Zoynal

To learn soil mechanics aspect of geotechnical engineering with aim to acquire besic knowledge of the geotechnical parameters needed for desiging foundations of any civil engineering infrastructure.

To acquire the knowledge & to evaluate the engineering properties of soil

To acquaint with the attributes of geotechnical engineering

To understand the compaction aspect of shallow depth ground improvement

③ Engineering properties → shear strength
compresibility
permeability

① Physical properties → unit wt
void ratio
Sp. gravity

② Index properties → Grain size Analysis
consistancy of soil.

[সহজে ভেঙ্গে form change হয়] gravel, sand } coarse grain soil
silt, clay } fine grain soil

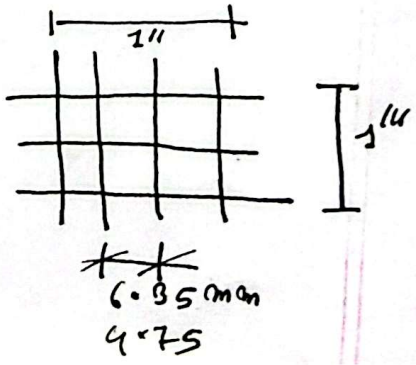
Consistency – condition in terms of strength

for coarse grain soil → very dense, Dense, Medium dense, Loose, very loose
" fine " " → Hard, very stiff, stiff, Medium stiff, soft, very soft

Chip size # 4-10, # 8-12, # 16-, # 30-8, # 50-30, # 100-20, # 200-20, Pan-4

(finess modulus) 100 টুকরা চেয়ে

F.M → measure of coarseness of sail



Condition of soil —

liquid → A material which can't sustain self wt and started to flow.

Soild → can't be remolded

semi soild → crack হয়

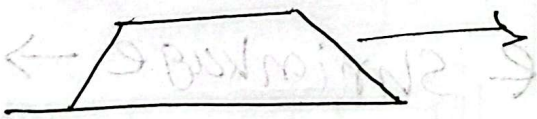
plastic → remolded to any shape without cracks

Compressible — Vol^n change হয় or 400+ minerals আছে

22/6/25



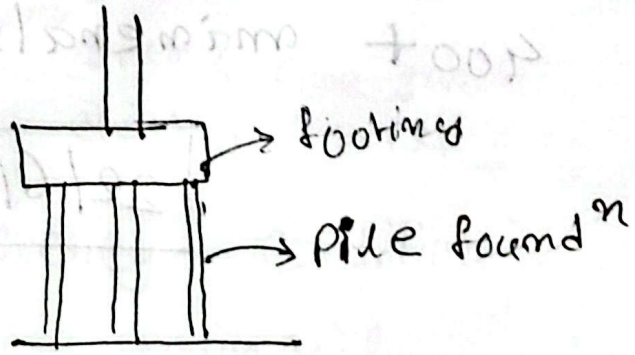
Mechanics → part of physical science that treats part of forces & masses.

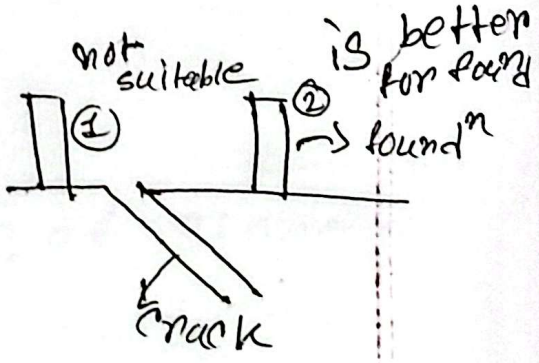


Geotekniska slope নিয়ে কাজ

Soil Mechanics → properties of soil
fluid mechanics & Hydraulics to soil

Rock Mechanics → properties of rock.
fluid mecha & Hydraulics to rocks. not bed rocks.





Frost action → thoing
any surface have electrical surface.
soil swelling & shrinkage → expansive soil

13/07/25

Classification of Soil

① soil deposite
- → OC ≤ 5%, inorganic
- → OC (6-20)% organic silt or organic clay
- → OC (21-74)% silty or clayey organic soil
- → OC ≥ 75% peat soil

Clay minerals { 1) Organic
- Kaolinite
- Illite
- Montmorrilonite (most flaky) has swelling properties

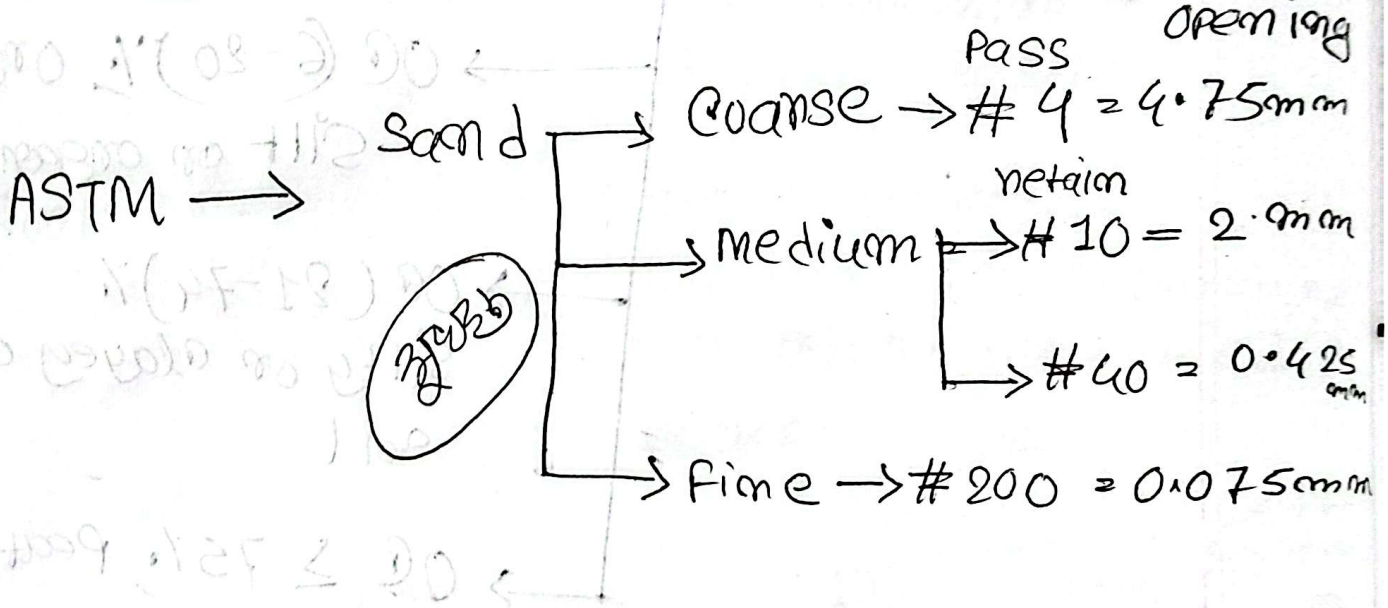
Q. (Im)

2) ~~A~~ Blak cotton, ~~organic~~ (expansive)

Under water soil deposits
Wind transported soil deposits

3) Dune → Loess → Collapsible Soil
Tuff or (black cotton) दोन्ही नाही

Q. Classfy soil depositie ?



(0.075 - 0.005) → Silt

(0.005 - 0.001) → Clay

≥ 0.001 → Colloids

20/7/25

Colour → dark brown to black colour [organic]
grey color [inorganic]

Odour → Bad smell [organic]

Appearance → Coarse grained soil
large enough to visible to naked eye

Feel → Gritty feelings for sandy soil

Dry strength → very low → slit
low
medium
high
very high → clay

Dilatancy & Shaking → rapid → sitly
slow
none → clay

plasticity & Toughness → weak & friable
medium
high

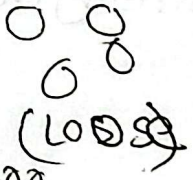
Dispersion → 30-60 s → fine sand
15-60 min → silt
≥ 60 min → clay

Cohesionless Soil : Gravel, Sand, Non-plastic silt.

Cohesive soil : Clay, Plastic silt

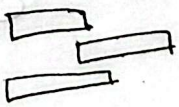
Q. What is the difference between plastic silt & non-plastic silt?

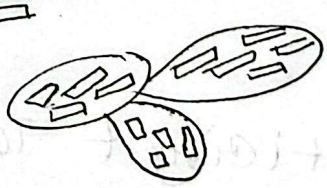
Soil structure & fabric

single grain structure →  (loose) or (dense)

Honey comb " → 

Flocculated " →  (not parallel)

Dispersed " →  (Parallel)

Packed " → 

Micro fabric

Macro "

Bulky → Angularity or $S = \frac{De}{Lp}$ $\left[De = \sqrt[3]{\frac{6V}{\pi}}\right]$

Flaky →

Needle → shape

24/07/25

Engineering Classification of Soils

unified

Classification Test → Grain Size Analysis
Classification Test → Consistancy test

Hydrometer

Sp Gravity correction

$$a = \frac{1.65\,G_s}{2.65(G_s - 1)}$$

Fine Grained Soil

27/07/25

1. Effective Grain Size

D_{10}

2. Uniformity Coefficient

$$C_u = \frac{D_{60}}{D_{10}}$$

3. Coefficient of Gradation / Curvature

$$C_z = \frac{(D_{30})^2}{D_{60} \times D_{10}}$$

Sand

$C_u \geq 6$

$C_z = 1 \text{ to } 3$

} well graded

Gravel

$C_u \geq 4$

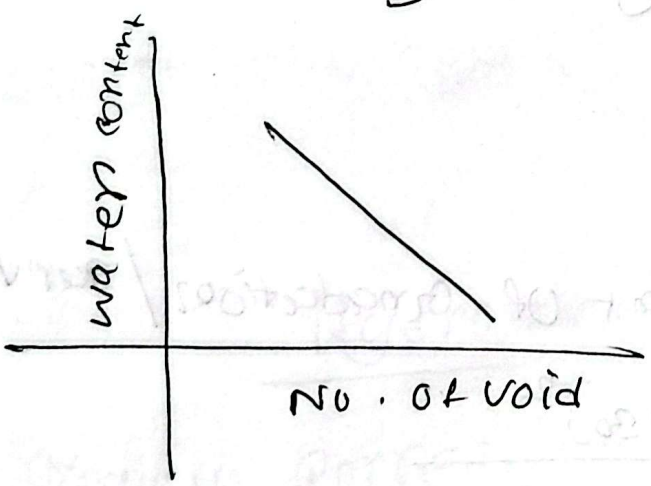
$C_z = 1 \text{ to } 3$

} well graded

liquid limit ⟶ difference

W_L = LL = 48
W_p = PL = 25

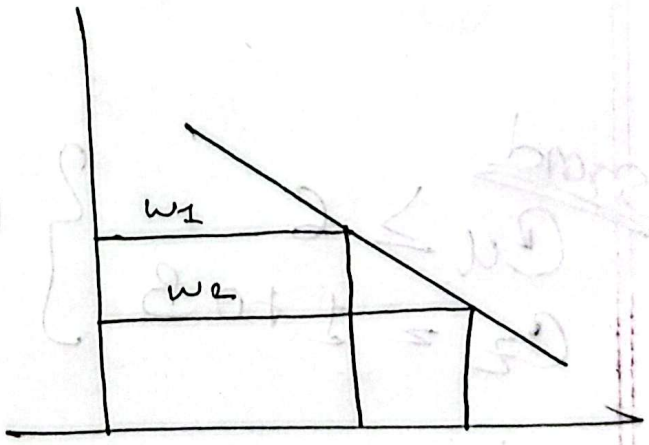
} Plasticity Index = I_p = 48 − 25 = 23



Flow Index ⟶

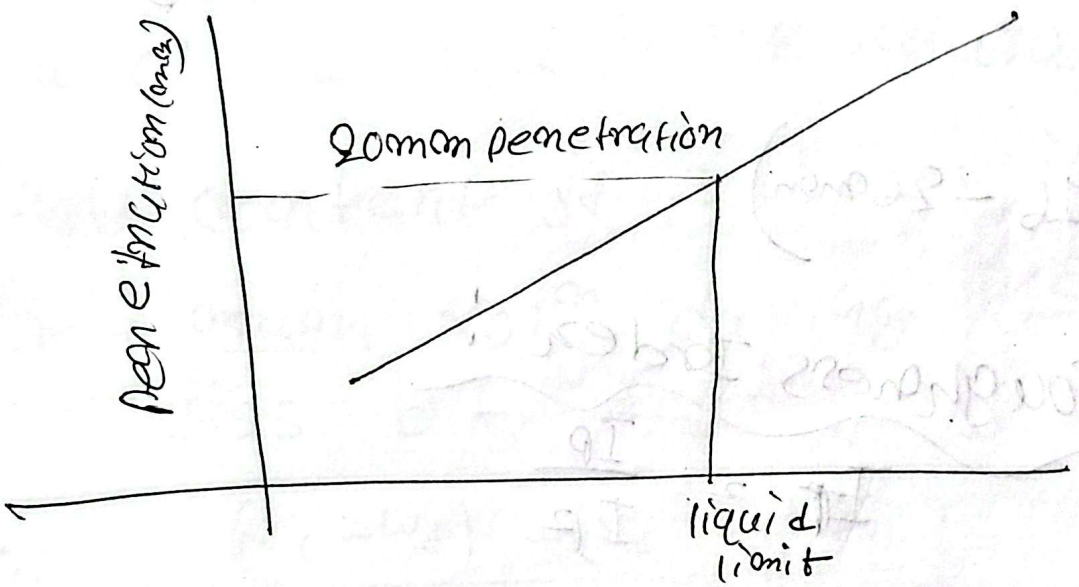
$$I_f = \frac{W_1 - W_2}{\log_{10} N_2 - \log_{10} N_1}$$

$$= \frac{W_1 - W_2}{\log_{10}\left(\frac{N_2}{N_1}\right)}$$



No of blow ধরা range (15-35) এর মধ্যে 25 এবং 26 ।

Cone Penetration Method



(10 - 30) mm range এর মধ্যে cone penetration হবে।

$n = 19$, $W = 35$, $e = 0.1$

$$LL = W_L = W\left(\frac{n}{25}\right)^{0.1}$$

$$= 35\left(\frac{19}{25}\right)^{0.1}$$

$$= 34$$

$$35\left(\frac{18}{25}\right)^{0.1}$$

liquid limit $W_L = \frac{w}{0.63 + 0.0175D}$

(16 – 26 mm)

Toughness Index :

$$I_T = \frac{I_P}{I_P}$$

(170 – 250)

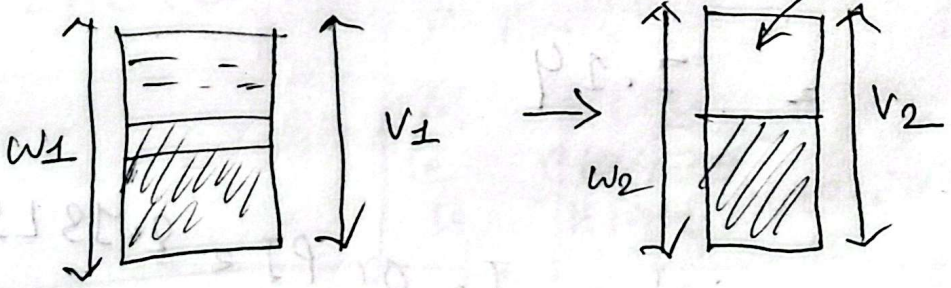
যে toughness বেশি plasticity বেশি
তত বেশি।

(derivation) (Xm) ଏ ଦେଖିବେ

Shrinkage limit:

It of a ~~soil~~ is the saturated H_2O content of soil at its minimum vol^n during its process of drying.

$$S_L = \frac{(W_1 - W_d) - (V_1 - V_d)\gamma_w}{W_d}$$



$$S_L = \frac{\text{wt of water}}{\text{wt of solid}}$$

$$= \frac{W_1 - W_2 - (V_1 - V_2)\gamma_w}{W_2}$$

$$= \left(\frac{V_d}{W_d} - \frac{1}{G_s}\right)$$

ଏହାର Q. Sp Gravity known when not known

$$\frac{V_d - \frac{W_d}{G_s}\gamma_w}{W_d}$$



আশা শেতনী/ আফা ভূতনী

soil এর shrinkage limit কম হওয়া ভালো না।



linear shrinkage → কম হওয়া ভালো

$$L_S = \frac{L_m - L_d}{L_m} \times 100$$

$$= \frac{140 - 130}{140} \times 100$$

$$= 7.14$$

plasticity index, I_p or $PI = 2.13 L_S$

	LL	PL
silt clay →	25-40	20-30
kaolinite ↳ →	40-70	20-40
montmorillonite ↳ →	300-600	100-200

Non plastic → চাই না প্রয়োজন

Unified Soil Classification System

Symbol	
1st letter	G gravel
	S sand
	M silt
	C clay
	O organic
	Pt Peat
2nd letter	W well graded
	P Poorly "
	M Silty
	C clayey
	H high plasticity
	L low "

GW → well graded gravel

#4 → 30 (70) coarse grained soil

#200 → 52 (48)

$\frac{30}{52} = 58$ G

$C_u = 20$

$C_z = 1.0$

% Passing # 200 sieve

① < 5 ⟶ (2nd letter) Gradation, C_u & C_z

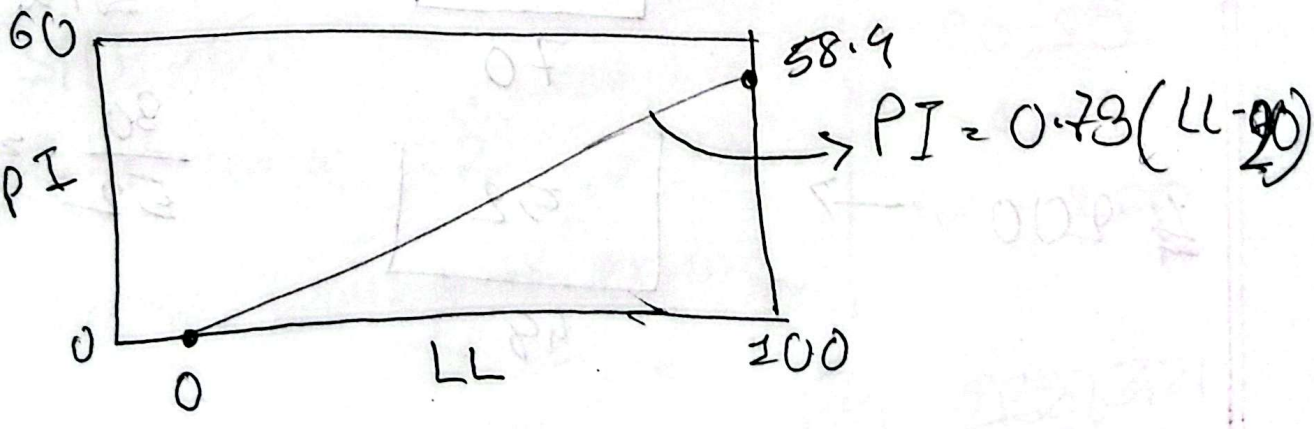
② 5 - 12 ⟶ " "

③ > 12 ⟶ (2nd letter) এর plasticity chart অনুযায়ী (consistency test)

4র্থ classification GW
GP
SW
SP

4 sieve
50
50

200
35
15



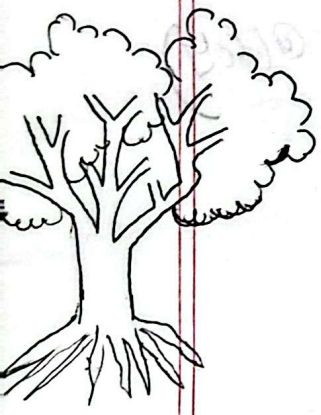
Example

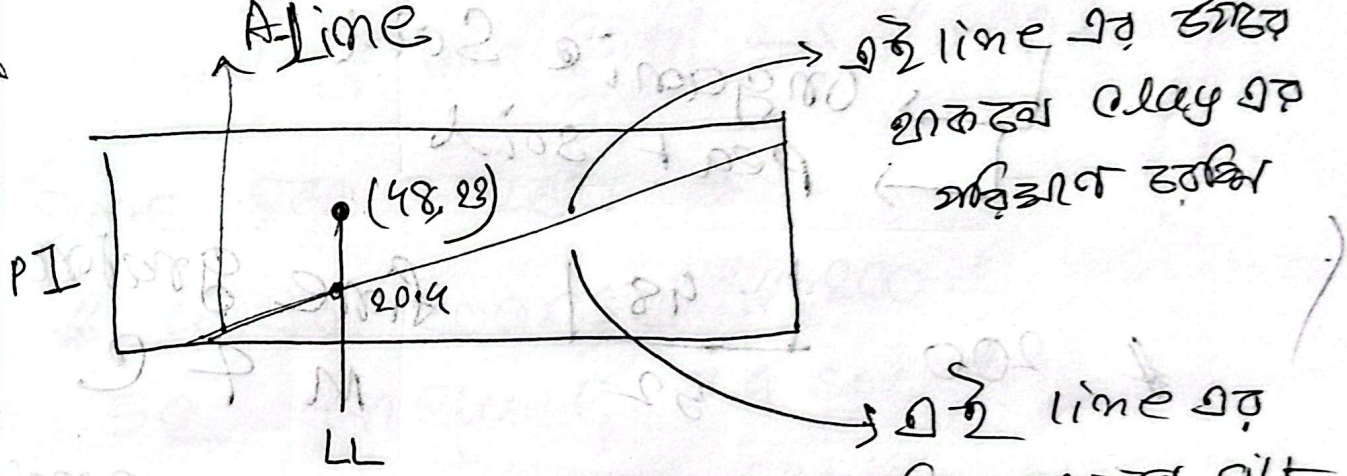
LL = 48

PL = 25

PI = LL − PL

= 48 − 25 = 23





GC
GM
SC
SM

4টি classification

10/8/25

United Soil Classification System

classified into 2 groups

grain size analysis ഉപയോഗിച്ച്

- Coarse Grained soil (Gravel & Sand)
- Fine " " (Silt & Clay)

2 additional groups,

- Organic Soil
- Peat soil

# 200	48	fine grain soil
	52	M & C

more than 50 retain ചെയ്യുന്നു → 52 → coarse grain soil

48

G & S → 1st letter

Retained on # 4 Sieve,

15% → Finer ← 85%

% finer

compare → $\frac{15}{52} \times 100 = 28.5\%$ — 50% এর বেশি retain করছে gravel এ

coarse material এর portion এবং

Sand বেশি → 1st letter

coarse material → #200 → 52%

Sure হতে চাইলে →

4 এর coarse # 200 এ অবস্থানের 52 include # 4 sieve

% passing # 200 → opening (0.075) mm → Gradation

① < 5
② 5 – 12
③ > 12

fine → consistency

passing 48 so ③ কে follow করব

fine material এর (plasticity chart) ব্যবহার

ধরি,

200 sieve [96] 4

Coarse grain Soil
G & S

% finer $\frac{15}{96} \times 100\% = 15.6\%$ retaining on # 4
→ Sand 28

4 sieve [~~G~~ 51] 49

% finer $\frac{51}{96} \times 100\% = 53.1\%$
→ Gravel 28

Grain size analysis এর জন্য

D_{10}
D_{30}
D_{60}

$C_u = \frac{D_{60}}{D_{10}}$

$C_z = \frac{D_{30}^2}{D_{60} \times D_{10}}$

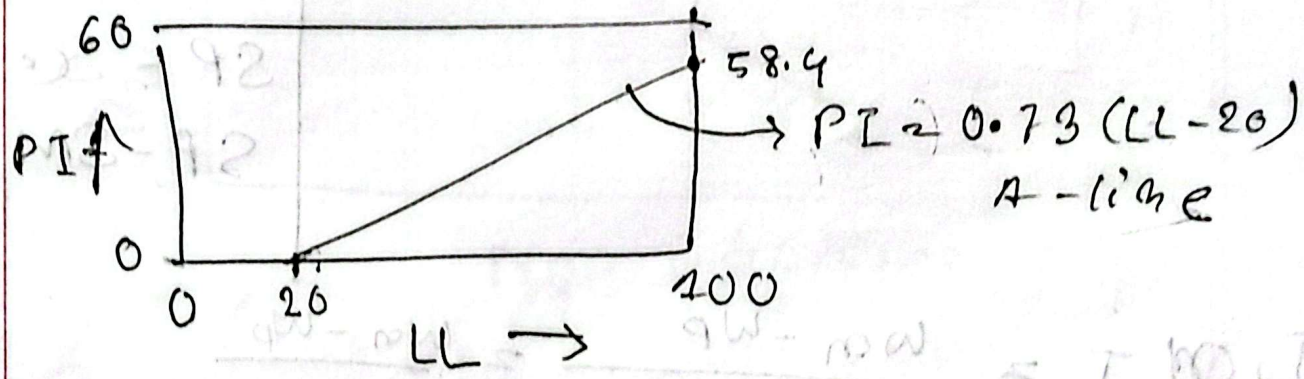
#200 passing

Soil → Gravel → $C_u \geq 4$, $C_z = 1 \text{ to } 3$ } Well graved GW

GP poorly graded gravel

Sand → $C_u \geq 6$, $C_z = 1 \text{ to } 3$ } SW SP

$PT = 0.73(LL - 20)$

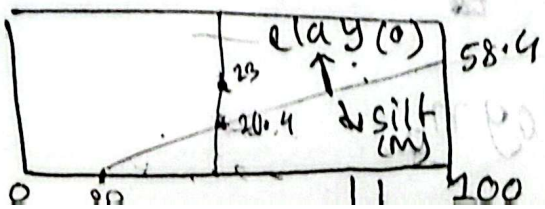


$y = 0.73(x^{100} - 20) = 58.4$

যদি, $LL = 48$, $PL = 25$ } $PI = LL - PL$
$= 48 - 25$
$= 23$
(48, 23)

GC
GM
SC
SM

GC → clay gravel



well graded clayi gravel

4G symbol

< 5%	> 12%	5 - 12
GW	GC	GW-GC
GP	GM	GW-GM
SW	SC	GP-GC
SP	SM	GP-GM
		SW-SC
		SW-SM
		SP-SC
		SP-SM

$$I_L \text{ or } LI = \frac{w_n - w_P}{w_L - w_P} = \frac{w_n - w_p}{I_P}$$

$$I_C \text{ or } CI = \frac{w_L - w_n}{w_L - w_P} = \frac{w_L - w_n}{I_P}$$

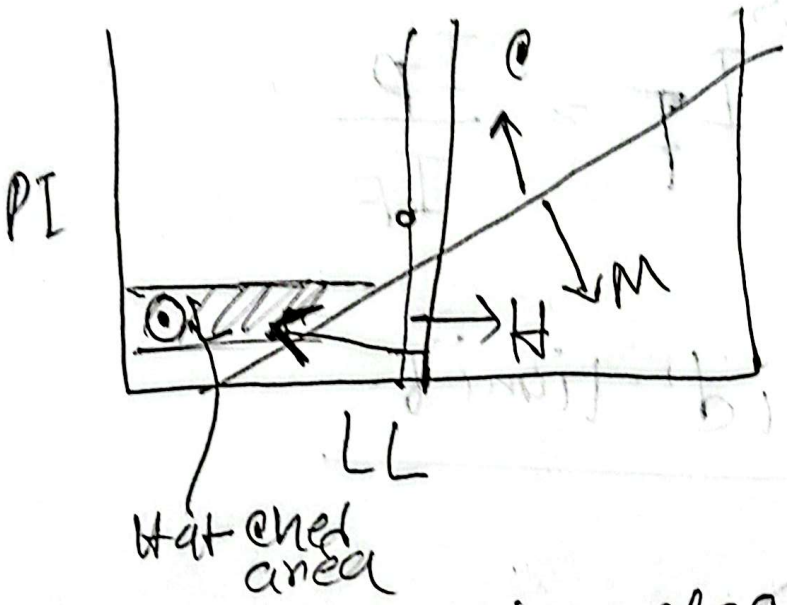
$$\text{flow Index } I_F = \frac{w_1 - w_2}{\log n_2 - \log n_1}$$

Toughness Index $I_T = \frac{I_P}{I_F}$

Liquid limit

H_2O content

No. of blows



CH ⟶ High plastic clay

CL ⟶

MH ⟶

ML ⟶

Hached area ⟶ (CL - ML)

$\frac{\text{LL oven dry}}{\text{LL air dry}} < 0.75$ 25% then

Soil organic

17/8/25

1. Passing # 200

< 5% → Grain distribution

5 - 12 → Both & Dual

> 12 → plasticity chart

< 5%	5 - 12	> 12%
GW	GW - GM	GM
GP	GW - GC	GC
	GP - GM	
SW	GP - GC	SM
SP	SW - SM	SC
	SW - SC	
	SP - SM	
	SP - SC	

LL = 48

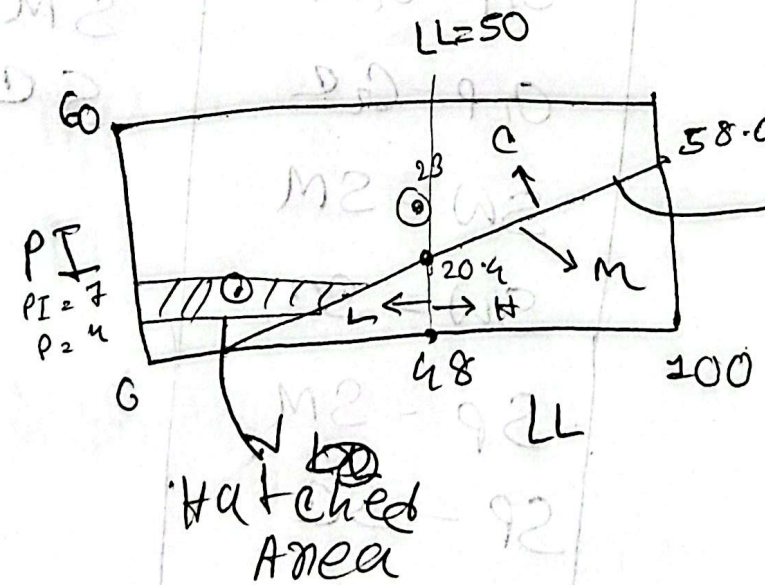
PL = 25 (48.23)

PI = 48 - 25 = 23

PI = 0.73(LL - 20) → A-line

48 → Coarse Grained Soil

52



C H
C L
M H
M L

$\frac{LL_{oven\,dry}}{LL_{air\,dry}} \leq 0.75$

Loss on Ignition

465°C ov. ganic content 75% or more

PI

LSU → Grain size distribution

S-12 → both fine

→

Soil

Granular material < 35% pass 200 sieve

Silt + clay material > 35% passing # 200 sieve

A-8 → organic soil

A-7 → inorganic

Granular (A-1 to A-3)

Silt-clay (A-4 to A-7)

~~#~~ passing #10 = 65

#40 = 51

#200 = ~~37~~

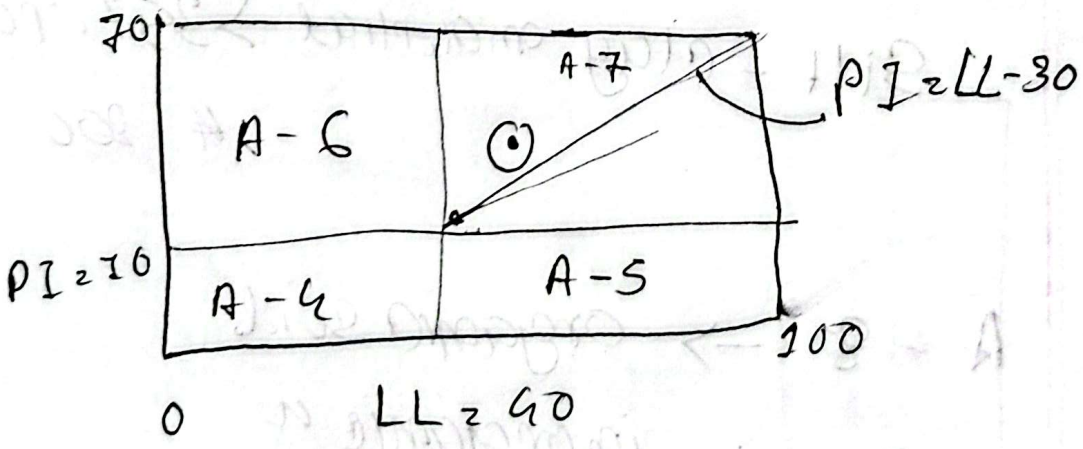
LL = 98

PI = 23

~~A-7~~

~~A-8 Organic~~

AASHTO soil classification



A-7-5 PI ≤ LL-30

A-7-6 PI > LL-30

Group Index (GI) = $(F-35)[0.2+0.005(w_L-40)$
$+0.01(F-15)(I_P-10)]$

F = % passing # 200 sieve (0.075 mm)

w_L = liquid limit %.

I_P = plasticity index (%).

A1, A2, A3 $\longrightarrow$ GI = 0

0 → best under that Grp

20 → worst under that Grp

math

200 passing − 37

$GI_{\#} = 0.48 + 2.86 = 3.34$

≈ 3

For A-6 & A-7

↳ GI = 3

(Vertical Group Index)

Cone penetration থেকে L.L বের
করতে —

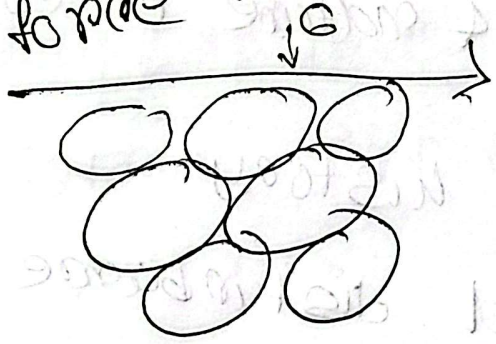
20 mm penetration এর cross-point
water content হল L.L.

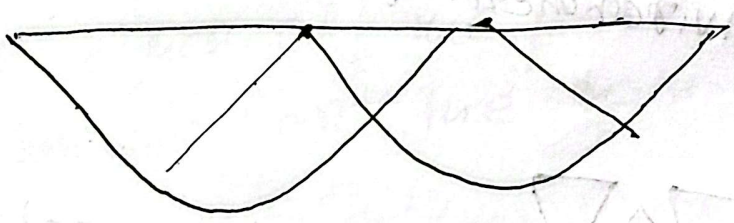
Shear Strength of Soil

24/8/25

* Shear failure mechanism within soil mass

* why shear force is important for soil?





Influencing factors of shear strength of soil

1. Heterogeneous nature of soil
2. the water table location & moisture contents.

(3) The drainage facility involving pore water pressure

(4) The type & nature of construction

(5) & stress history

(6) structural disturbance of soil

(7) chemical action

(8) Environmental conditions



normally consolidated soil

over consolidated soil



over burden pressure

Attributes of shear strength of soil

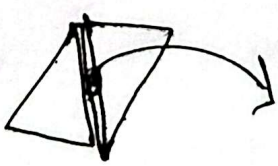
The shear strength of soil may be attributed to three basic components.

(1) Resistance due to interlocking of the particles.

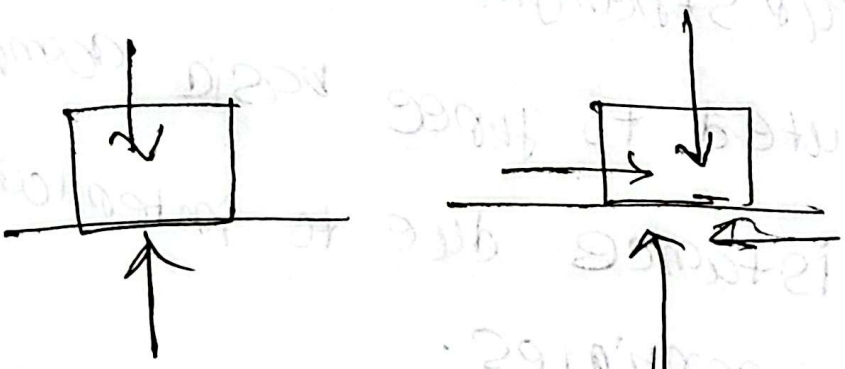
(2) Frictional resistance between the individual soil grains, which may be either of the sliding or rolling frictions or the both.

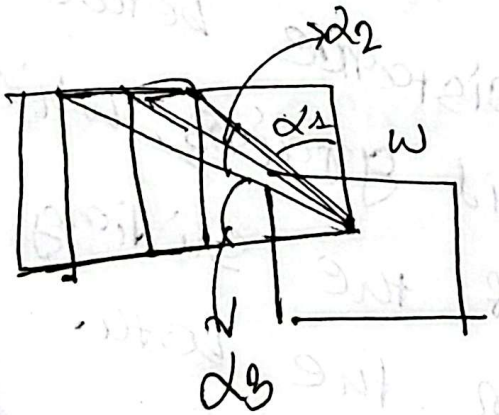
(3) Adhesion between soil particles caued cohesion.

$$f = \mu N \quad [\mu = \tan\theta]$$



Friction between solid Bodies





on the verge of failure condition of impending

α_3 = friction angle

= ϕ

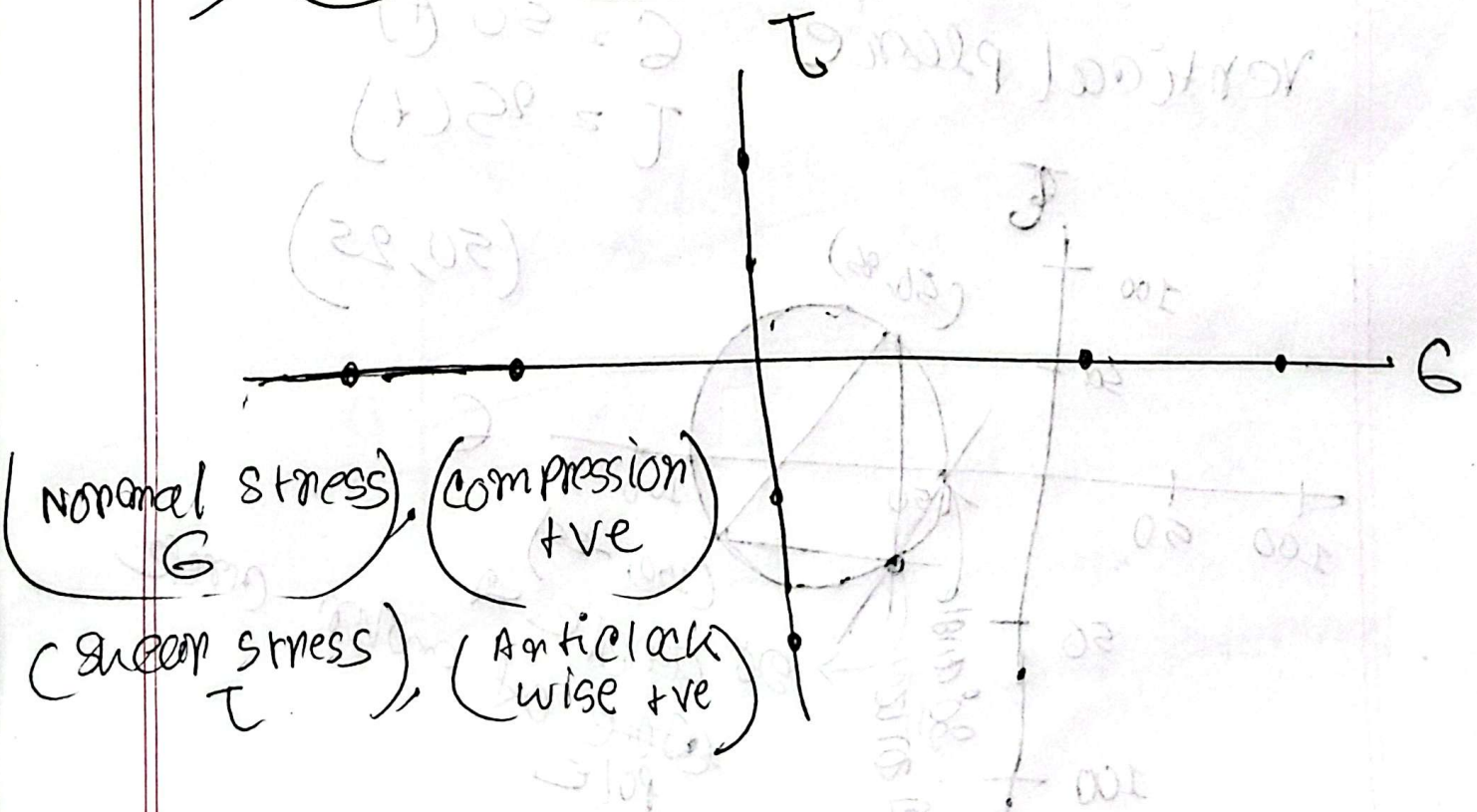


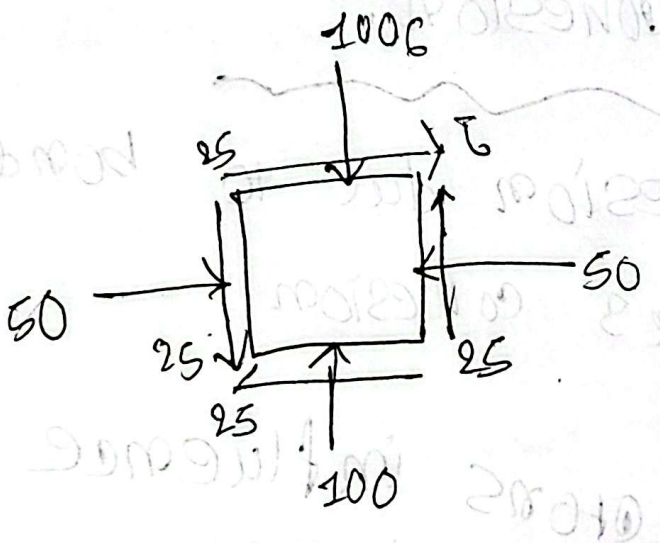
Concept of cohesion:

This adhesion due to bonding is known as cohesion

(Imp) What are factors influence cohesion strength

Mohr's circle of stresses





Horizontal plane $\sigma = 100 (+)$

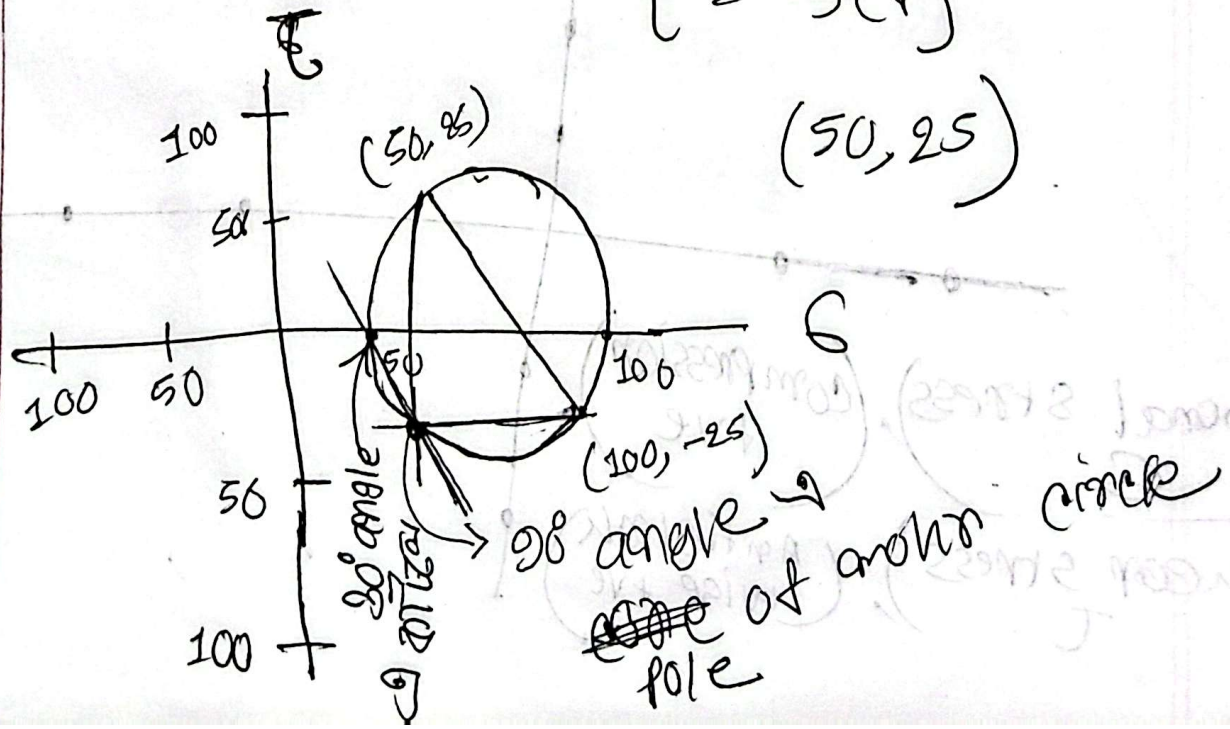
$\tau = 25 (-)$

$(100, -25)$

vertical plane $\sigma = 50 (+)$

$\tau = 25 (+)$

$(50, 25)$



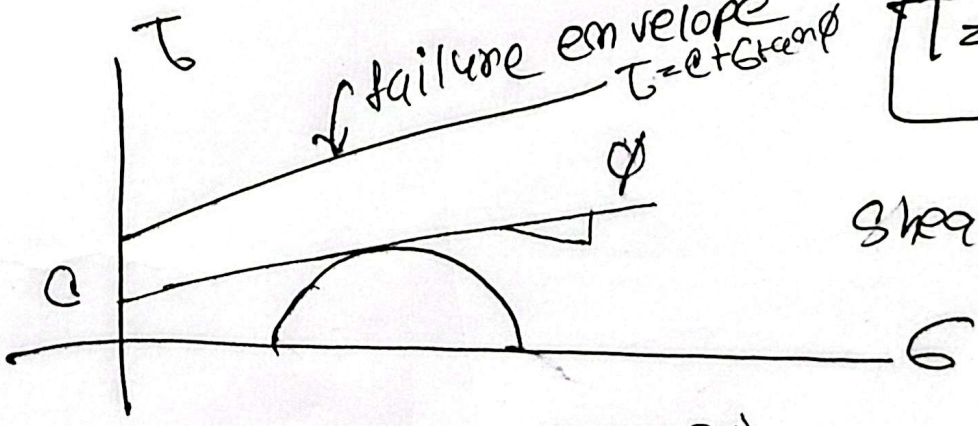
failure Theories:

① for ductile materials

- Max shear stress theory
- " strain Energy "
- Max shear - strain Energy "

② Brittle Materials

- max normal stress
- mohr failure theory



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

shear strength parameters

c → apparent cohesion

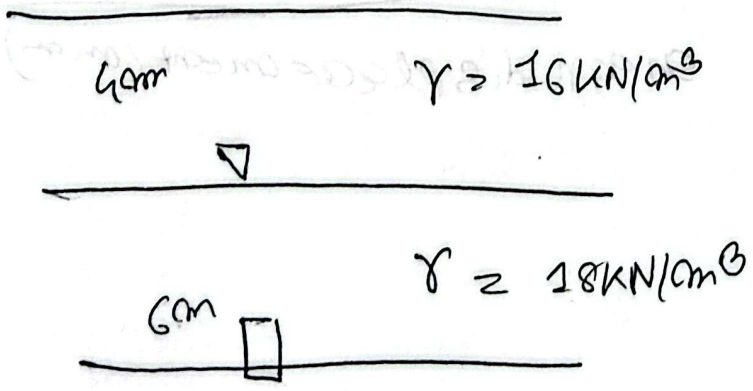
φ → apparent angle of internal friction

Shear Strength of soil

Determination of Shear Strength Parameters

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

Submerged unit wt



$= 16 + 6 \times (18 - 9.81)$

$= 113.1 \text{ kPa}$

$(60 \text{ mm} \times 60) \text{ mm}$

$= 36 \text{ cm}^2$

55 kPa
110 kPa
220 kPa

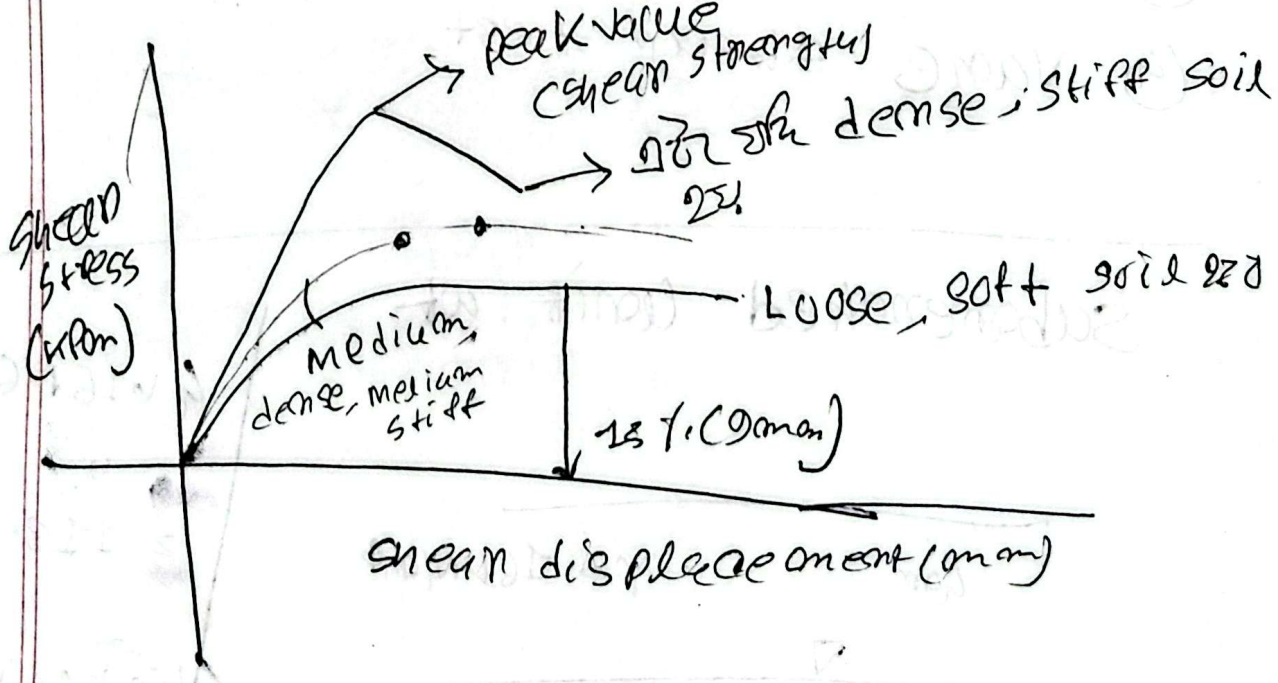
$$1\ kPa = \frac{1 \times 1000}{9.81} \times \frac{1}{100 \times 100}$$

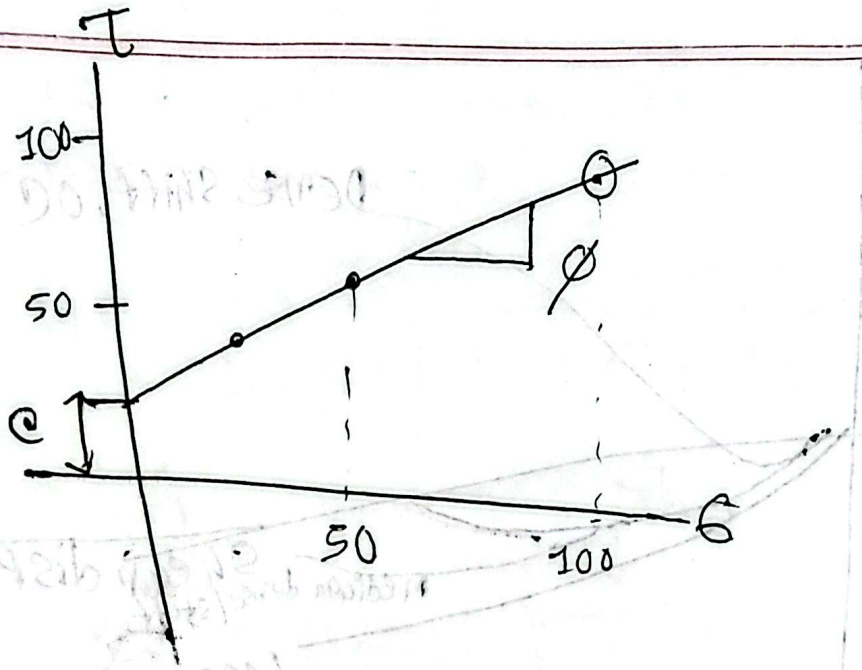
$$= 0.01\ kg/cm^2$$

25 kPa → 0.17 kg

50 kPa →

100 kPa →



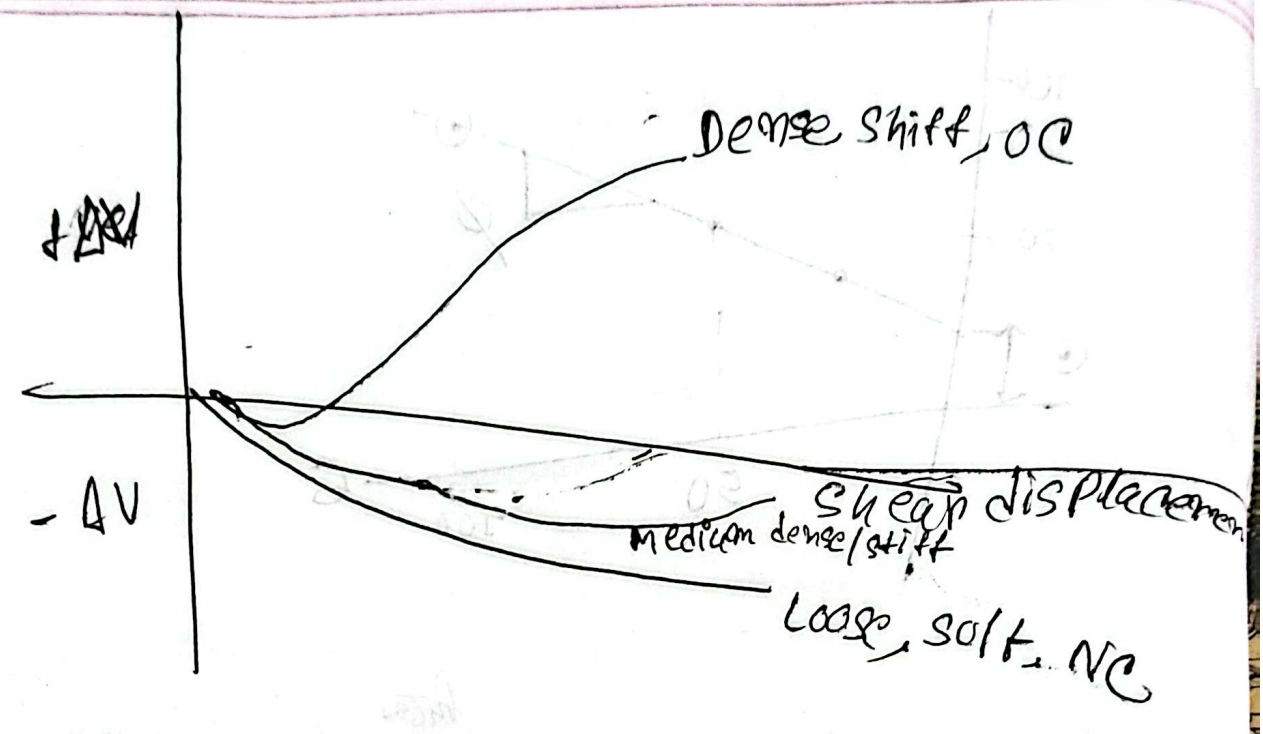


Loose soil ko shear → dense jaisa
dense " " " → loose jaisa

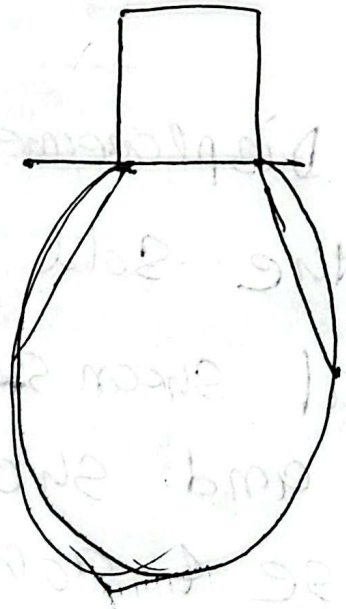
Critical state strength

Q. Draw shear Displacement Diagram and show the soil conditions?

Q. Draw tipical shear ~~Strength~~ Strain Diagram and show the following loose, dense & consilicated soil



Un grain condition এ pressure কম্বি
2য় grain এর ওপরে।



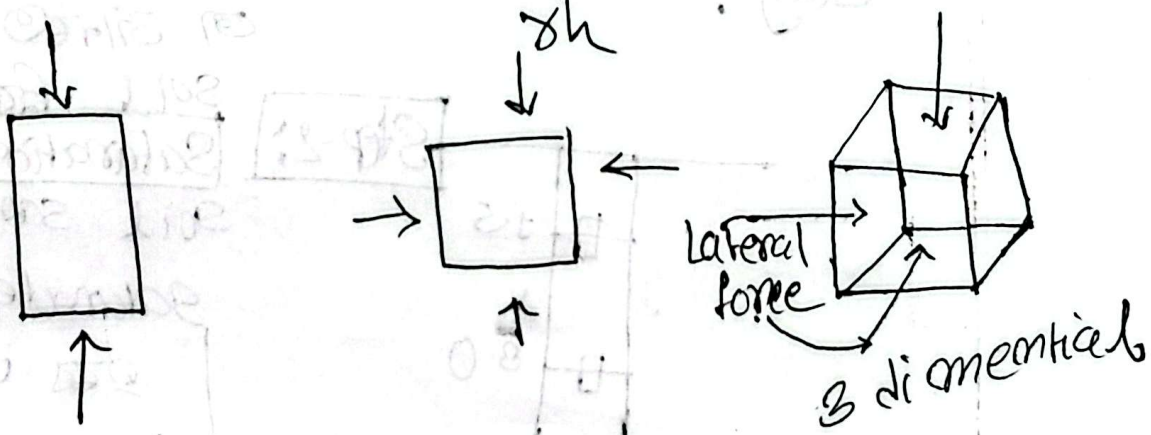
Triaxial Test

14/09/25

It is for detn the shear strength parameters of any type of soils.

2 type → Triaxial compression Test (most common test)

→ & extension Test



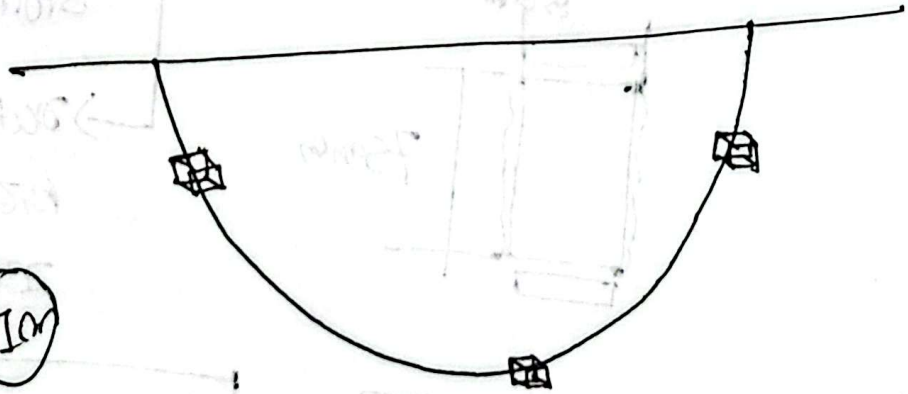


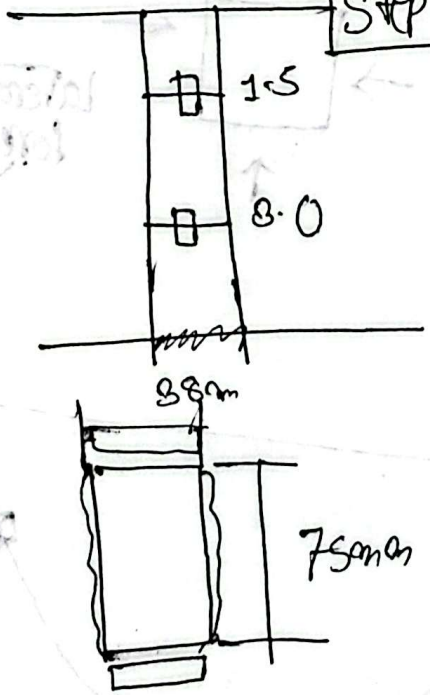
fig (1a)

Step 1: Preparation of soil sample

Compression, permeability দুই test খুবো undisturb soil এ করতে হবে।

↳ feild থেকে collect করতে হবে।

clay, silt, sand → কোন layer থেকে undisturbed soil নিব।



Step-2: Saturation of soil sample

soil sample কে saturated করতে হবে।

→ এজন্য কোরোয stone দিব

→ rubber membrane দিয়ে engage করব

* cell pressure
* Back pressure

→ **Step-3: Application of cell pressure**

Construction stage —

(1) Undrained → fast load দিবে

(2) Drained → Slow load দিবে

(Cell Pressure দ্বারা simulate করি)

Loading stage → (1) Undrained

(2) Drained

(Addition load on Deviator stress)

Construction stage এর ক্ষেত্রে only

Drainage & consolidation is same thing
এক্ষেত্রে Undrained কখন ও use করব না consolidated use করব। কোনটি Drained এর করব consolidated use করি।

Loading stage → এ পরিবর্তন হবে না Undrained, Drained ই থাকবে।

3য় test → Shear stress parameter differen

∴ soil গুলো হচ্ছে — classification —

1. Unconsolidated Undrained → UU → Test
2. Unconsolidated Drained → UD
3. Consolidated Undrained → CU → Test
4. Consolidated Drained → CD → Test

Same thing

Unconsolidate undrained

1. 50 [exit closed] + 60 [exit closed] =

110 [final stay]

Consolidated Undrained

3. 0 (exit open) + 60 (exit close) =

60 (final stay)

Consolidated Drained

4. 0 (exit open) + 0 (exit open) = 0 (final stay)

similar

Unconsolidated Drained

2. 50 (exit closed) + 60 (-50-60) (exit open) =

0 (final stay)

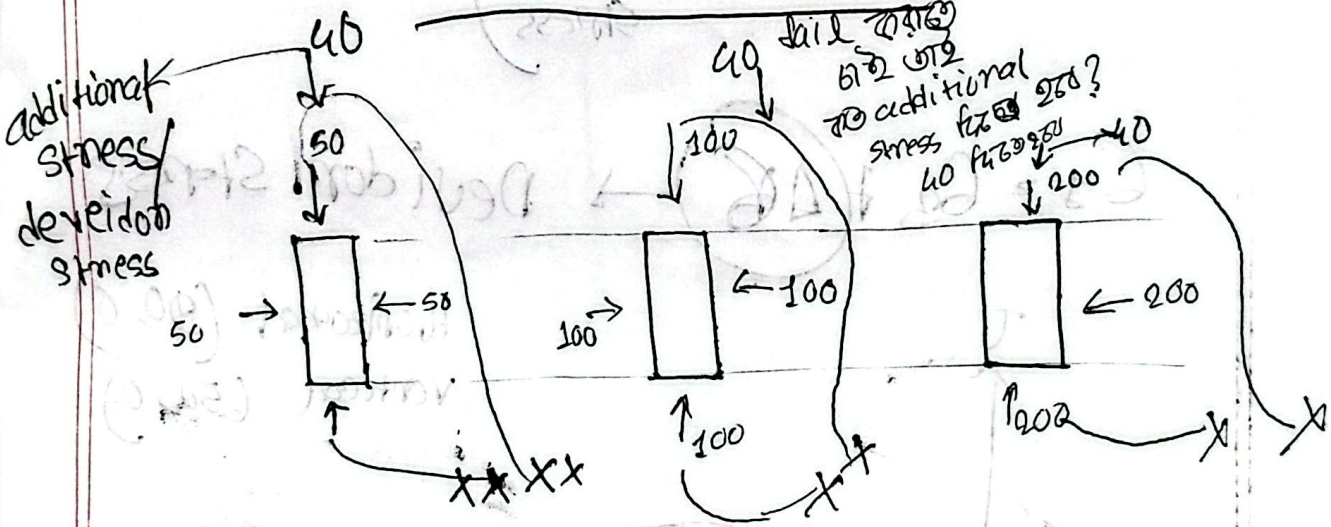
(এই chapter থেকে max Q. আসবে)

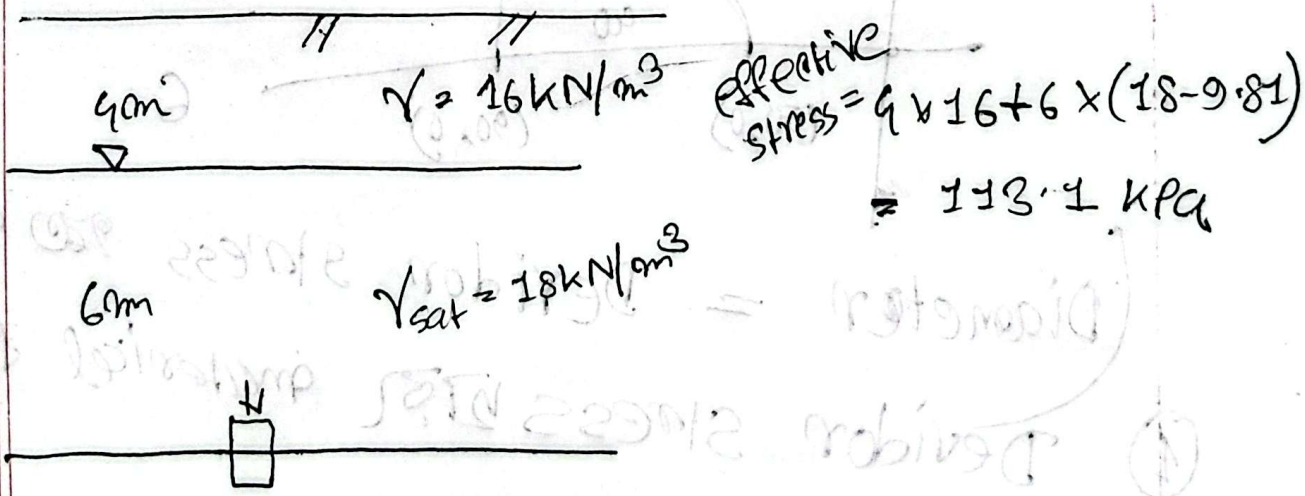
UU → Quick test → Q- test

CU → In between test → R- test

CD → Slow test → S-test

UU-test

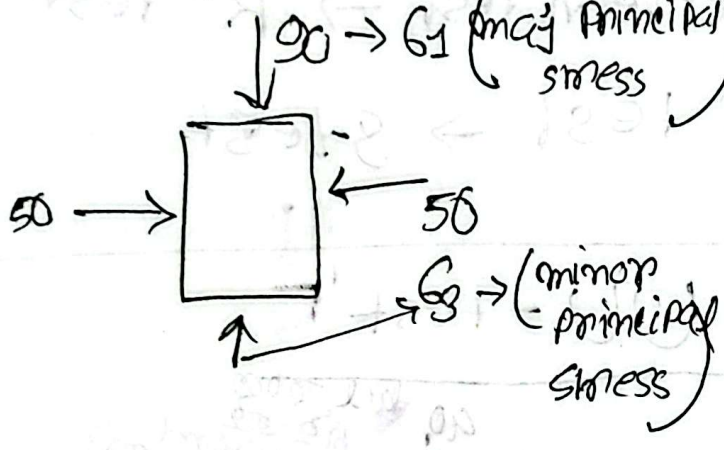




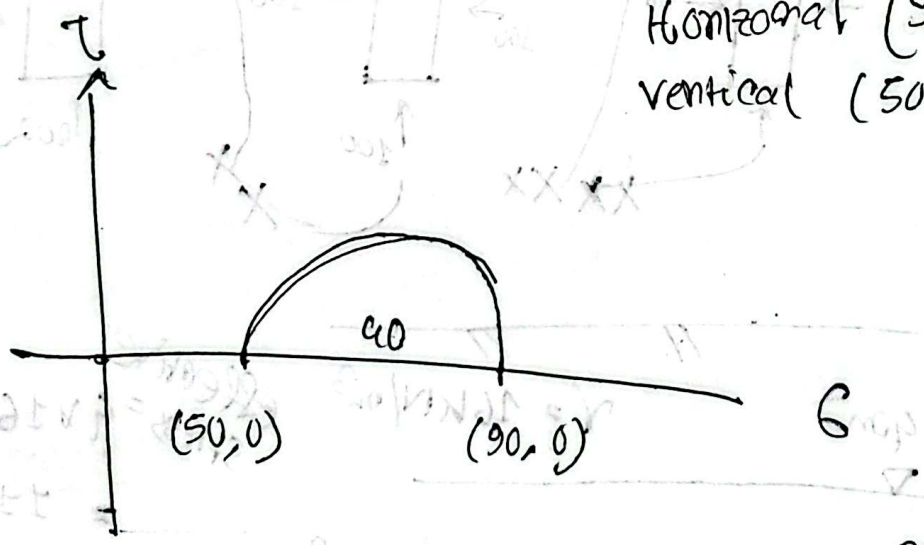
effective stress = 4 × 16 + 6 × (18 - 9.81)

= 113.1 kPa

এর উপর mohr circle, কোনো shear stress নাই. শুধু normal stress আছে principal stress হবে



$\sigma_1 = \sigma_3 + \Delta\sigma$ → Devidor. Stress

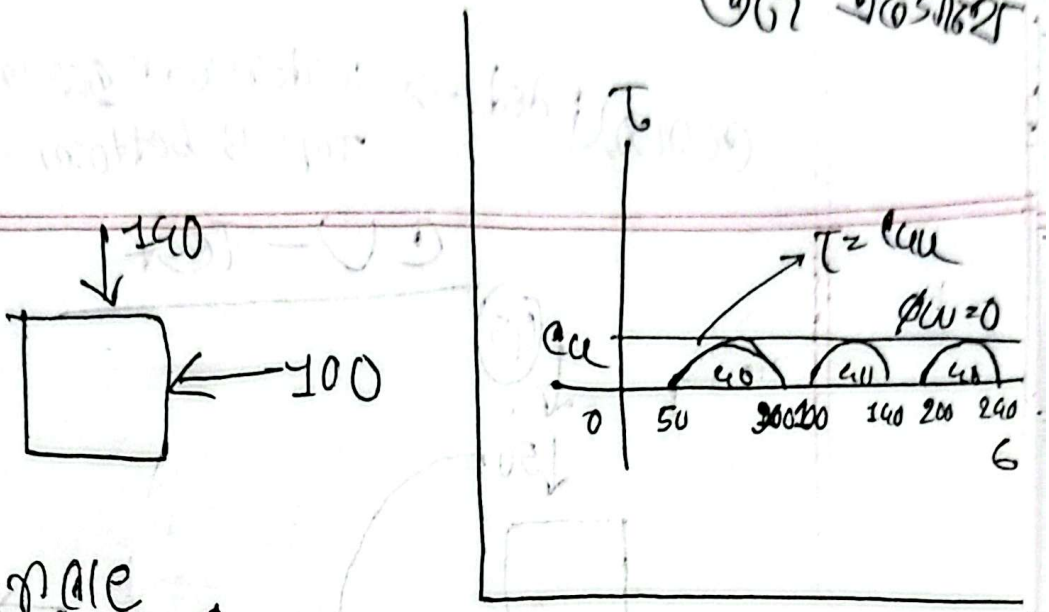


(Diameter = Devidor. stress এর বড়)

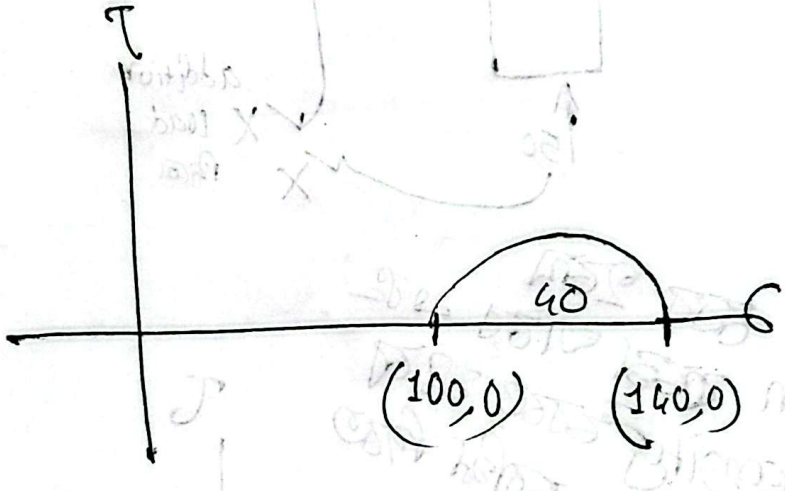
(1) Devidor stress দ্বারা material fail করছে না।

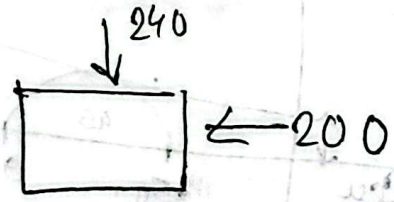
(2) strength is func of drainage density

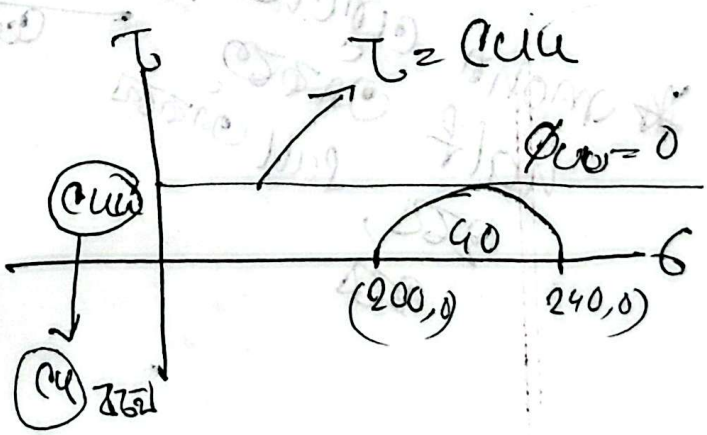
(3) strength is func of drainage condition



Mohr circle



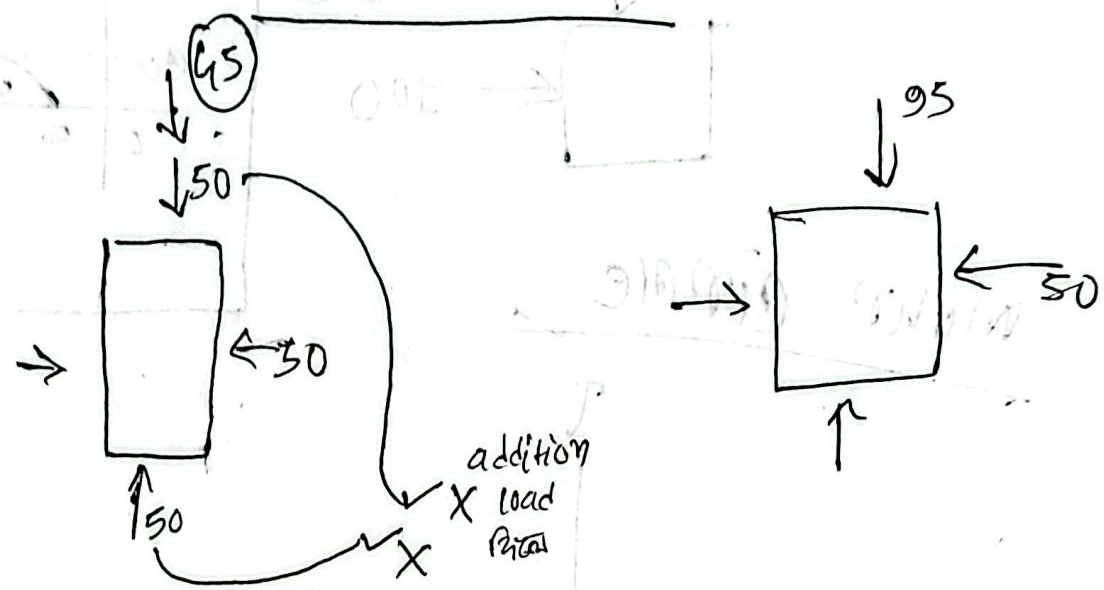




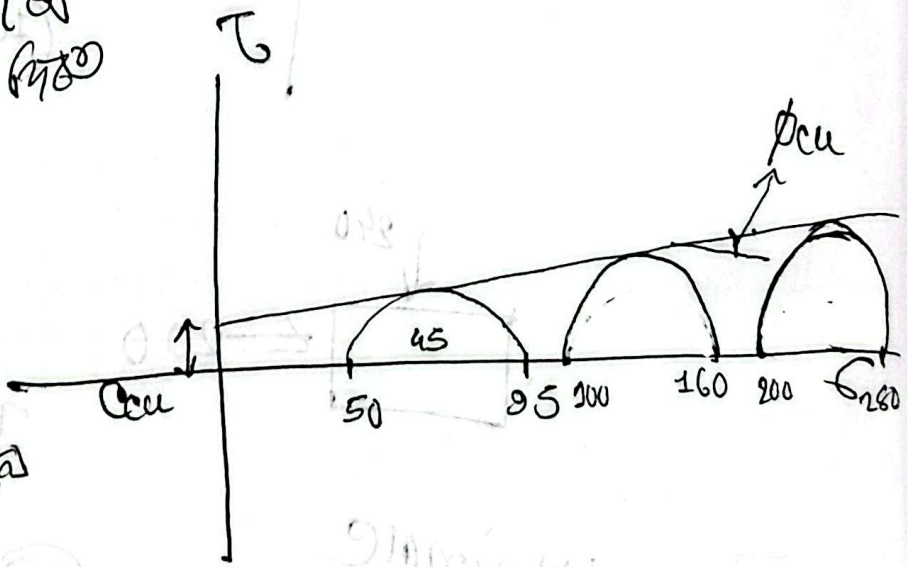
3D mohr circle
Δ; dσ -40
Parallel line 2D
Drainage → 2D

consolided → water বের হতে পারে
top & bottom should open

CU-Test

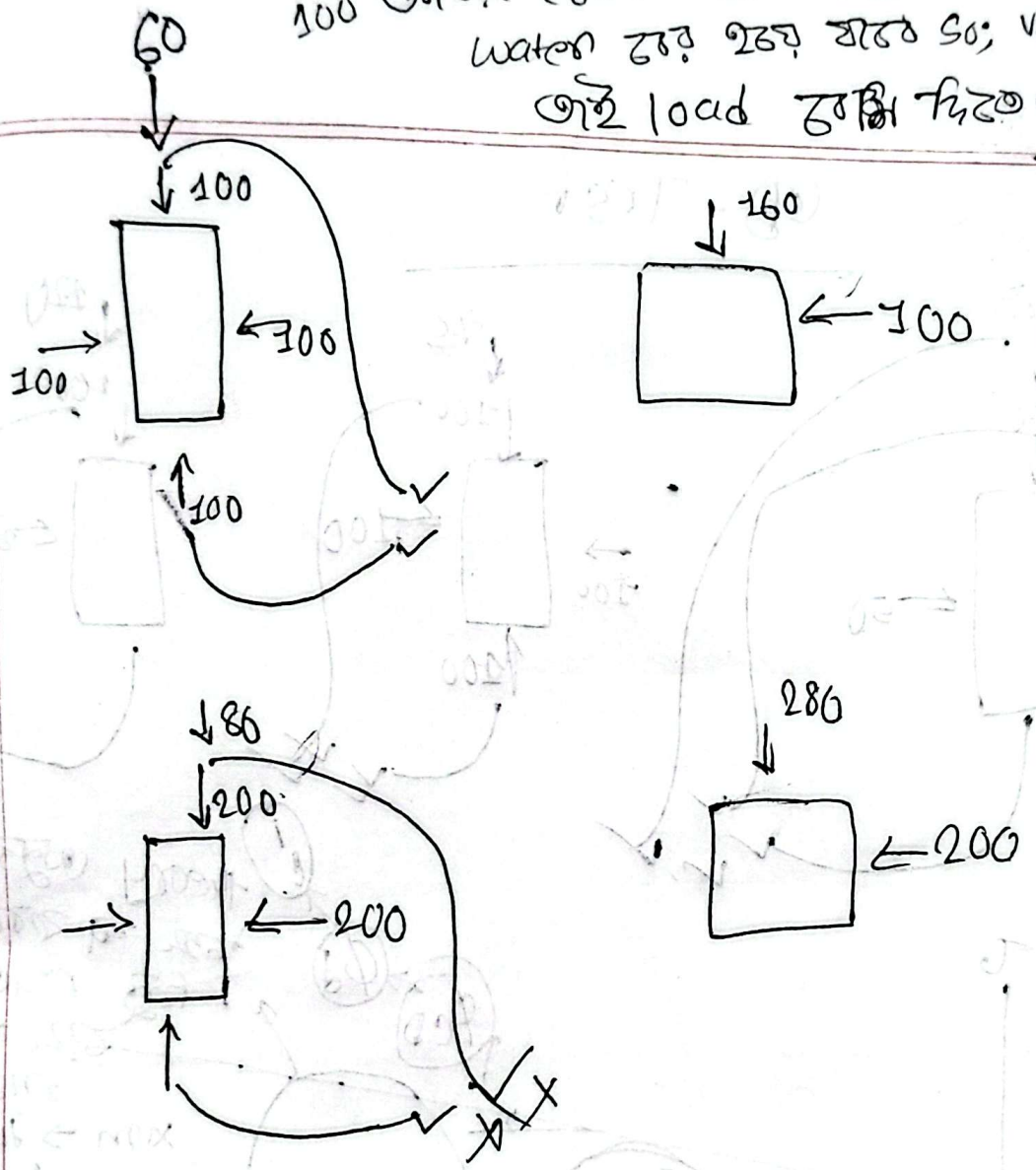


যদি ছোট হলে
বেশি বল্লে যাবে এবং
density বেড়ে যাবে
so load বেশি দিতে হবে,

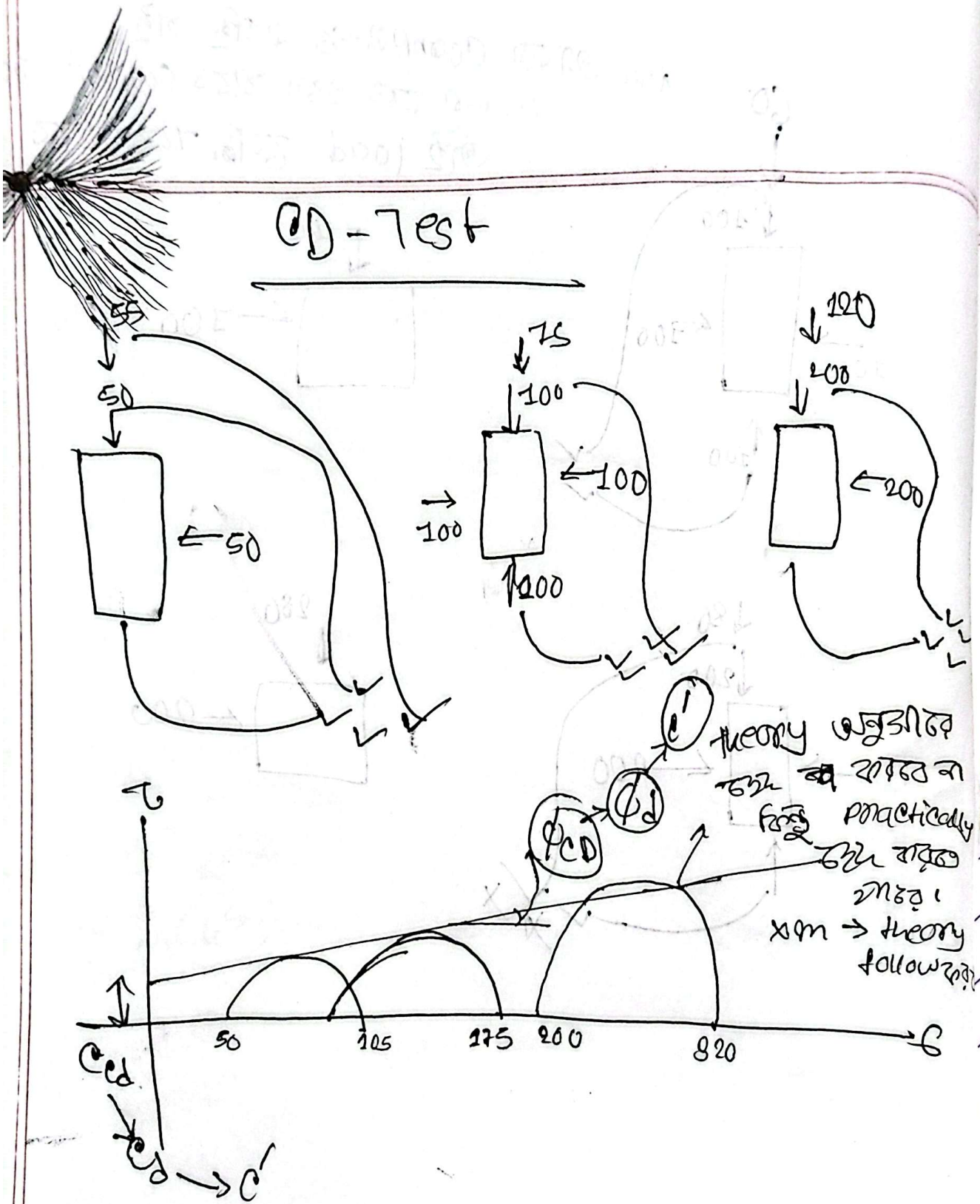


* mohr circle
half আসবে,
full আসবে

100 তাকে compress করছি তাই
water চার হবে যারে so; vof কাজে যাবে
তাই load চাপ্পি দিতে হবে

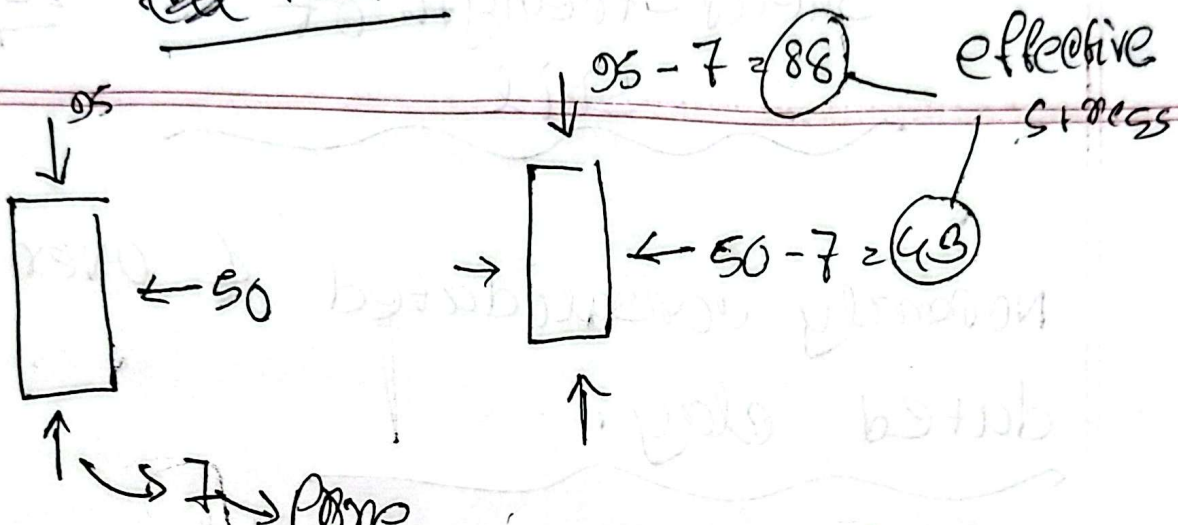


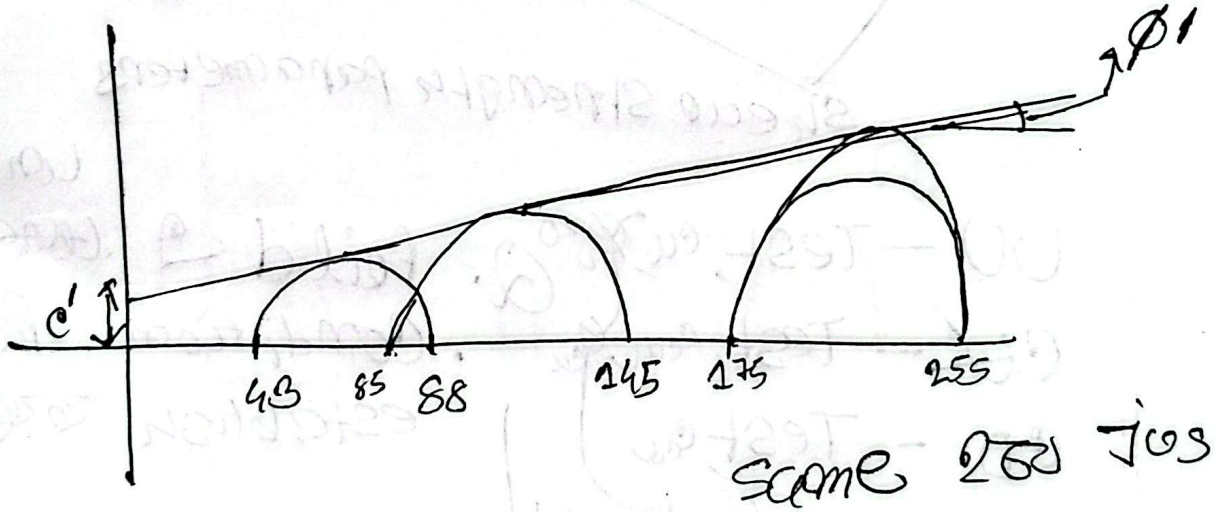
CD-Test


50
50
50
75
100
100
100
100
120
200
200
C'
ϕ_{CD}
ϕ_d
theory অনুযায়ী
হচ্ছে কিন্তু
practically
হচ্ছে না।
xm → theory
follow করে।
C
50
105
175
200
320
C_d
$C_d \rightarrow C'$

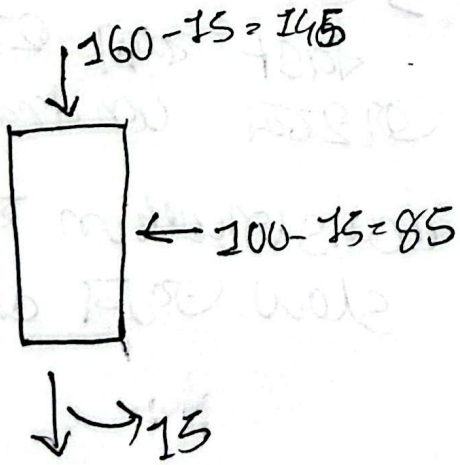
CU Test

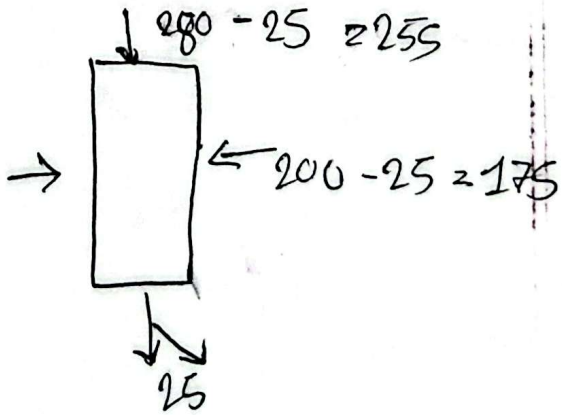
void থাকে বলে যাবে।





same বল just বাম side এ বল বসে।





Shear Strength of Soil

21/9/25

Normaly consolidated & over consolidated clay.

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

Shear strength parameters

UU – Test, c_u, $\phi_u = 0$

CU – Test, c_{cu}, ϕ_{cu}

CD – Test, c_d, ϕ_d

ϕ_{cd} | c_d, ϕ_d | c', ϕ'

Q. field এ undrained condition কিভাবে establish করবে?

→ construction যদি fast করা হয় তবে undrained

construction যদি slow তবে drained

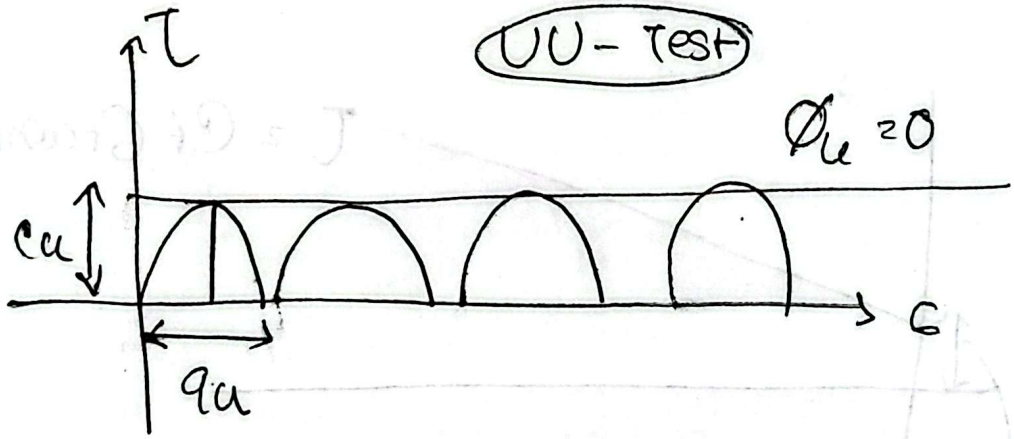
UU Test → c_u, $\phi_u = 0$

CU Test → c_{cu}, ϕ_{cu}

CD Test → c_{cd}, ϕ_{cd} | c_d, ϕ_d | c', ϕ'

CU with pore water pressure measured

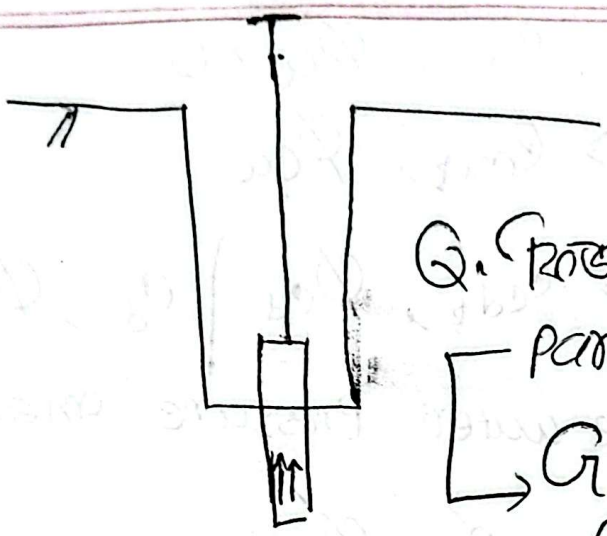
↳ CU test c', ϕ'



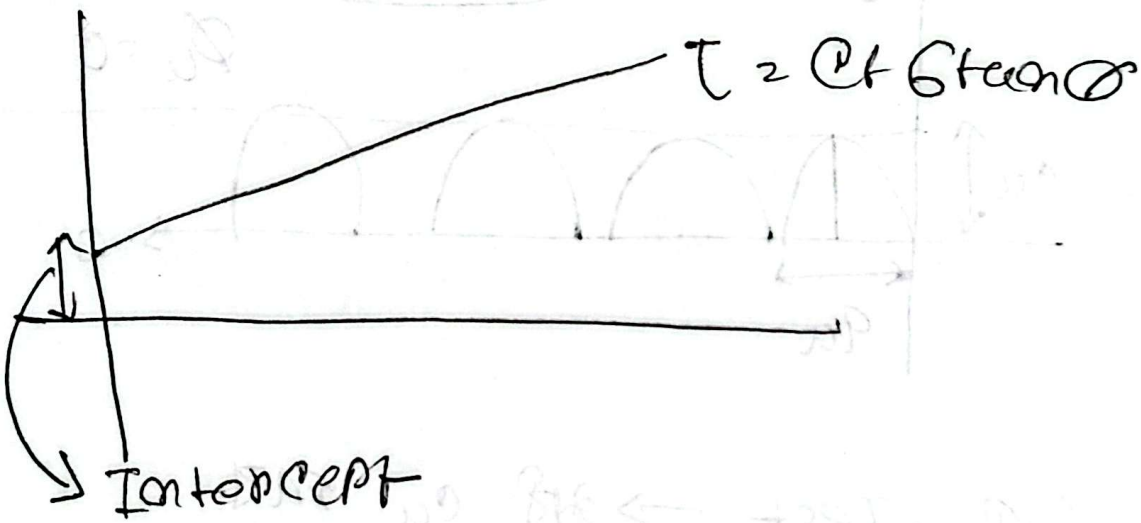
UC - Test → শুধু c_u পাব

DS - Test → সব ধরনের soil এর জন্য করতে পারি (c_d, ϕ_d পাব) | c_u, ϕ_{cu}

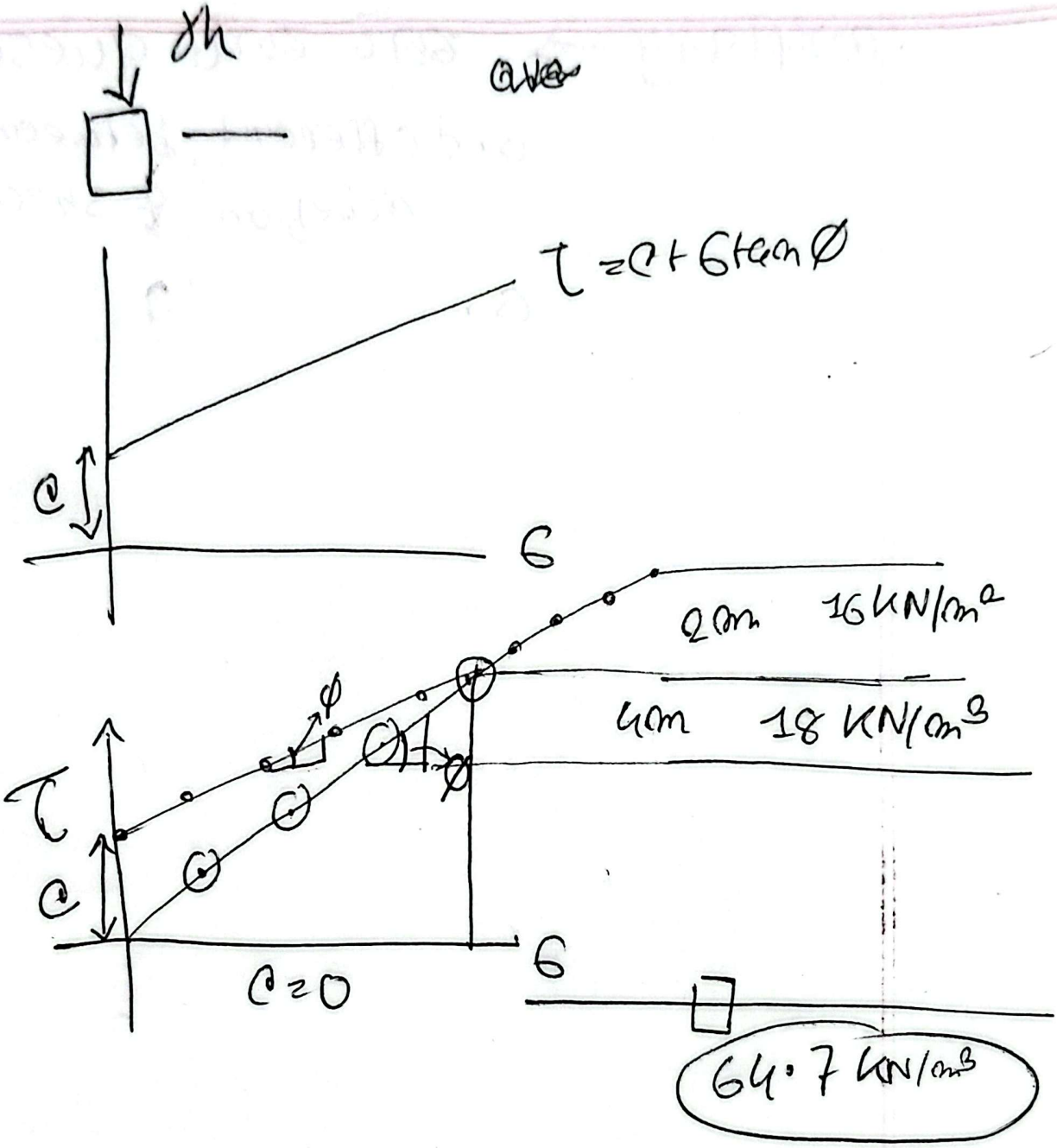
* Unconfined test তাদের জন্যই করতে পারি যেগুলো soil saturated, undisturb and clay হবে.



Q. কিভাবে জানব soil particle saturated?
↳ G.L এর নিচে থাকলে নিচে saturated



Overburden Pressure
Normally consolidated
over consolidation
under consolidated



Vane Shear Test

$$T = \pi c_u \left(\frac{D^2 \times 2D}{2} + \frac{\alpha D^3}{6} \right) = \pi c_u D^3 \left(1 + \frac{\alpha}{6}\right)$$

$$= \frac{\pi c_u D^3 (\alpha + 6)}{6}$$

$$c_u = \frac{6T}{\pi D^3 (\alpha + 6)}$$