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Shear Behaviour of Misurata Wet Sand

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Abstract. The foundation design of buildings depends on the bearing capacity of soil and foundation shaft resistance, upon this reason, for buildings safety, the study of shear behaviour of soil is very important to analyse and evaluate the foundation settlement and friction between soil and foundation surface. especially in the case of deep foundation. The paper is to study and evaluate the shear behaviour of Misurata wet sand around foundation surface under the effect of different axial loads by using direct shear box test. This study contains nine laboratory tests were done to measure the Sand-Aluminum interface of smooth surfaces, and other nine tests for Sand-Aluminum interface of rough surfaces, to simulate foundation surface in the site. Also, another nine tests were done to measure Sand-Sand interface shear behaviour resulting from friction between wet sand grains under different normal loads, soil type and initial sand density in three cases of soil, loose, medium and dense wet sand. The test results showed that the value of soil displacement and interface friction angle (δ) are very important for foundation design, especially for deep foundations. Also, from the evaluation of experimental test results we found that the interface friction angle (δ) depends on roughness of the foundation, initial compactness, water content and porosity of sand.

1 Introduction

The foundation design of buildings depends on the bearing capacity of soil and foundation shaft resistance, upon this reason, for buildings safety, the study of static behaviour of sand shear resistance is very important to analyse and evaluate the foundation design, especially in deep foundation [1] Figure (1) shows the direct shear box, which used to measure soil bearing capacity factors (φ , c).

Nine laboratory tests were done to measure the sand-aluminum interface shear friction of smooth surfaces, and other nine tests for rough surfaces to simulate foundation surfaces in the site. Also, another nine tests were done to measure sand-sand interface shear behaviour resulting from friction between wet sand grains under different normal loads, soil type and initial sand density.

To analyse the interface friction between soil and foundation, and to evaluate the foundation settlement, it is necessary to know the shear behaviour of sand around and underneath the foundations. The roughness of foundation surface has high effect on foundation shaft friction development especially for deep foundation [2].

The study contains interface friction tests between soil and two types of construction materials with smooth and rough surfaces by using the direct shear box under different axial loads.

The aim of the tests is to study the effect of normal stress, initial soil density, foundation type and roughness of foundation surface on the friction resistance. From the test results, we can know the interface friction angle values (δ), and we can make comparison between these values and internal friction angle values (φ) of wet sand.

2 Soil properties

Table (1) shows the physical properties of sand, which used in the study of this paper. From this paper, we found that, the shaft resistance between sand and foundation surfaces increasing directly with increasing their surfaces roughness, but some papers confirmed that, the interface friction angle (δ), approximately equal sand-sand friction angle (φ), where the failure may happened in sand neighboring the foundation surface.

Table 1. Physical properties of sand

Condition of soil	Specific density	Dry density gm/cm^3	Void ratio e	Relative density Dr %
Loose wet sand	2.70	1.48	0.81	28
Medium wet sand	2.70	1.58	0.66	63
Dense wet sand	2.70	1.69	0.55	72

3 Experimental works

All the experimental tests were done on the models of construction materials in three different soil conditions, loose, medium dense and dense wet sand in direct shear test apparatus. The direct shear test apparatus which shown in figure (1) is used to measure the values of internal friction angles.

Fig. 1. Direct Shear Box

For preparing the model tests, the sand was poured in the shear box to simulate loose sand as in the site with initial density 1.45 gm/cm^3, where in the case of medium dense sand the soil was poured in the box and tamped by tamper until initial density 1.56 gm/cm^3 is received, but in the case of dense dry sand the soil was poured in the box by layers and every layer is compacted by a tamper until we get the initial density 1.67 gm/cm^3. sand-construction materials shaft shear tests, two aluminum model plates were prepared by dimensions (60 mm, 60 mm, 10 mm) one of them has smooth surface, where the other with rough surface, which equal the volume of bottom half of shear box, the sand was poured in the upper half of the box as mentioned before in three cases of sand, then the shear box instrument was started to work horizontally with 1 cm / min under applied normal load, Surface roughness of the aluminum model structural has an important effect on the shear stresses.

4 Test results

The maximum shear stresses developed by rough surfaces of structural models is higher than that developed by smooth surfaces, hence, from figures (2) and (3) we found that the values of horizontal displacements at maximum shear stresses in the case of sand-sand interfaces approximately equal that values for maximum shear stresses in the case of sand-rough aluminum interfaces, which ranges between (2.0-5.0) mm. This is attributed to that, the surface roughness of aluminum models approximately equal to the roughness of sand grains.
Figure (3) and (4) shows that in the case of rough model surface the maximum interface shear stresses are developed at smaller horizontal displacement than that in the case of smooth surfaces.

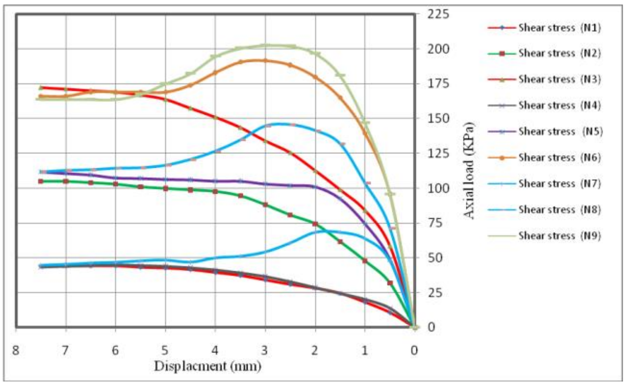

Fig. 2. The Relationship between Shear Displacement and Shear Stress for Sand-Sand Interface

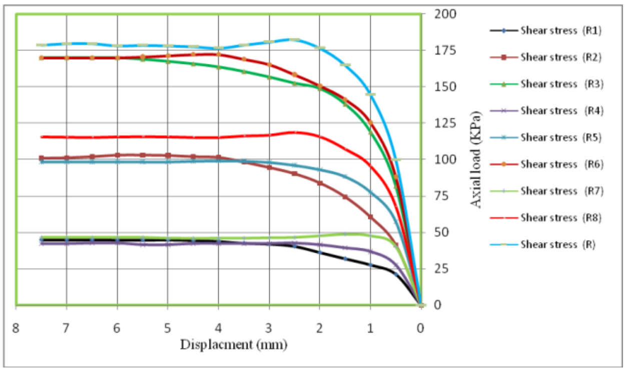

Fig. 3. The Relationship between Shear Displacement and Shear Stress for Sand-Rough Alum. Interface

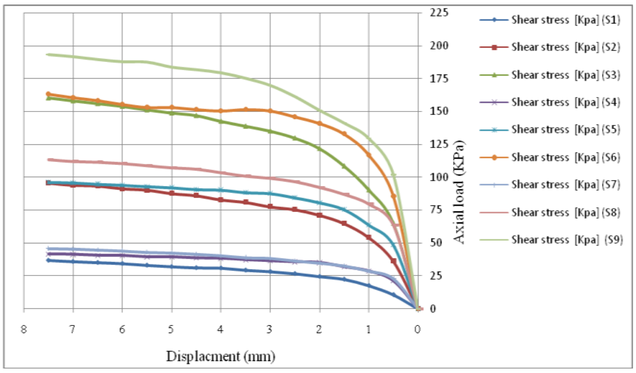

Fig. 4. The Relationship between Shear Displacement and Shear Stress for Sand-Smooth Alum. Interface

Table (2) shows the results of direct shear tests sand-sand interface, which done on wet sand under different normal loads (100 KPa , 200 KPa , 300 KPa) where, table (3) shows the results of direct shear tests which done on the wet sand and models of aluminum in smooth surfaces under different normal loads, and table (4) shows the results of direct shear tests, which done on the wet sand and models of aluminum rough surfaces under different normal loads.
The results of testing shows that, the sand-sand shear stresses, increases directly with increasing normal stress (σ) and with increasing the initial density of sand for smooth and rough aluminum model surfaces.
In the case of rough surfaces, we got the maximum values of shear stresses (τ_P), at the horizontal

displacement between (2.0-5.0) mm, and equal (7.0-7.5) mm in the case of model alumimum smooth surfaces.

Table 2. Results of Direct Shear Test for Wet Sand.

Sand–Sand Interface						
Soil condition	**σ KPa**	**Test No.**	τ_P	τ_U	φ_P	φ_u
Loose wet sand	100 200 300	N_1 N_2 N_3	44.1 105 172	44.1 105 172	32.6	32.6
Medium dense wet sand	100 200 300	N_4 N_5 N_6	44.6 112 191	43.6 112 166	36	31.5
Dense wet Sand	100 200 300	N_7 N_8 N_9	68.3 146 203	44.6 112 164	34	30.8

Table 3. Results of Direct Shear Test for Sand-Rough Aluminum Surfaces.

Sand–Ruogh Aluminum surfaces						
Soil Condition	**σ KPa**	**Test No.**	τ_P	τ_U	δ_P	δ_u
Loose Wet Sand	100 200 300	R_1 R_2 R_3	43 99 170	41.5 98.3 167	32.4	32
Medium Dense Wet Sand	100 200 300	R_4 R_5 R_6	44.9 103 172	44.2 101 170	32.4	32.2
Dense Wet Sand	100 200 300	R_7 R_8 R_9	48 119 182	46.8 116 179	33.8	33.4

Table 4. Results of Direct Shear Test for Sand-Smooth Aluminum Surfaces.

Sand–Smooth Aluminum surfaces						
Soil Condition	**σ KPa**	**Test No.**	τ_P	τ_U	δ_P	δ_u
Loose Wet Sand	100 200 300	S_1 S_2 S_3	35.7 95.7 160	35.7 95.7 160	32	32
Medium Dense Wet Sand	100 200 300	S_4 S_5 S_6	42.5 96.2 167	42.5 96.2 167	31.8	31.8
Dense Wet Sand	100 200 300	S_7 S_8 S_9	45.7 114 193	45.7 114 193	36	36

Figures (5), (6) and (7) shows the sand-aluminum interface shear resistance in two cases of aluminum model surfaces smooth and rough in three cases of wet sand, loose, medium dense and dense wet sand.
Figures (5), (6) and (7) shows the maximum sand-sand interface friction angles (φ_P) and the maximum sand-aluminum interface friction angles (δ_P) in the case of smooth and rough surfaces in three conditions of sand, loose, medium dense and dense wet sand, Also, the figures show the ultimate sand-sand interface angles (φu) and the ultimate sand aluminum interface angles (δu) in smooth and rough surfaces in three cases of loose, medium dense and dense wet sand
Figures, (5), (6) and (7) shows that the sand-sand interface friction angles (φ_P,φu) approximately equal the sand aluminum interface friction angles (δp, δu) in the case of rough surfaces, this attributed to the roughness equality of sand grains and the aluminum model structural surfaces, where, in the case of smooth surfaces, we found that the sand-aluminum interface friction angles (δp, δu) is smaller than the sand-sand interface angles (φp, φu), similar results were shown in papers [1],[2],[4] and [5].

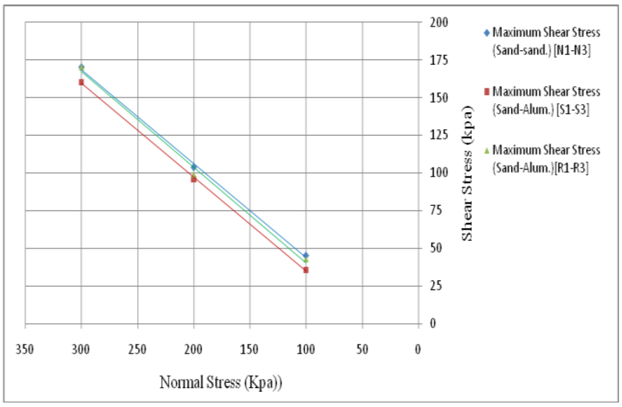

Fig. 5. The Maximum Sand-Aluminum interface angles and the Maximum Sand-Sand friction angles for loose wet sand

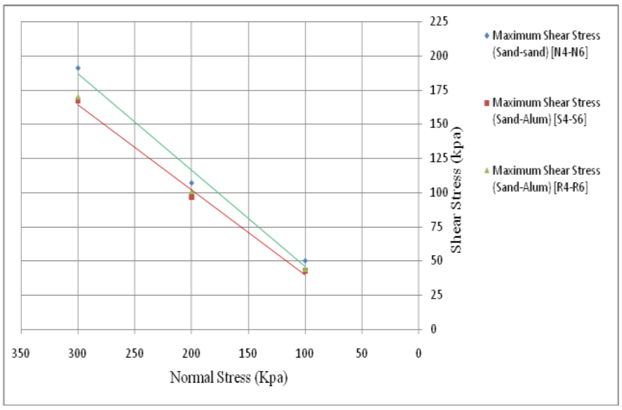

Fig. 6. The Maximum Sand-Aluminum interface angles and the Maximum Sand-Sand friction angles for medium wet sand

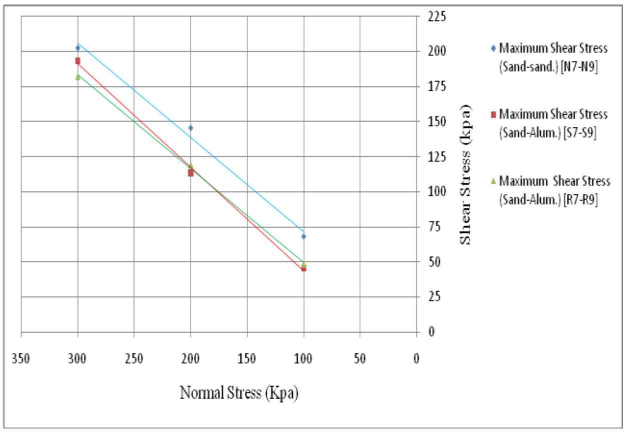

Fig. 7. The Maximum Sand-Aluminum interface angles and the Maximum Sand-Sand friction angles for dense wet sand

5 Summary

The test apparatus, direct shear box is more important methods to study shear behaviour between soil and construction material surfaces, it offers certain features that can be advantageous in analysing the foundation–soil interaction.
For this reason, tests were done on sand-aluminum interface shear behaviour in two cases smooth and rough surfaces, Also, sand-sand interface tests were done to know sand shear behaviour under different conditions.

6 Conclusion

On the basis of the tests, which were done (9 sand-smooth aluminum interface, 9 sand-rough aluminum interface and 9 sand-sand interface) the fallowing conclusion can be drawn:
1-The maximum sand-sand interface shear resistance (τp) and the ultimate sand-sand interface shear resistance (τu) depends on the effects of shear stresses.
2-The shear displacement to mobolise the maximum shear stresses (τp) for sand in the case of aluminum rough surface is smaller than that in the case of smooth surface.
3-In dense wet sand, the shear displacement to mobolise maximum sand-sand shear stresses (τp) smaller than that in the case of loose wet sand to reach the maximum values of shear stresses.
4-The value of maximum and ultimate shear stresses increases directly with increasing surface roughness of structural materials.
5-The sand-aluminum interface friction angles (δ) decreases with density decrease and porosity increase.

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