Table of Contents

[Purpose of the Test 2](#_Toc406161345)

[Equipment 2](#_Toc406161346)

[General Rules 3](#_Toc406161347)

[Calibration 3](#_Toc406161348)

[Specimen 4](#_Toc406161349)

[Test Procedure 4](#_Toc406161350)

[Theory 5](#_Toc406161351)

[Calculations 6](#_Toc406161352)

[Discussion of Results 8](#_Toc406161353)

DIRECT SHEAR TEST

# Purpose of the Test

The purpose of the test is to acquire strength- deformation characteristics of dry sand at a specified density by means of direct shear test.

# Equipment

* direct shear box with two separator bolts and two restraining bolts.
* top cap (a steel ball is placed on top of the cap in many setups, but here we do not need it)
* porous stones and ribbed plates
* direct shear load frame with lever arm and weights
* shear load measurement device (proving ring)
* horizontal and vertical displacement measurement devices (dial gages)
* Vernier calipers
* gauging disc (or block for square specimens).
* dish, spoon, spatula.



Figure-1: Direct Shear Test Machine

# General Rules

In this experiment, cohesionless soil is used. This type of soil change density, mechanical properties when it is subject to vibrations. Therefore, students of tester should not touch the table during the experiment or the assembly should not be shaken. Observers are warned by the assistant. In the transportation of the soil box it is observed that the assistant was holding it parallel to the ground and she is careful about not shake the box.

# Calibration

* Note the mechanical advantage of the loading arm. This is usually 10, and is given by the manufacturer. But if necessary, it can be calculated by determining the dimensions of the loading arm and taking the ratio of the moment arms of applied load and normal stress on the specimen.
* Notice the load transmitted by the lever arm to the specimen is not zero when there is no load. Weigh the individual components that will rest on the specimen (i.e. top cap, porous stone, top half of the shear box) to figure out the zero load. (If the loading arm itself is not balanced, a balancing load can be figured out by applying external weights on one side.) For our equipment, the arm is balanced, so zero load on the lever arm corresponds to the total weight of components on the specimen (about 1.5 kg).
* Note which bolts restrain relative movement of the two halves of the shear box, and which bolts separate the two halves from each other.
* Determine how many turns of the separator bolts make a gap equal to the maximum grain diameter. This can be done by measuring the thread width on the bolts. The bolts of our setup have 0.8 mm threads.
* Adjust the separator bolts such that they barely touch the bottom half. Fix the two halves to each other by the restraining bolts.
* Measure inner diameter or width of the box.
* Place the lower porous stone into the box.
* Place the ribbed plate into the box, with ribs facing up and perpendicular to shearing.
* Measure the depth of the shear box from its top to the ribbed plate.
* Measure the height of the small diameter (or width) portion of the gauging disc (or block).
* Calculate specimen volume from the measurements in steps 6, 9 and 10 above.

# Specimen

* + Constitute the specimen in the shear box. This process may vary depending on soil type and desired density.
  + Calculate the mass of sample material to be placed in the shear box, from volume of the shear box and the desired density.
  + Weigh a batch of soil such that it has exactly the required mass.
  + Place the required mass of soil into the box (without spilling any soil outside the box).
  + Smoothen the soil surface by fingers or a spatula.
  + Compact the soil to desired density by pressing and rotating the gauging disc on it.
  + Place the ribbed plate with ribs facing down and perpendicular to shearing
  + Place the top porous stone.
  + Place the top cap (and the steel ball for many other setups).
  + Place and connect the shear box into the frame with minimal vibration.
  + Remove the restraining bolts.
  + Create a gap between two halves of the shear box, equal to the maximum grain size, by rotating the separator bolts by the amount determined in calibration step 4.

# Test Procedure

* Affix the measurement devices to the shear box.
* Take zero readings of the displacement measurement devices.
* Calculate the normal force you must add (based on calibration step 2) to achieve desired normal stress.
* Apply the vertical load. The loading lever must remain horizontal – if it does not, adjust by rotating the loading screw.
* Record vertical settlement.
* Loosen the separator bolts.
* Adjust the motor to shear the specimen at about 0.7 mm/min.
* Start shearing, read the shear force at every 0.1 mm displacement at the beginning. You can widen the interval once the test passes the point of peak shear force. Also record the elapsed time every 5-10 readings, in order to verify the rate of shear displacement.
* Stop beyond the observation of peak shear force, or at 3mm shear displacement.
* Repeat steps 2 to 9 at twice the vertical load. (In a real test, a new specimen is prepared and the test is restarted at each normal load. But in this lab session, due to time constraints, the same specimen will be used, and shearing will continue from the final shear deformation reading of the first loading.)

# Theory

A vertical force is applied to the specimen with the help of a loading plate and shear stress is gradually applied on a horizontal plane by causing the two half of the box to move relatively. The shear force is recorded with the corresponding shear displacement. Thickness change of the specimen is also recorded. The test is repeated with different soil samples under different vertical forces. And, the failure shear stresses of each test are plotted against their normal stresses. The shear strength parameters can be obtained from the best line fitting the plotted points.

The strength of a soil depends of its resistance to shearing stresses. It is made up of basically the components;

1. Frictional – due to friction between individual particles.

2. Cohesive - due to adhesion between the soil particles

The two components are combined in Colulomb’s shear strength equation,

τf = c + σf tan ø

Where τf = shearing resistance of soil at failure

c = apparent cohesion of soil

σf = total normal stress on failure plane

ø = angle of shearing resistance of soil (angle of internal friction)

This equation can also be written in terms of effective stresses.  
τf = c’ + σ’f tan ø’

Where c’ = apparent cohesion of soil in terms of effective stresses

In this laboratory session C=0

σ'f = effective normal stress on failure plane

ø’ = angle of shearing resistance of soil in terms of effective stresses

σ'f = σf - uf

uf = pore water pressure on failure plane

# Calculations

Table 1 : The table that shows all the calculated values by means of Microsoft Excel.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Shear disp(u\*) | u (mm) | Vertical deflection, v\* | v (mm) | Proving ring deflection δ\* | δ | Area(A)(mm2) | Shear stress(kPa) | sigma1 | phi(rad) | phi(degree) |
| 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 3166.90 | 0.00000 | 0.00000 |  |  |
| 0 | 0.00 | 30 | 0.30 | 0 | 0.00 | 3166.90 | 0.00000 | 0.06660 |  |  |
| 10 | 0.10 | 31 | 0.31 | 26 | 0.26 | 3160.57 | 0.00011 | 0.06673 | 0.001717 | 0.04919437 |
| 20 | 0.20 | 32 | 0.32 | 31 | 0.31 | 3154.22 | 0.00014 | 0.06687 | 0.002047 | 0.05865481 |
| 30 | 0.30 | 32 | 0.32 | 61 | 0.61 | 3147.87 | 0.00027 | 0.06700 | 0.004029 | 0.11541706 |
| 40 | 0.40 | 32 | 0.32 | 68 | 0.68 | 3141.52 | 0.00030 | 0.06714 | 0.004491 | 0.12866147 |
| 50 | 0.50 | 31 | 0.31 | 61 | 0.61 | 3135.17 | 0.00027 | 0.06727 | 0.004029 | 0.11541706 |
| 60 | 0.60 | 30 | 0.30 | 82 | 0.82 | 3128.82 | 0.00037 | 0.06741 | 0.005416 | 0.15515012 |
| 70 | 0.70 | 29 | 0.29 | 88 | 0.88 | 3122.47 | 0.00039 | 0.06755 | 0.005812 | 0.16650233 |
| 80 | 0.80 | 28 | 0.28 | 93 | 0.93 | 3116.12 | 0.00042 | 0.06769 | 0.006142 | 0.17596245 |
| 90 | 0.90 | 26 | 0.26 | 99 | 0.99 | 3109.77 | 0.00044 | 0.06782 | 0.006539 | 0.18731456 |
| 100 | 1.00 | 25 | 0.25 | 103 | 1.03 | 3103.42 | 0.00046 | 0.06796 | 0.006803 | 0.19488259 |
| 110 | 1.10 | 24 | 0.24 | 106 | 1.06 | 3097.08 | 0.00048 | 0.06810 | 0.007001 | 0.2005586 |
| 120 | 1.20 | 23 | 0.23 | 109 | 1.09 | 3090.73 | 0.00049 | 0.06824 | 0.007199 | 0.20623459 |
| 130 | 1.30 | 21 | 0.21 | 111 | 1.11 | 3084.38 | 0.00050 | 0.06838 | 0.007331 | 0.21001858 |
| 140 | 1.40 | 19 | 0.19 | 113 | 1.13 | 3078.03 | 0.00051 | 0.06852 | 0.007463 | 0.21380256 |
| 150 | 1.50 | 18 | 0.18 | 114 | 1.14 | 3071.68 | 0.00052 | 0.13254 | 0.003901 | 0.11174691 |
| 160 | 1.60 | 16 | 0.16 | 114 | 1.14 | 3065.33 | 0.00052 | 0.13281 | 0.003901 | 0.11174691 |
| 170 | 1.70 | 14 | 0.14 | 114 | 1.14 | 3058.98 | 0.00052 | 0.13309 | 0.003901 | 0.11174691 |
| 170 | 1.70 | 14 | 0.14 | 114 | 1.14 | 3058.98 | 0.00052 | 0.13309 | 0.003901 | 0.11174691 |
| 170 | 1.70 | 22 | 0.22 | 114 | 1.14 | 3058.98 | 0.00052 | 0.13309 | 0.003901 | 0.11174691 |
| 180 | 1.80 | 22 | 0.22 | 189 | 1.89 | 3052.64 | 0.00086 | 0.13337 | 0.006467 | 0.18526298 |
| 190 | 1.90 | 21 | 0.21 | 205 | 2.05 | 3046.29 | 0.00094 | 0.13364 | 0.007014 | 0.20094612 |
| 200 | 2.00 | 20 | 0.20 | 212 | 2.12 | 3039.94 | 0.00097 | 0.13392 | 0.007254 | 0.20780746 |
| 210 | 2.10 | 19 | 0.19 | 213 | 2.13 | 3033.60 | 0.00098 | 0.13420 | 0.007288 | 0.20878765 |
| 220 | 2.20 | 18 | 0.18 | 215 | 2.15 | 3027.25 | 0.00099 | 0.13448 | 0.007356 | 0.21074802 |
| 230 | 2.30 | 17 | 0.17 | 214 | 2.14 | 3020.90 | 0.00099 | 0.13477 | 0.007322 | 0.20976784 |
| 240 | 2.40 | 16 | 0.16 | 210 | 2.10 | 3014.56 | 0.00097 | 0.13505 | 0.007185 | 0.20584708 |

Table 2: Data obtained in the laboratory and the calculated values are bolted in the table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Normal Loads | P1-P2 | 21.5 | 41.5 | kg |
| Internal Diameter of Shear Box | D | 63.500 | | mm |
| Initial Area of Specimen | A0 | 3166.922 | | mm2 |
| Depth to the Top of the Lower Porous Stone | d | 31.500 | | mm |
| Thickness of Small-Radius-Part of Gauging Disc | t | 11.000 | | mm |
| Initial Thickness of the Specimen | T=d-t | 20.500 | | mm |
| Mass of Specimen | M | 100.000 | | gr |
| Density of Specimen | p | 1.540 | | gr/cm3 |
| Proving Ring Constant | Cp | 0.142 | | kg/div |

* The initial area of the specimen is

A0 = pi\*(63.5)^2/4 =3166,922 mm2

* In order to calculate the density

ρ = M/V = 100\*1000 / (3166.921744\*20.5)=1.540 g/cm3

* u, δ and v are multiplied by 0.01 to convert them to mm.



Figure-2: Shear area for cirular box, D is specimen diameter and u is the shear displacement (total from the start)

* The corrected area is calculated from the formulation given in Figure-2.

A=(63,5^2/2)\*(ACOS(0,1/63,5)-(0,1\*SQRT(63,5^2-0,1^2))/(63,5^2))= 3160,57 mm2

All corrected areas are calculated and they are tabulated in Table-1.

* In order to find shear stress

τ = ( Cp\*δ ) / A

* A sample calulation for shear displacement 0.1mm is

τ3=(0.142 \* 0.26\*9.81)/ 3160,57 = 0.00011 kPa

# Discussion of Results

The graphs are shown below. All sample calculations are shown in the calculation part. Because of the calibration of the equipment, some errors exist in this experiment. Moreover, sand may not be as clean as it is mentioned. While reading the datas, observer may make some mistakes. If one touch the machine or the table on which the machine stand, it could vibrate the machine and disturb its calibration.

This test is normally should be done at least three times, but owing to time constraints it is done once just to investigate the process.

It is observed and plotted that if the horizontal load is constant, it can be comprehended that the material is failed.

During the test, the surface area of the specimen is changed; therefore, in each step, corrected area is calculated.

With the guiadence of Yeşim Ünsever, the purpose of the direct shear test is comprehended. At least, all students are now familiar with this device and test. Shear strength of the cohesionless soils are understood.

The students are supposed to find the shear displacement&shear stress graph, normal stress&shear stress graph, shear displacement&vertical displacement graphs. All of them are given below.

Figure-3: Shear Displacement&Shear Stress Graph

Figure-4: Normal Stress&Shear Stress Graph

Figure-5: Shear Displacement&Vertical Displacement Graph