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Experimental study of stabilization of natural soil with geopolymer based on glass powder and calcium carbide

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ABSTRACT: Considering cement environmental sustainability issues, an experimental comparative study on three series of untreated silty sandy soil, cement-stabilized, and geopolymer-stabilized soil mixtures based on glass powder, in terms of their static and dynamic properties are presented. Results showed that the optimal geopolymer combination ratios from the viewpoint of bearing the maximum compression, was obtained composed of 15% glass powder, 7% calcium carbide, and 25% silt, and concentrations of higher/lower of the optimum value, will be reduced the compressive strength. Dynamic shear modulus of soil-geopolymer was higher than soil-cement, while it was the reverse in terms of damping ratio. Shear strength, stiffness and damping ratio of the soils with various fines content increases up to fines threshold (50% silt). optimal values of soil static and dynamic properties were found in 25% and 50% silt, respectively.

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1- Introduction

The topic of soil improvement is generally discussed in soil engineering topics, especially for weak soils. Usually, the soil at the construction site of the projects does not contain desirable mechanical properties, and it is necessary to improve and consolidate the soil with chemical additives such as cement, which is one of the most common methods [1, 2]. Paying attention to the environmental and economic benefits of replacing cement with recycled materials such as glass powder as a complete or partial replacement can be effective in reducing cement consumption. Therefore, the research related to the use of cement substitute materials such as geopolymers in the improvement of problematic soils has attracted the attention of civil engineering researchers in recent years [3-7]. In this article, in order to determine the percentage of optimal mixing of geopolymer components for the improvement of silty sandy soils, different ratios of glass powder and calcium carbide were used and in order to find the optimal mixing plan or the optimal geopolymer that has the highest uniaxial compressive strength. The stabilization of each mixture on the soil sample has been checked. Then, soil stabilization by the optimal amount of geopolymer has been compared with the values of soil stabilization by different percentages of cement by testing uniaxial compressive strength, and then the microstructure of the selected geopolymer soil samples by X-ray diffraction (XRD) and scanning electron microscopy (SEM) has been studied and evaluated [8].

2- Methodology

In order to have samples with uniform density along the height, the wet compaction method with reduced density was used according to what was proposed by Lade and her colleagues in 1989 [9]. In this research, different contents of the silt (0%, 10%, 25% and 50% by weight of dry sand) were used. UCS tests were carried out under constant conditions and according to ASTM D2166-2013 [10] to evaluate the effect of different percentages of cement (2%, 4% and 6%) and geopolymer as stabilizers on mechanical strength. In order to evaluate the optimal mixing design of GSS soils based on glass powder and calcium carbide, different samples of the geopolymer mixture design are examined. (Table 1) Scanning Electron Microscope (SEM) experiments have been conducted to investigate the chemical properties of Sx and GSS soils. To perform cyclic triaxial test, samples were made by wet compression method, samples with a diameter of 71 mm and a height of 160 mm with a density of about 50%

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Table 1. The percentage of chemical compounds of materials used to make three series of natural and stabilized soil

Materials / Chemical compounds	Soil	Glass powder	Calcium carbide	Cement
SiO2 (%)	**95-98**	**66.5**	**3.19**	**20.8**
Al2O3 (%)	**0.5-1**	**1.5**	**1.24**	**5.2**
CaO (%)	**0.5-1**	**11.5**	**63.35**	**63.3**
Na2O (%)	**0.2-05**	**12.5**	**0.28**	**0.3**
MgO (%)	**------**	**4**	**0.16**	**1.8**
Fe2O3 (%)	**0.5-1**	**0.44**	**0.24**	**3.65**
K2O (%)	**0.5-0.7**	**0.39**	**0.01**	**0.55**
SO3 (%)	**------**	**0.3**	**0.64**	**2.5**
TiO2 (%)	**------**	**0.53**	**0.06**	**------**
LOI (%)	**------**	**0.26**	**30.69**	**------**

after construction in order to prevent moisture evaporation, were placed in watertight bags in a water bath for 28 days.

Next, three types of natural soil (P), soil-cement (C) and soil-geopolymer (G) were comprehensively and uniformly subjected to triaxial pressures of 50kPa, 100kPa and 150kPa, then loading up to 50 cycles with a frequency of 0 /1Hz, with different strain amplitudes (0.01, 0.03, 0.1 and 0.3) were applied to the samples.

Since the results of various researchers indicate that the tenth cycle of the test will be given good results (due to achieving stability in the stress-strain curve), in the current study, the tenth cycle is considered as a criterion for evaluating soil damping and shear stiffness.

3- Results and Discussion

The soil-cement mixtures, cement additive in different contents of 0 (untreated soil), 2, 4 and 6% has been added to the 4 categories of silty soils and UCS test have been investigated. The UCS test results for optimal mix design of soil-geopolymer (G15% + K7%) with 0% silt, obtained 780 kPa. The UCS test results for optimal mix design of soil-geopolymer (G15% + K7%) with 10% silt, obtained 699 kPa. The UCS test results for optimal mix design of soil-geopolymer (G15% + K7%) with 50% silt, obtained 660 kPa. Therefore,

The maximum amount of unconfined compressive strength for the optimal mix design of soil-geopolymer (G15% + K7%).

In order to evaluate the effect of soil stabilization on the dynamic shear modulus values of soil, three kinds of soil including, silty sandy soil (P), soil-cement (C) and soil-geopolymer (G) have been investigated. the dynamic shear modulus - shear strain curves of studied samples for the various silt contents of 10, 25 and 50% under different confining pressures (50, 100 and150 kPa), with various shear strains ranges (0.01, 0.03, 0.1 and 0.3%). The results show that dynamic shear modulus is a function of the type of additive, fines content and confining pressure. the damping ratio- Shear strain curves of studied samples for the various silt contents of 10, 25 and 50% under various cyclic triaxial loading (50, 100 and 150 kPa), with various shear strains (0.01, 0.03, 0.1 and 0.3%). The results show that damping ratio is a function of the type of additive, fines content and confining pressure. Therefore, factors affecting the dynamic behaviors of the plain soil, including the soil additives, silt content and confining pressure are studied.

4- Conclusions

Glass powder-based geopolymer is an effective stabilizer additive for silty sandy soil. The combination of 15% glass powder as a base material with 7% calcium carbide as an alkaline activator with 25% silt has the highest unconfined compressive strength for silty sandy soils and concentrations of higher or lower than the optimum value reduces the compressive strength. SEM analysis indicates that geopolymer based on glass powder and calcium carbide as an alkaline activator, is a suitable material for soil stabilization and clogging the pore spaces, thereby increasing the strength and integrity and reducing soil permeability.

The results show that the dynamic shear modulus and stiffness of soil stabilized with geopolymer are higher than the cement and silty sand. For all samples of silty sandy soil, geopolymer stabilized soil and soil-cement mixture, the dynamic shear modulus is directly proportional to the amount of confining pressure and silt content.

The damping ratio of studied samples was a function of confining pressure and types of additives. Soil-cement contains the highest damping ratio and soil-geopolymer have a less damping ratio than even silty sandy soil.

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