Experimental investigation of cyclic behavior of zeolite cemented sand

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ABSTRACT

Shear module is of the most crucial soil dynamic properties in seismic geotechnical engineering. The replacement of a part of cement, the production of which is one of the most important sources of CO2 emission in the world, with natural materials such as zeolite is of great importance. In the present study, the cyclic behaviour of pure sand is compared with the cyclic behaviour of sand grouted with cement and zeolite. The sand used in this research was taken from Babolsar, which is classified as a poorly graded sand based on the Unified soil classification system. The effects of the confining pressure, the shear strain and the replacement of cement by zeolite on the shear modulus are studied. All the specimens were prepared by the wet tamping method and cyclic triaxial tests were performed with three different confining pressures of 100, 200, and 300 kPa in the moderate shear strain range. The results show that Shear modulus values of the cemented sand specimens with a water-to-cement ratio of 1 are greater than that of the pure sand specimens in all range of shear strains. The shear modulus values increased with the replacement of cement by zeolite of cemented samples. Therefore, the replacing of cement with zeolite can be considered from an environmental point of view. By increasing the confining pressure, the shear modulus values of the pure sand, cemented sand, zeolite cemented sand specimens increased. This increase is significant for cemented and cemented zeolite specimens at larger confining pressure range.

KEYWORDS

Cyclic triaxial test, Babolsar sand, shear modulus, Cement, Zeolite.

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1. Introduction

A method to improve granular soils, which causes important changes in soil properties including shear strength and deformation module, is cementation. In recent years, much research has been con-ducted on sand stabilization using cement grouting [1-7] to strengthen soil characteristics.

Li et al. [8] performed resonant column tests on grouted sand specimens including three different types of grout (a microfine slug-cement suspension with water-to-cement ratio (W/C) of 2, an acrylic solution, and a solution of sodium silicate) and studied the effect of grout type and confining pressure on the dynamic properties of Ottawa sand. The results showed that the microfine slug-cement suspen-sion had greater dynamic module values in the elastic range than the chemical solutions.

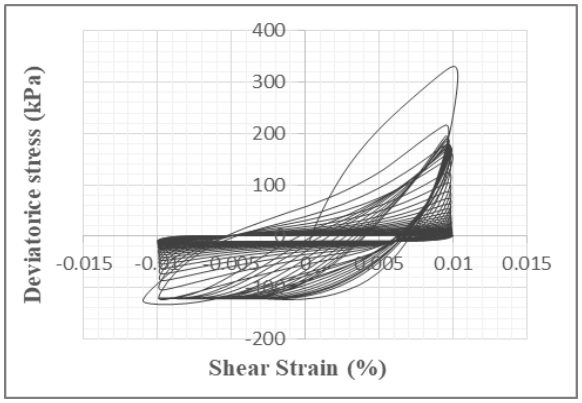
A lot of energy is consumed for cement production, accounting for 7% of global CO2 emission [9]. So, the use of pozzolans, especially naturally-occurring pozzolans, as an alternative for cement can be a remarkable option for reducing cement consumption. Since zeolite has appropriate chemical properties and is environmentally-friendly and economical, it has been used in several ge-otechnical studies. This research studied the shear module of Babolsar silicate sand improved by zeo-lite and Portland cement in a moderate range of shear strain using a cyclic triaxial apparatus and ana-lyzed the effect of cement replacement with zeolite, confining pressure, and shear strain on the shear modulus of the specimen.

2. Methodology

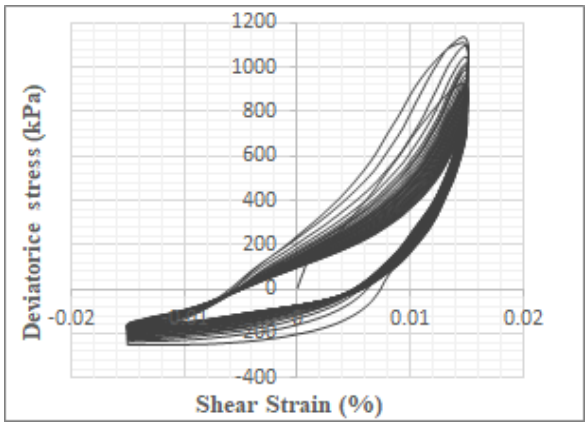
The research used Babolsar sand as well as Portland cement type 2 and zeolite of clinoptilolite type. To have samples with uniform density across the height, the wet tamping method was used with reduced density according to the approach proposed by Ladd [10].

3. Results and Discussion

Figure 1 displays the results of the hysteresis loop of the triaxial test of the clean sand, cemented sand, and zeolite-cemented sand sample with a relative density of 50% and effective confining pressure of 200 kPa with isotropically consolidation. The results show that since the specimens were consoli-dated in the same conditions, the stress-strain graph started from the origin of coordinates.



(a)



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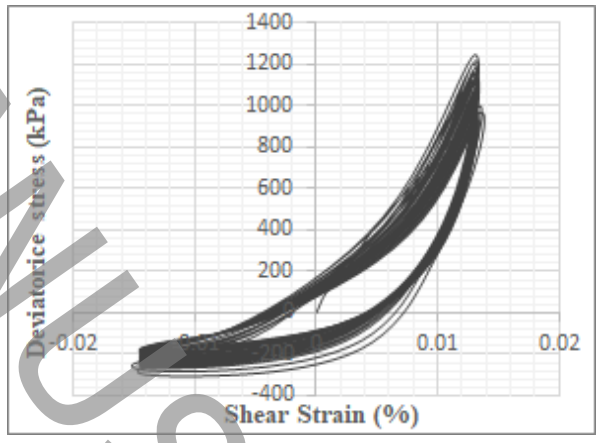

(c)

Figure 1. Results of the hysteresis loop versus number of loading cycles a) clean sand, b) cemented sand, c) zeolite-cemented sand sample

The effect of cementation was studied on the improvement of dynamic properties and the effect of zeolite replacement for cement in cyclic triaxial experiments on clean sand, cemented sand, and zeolite-cemented sand with a water/cement ratio of 1. In all cyclic triaxial experiments, the percentage of cement

used in the cemented samples was 4% of the weight ratio of the base soil and the percentage of zeolite used for the zeolite-cemented sample was 30% of the weight ratio of the cement. As is evident in Figure 2, when zeolite was replaced for 30% of the cement in the cemented samples, the shear modulus values were increased. This increase is more evident in the smaller shear strain (0.015%). This behavior is similar to the one reported by Kordnaeij et al. [11] in their bender element experiment on the maximum shear module of a zeolite-cemented sand sample although they reported a higher coefficient of the shear module ratio of zeolite-cemented sand to clean sand, which is related to the quantity of cement, which was over 20% of the weight ratio of the base sand whereas this ratio was 4% in the present work.

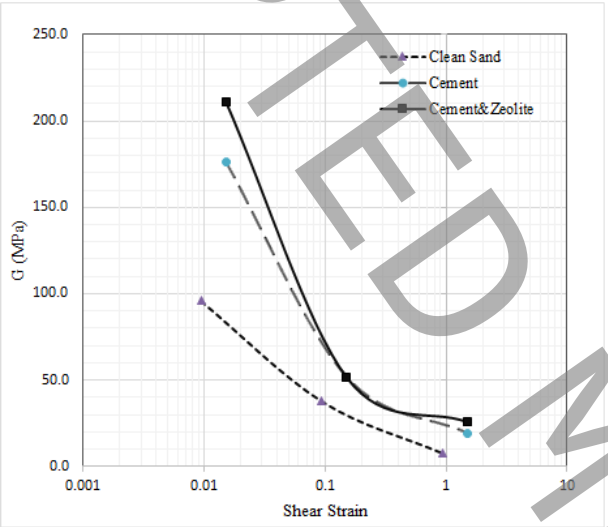

Figure 2. Variation of the shear modulus with shear strain, confining pressure of 200 kPa

In general, the amounts of SiO_2 and Al_2O_3 versus CaO in the cement pozzolan reaction and hydration have a significant impact on the resistance of the cemented sample. When CaO is adequate, an increase in SiO_2 and Al_2O_3 contents results in a more active pozzolan reaction and higher hardiness of the cemented sand sample. When 30% zeolite is replaced for the cement, this means an increase in SiO_2 and Al_2O_3 contents whereas CaO content is decreased. So, in soil improvement projects, a fraction of cement is replaced with a natural pozzolan, such as zeolite, which is readily extractable and environmentally-friendly and causes a significant increase in soil hardness is of great importance.

4. Conclusions

For all samples including clean sand, cemented sand, and zeolite-cemented sand samples, an increase in shear strain reduced the shear modulus values.

The shear modulus of the cemented sand samples with a water-to-cement ratio of 1 was greater than that of the clean sand sample across whole the shear strain range.

When confining pressure was increased, the shear modulus of the clean sand, cemented sand, and zeolite-cemented sand samples were increased. This increase was significant for the cemented and zeolite-cemented samples at confining pressure ranges of 200 and 300 kPa.

5. References

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