Experimental Study on the Effect of Adding Polypropylene Fibers on Soil Stabilized by Cement and Zeolite Replacement

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Abstract

Soil properties improvement involves a variety of approaches. Among them, the addition of specific materials to the soil has been widely adopted in the literature. Cement impact on environment is negative, but it has been widely-used in many construction projects. Main purpose of this research is to find suitable alternative methods to decrease cement usage, one of which is the addition of polypropylene fibers and zeolite. 126 types of unconfined compression tests with different ingredients were carried out with the aim of decreasing cement usage and improving soil properties. Two types of sandy soil were adopted in this study, i.e., SP and SW soil. They were improved by 4% cement, 0, 0.25, 0.5, 0.75, and 1% of polypropylene fibers with random distribution, and 0, 10, 30, 50% of zeolite were used during curing periods of 7, 14, 28 days. According to the compaction test results, with the addition of 0.5% polypropylene to the SW soil, and 1% to SP soil, the value of optimum moisture increases, and then decreases. On the other hand, the addition of polypropylene fibers resulted in decrease of the special dry weight of both type of soils. It also revealed the optimum percentage of zeolite and polypropylene fibers in SW soil are 30% and %0.5, respectively, while this values in the SP soils are 10% and %0.75, respectively. The proper adoption of zeolite and polypropylene in cement led to increase in unconfined compression tests as well as elastic deformation strength.

Keywords

Soil stabilization, polypropylene fiber, Portland cement, zeolite, UCS test

1. Introduction

There are several methods to improve soil engineering properties. In recent decades, soil reinforcement has been considered by geotechnical engineers [1-3].

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Granular soils have always been problematic due to their resistance properties. The main character of loose and uniform sandy soils are their low strength and non-adhesion. To stabilize this type of soil, adding cement is one of the most commonly-used options [4].

Finding a suitable alternative to cement consumption in construction projects can be one of the best solutions to protect the environment. Meanwhile, pozzolans, which have long been used as an alternative to cement in construction, can greatly ameliorate the problems. Pozzolans such as zeolite have been able to increase soil's compressive strength and durability by replacing them with cement. This approach will lead to energy saving (because cement production is energy-demanding) and reduce CO2 emissions [5-7]. The general chemical formula of zeolites is given in Equation 1 [8].

$$[(M^{+},M^{2+}_{0.5})AlO_{2}]x.[SiO_{2}]y.[H_{2}O]z \quad (1)$$

usage of polypropylene fiber has a lot of positive impacts on soil, for instance: increasing tensile strength, flexural strength, stiffness, and improving fracture mode in the composition.

2. Methodology

In this research two types of soils, i.e., SP and SW were used. 7, 14, and 28 days were considered as curing periods and a total of 126 samples for unconfined compression tests were considered. In order to improve these two types of soils, 4% by weight cement, 0, 10, 30, and 50% of zeolite replacement with cement and 0, 0.25, 0.5, 0.75, and 1% of polypropylene fibers were used. To prepare the samples, first cement and zeolite were mixed with the dry sandy soils then polypropylene fibers were mixed with soil to cover all parts of the soil. In the next step distilled water was added to the soil. The curing process needs time and samples were stored in the mold so that a Polyvinyl chloride (PVC) pipe was used as a mold. The curing samples were placed separately in wet cloths and then covered with nylon bags in order to stop evaporation and were tested according to the schedule (Figure 1).

Figure 1. Steps for making and curing samples - a) PVC mold, b) processing of samples inside wet coating, c) samples removed from wet coating, d) a sample before UCS test

3. Results and Discussion

The maximum unconfined stress in SW soil by replacing 30% zeolite with cement is higher than that non-zeolite specimens, and by increasing zeolite content, the unconfined compression strength of samples decreases. Also, the rupture strain of the stabilized sample by 30% zeolite replacement is higher than the non-zeolite sample. On the other hand, in SP soil by replacing 10%

zeolite instead of cement, the maximum unconfined stress is higher than samples without zeolite, and by increasing the percentage of zeolite replacement, the unconfined strength of the samples decreases. Also, the rupture strain of the stabilized sample by 10% zeolite replacement is higher than the non-zeolite sample, which indicates an increase in the ductility of zeolite samples compared to cement samples.

Addition of polypropylene fibers to cemented samples significantly increases the stress and strain rupture of both type of sandy soils. The increase in strain of the specimens is due to the filaments of polypropylene fibers, which cause a connection between the far soil particles with each other, and at the moment of rupture, the fibers stretch and show greater resistance. In SW soil the optimum percentage of fibers is 0.5% of the total soil weight and in SP soil this value is 0.75%. The reason for this difference is the presence of fine-grained soil in the SW soil, which fills the pores between the sandy grains and creates more adhesion in the sample.

4. Conclusion

In poorly sandy soil (SP), 10% zeolite replacement with cement increased the stress and strain properties of the samples, and by increasing the zeolite replacement percentage, the unconfined strength of the samples decreased. On the other hand, in the well-grained sandy soil samples (SW), zeolite by 30% replacement with cement the stress and strain properties of the samples increased and by further increasing the zeolite, the unconfined strength of the samples decreased. The reason for this difference in the samples stabilized with these two soil types is the presence of more empty space in poorly granulated sand samples, which can place a higher percentage of zeolite between its empty pores in a way that prevents the hydration process. Also, the absence of fine granular in poorly granulated soil prevents proper mixing of materials with each other and reduces soil cohesion.

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