UNIT: IV Shear Strength

Shear Strength of cohesive & cohesionless soil - Mohr - Coulomb failure theory - Saturated Soil - Strength parameters - Measurement of shear Strength, direct shear, Triaxial compression, UCC - & Vane shear tests - Types of shear tests based on drainage & their applicability - Drained & undrained behaviour of clay & sand - Stress path for conventional triaxial tests.

* Shear Strength (or) shearing strength of a soil

Shear strength is a term used in soil mechanics to describe the magnitude of the shear stress that a soil can sustain (to keep its maintain) - (on existence)

* Measurement of shear strength:

The measurement of shear strength of soil involves certain tests observations at failure with the help of which the failure envelope.

Shear resistance of soil can be determined in the laboratory by the following four methods

1. Direct shear test
2. Triaxial shear test
3. Unconfined compression test
4. Vane shear test.

Depending upon the Drainage condition three types of shear test are developed.

Unconsolidated Unconsolidated
(a) Undrained test (or) quick test

Drainage is not permitted at any stage of the test that is either before the test during the application of the normal stress. Usually this test takes only 5 to 10 mins. Performed only for soils of low permeability.

(b) Consolidated undrained test : (or) consolidated quick test

Drainage is permitted fully in this type of test during the application of normal stress & no drainage is permitted is permitted during the application of normal shear stress. 5 to 10 minutes.

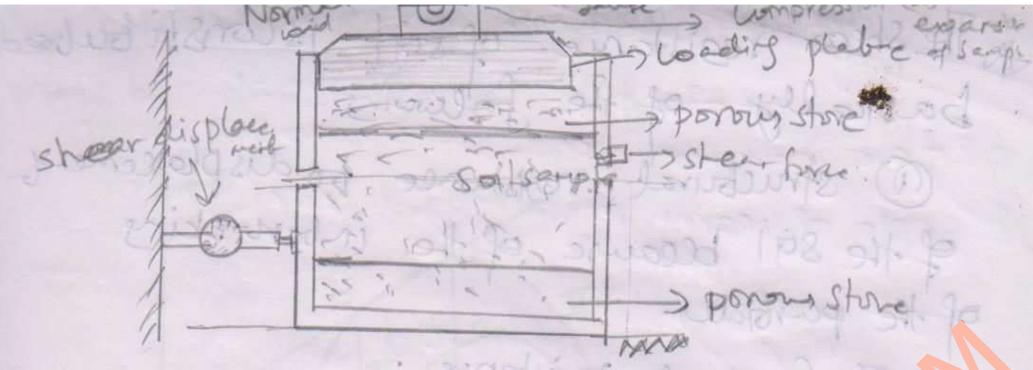
(c) Drained test (or) consolidated slow test

Drainage is permitted fully before & during the test at every stage during the application of both normal & shear stress. No excess pore pressure develops at any stage. It may takes 4 to 6 weeks to complete. Cohesive soils.

Laboratory:

(i) Direct shear test

Shear box apparatus essentially consists of brass box, split horizontally at midht of the soil specimen



The soil is gripped in performed metal grilles, behind which porous discs can be placed if required to allow the specimen to drain. Normal load is applied on the specimen from a loading gauge. Usualy the plan size of the specimen is 60mm Square. but large size or even more is employed for 300mm Square testing large size granular material such as gravel. ht : 20mm. Shear force is applied upper half of the box which is zero initially & is increased until the specimen fails.

Two types of application of shear are possible. one → shear stress controlled, shear strain is controlled. Stress controled type load is applied at constant rate or more commonly in equal increments at means of calibrated wt. shear displacement is measured with the aid of a dial gauge attached to the side box.

In strain controlled type shear displacement is applied at a constant rate by means of a screw operated manualy or by motor → deflection of the annual ring.

... the another

The shear resistance of soil is constituted basically of the following

(1) structural resistance to displacement of the soil because of the interlocking of the particles.

(2) The frictional resistance.

(3) Cohesion (or) adhesion b/w the surface of the soil particles.

Columb's law:

$S = C + \sigma \tan\phi$.

where c – cohesion – kN/m²

S = shear strength – kN/m²

ϕ = slope of the straight line of above equation.

= angle of internal friction or angle of shearing resistance

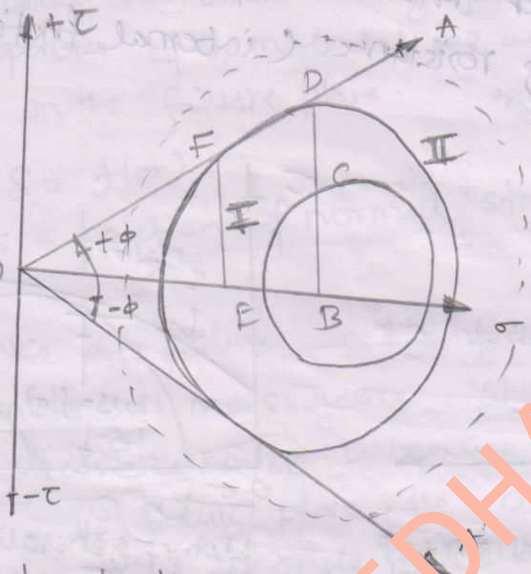
C & φ are not constant for particular soil. They depend on the drainage conditions.

Strength theories for soils: No of theories have been propounded for explaining the shear strength of soil.

Mohr-Coulomb failure theory: & Mohr strength theory are a generalisation & modification of the Columb's equation.

Mohr: strength theory:

shearing stress may be expressed as $\tau = \sigma \tan\beta$ on any plane. where β is the angle of obliquity. angle ↑ or has limiting value ... as φ for cohesionless soil of the shearing strength may be $S = \sigma \tan\phi$.



Mohr strength theory cohesionless soil

stress condition of a point are represented by Mohr's circle I.

BC → shear stress on a plane.
OD ⇒ Normal stress.

BD = shearing strength for this normal stress is > than BC

stress condition as represented by the Mohr's circle II which tangential to the mohrs envelope at F. Stress condition is impossible to apply to the Mohr's circle III dashed to this soil sample.

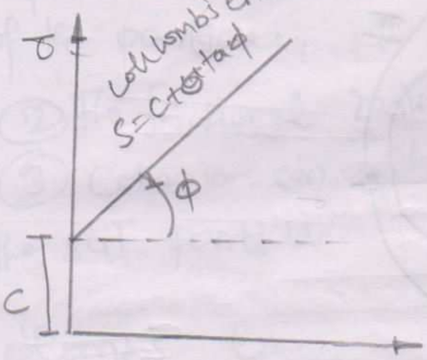
Mohr coulomb theory:

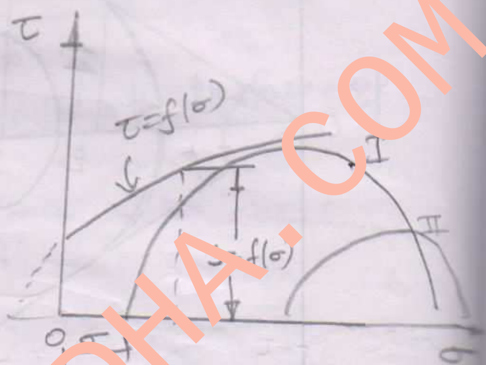
First propounded by coulomb (1776) & later generalised by Mohr it is most commonly used concept. The functional relationship between the normal stress on any plane & the shearing strength available on the plane was assumed to be linear

Usualy known as coulomb's law :

$S = c + \sigma \tan\phi$.

c & φ are parameter known as apparent cohesion & angle of shearing resistance (internal friction)





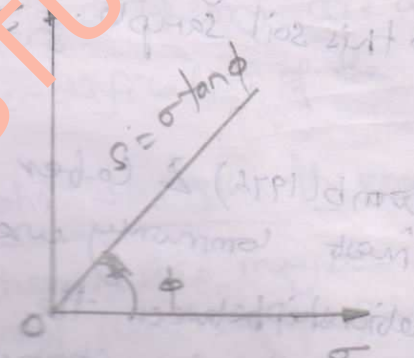
(a) coulomb's envelope for c-φ soil

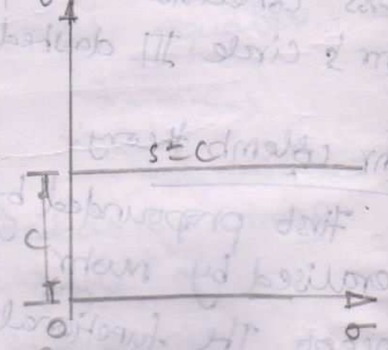
Mohr's generalised failure envelope

Mohr Coulomb theory - failure envelope

Mohr generalisation of the failure envelope (or) failure envelopes as a curve which becomes flatter with increase in normal stress. (or) strength envelope.

The coulomb envelope in special cases may take the shapes for purely cohesionless (or) granular soil (or) pure sand.





Pure Sand (c = 0 (or) φ soil)

(Pure clay (φ = 0 (or) "c" soil)

Mohr's theory Assumptions:

* Material fails essentially by shear.
* Critical shear stress causing failure depends upon the properties of the material as well as normal stress on the failure plane.

$S = f(\sigma)$

S is a function of normal stress.

The stresses at failure on the failure plane in a cohesionless soil mass were shear stress (τ) = 4 kN/m². Normal stress (σ) = 10 kN/m². Determine the resultant stress on the failure plane, the angle of internal friction of the soil & the angle of inclination of the failure plane to the major principal plane.

Resultant stress $= \sqrt{\sigma^2 + \tau^2}$

$= \sqrt{10^2 + 4^2} = 10.77\ kN/m^2$

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

$S = \sigma \tan\phi$

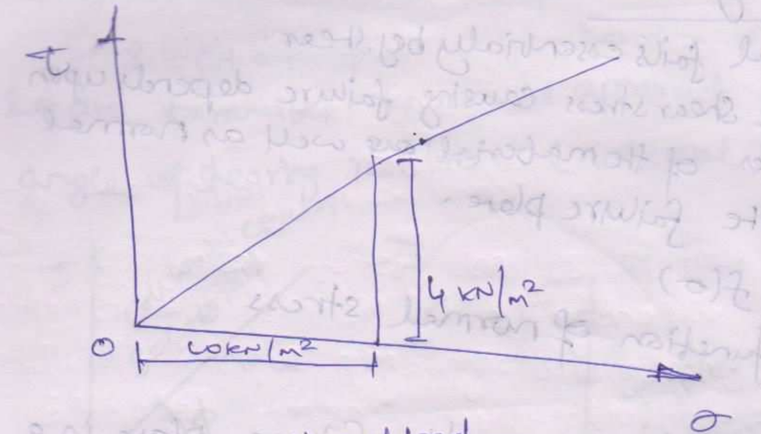
Angle of internal friction: $\tan\phi = S/\sigma = 4/10 = 0.4$

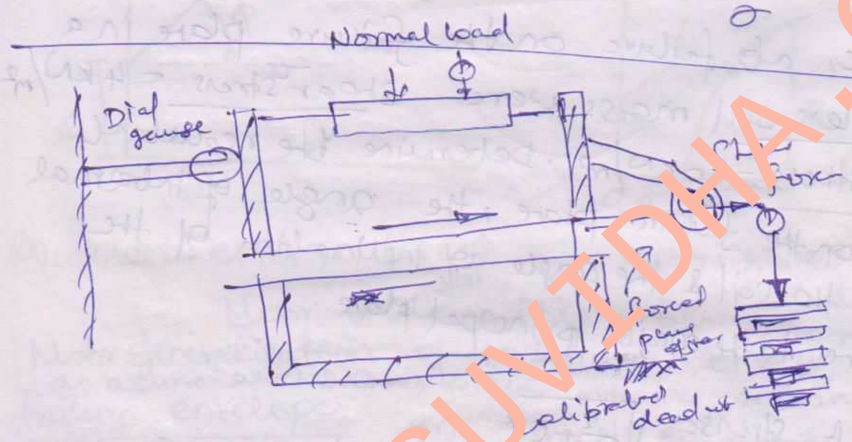
$\phi = 21°48'$

Angle of inclination: $\theta = 45° + \phi/2 = 45° + \frac{21°48'}{2}$

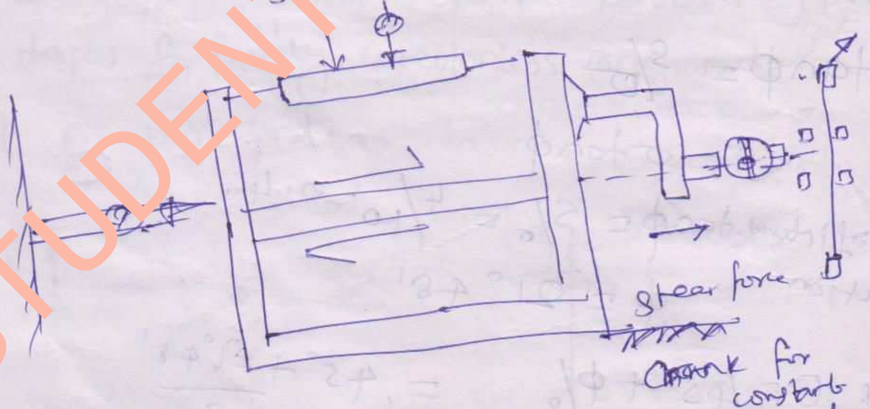
$= 55°54'$

Graphical Solution





Stress controlled.



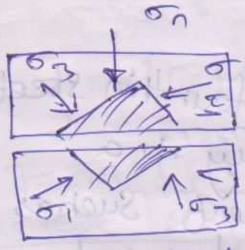
widely used. Strain control

Direct shear device.

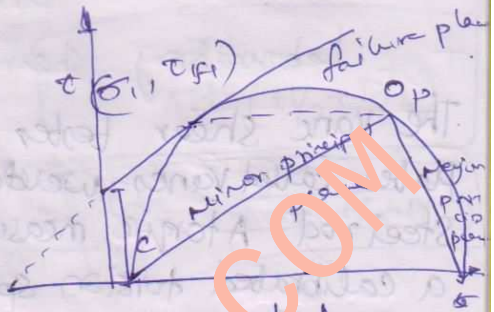
Both cases normal load is applied to which the normal load ratio of the shear displacement to the thks of the sample.

The mohr circle representation of stress conditions

indirect shear test:



Conditions of stress in the shear box



Mohr's circle for d.s.t.

Simple test.

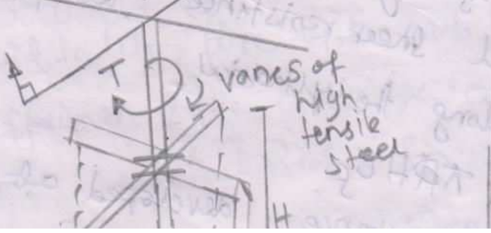
Disadvantages:

As compared Triaxial test there is little control on the drainage of soil.

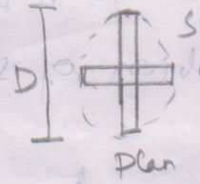
* The distribution of normal & shear stress is not uniform.
* not used for cohesive soil.
* There is effect of lateral restraint by the side wall of the shear box.

VANE SHEAR TEST

It is a Quick test used either in Labouratory or in the field. to find out the undrained shear strength of cohesive soil. Labouratory Vane shear apparatus is smaller than field vane shear apparatus.



Lab
H = 20mm
D = 12mm
t = 0.5 to 1 mm
Field
H = 10 to 20 cm



Labouratory Shear vane

The vane shear tester consists of four thin steel plates called vanes welded orthogonally to a steel rod. A torque measuring arrangement such as a calibrated torsion spring is attached to rod which is rotated by a worm gear & worm wheel arrangement. After pushing the vanes gently into the soil, the torque rod is rotated at a uniform speed (usually at 1° permin). The rotation of the spring in degress is indicated by a pointer moving on a graduated dial attached to the worm wheel shaft. The torque T is then calculated by multiplying the dial reading with the spring constant.

τ_f = unit strength of the soil.

H => height of the vane.

D => diameter of the vane.

When the topend of the vane is embedded in the soil, so that the both top & bottom ends partake in the shearing of the soil. the shear resistance of the soil is assume that the shear ... uniformly on the cylindrical surface ... shear resistance at failure

... cylindrical

Both cases ... developed at top & bottom tks dr will be $2\pi r\, dr\, \tau_f$.

Total resistance of both top & bottom faces will be

$$= 2\int_0^{\pi}(2\pi r\, dr)\tau_f$$

$$T = \pi d^2 \tau_f \left(H/2 + D/6\right)$$

$$\tau_f = \frac{T}{\pi d^2 (H/2 + D/6)}$$

$$T = \pi d^2 \tau_f \left[H/2 + D/12\right]$$

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

This test is suited for clayey soil

Triaxial Compression Test:

This test was introduced by Casagrande & Terzaghi in 1936, most popular test used in field & for the purpose of research. Name itself suggests the soil specimen is subjected to three compressive stresses in mutually ⊥ direction. If one stress in the specimen increases the specimen fails in shear. Usually a cylindrical specimen of H is equal to twice its diameter is used. A common solid cylindrical test the major principal stress σ_1 is applied in the vertical direction & other two principal stresses σ_2 & σ_3 are applied in the horizontal direction by the fluid pressure around the specimen.

The test equipment specimen consists of a high pressure cylindrical cell made of perspex or (or) other transparent material fixed b/w the base & the top cap. Three outlet connections are generally provided through the base: cell fluid inlet, pore H_2O outlet from the bottom of the specimen & the drainage outlet from the top of the specimen. cylindrical specimen is Depending upon e drainage conditions of the test, solid nonporous disc or end caps (or) porous disc are placed on the top & bottom of the specimen.

Test procedure:

① A saturated porous stone is placed on the pedestal & the cylindrical soil specimen is placed on it.

② The specimen is enveloped by a rubber membrane to isolate it from water with which the cell is to be filled, it is sealed with the pedestal & top cap by rubber "O" rings.

③ Cell is filled with H_2O & pressure is applied to the H_2O, which in turn is transmitted to the soil specimen all round & at top, this pressure is called cell pressure; chamber pressure (or) confining pressure.

④ Axial stress is continuously ↑ until failure of the specimen occurs.

Number of observation:

① As the cell pressure is applied pore H_2O pressure develops in the specimen, which can be measured with the help of a pore pressure measuring apparatus such as Bishops pore

(ii) Pore pressure is to be dissipated, pore water line is closed, the drainage line opened & connected to the burette.

(iii) The axial strain associated with the app of download axial stress can be measured by means of a dial gauge, set to record the downward movement of a loading piston.

Area Correction for the Determination of Additional Axial Stress (or) Deviator Stress.

* The additional axial load applied at any stage of the test can be determined by from the providing ring reading. During the application of the load, the specimen undergoes axial compression & horizontal expansion to some extent. Area of cross section varies as axial strain.

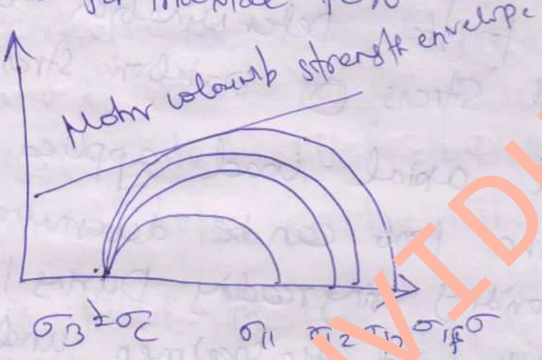
A_0, h_0 & V_0 are the initial area of cross section, ht & volume of the soil specimen respectively & if A, h & V are the corresponding values at stage of the test, the corresponding changes in the values being ΔA, Δh & ΔV then

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

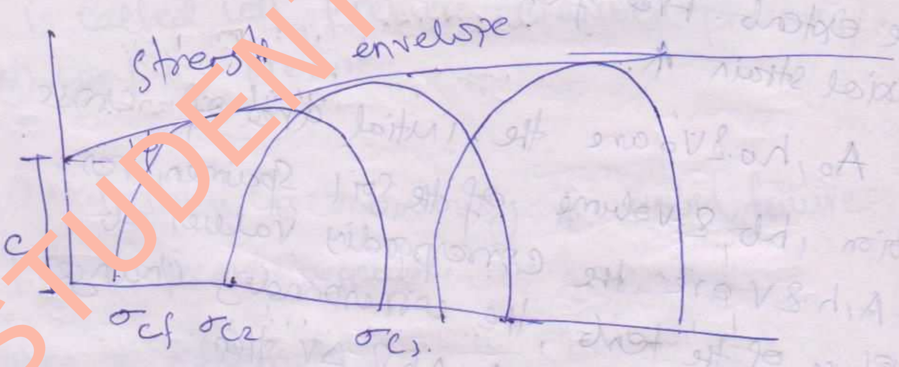
$$A = \frac{V_0 + V_h}{h_0 + \Delta h}$$

$$A = \frac{V_0+\Delta V}{h_0-\Delta h} = \frac{V_0\left(1+\frac{\Delta V}{V_0}\right)}{h_0\left(1-\Delta h/h_0\right)} = \frac{A_0\left(1+\Delta V/V_0\right)}{(1-\varepsilon_a)} \qquad \varepsilon_a = (\Delta h/h_0)$$

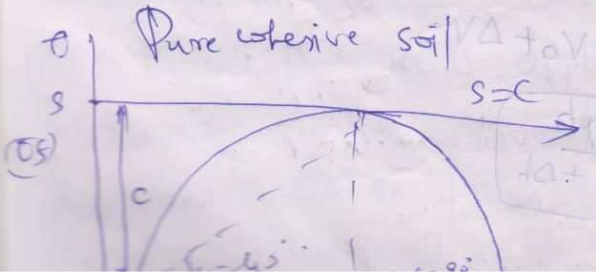
Mohr Circle for Triaxial test.



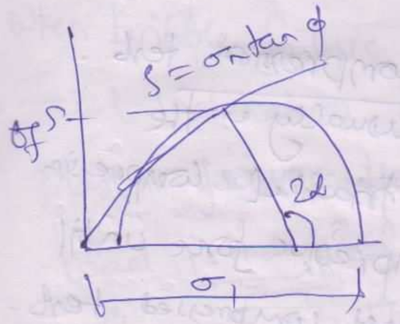
Different cell pressure & strength.



Pure cohesive soil



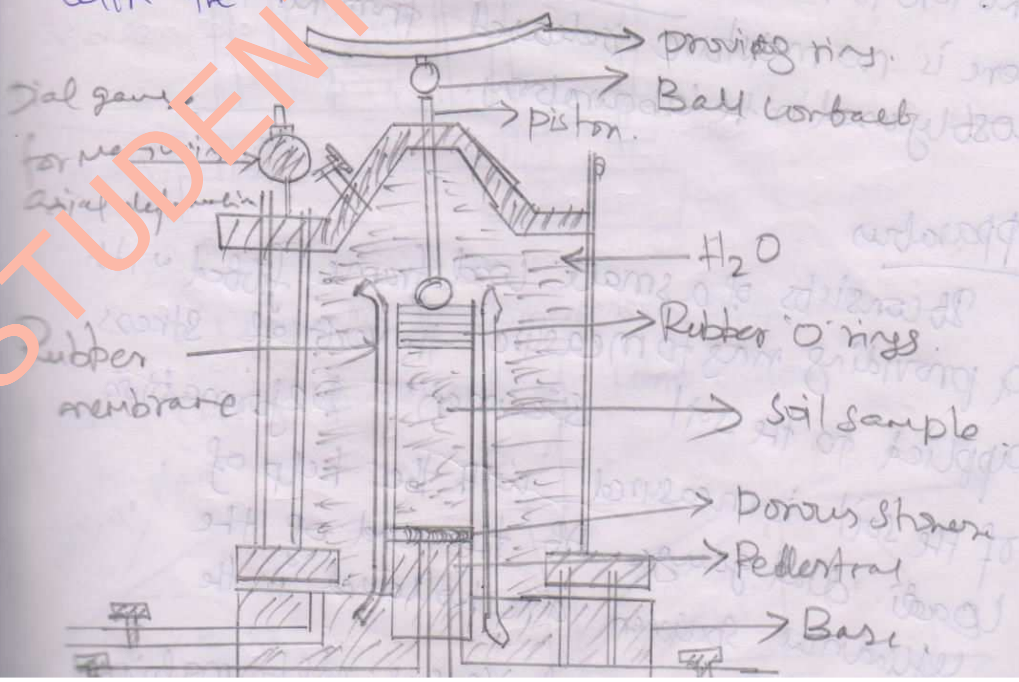
Cohesionless soil



$N_\phi = \tan^2\alpha = \tan^2(45° + \phi/2)$.

Merits:

* Shear tests under all the three drainage conditions are applied
* Accurate measurement of [illegible] pressure & volume change during the test are possible.
* Stress distribution is uniform
* Extension tests are possible to be conducted with the triaxial testing apparatus.



Unconfined Compression test:

Special case of triaxial compression test.

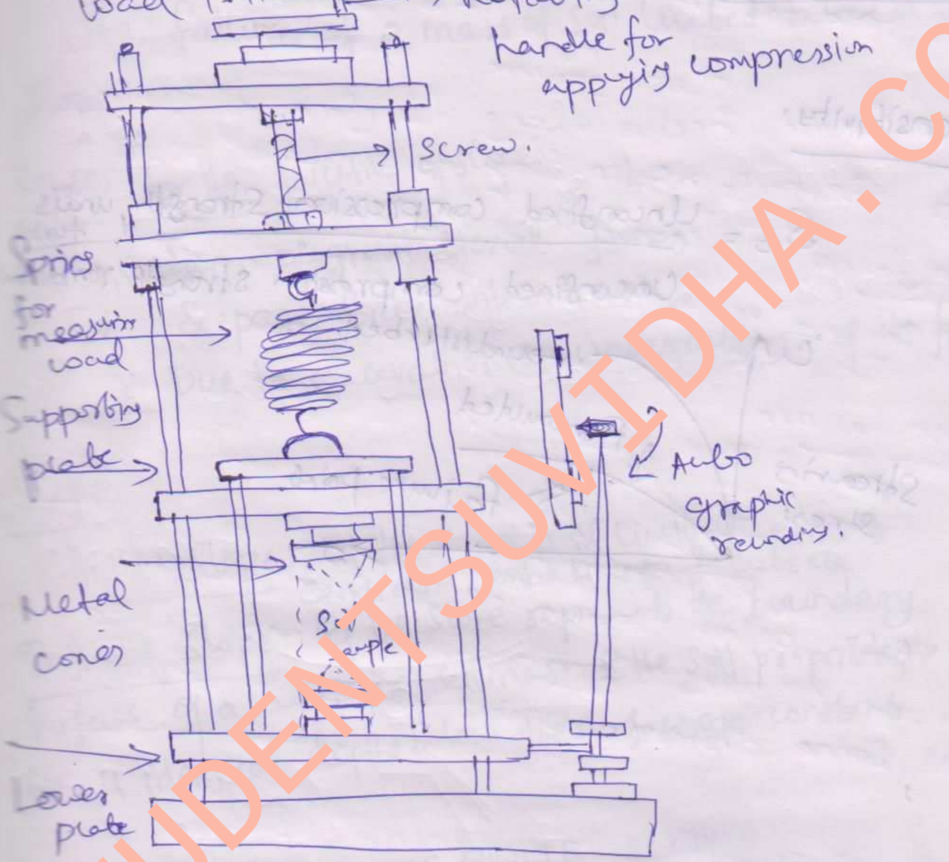
A cylindrical soil specimen usually as the same size as that for the triaxial compression is loaded axially by compressive force until failure takes place. Unconfined compressed test. No need of the rubber membrane. axial stress is the major principal stress and other two principal stresses are zero $\sigma_2 = \sigma_3 = 0$.

This test is may be conducted on undistributed (or) remoulded cohesive soil. cannot be conducted for coarse grained soil such as sand & gravels. This test is known as undrained test because there is no moisture released from this test. mostly used in the laboratory.

Apparatus

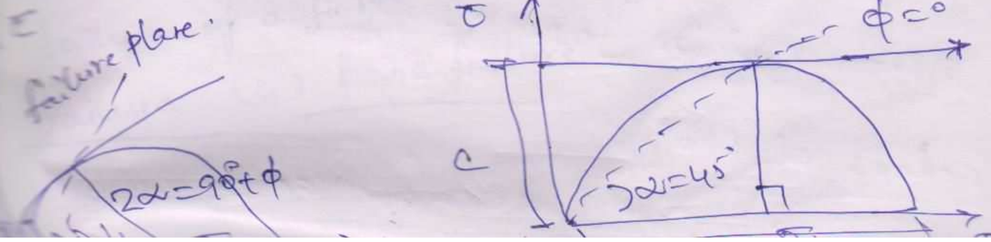
It consists of a small load frame fitted with a providing ring to measure the vertical stress applied to the soil specimen. Deformation of the soil is measured with the help of dial gauge. At the end of the load: dial gauge. At the end of the loadi cylindrical specimen are hollowed in the ... versus deformation

readings are taken & graph is plotted.
When brittle failure occurs the providing ring dial indicates a definite maximum load.
Plastic failure there is no definite maximum load is indicated.



unconfined compression apparatus.

Mohr Circle for unconfined compression



$\sigma_1 = 2c\tan(45^\circ + \phi/2)$

$\sigma_1 = \phi_u = 2C_u$

$$C_u = \frac{\phi_u}{2}$$

ϕ_u = unconfined compression strength

Sensitivity.

$$S_t = \frac{\text{Unconfined compression strength, undisturbed}}{\text{Unconfined compression strength, remoulded}}$$