TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

# DEPARTMENT OF CIVIL ENGINEERING

# Soil Mechanics


## SUBMITTED BY

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DEPARTMENT OF CIVIL ENGINEERING

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A LAB REPORT

ON

# SOIL COMPACTION

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# SOIL COMPACTION

## OBJECTIVE

- To determine relationship between moisture content of soil and its dry density and determine optimum moisture content and maximum dry density of a soil by standard proctor test.

## APPARATUS REQUIRED:

1. 3.0 kg of soil sample
2. 4.75 mm sieve
3. 2250 $mm^3$ proctor cylindrical mould (150mm $\phi$ and 127.3mm height)
4. Spatula
5. Rammer consisting 2.5kg mass
6. cups

## THEORY:

Compaction is any process by which the soil particles are artificially arranged and packed together into a closer state of contact by mechanical means so that dry density of soil is increased. The process of compaction is accompanied by expulsion of air and the volume of water in the soil remains unchanged.

Application:

- Due to compaction, the density, shear strength and bearing capacity of soil increase
- The stability of earthern dams, embankments, roads are achieved from results of compaction test.
- The result of compaction is to reduce void ratio, porosity, permeability and settlements.

→ compaction is measured in term of dry density, so the dry density achieved after compaction is also called as degree of compaction. Thus,

$$\text{Degree of compaction } (\gamma_d) = \frac{\gamma}{1+w_c} \quad ; \quad \gamma \rightarrow \text{Bulk density},\ w_c \rightarrow \text{water content.}$$

The maximum dry density only can be achieved at a moisture content known as optimum moisture content (OMC).

→ The curve showing the relation between dry density and moisture content is known as compaction characteristic curve and unique for each soil.

LAB TEST OF COMPACTION BY STANDARD PROCTOR TEST:

PROCEDURE:

(i) 3kg of soil sample was taken, pulverized and passed through 4.75mm sieve.

(ii) A cylindrical mould of 2250c.m$^3$ volume having diameter of 150mm and height of 127.3mm was taken and a detachable collar was attached to the mould on top and bolted. Mould was bolted to base plate.

(iii) Soil sample was mixed with water (say 13% of 3000ml) and kept inside the mould making a layer of uniform thickness (say 400mm).

(iv) Soil was compacted using rammer consisting of 2.5kg mass falling freely such that each layer received 25 number of blows.

(v) Process was repeated ~~for~~ such that three layers of soil was compacted.

(vi) Weight of compacted soil with mould was taken and some amount of compacted soil (from top, bottom and middle) of mould was taken for dry density test.

(vii) Process of compaction was repeated for different water contents (increasing 5% each time) until the weight of soil decreased.

(viii) Computation of dry density and moisture contents were done.

(ix) Graph was plotted for moisture content v/s dry density and optimum moisture content and maximum dry density was determined.

# Compaction Test

## Objectives

To determine the optimum moisture content and maximum dry density of a soil by standard proctor test.

## Apparatus:

## Theory :

## Application

Due to compaction, the density, shear strength and bearing capacity of soil increase. The result of compaction is to reduce void ratio, porosity, permeability and settlements. The stability of earthen dams, embankments, roads are achieved from results of compaction tests.

**Procedure:**

**Observation and calculations :**

**Standard proctor test**

Volume of mound (v) = 2250 $cm^3$

Weight of rammer = 2.5 kg

Number of blows = 25

Number of layers = 3

**Determination of bulk density of soil ($\gamma_b$),**

| Observation no. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1.weight of mould + base plate, $W_1$(g) | 5991.5 | 5991.5 | 5991.5 | 5991.5 |
| 2.weight of mould + base plate + compacted soil ,$W_2$(g) | 9293.0 | 9174.0 | 9434.0 | 9463.0 |
| 3.weight of compacted soil (w) = ($W_2$-$W_1$) | 3301.5<br>V = ~~1000~~ 2250 | 3182.5<br>V= 2078.34 | 3442.5<br>V= 2088.43 | 3471.5<br>V= 2032.89 |
| 4.Bulk density, $\gamma_b = \frac{w}{V}$ g/cm³ | 1.4673 | 1.5313 | 1.6484 | 1.7077 |

**Determination of water content and dry density of each compacted soil sample**

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| Observation no. | 1 | 2 | 3 | |
|---|---|---|---|---|
| 1. Can no. | 112 | 2 | 1 | 1[illegible] |
| 2.weight of can($w_1$) | 6.529 | 6.318 | 6.514 | 4[illegible] |
| 3.weight of can +wet soil ($w_2$) | 18.188 | 11.818 | 14.566 | 12.[illegible] |
| 4. weight of can +dry soil ($w_3$) | 16.677 | 10.984 | 13.165 | 10.[illegible] |
| 5.weight of water = $w_2$-$w_3$ ($w_w$) | 1.511 | 0.834 | 1.401 | 1.[illegible] |
| 6. weight of dry soil ($W_d$) = $w_3 - w_1$ | 10.148 | 4.666 | 6.651 | 5.[illegible] |
| 7.water content $W = \frac{Ww}{Wd} * 100\%$ | 14.89% | 17.874% | 21.065% | 27[illegible] |
| 8.Dry density $= \frac{\gamma b}{1+w}$ g/cm$^3$ | 1.277 | 1.299 | 1.3616 | 1.[illegible] |

Plot a graph between dry density and water content and find out the optimum moisture content and maximum dry density from the graph where dry density is plotted as ordinate and water content as abscissa.

**RESULT:**

**DISCUSSION AND CONCLUSION:**

OBSERVATION

Weight of rammer = 2.5kg

Number of blows = 25

Number of layers = 3

Determination of bulk density of soil ($\gamma_b$),

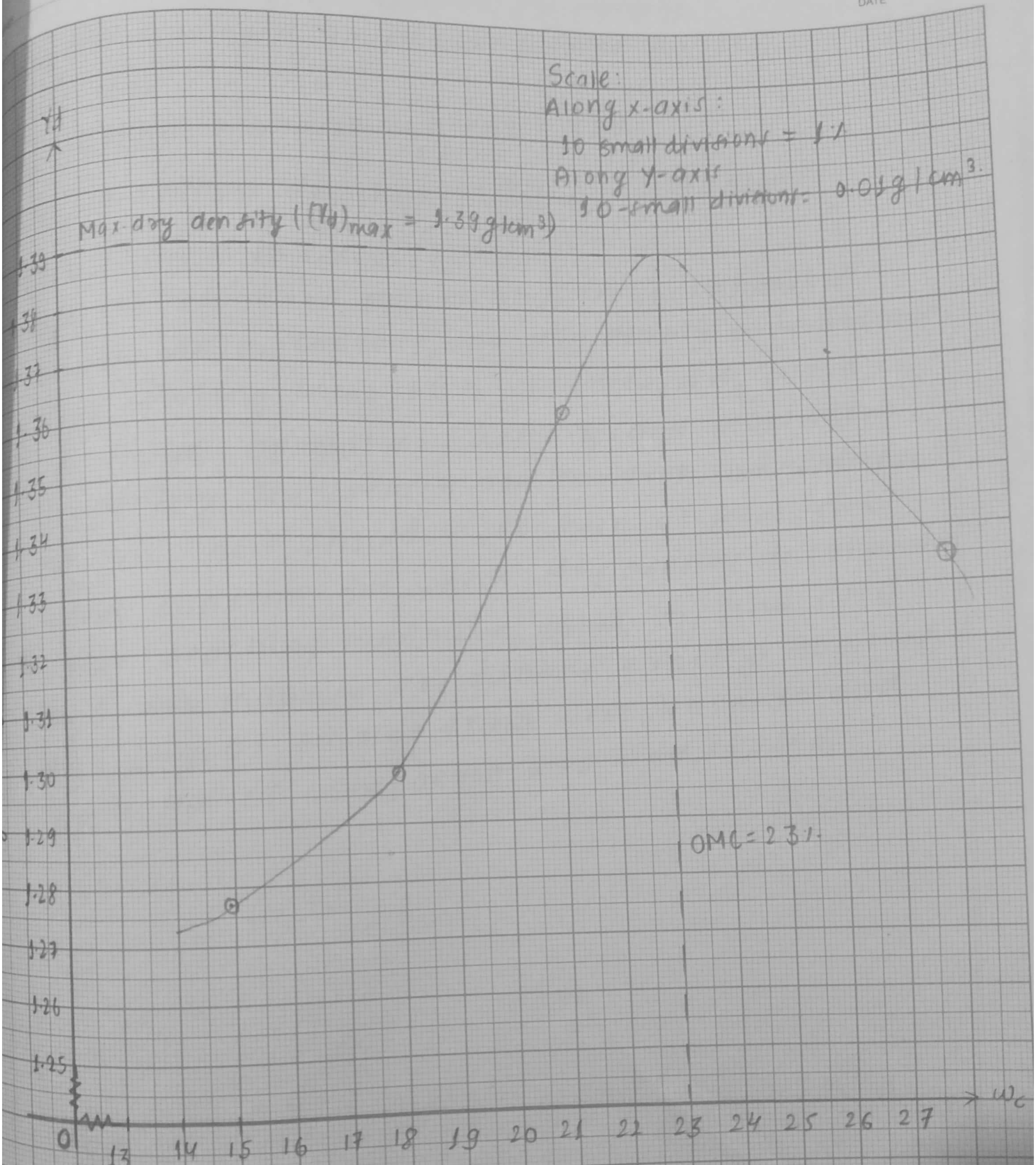
| Observation no. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Wt. of compacted soil (w) (in gram) | 3301.3 | 3182.5 | 3442.5 | 3471.5 |
| volume of compacted soil (V) (cm³) | 2250 (d=0cm) | 2078.34 (d = 1.7cm) | 2088.43 (d = 1.6cm) | 2032.89 d=2.15cm) |
| Bulk density, $\gamma_b = \frac{w}{V}$, g/cm³ | 1.4673 | 1.5313 | 1.6484 | 1.7077 |

Determination of water content and dry density for each compacted soil sample

| Observation no. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Wt. of water (Ww), g | 1.511 | 0.834 | 1.401 | 1.665 |
| Wt. of dry soil (Wd), g | 10.148 | 4.666 | 6.651 | 5.967 |
| Water content, $W_c = \frac{Ww}{Wd} \times 100\%$ | 14.89% | 17.87% | 21.065% | 27.90% |
| Dry density, $\gamma_d = \frac{\gamma_b}{1+W_c}$ (g/cm³) | 1.277 | 1.299 | 1.3616 | 1.3352 |

...taken soil were not enough for plotting

$\gamma_d$ v/s $w_c$



RESULT:

The observations for given soil were not enough for plotting the relation between dry density ($\gamma_d$) and moisture content ($w_c$) to find optimum dry density.
However, assumped graph was plotted for it.

We got,

Optimal moisture content (OMC) = 23%.

Maximum dry density ($(\gamma_d)_{max}$) = $1.39\ g/cm^3$.

DISCUSSION AND CONCLSION:-

From the standard proctor test, the relationship between water content and dry density was obtained. After plotting compaction characteristic curve, we found optimal dry density and maximum dry density. The results are however not-satisfactory as there should have been at least two water contents for which dry density decreased after reaching maximum value to find OMC and ~~dry~~ maximum dry density exactly. However, the ways of finding them were learned and application of compaction was addressed.

TITLE: Direct Shear Test

OBJECTIVE:
To determine shear parameters of sand specimen

SCOPE:
Shear strength is an important engineering properties of soil which controls the stability of soil mass under load. It governs the bearing capacity of soil, the stability of slope, the earth pressure against retaining structures and many other phenomena. so it is essential to find out the shear properties of soil.

THEORY:
Shear strength of a soil is its maximum resistance to shearing stresses. The shear strength of soil may be represented as:

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

where, $c'$ = effective cohesion
$\sigma'$ = Effective stress
$\phi$ = Angle of friction of soil or effective angle of shearing resistance.

The shear tests can be conducted under three different drainage conditions. The direct shear test is generally conducted on sands or sandy soil as a consolidated drained test.

APPARATUS REQUIRED:
(i) Shear box divided into two halves by a horizontal plane.
(ii) Porous stone, 6mm thick, 2NOs.
(iii) Loading pad, loading yoke
(iv) Proving ring, capacity 2KN
(v) Dial gauge, accuracy, 0.01mm,
(vi) Spatula.

PROCEDURE:

(i) Internal dimensions of shear box were measured.

(ii) Grooves and porous plate was kept in lower half of the box.

(iii) Soil was kept upto 15mm to 20mm and again porous plate and Groove was kept in upper half portion. after levelling the soil sample.

(iv) Both half portions were fixed with help of locking screw and the box was mount on the loading frame.

(v) Upper half was brought in contact with proving ring. The contact was checked by giving slight movement. The loading yoke was mount on the ball placed on the loading pad.

(vi) One of the dial gauge was mounted on the loading yoke on the ball placed on loading pad and another on the container to record the horizontal displacement

(vii) The weight of loading yoke was placed to apply the normal stress.

(viii) A horizontal shear load was applied at a constant rate of strain and reading of proving ring, the horizontal and vertical displacement dial gauge were recorded. Few reading were taken at close interval.

(ix) The test was conducted until the specimen failed.

(x) The vertical load was changed and above steps were recorded. & repeated.

Note: Locking pins are removed before applying Horizontal force.

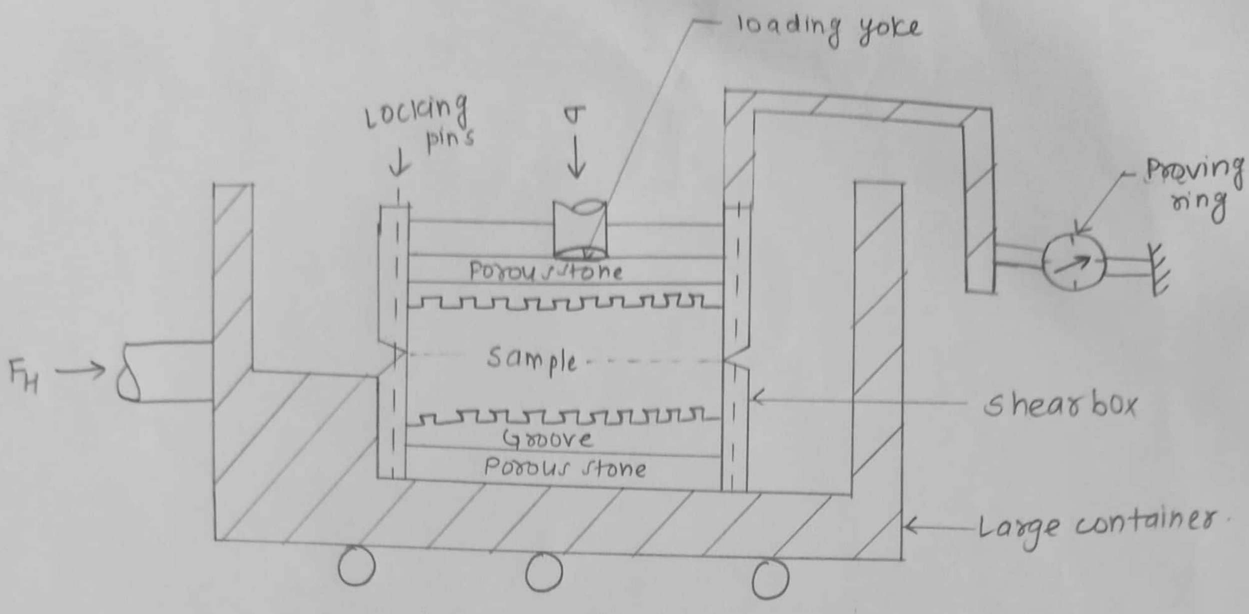



Fig: Direct shear test

The results of the test are presented in the form of graphs. The value of c and Φ are obtained from the maximum shear stress obtained from shear test and varying normal load.

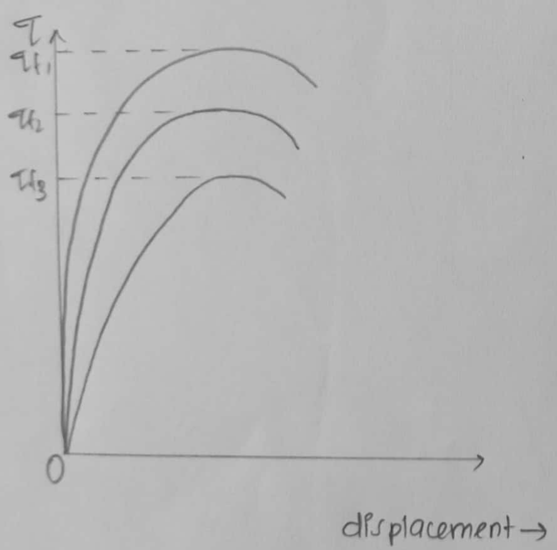



Fig: shear stress v/s displacement

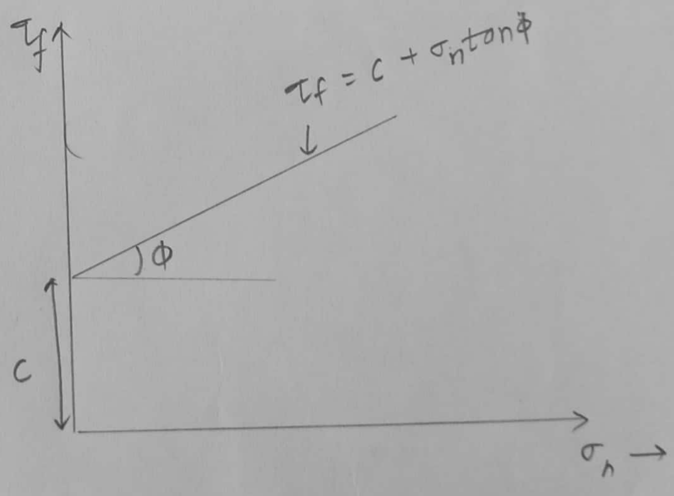



Fig: shear stress v/s Normal stress curve

OBSERVATION AND CALCULATION

Calibration factor for load = 0.34 kg per division

least count for deflection = 0.01 mm

Size of speciment = $60 \times 60 \, mm^2$ $= 3600 \, mm^2 = 3.6 \times 10^{-3} \, m^2$.

For Normal load of 5 kg, $Q_1 = 5kg$. ⟹ Normal stress, $\sigma_1 = 1388.89 \, kg/m^2$.

| S.N. | Dial gauge Reading(a) | Deflection (a x 0.01) mm | Proving Ring Reading (b) | (b) x 0.34 shear Load (kg) | shear stress ($\tau$, kg/m²) |
|---|---|---|---|---|---|
| 1 | 20 | 0.02 | 1 | 0.34 | 94.44 |
| 2 | 40 | 0.04 | 5 | 1.7 | 472.22 |
| 3 | 60 | 0.06 | 6 | 2.04 | 566.67 |
| 4 | 80 | 0.08 | 9 | 3.06 | 850 |
| 5 | 100 | 0.1 | 10 | 3.4 | 944.44 ($\tau_{f_1}$) |
| 6 | 120 | 0.12 | 0 | 0 | 0 |

For Normal load of $Q_2 = 10kg$.

Normal stress; $\sigma_2 = \frac{10}{3.6 \times 10^{-3}} = 2777.78 \, kg/m^2$.

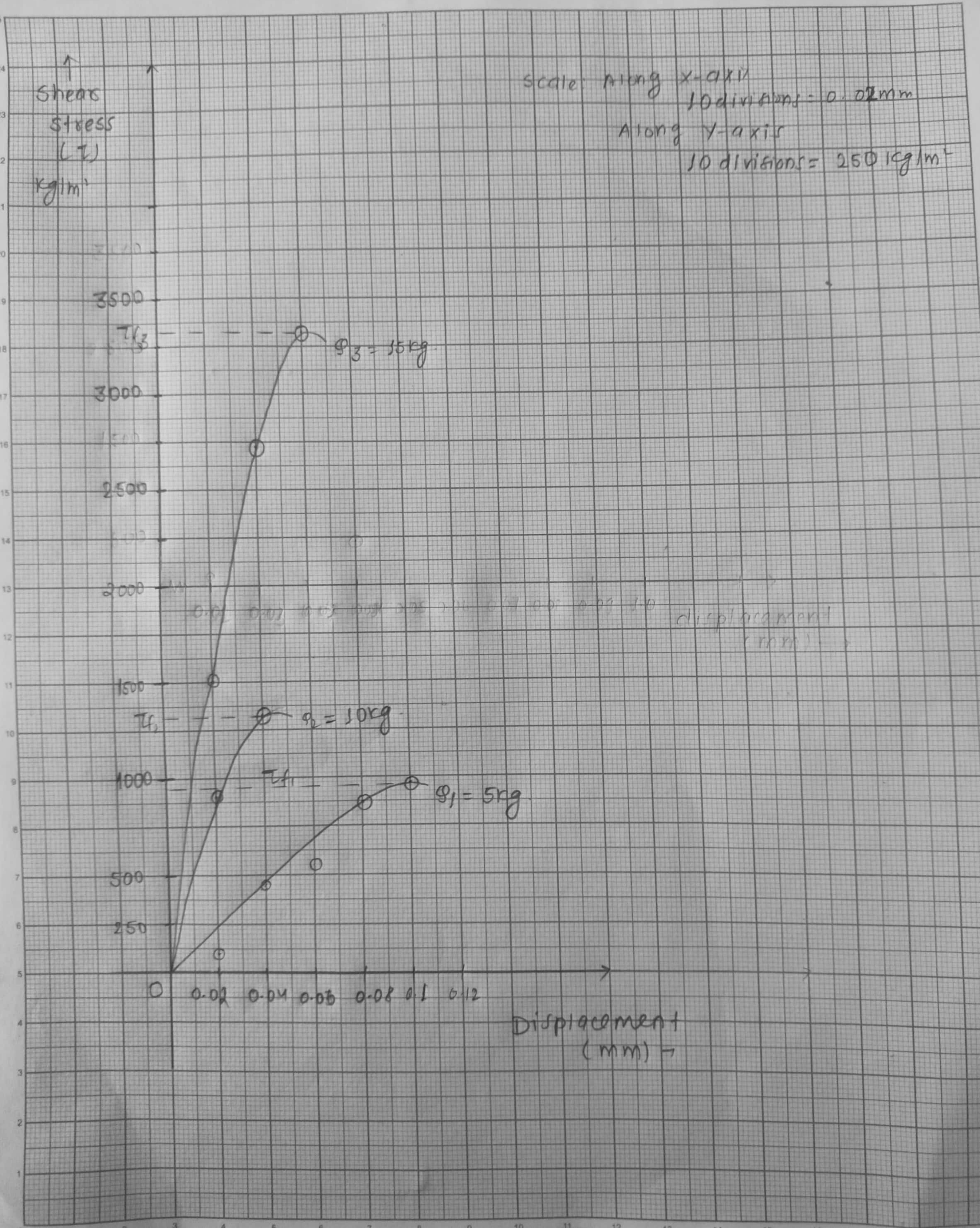
| S.N. | Dial gauge Reading (a) | Deflection (a x 0.01), mm | proving Ring reading (b) | Shear load (b x 0.34) kg | shear stress, ($\tau$), kg/m² |
|---|---|---|---|---|---|
| 1 | 20 | 0.02 | 9 | 3.06 | 850 |
| 2 | 40 | 0.04 | 14 | 4.76 | 1322.22 ($\tau_{f_2}$) |

For Normal load of $Q_3 = 15kg$

Normal stress; $\sigma_3 = \frac{15}{3.6 \times 10^{-3}} = 4166.67 \, kg/m^2$.

| S.N. | Dial Gauge Reading, (a) | Deflection, (a x 0.01), mm | Proving Ring Reading (b) | Shear load (b x 0.34) kg | Shear stress, $\tau$, kg/m². |
|---|---|---|---|---|---|
| 1 | 20 | 0.02 | 16 | 5.44 | 1511.11 |
| 2 | 40 | 0.04 | 29 | 9.86 | 2738.89 |
| 3 | 60 | 0.06 | 35 | 11.9 | 3305.56 ($\tau_{f_3}$) |

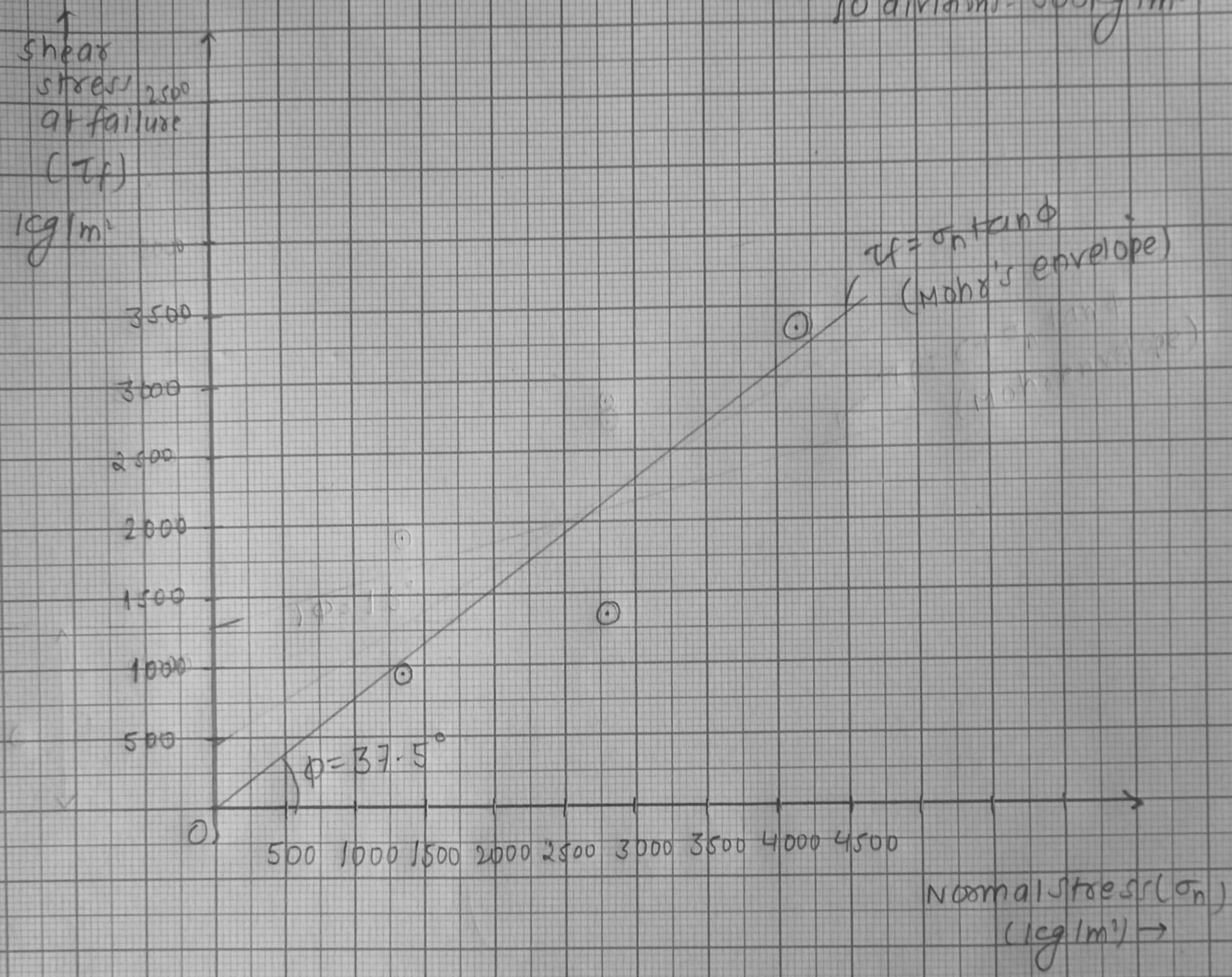
SUB/REF ______ (I) Shear stress v/s displacement NO ______ DATE ______



SUB/REF NO DATE

(II) Shear stress v/s Normal stress curve

Scale : Along x-axis
10 divisions = 500 kg/m²
Along Y-axis
10 divisions = 500 kg/m²



RESULT AND CONCLUSION

Hence, from graph friction angle, $\phi = 37.5°$ and cohesion=0, as the given sample was sand.

Hence, from the direct shear test shear parameters of given soil, c and $\phi$ can be found. It is quick method of finding shear parameters which is essential for design and construction of structure.

There might have occured some error due to aging of equipments, error which observing measurements and callibration error.

TITLE: VARIABLE/ FALLING HEAD METHOD

OBJECTIVE:
To determine permeability of given soil sample

SCOPE:
Variable head method is suitable for determination of permeability of fine grained soil.

THEORY:
A soil sample is kept between two porous plate. The vertical graduated stand pipe of known diameter called burette is fitted to permeameter. The porous is saturated by keeping it under water for 24 hours or by keeping it in boiling water for 8-10 minutes. The soil sample is saturated by upward flow of water.
Unlike, constant head method head in burrete changes with time. Thus, initial head in burrette at time (t=0) is noted and head in burette after time (t=t) is noted.
Finally, we can find permeability of given soil sample by

$$k = 2.303 \frac{aL}{At} \log_{10}\left(\frac{h_1}{h_2}\right) \quad -(1)$$

where,
a = cross-sectional area of burrette
L = Length of soil sample
A = cross sectional area of sample
t = Final time
$h_1$ = head in burrette at t=0
$h_2$ = head in burrette at t = t
k = permeability of soil sample.

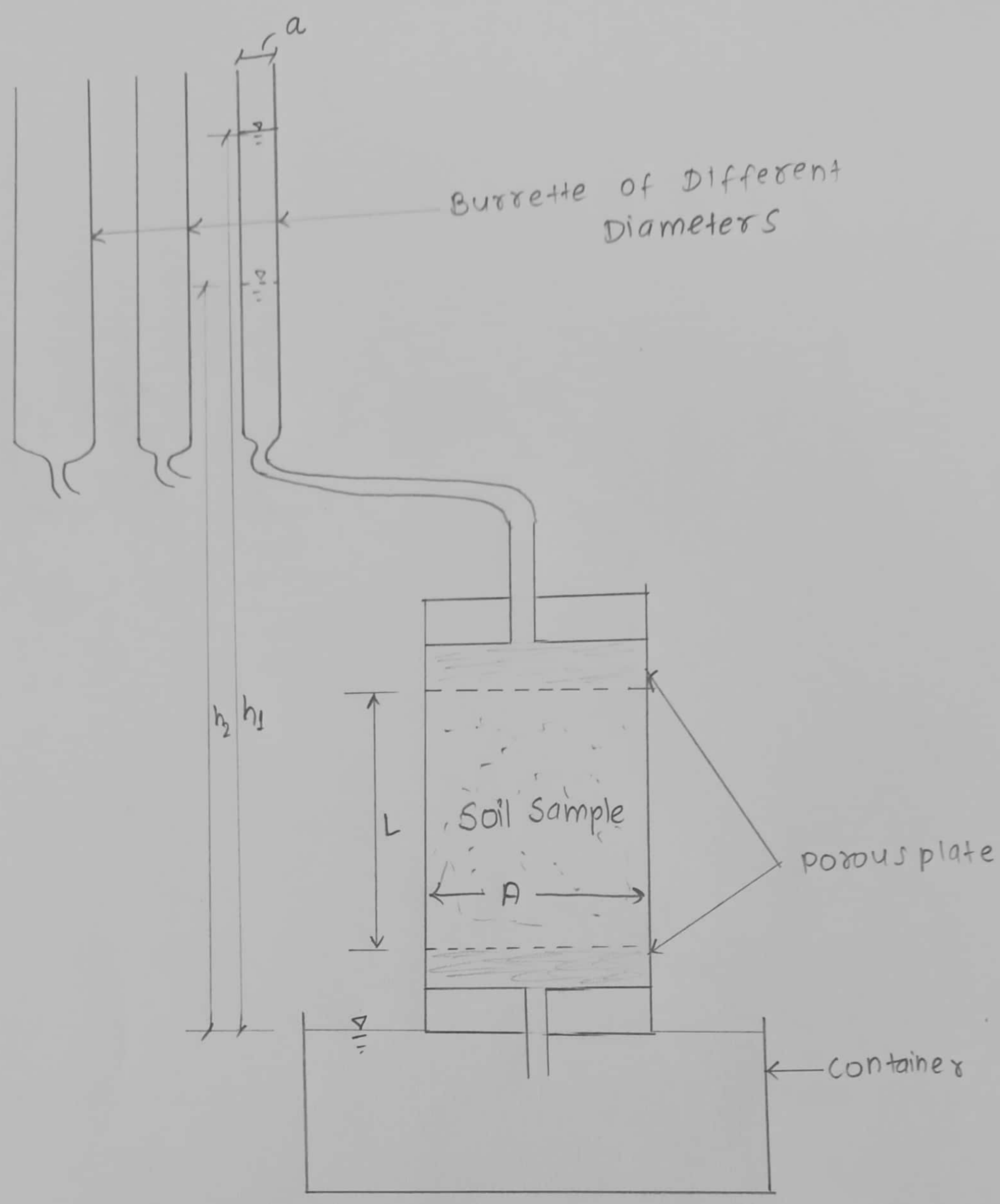



Fig: Variable/ Falling head Method

Selection of Burrette:

Higher the permeability of soil sample, larger the diameter of burrette used.

Example: for sand we use larger diameter burrette

TITLE: UNCONFINED COMPRESSION TEST

OBJECTIVE:

To determine the value of $C_u$ (undrained cohesion) for a clayey soil.

SCOPE:

For quick measurement of unconsolidated undrained shear strength of intact saturated clay, unconfined compressive test can be used. It provides the shear strength of soil after immediately being loaded. Also, the sensitivity of the soil may be easily determined by conducting the test on undisturbed sample and then on remoulded sample.

THEORY:

Unconfined compression test is a special form of a triaxial test in which the confining/lateral pressure is zero. This test can be conducted only on clayey soil which can stand on its own. It is generally performed in intact (non-fissured) saturated clay specimens.

Shear strength of soil can be given by Mohr-columb failure criteria as:

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

where, $S$ = shear strength

$C$ = cohesion

$\sigma'$ = normal stress

$\phi$ = angle of friction.

For undrained test of saturated clayey soil, ($\phi = 0$)

$$\therefore S = C_u$$

where $C_u$ = undrained cohesion

Also,

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

where, $q_u$ = unconfined compression strength.

APPARATUS REQUIRED:

(i) Unconfined compressive apparatus
(ii) Proving ring
(iii) Dial gauge
(iv) Sampling tube
(v) Split mould 38mm dia and 76mm long.
(vi) Sample extractor

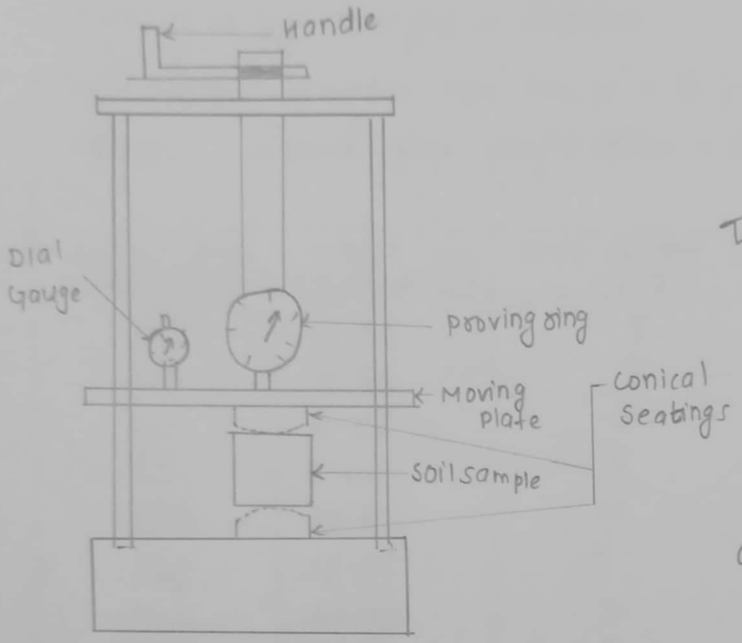



Fig: Unconfined compressive strength test Apparatus

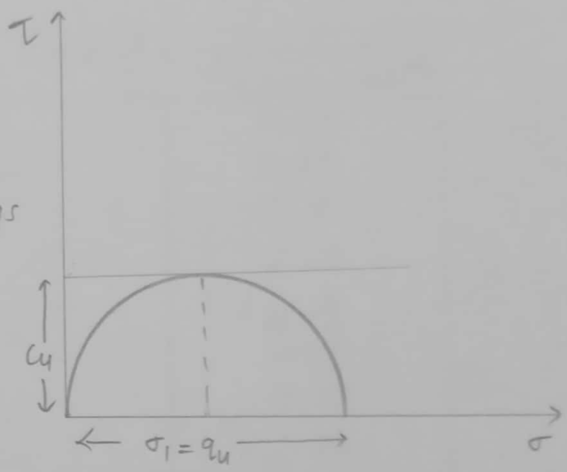



Fig: τ v/s σ graph

PROCEDURE

(i) An undisturbed specimen from the field was obtained in the extraction sampling tube. Proper size was trimmed for the test by using specific trimmer. The cylindrical specimen had a height to diameter 2:1.

(ii) The specimen was placed centrally between the two loading plates of the machine. The top loading plate was moved carefully just to touch the top of the specimen.

(iii) The dial gauge and proving ring were adjusted to zero

(iv) The compression load was applied to cause the axial strain.

(v) The dial gauge and the proving gauge reading after every certain unit strain was taken.

(vi) The test was continued until failure surface had clearly developed or reading stopped increasing

OBSERVATION:

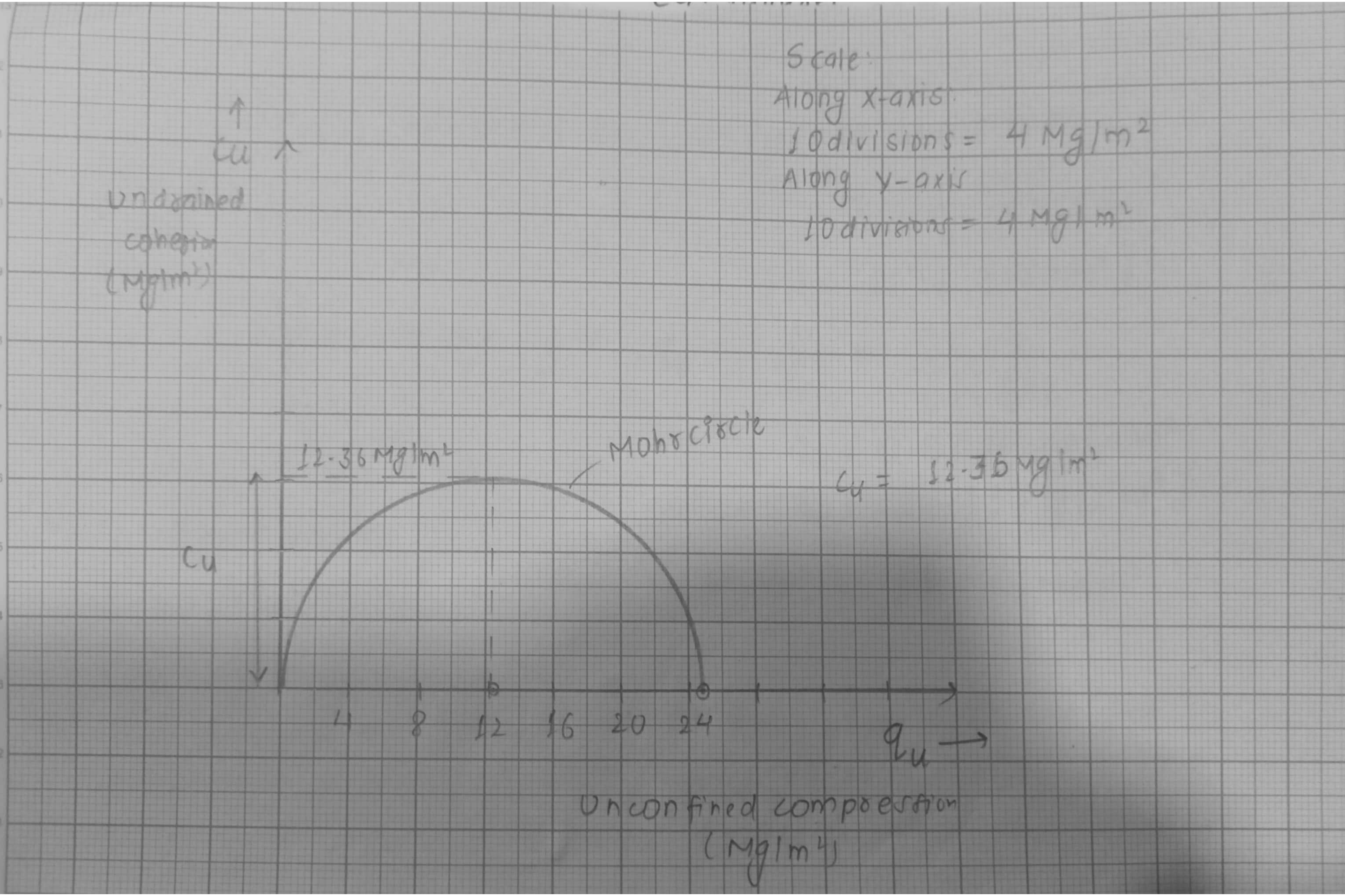
Height of sample = 76mm

Diameter of sample = 38mm

Calibration factor for load = 0.108 kg/div

Least count for deflection = 0.01 mm

| Proving ring Reading (P) | Load (P X 0.108) kg | Dial gauge reading (D) | Deflection (D X 0.01mm) mm |
|---|---|---|---|
| 20 | 2.16 | 8 | 0.08 |
| 40 | 4.32 | 8 | 0.08 |
| 60 | 6.48 | 8 | 0.08 |
| 80 | 8.64 | 8 | 0.08 |
| 100 | 10.8 | 9 | 0.09 |
| 120 | 12.96 | 9 | 0.09 |
| 140 | 15.12 | 9 | 0.09 |
| 160 | 17.28 | 9 | 0.09 |
| 180 | 19.44 | 9 | 0.09 |
| 200 | 21.6 | 12 | 0.12 |
| 220 | 23.76 | 12 | 0.12 |
| 240 | 25.92 | 13 | 0.13 |
| 260 | 28.08 (Peak) | 15 (Peak) | 0.15 |
| 280 | 30.24 | 15 | 0.15 |
| 300 | 32.4 | 15 | 0.15 |
| 320 | 34.56 | 13 | 0.13 |
| 340 | 36.72 | 13 | 0.13 |
| 360 | 38.88 | 13 | 0.13 |
| 380 | 41.01 | 10 | 0.10 |


Scale:
Along x-axis:
10 divisions = 4 Mg/m²
Along y-axis
10 divisions = 4 Mg/m²
Cu
Undrained cohesion (Mg/m²)
12.36 Mg/m²
Mohr circle
Cu = 12.36 Mg/m²
Cu
4
8
12
16
20
24
qu
Unconfined compression (Mg/m⁴)

At peak deflection & loading condition,

Load $(P) = 28.08\,kg$.

Initial cross-section area $(A_0) = \frac{\pi}{4} \times (38)^2 = 1134.115\ mm^2$.

$$\text{Strain } (\varepsilon) = \frac{\text{Change in height}}{\text{Final height (at failure)}} = \frac{0.15}{76}$$

$[\varepsilon = 0.002]$

Cross-sectional Area at failure condition,

$$A = \frac{A_0}{1-\varepsilon} = \frac{1134.115}{1-0.002}$$

$[A = 1136.388\,mm^2]$

$$\text{compressive strength}, q_u = \frac{P}{A} = \frac{28.08}{1136.388}$$

$q_u = 0.0247\ kg/mm^2$

$[q_u = 24.71\ Mg/m^2]$

From graph,

$$\text{Undrained cohesion}; C_u = \frac{q_u}{2} = 12.355\,Mg/m^2$$

CONCLUSION

Unconfined shear strength test is suitable for unconfined undrained test since it is easy, simple and quick, it is preferred over triaxial test. The specimen is free to fail along its weakness plane and it is not laterally strained.

# DETERMINATION OF INSITU DENSITY OF SOIL BY SAND REPLACEMENT METHOD

## OBJECTIVE

→ To determine insitu density of soil

## SCOPE:

By calculating the in situ density of soil in the field, we can calculate the volume of earthwork required for any project. The insitu density of soil also helps to know about the field soil compaction.

## Apparatus Required:

(a) Tray
(b) Sand cone fitted with cone
(c) Sand bucket
(d) Mould
(e) Standard sand
(f) Spatula
(g) Metal tray with central hole and impression

## THEORY:

Density is an important property by which void ratio, porosity, degree of saturation, particle size distribution, compaction, etc are determined. It is defined as mass per unit weight of soil. The density calculated from the field is insitu density of soil.

Sand replacement method is used to determine insitu density of cohesionless or coarse grained soil. Since, core-cutter method cannot be used to penetrate through coarse-grained particles like minor rock chunk.

$$\text{Volume of hole dug in field} = \frac{\text{Weight of sand on hole}}{\text{Density of sand}}$$

$$\text{Insitu density of soil} = \frac{\text{Weight of soil}}{\text{Volume of hole dug}}$$

EXPERIMENTAL PROCEDURE

(1) Deterimineng Density of sand

(i) The Internal diameter, height and weight of mould is measured.

(ii) Mould is filled with sand and its weight is determined.

(iii) Finally density of sand is determined.

(2) Density of mass of sand in cone:

(i) The mass of ~~sand~~ cone fitted with enough sand was measured.

(ii) The sand jar was inverted over a tray until the sand kept falling.

(iii) The mass of jar was taken again.

(iv) Finally mass of sand in cone is determined by subtracting two masses.

(3) DEtermination of insitu density of soil

(i) Top soil in field was removed in order to throw away soil less garbages and then the ground was levelled.

(ii) A pit of about 4-5cm depth was excavated with the help of knife.

(iii) The mass of soil was collected in a tray and was weighed.

(iv) The sand jar with cone was inverted and sand was poured in the hole.

(v) The difference of weight of sand jar gave mass of sand used in filling excavation from which volume of hole and density of soil was obtained.

OBJECTIVES: To determine field density of soil by sand replacement method

APPARATAUS: ......................................

Theory: ................................

Procedure -:

- Determination of density($W_1$) of sand in laboratory
- Density of soil in the field

Observation and Calculations :

1) FOR DENSITY OF SAND:

Volume of mould ($v_{mould}$) =...cm$^3$ 0.0009478 m$^3$ = $\pi \times \frac{(0.102)^2}{4} \times (0.116)$

Weight of mould ($W_1$) = ...gm 2.940 kg

Weight of mouid +sand ($W_2$) = ...gm 4.360 kg

Weight of sand ($W_s$) = ($W_2$- $W_1$) gm =(4.360 − 2.940) = 1.420 kg.

Density of sand=$\frac{(Ws)}{(Vmould)}$= $g/cm^3$ = $\frac{1.420 \times 10^3 \, g}{0.0009478 \times 10^6 \, cm^3}$ = 1.498 g/cc

2) FOR DENSITY OF SOIL:

Total weight of vessel+sand($W_1$)= 4.760 kg

Weight of tray ($W_2$) = 0.885 kg

Weight of excavated soil+tray ($W_3$) = ... 2.170

Net weight of excavated soil=$W_3$- $W_2$ = 1.285 kg

Now,

After pouring,

Weight of vessel+sand ($W_4$) =...~~4.760 kg~~ 1.505 kg

Weight of cone+sand ($W_5$) =.... 2.310 kg

Weight of cone ($W_6$) =.0.670 kg

OBSERVATION AND CALCULATION

Weight of total sand ($W_7$) = $W_1$- $W_4$ = 3.255

Weight of sand in cone ($W_8$) = $W_5$- $W_6$ = 1.64

Weight of sand in pit ($W_9$) = $W_7$- $W_8$ = 1.615

Volume of pit = $\frac{W_9}{\text{density of sand}}$ = $cm^3$ = ~~10~~ 1078.104 cc

Density of soil = $\frac{\text{Net weight of excavated soil}}{\text{volume of pit}}$ = $gm/cm^3$

= 1.19

RESULTS: ............

CONCLUSION: .........

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## OBSERVATION AND CALCULATION

(1) For Density of sand

Diameter of mould, $d = 10.2\,cm$

height of mould, $H = 11.6\,cm$

volume of mould, $V_{mould} = \frac{\pi}{4} \times (10.2)^2 \times 11.6$

$= 947.869\,cm^3$

weight of mould, $W_1 = 2.940\,kg = 2940\,gm$.

Weight of mould + sand $(W_2) = 4360\,gm$

weight of sand $(W_s) = W_2 - W_1 = 1420\,gm$.

$$\text{Density of sand} = \frac{W_s}{V_{mould}} = \frac{1420}{947.869} = 1.498\,g/cc$$

(2) For Density of soil

Total weight of vessel + sand $(W_1) = 4.760\,kg$

weight of tray $(W_2) = 0.885\,kg$.

weight of excavated soil + tray $(W_3) = 2.170\,kg$.

Net weight of excavated soil $= W_3 - W_2 = 1.285\,kg$.

Now,

After pouring,

weight of vessel + sand $(W_4) = 1.505\,kg$.

weight of sand + cone $(W_5) = 2.310\,kg$

weight of cone $(W_6) = 0.670\,kg$.

Weight of total sand $(W_7) = W_1 - W_4 = 3.255\,kg$.

weight of sand in cone $(W_8) = W_5 - W_6 = 1.640\,kg$

weight of sand in pit $(W_9) = W_7 - W_8 = 1.615\,kg$

$$\text{Volume of pit} = \frac{W_9}{\text{density of sand}} = \frac{1.615 \times 1000}{1.498} = 1078.104\,cc$$

$$\text{Density of soil} = \frac{\text{Net weight of excavated soil}}{\text{Volume of pit}}$$

$$= \frac{1.285 \times 1000}{1078.104} = 1.192\,g/cc$$

RESULT

DENSITY of sand = 1.498g/cc

Insitu density of soil = 1.192g/cc

CONCLUSION

Thus, by replacing the excavated soil volume by dry standard sand of known density, we were able to determine the insitu density of soil - which is done without disturbing its state of occupied volume or void ratio or any other properties.

PRECAUTION

(I) Care should be taken while excavating the pit so that it is not enlarged as we level below surface which could cause decrease in density.

(II) No loose material of soil particles should be left in pit.