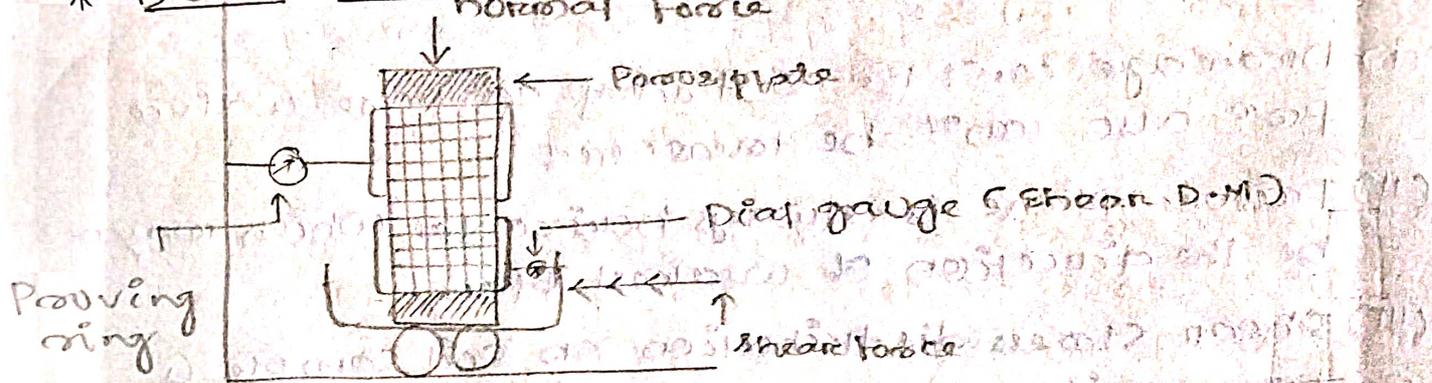


* Direct shear test: —



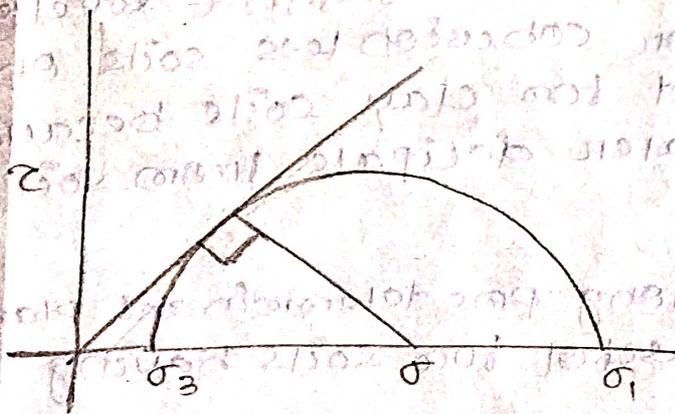
- Vertical load is applied through horizontal plane at top surface
- Soil is sheared gradually by applying horizontal force.
- Shear is normally applied at constant rate of strain i.e this test is strain controlled test
- Magnitude of shear force is measured by proving ring.
- Shear deformation and vertical deformation are measured during test by dial gauges.
- Shear stress and normal stress are found out by dividing shear force and normal force by nominal area of specimen i.e original cross-sectional area.
- As drainage can't be controlled then rate of loading such that pore water pressure shouldn't develop.
i.e this test is used for cohesion less soils only. This test can't be used for clay soils because the time taken by water to seep out from soil sample is on higher side.
- As the specimen fails along predetermined plane hence this test is very useful for soils having pre-determined faults.
- This test is quick and inexpensive and soil sample preparation is very easy.

Disadvantages :-

- (i) Drainage can't be controlled so pore water pressure can't be measured.
- (ii) Failure plane is always horizontal which may not be the direction of weakest plane.
- (iii) Shear stress distribution on soil sample is non uniform.
- (iv) Area of specimen under normal and shear load does not remain same. So calculation of normal and shear stress obtained from these results are not very accurate.

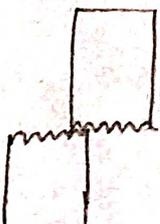
Result of test :-

- Numbers of specimen of soil are tested each under different vertical load and value of shear stress at failure are plotted against normal stress for the test.
- Shear strength parameters are obtained from best fit straight line method.
- Even if the line doesn't pass through origin we forcibly pass through origin because for this test the value of 'c' must be zero.



$$c = 0$$

$$NS =$$



- Let n is the proving ring dial gauge reading at failure and one division equal to one micrometer.
- Let K is the proving ring constant in N/mm^2 then shear force on failure plane is

$$SF = Kn$$

$$SS = \frac{Kn}{A}$$

Q:- A direct shear test on a remoulded sample of sand use the following observation at failure.

Normal load = 288 KN.

Shear load = 173 KN

Crosssectional area = 36 cm²

- Determine angle of internal friction.
- magnitude and direction of principal stresses in the zone of failure.

$$\tau = \sigma \tan \phi \text{ at } \tau^0$$

$$\tan \phi = \frac{\tau}{\sigma}$$

$$\phi = \tan^{-1} \left(\frac{173}{288} \right)$$

$$= 30.99^\circ$$

$$\sigma_f = \frac{\sigma_1 + \sigma_3}{2} + \left(\frac{\sigma_1 - \sigma_3}{2} \right) \cos 2\theta$$

$$\theta = 45^\circ + \frac{\phi}{2}$$

$$\tau_f = \frac{\sigma_1 - \sigma_3}{2} \sin 2\theta$$

$$8 = \frac{\sigma_1 + \sigma_3}{2} + \left(\frac{\sigma_1 - \sigma_3}{2} \right) \cos 2 \times 60.495$$

$$4.80 = \frac{\sigma_1 - \sigma_3}{2} \sin 2 \times 60.495$$

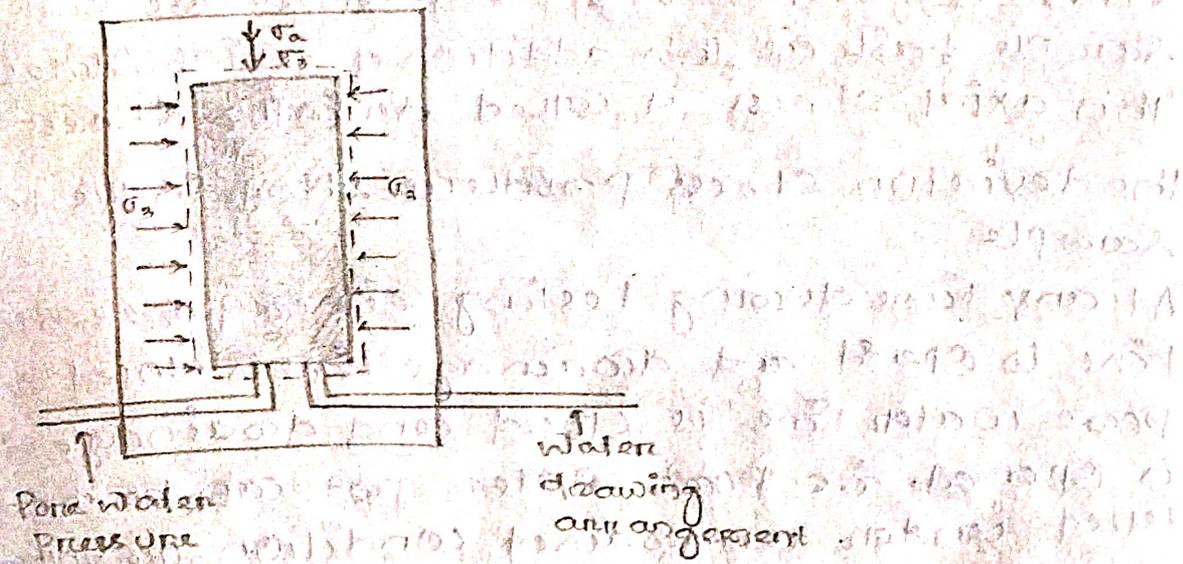
$$\Rightarrow (\sigma_1 + \sigma_3) + (\sigma_1 - \sigma_3) \cos 2 \times 60.495 = 16$$

$$\Rightarrow (\sigma_1 - \sigma_3) \sin 2 \times 60.495 = 4.80 \times 2$$

$$\sigma_1 = 16.482 \text{ KN/cm}^2$$

$$\sigma_2 = 5.213 \text{ KN/cm}^2$$

* Triaxial Shear test :-



* We always perform test on saturated soil sample because value of effective stress will be min^m and all the properties of soil depends on effective stresses and if a soil has min^m strength to bear the load in case of saturated soil condⁿ then soil can easily bears the load easily in other conditions also. Because effective stress value is higher in all other cases.

- This is the most widely used shear strength test and it is suitable for all types of soils.
- Drainage can be controlled whatever the soil may be i.e sand can be tested on undrained condition and clay can be tested under drained condition also.
- Pore water presⁿ can be measured. Failure plane is not forced and stress distribution on failure plane is fairly uniform.
- The triaxial ~~cell~~^{cell} is filled with water and specimen is covered with a rubber membrane and cell presⁿ is applied and this presⁿ is called confining presⁿ. (σ_3)
- This presⁿ doesn't cause any shear failure as it acts in all directions.

- With the cell pressure is held const additional axial stress is gradually applied until the soil sample fails at this additional axial stress. This axial stress is called deviator stress.

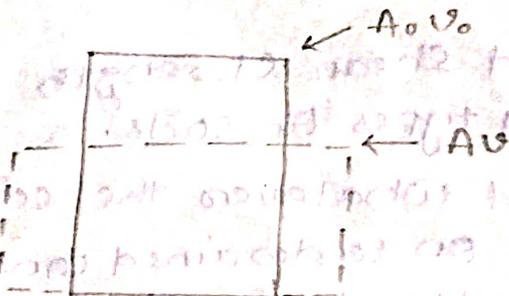
- The deviator stress produces shear in the soil sample.

- At any time during testing either pore water line is opened and drainage line is closed or pore water line is closed and drainage line is opened. i.e. pore water pressure can be measured under undrained condition or volume change can be measured under drained condition.

- Horizontal plane becomes major principal plane and vertical plane becomes minor principal plane.

$$\sigma_1 = \sigma_3 + \sigma_a \leftarrow \text{deviator stress}$$

$$\sigma_3 = \sigma_3$$



change in area of soil specimen

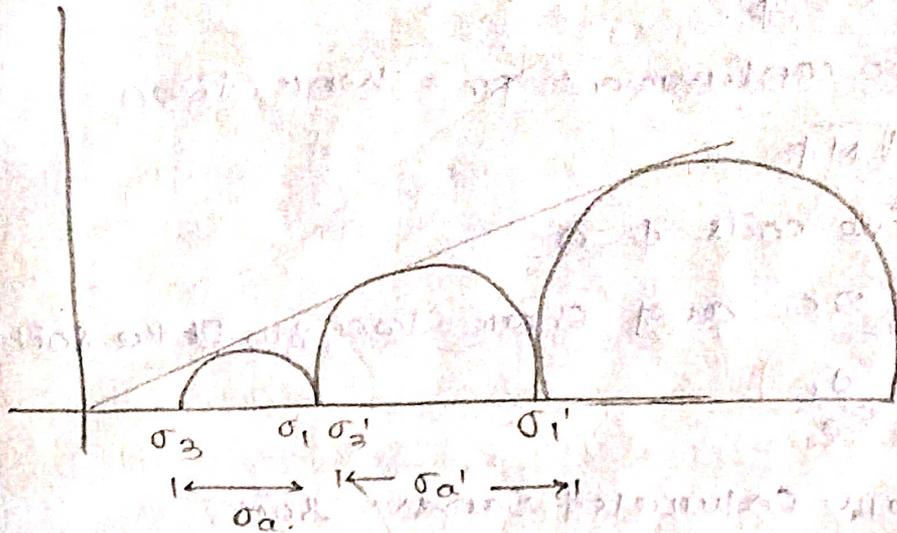
$$A(h_0 - \Delta h) = V_0 - \Delta V$$

$$A = \frac{V_0 - \Delta V}{h_0 - \Delta h} = \frac{V_0 \left(1 - \frac{\Delta V}{V_0}\right)}{h_0 \left(1 - \frac{\Delta h}{h_0}\right)}$$

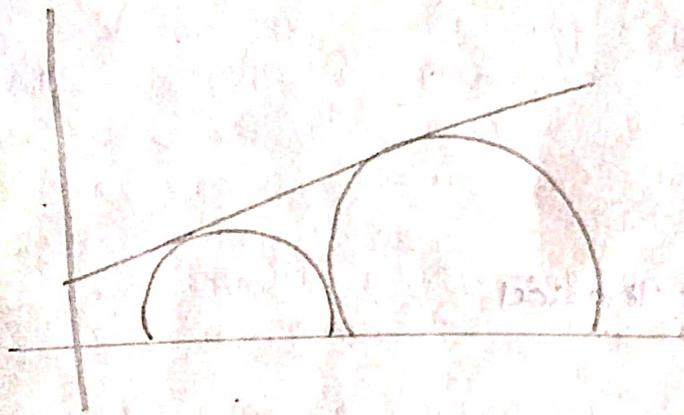
$$= A_0 \frac{\left(1 - \frac{\Delta V}{V_0}\right)}{\left(1 - \frac{\Delta h}{h_0}\right)}$$

$$A = A_0 \left[\frac{\left(1 - \frac{\Delta V}{V_0}\right)}{\left(1 - \frac{\Delta h}{h_0}\right)} \right]$$

By performing triaxial test on two or three specimens at diff cell pres (at different deviator stresses) Mohr's circle can be plotted and shear strength parameters are obtained from common tangent.

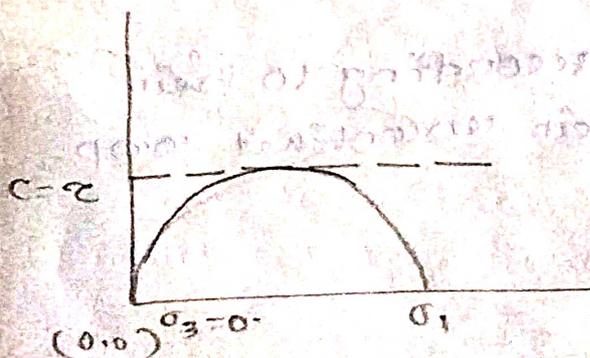


$$\sigma_a' > \sigma_a$$



Unconfined comp. test :-

- No confining pres is applied. It is a special type of triaxial test in which $\sigma_3 = 0$.
- It is used for cohesive soils and partially saturated (due to capillary rise) sandy soil.
- Load is applied rapidly. Hence it is a undrained test.



(For cohesive soils only)

$$\tau = \sigma \tan \phi$$

$$\sigma_1 = \sigma_3 \tan^2 \phi + 2c \sqrt{N\phi}$$

$$\sigma_1 = \sigma_3 \cdot 2c \sqrt{N\phi}$$

There is no confinement pressure hence $\sigma_3 = 0$

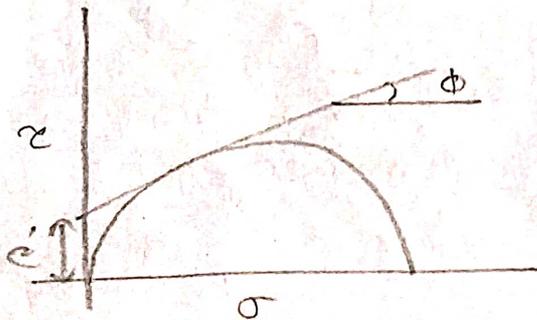
$$\sigma_1 = 2c \sqrt{N\phi}$$

For cohesive soils $\phi = 0$

hence $\sigma_1 = 2c$ and shear strength of the soil is

$$\tau = c = \frac{\sigma_1}{2}$$

For partially saturated sandy soil.



Shear strength of the soil

$$\phi = \phi_1$$

$$\sigma_1 = 2c \sqrt{N\phi_1}$$

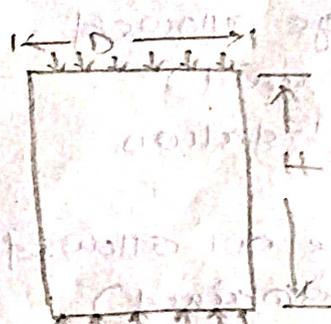
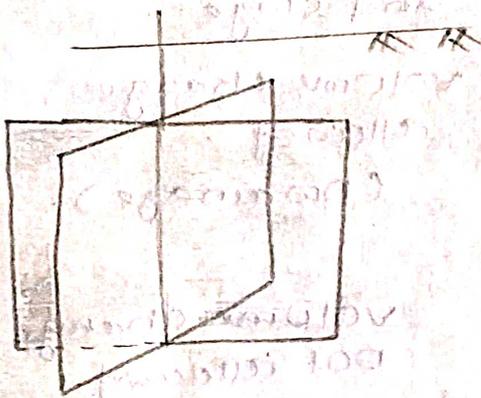
$$\tau = c_1 + \sigma \tan \phi_1$$

Advantages:-

- Unconfined comp. test uses simple equipment.
- Test can be conducted in field also.
- This test is used for rapid construction settlement.
- ~~The~~ clays are classified according to their consistency based on their unconfined comp. strength test data.

* Vane shear test :-

- In plastic cohesive soil which is very sensitive in nature, obtaining undisturbed soil sample is very difficult. Hence shear strength of such soil may be changed during sampling so ^{for} such soil vane shear test is performed in field.
- Vane shear test can also be performed in lab. Field equipment is large as compared to lab equipment.
- Vane is pushed into soil and twisted until soil fails.
- Max^m torsion applied corresponds to total shear resistance.



$$T = \int_0^{D/2} 2(\pi r dr \tau_f) r + \tau_f \times \pi D H \frac{D}{2}$$

$$= \tau_f \left[\left(\frac{4\pi r^3}{3} \right)_0^{D/2} + \frac{\pi D^2}{2} H \right]$$

$$= \tau_f \left[\frac{4\pi}{3} \times \frac{D^3}{4 \times 2} + \frac{\pi D^2}{2} H \right]$$

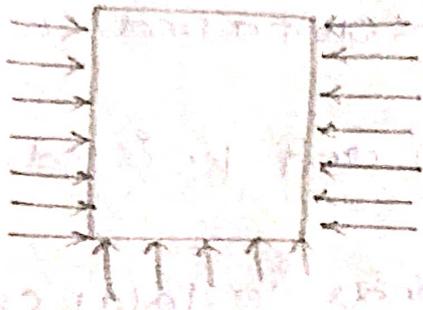
$$= \tau_f \frac{\pi D^2}{2} \left[\frac{D}{3} + H \right]$$

$$= \tau_f \pi D^2 \left[\frac{D}{6} + \frac{H}{2} \right]$$

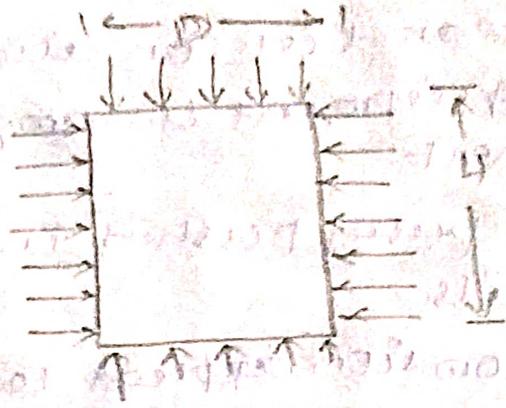
$$\tau_f = \frac{T}{\pi D^2 \left[\frac{D}{6} + \frac{H}{2} \right]}$$

- When shearing is done such that top end of the weibe doesn't shear the soil, then

$$\tau_f = \frac{T}{\pi D^2 (D/12 + H/2)}$$



1st Stage



2nd Stage

- Drainage allowed
(Drained)
consolidation

Volume change
allowed.
(Drainage).

- Drainage not allowed
(Undrained)
UN~~not~~. consolidation

Volume change
not allowed
(Undrained).

CU - consolidated
CD
UU

CU - consolidated undrained
CD - consolidated drained
UU - unconsolidated undrained

Types of triaxial test:

Triaxial test is performed in two stages.

(i) 1st stage

(ii) 2nd stage

as described above.

consolidated drained test takes longest time duration.

consolidated undrained test takes 24 hrs for 1st stage and 2nd stage takes 2hrs.

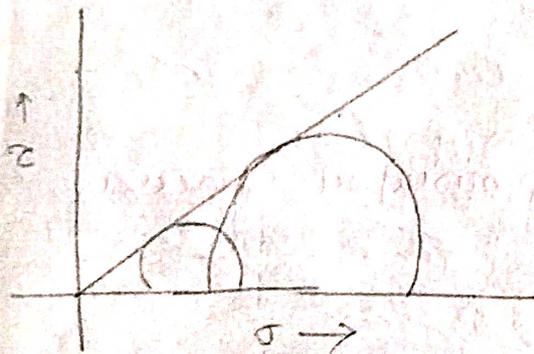
unconsolidated undrained test takes only 15 min.

4th combination UD (unconsolidated drained) test is not possible as it doesn't occur in field situation.

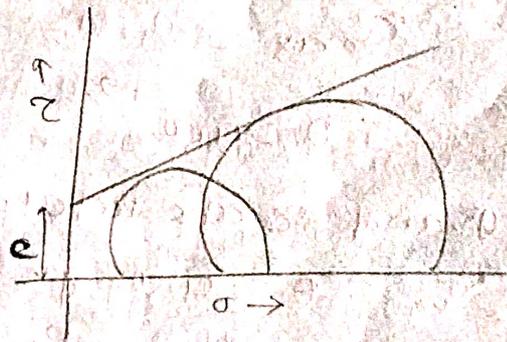
- If rate of loading is more than rate of dissipation of water then this situation is called undrained condⁿ.
- If rate of loading is less than rate of dissipation of water then this situation is called drained condⁿ.
- If we are not capable to measure pore water presⁿ then effective stress will be same as total stress.

Consolidated - Drained test:

If test is performed and drainage is allowed in both the stages then there will not be any pore water presⁿ in the test hence for normally consolidated test shear strength eqⁿ will pass through origin. This test will take longest time to dissipate water from the system.

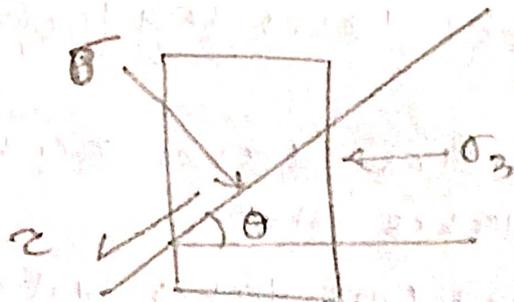


N.C. clay



O.C. clay

$$\tau = \sigma \tan \phi$$



σ_1 = major principal stress.

σ_3 = confining pressure

σ_a = Deviator stress

UU - Total stress.

CU - total stress and effective stress

CD - Effective stress

$$(1) \sigma_1 = \sigma_3 N_\phi + 2c \sqrt{N_\phi}$$

$$N_\phi = \tan^2 \left(45^\circ + \frac{\phi}{2} \right)$$

$$\sigma_1 > \sigma_3$$

$$(2) \tau = c + \sigma \tan \phi \quad (\text{on failure plane})$$

$$(a) \sigma = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2} \cos 2\theta$$

$$(b) \tau = \frac{\sigma_1 - \sigma_3}{2} \sin 2\theta$$

$$\tau_{\max} = \frac{\sigma_1 - \sigma_3}{2}$$

$$\sigma_3 = 200 \text{ kPa}$$

$$\sigma_1 = 512 \text{ kPa} \quad \theta = 45^\circ$$

σ and τ are related to principal stresses.

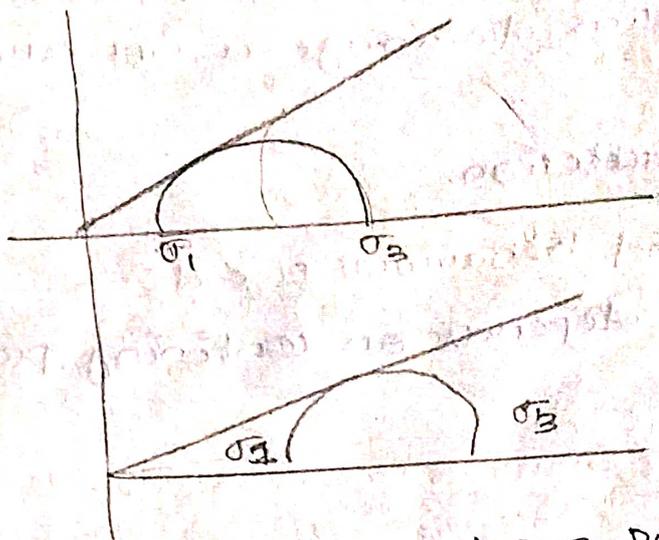
$$\sigma_1 = 512 \quad \theta = 45^\circ + \frac{\phi}{2}$$

CD - Effective stress parameters with $c \neq 0$.

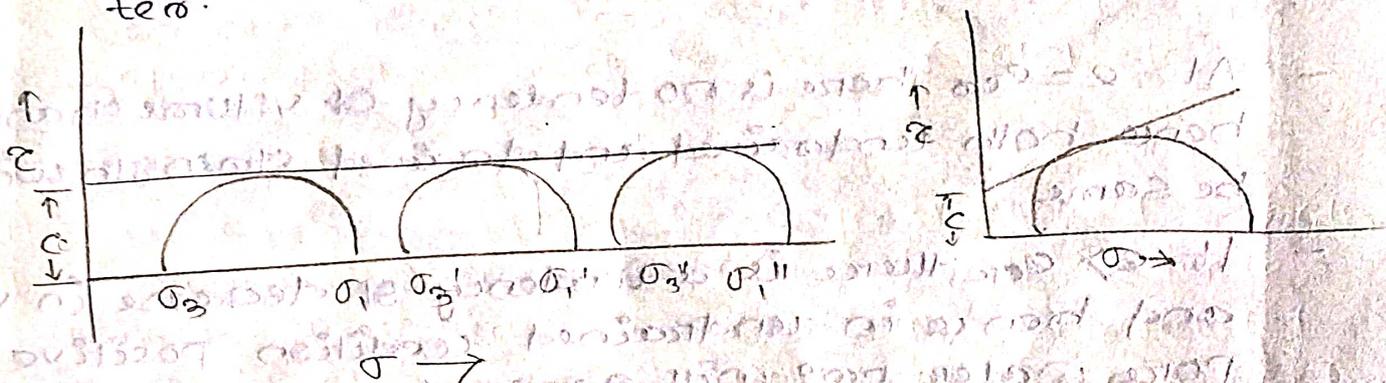
UU - Total stress parameters with $\phi = 0$.

CU - Total stress and effective stress parameters with variable value of c .

consolidated undrained test:-



Slope of effective stress parameter is more to find out shear strength of the soil sample, we may use total stress parameter and effective stress parameter.



By increasing confinement pressure the arrangement of soil solid changes without change in volume. But this will not cause any shear failure of the soil sample. But if we apply deviator stress then the failure of the soil sample will definitely occur.

- The above phenomena can only be possible if w_c , void ratio, no consolidation is allowed in the soil sample. Hence for the UU test the Mohr's circle will be the same and $\phi = 0$ as there is no change of consolidation. If we draw effective stress diagram for the above case then there will be only one effective stress Mohr's circle for all applied stresses. That circle can't be used for the practical purpose as experiments are performed to obtain the results for field condition. But in this case we will get only one Mohr's circle.