EXPERIMENT NO. 3

To determine the shear strength parameters (ϕ) and (c) of a given soil sample with the help of direct shear test

3.1 Reference

Direct shear testing is covered in ASTM standard D-3080

3.2 Apparatus

- Direct shear machine with proving ring and appropriate dial gage
- Direct shear box and shear box cart
- Balance or scale sensitive to 0.001g
- Horizontal dial gage sensitive to 0.001 in per division

3.3 Related Theory

3.3.1 Shear Strength

The shear strength of a soil is a measure of its resistance to deformations by continuous displacement of its individual soil particles. Soil shear strength is an important consideration in foundation bearing capacity analysis, highway and airfield design and construction, slope stability of earth, embankments and retaining wall construction.

3.3.2 Basic Components of Shear Strength

The shear strength of soil is derived from three basic components:

a) Resistance to displacement because of interlocking of individual particles
b) Resistance to particle translation because of friction between individual soil particles
c) Cohesion between surfaces of the soil particles

Which of these components, or combinations of components, are actually effective in resisting shear deformation depends on whether the soil is cohesive or cohesion less, and on the soil drainage and consolidation conditions before and during the shearing process.

3.3.3 Cohesion less Soil

A cohesion less soil is a soil that possesses little or no cohesion. Usually, soils that classify as sands or gravels are considered to be cohesion leas

3.3.4 Cohesive Soil

A cohesive soil on the other hand, is usually a fine-grained soil containing greater percentages of clay particles.

True cohesion can be developed between fine-grained soil particles that have been in stationary 'contact' over a long period.

3.3.5 Coulomb's Hypothesis on Shear Strength of Soil

The first hypothesis on soil shear strength was presented by Coulomb. Coulomb hypothesized that the shear strength of a soil was dependent on the two components, cohesion and friction

$$\tau = c + \sigma \tan(\phi)$$

Where τ = Shear strength (force/area)

c = Soil cohesion (force/area)

ϕ = Angle of internal fiction (degrees)

σ = Normal stress on the critical plane (force/area)

3.3.6 Tests for the Determination of Shear Strength

1) Tri axial shear test
2) Un-confined compression test
3) Direct shear test

3.3.7 Direct Shear Test

3.3.7.1 General

A direct shear test can be used to determine the shear strength of cohesive as well as cohesion-less soils. However, we will confine our self to the determination of the shear strength of cohesion-less soils only. Figure (3.3.7a) describes a direct test shear box, its component parts, and its carriage device, Figure (3.3.7b) depicts a soil specimen confined in a shear box undergoing shear testing. The upper half of the shear box is being displaced to the right. The arrangement shown is for strain controlled test. From this figure the shearing stress τ can be determined as

$$\tau = F/A$$

Where F = force causing displacement (shearing force)

A = cross-sectional area over which the shearing force is acting

The normal stress σ_n is similarly defined as

$$\sigma_n = N/A$$

Where N = normal force (the force perpendicular to the shearing plane).

The greatest resistance to shearing occurs when the angle α becomes a maximum (See Figure 3.3.7b). The maximum value of α is termed the ***angle of internal friction*** ϕ.

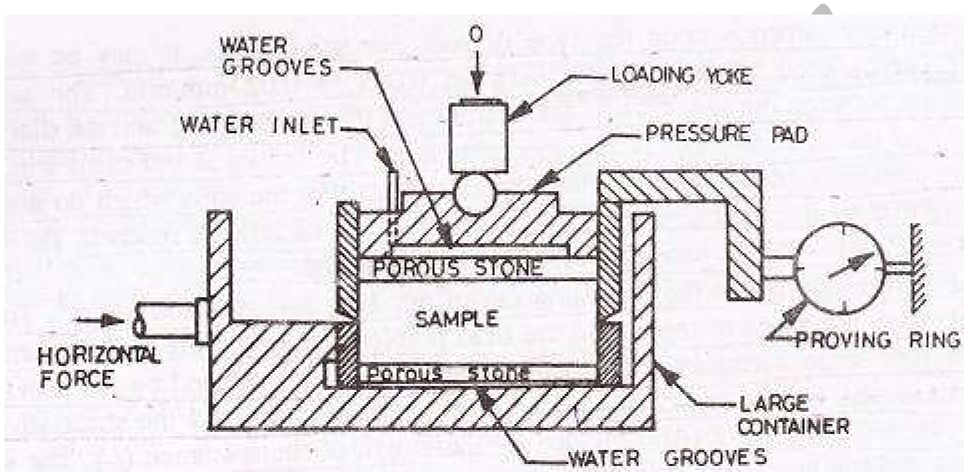


Fig 3.3.7a

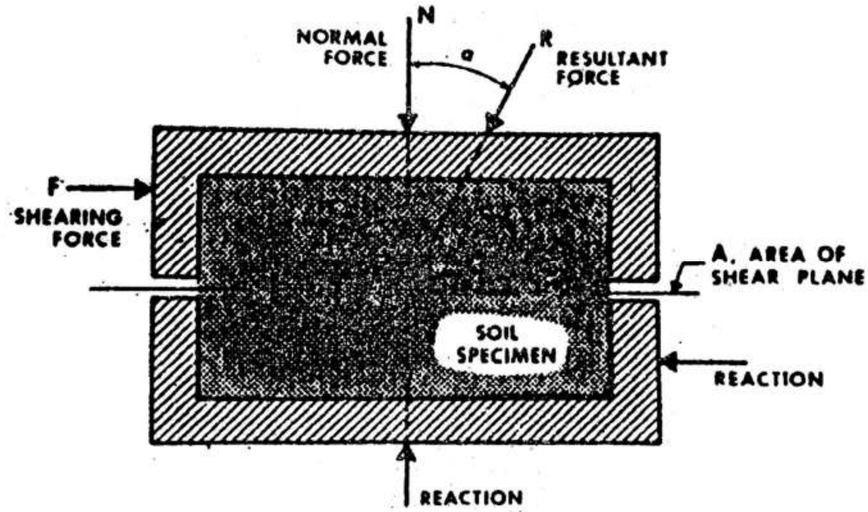


Fig 3.3.7b

3.3.7.2 Types of Direct Shear Test Procedure

There are three basic types of direct shear test procedures, determined by the sample drainage condition.

- **Unconsolidated Undrained**

  For a UU (Un-consolidated un-drained) test. shear is started before the soil sample is consolidated under the applied normal load.

- **Consolidated Undrained**

  For a CU (consolidated un-drained) test, shearing force is not applied until after settlement resulting from the applied normal load stops.

- **Consolidated Drained**

  For a CD (consolidated drained) test, shear is not started until after settlement resulting from the applied normal load stops. The shear force is then applied so slowly that no pore pressures developed in the sample.

3.3.7.3 Advantages of Direct Shear Test

3.3.7.4 Disadvantages of Direct Shear Test

3.4 Procedure

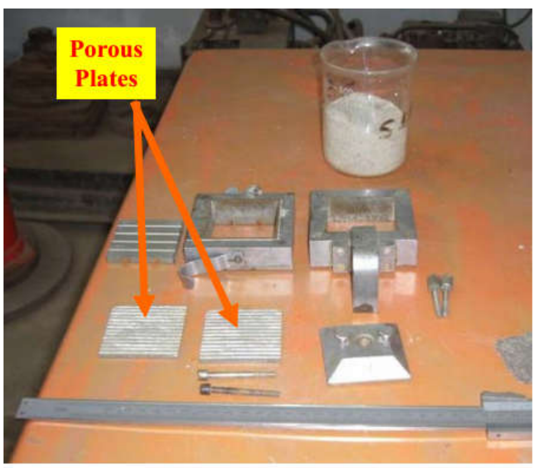
3.4.1 Assemble the Shear Box

- Place the upper half of the shear box on the lower half.
- Place the two clamping screws in their proper holes to hold the two shear box halves in place
- Turn the separation screws counter clockwise until they no longer extend beyond the base of the upper shear box half.
- Place the assembled shear Box in the shear box cart making certain that it is pointed in the correct direction.
- Place the lower gripper plate (grid plate) in the shear box with the grippers extending upward. The gripper vanes should be perpendicular to the direction of travel during shear.

3.4.2 Preparation of soil sample

- Carefully measure the dimensions of the shear box to find the volume
- Prepare three samples of same soil with same dry density.
- Carefully place the soil specimen in the shear box until approximately one-third of the shear box volume is filled. Use a wooden or metal rod with a flat end to compact the soil to the desired density. Repeat this filling and compacting operation two more times
- Carefully place the upper gripper plate and loading cap on the levelled soil specimen
- Place the shear box cart on the direct shear machine.
- Place the loading ball on the loading cap and carefully lower the loading frame in to its place. Apply the desired normal load by placing weights in the loading frame. Remember to include the weight of frame as part of normal load.

- Apply the load by manually operating the machine until the dial gage on the proving ring just begins to move Immediately stop the machine and then back off slightly.
- Advance the separation screwed in the upper shear box half clockwise until they just touch the lower half. Then advance each of them an additional amount to separate the shear box halves and create the shear plane (The amount of separation should be just slightly larger than the largest soil particle.)
- Carefully remove the clamping screws from the shear box.
- Zero all gages and prepare to begin-the test.
- Start the horizontal (shear) loading and take reading of load dial gage and horizontal shear displacement gage. Take these readings at horizontal, displacements every 10 or 20 horizontal dial displacement units.
- Continue the test until the shear stress becomes essentially constant which is indicated by load dial gage or until a shear deformation of 10 percent of original dimension has been reached.

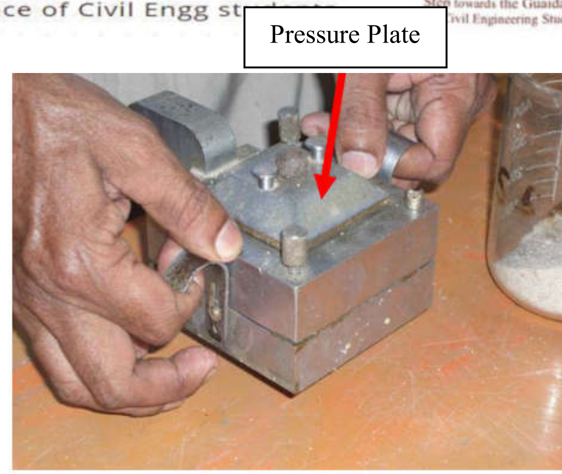


Components of Shear Box

Preparation of Sand specimen

Fig3.4.2a

Leveling the top surface of specimen



Specimen preparation completed

Fig3.4.2b

3.4.3 Remove the sample after failure.

- When the failure had occurred, and the last measurement recorded, stop the motor. and reverse the applied load. Continue to withdraw the load until the load cart can be removed
- Remove the soil from the shear box. Repeat the test at least two more times with same density and different normal loads to provide at least three points on the shear stress versus normal stress plot.

Note

If the test is to be performed under saturated conditions the following alterations are suggested.

- Place porous stone at the bottom and top of the shear box along with gripper plate
- After placing the shear box cart in direct shear machine fill the cart completely with water and allow the sample to saturate for sufficient time.
- Rest of the procedure is same as that for testing under dry conditions.

3.4.4 Correction for Cross Sectional Area

As $\tau = c + \sigma \tan(\phi)$

σ = Normal Stress = Normal load (P) / Cross sectional area of sample

τ = Shear Stress = Shear resistance developed at the sliding surface (F) / Cross sectional area of sample

But cross-sectional area of the sample changes with the horizontal displacement

Therefore

$$Ac = Ao - b.\Delta h$$

Ac = Corrected area
Ao = Original area
B = width
Δh = sample deformation

3.5 Observations & Calculations

Test Specimen = Dry Sand

Sample No. 1

Volume of sand = 6 × 6 × 2 = 72 cu cm
Original cross-sectional area = Ao = 6 × 6 = 36 sq cm = 3600 sq mm
Dry Density of sand = 100 pcf = 1601.85 kg/cu m
Mass of sand specimen = vol × density = 115.3 g
DDG constant = 0.01 mm/div
Proving Ring constant = 0.82 lb/div
Weight of Hanger = 8 lb 15 ounce = 8.9375 lb (1 lb = 16 ounce)
Normal Load = 10 lb
Total Normal Load = 18.9375 lb

Sample No.	**Normal Load N**		**Horizontal D/R**	**Horizontal Displacement ΔH = Col4×L.C**	**Corrected Area Ac=Ao-bΔH**	**Load Dial Reading**	**Horizontal Shear Force F=Col7×PRC**		**Normal Stress σn=N/Ac**	**Shear Stess τ=F/Ac**
	lb	N		mm	sq mm		lb	N	kN/m^2	kN/m^2
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	18.938	84.272	20	0.2	3588	8	6.56	29.192	23.487	8.136
	18.938	84.272	40	0.4	3576	10	8.2	36.49	23.566	10.204
	18.938	84.272	60	0.6	3564	11.5	9.43	41.9635	23.645	11.774
	18.938	84.272	80	0.8	3552	13	10.66	47.437	23.725	13.355
	18.938	84.272	100	1	3540	14	11.48	51.086	23.806	14.431
	18.938	84.272	120	1.2	3528	15	12.3	54.735	23.887	15.514
	18.938	84.272	140	1.4	3516	15	12.3	54.735	23.968	15.567

Sample No. 2

Normal Load = 20 lb

Sample No.	Normal Load N		Horizontal D/R	Horizontal Displacement ΔH = Col4×L.C	Corrected Area Ac=Ao-bΔH	Load Dial Reading	Horizontal Shear Force F=Col7×PRC		Normal Stress σn=N/Ac	Shear Stess τ=F/Ac
	lb	N		mm	sq mm		lb	N	kN/m^2	kN/m^2
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
2	28.938	128.772	20	0.2	3588	10	8.2	36.49	35.890	10.170
	28.938	128.772	40	0.4	3576	14	11.48	51.086	36.010	14.286
	28.938	128.772	60	0.6	3564	16	13.12	58.384	36.131	16.382
	28.938	128.772	80	0.8	3552	17	13.94	62.033	36.253	17.464
	28.938	128.772	100	1	3540	18	14.76	65.682	36.376	18.554
	28.938	128.772	120	1.2	3528	19	15.58	69.331	36.500	19.652
	28.938	128.772	140	1.4	3516	19.5	15.99	71.1555	36.625	20.238
	28.938	128.772	160	1.6	3504	20	16.4	72.98	36.750	20.828
	28.938	128.772	180	1.8	3492	20	16.4	72.98	36.876	20.899

Total Normal Load = 28.9375 lb

Sample No. 3

Normal Load = 30 lb
Total Normal Load = 38.9375 lb

Sample No.	Normal Load N		Horizontal D/R	Horizontal Displacement ΔH = Col4×L.C	Corrected Area Ac=Ao-bΔH	Load Dial Reading	Horizontal Shear Force F=Col7×PRC		Normal Stress σn=N/Ac	Shear Stess τ=F/Ac
	lb	N		mm	sq mm		lb	N	kN/m^2	kN/m^2
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
3	38.938	173.272	20	0.2	3588	14	11.48	51.086	48.292	14.238
	38.938	173.272	40	0.4	3576	18	14.76	65.682	48.454	18.367
	38.938	173.272	60	0.6	3564	20	16.4	72.98	48.617	20.477
	38.938	173.272	80	0.8	3552	22	18.04	80.278	48.781	22.601
	38.938	173.272	100	1	3540	23	18.86	83.927	48.947	23.708
	38.938	173.272	120	1.2	3528	24.5	20.09	89.4005	49.113	25.340
	38.938	173.272	140	1.4	3516	25	20.5	91.225	49.281	25.946
	38.938	173.272	160	1.6	3504	25.5	20.91	93.0495	49.450	26.555
	38.938	173.272	180	1.8	3492	26.5	21.73	96.6985	49.620	27.691
	38.938	173.272	200	2	3480	27	22.14	98.523	49.791	28.311
	38.938	173.272	220	2.2	3468	27	22.14	98.523	49.963	28.409

3.5.1 Graph between Shear Stress and Shear Displacement

Fig 3.5.1

Shear Stress at Failure τ_f (kPa)	Normal Stress σ_n (kPa)

In the above table shear stress and normal stress values are the values calculated on the basis of corrected areas.

3.5.2 Mohr – Coulomb Failure Envelope

Mohr coulomb failure envelope is obtained by plotting graph between normal stress and shear stress. From mohr coulomb failure envelope shear strength of soil can easily be determined.

The equation for the mohr coulomb failure envelope is

$$\tau = c + \sigma \tan(\phi)$$

Where τ = Shear strength (force/area)
c = Soil cohesion (force/area)
ϕ = Angle of internal fiction (degrees)
σ = Normal stress on the critical plane (force/area)

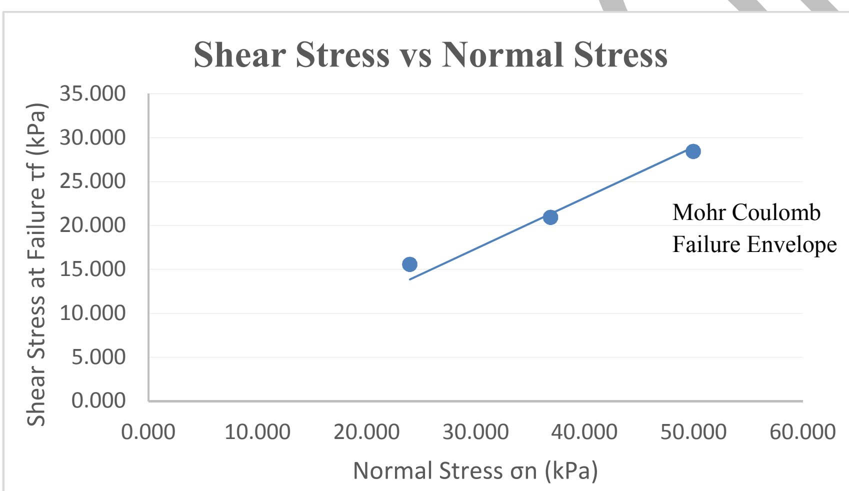


Fig 3.5.2

Comparing the equation of above line with Mohr coulomb failure envelope equation

$y =$

$\tau = c + \sigma \tan(\phi)$

we get $c =$

$\tan(\phi) =$ $\phi =$

3.6 Results

The shear strength parameters of the given clayey soil are

c = Soil cohesion =
ϕ = Angle of internal fiction = °

So, the Mohr-Coulomb Failure Envelope is

$$\tau = \quad + \sigma \tan(\ \ ^\circ)$$

3.7 Comments