STUDY OF THE EFFECTS OF SPECIMEN SHAPE AND REMOULDING ON SHEAR STRENGTH CHARACTERISTICS OF FINE ALLUVIAL SAND IN DIRECT SHEAR TEST

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ABSTRACT;*Shear strength of soil is basic parameter in the studies like liquefaction, slope stability and shallow foundation design, etc. Direct shear test is most widely used for the determination of shear strength of soil. There are various modifications in specimen size and shape for this test. According to ASTM D 3080, both square and circular shear boxes can be used for the evaluation of shear strength characteristics of soil in a direct shear test. An effort has been made in this research to evaluate basic differences in assembly of two apparatuses with circular and square shear boxes for direct shear test and to study the effects of specimen shape on the results of this test. Moreover remoulding effects on the shear strength characteristics of granular soils are also evaluated. For this purpose Ravi sand is tested in both circular and square shear box apparatuses. Similarly undisturbed and remoulded samples were tested in circular shear box. Remoulded samples were remoulded on in situ density and moisture content. Results from two apparatus shows that there is no much significant difference in angle of internal friction for the specimen tested in a direct shear test. However the angle of internal friction values obtained from circular shear box apparatus are higher (2^0 to 3^0) as compared to Square shear box. Similarly, samples which were tested in circular shear box show more horizontal resistance values and higher shear stress values. It may be due to difference in area to be sheared and shape of the specimen and also the assembly of the apparatus. Similarly, there are little differences in values of fine alluvial sand due to remolding.But the values of angle of internal friction in this research from undisturbed samples are higher and more accurate then remolded specimens. This may be, mainly due to disturbance in fabric of sand particles. So it recommended that undisturbed specimens should be used for more accurate results where possible. But the results are more sensitive to other factors like density, moisture content and type of soil then remolding and shape of specimen in direct shear test*

Keywords: Direct shear test, shear strength, fine alluvial sands, specimen shape, remoulding

1. INTRODUCTION

Shear strength of soil is basic parameter in the studies like liquefaction, slope stability and shallow foundation design etc. Direct shear test is most widely used for the determination of shear strength of soil as this test is simple and gives reliable results. Several publications (Shibuya, Mitachi & Tamate 1997, Stoewahse 2001, Goldscheider 2003, Lindemann 2003) have shown that various aspects, e.g. the assembly of the upper box, scaling, specimen size and shape, influence the results of direct shear tests [4, 6, 9, 11]. Po-kai Wu *et al.*studied the effects of specimen size and specimen shape on the shear zone and shear bands development in the dense Toyoura sand and sandy gravel and concluded that there were significant effects on deformation properties, peak shear strength, dilatancy and peak frictional angle values. They also suggested that to get more accurate results in direct shear test, rectangular cross section specimens should be preferred, especially for granular material [7]. Thermann K.,*et. al.*. showed that specimen shape and size are of secondary importance as there is no significant difference in shear strength parameters by altering possible influence of different laboratory parameters, resulting different quality of specimen preparation and the influence of different displacement rates.[10]. Sadrekarimi A. *et. al.* studied the effect of specimen preparation method and resulting sand fabric of sandy soils. Three sands were selected for this study i.e. Ottawa 20/40 sand (OT), Illinois River sand (IR) and Mississippi River sand (MR). The results indicate that the shearing behaviour of sand is not only affected by the specimen-preparation method (i.e., sand fabric), but also by particle damage and compressibility [8]. Cerato A.B showed that the friction angle can be dependent on specimen size and that the influence of specimen size is also a function of sand type and relative density [5]. Amšiejus J. *et. al*. presented the modified direct shear apparatus after comparing shear strength parameters of sandy soils obtained by various constructions of direct shear apparatuses and concluded that applying the modified direct shear apparatus it is possible to measure the normal stress on the shear plane. This constructional approach influences for determining of the actual shear strength parameters [1].

According to ASTM D 3080, both square and circular shear boxes can be used for the evaluation of shear strength characteristics of soil, in the direct shear test. The essential feature of the apparatus is a shear box, divided horizontally into two halves and containing a specimen of soil. While the soil is subjected to a constant vertical compressive force, an increasing horizontal force is applied to the upper half of the box, thus causing the soil to shear along the dividing plane of the box. The test is normally carried on a number of identical specimens using different vertical stresses so that a graph of shearing resistance against vertical stress can be plotted. The vertical movement of the top surface of the specimen, which indicates changes in volume, is also measured and enables changes in density and voids ratio during shear to be evaluated. In this research paper, results from two shear boxes i.e. circular (63mm diameter, 20mm thickness) and square (60mm x 60mm, 20 mm thickness) are evaluated for Ravi sand specimens. Further difference in results for angle of internal friction is evaluated for undisturbed and remolded soil samples for circular shear box apparatus. There is also difference in assembly of two apparatus in applying normal load. So it can be concluded that which apparatus gives more reliable results.

2. MATERIAL AND METHODS

This research is done on Ravi sand specimens, both disturbed and undisturbed. Site selected for the collection of samples was from Ravi, near Thokar niaz baig Lahore, Pakistan i.e. Ravi sand. Figure 2 shows the satellite image of the site selected for collection of sample. Both undisturbed and disturbed samples were collected. First of all site visits were done, test pits were selected and samples for the determination of physical properties were collected. Figure 1 shows the cross section and plan of test pits. After determination of physical properties Samples were collected and total 27 specimens were made for determination of shear strength of soil in direct shear test for 9 tests (3 on undisturbed samples and 6 on remolded sand samples)

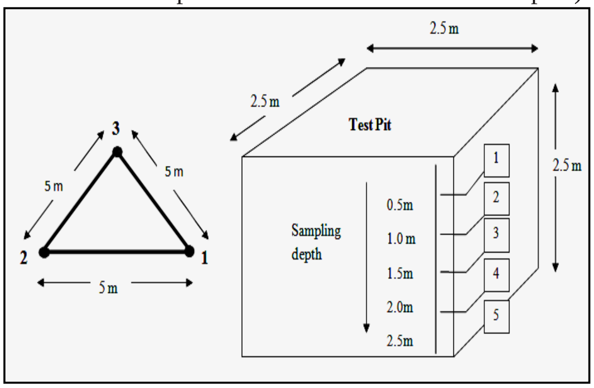

Figure 1: Plan and cross section of test pits.

Undisturbed samples were extruded from tube samplers. Sand samples were collected in tubes by using static load technique and very carefully transported to laboratory with proper arrangements for extrusion. Using soil sample extruder UDS is extruded directly into circular mold of size that of circular shear box in direct shear test. Disturbed bag samples were collected and remolded in lab, on in situ density and moisture content for direct shear test for both apparatuses.

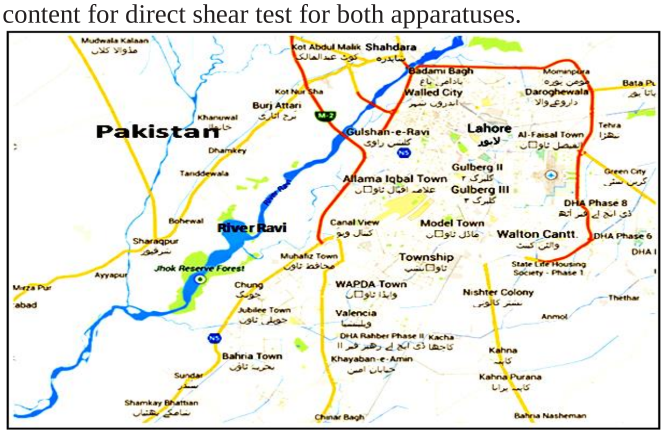

Figure 2: Satellite image showing location of test pit for collection of samples

Two types of direct shear apparatuses are used for this research. Both are in accordance with ASTM D 3080. First apparatus has square shear box having dimensions 60 mm x 60 mm x 20 mm. Normal load is applied directly by hanger assembly. Dial gauges for shear force and Proving ring (PRC = 0.003649 KN) for the determination of horizontal displacement are employed. There is no arrangement for the determination of vertical settlement or volume change in this apparatus. Only remolded samples are tested on this apparatus.

Second apparatus has circular shear box with specimen size of 63.7mm diameter and 20mm thickness. In this apparatus arrangement for settlement or volume change in specimen during consolidation is also provided. Normal load is applied by lever arm frame. Both undisturbed and remolded samples are tested on this apparatus. Figure 3 shows the two direct shear apparatuses used in this research.

Figure3: Direct shear test apparatus a) Circular shear box b) Square shear box

Other apparatus used for the determination of properties include set of sieves, relative density apparatus, sample extruder, tubes and bags for collection of samples, electric oven etc.

3. RESULTS AD DISCUSSION

Different test were performed on the bag samples and results are listed in table 1. Bulk density is calculated in field using tube samplers. Other tests like specific gravity, relative density and moisture content determination are done in lab in accordance with the ASTM standards. In order to get the profile of test pit, these tests are performed on samples taken from 5 different depths up to 2.5m.

Table 1:
Index properties of soil in selected test pit

Sample taken from (m)	Specific gravity	Moisture Content (%)	Dry density (Kg/m^3)	Relative density (%)	Normal Load for Direct shear Test (Kg)
0.5	2.69	3.98	1067.25	0.83	1.92
1		4.31	1147.97	1.17	3.07
1.5		5.84	1142.68	1.19	5.39
2	2.58	7.41	1359.23	1.76	9.79
2.5		10.35	1221.70	1.23	11.00

Results show that in situ density and moisture content increases with the increase in depth. Similarly relative density increases from 0.83 to 1.23 for the depth 0.5m to 2.5m. Direct shear tests are performed taking the normal load value similar to that the sample is experiencing in field (overburden load), that's why overburden load using density and depth,are also calculated in table 1.

Gradation curve for the sample is given in figure 4. Gradation of the soil does not change significantly from top to the depth of 2.5 m of the pit. % age of Fines is less than 5 %. And there is no percentage of gravels in the test pit soil.

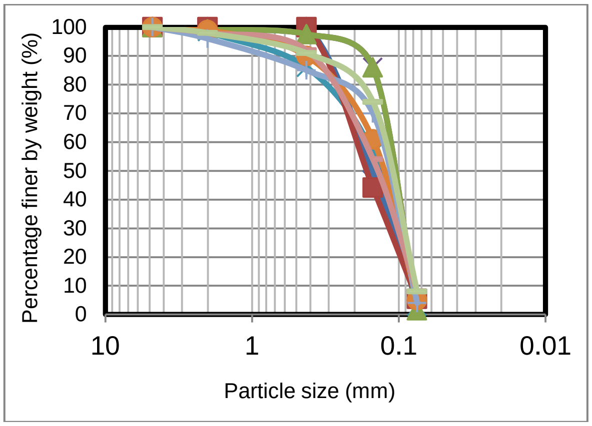

Figure 4: Gradation curve for the soil sample

D10= 0.08mm	D30= 0.09mm	D50= 0.12 mm	D60= 0.14 mm
C_U = 1.75		C_C = 0.73	
Soil Classification		AASHTO: A-3 (0)	USCS: SP

Soil classification is done in accordance with ASTM D2487 and ASTM D3282. According to USCS soil is poorly graded sand (SP) and according to AASHTO soil is A-3 soil which is fine sand.

Direct shear test results

Direct shear tests were performed on both apparatuses having circular and square shear box. Figure 5 and 6 gives the results of horizontal displacement vs. shear stress in circular shear box apparatus for both undisturbed and remolded soil samples. Samples were taken from three different depths (0.5 m, 1m and 1.5 m) .UDS were extruded from tubes and RM samples were remolded on in situ density and moisture content.

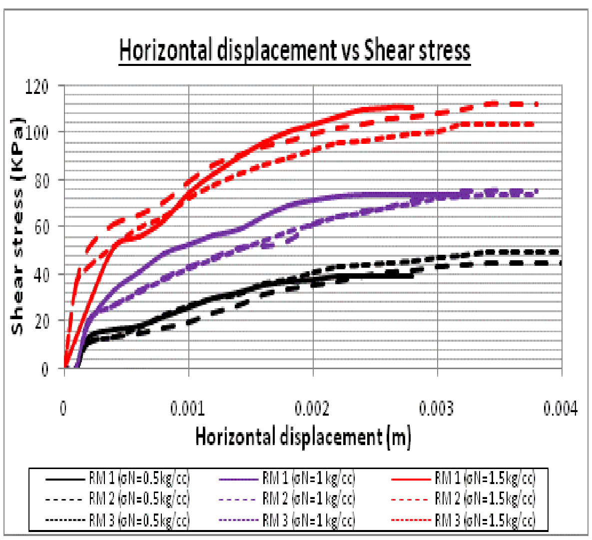

Figure 5: Shear stress vs. horizontal displacement curve for Remolded specimen

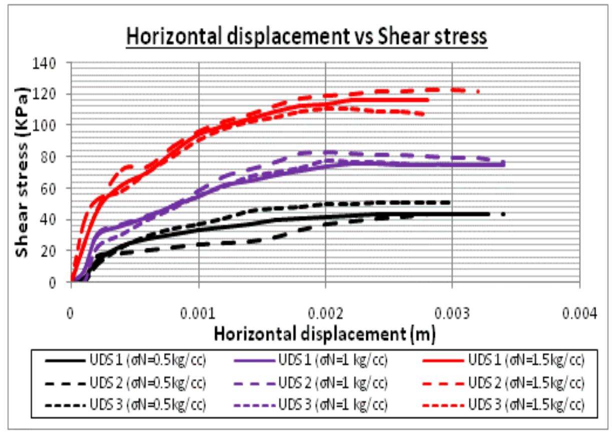

Figure 6: Shear stress vs. horizontal displacement curve for Undisturbed Specimens

Results show that there is not much difference in trends of graphs for undisturbed and remolded specimens. Although remolded samples show less resistance to shear force and horizontal displacement values are higherthan those of undisturbed samples. But undisturbed samples show high values of Shear stress than those of remolded samples. Undisturbed specimens show less horizontal displacement values and high shear stress values.

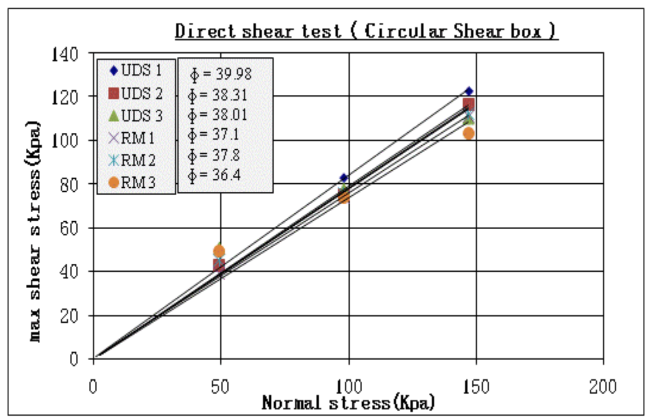

Figure 7: Failure envelops for direct shear test (Circular specimens)

Figure 7 shows the failure envelops for all six samples tested on circular shear box apparatus. Results show that Angle of internal friction does not vary significantly with remolding of specimen as ϕ values for both undisturbed and remolded specimens are very similar. Although ϕ values for undisturbed samples are high then remolded and sensitivity is about 0.95.

Direct shear test is performed for remolded samples for square shear box apparatus. The samples were remolded on in situ density and moisture content for three different depths (0.5m, 1m ad 1.5m) as given in table 1. Results in figure 5 shows that sample resist less shear forces and show lower values of horizontal displacement.

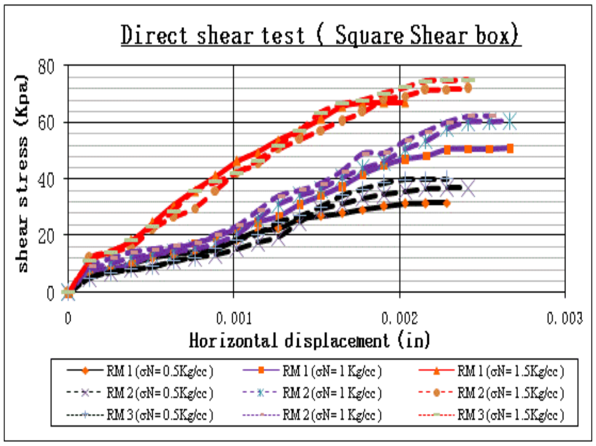

Figure 8: Shear stress vs. Horizontal displacement for Remolded soil samples (Square shear Box)

Graph of Normal stress vs. max shear stress (Figure 9) shows that angle of internal friction values are quite similar for three samples.

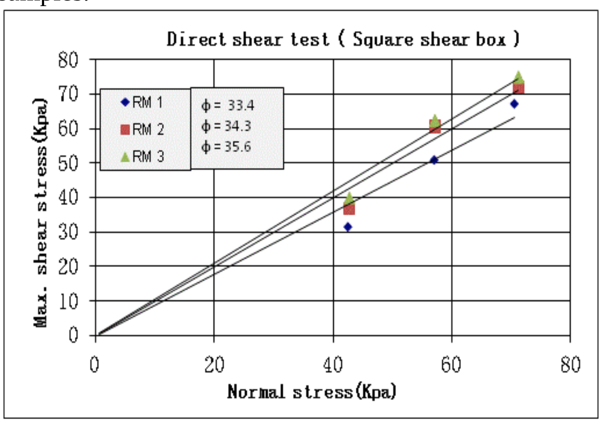

Figure 9: Failure envelope for the direct shear test (square specimens)

Table 2 shows the difference in two apparatus used for the comparison in this research paper.

Table 2:
Difference in two direct shear apparatus

Property	Direct Shear Test	
	Circular shear box	Square shear box
Sample tested	UDS/RM	RM
Specimen Dimensions	63.7 dia., 20mm thickness	60mm x 50 mm, 20mm thickness
Area (cm^2)	31.22	36
Volume (cc)	62.44	72
Least count of dial guage	0.1 mm	0.0127 mm
Proving ring constant	2.002 N	3.649 N
Liver arm assembly	yes	No
Volume change	yes	No

Results from two apparatus shows that there is no much significant difference in angle of internal friction for the specimen tested in direct shear test by two apparatuses i.e. square shear box and circular shear box. However table 3 and table 4 shows the differences in results. The angle of internal friction values obtained from circular shear box apparatus are higher (2^0 to 3^0) as compared to Square shear box. Similarly samples which were tested in circular shear box show more horizontal resistance values and higher shear stress values. It may be due to difference in area to be sheared and shape of specimen and also assembly of the apparatus. It can be concluded that although there are little difference in results from two shapes of specimen in direct shear test but any of these two apparatus can be used for the determination of shear strength with full confidence, keeping in view the other factors like specimen size, apparatus assembly, loading arrangements and calibration of apparatus etc.

Table 3:
Difference in ϕ values from circular and square specimens

Angle of internal Friction (ϕ)			
	Circular Shear Box	Square shear Box	% difference
RM 1	37.1	33.4	9.97
RM 2	37.8	34.3	9.25
RM 3	36.4	35.6	2.2

Table 4:
Comparison of results of UDS and RM

	UDS		RM (circular)		RM (square)	
	ϕ	Max. displacement (m)	ϕ	Max. displacement (m)	ϕ	Max. displacement (m)
1	39.98	0.0034	37.1	0.0032	33.4	0.02667
2	38.1	0.0034	37.8	0.004	34.3	0.02667
3	38.01	0.004	36.4	0.004	35.6	0.0254

Similarly table 4 and graphs in previous section show that there are little differences in values of shear strength of fine alluvial sand due to remolding. But as far as direct shear test is concerned these values are not significantly different. It is recommended that for more accurate results tests on undisturbed samples should be done. These vales in this research from undisturbed samples are higher and more accurate then remolded specimens. This may be, mainly due to disturbance in fabric of sand particles. But results are more sensitive to other factors like density, moisture content and type of soil then remolding and shape of specimen in direct shear test.

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