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Laboratory investigation of chemical-mechanical stabilization conditions and durability of SP sand samples under the effect of freeze-thaw periods

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ABSTRACT: The occurrence of ice lenses and the subsequent melting of the ice causes a lot of damage to the beds consisting of fine sand soils every year. Volumetric changes of soil during freezing-thawing is a factor that reduces soil strength and increases deformations. In this study, several laboratory measurements are presented to investigate the effects of freeze-thaw cycles on the behavior of cylindrical sand-cement-fiber specimens. Fine-grained sand has been chosen to investigate the effects of freeze-thaw. At the same time, chemical stabilization methods of soil by mixing with cement with amounts of 2, 4, and 6% by weight of dry soil and mechanical reinforcement by adding 0, 0.5, and 1% by weight of recycled nylon fibers have been used. This study shows that the presence of fibers next to cement causes obvious changes in the stiffness, strength, and durability characteristics of the samples under the effect of freeze-thaw cycles. From the findings of this study, it can be concluded that in samples without fibers, distinct and wide cracks are observed. While, in samples armed with fibers, the cracks are smaller and distributed in a wider width. The results related to the behavior of the samples during loading showed that in the samples reinforced with fibers, failure occurred due to the pull-out of the fibers. In 7-day dry samples (without the freezing-thawing cycle effect), the compressive strength of the samples increases with the addition of fibers. In the 28-day samples, with an increase of only 0.5% of fibers with a length of 0.5cm, the unconfined compressive strength increased , and its decrease was observed after that. In all 7d and 28d dry samples, with the increase of fiber size from 0.5cm to 1 and 1.5cm, the compressive strength of the samples has a decreasing trend. Also, by adding the percentage of fibers from 0.5 to 1%, the trend of decreasing strength of the specimens can be seen.

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1- Introduction

Fine-grained sandy soils show various weaknesses in front of the environmental conditions. One of the important weaknesses of such soils is the occurrence of large volume changes in their internal structure at temperatures below zero degrees Celsius, due to freezing. If such soils are chosen as a base for the construction of structures or for the implementation of road bodies, after enduring several time cycles of freezing and thawing, they will suffer a significant reduction in strength and stiffness. There are various solutions to improve and strengthen soils, against the effects of changing temperature conditions. Two of the most important solutions include chemical stabilization and mechanical reinforcement of the soil by some types of fibers. A review of past researches shows that the studies conducted on stabilizers such as cement and reinforcements such as fibers are more focused on their separate effects than their combined effect.

Some researchers found that the use of individual fibers greatly increases the toughness and leads to the improvement of the strength behavior of soil-cement [1]. Liu and Peng [2] reported that after reinforcing the soil with separate polypropylene fibers, there is a significant increase in shear strength, toughness, and ductility of cohesive soils. Extensive research has been done on the recognition and evaluation of the mechanical behavior of fiber-reinforced soil as well as its use (Lee and Adams [3], Gray and Owahshi [4] and Freitag [5]). The results of research in this field show the effect of improving compressive strength, shear strength, and CBR and increasing soil ductility; Therefore, the random distribution of fibers in the soil can be considered as a reinforcing material that improves the engineering properties of the soil.

Even today, many studies have been conducted on the effect of different types of fibers and their use in reinforcing all types of soils, Most of these studies are on sandy soils and the fibers used are more synthetic [6], The study of the shear strength of sand reinforced with polypropylene fibers with the help of direct shear test by Yatim Oqlo and Salbas [7], Evaluating the bearing capacity of a sand embankment armed with separate polymer fibers with random distribution

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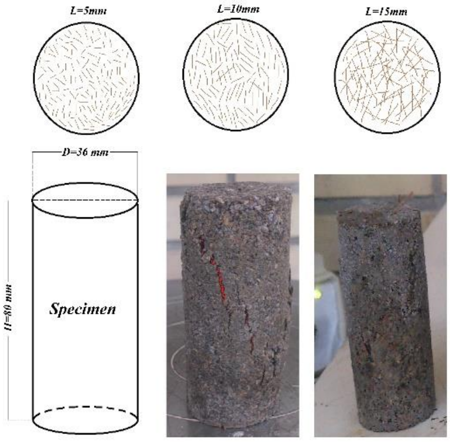

Fig. 1. The dimensions of the cylindrical specimens, the failure of the specimens, and the fibers with three lengths.

Table 1. Mechanical and physical characteristics of recycled fibers and sandy soil.

Strength characteristics of recycled fibers					
Fiber diameter mm	Specific Weight gr/cm^3	Elastic modulus N/mm^2	The force at the ultimate strength N	strain at ultimate % strength	% water absorption
0.54	0.91	104.99	284	27.99	13.97
Physical characteristics of SP fine-grained sandy soil (granulation and Atterberg limits)					
PL LL,	C_u (-)	C_c (-)	G_s(-)	γ_{dmax}(kN/m^3)	ω_{opt} (%)
-	2.50	0.94	2.66	1.70	10

placed on a layer of soft clay, has been studied using the CBR test by Yatim Oglu et al. [8]. Also, conducting tests on the behavior of fine-grained sand armed with curly polypropylene fibers (Ebraim and Furment9]]). Among other researches is investigating the mechanical characteristics of silty sand reinforced with waste tire yarn, with the help of uniaxial, CBR, and direct shear tests by Asadi [10]. Also, valuable research on the effects of freezing-thawing periods on the strength and stiffness characteristics of sandy soils11-] 13], river silt [14], and silty clay [15] has been presented. However, according to comprehensive investigations, the simultaneous effect of chemical stabilization of sandy soil with cement and its reinforcement with fibers under the simultaneous effect of curing periods and freeze-thaw cycle has been addressed to a lesser extent. These cases have been investigated as innovations in the present study.

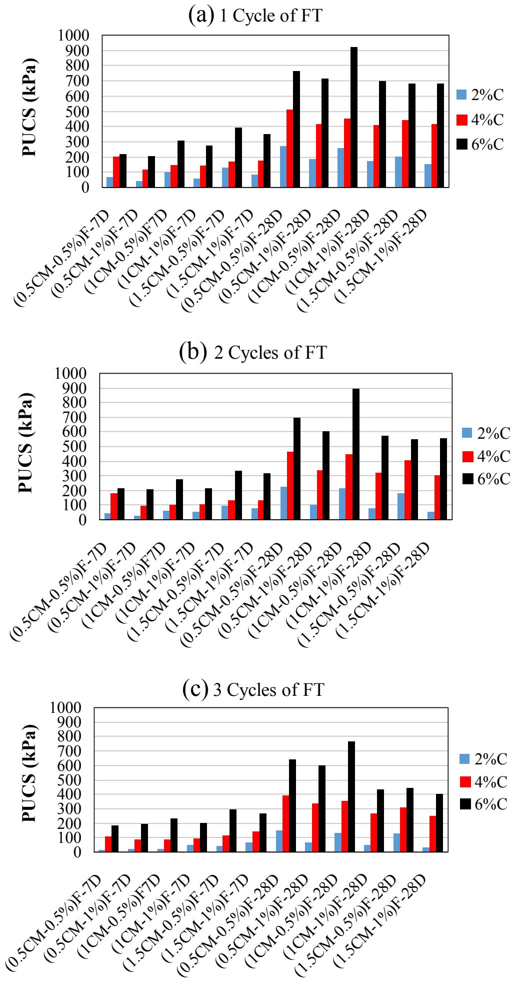

Fig. 2. Comparison of maximum UCS of samples with different cement-fiber percentages.

2- Methodology

In this study, cylindrical samples of sand, improved with cement and recycled fibers, were subjected to freeze-thaw cycles and UCS (unconfined uniaxial compressive strength) tests. The dimensions of the samples are H=8cm in length and D=3.6cm in diameter (i.e., H/D ratio=2.22). Poorly-graded fine sand (SP) has been used to make the samples. The number of 0, 1, 2, and 3 freeze-thaw cycles has been applied on three sand-cement combinations containing 2%, 4% and 6% by weight of cement. In addition, 0%, 0.50% and 1% by weight of recycled tire yarn fibers have also been added to these samples. Each of these three percentages of fibers has been used in three different lengths including 0.5, 1 and 1.5cm in the produced samples (Fig. 1, Table 1).

3- Discussion and Results

In Figure 2, the general results of the effects of freeze-thaw periods on the unconfined compressive strength (UCS) behavior of cement- treated sand samples stabilized with different percentages of cement and reinforced with different lengths and percentages of recycled fibers are drawn. According to this figure, increasing the curing days from 7 to 28 days in all samples and all freeze-thaw cycles increases the strength of the samples. Also, increasing the number of cycles decreases the strength of the samples. On the other hand, increasing the length of fibers also causes a decrease in strength in many cases.

4- Conclusion

This paper investigates the cylindrical laboratory specimens under the effect of freeze-thaw periods that are reinforced with recycled fibers and stabilized with cement. The results of this study can be described as follows:

The addition of fibers reduces the strength of samples against freezing and thawing.

Fibers along with cement increase the ductility of samples.

Fibers affect the durability of samples against freeze-thaw cycles.

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