EXPERIMENT NO. 5

To determine the shear strength parameters (ϕ) and (c) of a given soil sample using the triaxial compression test

5.1 Reference

Triaxial shear testing is covered in the following ASTM standards

- D2850 – "Unconsolidated Undrained Compressive Strength of Cohesive Soils in Triaxial Compression"
- D4767 – "Consolidated-Undrained Triaxial Compression Test on Cohesive Soil"

5.2 Apparatus

- Triaxial compression device (electrically driven strain controlled device)
- Triaxial cell
- Specimen mould
- Rubber membrane (typically 1.4 in or 2.8 in diameter)
- Membrane stretcher and ruler binding strips

5.3 Related Theory

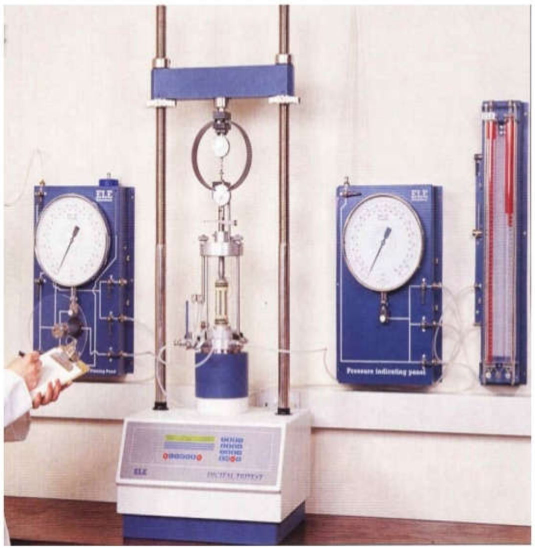
5.3.1 Triaxial Compression test

When a soil sample is removed from a soil mass all of the horizontal and vertical stresses acting on the soil in situ are removed. Thus, when the soil is tested in the laboratory to determine its strength, the, test should be conducted under test conditions that resembles the field conditions as closely as possible. The triaxial compression test is a procedure that permits different horizontal and vertical stresses to be applied to the soil specimen simultaneously and thus closely duplicate the expected field conditions.

5.3.2 Confining Pressure

The concept of the triaxial compression lest is that an all-around equal pressure is applied to the soil sample in the form of a confining pressure. The confining pressure is obtained by imposing a compressive stress on a fluid that completely surrounds the soil specimen. The fluids most commonly used are glycerin and water. Compressed air is also frequently used. The confining or chamber pressure is called the minor principal stress σ_3.

Usually, the principal change in stress experienced by soil. is a change in vertical stress due to the construction of a building, highway, airport, bridge, dam or other structure on the surface above the supporting soil. Consequently, it would be logical to test the soil specimen in a configuration that permits the specimen to be placed in the testing device and loaded in a manner that duplicates what will happen in the field. Thus specimens are tested in the triaxial test by applying a vertical loading to the specimen. (See figure 5.3.1)



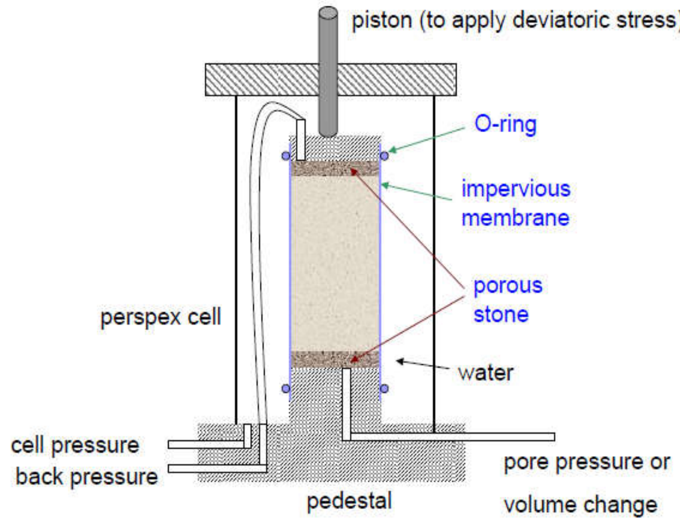


Fig 5.3.1

5.3.3 Deviator Stress

The vertical load being applied to the soil specimen cause it to feel a vertical stress that is increasingly larger than the confining pressure. This increase in vertical pressure is called the deviator stress ($\Delta\sigma$). When the deviator stress is being applied σ_1 the major principal stress is no longer equal to σ_3. Thus σ_1 now becomes

$$\sigma_1 = \Delta\sigma + \sigma_3$$

Triaxial compression test results are analysed by plotting Mohr circles for the stress conditions of each sample when failure occurs. Through evaluation of the plotted Mohr Circles strength parameters of the soil c and angle of internal friction (ϕ) can be determined.

Triaxial test can be applied to both cohesive and cohesionless soil.

5.3.4 Length to Diameter Ratio of Test Specimen

5.3.5 Correction of Cross Sectional Area

5.3.6 Types Triaxial Compression Test Procedure

There are three basic types of triaxial compression test procedur as determined by the sample drainage condition

- Unconsolidated Undrained (UU) test
- Consolidated Undrained (CU) test
- Consolidated Drained (CD) test

5.3.6.1 Unconsolidated Undrained (UU) Test

The un-consolidated undrained (UU) test is carried out by placing the sample in the chamber and introducing the confining pressure without allowing the sample to consolidate (drain) under the confining pressure. The axial load is then applied allowing drainage of the sample.

The UU test can be run rather quickly because the sample is not required to consolidate under the confining pressure or to drain during application of the axial load. Because of the short time required to run this test, it is often referred to as the ***Quick or Q Test***.

5.3.6.2 Consolidated Undrained (CU) Test

The consolidated undrained (CU) test is performed by placing the sample in the chamber and introducing the confined pressure. The sample is then allowed to consolidate under the all-around confining pressure by leaving the drain lines open. The drain lines are then closed and the axial stress is increased without allowing further drainage. The consolidated undrained (CU) test is also referred to as ***Rapid test***.

5.3.6.3 Consolidated Drained (CD) test

The consolidated drained (CD) test is similar to the CU test except that the sample is allowed to drain as the axial load is applied so that high excess pore pressures not to be developed. The consolidated drained test is often referred to as *the* ***Slow or S test***.

5.3.7 Advantages of Triaxial Compression Test

5.3.8 Modes of Failure of Test Specimen

5.4 Procedure

1. It density and moisture content of the soil is known, calculate the weight of the dry soil needed for preparation of three soil samples of 1.5-inch diameter and 3-inch height
2. Add specified moisture to the dry soil and mix thoroughly. Put some of the soil for moisture content determination
3. Prepare three soil samples of required density by packing the soil in the specimen mould
4. Take the correct size membrane stretcher and membrane and fit the membrane smoothly into the stretcher, folding the ends of the membrane over the ends of the stretcher
5. Insert the sample into the membrane and attach the lower platen using rubber bands or strips to seal the membrane
6. Remove the sample from the membrane stretcher and attach the lower platen to the base of the triaxial cell. Also attach the upper platen if this has not already been done. Use extreme case not to damage the soil specimen
7. Place the Lucite cover on the cell and place the cell in the compression machine. Bring the load bar in contact with the load piston until a load just flickers on the load dial
8. Apply a pre-determined chamber pressure for the lateral pressure σ_3
9. Attach a deformation dial to the machine so that the sample deformation can be obtained. Set the dial gage to zero then manually compress and release the dial plunger several times and observe the zero reading Readjust the gage to zero if necessary
10. Check deformation dial gage and cell pressure gage for final correct settings
11. Set the compression machine to the desired rate (generally between 0.5 and 1.2.5 mm/min)
12. Turn on the compression machine and take simultaneous load and deformation readings. Readings may be taken at 5,15.25,50, and every 50 to 100 division or as specified until;
    a) Load peaks and then falls off
    b) Somewhat past 20 percent strain
    c) Load holds constant for 3 or 4 successive readings.

Be sure to monitor the chamber pressure gage and do not let the chamber pressure vary by more than 0.05 Kg/cm^2. It takes only slight pressure changes to alter considerably the deviator stress which defines “failure”

13. After the sample fails, shut off and reverse the compression machine, release the chamber pressure and remove the same load
14. Remove the specimen. Obtain a final moisture content sample

15. Test at least two more samples by repeating steps 7 to 14 at different confining pressures.
16. Two graphs must be prepared for each confining pressure after necessary calculation.
    a) Plot deviator stress $\Delta\sigma$ versus axial strain ε. The maximum deviator stress is used to calculate the maximum value of σ_1 ($\sigma_1 = \Delta\sigma_{max} + \sigma_3$)
    b) Plot Mohr's circle using values of σ_1 and σ_3 as abscissa and shear stress as ordinate. From the Mohr's circle plot a curve tangent to each circle drawn. The slope of the tangent is the angle of internal friction and the intercept with the vertical axis is the value of the soil cohesion c

5.5 Observations & Calculations

Dia. Of Sample, D	=	38.1	mm
Length of Sample, Lo	=	76.2	mm
Orignal x-area of Sample, Ao	=	1140.0918	mm2
Volume of the Smaple, V	=	86874.9973	mm3
Wt. of the Specimen, M	=	174.16	g
Bulk Density, γb	=	2.0047	g/cm3
Moisture Content, w	=	10	%
Proving Ring Constant	=	9.03	N/div
DDG L.C.	=	0.01	mm

Sample No. 1 (Cell Pressure σ3 = 30 kPa)

Sample #	Cell Pressure σ3	DDG Reading	Proving Ring DG Reading	Sample Deformation ΔL= Col3xLC	Axial Strain ε=ΔL/Lo	Corrected Area Ac=Ao/(1-ε)	Axial Load Applied Col4xPRC	Deviator Stress Col8/Col7
	(kPa)	(div.)	(div.)	(mm)		(mm2)	(N)	(kPa)
Col-1	Col-2	Col-3	Col-4	Col-5	Col-6	Col-7	Col-8	Col-9
1	30	0	0	0	0	1140.0918	0	0
		20	11	0.2	0.00262	1143.0921	99.33	87
		40	15	0.4	0.00525	1146.1081	135.45	118
		60	29	0.6	0.00787	1149.1402	261.87	228
		80	33	0.8	0.01050	1152.1883	297.99	259
		100	36	1	0.01312	1155.2526	325.08	281
		120	39	1.2	0.01575	1158.3333	352.17	304
		140	43	1.4	0.01837	1161.4304	388.29	334
		160	44	1.6	0.02100	1164.5442	397.32	341
		180	46	1.8	0.02362	1167.6747	415.38	356
		200	47	2	0.02625	1170.8221	424.41	362
		220	48	2.2	0.02887	1173.9864	433.44	369
		240	49	2.4	0.03150	1177.1680	442.47	376
		260	49.5	2.6	0.03412	1180.3668	446.985	379
		280	50	2.8	0.03675	1183.5831	451.5	381
		300	50.5	3	0.03937	1186.8169	456.015	384
		320	51	3.2	0.04199	1190.0685	460.53	387
		340	51	3.4	0.04462	1193.3379	460.53	386
		360	51	3.6	0.04724	1196.6253	460.53	385

Sample No. 2 (Cell Pressure σ_3 = 60 kPa)

Sample #	Cell Pressure σ3	DDG Reading	Proving Ring DG Reading	Sample Deformation ΔL = Col3xLC	Axial Strain ε=ΔL/Lo	Corrected Area Ac=Ao/(1-ε)	Axial Load Applied Col4xPRC	Deviator Stress Col8/Col7

Sample No. 3 (Cell Pressure σ3 = 90 kPa)

Sample #	Cell Pressure σ3	DDG Reading	Proving Ring DG Reading	Sample Deformation ΔL=Col3xLC	Axial Strain ε=ΔL/Lo	Corrected Area Ac=Ao/(1-ε)	Axial Load Applied Col4xPRC	Deviator Stress Col8/Col7

5.5.1 Graph b/w Deviator Stress & Axial Strain

Graph between deviator stress $\Delta\sigma$ and axial strain ε (%) is plotted to determine the maximum deviator stress which is the deviator stress at failure

From the above chart, maximum value of deviator stress is obtained with respect to corresponding cell pressure σ_3

Cell Pressure σ_3	Deviator Stress at Failure $\Delta\sigma$	Major Principal Stress σ_1
(kPa)	(kPa)	(kPa)
30		
60		
90		

5.5.2 Mohr-Coulomb Failure Envelope

From the triaxial test we have the values of σ_1 and σ_3. Using principal stress values corresponding Mohr's circles are drawn and upon them a common tangent is drawn which is the mohr coulomb failure envelope and shear strength parameters of the given soil can be determined using the equation of mohr coulomb failure envelope line which 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)

Shear Stress vs Normal Stress

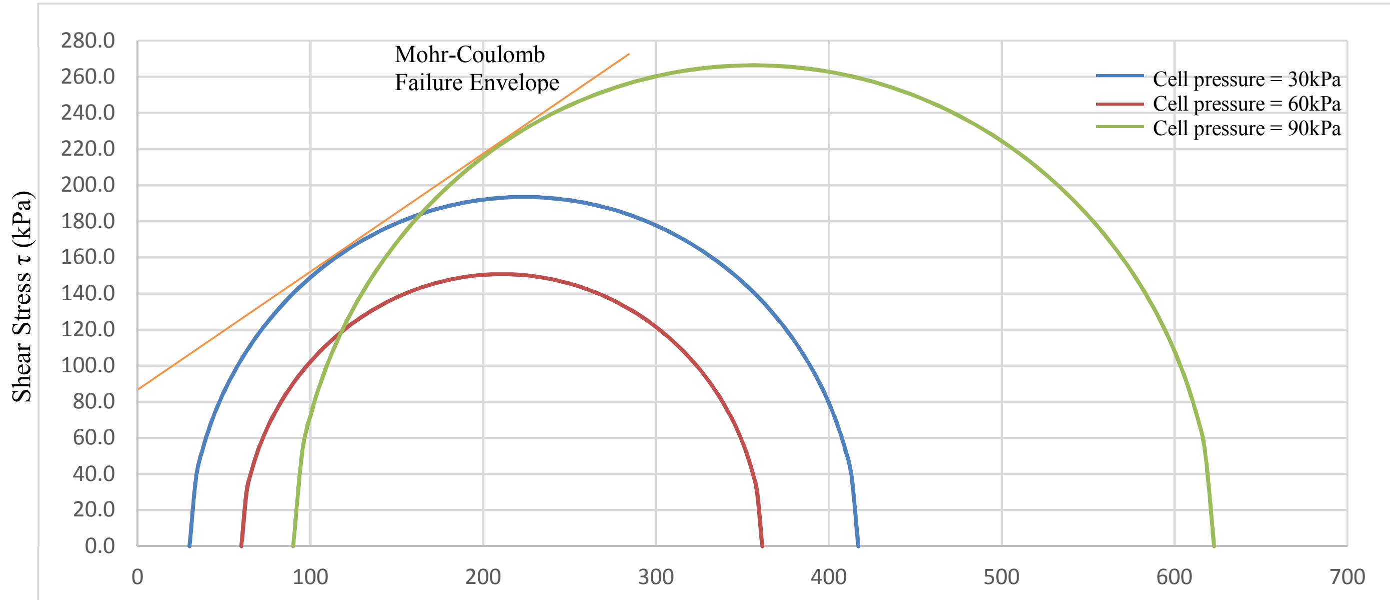


Fig 5.5.2

From the Mohr coulomb failure envelope, we get

Slope of line = ° & y-intercept = kPa

5.6 Results

The shear strength parameters of the given clayey soil are

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

So the Mohr-Coulomb Failure Envelope is

τ = + σ tan (°)

5.7 Comments