Soil Mechanics

Muktadin Sir
Mon , Tues
29/04/19
$\boxed{\text{Lec-01}}$

Reference → Foundation Engineering by Peck , Henson [ ] Mandatory

Supplimentary → Soil Mechanics by B.M. Das → ভালো বিষয়

Advanced soil Mechanics by B.M. Das

Soil Mechanics → Craig

Syllabus :

C.T. 1
- # Weight - Volume relationship of soil (Phase diagram)
- # Density index
- # Compaction characteristics of soil — 5 lecture

2nd C.T. → # Fluid flow through porus media — 8 lecture

~~#~~

3rd C.T. → # Consolidation characteristics of soil — 10-11 lecture

Stress distribution in soil

Principal of soil Mechanics

Foundation design এর জন্য ২টা criteria satisfy করতে হবে :

$\boxed{1.}$ মাটি tension নিতে পারে না। Compression নিতে পারে।

মাটির Bearing capacity before it fails in shear হবে

করতে হবে। You have to make sure soil & foundation doesn't ~~fail~~ fail in shear.

Soil এর bearing capacity 6 ~~psf~~ tsf (6 ton /sq. ft)

U.S. ~~ton~~ ton per sq.ft [S.I unit না এটা]

2 kip = 1 ton

Soil 6 ~~psf~~ tsf এ fail করলে this is ultimate failure.

Soil rod এর মত uniform না তাই বড় factor of safety লাগবে (Bd তে min. 3)

Summary: Bearing capacity এর against এ F.O.S. নিতে হবে।

② Your foundation must not experience excessive settlement. limit -> 1" for normal/common structure. [like normal building এ. Neuclear plant এ design করতে গেলে আরো অনেক কম হবে limiting settlement] as এই plant collapse করলে massive distruction হবে।

Mechanics → action of force on bodies (body may be at rest or in motion)

$\boxed{\text{Principal} \rightarrow \text{hook's law}}$

dynamic হলে acceleration থাকতে হবে। uniform speed- dynamic problem না।

Static হলে,

$\Sigma f_x = 0 \quad \Sigma f_y = 0 \quad \Sigma f_z = 0$

in general $ma + \Sigma F = 0$ অন্য সব ধরনের force এর sum

soil is not a solid body.

Soil Mechanics:

1 of the branches of CE which deals with the application of soil science, laws of statics and dynamics and the principal of mechanics and hydraulics to understand the behaviour and use of soil as an

engineering material.

late 17th century থেকে soil mechanics development শুরু হয়।

30/4/19

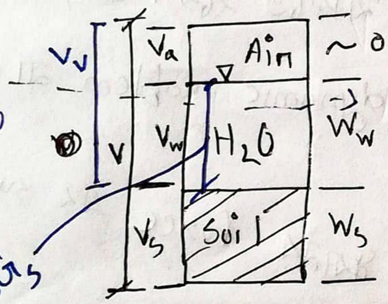
Lec-02

Weight-Volume Relationship of soil:

$w = \frac{W_w}{W_s} \cancel{\times 100}$ $[W_s = V_s \times \gamma_s]$

$W_w = w \cdot V_s \cdot \gamma_s = w \cdot V_s \cdot \gamma_w \cdot G_s$

by Vol^m by weight



~ 0

$w = \frac{W_w}{W_s} \times 100$

$W_w = w V_s \gamma_w G_s$

$w V_s G_s$

$W_s = V_s \gamma_s = V_s \gamma_w G_s$ — specific gravity of soil skeleton

$m = \rho V$

$W = \rho g V = \gamma V$

Microscopic point দিয়ে দেখলে পাওয়া যায় soil + void
↓
air/water/
comb. of air-water
থাকবে always থাকবে

Existance of soil in different state (Soil skeleton, water and air can be represented by a ~~bag~~ block of phase diagram. It is called 3 phase diagram. And fully saturated soil sample

if the soil contains only soil skeleton and water only, it is called 2-phase diagram. If soil + air → complete dry soil

তাহলেও 2 phase diagram

Partially saturated soil → Soil + air + water

* Soil skeletons are incompressible] → load দিলে vol^m change হবে না। water particle ও vol^m change হবে না] assumption

Void → $V_w + V_a$ / V_a / V_w

1st always the ←

Water content/moisture content : expressed in %

moisture contend can be defined by $\frac{\text{weight of water}}{\text{weight of solid}}$

অথবা

$\omega = \frac{W_w}{W_s} \times 100$ [It can have value more than 100% like volcanic ash এ]

soil sample নিয়ে dry করে ফেললে W_s পাবো। initial weight − dry weight = W_w

2. Void ratio: [Expressed in decimal] → load দিলে শুধু V_v change, V_s same

$$e = \frac{\text{Volume of void}}{\text{Volume of solid}} \qquad e = \frac{V_v}{V_s}$$

load দিলে ভেতরের n change হবে & V_v আর V দুটোই vary

3. Porosity: [% এ express]

V_v = Volume of void

$$n = \frac{V_v}{V} \times 100$$ — [Total volume]

এটা কখনোই 100% হবে না

4. Degrees of saturation: [normally expressed in %]

It represents to what extent void spaces are filled up with water.

$$S_r = \frac{V_w}{V_v} \times 100$$] fully saturated হলে ~~100 হবে~~ 1 হবে

$$\boxed{e = \frac{V_v}{V_s} = \frac{V_v}{V - V_v} = \frac{\frac{V_v}{V}}{1 - \frac{V_v}{V}} = \frac{n}{1-n}}$$

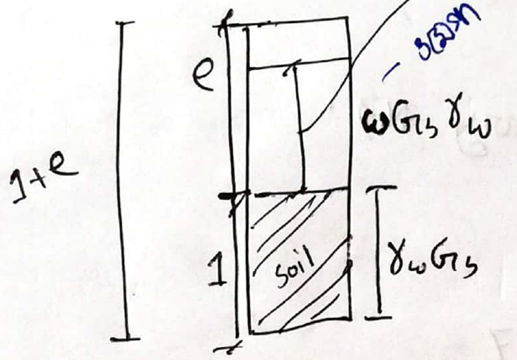
relationship bet^n void ratio and porosity

$$n = \frac{V_v}{V} = \frac{V_v}{V_s + V_v} = \frac{V_v/V_v}{V_s/V_v + \frac{V_v}{V_v}} = \frac{1}{1 + \frac{1}{e}} = \frac{e}{1+e}$$

$e = \dfrac{V_v}{V_s = 1}$ ধরে নাও unit volume

Volume of air $= e - \omega G_s$

$\omega G_s \rightarrow$ volume



$\rightarrow$ এই diagram হল based on $V_s = 1$

volume of void এখানে e

$$S_r = \frac{\omega G_s}{e}$$

$$\omega = \frac{W_w}{W_s} = \frac{\gamma_w V_w}{\gamma_s V_s} = \frac{\cancel{\gamma_w} V_w}{\cancel{\gamma_w} G_s \cancel{V_s}} \quad (V_s \rightarrow 1)$$

$$\Rightarrow V_w = \omega G_s$$

3 phase diagram

porosity $n = \dfrac{V_v \,(= a)}{V = 1}$ ধরে diagram redraw করব।

S_r এর value n দিয়ে express করব।

Unique relationship exists between

Basic definition থেকে,

$$\omega = \frac{W_w}{W_s} = \frac{V_w \gamma_w}{V_s \gamma_s} = \frac{\frac{V_w}{V_v}}{\frac{V_s}{V_v}} \cdot \frac{1}{G_s} = \frac{S_r}{\frac{1}{e} \cdot G_s}$$

$$\gamma_s \Downarrow \gamma_w G_s$$

$$\omega = \frac{S_r \cdot e}{G_s}$$

$$\boxed{S_r = \frac{\omega \cdot G_s}{e}}$$

* Basic def. আর block diagram দেখব সেটা থেকে যেকোন relation develop.

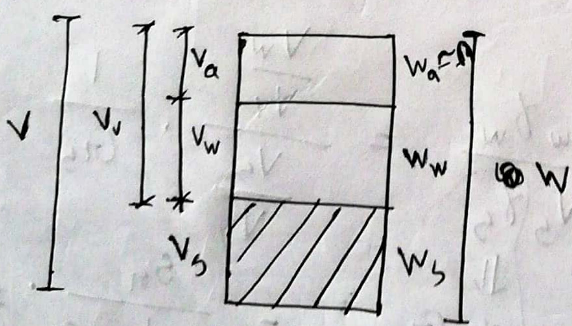
G_s অনেক কম range এ vary করে।

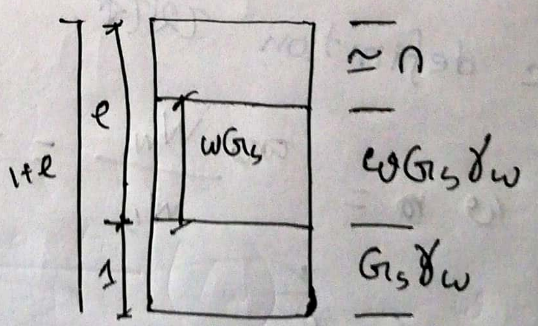
Typical values of G_s:

1. Sand = 2.65 ~ 2.67
2. Silty sand (fine sand) = 2.67 ~ 2.7
3. Inorganic clay = 2.7 ~ 2.8
4. Organic soil (জীবাশ্ম থাকে, বেশি পুরানো না) = variable; it could be under 2 even.

6/5/19

Lec – 03





$$\gamma_{bulk} = \frac{G_s\gamma_w + wG_s\gamma_w}{1+e}$$

$$= \frac{1+w}{1+e}(G_s\gamma_w)$$

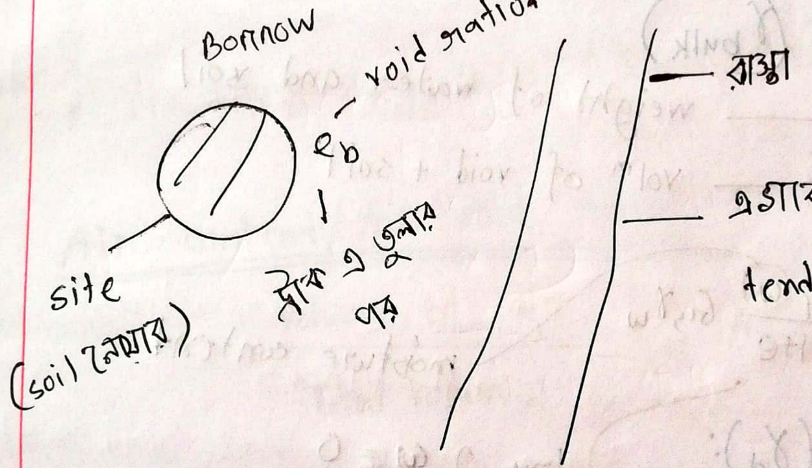
ω এর value put হবে decimal এ

$$V = V_v + V_s \qquad W = W_s + W_w$$

$$= V_s\left(\frac{V_v}{V_s} + 1\right) = V_s(1+e)$$

constant যেহেতু change হবে না

$$V \propto (1+e)$$



এখানে কত void ratio হবে tender এ বলে দেয়া (e_f)

যেখান থেকে soil নিচ্ছি → Borrow area

$V_b \propto (1+e_b)$ — borrow area এর soil

$V_f \propto (1+e_f)$ — finished volume of soil (compact করার পর)

$$\frac{V_b}{V_f} = \frac{1+e_b}{1+e_f}$$

e_b — জানা

e_f — tender এ দেয়া

V_f — tender এ দেয়া

সে থেকে কত volume লাগবে বের করব।

Unit Weight

Bulk unit weight (γ_{bulk})

$$\gamma_{bulk} = \frac{W}{V} \quad \begin{matrix}W \text{ — weight of water and soil} \\ V \text{ — vol}^m \text{ of void + soil}\end{matrix}$$

$$\gamma_{bulk} = \frac{1+w}{1+e} G_s \gamma_w$$

moisture content

Dry unit weight (γ_d):

dry এ $w = 0$

$$\gamma_d = \frac{G_s \gamma_w}{1+e}$$

আগের diagram থেকে

$$\gamma_d = \frac{W_s}{V} = \boxed{\frac{G_s \gamma_w}{1+e}}$$

$$\gamma_{bulk} = \frac{W_s + W_w}{V} = \frac{W_s}{V}\left(1 + \frac{W_w}{W_s}\right) = \boxed{\gamma_d (1+w)}$$

Saturated unit weight (γ_{sat})

করে

$$\gamma_{sat} = \frac{\overbrace{e\gamma_w}^{\text{weight of water (void fill)}} + G_s \gamma_w}{1+e} = \frac{e + G_s}{1+e} (\gamma_w)$$

$$S_r = \frac{w G_s}{e}$$

$$w = \frac{S_r e}{G_s}$$

$$= \frac{1 + \frac{S_r e}{G_s}}{1+e} G_s \gamma_w$$

$S_r \rightarrow$ fully saturated এ 1

$S_r \rightarrow$ dry এ 0

buyancy

Submerged / effective / unit weight ($\gamma_{sub} = \gamma_b = \gamma'$):

$$\gamma_{sub} = \gamma_b = \gamma' = \gamma_{sat} - \gamma_w$$

$$= \frac{e + G_s}{1+e}\gamma_w - \gamma_w$$

$$= \left(\frac{G_s - 1}{1+e}\right)\gamma_w$$

- 117, 118 – 125 lb/ft^3 → ঢাকার পানির unit weight

Air content / Air void ratio:

$\frac{\text{Volume of air}}{\text{Total volume}}$ $\quad A_v = \frac{V_A}{V} = \frac{V_v - V_w}{V_v + V_s}$

$$= \frac{\frac{V_v}{V_v} - \frac{V_w}{V_v}}{1 + \frac{V_s}{V_v}} = \frac{1 - S_r}{1 + \frac{1}{e}}$$

$$= \frac{e}{1+e}(1 - S_r)$$

$$\boxed{= n(1 - S_r)}$$

Determination of void ratio:

$$\gamma_d = \frac{G_s\gamma_w}{1+e}$$

γ_d বের করতে হবে sand replacement method এ।

$$\gamma_d = \frac{G_s \gamma_w}{1+e}$$ — e বের করব, বাকিগুলা known.

e/n → represents how much void in the soil.

e, n → represents the compactness of the soil.

~~dasic~~ dacity

দুই type এর soil এর e আর n same হলেও compacthess same না হতে পারে।

So, e and n does not determine compactness of soil uniquely. Two soil at 2 diff places ~~sites~~ ~~can~~ may ~~hada~~ have same void ratio, but they may not ~~had~~ have same degree of compactness.

Granular soil এর জন্য এটা হয়।

To define the compactness of soil we use -

Granular soil এর

① density index or relative density which can be defined as,

$$\frac{e_{max} - \cancel{e_{min}}\, e_f}{e_{max} - e_{min}} = I_d$$ — %. এ

e_f — fill void ratio

$$\boxed{\text{mass } \cancel{\text{dengity}}^{\text{density}} \times g = \text{unit weight}}$$

$$\gamma_d = \frac{G_s \gamma_w}{1+e} \Rightarrow (1+e) = \frac{G_s \gamma_w}{\gamma_d}$$

$$1+e_{max} = \frac{G_s \gamma_w}{\gamma_{d(min)}}$$

$$1+e_{min} = \frac{G_s \gamma_w}{\gamma_{d(max)}}$$

$$I_d = \frac{(e_{max}+1) - (e_f+1)}{(e_{max}+1) - (e_{min}+1)}$$

$$= \frac{\frac{1}{\gamma_{d(min)}} - \frac{1}{\gamma_{d(f)}}}{\frac{1}{\gamma_{d(min)}} - \frac{1}{\gamma_{d(max)}}}$$

7/5/19

Lec-04

I_d / D_r = density index

5টা catagory তে ভাগ করা যায় - (cohesion)

		I_d
①	Very loose	0-15
②	loose	15-35
③	Medium dense	35-65
④	Dense	65-85
⑤	Very dense	>85

earthquake prone

safer from earthquake

bd তে most designable

এ দুটার উপর direct foundation করা যাবে না; dense করে নিতে হবে।

যেনে γ_d বের করা

(i) $\gamma_d, \gamma_{min}, \gamma_{max}$ → in terms of porosity derive করব

(ii) in " " volume

$e_{max} = \dfrac{n_{max}}{1-n_{max}}$ এটা দিয়ে করব

$1+e =$ ~~tot~~ total Vol^m

$\gamma_d = \dfrac{G_s \gamma_w}{1+e} \Rightarrow (1+e) = \dfrac{G_s \gamma_w}{\gamma_d}$

max, min চিন্তা করব।

$$\frac{V_{max} - V_f}{V_{max} - V_{min}}$$

বই এর example করব।

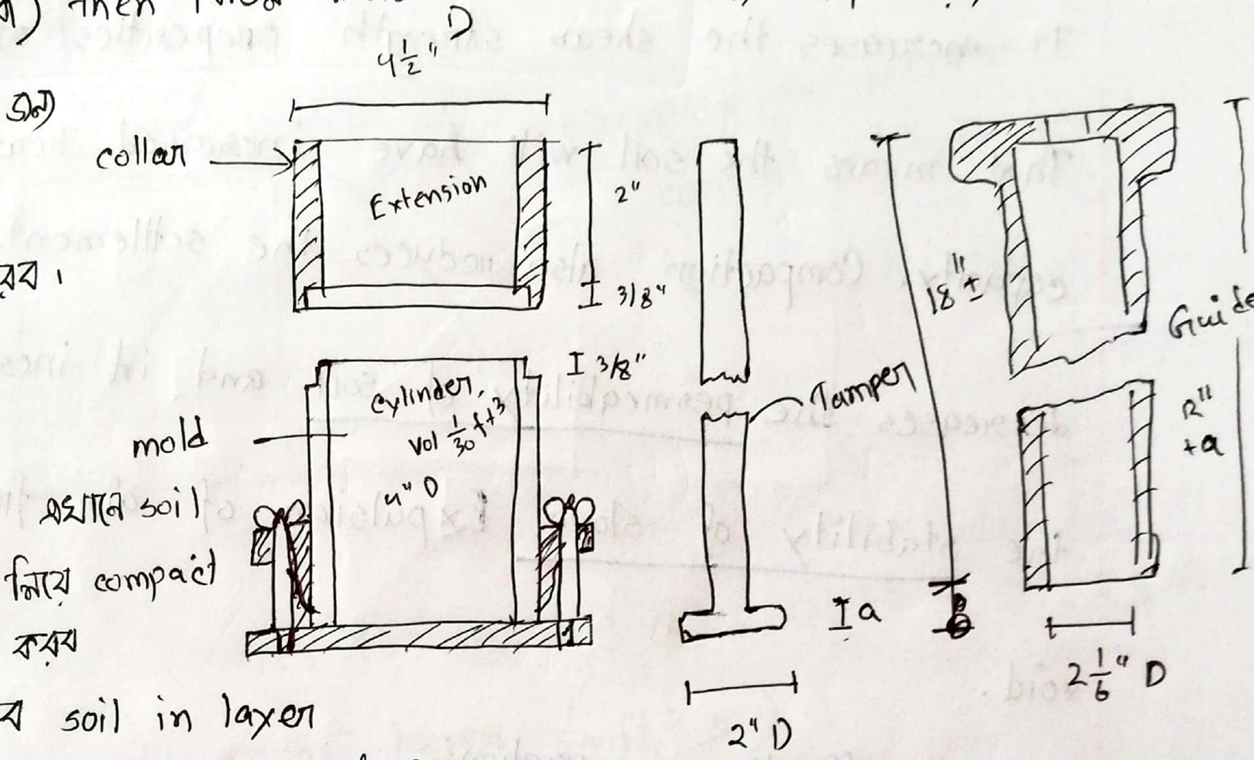
Compaction

~~Ay~~ ~~Am~~ Any earth ~~er~~ related work → compaction লাগবে।

Soil compact করতে হলে void কমাবো (basically air; water generally কমানো যাবে না)

1/3 soil sample কে 3 বারে নিয়ে 25 বার করে blow করা হয়।

10% moisture content দিয়ে start (last এ oven এ দেওয়ার পর dry unit weight পাবে) then বিভিন্ন moisture content দিয়ে exp. করে, max dry density এর জন্য moisture content বের করব।



compact করব soil in layer

soil seive 4 দিয়ে pass করব এবং এ process পড়ব বই *

Compaction is the process of densification of soil by giving mechanical energy into it.

The process of desification of soil for increasing the ~~unight~~ unit weight of soil (frequently called filled material) by ① rolling ② Temping ③ Vibrating or other mechanical means is called compaction

It increases the shear strength properties of soil. That means the soil will have increased bearing capacity. Compaction also reduces the settlement. It decreases the permeability of soil and it increases the stability of slope. Expulsion of air from the void.

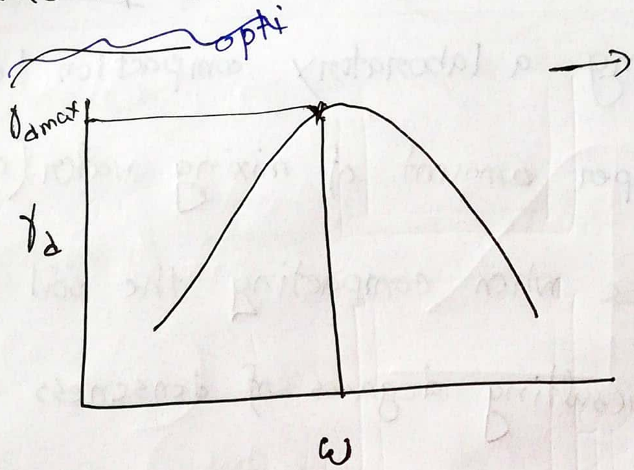
Factors affecting compaction:

এটার উপর control নাই কারণ site এর soil দিয়ে কাজ করব

1. Types of soil (sandy, clay, gap graded, well graded ....)
   which type of soil
2. Moisture content of soil.
3. Compactive effort

Moisture content plays a dominant role ~~in dseer~~ to achieve ~~desid~~ desired degree of compaction.

Lab এ Test



→ optimum moisture content highest density হয়।

mgh দিয়ে (tamper এর ওজন 5.5 lb, height এ 1', 25টা blow, 3টা layer, $\frac{1}{30} ft^3$ এ)

total mechanical energy soil কে compact করতে $= 5.5 \times \frac{12}{12} \times 25 \times 3 \div \frac{1}{30}$

$= \cancel{13.75}$ 12400 per cft

13/5/19

Lec-05.

The purpose of doing a laboratory compaction test to determine the proper amount of mixing water (optimum moisture content) to use when compacting the soil in the field and the resulting degrees of denseness which can be expected from this compaction at this moisture content (optimum moisture content). (~~pg 16 ঘরে~~)

আগের compaction instrument → standard proctor

এখন পড়ব modified proctor

ASTM D1557

	modified proctor	standard proctor
পার্থক্য →	5টা layer এ নিব	3টা layer
→	tamper এর ওজন 10 lb	$5\frac{1}{2}$ lb
→	height of fall 18"	12"

এখানে energy লাগবে 56 250 (4.5 গুণ বেশি)

তাই costing ও বেশি

(compared to standard proctor)

but γ_d এর value বাড়বে (5-10%) → it's a big achievement

(bearing capicity অনেক বাড়বে, settlement significant)

Degrees of compaction → 95% of standard proctor
↵
field এ যেটা হবে।

$$\frac{\gamma_d \max (field)}{\gamma_d \max (standard)} = 95\% \rightarrow \text{requirement}$$

/98%

End product specification (তুমি কিভাবে কোন process এ করছ) আমি খালি check করব আমার 95% compaction কাজ করছ)

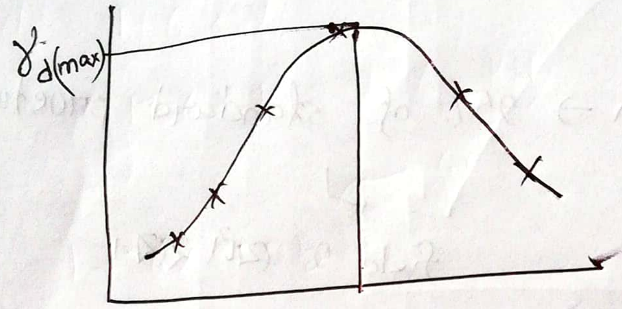
method specification (কম use করি)

layer thickness কত, number of pass → এসব process

(আবার কোন method এ কাজ করবে)

বলে দিব, ultimate value কত হবে সেটাই use করব (90%, 95% .....) accept করতে হবে

Characteristics of compaction curve :



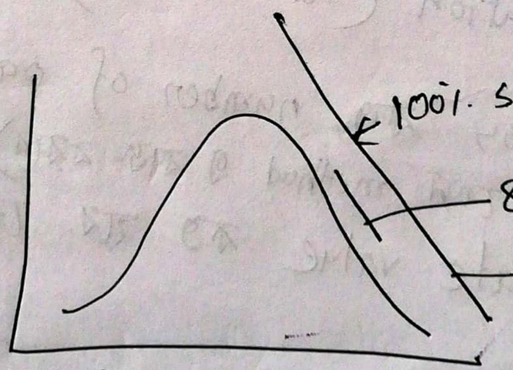
compactive effort (standard বা modified) এর উপর γ_d change হয় (not unique value)

γ_d (std) 95%

field এ এর চেয়ে বেশিও পাওয়া সম্ভব (like যদি আমি number of pass বেশি দেই, compact বেশি হবে) layer thickness ~~কম~~ change করি

~~Contt~~

~~Math~~



curve এ কিভাবে draw করতে হয় লিখব, না

$$\gamma_d = \frac{G_s \gamma_w}{1+e} = \frac{\gamma_{bulk}}{1+w}$$

$$S_r = \frac{wG_s}{e}$$

$$= \frac{G_s \gamma_w}{1 + \frac{wG_s}{S_r}}$$

$$e = \frac{wg}{S_v}$$

A nature soil deposit has bulk unit weight of 18.44 kN/m³ at moisture content of 5%. Calcu. the volm of water needed to raise the moisture content to 15%. Also calculate the volm of water required to make the soil sample fully saturated. Assume volm of the soil is given as 1 m³. $G_s = 2.67$

$\Rightarrow \gamma_{bulk} = 18.44 \text{ kN/m}^3$

$w = 5\%$ + addition water

$w = 15\%$

$\text{Vol}^m = 1 \text{ m}^3$

$$\gamma_d = \frac{\gamma_{bulk}}{1+w} = \frac{18.44}{1+0.05} = 17.6$$

weight of solid

$$\gamma_d = \frac{W_s}{V}$$

$$W_s = 17.6 \times V$$
$$= 17.6 \times 1 = 17.6 \text{ KN}$$

$$W_{w(5\%)} = 17.6 \times .05$$ ← ω

(−)

$$W_{w(15\%)} = 17.6 \times 0.15$$

1.76 KN ⇒ weight of water needed

$$\frac{\text{weight}}{\text{sp. gr.}} = \text{Volume}$$

~~1.76/9.8~~ $\boxed{\frac{1.76 \times 1000}{9.8} = 180 \text{ L} = V}$

Ans.

$$S_r = \frac{\omega G_s}{e}$$

$$\gamma_d = \frac{G_s \gamma_w}{1+e} \Rightarrow \cancel{17.6} = 2.6\times$$

$$= \frac{\omega G_s}{e} \quad G_s = 2.67, \; e = 0.49$$

$$\Rightarrow e = 0.49$$

$$\Rightarrow \omega = .18$$

18% পানি দিলে soil fully saturated হবে।

$$W_{w(18\%)} = 17.6 \times .18 = \cancel{3.168} \; \cancel{\text{KN}} \; 3.168$$

$$\frac{316.8 \times 1000}{\text{sp. gr}} = \text{vol}^m \text{ of water}$$

Ans

xm এ থাকবে
এমন math

Soil is to be excavated from a borrowed pit area having mass density 1.75 gm/cc at a moisture content of 12%. The soil is compacted at a moisture content of 18% at the finished site. And the dry density was 1.65 gm/cc. For 1000 m³ of soil in the finished site, estimate the volᵐ of soil to be excavated from the borrow area and also calculate amount of water to be needed at the finished site.

Gₛ না দেওয়া থাকলে কিভাবে করব? xm এ ওটা থাকবে

⇒ Borrow

1.75 gm/cc at 12%. $w = 12\%$

$$\gamma_d = \frac{1.75}{1+.12} = \frac{G_s \gamma_w}{1+e_b}$$

Finished

$w = 18\%$

$\gamma_d = 1.65$ gm/cc

$V_f = 1000\ m^3$

$$\gamma_d = 1.65 = \frac{G_s \gamma_w}{1+e_f}$$

পানি

?

$$\frac{V_b}{V_f} = \frac{1+e_b}{1+e_f}$$

1000

Ans. of moisture content ~~99 m³~~

Volᵐ of water needed 99 m³

14/5/19

$\boxed{\text{Lec-06}}$

Relative/percent compaction:

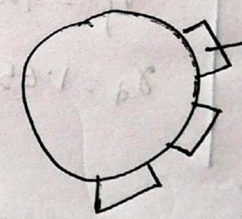
$= \gamma_{df}$ — field এর dry density

$$\frac{\gamma_{df}}{\gamma_{d\,max}\ (STD/MMD)}$$

standard/modified proctor

Equipment গুলো (field compaction)

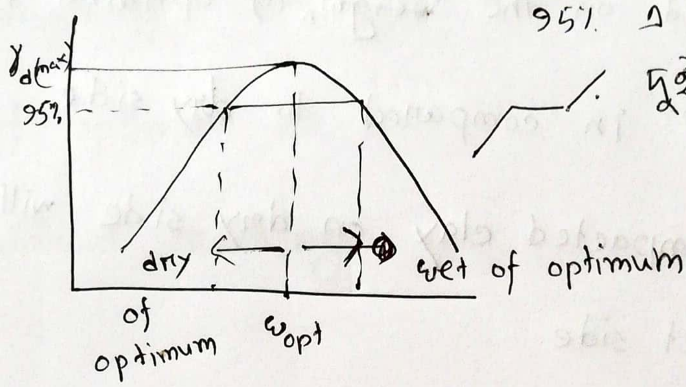
- smooth drum roller [300 - 380 KN/m² pressure]
- Pnumetic roller (4-6 টা time থাকে 600-800 KN/m² pressure]
- ~~seive~~ sheep foot roller



এটা হবে পায়া

- Vibratary roller (sandy type of soil এর জন্য)
- Impact hammer

এগুলোর short note (দরকার)

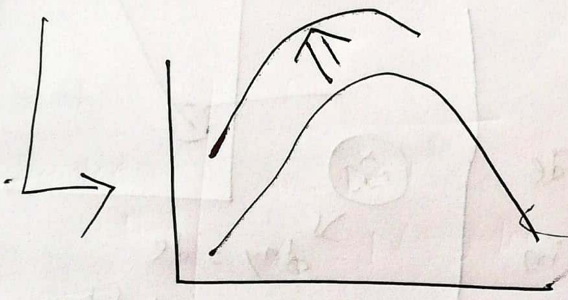


95% এ দুই type moisture content

দুই " "

এই 95%.

If you increase the compactive effort, this curve shifts to the left



Characteristics

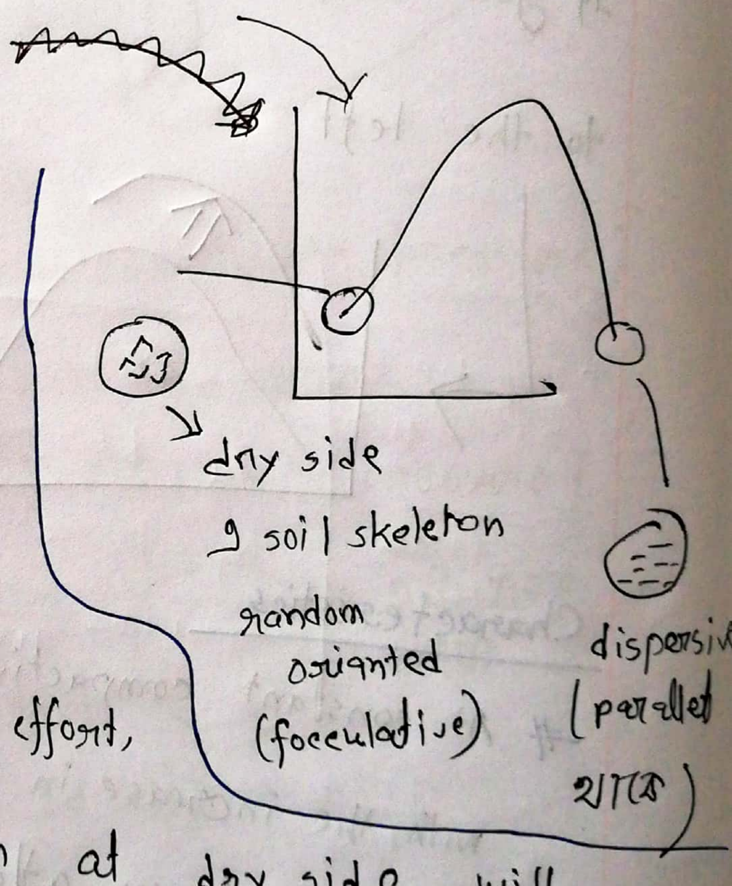
\# At constant compactive effort, permeability decreases with the increase in moisture content on the dry side of optimum, attains it's minimum value near about its optimum moisture content or little bit more than optimum. (wet side এ)

Clay compacted on the ~~weight~~ wet of optimum is more compressible in compared to dry side

Swelling of compacted clay on dry side will be higher than wet side.

Soil compacted on the wet of optimum show much more shrinkage.

The strength of compacted on the dry side of optimum will be more in compared to the wet side.



For the same compactive effort, the magnitude of strength at dry side will be lower in compared to the wet side

The soil compacted on the wet of optimum can undergo large deformation without failure /

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cracking. Earth dam usually compacted on the wet of optimum so that it can tolerate large settlement without cracking.

#

In short,

Left side (dry side) ⇒ opposite এগুলা wet side এ

High swelling

less shrinkage

Higher strength

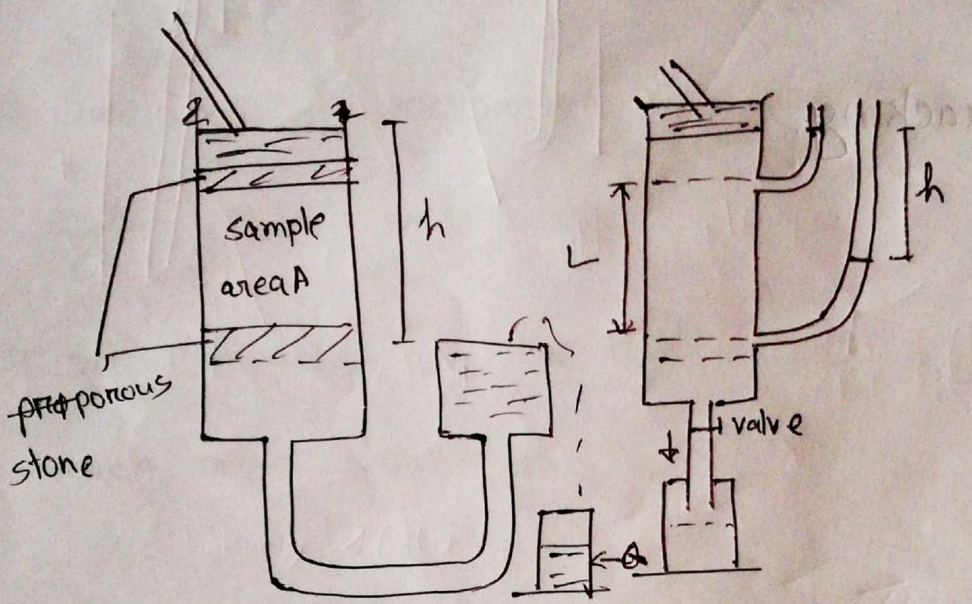
low strain

less compressible

Fluid flow through porous media: (seepage)

24/6/19

Lec-07



constant head method

Basic consumption:

1. Soil contains $\boxed{\text{continuous}}$ void. [Continuous নাহ হলে এ theory applicable না]

2. Soil must be fully saturated

3. laminar flow exist.

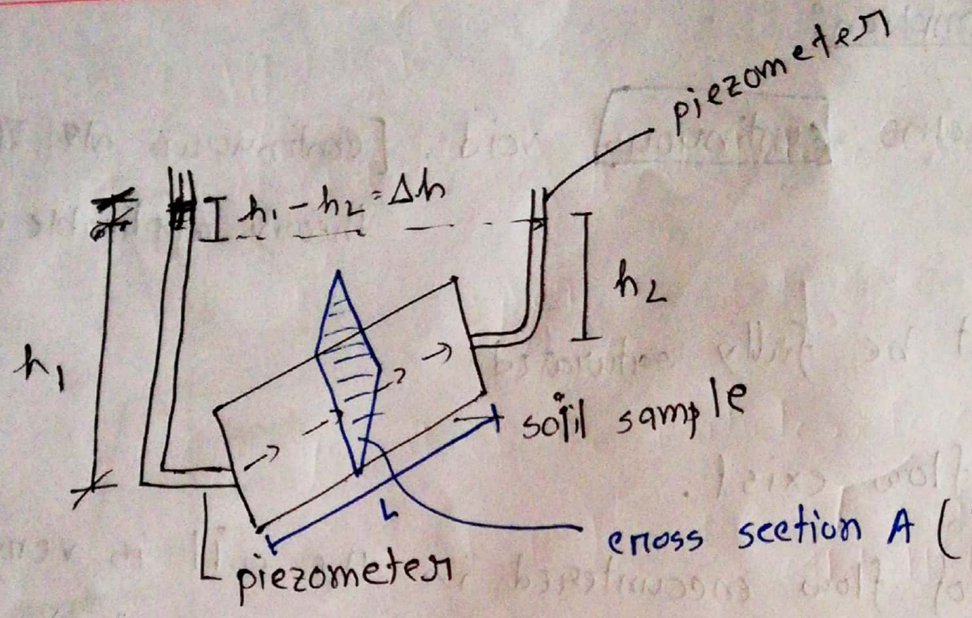
4. magnitude of Velocity of flow encountered in the soil is very small and that's why we neglect the contribution of velocity head $\left(\frac{V^2}{2g}\right)$.

Seepage:

The slow movement of water through the continuous voids of the soil sample is called seepage.

Permeability is the property which indicates how easily water can flow through the media

Gravel, বড় ... permeable, fine হতে থাকলে কমতে থাকে permeability, clay তে ~~প্রায়~~ is impermeable প্রায়।



~~veloci~~ Darcy বলেছে,

$v \propto i$ — Hydraulic gradient (no unit)

Discharge/ Apparent/ fictitious velocity — $v = ki$ — k co-efficient of permeability (velocity এর unit)

k যত বেশি তত easily পানি pass করবে।

Head loss

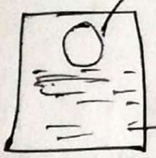
$$i = \frac{h_1 - h_2}{L} = \frac{\Delta h}{L}$$

[Head loss per unit length of the soil sample is i]

এটা gross area
এর ভিতর দিয়ে flow

∅ Fictitous velocity এর physical meaning কি ?

void area এর ভিতরে দিয়ে পানি flow করবে
(seepage)



Discharge V আর seepage V এর relation ?

Flow rate same, তাই seepage V > fictitous V

$$\frac{q}{t} = VA \qquad A_g = \text{gross area}$$

$$= V A_g = V_s A_v \qquad A_v = \text{void ''}$$

$$V = V_s \frac{A_v}{A_g} \qquad \text{[বের করব বাকিটা]}$$

Discharge Velocity: The quantity of water the percolates in unit time across unit areas of cross section which is oriented at right angle to the direction of flow.

পড়তে হবে short note Bowels থেকে xm এ আসে

Factors affecting k :

1. Size and shape of particle : Coarser the matter, k will be higher.

2. Arrangement of the particles : Foccculated / Dispersive
   বেশি পানি যেতে পারবে | সবচেয়ে কম যাবে

3. Void ratio : Higher হলে k এর value ও high.

4. Properties of the pore fluids (water):
   Unit weight আর viscosity (Temp.)
   ↓ বেশি হলে k কম ↓ বেশি হলে k কম

5. Degrees of Saturation : যত বেশি DOS, k তত বেশি,

☒ Determination of k value : (in terms of e and n

Co

Imperical formula:

Allen-Hazen Formula (1911): বই eq^n 2.4

$\boxed{K = CD_{10}^2}$ loose, coarse and ~~thin~~ clean sand

D_{10} cm এ express $C = 100$ ~~tems~~ per ~~cms~~ cm/s

Lab determination:

1. Constand Head Method: For coarser sand; $K > 10^{-2}$ mm/s generally. $\boxed{\text{Permeometer}}$ → এ apparatus use করব।

ছবি দেখার সুযোগ

Head remains constant throughout the period.

$Q/t = kiA = k.\frac{h}{L}.A$ [মোট container এ যত পানি জমা → Q]

2. Falling Head Method:

$10^{-2} - 10^{-5}/10^{-4}$ mm/sec $\}$ K

finer sand এর জন্য use করা হয়

ছবি বই এ permeometer এর.

saturated soil sample fully saturated হতে time লাগে অনেক। saturated হলে valve খুলে দিলে পানির level নামতে থাকে তাই falling/variable head.

$\underbrace{-a\,dh}_{Vol^m} = \frac{q}{k} \times dt = k\frac{hA}{L}dt$

reduction in head এর জন্য (−)

$\therefore -\int_{h_1}^{h_2} \frac{dh}{h} = \frac{kA}{La}\int_0^t dt$

xm এ আসবে
বই দেখব

দুটো system এর drawback:

field এর density lab এর করতে পারছি না

field এর arrangement disturb করছি lab এ আবার ~~Evor~~ time এ।

" " void ratio disturb করছি।

Air entrapped হয়ে থাকলে পানির flow তে disruption করে, k কম পাবো। lab এ admixture দিয়ে হয় air বের করার জন্য তাতে density নষ্ট হয়।

Ans.

~~Determination of 'k' is misnomar – explain~~ – Ques.

Determination of 'k' is misnomar – explain – Ques field condⁿ এ test করে এটা

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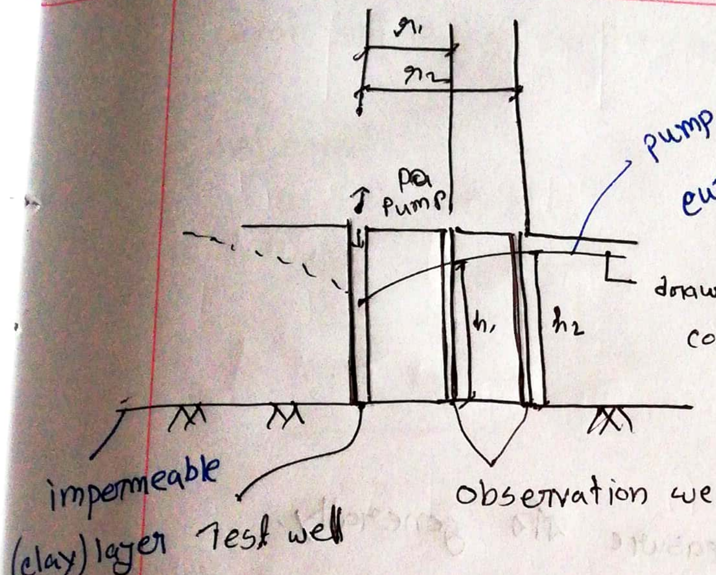
Lec-08

pump চালুর পর water table এমন curve হবে; আগে Horizontal ছিল (কারণ মোটা pipe এ বেশি পানি উঠবে)



$$q = kiA = k \cdot \frac{dh}{dr} 2\pi r h$$

$$\therefore q \int_{r_1}^{r_2} \frac{dr}{r} = \int_{h_1}^{h_2} 2\pi h \, dh$$

$k =$

ear n 2·7 হই এ

expensive এই method.

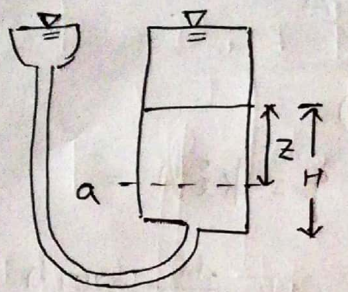
যেখানে অনেক depth এ ~~measure করে~~)

~~হবে~~ suppose deep tubewell বসানো হবে।

clay থেকে পানি extract করা যাবে না।

মোটা sand layer এ কম power দিয়ে পানি তোলা যাবে। (মোটা sand layer খুঁজে বের করতে হবে) ঢাকায় আগে 300'-350' নিচে ছিল আগে। এই layer water supply দেয় → Aquefa(?) → porous formation হই।

Stress in soil:



ছবি বই ৩ →

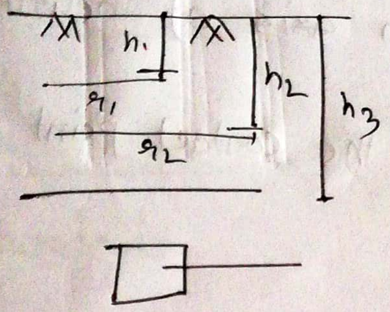
Stress at a point always measure কৰি generally.

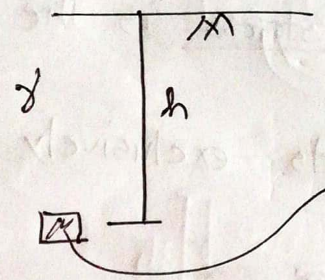
The total stress at a point on a mass of a saturated soil is composed of 2 part →

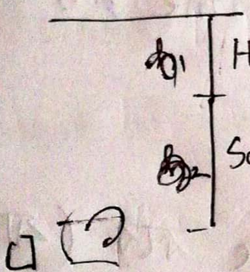
1. Neutral stress / pore water pressure
2. Effective stress

→ it acts in equal magnitude in all direction (F.M. ৰ Hydrostatic pressure)

Total stress σ is the stress contributing by overlying material.







$\gamma_w \times$ ~~h_1~~ heigh
$+$
~~$\gamma_s \times h_2$~~
$=$ ~~Total stress~~ $=$ total stress

H_2O এর $\gamma \times$ height $+$ soil এর $\gamma \times$ height

One part is called neutral stress which acts in the water and on soil skeleton with equal magnitude in all direction.

principle of effective stress and its importance — Ques.

$$\overset{10}{p} = \overset{3}{u_w} + \bar{p}$$

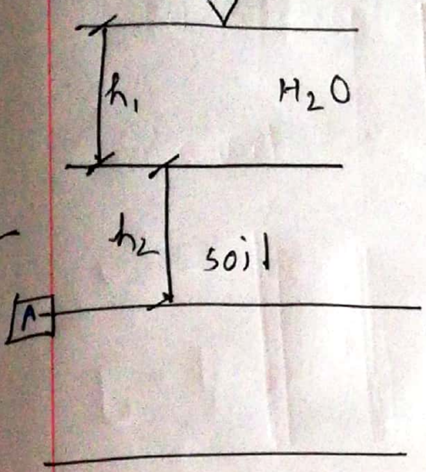
$$\bar{p} = p - u_w$$

Effective stress is the stress in ~~axis~~ excess of neutral stress which acts exclusively between the contact point of soil skeleton.

Effective stress is solely responsible for inducing volume change behaviour and it also provides the ~~fr~~ frictional resistance.

effective stress এর কারণেই soil settle করে (মানে volume change). Frictional resis

Neutral stress has no role in inducing volume change behaviour ~~not~~ ~~n~~ nor does it ~~provide the responsib~~ provide any frictional resistance.



soil fully saturated

Total stress

$p_A = h_1 \gamma_w + h_2 \gamma_{sat}$

Neutral stress at A, $u_A =$

$(h_1 + h_2)\gamma_w$ [principle of hydrolaics)

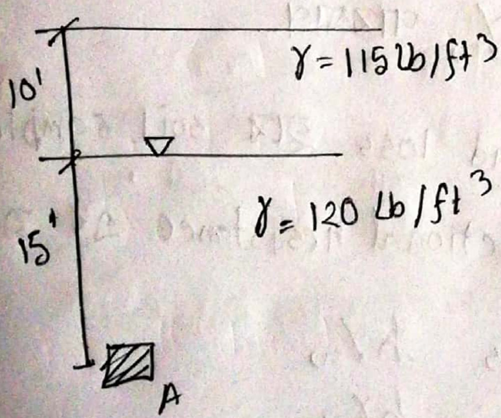
effective stress $p_A - u_A =$

$h_2 \gamma_{sat} - h_2 \gamma_w$

$\bar{p} = \underbrace{(\gamma_{sat} - \gamma_w)}_{\gamma' \text{ (}\gamma \text{ effective} / \gamma_{submerged} / \gamma_{buiyant})} h_2$

$= \gamma' h_2$

Effective stress is independent of water height above the soil sample (h_1 নাই)



$p_A = 115 \times 10 + 120 \times 15 = 2950$

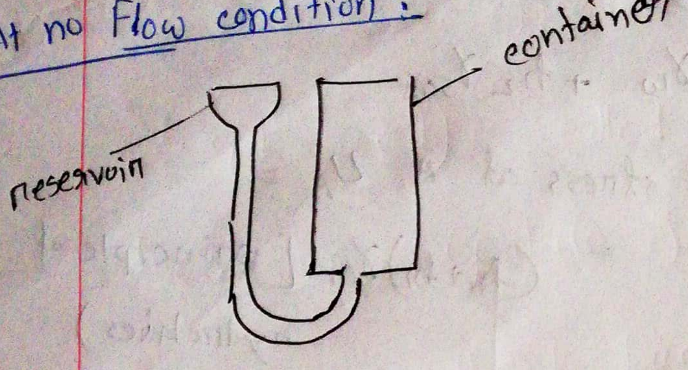
$u_A = \underbrace{15}_{\text{যতটুকু পানি আছে}} \times \gamma_w (62.4) = 936$

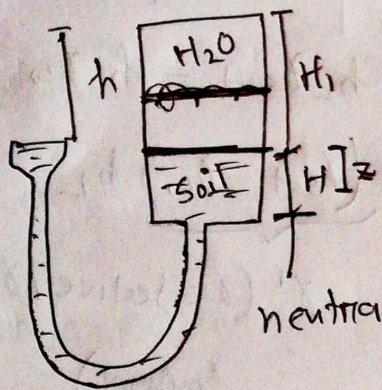
$\bar{p} = p_A - u_A = 2014$

$115 \times 10 + (120 - 62.4) \times 15 = \bar{p}$

পানি নাই উপরে soil এর conth

At no Flow condition :





neutral ~~stress~~ stress $u_w = (H_1 + H - h)\gamma_w$

neutral stress কমে যাবে ~~$H_1\gamma_w + \gamma_s$~~ $h\gamma_w$

h নামালে neutral stress কমে। p same থাকে।

∴ $\bar{p}$ বাড়বে। বাড়বে $h\gamma_w$ পরিমাণ

↓

head loss হবে soil sample

এর frictional resistance এর জন্য

H এর জন্য Head ~~Ho~~ loss $h\gamma_w$

1 " " " " $\frac{h\gamma_w}{H}$

z " " " " $\frac{h\gamma_w}{H} \times z$

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Total stress same থাকবে।

$\frac{h}{H} = i$ $\frac{h}{H}\gamma_w \times z$

$\boxed{= i z \gamma_w}$

$\therefore$ effective stress $\bar{p} = \gamma' z$ [at no flow condition]

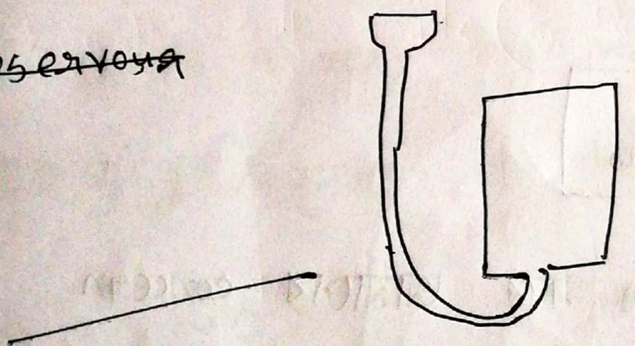
(z depth এ)

~~fro~~ flow এর time এ head loss এর জন্য $\bar{p}$ বেড়ে যাবে

$$\bar{p} = \gamma' z + \underbrace{i z \gamma_w}_{\text{seepage pressure}}$$

direction of flow ছিল downward এই case এ

~~reservoir~~



পানি reservoir থেকে container এ flow করে

এই case এ upward movement হবে water এর। এই case এ effective stress কমবে

$$\bar{p} = \gamma' z - i z \gamma_w$$

Lec-09

26/6/19

The increase in effective stress due to the flow of water (downward) is called seepage pressure or seepage stress. The magnitude of " " is $iz\gamma_w$.

It is the result of frictional drag of the flowing water onto the soil skeleton.

Reservour যদি container এর চেয়ে উপরে থাকে flow will be from reservour to container (upward)

তখন $\bar{p} = \gamma' z - iz\gamma_w$

$$\boxed{\therefore \quad \bar{p} = \gamma z \pm iz\gamma_w}$$

Upward movement problem করে আমাদের concern

যত reservour তুলব, $\bar{p}$ কমাতে কমাতে 0 হবে।

$i_c \rightarrow$ critical hydraulic gradient $\rightarrow$ যেখানে effective stress 0 হবে (upward flow তে)।

$\bar{\sigma} = \gamma' z - z i_c \gamma_w = 0$

$$i_c = \frac{\gamma'}{\gamma_w} = \frac{G_s - 1}{1+e}$$

Quick

~~Quick~~ sand (under this condition) completely looses it's strength.

finer material (fine silt এর মত)

Quick sand is not a particular type of soil.

It refers to a particular condition (when it completely looses it's strength, co-efficient of permeability reaches a very high value, severe edgitation (জলের মত বুদবুদ) occurs of the cohesionless soil.

$e \rightarrow 0.5 \sim 0.9$

0.7 – mean value ধরলে i_c approaches unity.

i_c এর value $(0.9 \sim 1)$

In water to exist quick condition, 2 condth:

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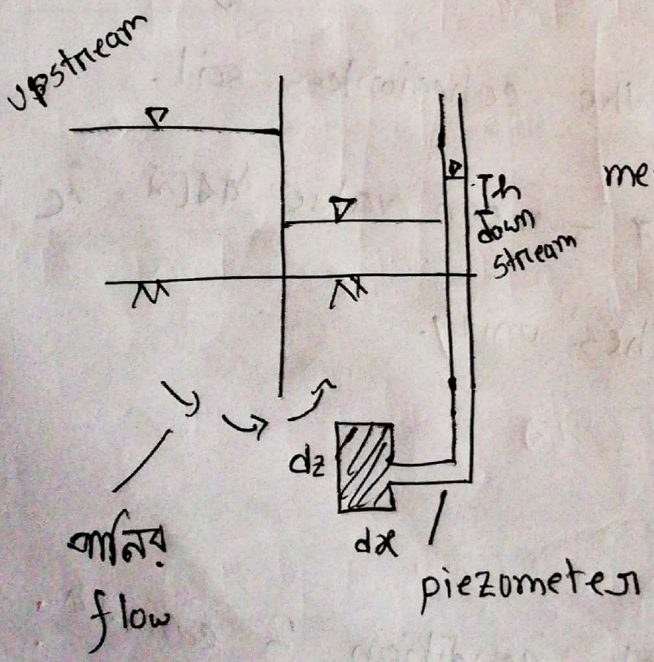
① effective stress must be 0

② frictional resistance ~~∝~~ proportional to the effective stress.

It occurs mostly in fine sand and silt.

It can't occur in coarse sand because larger the particle size, greater the porosity and to maintain critical hydraulic gradient, larger velocity of flow is required which normally doesn't occur in nature.

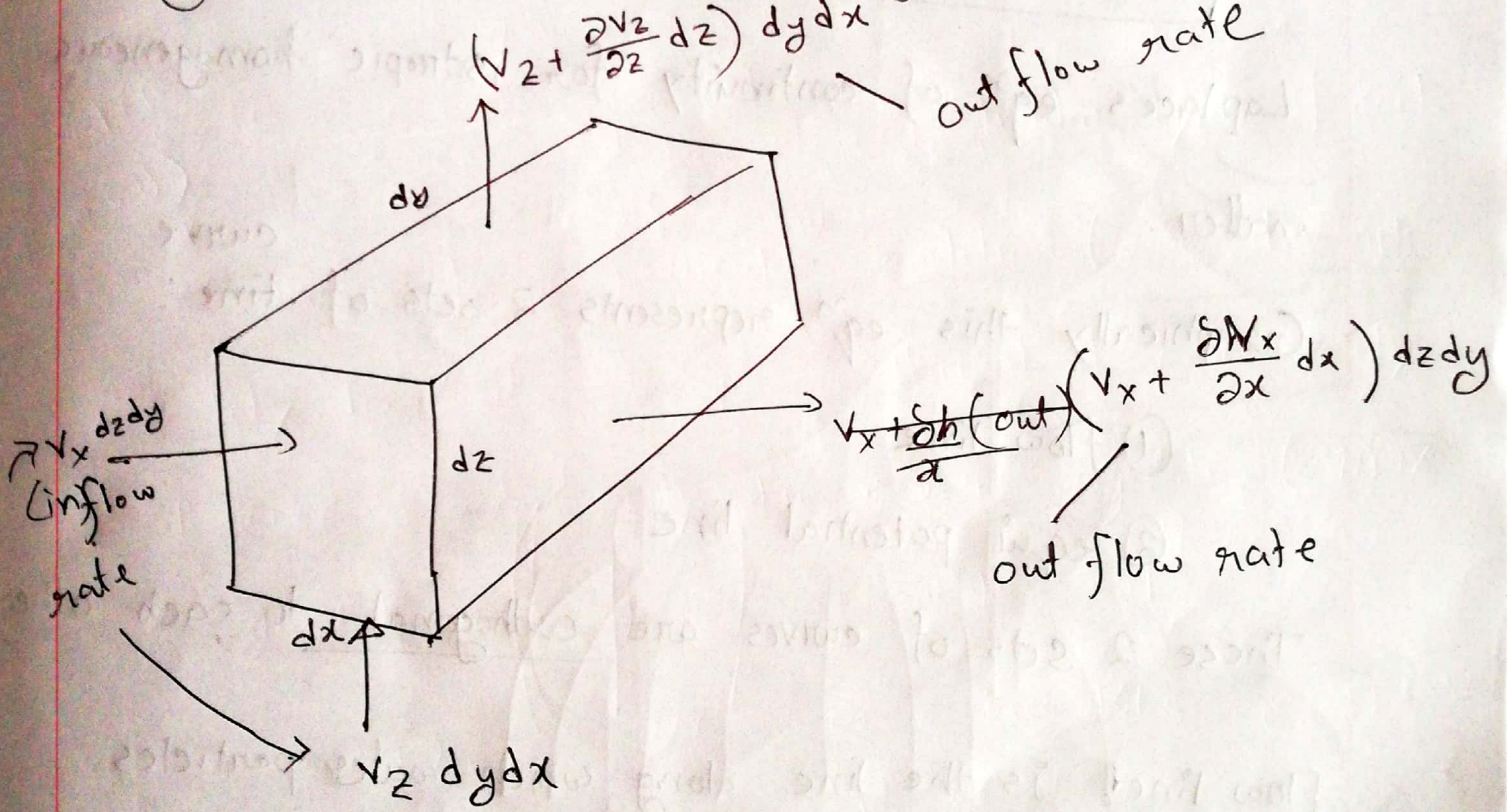


sheet pile → completely stops the flow of water.
/
metal

h → driving head responsible for flow of water from upstream to downstream.

Assumption:

1. Soil is fully saturated
2. Darcy's principal applicable
3. Steady state $cond^n$ (no volume change)
4. ~~Madem~~ Material must be homogeneous and isotropic.



Net rate of flow = 0 $\qquad$ $dx\, dy\, dz \neq 0$

$$\therefore \frac{\partial V_x}{\partial x} dx\,dy\,dz + \frac{\partial V_z}{\partial z} dx\,dy\,dz = 0$$

$$\therefore \frac{\partial V_x}{\partial x} + \frac{\partial V_z}{\partial z} = 0$$

$v_x = ki$

$v_x = k \frac{\partial h}{\partial x}$ $\qquad$ $v_z = k \frac{\partial h}{\partial z}$

coefficient of permeability $\neq 0$.

$$\boxed{\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial z} = 0}$$

Laplace's eq^n of continuity for istropic homogeneous matter.

Graphically this eq^n represents 2 sets of ~~line~~ curve:

① flow line

② equi potential line

These 2 sets of curves are orthogonal to each other.

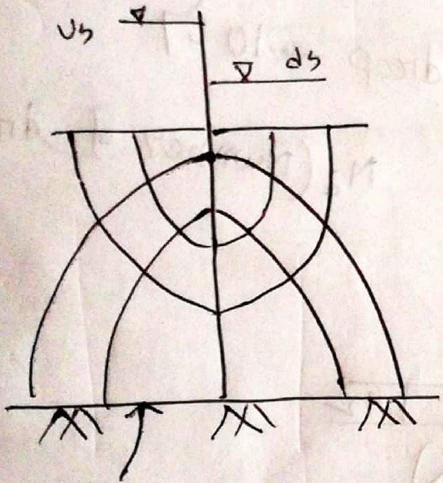
Flow line: is the line along which water particles moves from upstream to downstream

Equipotential lines: are lines where all piezometric reading will be same.

1/7/19

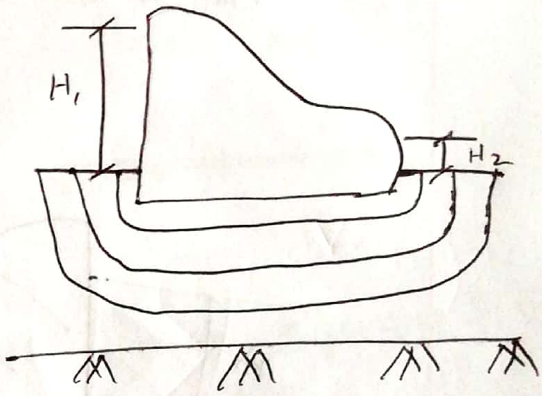
Lec-10

The region bounded ~~by 2~~ between 2 successive / adjacent line is called flow channel. And the element bounded by 2 adjacent flow line and 2 adjacent equipotential line is called flow element.



impermeable layer/ clay layer

sheet dam



concrete dam

And the combination of equipotential line, flow line, flow channel and flow elements is called flow net diagram.

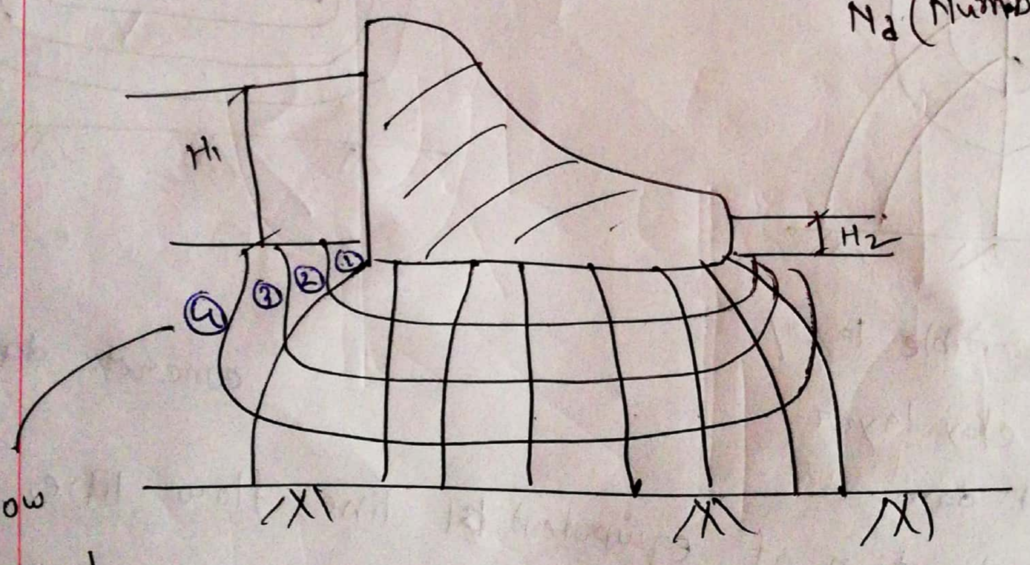
Using this, we can calculate seepage loss (flow that occurs from upstream to downstream). We can also compute the effective stress and pore water pressure in the entire domain (flow net diagram) which helps us to determine the stability of hydraulic structure.

Flow Net diagram কিভাবে draw করব:

1st এ boundary তে কি কি condition আছে চেক করব।

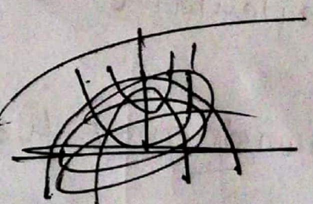
drop — 10 টা

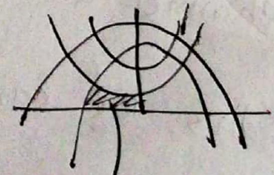
N_d (Number of drop)



flow channel 4 টা

channel number fraction ও হতে পারে। (যেখানে ঘর curvilinear square না) যেমন

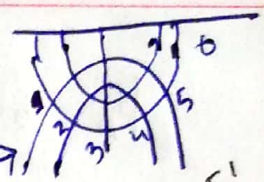




এই channel square না, fraction আসবে; না

No. of drop will be 1 less than no. of equipotential line

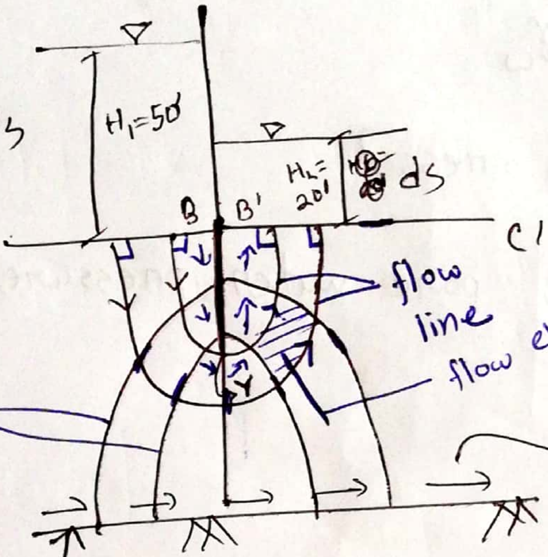
পানি flow করে 30' loss হলো



6টা drop → (Head loss)

1টা drop = 5'

$\gamma = 130\ \#/ft^3$



Impermeable layer.

B'C' equipotential line

AB' ও line

~~B'Y → flow line~~

$N_d = 6$

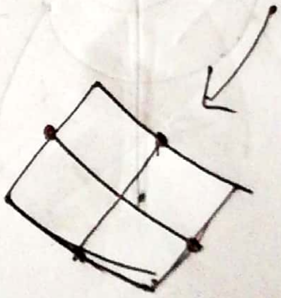
$H = H_1 - H_2$

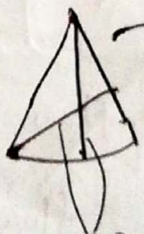
$= 30 = H$

$\dfrac{H}{N_d}$

xm এ (2-4)টা flow line draw

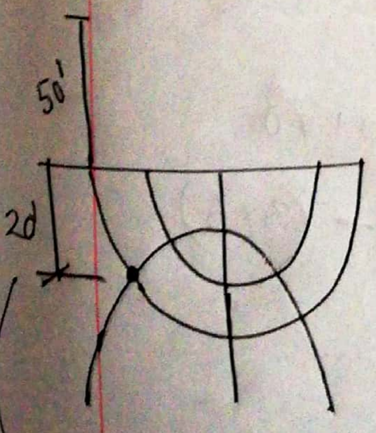
flow element curvilinear square হবে





এ রকম আসবে

এই দুই length আসবে



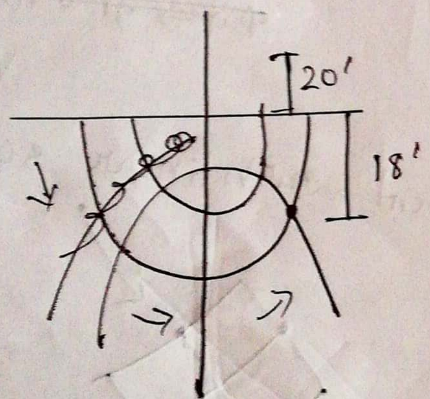
এখানে piezometer বসালে 70' পাওয়ার কথা। 5' drop এর জন্য 65' পাবো।

$p_A = 50\gamma_w + 20\gamma_{sat}$

$U_A = (70-5)\gamma_w$

effective ~~pressure~~ stress?

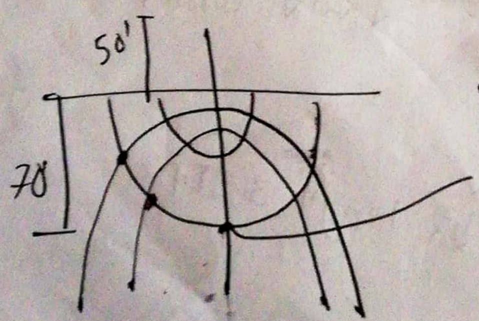
* যে কোন point এ pore water pressure, effective stress → Ques.



$\gamma_B = 43\gamma_w$

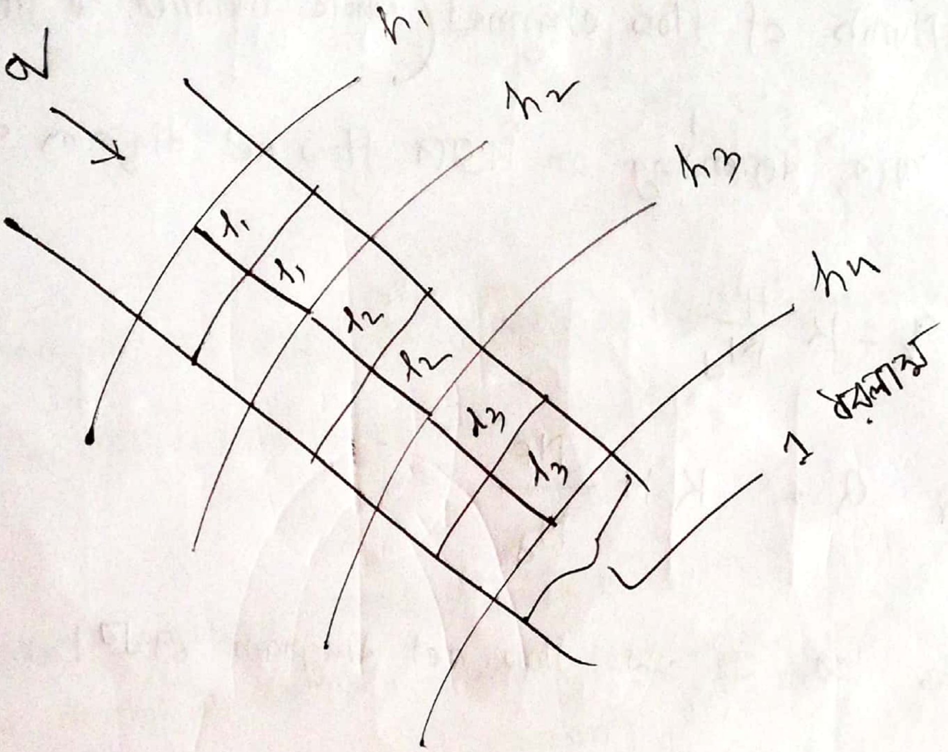
$(20+18+5)$ → এখানে (+)ve হবে downstream এ নিয়েছি

upstream এ করলে (−)ve হবে।



No flow condn এ 50+70

flow হলে → $120 - (3\times5)$



$q = kiA$

যে পানি এই channel

দিয়ে ঢুকবে, সেটাই বের হবে;

no flow across the channel.

$h_1 - h_2 = \text{drop}$

$$q = k \cdot \frac{(h_1 - h_2)}{l_1} l_1 \times 1 = k \frac{h_2 - h_3}{l_2} l_2 \times 1 = \ldots$$

$$k(h_1 - h_2) = k(h_2 - h_3) = k \ldots$$

$$\therefore h_1 - h_2 = h_2 - h_3 = h_3 - h_4 = \ldots$$

[সব drop এর মান সমান

$$\therefore q = k \cdot \frac{H}{N_d}$$

N_F = Numb. of flow channel (whole number বা fraction হতে পারে depending on কিভাবে flow net diagram draw করছি)

$$q = K\frac{H}{N_d}$$

$$Q = KH\frac{N_F}{N_d}$$

B. M. Das এর বই এর flow net diagram দেখবো।

Peck এর বই এর টা modify করে sin xm এ দেয়।

2/7/19

Lec – 11

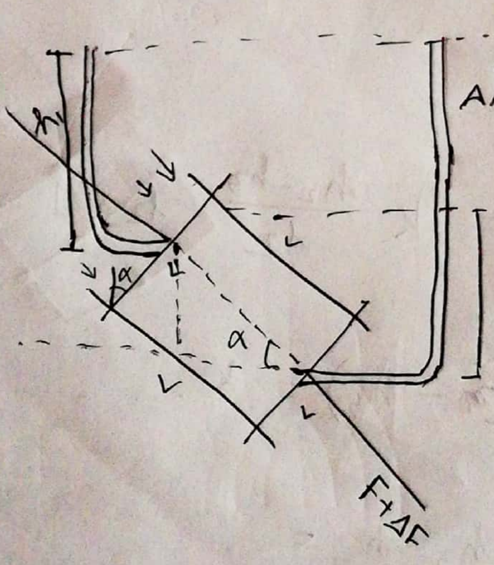
বই ⇒

γ_{sat}

~~L×ΔY~~

$L \times L \times 1 \times \gamma_{sat}$

self weight downward কাজ করবে



$$\Delta F = h_1\gamma_w \times L \times 1 - h_2\gamma_w L \times 1 + L.L.1.\gamma_{sat}.\sin a$$

$$h_1 + L\sin a = \Delta h + h_2$$

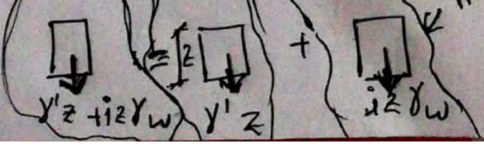
$$h_2 = h_1 + L\sin a - \Delta h$$

⇓

$\Delta F =$

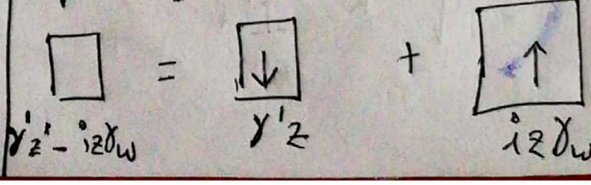
Flow through a inclined flow element

$p' = \gamma' z \pm iz\gamma_w$ downward movement



upward movement

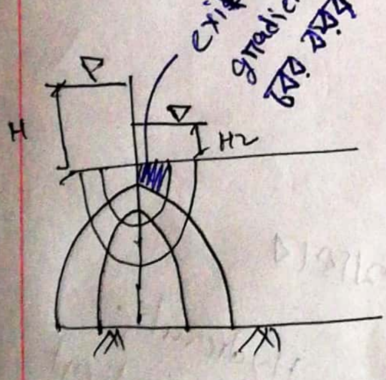
$p' = \gamma' z - iz\gamma_w$



Hydraulic gradient বেশি হলে prob ⇒
upward এর flow বেশি হলে quick condⁿ হবে soil এ; soil সরায় ফেলবে। তাই river bed এ upward movement quick sand condⁿ হতে পারে।

Exit gradient বের করে যদি দেখি critical hydraulic gradient থেকে কম, তাহলে structure stable.

check the stability বললে → Quick condition যেন develop না ~~হবে~~ করে। → Heaving (subsurface erosion)



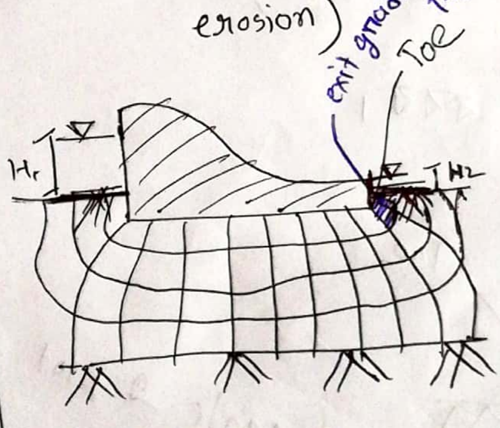
No. ~~fo~~ of flow channel

$N_F = 2.5/2.6/2.7$

$q = KH\frac{N_F}{N_d}$ $N_F = 2.5$, $N_d = 6$

6 মাসের জন্য seepage loss?

width দেওয়া না থাকলে unit.



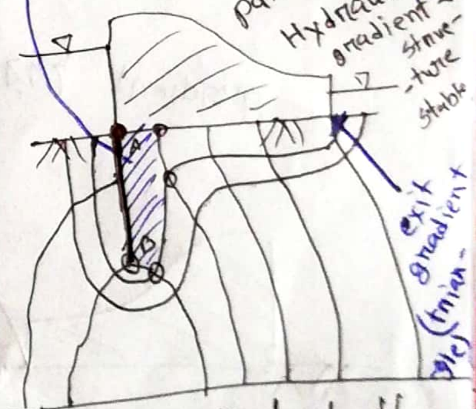
$N_F = 4$

$N_d = 11$

$H = H_1 - H_2$

Curvilinear square না

AB – steel এর section
Length of the drain path বাড়বে।
Hydraulic gradient কম structure stable



A B vertical cut off

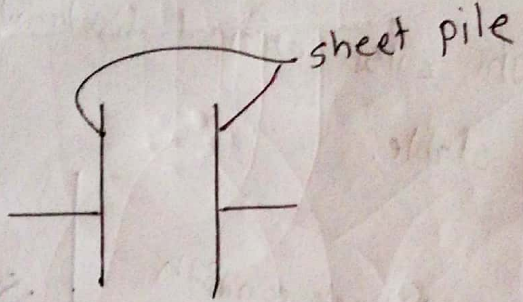
দুটো vertical cut off?

কেমন হবে দেখব

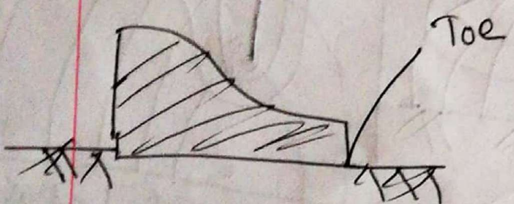
Scanned by CamScanner

$$i_{cr} = \frac{\gamma'}{\gamma_w} = \frac{G_s - 1}{1+e} \approx \boxed{0.9 \text{ to } 1.1}$$ যদি না দেয়া থাকে

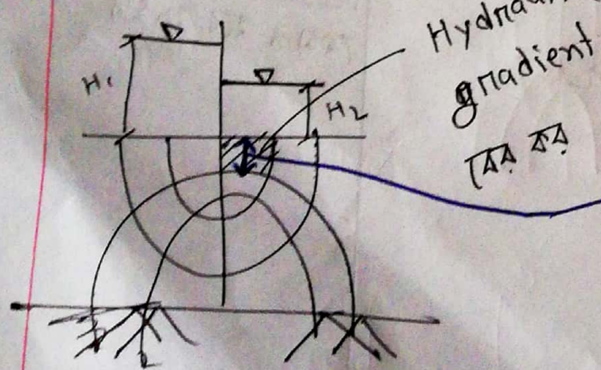
[illegible]



Nearest toe তে যে flow element থাকে তার exit gradient বের করব।



scale এ plot করা থাকবে



$$\frac{\overbrace{\dfrac{H_1 - H_L}{N_d}}^{\text{Hydraulic gradient}}}{l}$$

বের করে critical hydraulic gradient এর সাথে compare করে দেখব Quick cond^n থাকবে নাকি না।

F.S. → Harza ~~বড়~~ হলেও 3 দিতে হবে।

$$F.S. = \frac{i_{exit}}{i_{cr}} > 3$$

Flow through inclined এর continue →

seepage force

$i\gamma_w$

$$\frac{\Delta h \gamma_w L}{\underbrace{L^2 \times 1}_{vol^m}} = \underbrace{\frac{\Delta h}{L}}_{i} \gamma_w = \text{seepage F}$$

per unit volume of the soil sample is always equal to $i\gamma_w$

it acts along the direction of flow

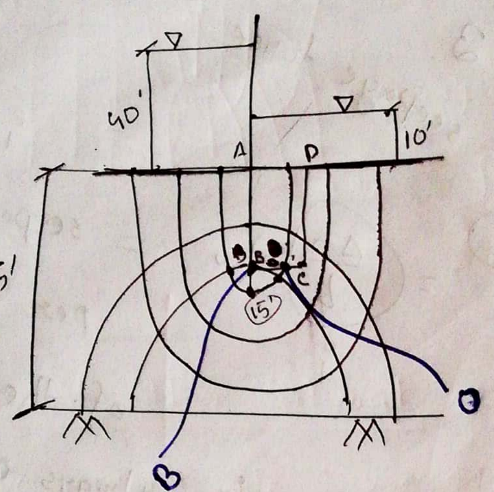
$i_z \gamma_w$

$iz\gamma_w \Rightarrow$ seepage pressure

$A.iz\gamma_w \Rightarrow$ seepage force

$$\frac{\cancel{A}.i\cancel{z}\gamma_w}{\cancel{A}.\cancel{z}} = \text{" " per unit volume} = i\gamma_w$$

#



Q1 $N_F = 3.6$

$H = 30'$

$N_d = 6$

$K = ?$ — (দেয়া থাকবে)

q বের করব

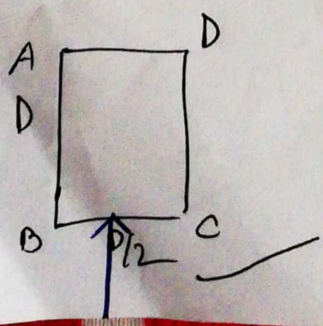
stability check কর।

নদীর fine siltty sand এ highly susceptable to quick condition

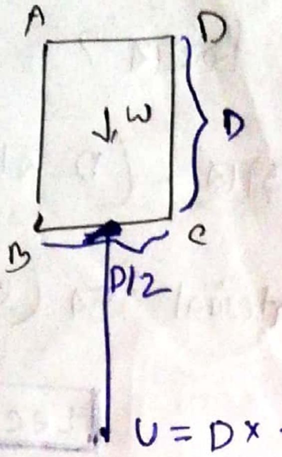
clay তে quick cond^n arise করে না কেন? → Ques.

$AB = D$ $BC = D/2$

ABCD area ~~এর~~ এর soil কে protect করাতে পারলে (downstream side of the sheet pile) তখন বলা যাবে structure good condition এ আছে।



seepage force কাজ করছে (upward)



$$W = D \times \frac{D}{2} \times 1 \times \gamma'$$
$$\downarrow$$
$$(\gamma_{sat} - \gamma_w)$$

downward direction

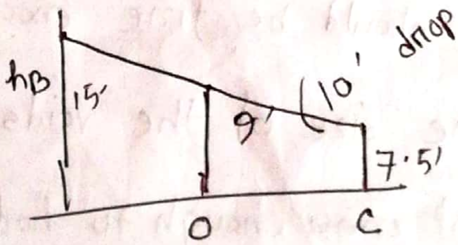
$$U = \underbrace{D \times \frac{D}{2} \times 1}_{\text{volume}} \times \underbrace{i\gamma_w}_{\text{seepage F per unit volume}}$$

soil এর ভিতর দিয়ে যাওয়ার time এ frictional loss উপরে

1টা drop 5'

$h_B = 15'$

(drop এ loss হওয়ার পর)



(10' drop এর পর একটু উপরে c point 60 হয়েছিল 1' drop হয়ে 9' হল)

h Avg বের করব $= \frac{15' + 7.5'}{2}$

$\frac{15' + 9' + 7.5'}{3}$

time থাকলে weigted avg বের করব (moment নিয়ে)

driving head এর magnitude → h_{avg}

$$i_{av} = \frac{h_{avg}}{D}$$

$$F.S. = \frac{\gamma'}{i_{av}\gamma_w} = \frac{i_{cr}}{i_{av}}$$

L এই formula তে 4~5 দিতে হবে

যদি F.S. কম হয়, তাহলে বাড়াবো কিভাবে ?

Length of drainage path বাড়াবে (D বাড়াবো) /

Downstream side এ filter material দিব (তাতে

Lee-12

8/7/19

Use of filter material:

Downstream side এ use করব। কিছু condition satisfy করতে হবে filter material কে। 2 criteria -

downstream side এর material

(1) A filter " should be fine enough to retain the base materi

that means the size of the voids in the filter material should be smal ~~enao~~ enough to hodd the larger particles—

of the ~~#~~ protected material in place (নাহলে subsurface erosion হবে)

② A filter material should be coarse enough ~~to show~~ so that water can readily pass through it without creating obstructions. That means the filter mat. should have high permeability to prevent build up of large seepage force and hydraustatics pressure in the filter material

২টো criteria কে বলে Permeability criteria.

Condition 1 will be satisfied if $\boxed{\frac{D_{15}(F)}{D_{85}(B)} \le 4 \text{ to } 5}$ filter mat. Base mat.

1971 এ হয়েছে Condition 2 " " " " $\frac{D_{15}(F)}{D_{15}(B)} \ge 4$ to 5

$D_{15}(F)$ means diameter through which 15% of the filter material will pass. The following conditions for design of filter :

① To avoid movement of the particles of protected soil (Base soil).

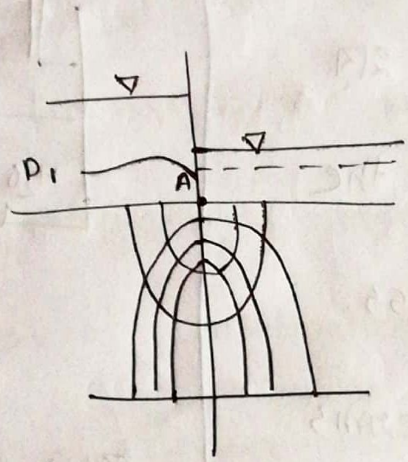
$\frac{D_{15}(F)}{D_{85}(B)} < 5$ and $\frac{D_{15}(F)}{D_{15}(B)} < 25$ and also $\frac{D_{15}(F)}{D_{15}(B)} < 20$

If uniformity co-efficient of the protected soil is ≤ 1.5, then $D_{15}(F)/D_{85}(B)$ may be increased to 6.

cont. (পরের 1 পৃষ্ঠা পরে)

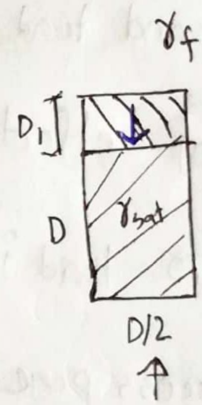
If e_v of the protected soil > 4, then $\frac{D_{15(F)}}{D_{15(B)}}$ may increase to 40. Further, avoiding build up of seepage F, US Navy recommends $\frac{D_{15(F)}}{D_{15(B)}} > 4$.

$F_s = ?$ বের করো



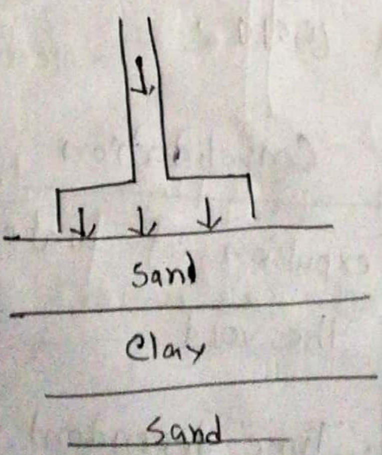
AB = D

γ_f



next class এ ct (মঙ্গলবার)

Capilary rising soil:



load → 10 psi ; load নিবে
effective stress আর neutral stress

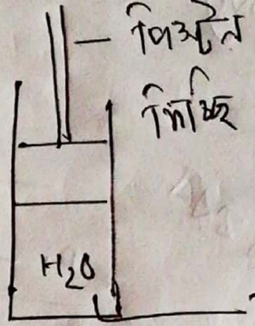
sand এর coeff. permeability clay " " " এর চেয়ে 10^8 গুণ বেশি।

Sand layer এ load আসলে

পানি আর বের হয়ে যাচ্ছে। Normal stress অল্প একটু হয়ে নাই, আর effective stress. Clay layer দিয়ে পানি বের হতে অনেক বেশি time নিবে।

Sand layer এ পানি বের হয়ে গেলে sand load নিবে in the form of effective stress.

Clay তে load নিবে in terms of excess pore water pressure.



— পিস্টন দিয়ে load দিচ্ছি

— পানি load নিবে কারণ পানি বের হতে পারছে না। তখন এই P কে বলবে excess pore water pressure.

Dissipation?
~~Precipition~~ of excess pore water pressure → পানি বের হবে অনেক আস্তে, ~~voi~~ volume decrease করবে → settlement দেখাবে।

Compaction	Consolidation
expulsion of air from void	expulsion of water from the void
মোটামোটি জলদি হয়।	Time dependant process (অনেক time লাগে)

A decrease in water content of a saturated soil without the replacement of water by air — Consolidation.

Vol^m change ~~va~~ হয় void space থেকে পানি যাওয়ার জন্য।

The process of gradual load transfer from the excess pore water pressure to the soil skeleton (effective stress) and the corresponding gradual compaction (settlement) is called process of consolidation. It is a time dependant process. [xm এ ~~effective~~ excess pore water pressure define আগে করতে হবে।]

Excess pore water P → piezometer দিয়ে measure। 10 psi দিলাম।

8 hr পর দেখলাম piezometer reading 9 psi, বাকি 1 psi effective stress.

2 দিন পর piezo " 8 psi, " 2 psi

হবে " " "

এর theory

Tarzaki 1 dimensional consolidation theory

1D কারণ পানি শুধু vertical direction এ বের হবে।

Oedometer / Consolidometer :

Cylindar ~~sape~~ shape curve ; 60 mm – 75 mm Dia ;

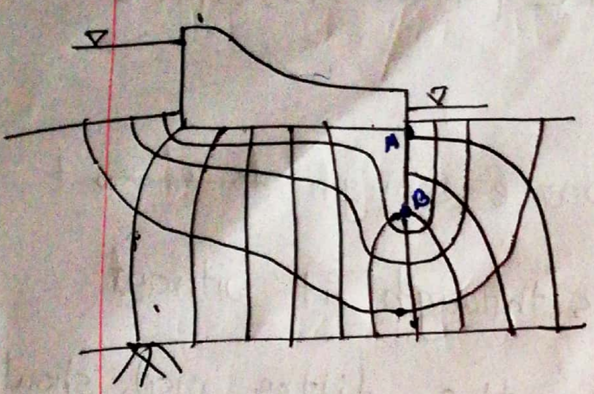
3/4" – 1" → thickness   Oedometer .

এর ভিতরে sample নিয়ে consolidation test করব।

Settlement criteria controlling factor → structure এর (90% time Consolidation থেকে পাবো।

Lec – 13
9/7/19

downstream
→ cut of দিলে
length of drainage
বেড়ে যেল



$N_F = 3.4$

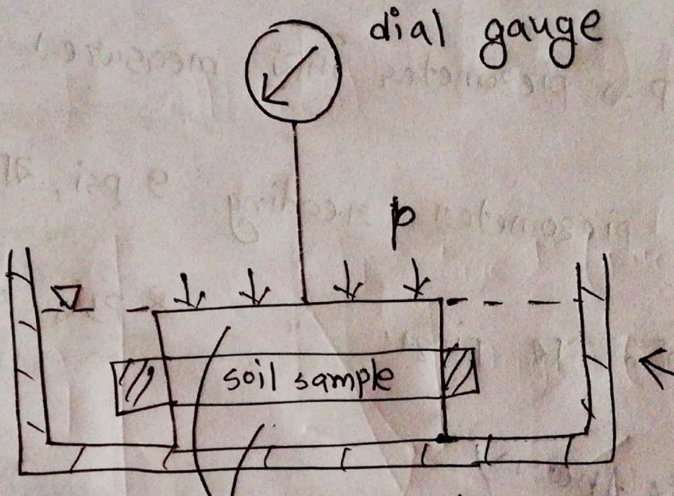
$N_d = 11$

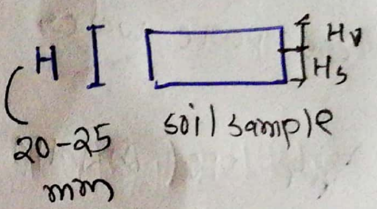
Hydraulic structure এর width বাড়ালেও length বাড়বে (but expensi

Filter material → Quick condt^n যাতে arise না করে তা ensure করবে।

Consolidation থেকে শেষ।

Lec-13
9/7/19





যে depth এ consolidation characteristic দরকার হবে

depth এর soil নিব (shelvi tube)?? দিয়ে drive করে

soil sample collect করি, the wax দিয়ে seal করে lab এ

আনি যেন moisture loss না হয়। খুব soft clay - 2.5 kPa
normal " - 5-10 kPa

Oedometer এ soil এ pre-loading দেই ; তখন soil swell

করে। 24 hour রাখা হয় এখন এভাবে (stable করার জন্য)

porous stone এর dia sample এর dia থেকে হালকা কম হয়

যাতে penetrate করতে পারে।

15 sec, 30 sec, 1 min, 2 min, 4 min, 8 min, 15 min, 30 min,

1 hr → reading নিব then 2 hr, 4 hr, 8 hr পর্যন্ত যায়

overnight রাখা হয়। { পরের দিনে এটা 16-18 ঘন্টাই হয়

reading নিয়ে আবার load increment করা হয়।

10, 20, 40, 80, 160, 320, 640 kPa → এ এভাবে

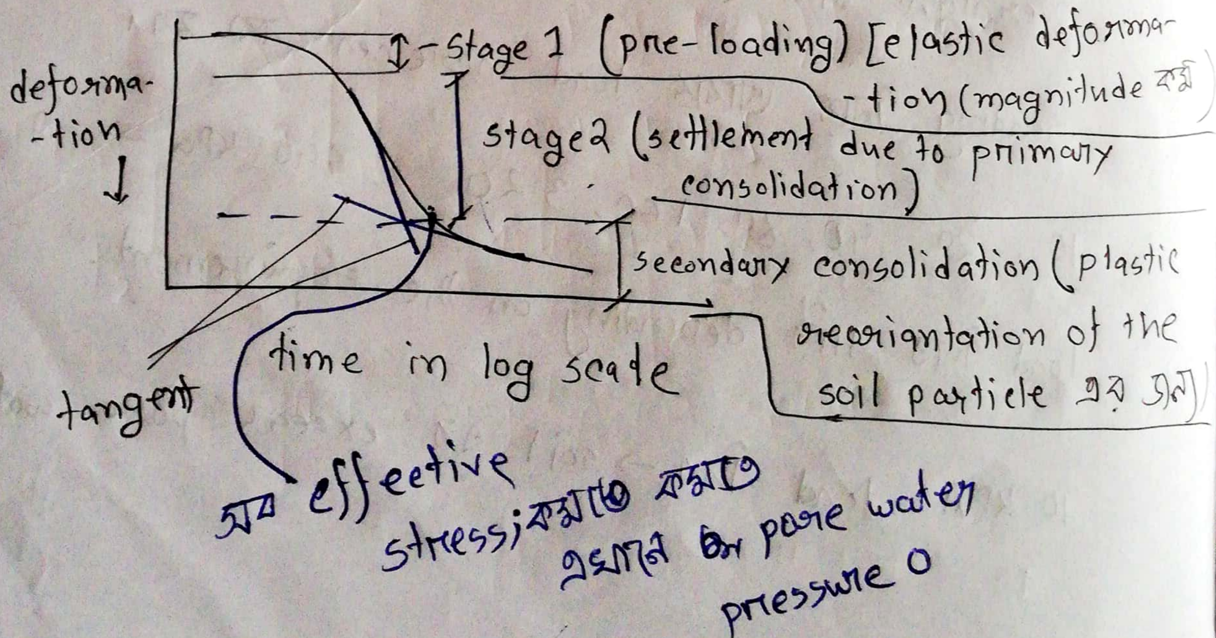
load দিতে পারি depending on the requirement.

10 kPa load দিব → soil এর excess pore water pressure

→ then soil squeeze করবে → Pressure release → dial gage এর reading কমে যাচ্ছে → ~~২৪ hr পর পর্যন্ত~~ suppose 8 kPa হল → ৪ (মানে ৪ kPa effective stress এ convert হল) → ২৪ hr পরেও যদি দেখি reading ~~change না~~ না পাই আর dial gauge এর তাহলে বলতে পারব যে load দিয়েছি তা fully converted to effective stress.

এটা consolidation settlement ~~assoc~~ / ~~consolidation~~ settlement related with primary consolidation.

3 types of settlement



secondary consolidation → soil এ organic matter থাকলে excess pore water pressure ~~শূন্য~~ 0 হয় যাওয়ার পরেও settlement হতে পারে।

sand এ → stage ২ নাই (শুধু stage 1)

Normally stage 1 আর 3 এর settlement এর magnitude কম; তাই settlement বলতে stage ২ বুঝবে।

void ratio vs. effective stress

Steps in calculating void ratio vs. effective stress:

~~10 → 20 → 40~~ → loading কিভাবে করলাম ? 10 → 20 → 40 → ~~...~~ 640

1. Calculate H_s

$$H_s = \frac{W_s}{A G_s \gamma_w}$$

W_s – weight of soil

A – cross-section area

$H = H_s + H_v$

2. $H_v = H - H_s$

3. Calculate initial void ratio (load apply এর আগে)

$$e_0 = \frac{V_v}{V_s} = \frac{AH_v}{AH_s} = \frac{H_v}{H_s}$$

soil sample এর 1st test always moisture content.

/ H_s, ~~W_v~~ দেয়া না থাকলে;

e দেয়া না থাকলে moisture content দেয়া;

soil sample fully saturated $S_r = 1$

$$S_r = \frac{G_s \gamma_\omega}{e}$$ এখান থেকে e_0 বের করতে পারব।

4। At the end of 1st increment of load, the change in void ratio will be equal to.

$$\Delta e_1 = \frac{\Delta H_1}{H_s}$$ (একদম last to reading থেকে পাবো)

5। New void ratio at the end of 1st load increment.

$$e_1 = e_0 - \frac{\Delta H_1}{H_s}$$ (corresponding to 1st increment of load) [আমাদের example এ 10 kPa]

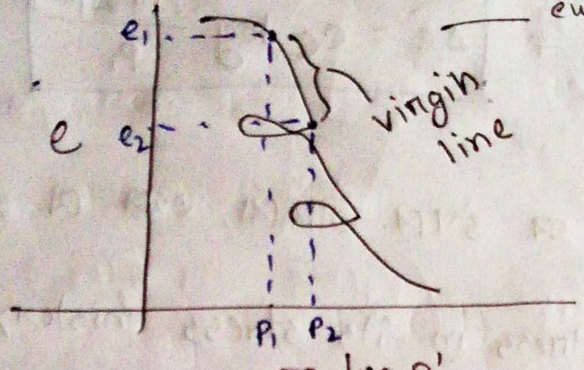
next load 20 kPa,

$$p_2 = \underbrace{p_1}_{10\,kPa} + \underbrace{\Delta p}_{\text{আরো } 10\ kPa \text{ দিব}}$$

পরে e_2 কে পাবো change in void e_1 থেকে – করে।

Δp = e_1 থেকে e_2 তে যাওয়ার time এ যে additional p লাগে।

আমার loading থাকলে এই graph



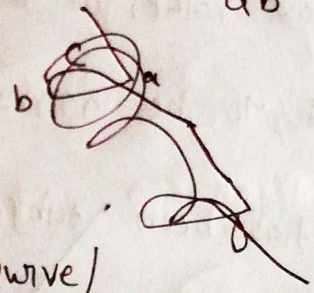
curve এর slope compression index (C_c) (virgin line এর slope)

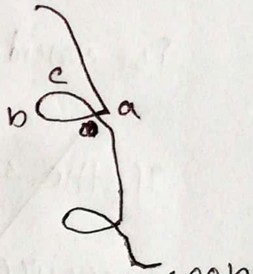
$$C_c = \frac{\Delta e / e_1 - e_2}{\log\left(\frac{P_2}{P_1}\right)}$$

$P_2 = P_1 + \Delta P$

follow করে।

1st এ curve টা concave downward. Then straight line, — virgin line। then ab path এ unloading হয় (rebound curve)।





bca তে reloading (loading curve/ compression curve). In the process of reloading, as soon as curve passes the past max pressure (a), the curve follows a straight path. At a very high pressure, the bottom portion of the curve is concave upward.

(3-1, 3-2 article এর peck এর)

$$c_c = \frac{\Delta e}{\log \frac{P_1 + \Delta P}{P_1}} \Rightarrow \boxed{\Delta e = C_c \log \frac{P_1 + \Delta P}{P_1}}$$

যখন straight line এর উপরে থাকবো, তখন যে stress দেখাবো তা max stress in its stress history.

If the existing overburden/effective P on a soil sample has its max value, in its stress history, then the soil is considered to be a normally consolidated clay (NC).

stress history জানা must (যেটা lab field এ জানা নাই,

If the soil has been subjected to a pressure which has been more than what it is experiencing now (past এ load আরো বেশি ছিল)

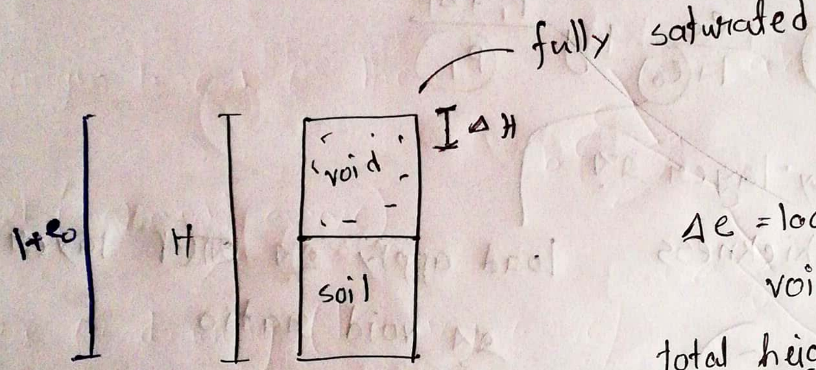
The soil whose present overburden P is less than that which the soil experienced in the past and the past max pressure is called Pre-consolidation pressure ; denoted by (Pc) [like পাহাড় কেটে ফেললাম, তার নিচের soil ; এই soil অনেক stiff.

Over consolidated clay বলা হয় এগুলোকে (OC). And the ratio b/m past max p and ~~the~~ current p. is called Over consolidation Ratio (OCR).

OCR < 1 [NC] . OCR = 1 হলে

OCR > 1 ⇒ [OC]

OCR যত বেশি, degrees of over consolidation তত বেশি।



Δe = load এর জন্য change in void ratio

total height = $1 + e_0$

strain $\varepsilon = \dfrac{\Delta e}{1+e_0}$

আবার, yeild এ strain, $\varepsilon = \dfrac{\Delta H}{H}$

$$\therefore \frac{\Delta H}{H} = \frac{\Delta e}{1+e_0}$$

$$\boxed{\therefore \Delta H = H \cdot \frac{\Delta e}{1+e_0}}$$

$\boxed{\Delta H = \text{settlement}}$

Assumption → (১) soil sample pressure এ আছে তাতে uniform strain হবে।

lab test থেকে বের করব

Settlement, $S = H \dfrac{\Delta e}{1+e_0}$ $\qquad \Delta e = C_c \log \dfrac{P_1 + \Delta P}{P_1}$ থেকে

ঐ clay এর test করব তার height

P_1 = overburden stress (নিজের ~~ওজন~~ ওজন) $= \gamma' H$

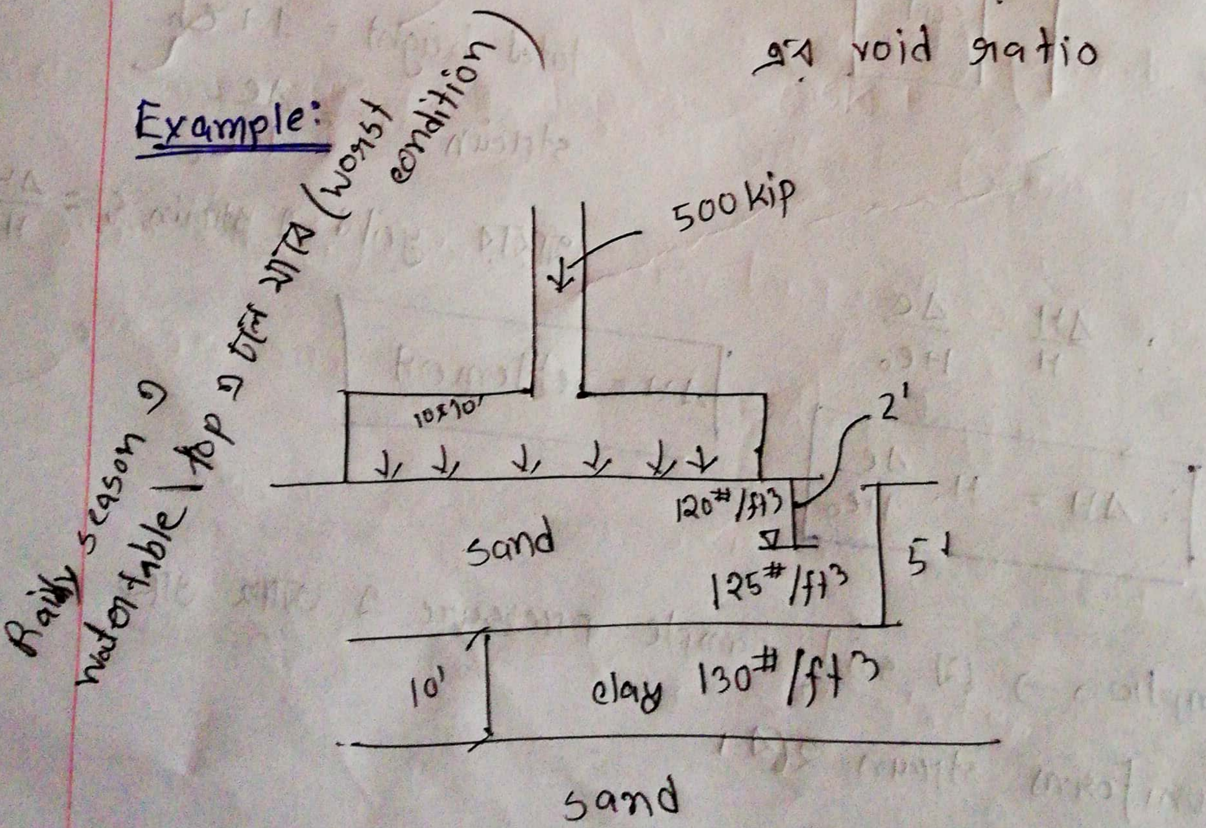
ΔP আর C_c বের করতে হলে $e - \log P$ curve থেকে,

$$S = H \frac{C_c}{1+e_0} \log \frac{P_1 + \Delta P}{P_1}$$

clay layer এর thickness

load apply এর আগে layer এর void ratio

Example:



$e_o, P, \Delta P, C_c$ লাগবে $H = 10'$ জানা

6ম layer under consideration, তার middle এ বের করতে হবে।

$$P_1 = \underbrace{120 \times 2}_{\text{unsat.}} + \underbrace{(125-62.4)}_{\text{saturated}} \times 3 + 5 \times \underbrace{(130-62.4)}_{\text{saturated}} = 765$$

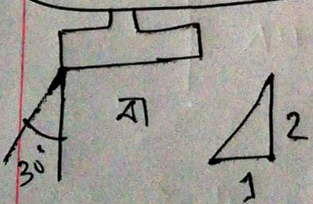
75 ksf

প্রতি layer এ moisture content দেয়া থাকলে, like clay layer এ $\omega = 30\%$ তাহলে

$$e_0 = G_s \omega$$
$$= 2.7 \times 0.3$$
$$= 0.81$$

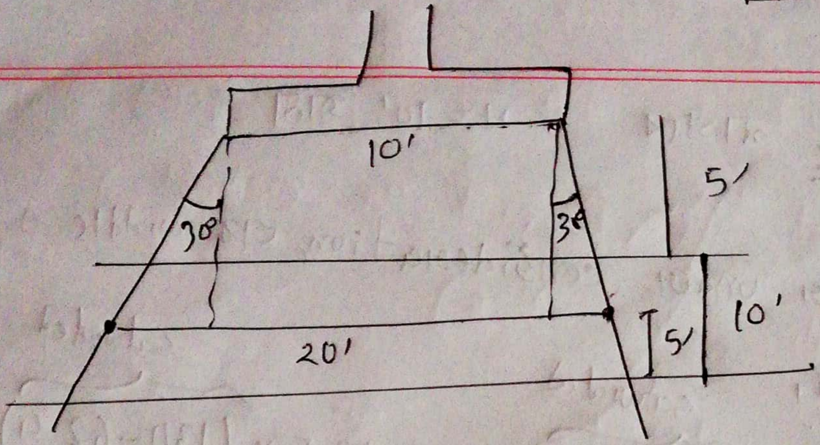
NC এর জন্য $C_c = 0.009(LL-10)$ } emperical (যদি C_c দেয়া না থাকে)

(accurate হবে না, curve থেকে নিলে accurate পাবো।



→ এই ratio তে load distribution হয় footing এর নিচের মাটিতে।

~~120x~~



30° angle এ load spread হয়ে clay তে যায় 20' span হবে।

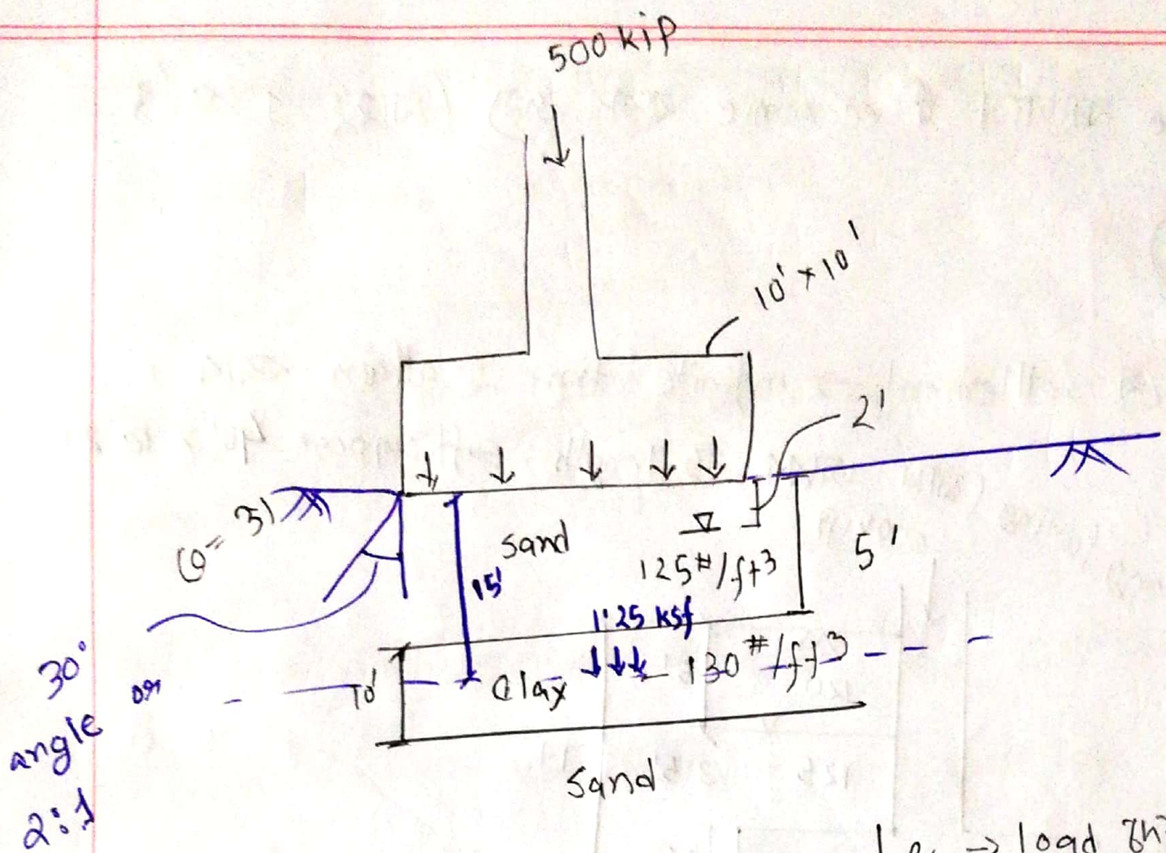
$\Delta P = \cancel{5 ksf}\ 1.25\ ksf$

$C_c \approx .21 - .35$ (soft clay to normally)

Footing এর size change করে (rectangle/circular) এর জন্য কিভাবে হবে dispersion দেখব।

15/7/19

Lee-14



$$S = H \frac{C_c}{1+e_0} \log \frac{p_0 + \Delta p}{p_0}$$

$\frac{500}{20 \times 20} = 1.25$ ksf $= \Delta p$ $\qquad p_0 = 756$ psf $= .756$ ksf

originally ছিল $\frac{500}{100} = 5$ ksf

$H = 10'$ (total clay layer)

$$S = 10 \times 12 \times \frac{0.2}{1+0.9} \log \frac{.756+1.25}{.756}$$

C_c = 0.2

$= 5.35$

$e_0 \rightarrow$ load দেওয়ার আগে যে layer এর settlement বের করছি তার void ratio

$p_0 \rightarrow$ যে clay layer under consideration তার middle এ

$\Delta P \Rightarrow$ 500 kip এর জন্য p_0 থেকে increase in effective stress (clay এর middle এ)

(1 এর নিচে আনতে হবে) → footing এর size বাড়িয়ে

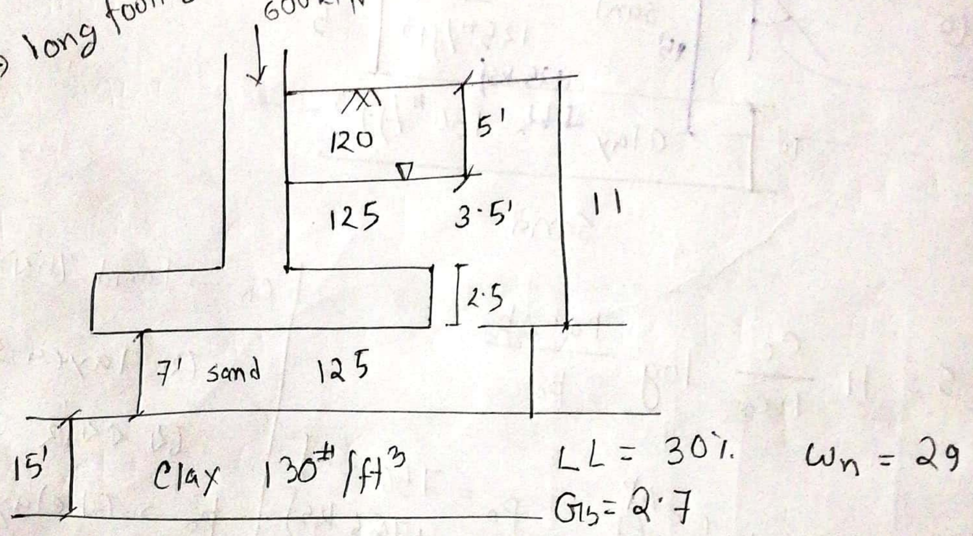
যদি .004" settle হয়, তখন footing

এর size বাড়ানো ও economic করার জন্য (যেহেতু 1" পর্যন্ত allowed)

5.35" এর settlement → infinite time এ attain করবে।

→ long footing মানে অনেক বড় length ; ~~suff~~ suppose 40' x 10' ও 10'

#



8' x 8" এর footing

8' x 10"

wall footing

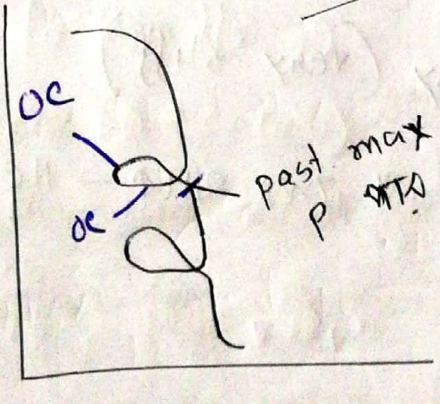
sand/silt এগুলো না

NC and OC clay don't refer to a particular type of soil. It refers to a condition.

Suppose → CE building হচ্ছে কেবল শুধু 50 তলা বানাবো। হচ্ছে কেবলমাত্র- তখন soil টা OC, 10 তলা পর্যন্ত new বানালাম, তখনও OC, 10 তলা exceed করে গেলে তখন soil NC.

It may emphasize that NC soil and OC soil are not different types of soil. But these are state of stress in which a soil may exist. The same type of soil can behave as NC in a certain pressure range and OC ~~press~~ in other pressure range.

→ if infinite point এ নিলে এমন curve পাবো,



past max p পার করার পর ই NC হয়ে যাবে soil

পড়বো বই থেকে

Causes of OC ~~clay~~?

⇒ পাহাড় ছিল সরায় ফেলসাস্থ। downward movement ~~of water~~

থাকলে OC

upward ~~movent~~ movement থাকে NC.

বদ্বীপ এলাকায় → NC

upstream এলাকায় soil erosion → ওখানে OC

Natural moisture content of a soil যদি significant lower than LL হয়, তাহলে ওটা OC clay ধরে নিতে পারি।

OC clay → LI → 0 − 0.6

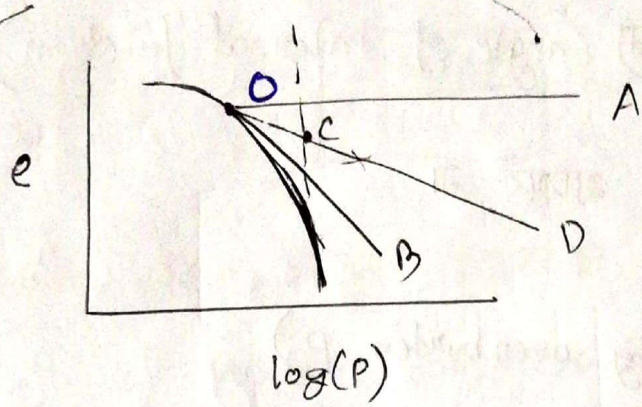
NC clay → LI → 0.6 − 1

লাল মাটি → বলা যায় OC clay (very stiff)

যদি problem এ soil type না দেওয়া থাকে → NC ধরে নিব

Determination of pre consolidation Pressure (P_c):

Casagrande



1 → Select a point visually on this curve which gives you min. radius of curvature / max curvature.

$\boxed{\text{এটা curve এর transition zone এ হবে।}}$

2 → Draw a horizontal line parallel to the x axis

3 → " " line which is tangent at O

4 → Bisect the angle AOB

5 → Extend the virgin portion backward which intersects the bisector OD at C. ~~The C~~ point ~~is called~~

The pressure corresponding to point C is pre consolidation pressure.

$$\frac{C}{P} = 0.10 + 0.004\, I_P$$

c শুধু clay এর জন্য (clay এ φ ও থাকতে পারে)

φ শুধু sand এর জন্য (angle of internal friction)

↓

sand এ কখনো c থাকবে না

$p_0 = 5$ ksf (existing overburden p)

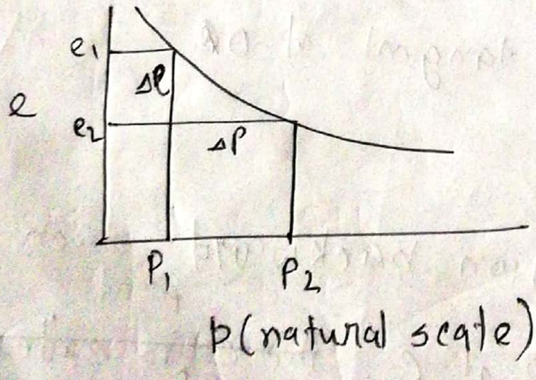
p যের কমলায় 3 ksf ⟶ NC clay

p যদি হয় 10 ksf ⟶ OC clay

B. M. Das এর soil mechanics এর বই পড়ব

Lec-15

16/7/19



p(natural scale)

Co-efficient of compressibility

(unit → p এর inverse)

It's a function of state of stres

$$a_v = \frac{\Delta e}{\Delta p} = \frac{de}{dp} = \frac{e_2 - e_1}{p_2 - p_1}$$

With the increasing value of effective stess, the value of Co-efficient of Comp. decreases.

settlement, $s = H \frac{\Delta e}{1+e_0}$ $\quad \Delta e = a_v \Delta P$

$= \boxed{H \frac{a_v \Delta P}{1+e_0}}$ in terms of co-efficient of compressibility

In terms of C_c আছে আরেকটা

Co-eff. of volume compressibility. It can be defined as the volumetric strain per unit increase in effective stress.

$m_v = \frac{\Delta V}{V_0} \cdot \frac{1}{\Delta P}$ effective stress change এর জন্য

আমরা normally linear strain নিয়ে কাজ করি

$P_2 - P_1 = \Delta P$ এর জন্য volumetric strain ~~change~~ $\Delta V / \Delta V_0$

1 unit এর জন্য কত ?

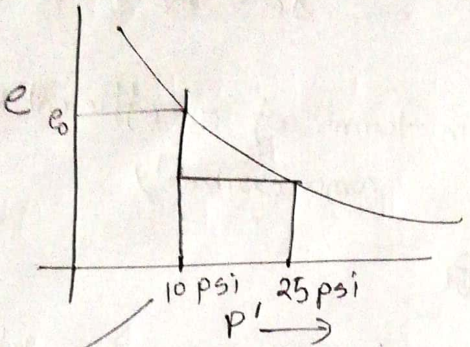
$= \frac{\Delta e}{(1+e_0)\Delta P}$

$= \frac{\Delta e}{\Delta P} \cdot \frac{1}{1+e_0}$

$\boxed{\frac{\Delta V}{V_0} = \frac{\Delta e}{1+e_0} = \frac{\Delta H}{H}}$

$= \frac{a_v}{1+e_0}$

$\boxed{S = H m_v \Delta P}$



initial overburden pressure

increase in p = 15 psi

$$m_v = \frac{\Delta e}{(1+e_0)\,\Delta p}$$

থেকে m_v বের করা যাবে।

e_0 হবে শুরুর pressure এর (10 psi) corresponding e

[curve দেওয়া থাকলে always curve থেকে e_0 বের করব]

① $S = H\frac{\Delta e}{1+e_0}$ = e_v এর respect এ
= m_v " " "
= a_v " " "

৩টা expression এ S মাপতে পারি।

Demolded soil sample → কিভাবে?

↳ এর জন্য soil এর stiff হয়ে যায়, a_v, c_c ছোট হয়ে যায় একটু

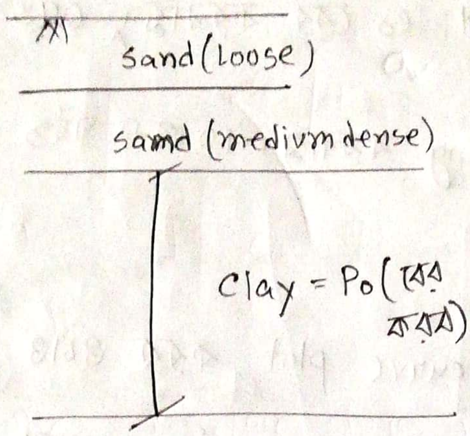
তার জন্য S একটু কম পাই। (disturbance এর জন্য)
lab test এ

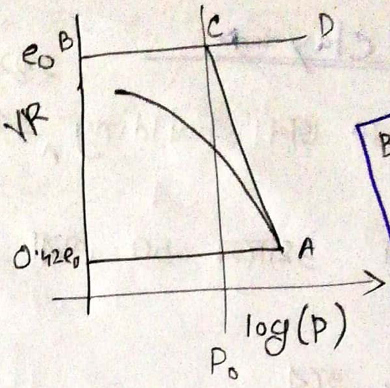
Scherdmann (1955) procedure:

lab এর e-logp curve থেকে field e-logp curve draw করব

$p_0 = 10$

$p = 25$





BCA is the field e-logP curve

slope বেশি।

lab e-loog curve and field e-log p curve passes through a common point of 42% of initial void ratio (e_0). Degrees of disturbance (lab এ) shift e-log p curve to the left. যদি Remolded করে ফেলি পুরা soil তাহলে আরো left এ shift করবে।

BCA → NC ~~soil~~ clay

p_0 ΔP

$(10 + 15) = 25$ psi

OC clay ⇒

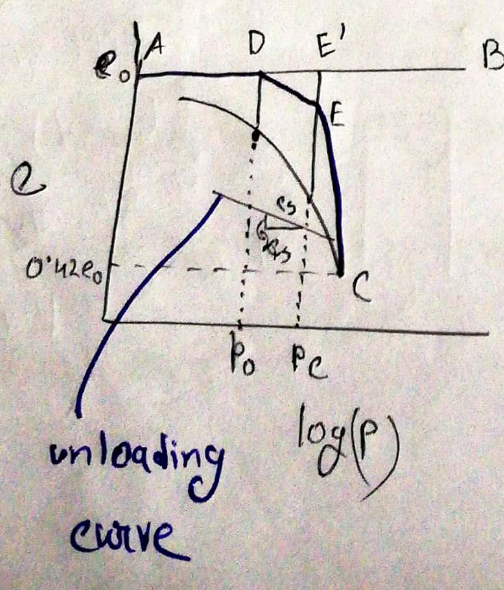
10 তলা building হওয়া এর আগে e_0 বের করলাম। ভেঙে ফেলে ওখানে 50 তলা building করলাম। 10 তলা পর্যন্ত OC clay হবে

OC এর জন্যও যে e-logP curve plot করব ওটাও field e-logp curve এর সাথে .42 e_0 point দিয়ে যাবে

existing overburden pressure = 10 psi

pre-consolidation pressure, $P_c = 25$ psi (past max pressure)

~~P_0 = ? P_c = ?~~ এখানে p_0 আর p_c জানা লাগবে। NC তে শুধু P_0 জানলেই হয়।



এটা plot করার জন্য unloading curve লাগবে ~~এ~~ at least একটা (unloading/rebound/expansion curve) → এই curve এর

• ~~sot~~ slope → swelling index denoted by $\boxed{C_s}$

P_o থেকে P_c পর্যন্ত যেতে slope হবে C_s এর সমান। DE portion which is parallel to the rebound curve.

ADEC টা field এর e-log P curve.

D → E পর্যন্ত soil will behave like OC

beyond E point → NC clay.

$$S = H \cdot \frac{C_c}{1+e_o} \log \frac{P_o + \Delta P}{P_o}$$ ~~→ NC হলে নিম্নলিখিত এর প্রভাবে~~

এখন হবে,

OC region

$$S = H \cdot \frac{C_s}{1+e_o} \log \frac{P_o + \Delta P}{P_o}$$

$\underbrace{P_o + \Delta P \leq P_c}$

P_c attain এর আগের পর্যন্ত

NC region এ ঢুকে পড়লে তখন

$P_o + \Delta P > P_c$

$$S = \frac{H C_s}{1+e_o} \log \frac{P_c}{P_o}$$ } @ E point এর settlement

$$S = \frac{H C_s}{1+e_o} \log \frac{P_c}{P_o} + H \frac{C_c}{1+e_o} \log \frac{P_o + \Delta P}{P_c}$$ } OC + NC Region এর জন্য settlement

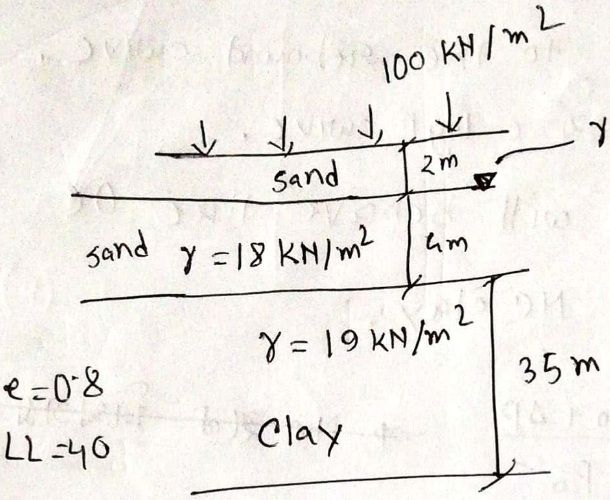
$$\boxed{10-20\% \text{ of } C_c = C_s}$$

$$\therefore C_s = \left(\frac{1}{5} \text{ to } \frac{1}{10}\right) C_c$$

[Exam এ C_s এর value না থাকলে normally 15% assume করে নিব]

Lec – 16

22/7/19



Ques:

What is settlement of the clay layer, (a) if clay is NC (b) if the pre-consolidation p is 200 kN/m² (c) P. if $P_c = 150$ kN/m²

(a) $p_o = 14 \times 2 + (18 - 9.81) \times 4 + \cancel{19.9}\,(19 - 9.81) \times 1.75$

$= 77$ kN/m²

$\Delta p = 100$ kN/m²

অনেক বিরাট area (footing এর মত ছোট না) তাই 100 kN/m² ই আসবে

$$S = H \frac{C_c}{1 + e_0} \log \frac{p_o + \Delta p}{p_o}$$

$$= 3500 \times \frac{.27}{1.8} \log \frac{77 + 100}{77}$$

$= 191$ mm

(b) 20%

$C_s = 0.2 \times 0.27 = 0.054$

$P_c = 200 \ kN/m^2$ [which is less than $\left[\begin{matrix}\Delta P & P_0 \\ 100 + 77\end{matrix}\right]$ তাই OC clay হিসেবে behave করবে ; P_c cross করে নাই ; 177]

$$H = 3500 \times \frac{0.054}{1.8} \log \frac{77+100}{77}$$

(c) So $P_c = 150$

$$S = \frac{0.054 \times 3500}{1.8} \log \frac{150}{77} + \frac{3500 \times .27}{1.8} \log \frac{76+100}{150}$$

Scanned by CamScanner

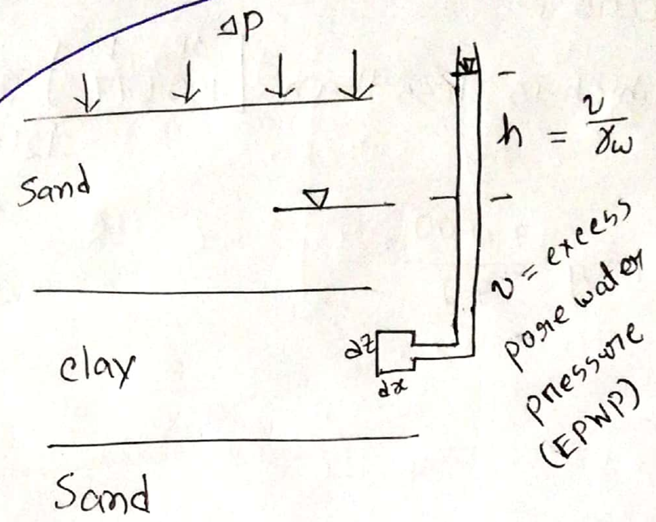
Rate analysis

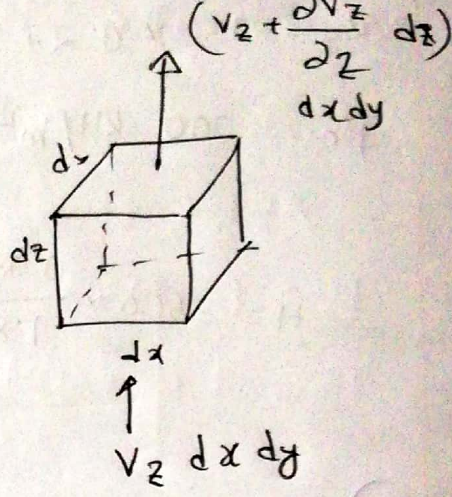
Tarzaki's 1D consolidation theory

Assumption

(i) soil homogenous, (ii) fully saturated, (iii) Darcy's principal apply (iv) water particle & (5) soil skeleton incompressible

#





(6) There is a unique ~~retai~~ relationshis that exists btwn change in void ratio associated with the effective stress / excess pore water pressure.

আগের laplace eq^n এ net ~~flot~~ flow rate 0 ছিল, 2D তে analysis ছিল। এখানে 1D.

Pore water pressure 1D তে flow করবে এখানে।

Net flow rate = ~~Volume~~ Rate of volume change হবে এখানে

Assumption এর justification আর
limitation ⇒ xm ?

$$\frac{\partial v_z}{\partial z}\, dx\,dy\,dz = \frac{\partial v}{\partial z}$$

$v_z = k_z i_z$ (Darey's principle থেকে)

$$= k \cdot \frac{\partial h}{\partial z} = -\frac{k}{\gamma_w} \cdot \frac{\partial u}{\partial z}$$

$$\therefore -\frac{k}{\gamma_w}\frac{\partial^2 v}{\partial z^2}\, dx\,dy\,dz = \frac{\partial v}{\partial t}$$

~~যদি ফিরাতে এত area থাকে~~

$$V = V_s + V_v = V_s + e V_s$$

$$\boxed{\frac{V_s}{V} = \frac{1}{1+e}}$$

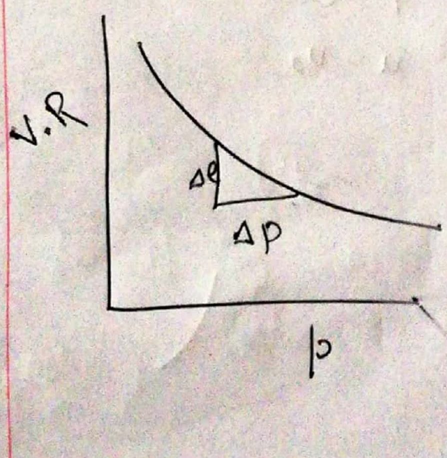
$$\frac{\partial V}{\partial z} = V_s \cdot \frac{\partial e}{\partial t}$$

$$= \frac{V}{1+e}\frac{\partial e}{\partial t}$$

$$= \frac{dx\,dy\,dz}{1+e} \cdot \frac{\partial e}{\partial t}$$

$$\therefore -\frac{k}{\gamma_w}\frac{\partial^2 v}{\partial z^2}\, \cancel{dx\,dy\,dz} = \frac{\partial v}{\partial t} = \frac{\cancel{dx\,dy\,dz}}{1+e}\frac{\partial e}{\partial t}$$

$$= \underbrace{\frac{a_v}{1+e}}_{m_v}\frac{\partial v}{\partial t}$$



$$\Delta e = \Delta p\, a_v$$

$$\partial e = \partial(\Delta p)\, a_v$$

$$\partial e = -\partial v\, a_v$$

Decrease in excess pore water pressure → increase in effective pressure

$$\frac{K}{\gamma_w} \frac{\partial^2 u}{\partial z^2} = m_v \frac{\partial u}{\partial t}$$

$$\boxed{\frac{\partial u}{\partial t} = \frac{K}{\gamma_w m_v} \frac{\partial^2 u}{\partial z^2}}$$

$\underline{m_v \text{ constant}}$

γ_w constant

increment of load এর জন্য

$\frac{k}{m_v}$ constant (for particular increment)

$$\frac{K}{\gamma_w m_v} = C_v$$

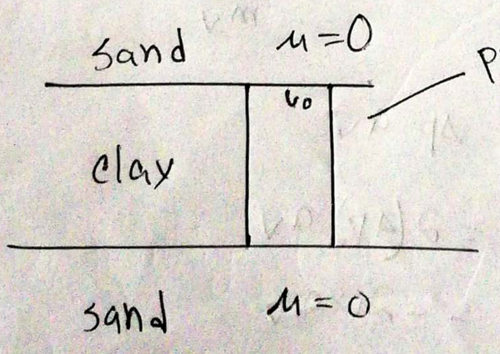
↓

co-efficient of consolidation

C_v → constant for particular increment of load

Boundary condn লাগবে → associated with geometry

Initial u associated with time



pore water p থাকবে clay তে শুধু

$t = 0$

$u = u_0$

$$u = \sum_{m=0}^{\infty} \left[\frac{2u_0}{M} \sin \frac{Mz}{H_{dr}} \right] e^{-M^2 T_v} \qquad T_v = \text{time factor}$$

$$M = \frac{\pi}{2}(2m+1) \qquad u_0 = \text{initial excess P.W.P.}$$

1 way drainage এ full length of clay layer

H_{dr} = Length of the drainage path
Both way drainage এ it will be $\frac{1}{2}$ of the clay layer thickness

4র্থ condn

wide area → উপরে যে load তাই Δp

rectangular — Δp change [L, W থেকেই Δp calcu হয়]

wall footing → শুধু width আছে, L ∞ হবে; Δp change

square — Δp change [শুধু L/W থেকে (যেহেতু same dimension)]

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$$\frac{\partial u}{\partial t} = C_v \frac{\partial^2 u}{\partial z^2} \qquad C_v = \frac{K}{m_v \gamma_w} = \text{constant}$$

There's no direct method to measure permeability coefficient for clay (cohesive soil)

Determination of K ?

2 methods for determining $c_v \rightarrow$

1. Casagrandre / Log of time method

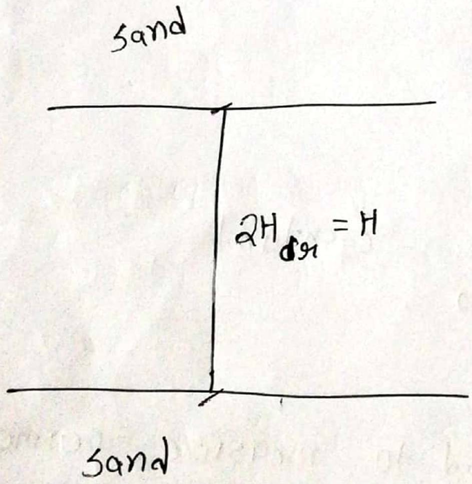
2. Taylor's method / square root of time method

10, 20, 40, 80, 160, 320, 640 → increment of loads

It is a time dependant $eq^n \rightarrow$ ২ ধরনের boundary $cond^n$ থাকবে

(I) ~~Geometry~~ Geometry related (II) Initial $cond^n$ (time dependant)

Fahum/Casancandre:



$z = 2H_{dr}$ $u = 0$

$z = 0$ $u = 0$

$I_c = t = 0,$ $v = v_0$

2 way drainage (bottom আর top এ drainage)। একটা particle max path travel করতে পারে H_{dr} (L of the drainag path $\left(\frac{2H_{dr}}{2}\right)$

Consolidation rate analysis এর time এ

For both way drainage, L of the drainage path will be half of the thickness of the clay layer. For 1 way drainage (যেটায় নিচে Rock hit করবে) L of the drainage will be the thickness of the clay layer. Both layer→ settlement তাড়াতাড়ি হবে।

u = যে কোন point এর excess pore water pressure.

Degrees of Consolidation:

$\Delta p = 50$ psi (overburden P)

তখন excess pore water $p = 50$ psi

10 ঘন্টা পরে যদি piezometer দিয়ে reading পাই 30 psi,

capital

$$U_z = \frac{u_0 - u_z}{u_0} = 1 - \frac{u_z}{u_0}$$ } – প্রতি point এ applicable Degree of consolidation

time যত বাড়বে, degree of consolidation will reach to 100.

u_z কে যদি across the thickness integrate করে total thickness দিয়ে devide করি, avg পাবো

$$U = 1 - \frac{\frac{1}{2H_{dr}}\int_0^{2H_{dr}} u_z\,dz}{u_0}$$ [avg degree of consolidation across the thickness এ applicable]

$$u = 1 - \sum_{m}^{\alpha} \frac{2}{M^2} e^{-M^2 T_v}$$

$$\boxed{T_v = \text{Time factor} = \frac{c_v \times t}{H_{dr}^2}}$$

Excess pore water P শূন্য হয়ে গেলে আর settlement হবে না।
ঐ time এ settlement চাচ্ছি এটা

$$U = 1 - \frac{\frac{1}{2H_{dr}} \int_0^{2H_{dr}} u_z dz}{u_0} = \frac{S_c}{S_f}$$

S_c → যে time এ settlement

S_f → in terms of C_c, C_v, A_v, m_v এর যেই eq^n ছিল; এটা ultimate settlement attained at infinite time

$$U = \frac{u_0 - u}{u_0}$$

$u_0 - u$ → dissipated excess pore water pressure

u_0 → initial pressure

$$= \frac{S_c}{S_f}$$

S_c → current settlement

S_f → final settlement

C_v lab থেকে জানা, T_v বের করলে t জানতে পারব।

$U = 0.4$ আর 0.9 দিয়ে বের করব T_v

$m = 0 \qquad M = \frac{\pi}{2}$

$$u = 1 - \frac{2}{(\pi/2)^2} e^{-(\pi/2)^2 \times T_v}$$

$$\Rightarrow 0.9 = 1 - \frac{2}{(\pi/2)^2} e^{-(\pi/2)^2 \times T_v}$$

$U = 0.5$ এ $\rightarrow 0.196$

$U = 0.9$ এ $\rightarrow 0.848$

The eq^n is extremely convergent (~~[illegible]~~ 1টা term এই accurate result)

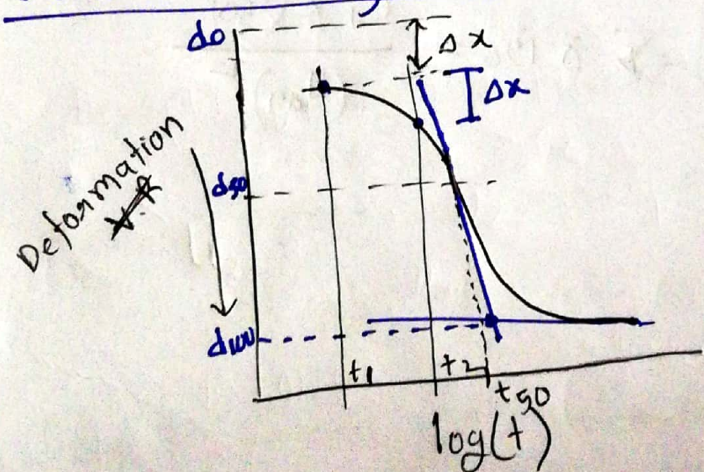
$$T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2 \quad U \leq 60$$

$$U > 60 \quad T_v = 1.781 - 0.933 \log_{10}(100 - u)$$

(U expressed in % for these formula)

এই দুটো expression দিয়ে approximate T_v এর value measure করা যায়।

Determination of Cv:



Step 1: Draw a line AD which is tangent to the straight portion. " another tangent to the final portion.

Intersected point corresponds to the 100% primary consolidation. (end of primary consolidation).

Natural scale এর plot করলে parabolic curve হয়।

Step 2:

take t_1, t_2 such that $t_2 = 4t_1$

d_0 = dial gage reading at 0 consolidation

5 50 $\quad d_{50} = \dfrac{d_0 + d_{100}}{2}$

t_{50} = time required to attain 50% consolidation

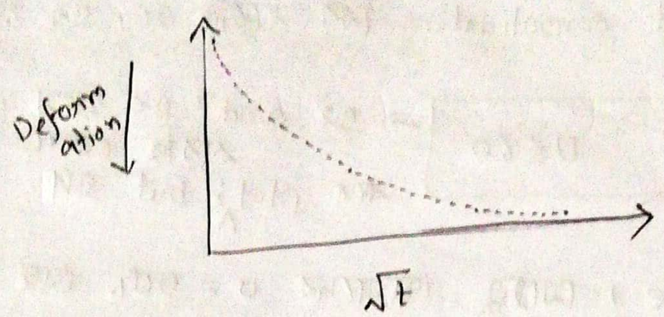
$\sqrt{\ }$ graph থেকে

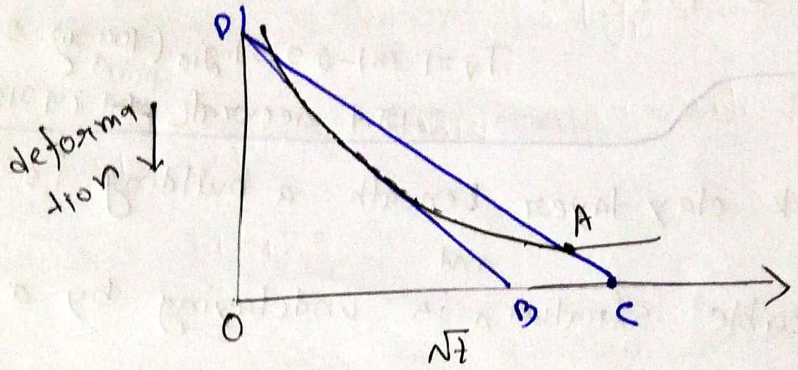
$$T_{v_{50}} = \frac{C_v \times t_{50}}{H_{dr}^2} \Rightarrow 0{\cdot}196 = \frac{C_v \times (t_{50})}{(H_{dr})^2}$$

H_{dr} → average thickness

(initially যত thick + ~~50% consolidation এর~~ load apply এর পর যত thick) এর avg.

Square root of time method :





Step 1 : straight portion দিয়ে straight line draw (BD)

Step 2 : Select a point C such that OC = 115% of OB .

Step 3 : Connect DC . Intersects the curve at A . Time corresponding to A is equal to time required for 90% consolidation .

$$T_v = \frac{C_v \times t}{H_{dr}^2} \Rightarrow 0.848 = \frac{C_v \times t}{H_{dr}^2}$$ graph থেকে

15% বেশি নিলাম কেন → curve এ আমি initial এর সাথে compare করেছি ; but consolidation বের করেছি 90% এর জন্য।

$$\boxed{T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2 \qquad U \le 60}$$ → এই condⁿ এর সাথে compare করেছি curve করে plot; but এটা U<60 এর জন্য applicable। যেহেতু আমাদের U = 90%. তাই error হবে ওই eqⁿ এ plot করলে। তাই 15% বেশি। (যদি $T_v = 1.781 - 0.933\log_{10}(100-U)$ এ plot করতাম তাহলে accurate ~~plot~~ point পেতাম)

Problem:

A 3 m thick clay layer beneath a building is overlaid by a permeable stratum and is undelaying by a inpervious rock. The coefficient of consolidation is given as .025 cm²/min. The final settlement is expected to be 8cm.

(a) How much time will it take for 80% of the settlement to take place. (3.89 yr)

(b) Determine the time required to reach a settlement of 2.5 cm (195 days)

ⓒ Compute the settlement that will occur in 1 year. (3·4 cm)

Final settlement দিয়ে না দিলে হয় যেটা eq^n দিয়ে t_i final settlement বের করতাম ওটা use করব (time, drainage $cond^n$ indepen-dent)

A homogenous clay layer 9 m thick is expected to have ultimate settlement of 308 mm. after a span of 2 years the average settlement was 108 mm. How much time will it take to attain 220 mm settlement? (8·73 yrs)

In a consolidation test, a clay specimen initially 25 mm thick attains 90% consolidation in 10 mins. In the field, the clay stratum from which the specimen was obtained has a thickness of 6 m. And this layer is sandwiched btn 2 sand layer. A structure is constructed here experience an ultimate settlement in 200 mm. Estimate the settlement at the end of 100 days after the construction of the structure (104 mm).

Muktadir Sir

2/9/19

Stress distⁿ is soil due to:

1. Point load
2. Infinitely long line load
3. Strip area carrying uniform load
4. Strip area carrying triangular load
5. " " " embankment "
6. Circular load
7. Rectangular shape of loading.
8. Any arbitrary shape of loading.

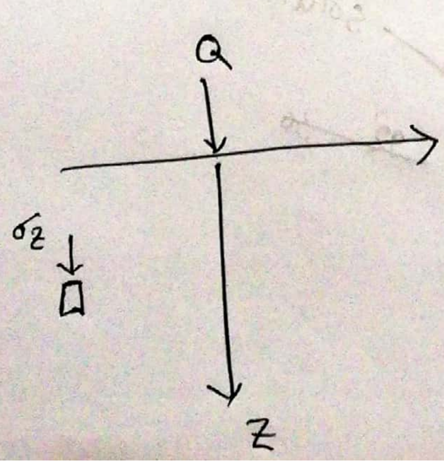
এখানে কোন expression derive করব না]

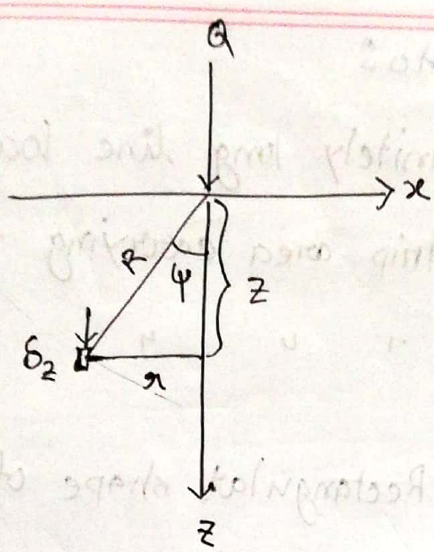
Assumption:

1. surface plane (not inclined) [যে surface এ load আসবে]
2. Soil weightless ($\gamma = 0$)
3. Material maintains hook's law
4. " isotropic, homogeneous
5. Domain under consideration is elastic half space

Point loading: Bressinsz's solⁿ (1885)

surface load Q এর জন্য vertical stress increase একটা element এর (domain এ) $\rightarrow \delta_z$





$$\sigma_z = \frac{3Q}{2\pi z^2}\left[\frac{1}{1+\left(\frac{r}{z}\right)^2}\right]^{5/2}$$

$$= \frac{3Q}{2\pi}\cdot\frac{z^3}{(r^2+z^2)^{5/2}}$$

$R = z^2 + r^2$ $\quad (r^2 = x^2 + y^2)$

$\therefore R = x^2 + y^2 + z^2$

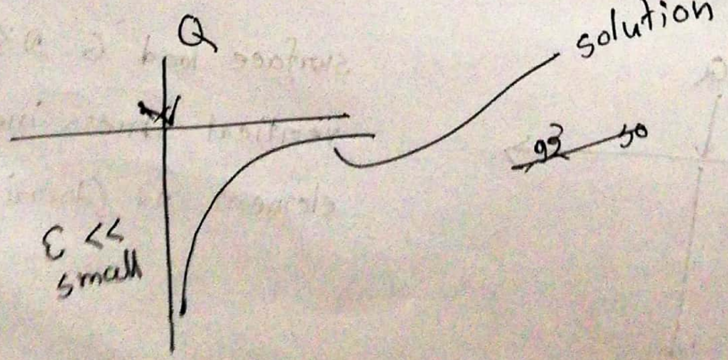
Point load হয় জন্য 3 টি condn consider:

1. stress distrn along z axis
2. " " " a horizontal ~~plane~~ a plane
3. " " " a vertical "

1.// যখন $r = 0$ $\quad \sigma_z =$

$$\sigma_z = \frac{0.478\,Q}{z^2}$$

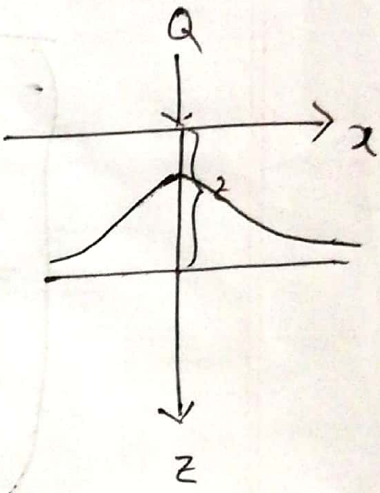
saint venant's principle → max stress হবে when $z = 0$ → near infinity



ε অনেক small

σ_z sol^n টা entire domain এ valid except in the vicinity of the application of ~~a~~ the point ~~ro~~ load (কারণ z ~~a~~ zero হয়ে infinite হবে)

along the horizontal axis:



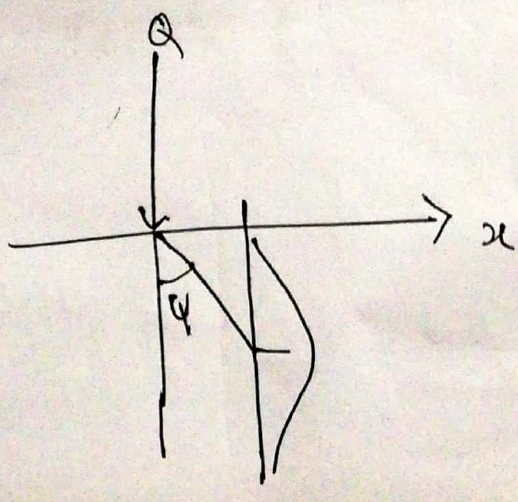
z constant থাকবে এখানে।

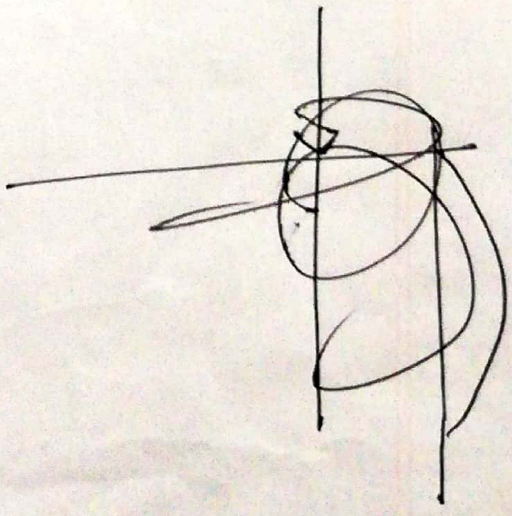
z ~~a~~ axis থেকে যত দূরে যাব, the value of stress decays rapidly. Point of loading বরাবর max^m magnitude পাব।

z এর value যত কম, max magnitude বাড়বে.

vertical plane:

r constant





σ_z max^m হবে কখন ? differentiate w.r.t. z.

ψ বের কর ?

$$\frac{\sigma_z}{dz} = \frac{3Q}{2\pi} \cdot \frac{z^3}{(r^2+z^2)^{5/2}}$$

$$= \frac{3Q}{2\pi} \cdot \frac{z^3 \cdot \frac{5}{2} \cdot (r^2+z^2)^{3/2} \cdot 2z - (r^2+z^2)^{5/2} \cdot 3z}{(r^2+z^2)^{10}}$$

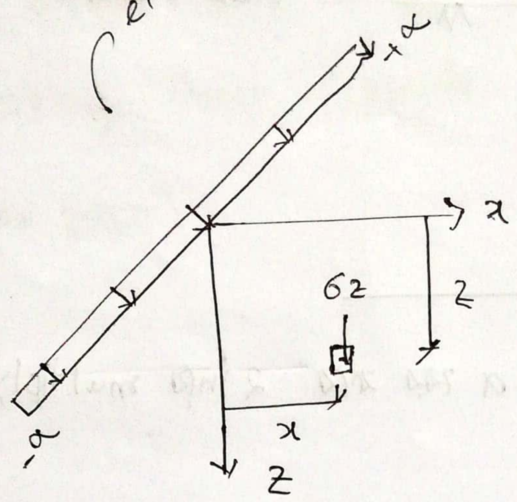
$$= \frac{3Q}{2\pi} \cdot \frac{\cancel{\frac{5z^3}{2} \cdot (r^2+z^2)^{3/2}} \cdot 5z^4 (r^2+z^2)^{3/2} - 3z (r^2+z^2)^{5/2}}{(r^2+z^2)^{10}}$$

$$= \frac{3Q}{2\pi} \cdot \frac{5z^4 - 3z(r^2+z^2)}{(r^2+z^2)^{8.5}}$$

$3r^2 = 2z^2$

$\psi = 39.23^\circ$ (rad এ নিব)

example কি এরকম loading হয়?

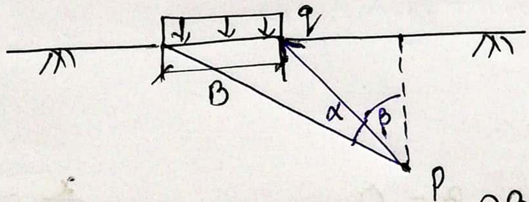


$$\sigma_z = \frac{2q}{\pi}\frac{z^3}{(x^2+z^2)^2}$$

y axis বরাবর load, কোন y value নাই। যদি x axis বরাবর load দিতাম, তাহলে x^2 এর জায়গায় y^2 হত।

3. Strip area carrying uniform pressure:

Point টা beyond the width of the strip footing.

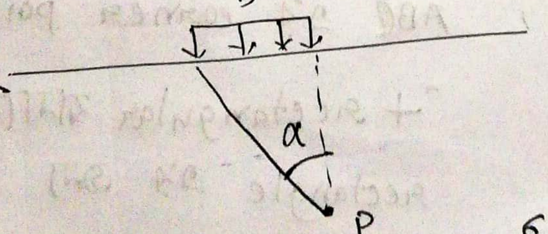


$\sigma_z = ?$

$$\sigma_z = \frac{q}{\pi}\left[\sin\alpha + \sin\alpha\cos(\alpha + 2\beta)\right]$$

α = angle subtended by the width to the point under consideration

দুটা expression এর a different a radian এ

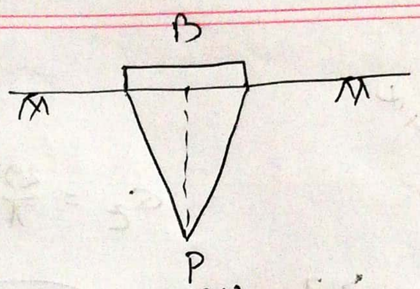


এই ক্ষেত্রে $\beta = 0$

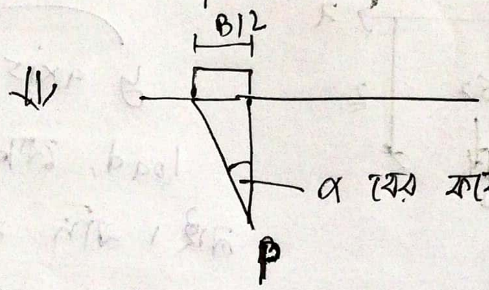
a = width দিয়ে যে angle

$$\sigma_z = \frac{q}{\pi}\left[\sin\alpha(1+\cos\alpha)\right]$$

Avg settlement 10x ... layer.



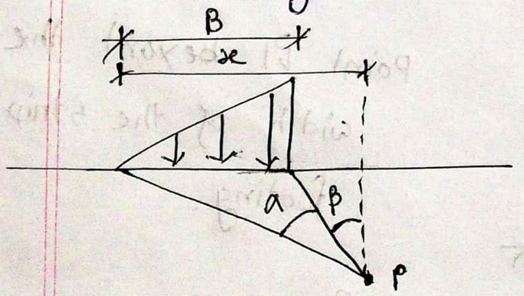
Max stress ?



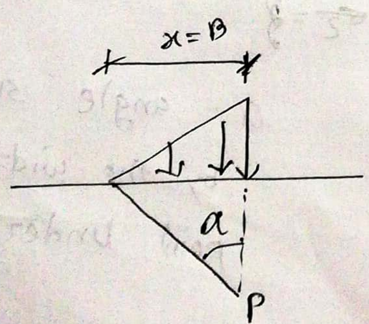
α বের করে 2 দিয়ে multiply

এরকম বিভিন্ন case practice করব।

Q.4. Triangular distn: Eg Embankment এর side এ দেখি।

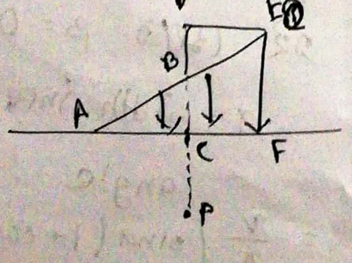


$$\sigma_z = \frac{q}{\pi}\left[\frac{x}{B}\alpha - \frac{1}{2}\sin 2\beta\right]$$



$\beta = 0$ $\qquad \frac{x}{B} = 1$ হবে

$$\sigma_z = \frac{q}{\pi}\left[\alpha\right]$$



ABC এর corner point C তে $\frac{q}{\pi}\alpha$

+ rectangular বানাবো (CDEF);

rectangle এর জন্য P point এ

বের করে উপরের BDE triangle subtract করব (ছোট triangle এর q linear interpolate করে বের করতে হবে বড় triangle থেকে)

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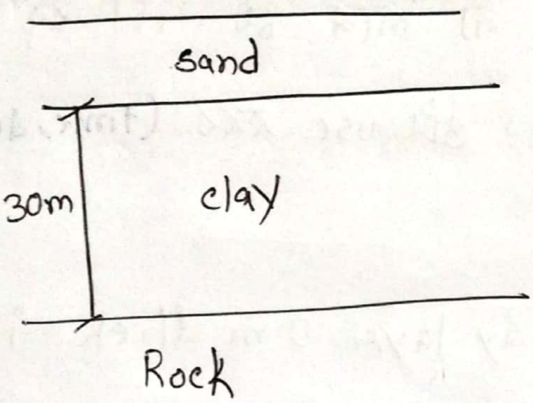
Lec-18

#



1 way drainage

$c_v = 0.025 \frac{cm^2}{min}$

Final settlement = 8 cm

(1) How much time it will take ~~40~~ for attaining 80% of total settlement

(2) ~~0.25~~ 2.5 cm settlement occur এর time

(3) 1 year পর settlement ?

Ans:

(1) settlement associated with primary consolidation এখানের final settlement (বের করা লাগবে) (অন্য data দিবে)

$$T_v = \frac{C_v \times (t)^?}{H_{dr}^2}$$

$$T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2 \leq 60$$

$$T_v = 1.781 - 0.933 \log(100 - u)$$

$H_{dr} = ~~100~~\ 300$ cm

(2 way drainage দেওয়া)

$T_v = 0.567$ ← $U = 80\%$ থেকে

$$T_v = \frac{C_v \times t}{H_{dr}^2} \Rightarrow t = 3.88 \text{ year}$$

$$\underset{0.567}{T_v} = \frac{\overset{0.025}{C_v} \times t}{\underset{\cancel{1500}\ 300}{H_{dr}^2}}$$

(2)

$$U = \cancel{208}\ \frac{2.5}{8} = 31.25\% \text{ consolidation}$$

$$T_v = \frac{\pi}{4}\left(\frac{31.25}{100}\right)^2 = 0.077$$

$$0.077 = \frac{0.025 \times t}{300^2} \Rightarrow t \approx 193 \text{ days}$$

(3)

$$T_v = \frac{0.025 \times 1 \times 365 \times 60 \times 24}{300^2}$$

$$= 0.146$$

[যখন 60% থেকে কম consolidation

$$.146 = \frac{\pi}{4} \times \left(\frac{U}{100}\right)^2 \Rightarrow U = 43\%$$

$$\text{consolidation} = 8 \times 0.43 = 3.44 \text{ cm}$$

308 mm → ultimate settlement in a homogenous clay layer.

After a span of 2 years, Avg settlement 108 mm

How time it would take to attain 220 mm settlement ?

$S_f = 308$ mm

↓

xm ২ বছর করাতে দিতে পারে।

⇒

$$\frac{220}{308} = 72\% \text{ consolidation}$$

$$T_V = 1.781 - 0.933 \log(100 - 72) = 0.42$$

$$T_V = \frac{C_V \times t}{H_{dr}^2}$$

[যদি both/single way drainage না বলা থাকে যেকোনটা assume করে নিব]

$$\cancel{0.42 = \frac{C_V \times 2}{}}$$

When 108 mm settlement, % consolidation $\frac{108}{308} \times 100$
$= 35\%$

$$T_V = 1.781 - 0.933 \log(100 - 35) = .56$$

C_V constant always for the same soil

$$C_V = \frac{T_{V_1} H_{dr}^2}{t_1} = \frac{T_{V_2}}{t_2} H_{dr}^2$$

$$\Rightarrow T_{v_1}/t_1 = T_{v_2}/t_2$$

$$\Rightarrow \cancel{T_{v_2} =} \; t_2 = \frac{T_{v_2} \times t_1}{T_{v_1}}$$

In a consolidation test,

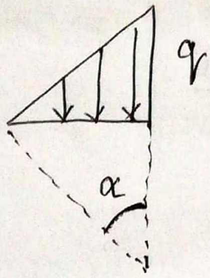
initial clay thickness → 25 mm

in the field, from which the sample was collected was 6000 mm. Sandwitched b/m 2 sand layer. structure e কড়ার

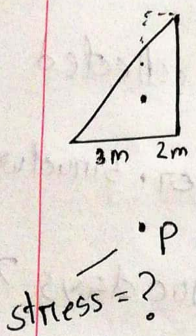
পর final settlement = 200 mm. settlement after 100 days?

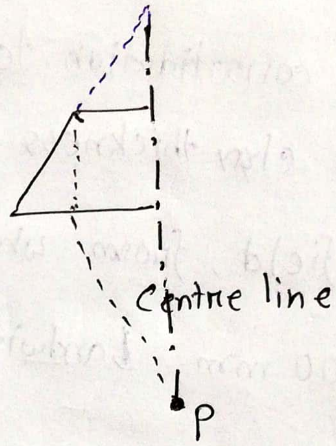
→ result 104 mm

embankment / রাস্তার settlement বের করব



$\sigma_z = \frac{q}{\pi}\alpha$



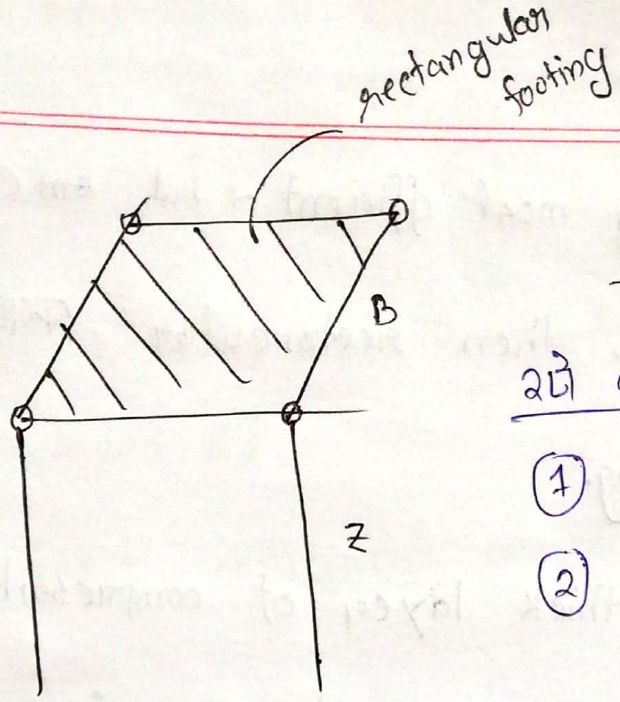


Practice করব বিভিন্ন ~~loading~~ condition. Xm এ আকারে।

triangle + rectangular loading এর জন্য যেকোন type এর condition তৈরি করতে পারব।

For rectangular shape of footing stress is calculated only at a point right below at 1 corner point. at a depth of z

এটা use করে যেকোন জায়গার stress বের করব।



$\frac{L}{Z} = m \quad \frac{B}{Z} = n$

২টা condition :

(1) $m^2+n^2+1 > m^2 n^2$

(2) $m^2+n^2+1 < m^2 n^2$

m and and mutually interchangable.

for $cond^n$ 1,

$$\sigma_z = \frac{q}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+1+m^2n^2} \times \frac{m^2+n^2+2}{m^2+n^2+1} + \sin^{-1}\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+1+m^2n^2}\right]$$

[সব radian এ হবে] +m এ দিয়ে দিতে হবে

for $cond^n$ 2,

$$\sigma_z = \frac{\pi}{4\pi}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1} \times \frac{m^2+n^2+2}{n^2+m^2+1} + \pi - \sin^{-1}\left[\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+1+m^2n^2}\right]\right]$$

square footing এ $m=n$ হবে।

[স্ট stress distribution এর সব math এর angle radian এ express]

Circular footing most efficient → but ~~am~~ cumbersome then square, then rectangular সবচেয়ে inefficient হল wall footing.

\# A 2m thick layer of compressible soil with an average void ratio of 1·02 is subjected to a overburde pressure of 100 kN/m^2. Laboratory consolidation test shows that the eq^n of $e - \log P$ curve is $e = e_0 - 0.125 \log_{10} \frac{p}{p_0}$ $[p = p_0 + \Delta p]$

(1) Find the change in volume per unit volume of the compressible layer. (মানে m_v বের করব)
($m_v = 1.49 \times 10^{-4}\ m^2/kN$)

(2) If the soil is <u>laterally</u> confined, so that all the volume change results in change in height (মানে 1D consolidation); calculate the settlement that would result due to the increased load. $S = m_v \frac{H}{2} \Delta p$

=

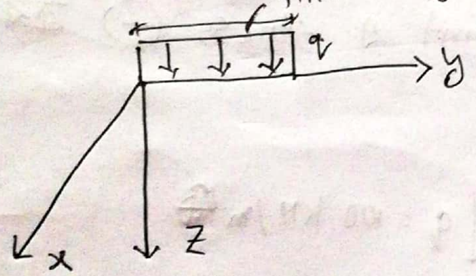
xm এ data দেয়া না থাকলে শুরুতে নিচে দিব বড় করে
কত assume করছি

+ Q a large structure at the ground surface increase the pressure 70 KN/m² (assume করে নিব Q mid layer এ)

[Ans. এ লিখব settlement acceptable নাকি না]

11/9/19

Infinite line load: [derive লিখব না]



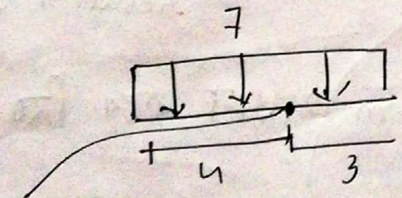
at the end point এ এ increase in vertical stress বের করার জন্য applicable. (at any depth)

$m = \frac{x}{z}$ $n = \frac{l}{z}$ (they are not mutually interchangable)

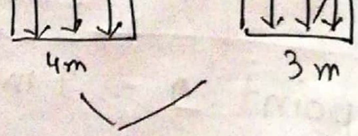
$$\sigma_z = \frac{q/z}{2\pi(m^2+1)^2}\left[\frac{3n}{\sqrt{m^2+n^2+1}} - \left(\frac{n}{\sqrt{m^2+n^2+1}}\right)^3\right]$$

করতে হবে diagram

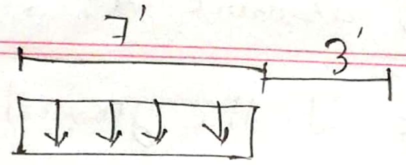
Application: middle এ করতে গেলে ২ ভাগে (middle এ highest stress



stress বের কর

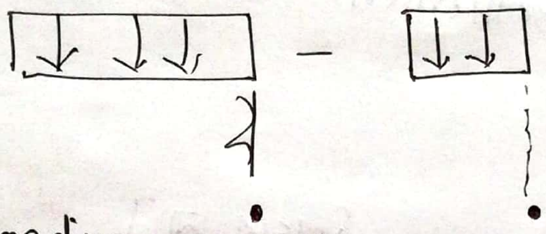


দুটোর corner এ বের কর



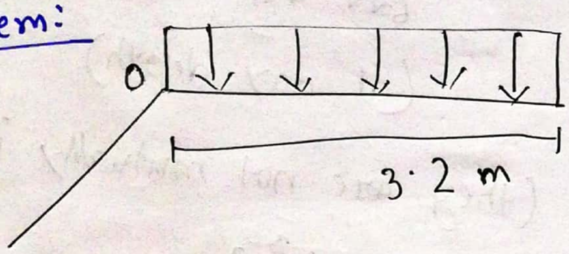
• — কত stress?

তখন



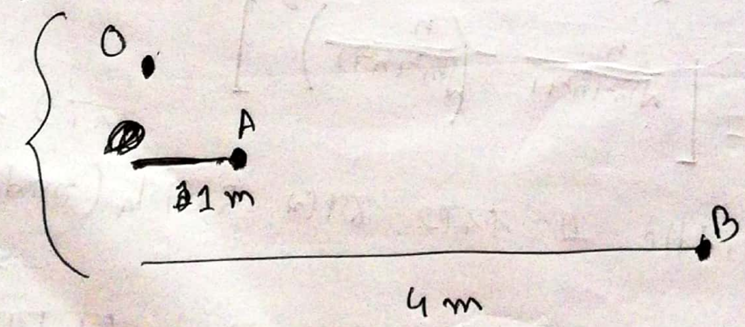
10' loading এর এক corner এ stress বের করে 3' loading এর ঐ corner point এ stress (−) করব

Problem:



$q = 100\ kN/m^2$

3 জায়গায় stress?



o point এ

$z = 4$

$x = 2$

$m = \frac{2}{4} \quad n = \frac{3.2}{4}$

result → 3.94 (0 point এর)

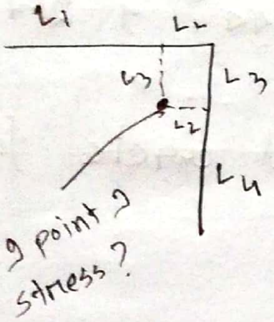
A point এ → 1 m আর 2.2 m এ ভাগ করে নিব

result → 4.778 kN/m2

B point এ → 4 m এর loading - 0.8 m এর ~~loadi~~ loading

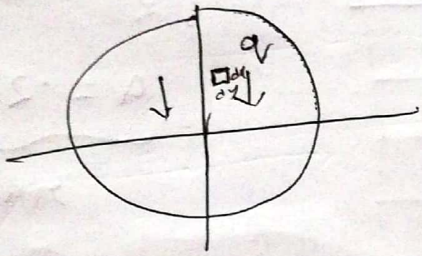
result → 3.01 kN/m²

#



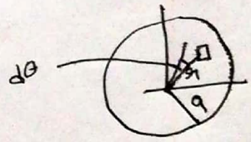
→ suppose দুটো wall joint

#



circular shape subjected to q intensity of load. axis বরাবর যেকোন point এ increase in stress?

$\square \quad q\,dx\,dy = q\,r\,d\theta\,dr$



$$\frac{3Q}{2\pi}\frac{z^3}{(z^2+r^2)^{5/2}}$$

তখন point load solⁿ এর concept → $\displaystyle\int_0^{2\pi}\int_0^{a}\frac{3\,r\,dr\,d\theta\,q}{2\pi}\frac{z^3}{(z^2+r^2)^{5/2}}$

Final expression ⇒ $\boxed{\sigma_z = q\left[1-\frac{1}{\left\{1+\left(\frac{a}{z}\right)^2\right\}^{3/2}}\right]}$

শুধু এটা মনে রাখব

$$\boxed{\frac{a}{z} = \left\{\left(1 - \frac{\sigma_z}{q}\right)^{-2/3} - 1\right\}^{1/2}}$$

$\sigma_z = \cdot 9$ পর্যন্ত value বের করতে পারব। 1 হলে α হবে।

This eq^n represents series of concentrated circle for various ratio of $\frac{\sigma_z}{q}$

σ_z/q	a/z
0.1	·27
0.2	·4
0.3	·52
0.4	·64
0.5	·77
0.6	·9
0.7	1·11
0.8	1·39
0.9	1·91
1.0	α

$\frac{a}{z} = \cdot 27$

$\underbrace{a = \cdot 27 \times z}_{\text{radius}}$

$\frac{a}{z} = 1 \cdot 92$

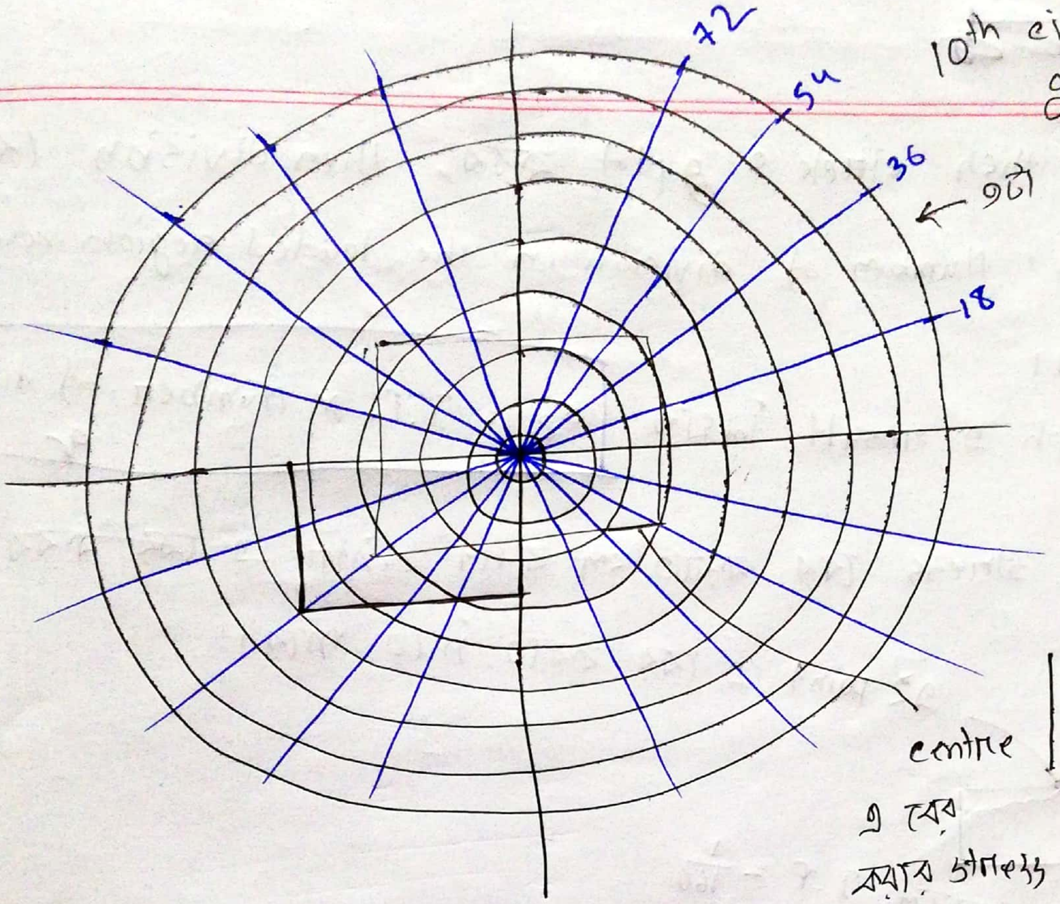
$\Rightarrow \underbrace{a = 1 \cdot 92 \times z}_{\text{radius}}$

xm এ graph paper এ সবচেয়ে বড় ~~circle~~ circle টা আগে plot করব। (scale বুঝার জন্য)

z scale fix করব আগে then বাকি সব circle এর radius বের করে draw করব (z এর সাপেক্ষে)

~~corresponding to~~

Approximate sol^n পাবো এখানে



প্রতি ~~এ co-or~~ quadrant এ 5 ভাগ করব

18, 36, 54, 72

প্রতি segment এ তাহলে ৯টা ভাগ

প্রতি quadrant এ number of division → 50টা

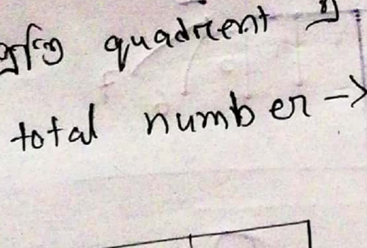
total number → 50×4 = 200

I.F. = $\frac{1}{200}$

10' depth এ A আর B point এ

10' depth → 2"

25' → " → O scale এ বের করব



~~sae~~ scale এ ~~covn~~ convert

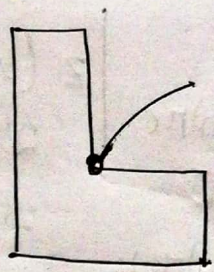
2" = z
(10' depth = 2" represent করবে)

করে then circle এ plot করব, then division বের করব। Number of division in the loaded region count করব।

graph এ result লিখব $\boxed{\sigma_z = I.f. \times \text{Number of divisions}}$

max stress বের করতে বললে centre এ বের করব.

এই point এ বের করতে দিতে পারে।



$I.F = \frac{1}{160}$

n ভাগ করলে

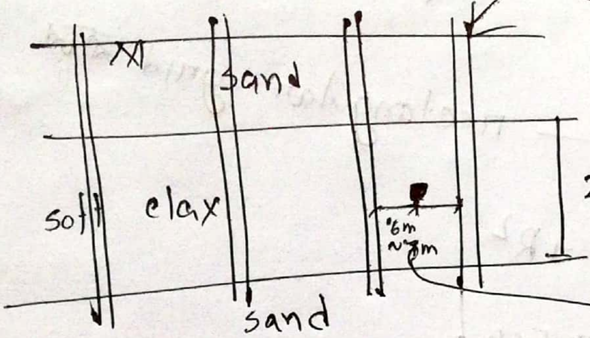
16/9/19

Application

embankment এর settlement 2, 3, 4 cm allow

settlement suppose achieve করতে 30 yr. লাগবে। But

আমাকে বলে দিল 3 yr এ attain করতে হবে।



$H_{dr} = 10$ m

যদি series of bore hole করি steel casing দিয়ে

(0.6 ~ 0.8)m হবে তখন Length of the drainage path

$$c_v = \frac{T_v \times (H_{dr1})^2}{t_1} = \frac{T_v (H_{dr2})^2}{t_2}$$

$$\left(\frac{H_{dr1}}{H_{dr2}}\right)^2 = \frac{t_1}{t_2}$$

$$\Rightarrow \left(\frac{10}{0.8}\right)^2$$

$$156 = \frac{t_1}{t_2}$$

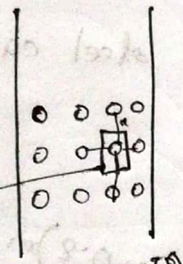
Conventionally দেখি যদি 90% settlement attain করতে 156 year লাগে। এভাবে drainage path change করে (Horizontally 3 flow করবে পানি) settlement time কমায় আনয়

এখানে Horizontally পানির flow করানো; আগে শুধু vertically flow হচ্ছিল।

$$\frac{\partial u}{\partial t} = c_v \frac{\partial^2 u}{\partial z^2} + c_h \left(\frac{\partial^2 u}{\partial r^2} + \frac{1}{r} \frac{\partial u}{\partial r} \right]$$

Bore hole এর spacing দিব (3 – 4.5 m)

rectangular grid করে বসানো

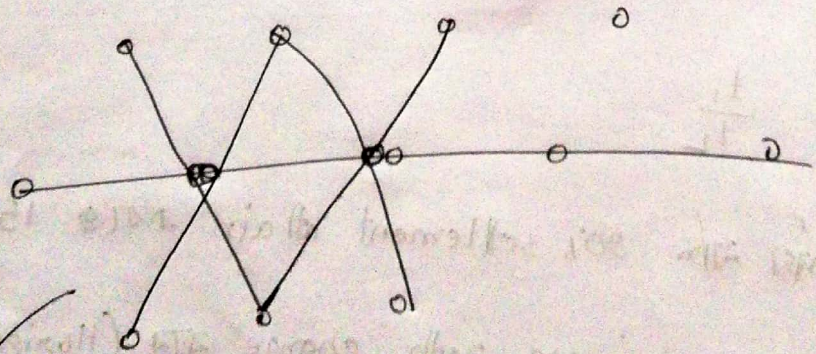


$a^2 = \pi R^2$

$R = 0.564\, a$

এতটুকু এ area তে pore water P dissipate করবে

বা triangular grid করে করতে পারি (Installation একটু tough)



Hexagonal area হবে তার $R = 0.525\, a$

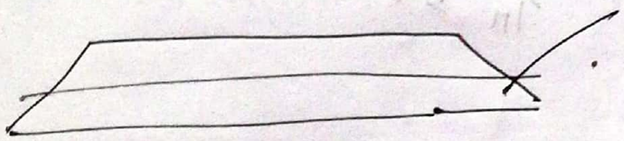
Depth of the sand grain : subsoil condⁿ এর উপর depend.

full thickness of the clay layer penetrate করতে হবে।

and টা কে permeable layer এ land করাতে হবে

Reported value → max

Drainage Blanket – উপরে use করে কারণ দেওয়া



gravel / coarse sand দিয়ে দিতে

Blanket .3m ~ 1m thickness হয় হবে

types of soil to be used :

where the settlement is significantly contributed by the primary consolidation and not suitable for the soil which have substantial secondary effect.

$$T_r \text{ (radial direction)} = \frac{c_h \times t}{\{H_{dr}(r)\}^2} = \frac{c_h \times t}{4R^2}$$

→ ARRangement থেকে আসবে (square grid / triangular grid)

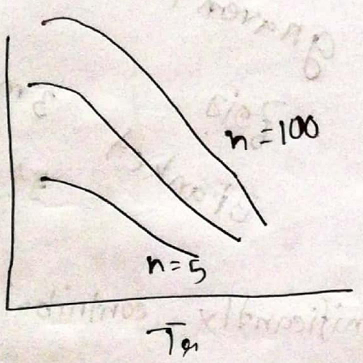
$$n = \frac{R}{r}$$

(300 mm ~ 600 mm) dia vary করে

steps: (in designing

1. ~~Dest~~ Determine U_z against T_z from the normal consolidation curve

2. Determine U_r (D.O.C ~~aff~~ associated with horizontal flow / radial flow from Barren's chart)



T_r এর value থেকে U_r

Resultant degrees of consolidation $U = U(U_z, U_r)$

$$= 100 - \frac{1}{100}(100 - U_z)(100 - U_r)$$

T_z, U_z fixed ঃ খালি n কে change করতে পারব

দরকার হলে (spacing কমায়, bore hole এর dia বাড়ায়..

pg 11-18 [peck এর] math + relationship

compaction বাইরে থেকে

seepage → coeff. of permeability কে কি effect করে ?

↳ determination (field + emperical) [cohesionless soil]

consolidation থেকে cohesive এর parameter

pg (39 - 43) ; table 2.1 page 43 → পড়ব

article 2.3 ×

article 2.4 - principal of effective stress, neutral stress, seepage pressure, quick sand condⁿ. [line by line পড়ব]

article 2.2 → ভালো করে পড়ব

Laplace eqⁿ of continuity - BM Das এর বই

Assumption, derive, eqⁿ এর mathmatical আর graphical interpretation (flow net diagram → থাকবে xm এ)

↓

confined layer এর টা পড়েছি এটাই পড়ব।

flow net dia জানা থাকলে effective stress কিভাবে বের করতে হয় ? seepage loss ?

uplift pressure in a hydraulic str.

hydraulic structure আর sheet pile এর stability check?

Harzard's criteria downstream side এর structure এর জন্য applicable.

Factors affecting the .... seepage force

↳ increase L of drainage path

↳ embankment depth ↑ → sheet pile

↳ filter material use

↳ downstream clay layer দিব না

Darcy's velocity আর seepage velocity এর relation

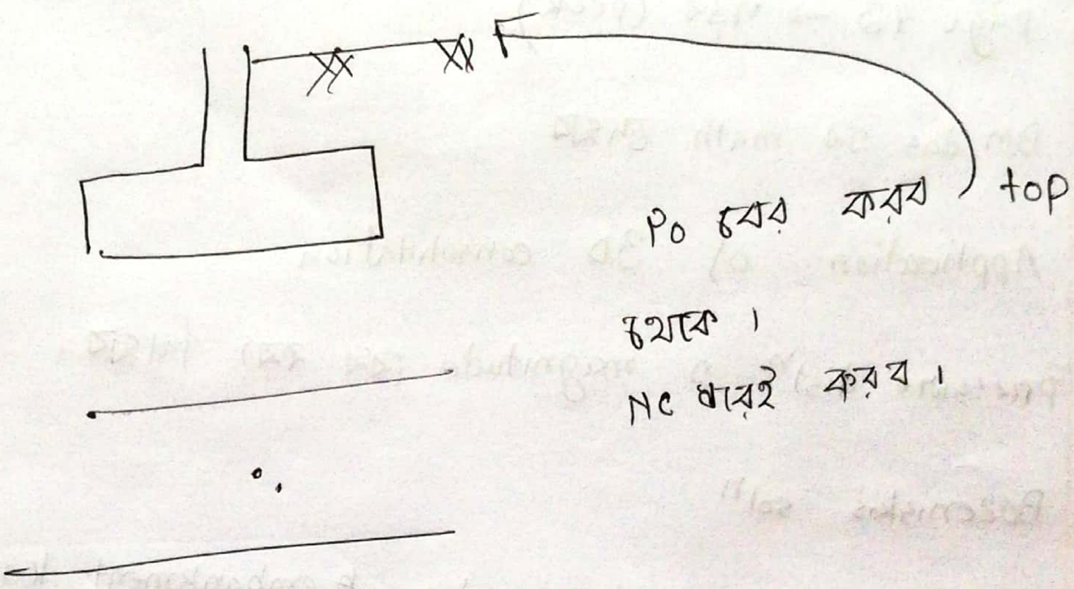
ques এ কিছু না বললে velocity বললেই discharge velocity বুঝবো।

Consolidation [অনেক imp.]

e vs P

earthquake, fluctuation of water table .... → কেন soil OC হয়।

এই course এ একটা layer ই থাকবে (clay এর)



~~settl~~ stage 1, 2, 3 (consolidation এর)

rate analysis, terzaki's 1D consolidation theory.
derivation যদি থাকে তাহলে কোন stage এ কোন assumption করেছি বলব।

Limitation → soil homogenous, uniform না, real এ 1D তে flow হয় না

settlement calculate করতে total length of the drainage path. rate analysis এ 'drainage path এর ভিত্তিতে half হবে কি হবে না।

60% — .283 (T_v) consolidation

exact বের করতে eq^n use করতে হবে solve করতে

Factors affecting secondary consolidation

page 73 → পড়ব (peck)

BM das এর math দেখব

Application of 3D consolidation

pressure distn ও magnitude বের করা শিখব।

Bozeniskis soln

finite line load, circular, & embankment loading ...

new mark chart

drawing + info দেয়া আছে শিখব + কি কি বের করতে

হবে লিখে ? দিব

mark আছে।

expression লিখব always direct লিখব না।