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Comparison of carbonate and quartz sand shear strength parameters with triaxial and simple shear tests

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ABSTRACT: Carbonate sediments are among the problematic soils in geotechnical engineering. These soils are different from quartz soils both in terms of production origin and engineering behavior. In this paper, for comparison of shear strength parameters, Bandar Abbas carbonate sand and Firoozkooh quartz sand were studied by common triaxial and simple shear tests. Experiments were performed under the same conditions of grain size, relative density and stress level. Parameters such as physical properties, shear behavior, stress path, modulus of elasticity, shear modulus, internal friction angle and dilation angle were compared. The results showed that Bandar Abbas carbonate sand had higher shear strength than quartz sand. The maximum internal friction angle of carbonate sand was higher than quartz sand due to its intrinsic interlocking in both triaxial and shear tests. The dilation angle decreases with increasing stress level for both experiments. Also, the internal friction angle obtained from the triaxial test was higher than the simple shear test for about 10 to 15% due to different stresses paths and the presence of a pre-shear in the simple shear test. Also, the presence of shear stress in simple shear tests reduces more the internal friction angle versus stress level compared to the triaxial test.

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1. INTRODUCTION

Carbonate soils contain significant amounts of calcium carbonate and differ from quartz soils in engineering behavior. Carbonate sediments are one of the problematic soils in geotechnical engineering. These soils have biological, mechanical and chemical origins and are found all over the world. Also, the degree of cementation of carbonate soils varies considerably. Usually, these soils have high porosity between grains, irregularity, fragility and high compressibility potential.

Coop et al. (2004), Zhang et al. (2020), by conducting several experiments on carbonate sand, found that grain crushing was a major factor in determining the shear strength and dilation angle [1, 2]. Brands (2012) stated that the volumetric behavior of carbonate sands is different from that of quartz sands. He also found that with increasing the normal stress in the simple shear test, the maximum internal friction angle of carbonate sand decreases more than quartz sand due to the brittleness of the grains [3]. Hassanlourad et al. (2014), Wang et al. (2019) examined the carbonate sand and stated that the shear strength of these sands depends on soil particle size distribution, grains shape and carbonate particles structure and the presence of intergranular cavities has a great effect on shear strength [4, 5]. Rasouli et al. (2016), by examining Chabahar carbonate sand and Firoozkooh quartz sand, found that with the confining stress increase, the dilation angle of both sands decreases. In carbonate sand, the dilation angle decreases more due to the crushing of the grains [6].

2. METHODOLOGY

In this research, two types of carbonate and quartz sand have been used. The carbonate sand was obtained from Bandar Abbas and Firoozkooh sand was used as quartz sand. BS-1377 standard was used to determine the percentage of calcium carbonate content in sands. 28 triaxial tests were performed according to the ASTM D7181 standard and 24 simple shear tests were performed according to ASTM D6528 standard. Samples were made with two loose relative densities (30%) and dense relative densities (70%) by the dry pouring method. The triaxial experiments were performed under confining stresses of 50, 100, 200, 300, 400, 500 and 600 kPa. Simple shear samples were also tested under vertical stresses of 50, 100, 200, 300, 400 and 500 kPa. All tests were done in dry condition.

3. RESULT AND DISCUSSION

Deviator stress versus axial strain diagrams resulted from triaxial tests for Bandar Abbas and Firoozkooh sands in loose and dense conditions under the same conditions in terms of relative density and confining stress showed that shear strength of Bandar Abbas carbonate sand is higher than Firoozkooh quartz sand. Shear stress versus shear strain diagrams obtained from simple shear tests for the two

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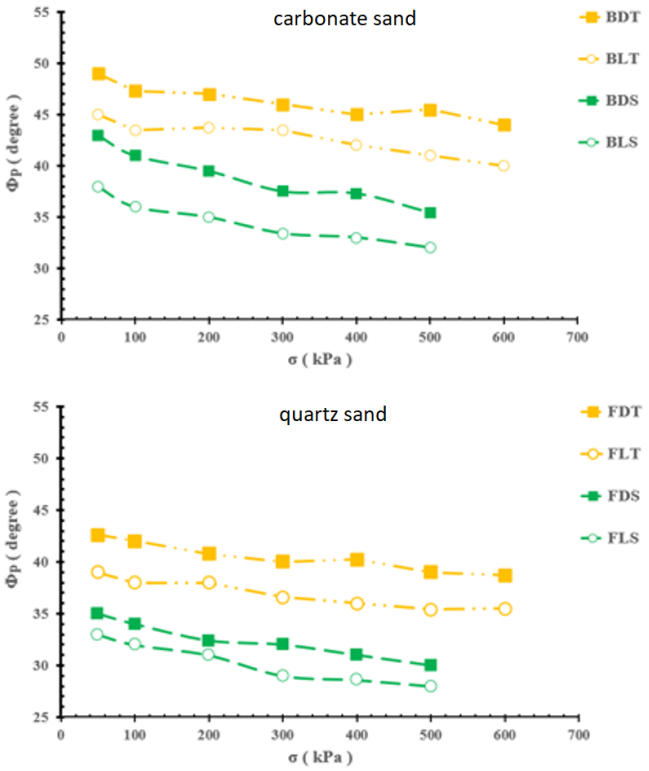

Fig. 1. Internal friction angle versus confining stress

sands of Bandar Abbas and Firoozkooh in loose and dense conditions illustrated that with increasing the relative density and vertical stress, the amount of shear strength increases. By comparing the two stress paths of two experiments, it was seen that the triaxial experiment has a larger stress path than the simple shear test under the same conditions of relative density and stress vel.

According to the results, the maximum internal friction angle of the carbonate sand at the same relative density and stress is considerably higher than that of quartz sand (Figure 1). This is a topic that has been reported by most previous researchers. This indicates an interlocking of the carbonate grains. Also, increasing the relative density increases the maximum internal friction angle of soil. Also, Increasing the vertical stress in the simple shear test reduces the maximum internal friction angle of both sands. Figure 1 also shows that the peak internal friction angle obtained from triaxial tests is more than that of simples shear tests due to different stress paths of two experiments and especially the presence of pre-shear stresses in simple shear tests during the initial consolidation phase. Notice that the samples are consolidated isotopically in the common triaxial test. Calculations showed that peak internal friction angle is 10 to 15% more, as an average, for carbonate sand in comparison with quartz sand. According to the results of the tests, it was seen that the amount of dilation angle of carbonate sand is higher than quartz sand due to its intrinsic interlocking and its decrease rate is greater with increasing stress level (confining pressure in triaxial tests and vertical stresses in simple shear tests) because of particles crushing of carbonate sand.

4. CONCLUSION

Shear strength of carbonate sand was higher than quartz sand. Also, carbonate sand showed softening behavior in both loose and dense states, while quartz sand, tends to harden, especially in the loose state.

The maximum internal friction angle of carbonate sand was significantly higher than quartz sand in both loose and dense states. Also, the presence of pre-shearing in simple shear tests has a greater effect on the crushing of the carbonate grains and thus reduces more the internal friction angle compared to the triaxial test.

In the simple shear test, due to the presence of a pre-shear during consolidation, the overall results of the two experiments show a more internal friction angle of about 10 to 15% for the samples tested by common triaxial apparatus.

The rate of dilation drop versus the stress level in carbonate sand is more than quartz sand due to its grains ability to crush. Also, the rate of dilation loss is higher in loose specimens because they have less initial interlocking and tightening than dense specimens.

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