Small and large scale direct shear tests on sand-concrete Interface

Engr Kamran Khan
KPK University of engineering & technology Peshawar, Pakistan
Engr.miankamrankhan@yahoo.com

Irshad Ahmad
Professor, Department of civil engineering, KPK University of engineering & technology Peshawar, Pakistan

Asmat Ullah
Under graduate student, Department of civil engineering Uet Peshawar

Waqas Ahmad
Under graduate student, Department of civil engineering Uet Peshawar

Bilal Ahmad
Under graduate student, Department of civil engineering Uet Peshawar

Abstract

Interface direct shear tests (small & large scale) were performed on sand & concrete interface using different normal stresses, constant shear rate and different sand densities. Small scale Interface direct shear tests were performed on sand & concrete interface in the conventional direct shear test apparatus under 5 different normal stresses. Similar procedure was adopted for large scale direct shear test. Shear stress verses shear strain data was plotted for each test. Mohr's circle was plotted for small and large scale interface direct shear test. An increase in the peak of Shear stress verses shear displacement curves was observed with the increase of normal stress and sand density. Interface friction angle (δ) was also increased with the rise in sand density but showed a decrease with the increase of scale of direct shear test.

Keywords

Direct shear test, Interface, Sand, Concrete, Small scale, Large scale

Introduction

Interface properties between soil and structures (retaining walls, piles shaft and earth reinforcements etc) needs to be properly addressed for proper designing of these structures.

Interface properties between concrete and sand in small scale direct shear tests are studied by many researchers in past as early as 1936. They varied different densities and scale (size) of direct shear box along with other parameters such as moisture content, shear rate and different normal stresses.

Parsons [1] in 1936 studied crushed quartz and clean uniform sand in direct shear test using three different size boxes. The experimental results showed that with the increase in size of the shear box values of angle of internal friction are decreased. Acar et al [2] in 1982 studied Interface properties of Sand using direct shear, and concluded that the ratio of interfacial friction to internal friction angle was independent of the void ratio and then on relative density. Palmeira and Milligan [3] in 1989 studied dense Leighton Buzzard Sand in small, medium, and large shear boxes and concluded that there was no significant influence of box size on the resulting friction angles. Amy et al [4] in 2006 did research on 5 different types of sand in direct shear test. Based on the results it was concluded that angle of internal friction was increased with increase in density and decreased with the increase in size of the box. Saibaba Reddy et al [5] in 2000 performed direct shear interface tests using four types of surfaces and two types of sands. The values of d obtained from these tests are compared with the internal friction angle of the sand and with the results obtained from soil-pile-slip tests. Based on the above working it was finally concluded that the interface friction angle cannot be expressed as a constant percentage of the internal friction angle of the soil, but it can be assumed from each individual case. Hammoud Boumekik [6] in 2006 studied the interfacial shearing between cohesive soils and solid materials. The results showed that the shearing resistance at the interface depends on the interface roughness, as well as on the properties of soils. Gireesha and Muthukkumaran [7] in 2011 studied the interface friction angle of different structural materials (concrete, steel and wood) against well and poorly graded sands with varying relative density. The experimental results showed that both internal and interface friction angle decreases with increasing relative density of both well and poorly graded sand. Lavanya et al [8] in 2014 investigated the behavior of interfaces between carbon fibre reinforced polymer and gravel soils. The experimental results showed that there is a significant decrease in the angle of interface friction with carbon fibre reinforced polymer (cfrp) wrapping.

In this paper result of an experimental study on sand verses concrete has been presented. Sand of Nizampur area (KPK) was used. Two types of scales for direct shear boxes (Small & large) along with different normal stresses and sand densities are utilized for interpreting the shaft capacity of piles embedded in sand.

Experimental Program for Small Scale Interface Direct shear test

Small scale direct shear test was performed in the conventional direct shear test (according with the ASTM D 3080-90) having the shear box diameter of 6 cm and height 2 cm as shown in fig 1.

Concrete sample was placed in the lower part of the shear box and sand sample was placed in the upper part of the shear box. Furthermore sand density was varied and tests were performed at three different densities (loose, medium & dense sand) using different normal stresses for each category.

Experimental Program for large scale Interface Direct shear test

Square Concrete samples of 12”X12”X12” (according with ASTM D 5321) were prepared with aggregate ratio of 1:2:4 for large scale direct shear test. Rectangular steel mould of 16”X12”X12” (according with ASTM D 5321) was made for large scale direct shear test as shown in fig 2. Sand was placed in the rectangular steel mould and concrete sample was placed above it. Tests were performed at three different normal stresses and three different densities. Normal load was applied through a vertical load cell having a capacity of 25 tons. Lateral load was applied through lateral load cell having a capacity of 50 tons.

Lateral deformation gauges were installed to record shear displacement. All the loadings and shear displacement data were recorded in data logger unit.

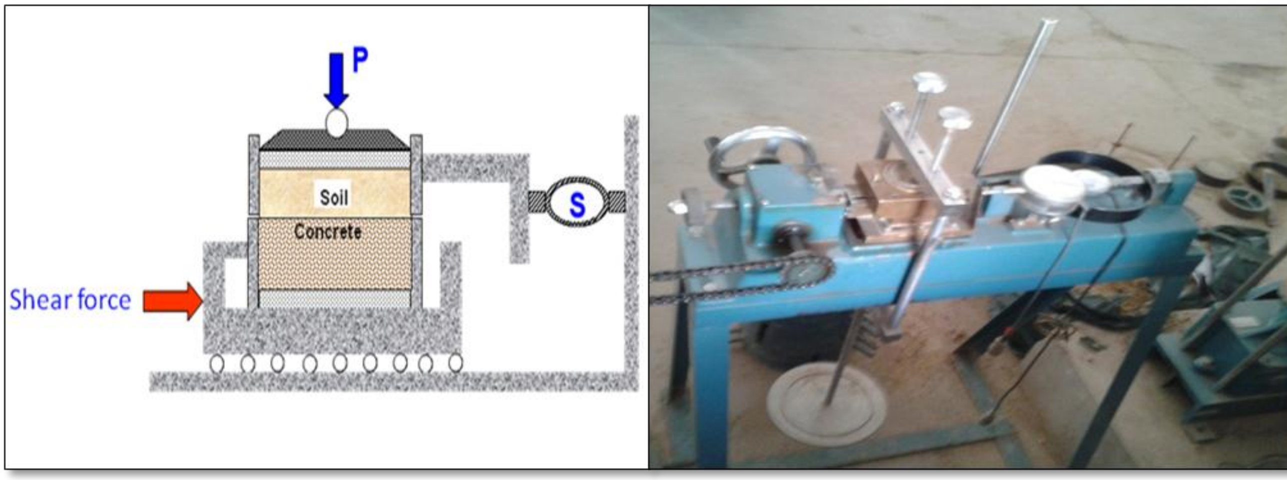

Fig 1 small scale direct shear test sketch & apparatus (left to right)

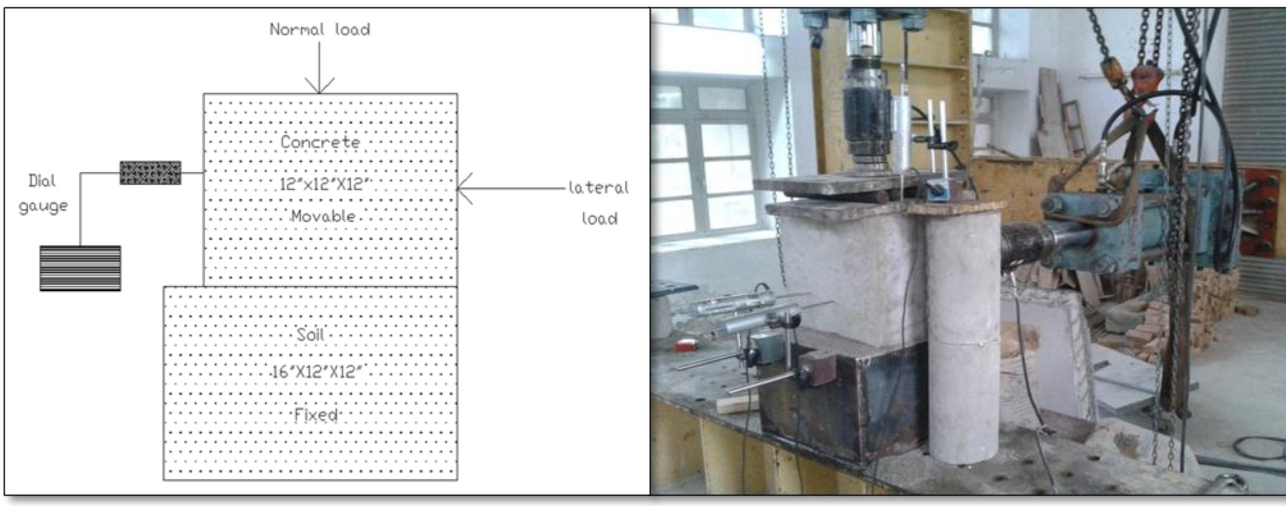

Fig 2: Large scale direct shear test sketch & apparatus (left to right)

Soil properties

Sand of Nizampur area was used in all the small & large scale tests. This sand was well graded with the following engineering prosperities as shown in table 1 & Table 2. Gradation curve is shown in figure 3.

Table 1--- Grain size analysis

D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	C_u	C_c
0.15	0.39	1	6.66	1.014

Table 2--- Other engineering properties

Natural Moisture content	18.5 %
Specific gravity	2.65
γ_{min}	1.582 gm/cc
γ_{max}	1.862 gm/cc

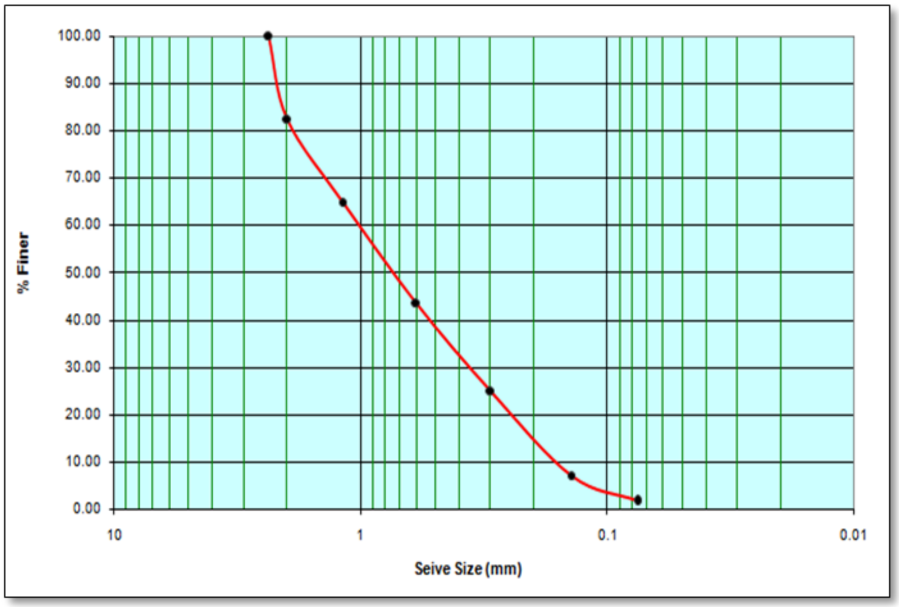

Fig 3: Gradation curve

Results

Experimental results for all the three sand densities for small scale interface direct shear tests are given in figure 4, 5 and 6 in form of Normalized Shear stress/Normal stress verses shear displacement. The interface friction angles were determined as a function of shear stress at the end of each test by plotting Mohr's circles for each category.

Experimental results for all the three sand densities for large scale interface direct shear tests are given in figure 7, 8 and 9 in form of Normalized Shear stress/Normal stress verses shear displacement. The interface friction angles were determined as a function of shear stress at the end of each test by plotting Mohr's circles for each category.

It is evident from the curves that peak of normalized shear stress/normal stress verses shear deformation curves decreases by increasing normal stress on the loose, medium and dense sand for both the small scale direct shear test and the large scale direct shear test.

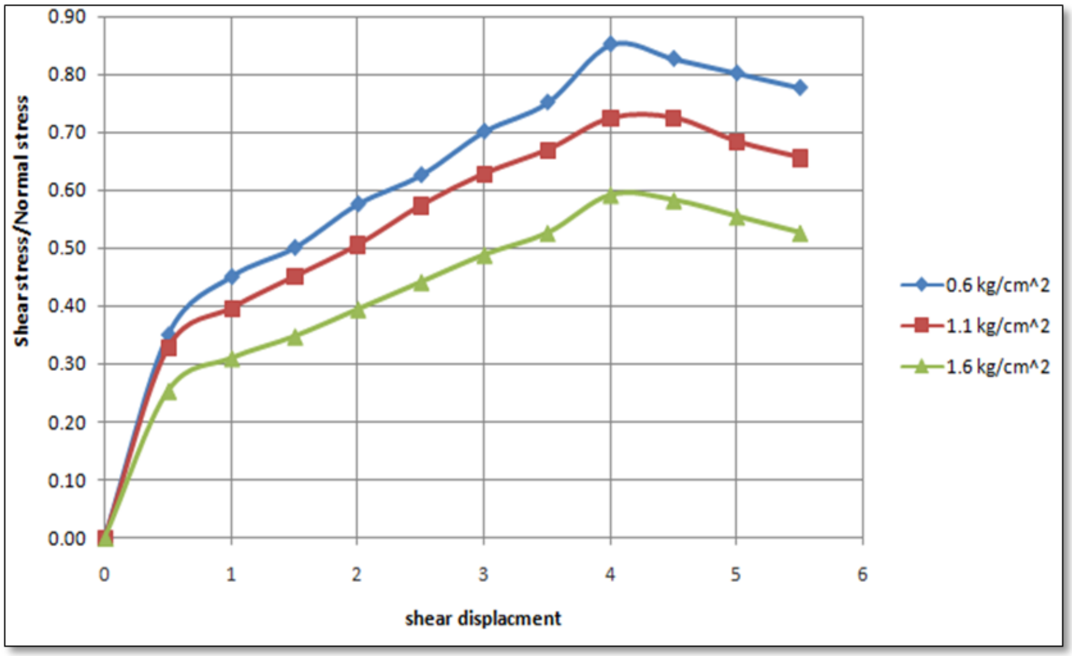

Fig 4: Loose sand

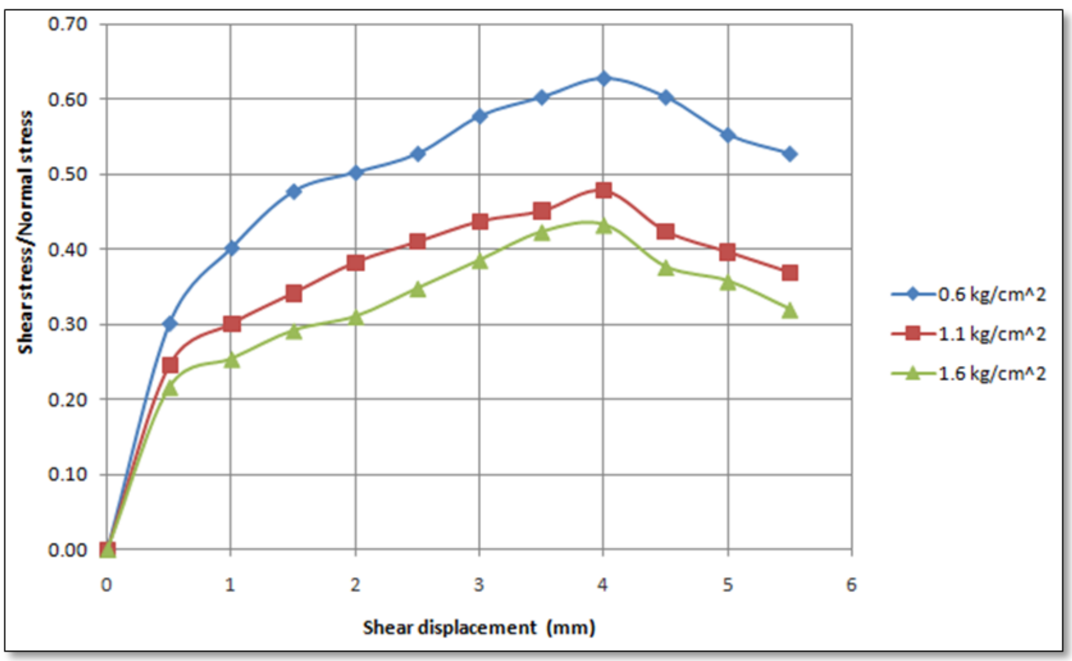

Fig 5: Medium sand

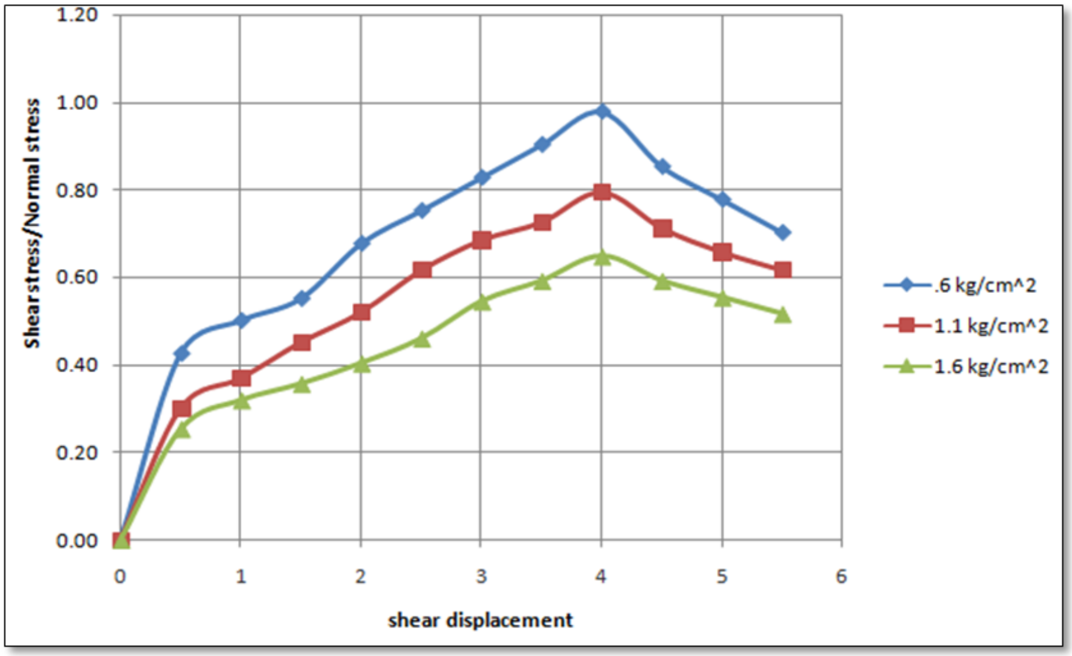

Fig 6: Dense sand

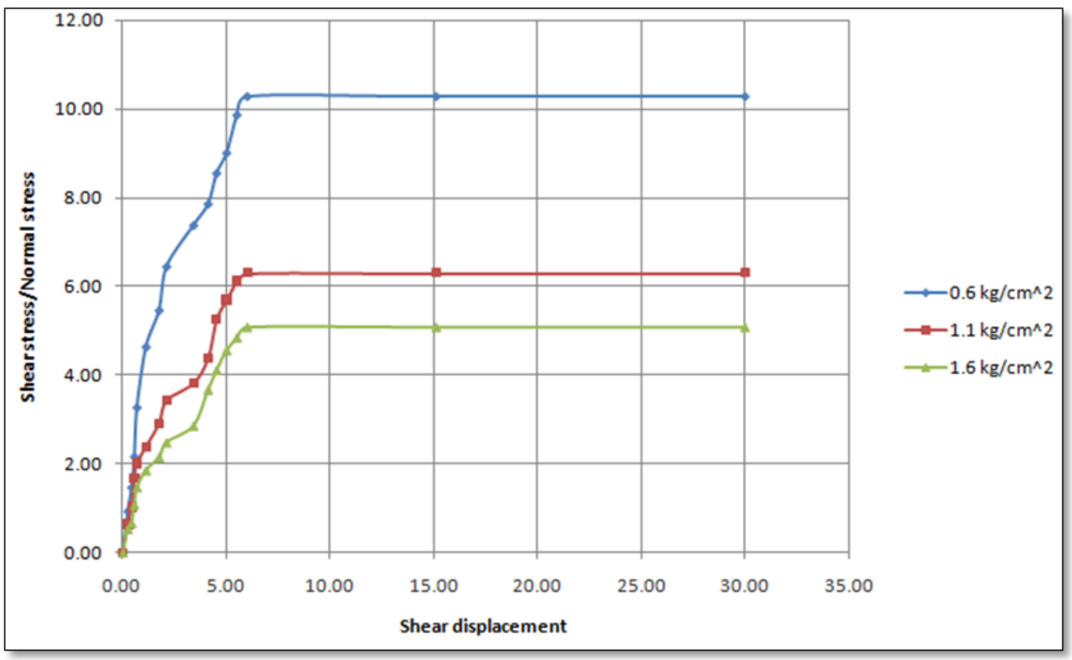

Fig 7: Loose sand

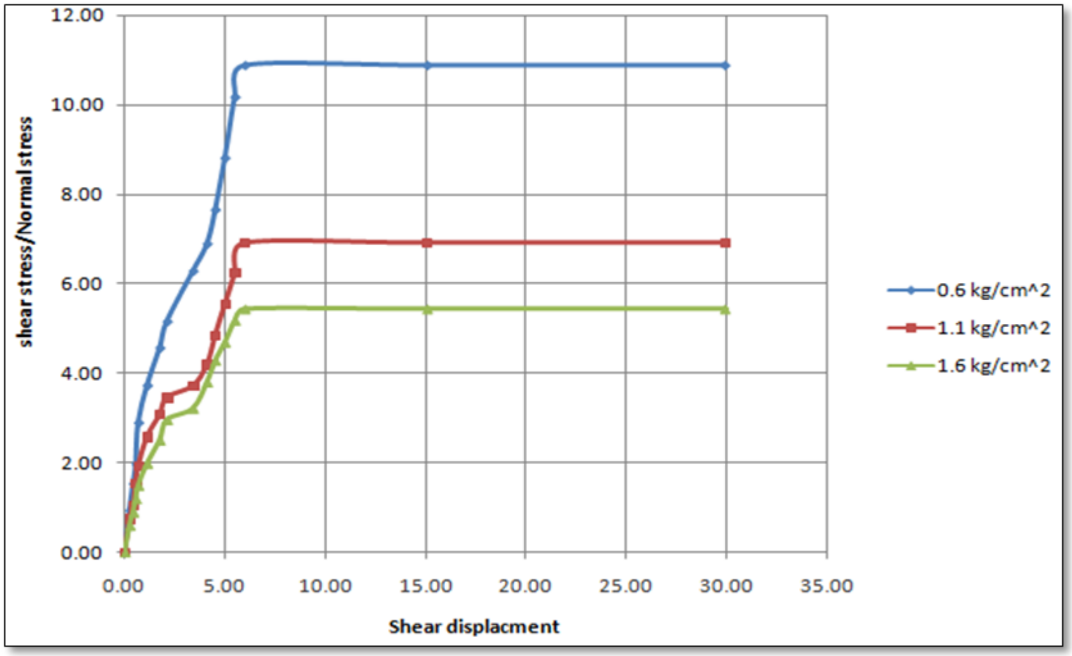

Fig 5: Medium sand

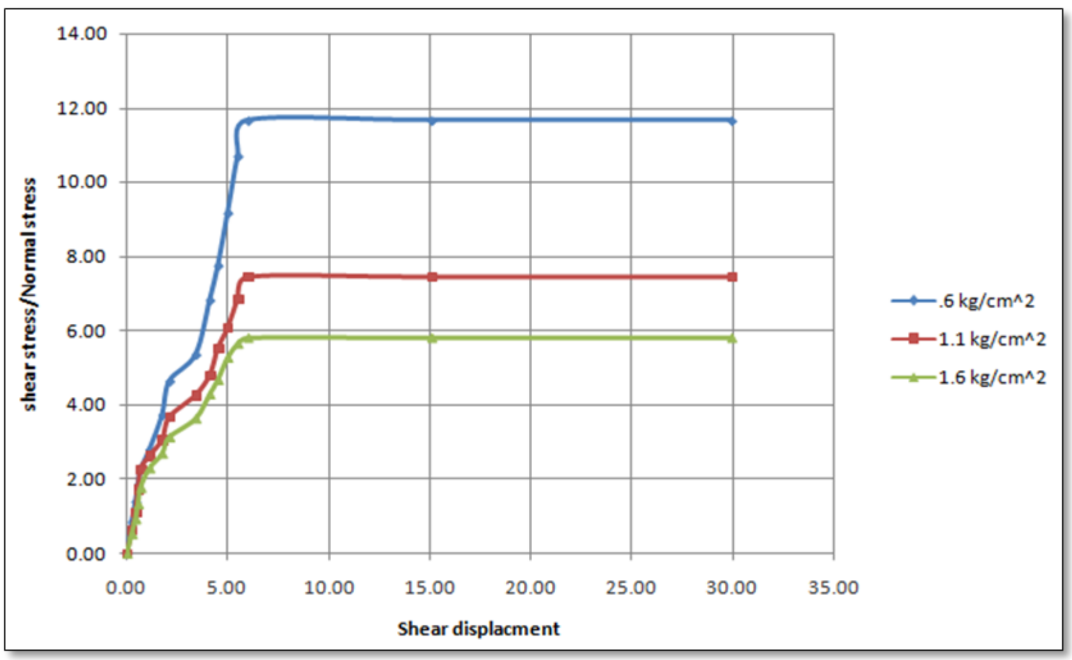

Fig 6: Dense sand

Table 3: Summary of test results

Sand type	γ_b **(gm/cc)**	**δ (deg) Small scale**	**δ (deg) Large scale**
Loose	1.582	18.1	13.7
Medium	1.735	20.7	15.8
dense	1.862	22.2	17.7

Discussions

It is evident from the above interface friction angle was decreased by increasing scale of the shear box. The higher values of interface friction angles might be due to the low H/Dmax and W/Dmax ratios.
The results show that loose, medium and dense sands are affected by box size equally. Sand density has a direct effect on the interface friction angle along the same size of the shear box. In the same size of the shear box interface friction angles increases with the increase in sand density, however for same sand density (loose, medium or dense) interface friction angles will decrease with the increase in scale of the shear box. Therefore extreme caution must be taken while using the interface friction angles obtained from small scale direct shear interface tests while calculating the shaft capacity of piles. The minimum ratio of H/Dmax=6 and W/Dmax=50 must be achieved according with the ASTM D 3080-90 standard test method for direct shear test. If the above criteria will not be fulfilled for the direct shear test then the values must be reduced by 5 % for accurate design of shaft capacity of piles embedded in sand.

References

[1] Parsons, J. D., 1936, "Progress Report on an Investigation of the Shearing Resistance of Cohesionless Soils," Proceedings of the 1st International Conference on Soil Mechanics and Foundation Engineering, Vol. 2, pp. 133–138.
[2] Acar Y B, Durgunoglu H T, Tumay M T. Interface properties of sand. Journal of Geotechnical Engineering, ASCE, 1982, 108(4): 648– 654
[3] Palmeira, E. M. and Milligan, G. W. E., 1989, "Scale Effects in Direct Shear Tests on Sand," Proceedings of the 12th International Conference on Soil Mechanics and Foundation Engineering, Vol. 1, No. 1. pp. 739–742
[4] E. Saibaba Reddy, D. N. Chapman, and V. V. R. N. Sastry (2000) "Direct Shear Interface Test for Shaft Capacity of Piles in Sand" American Society for Testing and Materials
[5] Amy B. Cerato and Alan J. Lutenegger (2006) "Specimen Size and Scale Effects of Direct Shear Box Tests of Sands" ASTM International, 100 Barr Harbor Drive, PO Box C700,West Conshohocken, PA 19428-2959
[6] Hammoud, F., and Boumekik, A. (2006), Experimental Study of the Behavior of Interfacial Shearing between Cohesive Soils and Solid Materials at Large Displacement, Asian Journal of Civil Engineering (Building and Housing), Volume 07, No 01, pp 63-80.
[7] Gireesha, N. T., and Muthukkumaran, K. (2011), Study on soil structure interface strength property, International Journal of Earth Sciences and Engineering, Volume 04, No 06 SPL, October 2011, pp 89-93.
[8] Lavanya, r. prabha, m. murugan (2014) "behaviour of interfaces between carbon fibre reinforced polymer and gravel soils" international journal of research in engineering and technology eissn: 2319 1163 | pissn: 2321-7308