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Shearing behavior of Carbonate Sand of Khark Island Cemented by a Pseudo-natural Method

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ABSTRACT: In the present study, the effect of natural cementation on the shearing behavior of carbonate sand of Khark Island, south of Iran, has been investigated. To do so, a pseudo-natural cementation method was employed. The importance of this technique lies in its suitability as a substitute for undisturbed samples of cemented carbonate soil that are hard and costly to prepare. Uncemented and cemented samples provided by this method were tested using direct shear apparatus and the results were analyzed and compared to one another. Furthermore, the effects of factors such as curing time and relative compaction on the shearing behavior of the Khark sand were studied. It was observed that cementation results in the rise of the shearing resistance, in particular at high vertical stresses, and leads to a decline in the tendency of soil to dilation. While cementation led to growth in the internal friction angle of soil, it may cause an increase, a decrease, or no change in the cohesion of the Khark sand. The increase in curing time led to a considerable rise in the cohesion and a minor change in the internal friction angle of the cemented soil. Furthermore, results showed that as the relative compaction of the investigated cemented carbonate soil goes up, the cohesion of the soil might increase, decline, or stay unchanged while the internal friction angle always increases. Factors that are likely to contribute to the development of the behavior stated earlier were introduced and their effects were discussed thoroughly.

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1- Introduction

In contrast to silica soils, aggregates of the carbonate soils have an irregular shape, more inter-particle and intra-particle porosity and are generally weaker and more compressible. Since natural deposits of carbonate soils exist in a broad range of degrees of cementation, they are generally inhomogeneous [1]. Studies on the behavior of carbonate soils can be divided into four main groups: (1) comparison of uncemented silica and carbonate soils, (2) uncemented carbonate soils, (3) comparison between cemented silica and cemented carbonate soils and (4) the effect of cementation on the carbonate soils. research indicate that the internal friction angle of carbonate soil is greater than that of silica soils [2]. Furthermore, some researches are devoted to the effects of anisotropy [3], permeability [4] and particle crushing on the behavior of carbonate soils.

In addition, different aspects of cementation, namely cementation method, curing time, cement type and physical properties of the carbonate soil, have been investigated so far [5-9]. In the present study, a pseudo-natural cementation method capable of simulating the natural process of shallow marine cementation [10] is utilized for the cementation of Khark sand. Then, the effects of relative compaction (RC) and curing time on the shearing behavior of cemented samples are investigated using a series of direct shear tests. The behavior of the cemented and uncemented soil are compared together and discussed.

2- Pseudo-natural Cementation in Laboratory

Conducting sieve analysis on the carbonate soil of Khark Island, the soil symbol was found to be SP according to USCS. In addition, performing the standard proctor tests, the optimum water content and maximum dry unit weight of this sand were obtained 13.1% and 16 kN/m^{3,} respectively.

Samples of carbonate soil of Khark Island were prepared in three different relative compactions, RC=85%, 90% and 95%. In order to ease the comparison, the moisture content of all uncemented and cemented samples was kept equal to 5%.

In order to simulate the shallow marine cementation, a continuous flow of dissolved supersaturated CaCo3 should move through the sediments and precipitate on the sediment particles. To do so, first, a mass of lime (CaO) was added to water to obtain Calcium Hydroxide. The produced $Ca(OH)_2$ then were passed through sieve number 200 and was mixed with distilled water to produce a lime slurry. Afterward, the lime slurry was moved to a glass container whereby adding CO_2, a saturated $CaCO_3$ solution at a pH of 6 was obtained. The solution was then supersaturated (PH≈7.3-7.4) by stirring the

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Table 1. Summary of direct shear tests

Test series	Cementation	Relative compaction (%)	Curing time	Number of tests
1	uncemented	85, 90, 95	-	9
2	cemented	85, 90, 95	2 days	9
3	cemented	85, 90, 95	7 days	9

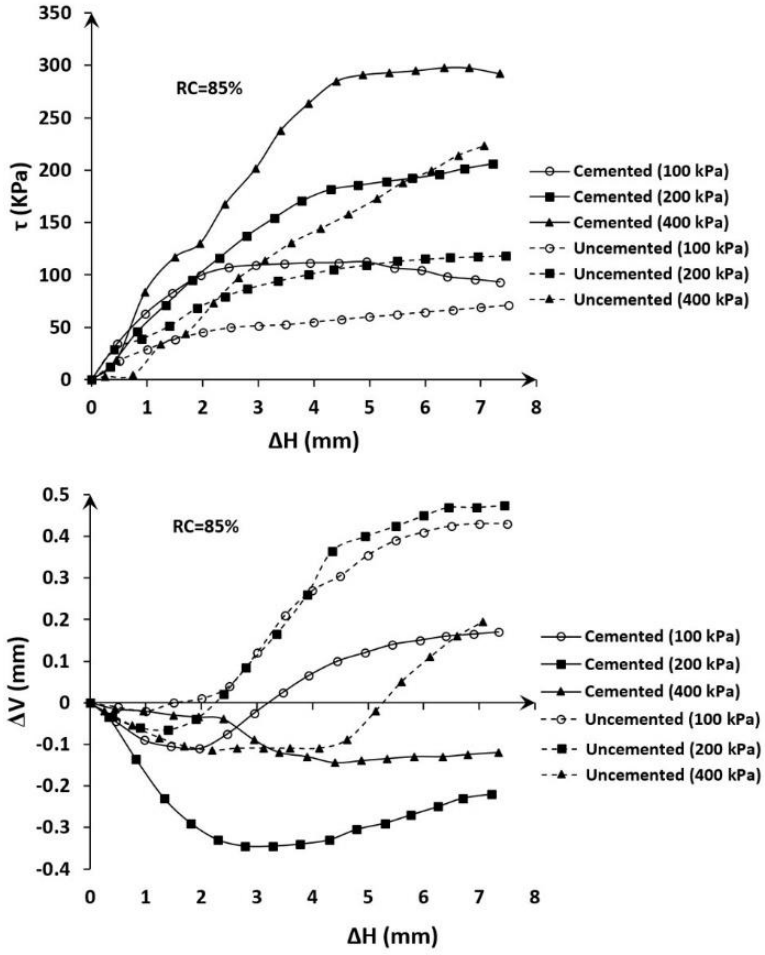

Fig. 1. Effect on cementation on the strength of carbonate soil of Khark (RC=85%)

solution and injecting oxygen (O_2) into the container. Then, samples of the soil were submerged in the supersaturated solution for 5 minutes to let the $CaCo_3$ precipitate onto the soil particles. The cemented samples were then carried to the incubator for curing. In order to see the effect of curing time, some of the samples were kept in the incubator for 2 days and some for 7 days.

3- Test Program

The direct shear test (DST) was performed applying three different vertical stresses, 100 kPa, 200 kPa and 400 kPa. A summary of DSTs carried out in this study is illustrated in Table.1.

4- Results and discussion

As Figure 1 indicates, at given relative compaction (here 85%), cementation leads to a significant rise in the shearing resistance of the Khark sand in comparison to uncemented soil. In terms of volume change, cemented soil develops a tendency to compaction compared to uncemented soil (Figure 1). In addition, results indicate that cementation always increases the friction angle of the Khark sand while it may cause growth, decline, or no change in the cohesion of this soil. The variations in the cohesion can be attributed to the change in the two opposing agents: unsaturation of the soil and cementation.

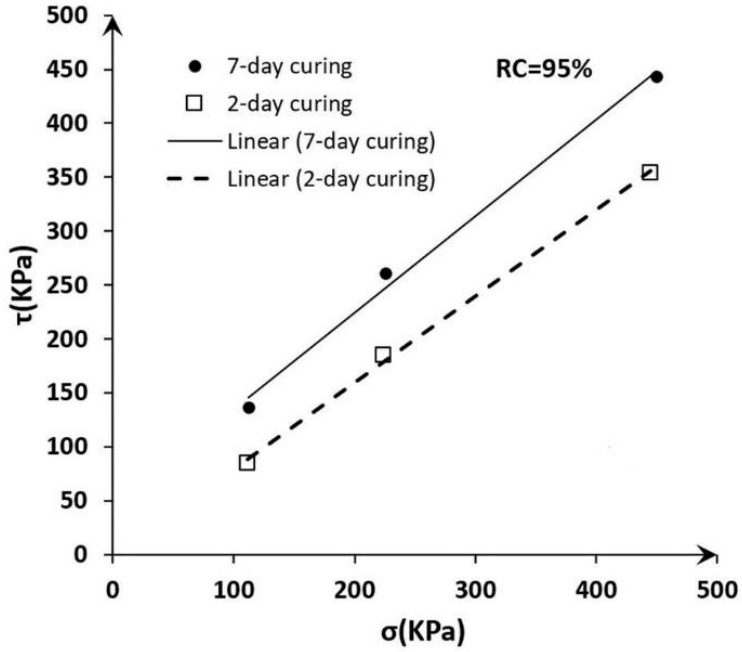

Fig. 2. Effect on curing time on the strength parameters of cemented carbonate soil of Khark (RC=95%)

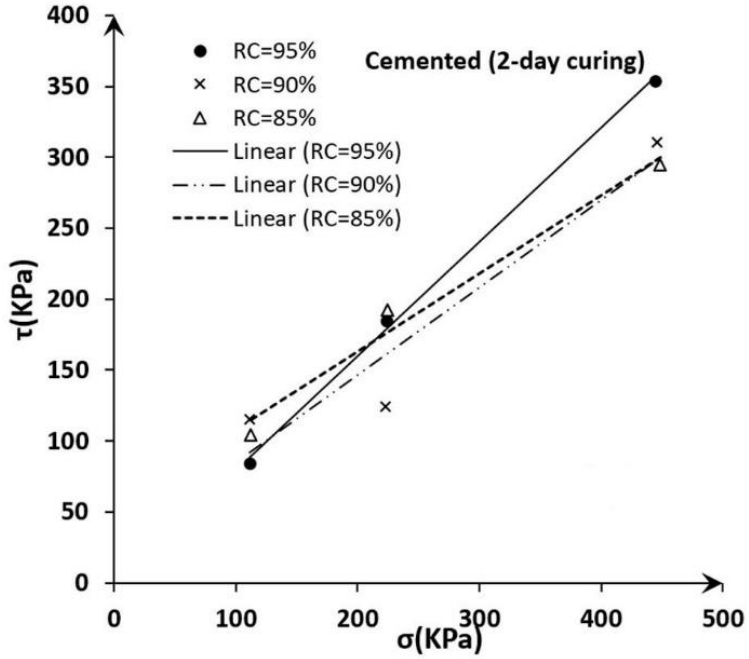

Fig. 3. Effect of RC on the strength parameters of cemented carbonate soil of Khark (Curing time=2 days)

Regardless of the RC, as the curing time increases from 2 days to 7 days, the cohesion significantly grows while there is only a slight rise in the internal friction angle of the cemented Khark sand. Fig.2 confirms the aforementioned phenomenon for RC=95%.

Furthermore, results indicate that with the increase in the relative compaction of the Khark cemented sand, both cohesion and internal friction angle may experience an increase, a decrease, or no change. It can be argued that compaction and cementation contribute to a decline in the apparent cohesion caused by unsaturation by lowering the void ratio and hence raising the degree of saturation.

Cementation, on the other hand, increases the apparent cohesion. The composition of these three opposing agents may be the reason for the cohesion variations.

5- Conclusions

In this study, the carbonate sand of Khark Island was cemented using a pseudo-natural cementation method. Effects of the relative compaction and curing time on the shearing behavior of the cemented samples were investigated using a series of direct shear tests. Then comparisons were made between the shear behavior of the cemented and uncemented samples. Variations of strength level, volume and strength parameters were then presented and the likely causative agents were introduced and discussed.

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