied. The results indicate that with the increase in the percentage of additive and lengthening the curing time, the modulus of elasticity is increased. This increase in the stabilization of both sandy clay and clayey sand soil is almost the same. In addition, in the case of sepiolite modification, the elasticity of sandy clay and clayey sand is approximately equal to 5 times in comparison to the initial value of unstabilized soil. However, in zeolite, the modulus of elasticity in clayey sand soils is almost 2 times, and sandy clay is nearly 5 times higher.

2. Permeability

To investigate the effect of additives on the soil hydraulic conductivity, clayey sand soil with additives 5, 10, 15, 20, and 25% was prepared using dry mixing method. The samples were saturated in a short period and permeability test was carried out immediately. Permeability coefficient changes were mostly influenced by physical factors. Therefore, due to the fineness of both types of additives, the hydraulic conductivity decreases with increasing additive content. The amount of reduced hydraulic conductivity in sepiolite stabilization is greater than zeolite due to the structure of the-sepiolite (fiber-shaped) compared to zeolite.

3. SEM imaging

In this study, attempts were made to examine the reasons behind the obtained results more carefully through SEM imaging.

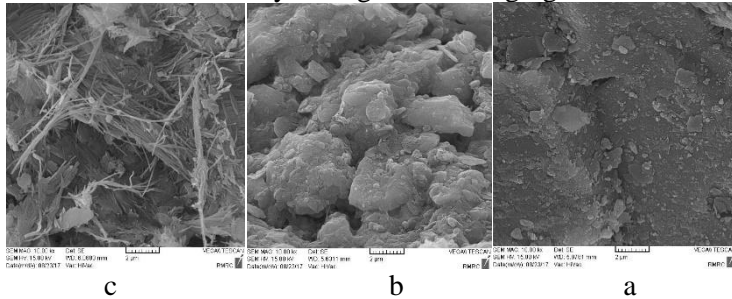


Figure 1. SEM image of non-stabilized clayey sand soil (a) soil stabilized with zeolite 15% (b) soil stabilized with sepiolite 15% (c) during the curing time of 28 days at magnifications 10000X

Figure 1a displays the SEM image of non-stabilized clayey sand soil. As can be seen in the figure, the soil structure is clear as layered and clay scales can be seen as laminated. Figure 1b demonstrates the SEM images of clayey sand soil stabilized with zeolite 15% during the curing time of 28 days. The sample has lost its layered structure in response to stabilization with zeolite during the curing time and changed into an integrated structure. This can be due to incidence of chemical reactions such as ion exchange and pozzolanic reactions in response to adding zeolite. Figure 1c demonstrates the SEM images of clayey sand soil stabilized with sepiolite 15% during the curing time of 28 days. As shown in the figure, the sepiolite has a fibrous-shaped structure that is longitudinally twisted. Also, with curing time increase, complex structures have emerged that could be due to the occurrence of chemical reactions.

Conclusion

This study examined the effect of zeolite and sepiolite additives on strength parameter of clayey soils. Accordingly, uniaxial compressive strength test was performed on clayey sand and sandy clay soil at percentages of 0, 5, 10, 15, 20 and 25% of zeolite and sepiolite with instantaneous curing times of 7, 14 and 28 days. Further, permeability test was conducted at different percentages on stabilized clayey sand soil. Also, to investigate the effect of these materials on soil microstructure, SEM imaging was performed at 28 days. The results show that both additives

increase the elastic modulus of clayey sand and sandy clay soils. Also, the results indicate a steady increase in the stiffness of the cured soil with sepiolite during processing time. However, reducing soil hardness can be seen in stabilizing with zeolite at lower rates and lower percentages. In permeability test, hydraulic conductivity decreases with increasing additive content. The rate of permeability reduction in sepiolite is higher than zeolite. SEM images show that chemical reactions create an integrated structure that ultimately increases uniaxial compressive strength and modulus of elasticity. Also, SEM imaging depicts physical changes along chemical reaction in soil stabilized with sepiolite. Ultimately, increasing soil strength resulting from additive alongside environmentally friendliness is recommended in superficial and deep improvement of soil.

Keywords: Elastic Modulus, SEM, Zeolite, Sepiolite, Hydraulic Conductivity, Soil Improvement

*Corresponding Author: amrajabi@ut.ac.ir