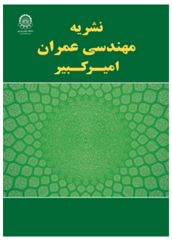

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Comparative Study of Carbonate and Quartz Sand Based on Energy Concepts

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ABSTRACT: Carbonate sands have being known as problematic soils in civil engineering and their strength is different from those of quartz sands. In this paper Triaxial consolidated-drained shear strength of a carbonate sand obtained from north beach of Oman sea is compared with Firoozkooh quartz sand. Energy concept is used for the analysis. Tests were performed in the same conditions such as particle size distribution, relative density and confining pressure on sands with different particles shapes. Tests results and analysis showed considerable differences between two sands regarding the shear strength and its components, soil volume changes, particle breakage potential and its effects on the shear strength, consumed energy for the particle crushing, dilation and particle crushing portion from the total internal friction angle of soils. At the end, it was found that there is a linear relation between the consumed energy for particle crushing from total applied energy to the soil specimen and particle breakage portion from the soil total internal friction angle. In the carbonate sand with high particle breakage ability a value of %14-31 and in the quartz sand maximum %10 of applied energy is consumed for particle breakage.

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1- Introduction

Carbonate sands are known as problematic soils in civil engineering projects. The first problem concern with these soils occurred in installation of driven piles in Lavan Island of Persian Gulf in 1961. During the pile driving process sudden free fall of the pile occurred (McClelland, 1988).

Carbonate grains generally have angular, platy and needle shape, whereas quartz grains usually have spherical and bulky shape. In platy and needle shape grains, stress among particles are more than bulky grains in the same conditions, so volume change because of grains abrasion and crushing is higher in carbonate soils (Fookes, 1988 and Noorani, 1989). Several behavioral issues have been enumerated in the past literatures for this type of soil without direct comparing it with quartz sand. In this paper, a carbonate sand sample is chosen for comparison purposes. The shear behavior of the sample is compared with a quartz sand sample with the same particle size distribution using the static triaxial drained test results and energy concept.

2- Materials

Carbonate sand was obtained from Tang port in northern shore of Oman Sea. Tang port is a small port at 70 km west of Chabahar port in south east of Iran. Firoozkooh quartz sand graded so it had the same particle size distribution with the Chabahar sand. Fig. 1 shows the particle size distribution of the both sands (ASTM D422-63).

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Table 1. Physical properties of the sands studied

Sands	Chabahar	Firoozkooh
e_{max}	0.982	0.865
e_{min}	0.697	0.580
Cu	1.13	1.13
Cc	1.54	1.54
USCS	SP	SP
$CaCO_3$ (%)	46.7	1.03
Gs	2.72	2.62

Table 1 shows the physical characteristics of the carbonate and quartz sands such as equivalent carbonate content, specific gravity, minimum and maximum void ratio, coefficient of curvature and uniformity and results of soils classification (ASTM D854). As seen in Table 1, the soil samples obtained from Chabahar and Firoozkooh are classified as extremely uniform sand by the Unified Soil Classification System (USCS). In order to determine the shape of soil grains, the scanning electron microscopy (SEM) images of the soils were prepared as well (Fig. 2a, b). According to Table 1 and Fig. 2, although these two types of sand have similar gradation and equal-sized grains, the maximum and minimum void ratios of Chabahar sand are approximately 13.5% and 20% more than those of Firoozkooh sand respectively. This emphasizes

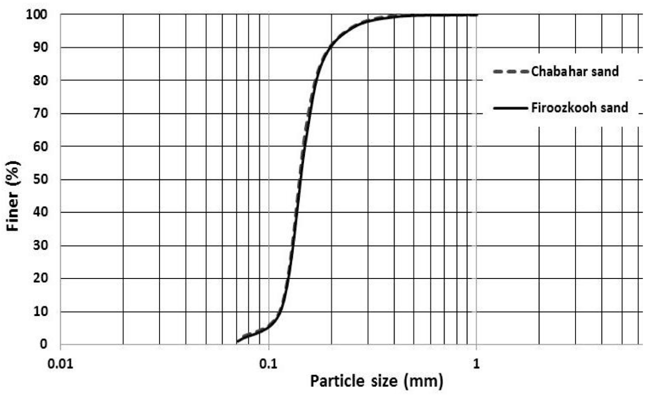

Fig. 1. Particle size distribution of sands

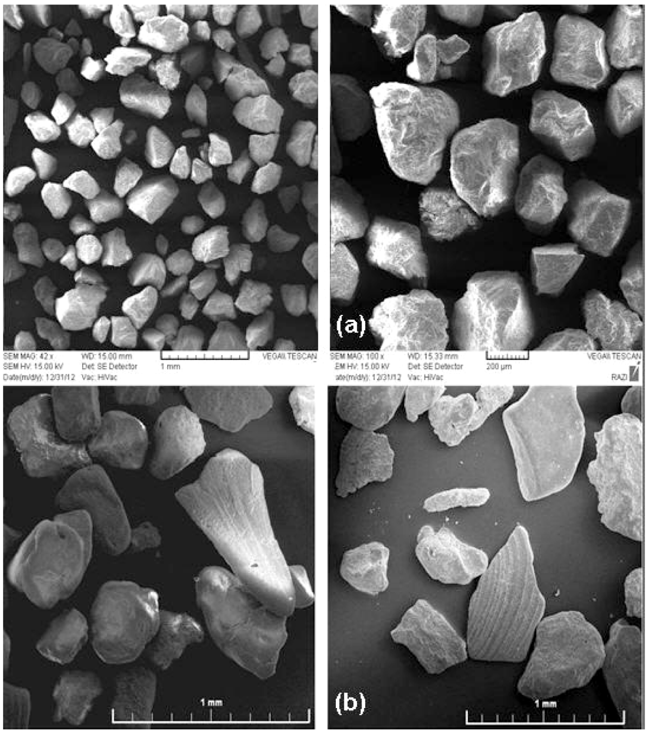

Fig. 2. Microscopic electronic images of sands: (a) Firouzkoh (b) Chabahar sand

the significance of the geometry of grains on soil packing. As seen in Fig. 3a, Firoozkooh sand has voluminous grains with sharp corners and rough surfaces while Chabahar sand is composed of variety of planar grains with sharp corners and semi-spherical grains with relatively smooth surfaces. It also shows a little bit of intra-granular and biological porosity.

3- Sample preparation and testing

A total of 28 consolidated-drained monotonic triaxial tests were performed (ASTM D7181-11). The samples were built with relative densities of 20% and 80% using the dry deposition method. The cylindrical samples had diameters of 3.8 cm and heights of 7.6 cm. In order to obtain homogenous samples, the soil was divided into 3 layers. Each layer was separately cast with a specific weight ratio and was built by mild strokes of a plastic hammer on the sample mold. The samples were 95 % saturated before the test. In order to accelerate the saturation of the samples, before allowing distilled water to pass the samples, they were targeted by carbon dioxide and were saturated under a back pressure of about 200 kPa. Experiments were carried out under confining stresses of 100, 200, 400 and 600 kPa.

4- Results

The obtained result from the tests and analysis of them based on energy concept are reported briefly.

4- 1- International friction angle

Peak internal friction angle based on Row's theory (1962) is demonstrated if Fig. 3 versus confining pressure. As shown in this figure, carbonate sand (Chabahar) has more internal friction angle than quartz sand, however, based on Fig. 4, mobilization of a such friction angle needs more deformation (axial strain). Also, increasing the confining pressure reduces the internal friction angle for both sand.

4- 2- Dilation angle

Fig. 5 shows the dilation angle of the two soils versus confining pressure. As seen in this figure, carbonate sand has more dilation angle under low confining angle (lower than about 150 kPa) and increasing the confining pressure reduces the dilation angle of carbonate sand with more rate in comparison with quartz sand due to high particle crushability of carbonate sand.

4- 3- Shear strength and particle breakage

Fig. 6 illustrates the maximum and minimum principal stresses ratio versus dilation parameters or shear strength

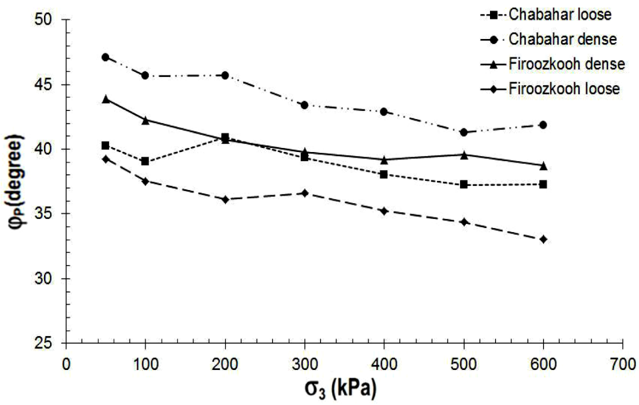

Fig. 3. Internal friction angle versus confining pressure

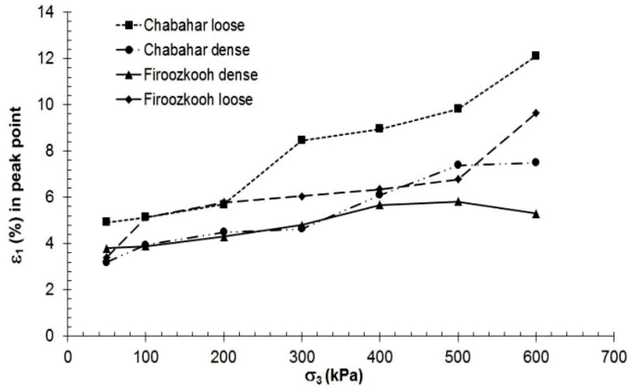

Fig. 4. Axila strain at peak point versus confining stress

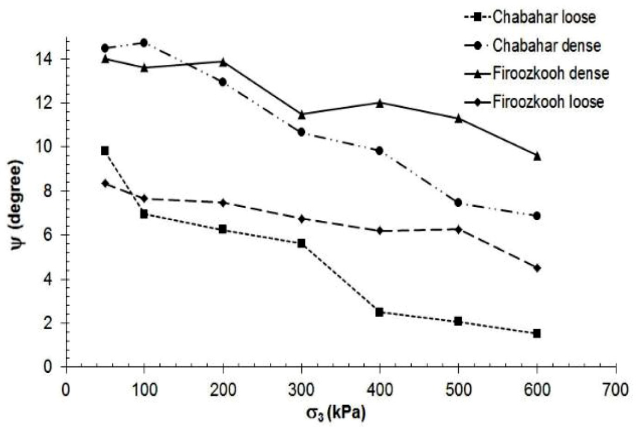

Fig. 5: Dilation angle versus confining pressure

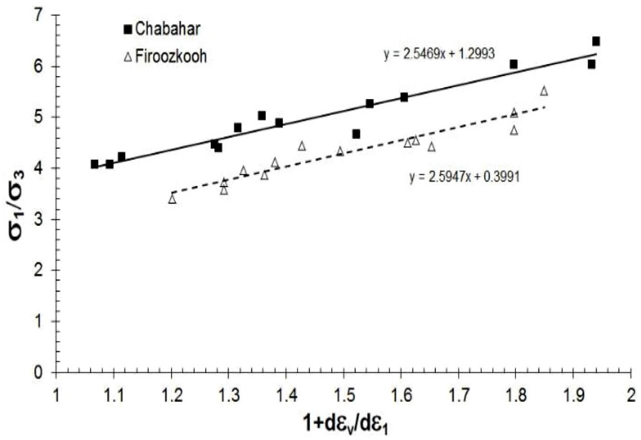

Fig. 6. Maximum and minimum principal stress ratio versus dilation parameters

of two soil. Based on Fig. 6, carbonate soil has more shear strength than quartz sand. Also carbonate sand have shown more dilation changes than quarts sand.

Fig. 7 shows the particle breakage angle (β) versus confining pressure. As seen in Fig. 7, carbonate sand has more particle breakage angle than quartz sand due to more particle breakage of carbonate sand. Also, particle breakage angle of carbonate sand is increased with increasing the confining pressure. It is noticeable that particle crushing is also increased with increasing the confining pressure. The way of particle breakage angle calculation has explained by Hassanlourad et al. (2012).

Particle breakage angle to peak internal friction angle ratio (β/φ_P) is shown in Fig. 8 versus consumed energy for particle breakage to total applied energy ratio ($\Delta E_B/\Delta E_T$). Regarding to this figure, β/φ_P ratio is related linearly to $\Delta E_B/\Delta E_T$ ratio for both soil. Also, β/φ_P ratio of carbonate sand is several times of quartz sand. It means that carbonate sand particles are more crushable than quartz sand.

References

[1] P. G., Fookes; The Geology of Carbonate Soils and Rocks and their Engineering Characterization and Description, *Proceeding International Conference Calcareous Sediments, Perth, Western Australia, ISSMFE*, Vol. 2, pp. 787-805, 1988.

[2] I., Noorani; Classification of Marine Sediment, *J. Geotech. Engineering*, Vol. 1, No. 115, pp. 23-37, 1989.

[3] B., McClelland; Calcareous Sediments: An Engineering Enigma, *1st International Congress on Calcareous Sediments*, Perth, Australia, pp. 777-784, 1988.

[4] P. W., Rowe; The Stress-dilatancy Relation for Static Equilibrium of an Assembly of Particles in Contact, *Proc. of Roy. Soc. London A269*, pp. 500-527, 1969.

[5] M., Hassanlourad; H., Salehzadeh; H., Shahnazari; Drained Shear Strength of Carbonate Sands Based on Energy Approach, *International Journal of Geotechnical Engineering*, 2013.

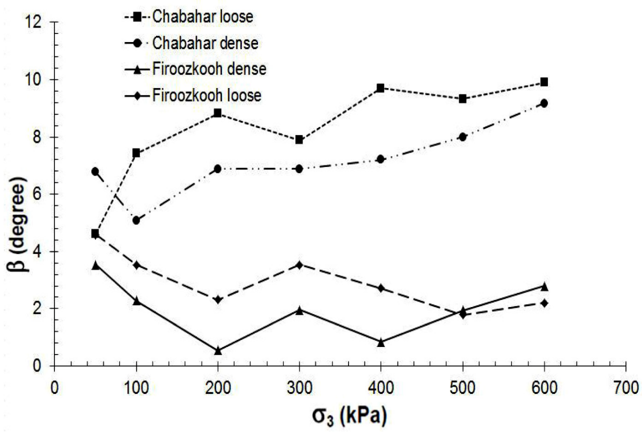

Fig. 7. Particle breakage angle versus confining pressure

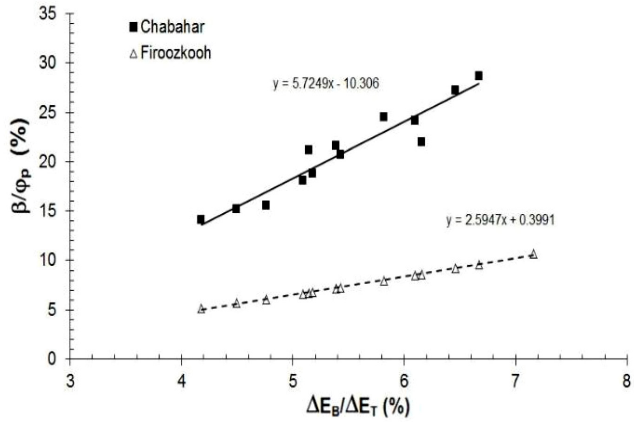

Fig. 8. Particle breakage angle to peak internal friction angle versus consumed energy for particle breakage to total applied energy

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