Soil Mechanics

Muktadin Sir
Mon , Tues
29/04/19
Lec-01

Reference → Foundation Engineering by Peck , Henson [ ] Mandatory

Supplimentary → Soil Mechanics by B.M. Das → এটাও কিনব

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 :

1. মাটি tension নিতে পারে না। Compression নিতে পারে। মাটির Bearing capacity before it fails in shear ঠিক করতে হবে। You have to make sure soil & foundation doesn't fail in shear.

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

↓

ton per sq.ft [S.I unit না এটা]

U.S. ~~ton~~

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।

Scanned by CamScanner

2 Your foundation must not experience excessive settlement. limit -> 1" for normal /common structure. [like normal building এ. Nevclear 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)

Principal → 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 $ma + \underbrace{\Sigma F}_{} = 0$ সব [illegible] 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

$\boxed{\text{Lec - 02}}$

Weight - Volume Relationship of soil:

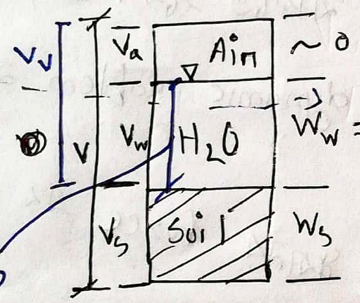
$$\left[W_s = V_s \times \gamma_s\right]$$

$$\omega = \frac{W_w}{W_s} \cancel{\times 100}$$

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

by Vol^m by weight

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



$\omega V_s G_s$

$W_w = \omega V_s \gamma_w G_s$

$W_s = V_s \gamma_s = V_s \gamma_w G_s$ — 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 ~~tog~~ 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 %

ওজন

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

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

[It can have value more than 100%. like volcanic ash এ]

soil sample নিয়ে ~~wei~~ dry করে ফেলে W_s পাবো। initial weight − dry weight = W_w

2. **Void ratio:** [Expressed in decimal]

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

$$e = \frac{V_v}{V_s}$$

→ load দিলে শুধু V_v change

V_s same

load দিলে
↳ এখানে n change হবে
ও Vv আর V দুটোই vary

3. Porosity: [% এ express]

V_v = Volume of void

$$n = \frac{V_v}{V} \times 100 \quad V - [\text{Total volume}]$$

এটা কখনোই 100% হবে না

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

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

$$S_r = \left(\frac{V_w}{V_v}\right) \times 100$$

] fully saturated হলে ~~100 হবে~~ 1 হবে

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

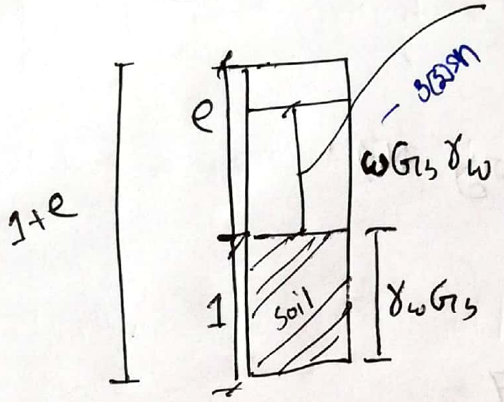
↓ relationship betn void ratio and porosity

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

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

Volume of air $= e - \omega G_s$

$\omega G_s \rightarrow$ volume



3 phase diagram

→ এই diagram হল based on $V_s = 1$

volume of void এখানে e

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

$$\boxed{\begin{aligned} \omega &= \frac{W_w}{W_s} = \frac{\gamma_w V_w}{\gamma_s V_s} = \\ \Rightarrow &= \frac{\cancel{\gamma_w} V_w}{\cancel{\gamma_w} G_s \cancel{V_s}} \; 1 \\ \Rightarrow & V_w = \omega G_s \end{aligned}}$$

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

S_r এর value n দিয়ে express করব।

Unique relationship exists between

Basic definition থেকে,

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

$$\gamma_s \Downarrow \gamma_w G_s$$

$$= \frac{S_r}{\frac{1}{e} \cdot G_s}$$

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

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

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

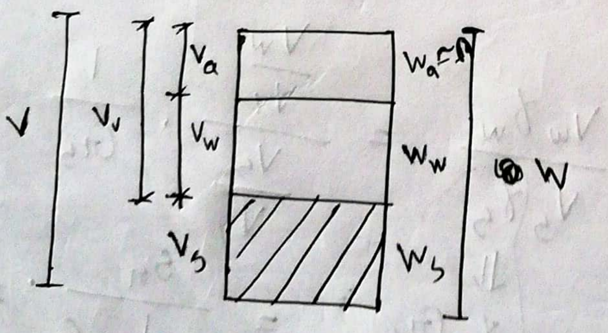
G_s অনেক কম range এ vary করে।

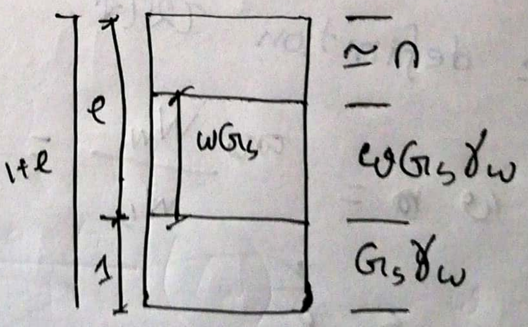
Typical values of G_s:

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





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

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

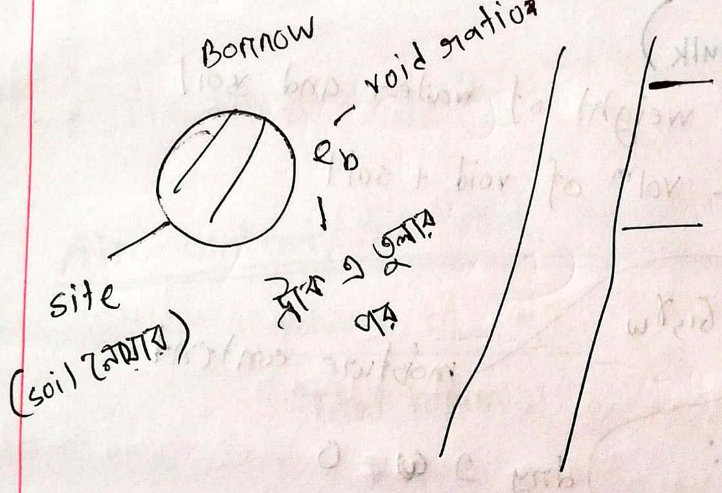
ω এর value put হবে decimal এ

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

$$= V_s\left(\frac{V_v}{V_s} + 1\right) = \underbrace{V_s}_{\text{constant}}(1+e)$$

constant যেহেতু change হবে না

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



এভাবে কত void ration 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)

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

V_f: tender এ দেয়া

e_b: জানা

e_f: tender এ দেয়া

সে থেকে কত volume লাগবে বের করব।

Unit Weight

Bulk unit weight (γ_{bulk})

$$\gamma_{bulk} = \frac{W}{V}$$

W — weight of water and soil

V — vol^m of void + soil

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

w — moisture content

dry এ $w = 0$

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

Dry unit weight (γ_d):

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

weight of water (void filla)

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

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

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

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

S_r → fully saturated এ 1

S_r → 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:

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

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

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

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

Determination of void ratio:

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

γ_d বের করতে হবে sand replacement method এ।

$\gamma_d = \dfrac{G_s \gamma_w}{1+\boxed{e}}$ — 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 ~~sites~~ soil at 2 diff places ~~can~~ ~~hada~~ may 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,

$$\frac{e_{max} - \cancel{e_{min}}\, \overset{\text{fill void ratio}}{e_f}}{e_{max} - e_{min}} = I_d \text{ — ১.৯}$$

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

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

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

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

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

7/5/19

Lec-04

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

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

①–③: earthquake prone

④–⑤: safer from earthquake

③ Medium dense: bd তে most designable

মানে γ_d বের হয়)

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

(II) in " " volume

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

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

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

∟max, min চিন্তা করব ।

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

বই এর example করব ।

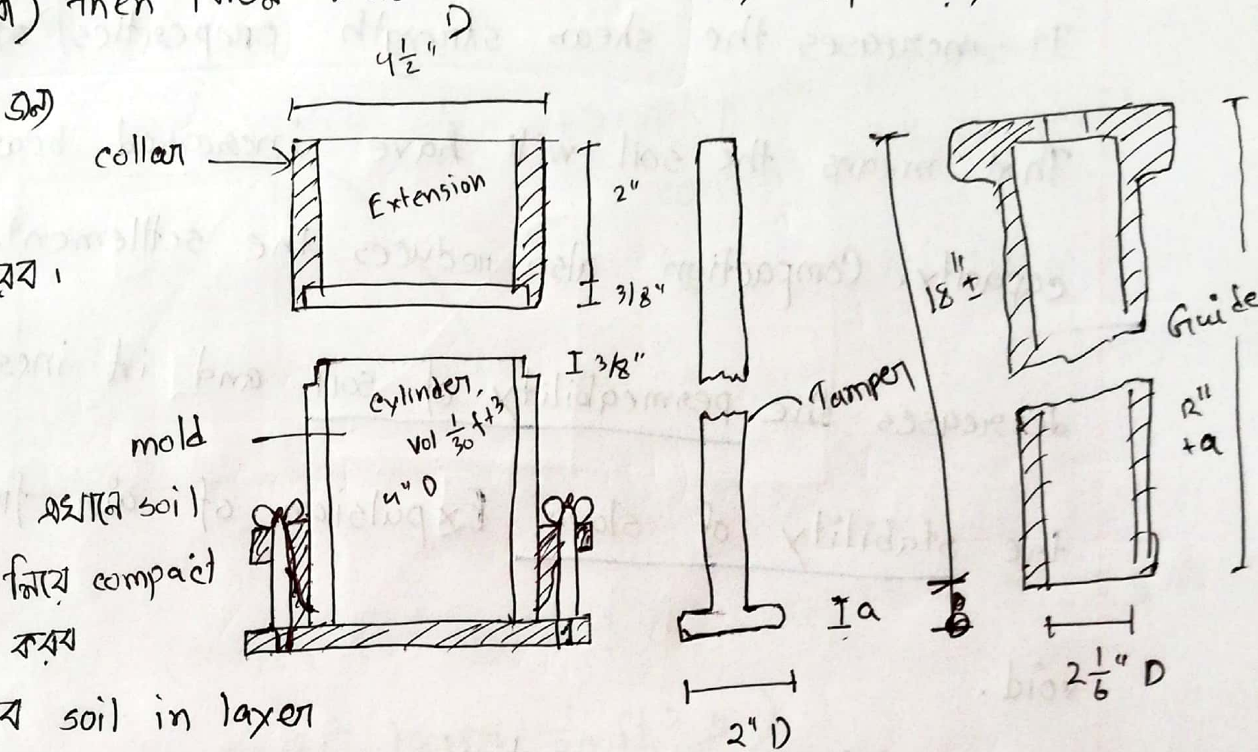
Compaction

~~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 দেয়ার পর dry unit weight পাবো) then বিভিন্ন moisture content নিয়ে exp. করে, max dry density এর জন্য moisture content বের করব।



compact করব soil in layer

soil seive 4 দিয়ে pass করব 1st 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.

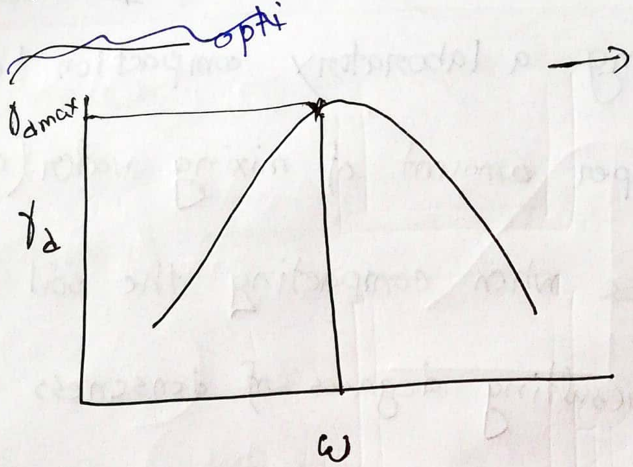
Factors affecting compaction:

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 1', 25টা blow, 3টা layer, $\frac{1}{30}$ ft^3 এ)

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

soil কে compact করতে

= ~~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 degraees of deneness which can be expected from this compaction at this moisture content (optimum moisture content). (~~pg 16 → ২৪২~~)

আগের compaction instrument → standard proctor

এখন পড়ব modified proctor

ASTMD1557

পার্থক্য → 5টা layer এ নিব	3টা layer
→ tamper এর ওজন 10 lb	5½ 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।

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

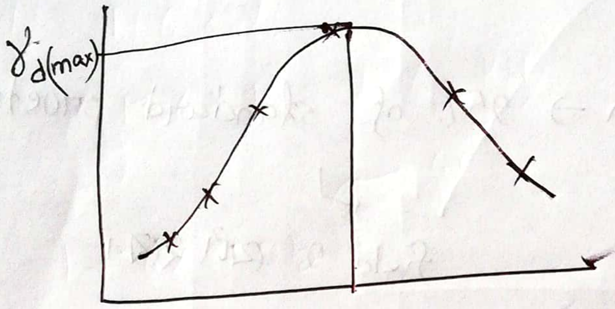
/98%

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

method specification (কম use করি)
layer thickness কত, number of pass → এসব process (আগে কোন method এ কাজ করবে) বলে দিব। ultimate value কত হবে সেটাই use করব (90%, 95

......) accept করতে হবে

Characteristics of compaction curve :



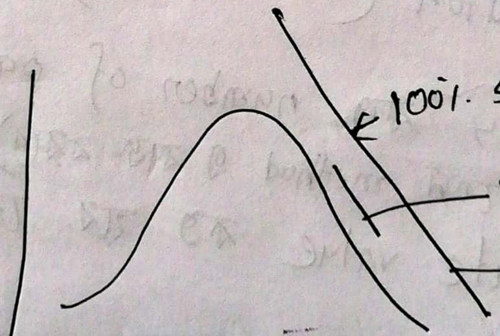
compactive effort (standard বা modified) এর উপর γ_d change হয় (not unique value)

γ_d (std) 95%

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

~~Conti~~

~~Math~~



100% saturation line

80% "

এটা কখনোই compaction curve touch করবে

curve এ কিভাবে draw করাতে হয় শিখব। 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 100 m³. $G_s = 2.67$

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

$w = 5\%$ + addition water

$w = 15\%$

$Vol^m = 1 \ m^3$

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

weight of solid

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

$$W_s = 17.6 \times V$$

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

w

$$W_{w(5\%)} = 17.6 \times \boxed{.05}$$

$(-)$

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

$1.76_{KN} \Rightarrow$ 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.

1

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

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

$$\Rightarrow e = 0.49$$

$$= \frac{w \overset{2.67}{\boxed{G_s}}}{\underset{0.49}{\boxed{e}}}$$

$$\Rightarrow w = .18$$

18% পানি দিলে soil fully saturated হবে।

$$W_{w(18\%)} = 17.6 \times .18 = \cancel{3168} \; \cancel{\text{KN}} \; 3.168$$

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

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 m^3 of soil in the finished site, estimate the vol^m ~~of soil~~ to be excavated from the borrow area and also calculate amount of water to be needed at the finished site.

Gs না দেয়া থাকলে কিভাবে করব? xm এ এটা থাকবে

⇒ Borrow	Finished
1.75 gm/cc at 12%. w=12%.	$w = 18\%$
$\gamma_d = \frac{1.75}{1+.12}$	$\gamma_d = 1.65$ gm/cc
$= \frac{G_s\gamma_w}{1+e_b}$	$V_f = 1000\ m^3$ $\gamma_d = 1.65 = \frac{G_s\gamma_w}{1+e_f}$

পানি

?

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

1000

Ans. of moisture content ~~99 m^3~~

Vol^m of water needed 99 m

14/5/19

Lec-06

Relative/percent compaction:

field এর dry density

$= \gamma_{df}$

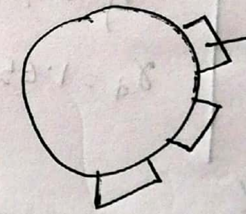
$$\frac{\gamma_{df}}{\gamma_{dmax}} \; \left(\begin{array}{c} STD/ \\ MMD \end{array}\right)$$

standard /modified proctor

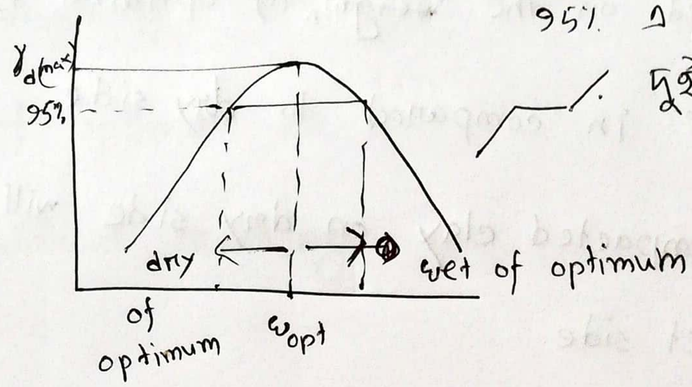
Equipment গুলো (field compaction)

এগুলোর short note (দেখব)

- smooth drum roller [300- 380 KN/m^2 — pressure]
- Pnumetic roller (4-6 টা time থাকে 600-800 KN/m^2 — pressure]
- ~~seive~~ sheep foot roller
- Vibratary roller (sandy type of soil এর জন্য)
- Impact hammer



এটা হবে যায়া

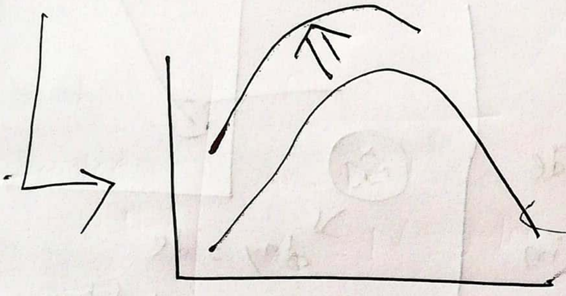


95% এ দুই type moisture content

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.

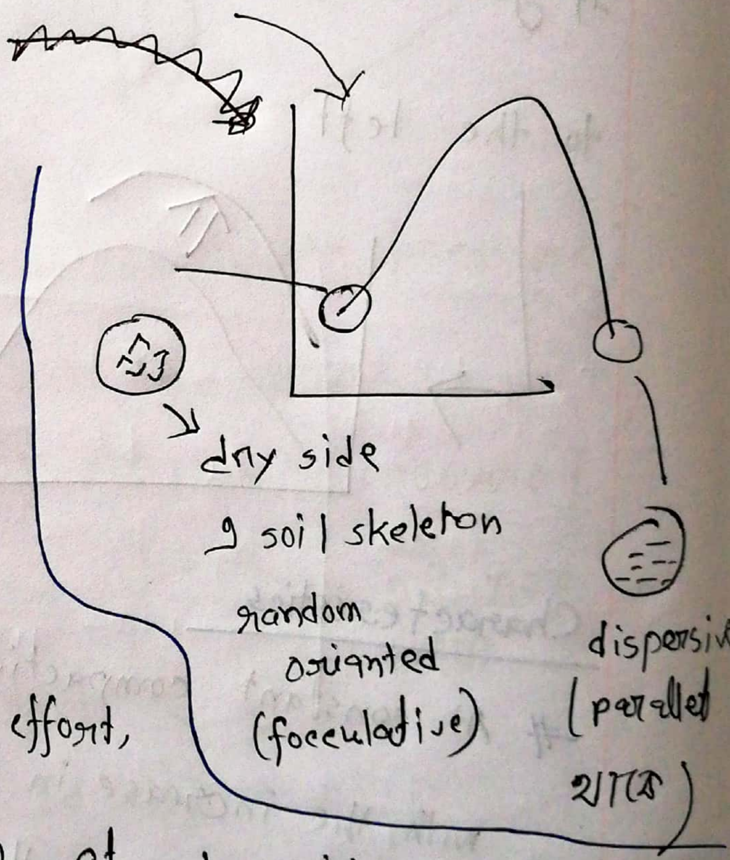
(wet side এ)

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 /

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 গুলা wet side এ

High swelling

less shrinkage

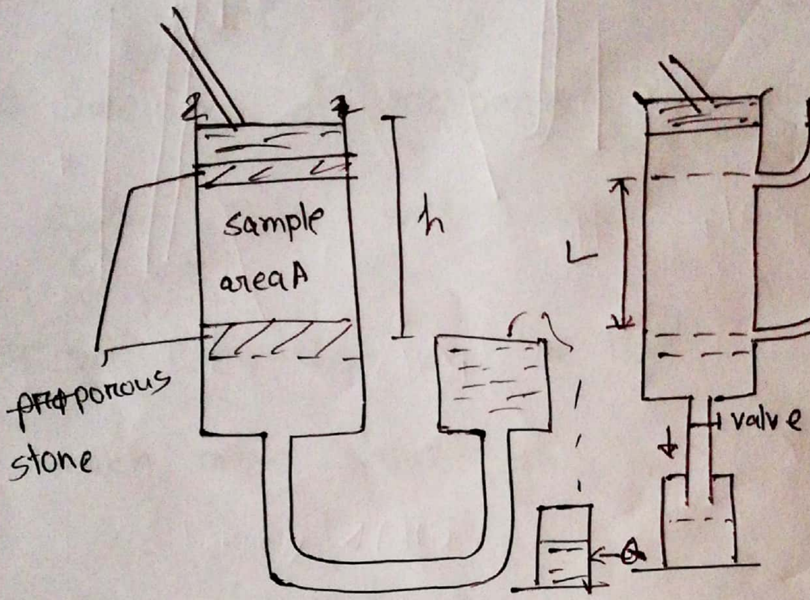
Higher strength

low strain

less compressible

24/6/19
Lec-07

Fluid flow through porous media:(seepage)



constant head method

Basic consumption:

1. Soil contains continuous void. [Continuous নাহ হলে এ theory applicable না]

2. Soil must be fully saturated

3. laminar flow exist.

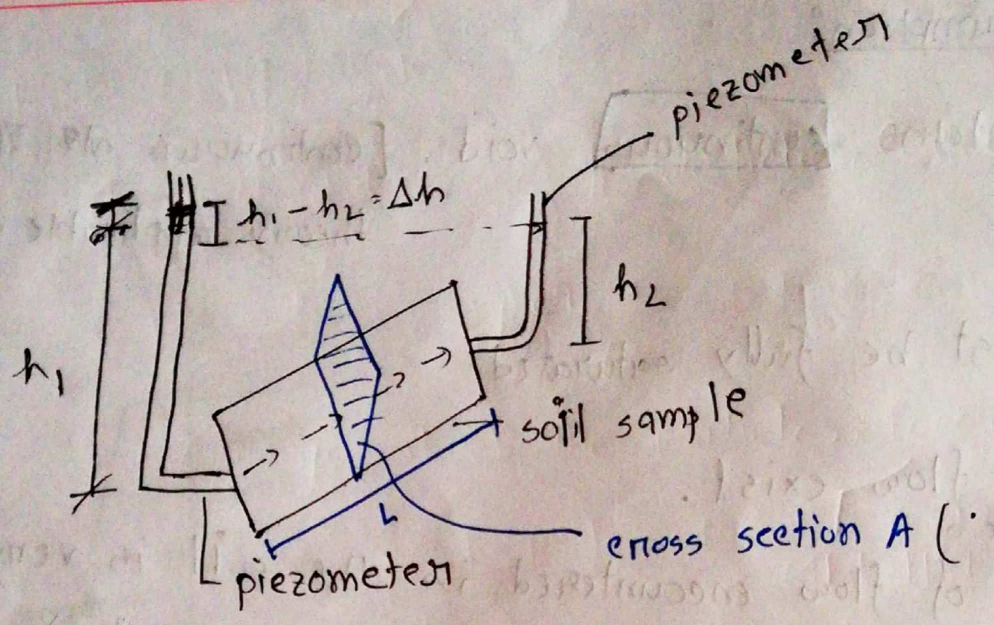
4. magnitude of Velocity of flow encountered in the soil is very small and that's why we neglect the contribution of velocity head $\left(\frac{V^2}{2g}\right)$.

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,

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

Discharge/ Apparent/ fictitious velocity — $\boxed{v} = \boxed{k} i$ — co-efficient of permeability (velocity এর unit)

k যত বেশি তত easily পানি pass করবে।

Head loss

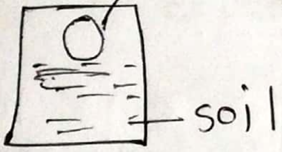
$$i = \frac{h_1 - h_2}{L} = \frac{\Delta h}{L}$$

[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

$$\frac{q}{t} = VA$$

$$= VA_g = V_s A_v$$

$$V = V_s \frac{A_v}{A_g}$$

A_g = gross area

A_v = void "

[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.

পড়াও 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: Focculated / Dispersive

   Focculated: বেশি পানি যেতে পারবে | Dispersive: 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.)

   Unit weight ↓ বেশি হলে k কম

   viscosity (Temp.) ↓ 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-Haizen formula (1911): বই eq^n 2.4

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

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

Lab determination:

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

ছবি দেখে বুঝতে

Head remains constant throughout the period.

$$Q/t = kiA = k.\frac{h}{L}.A$$ [যেহেতু 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~~ নামতে থাকে তাই falling/variable head.

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

reduction in head এর জন্য $\textcircled{-}$

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

xm এ আসবে
বই দেখব

দুটা system এর drawback:

field এর density lab এর করতে পারছি না

field এর arrangement disturb করছি lab এ আনার
Ever

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।

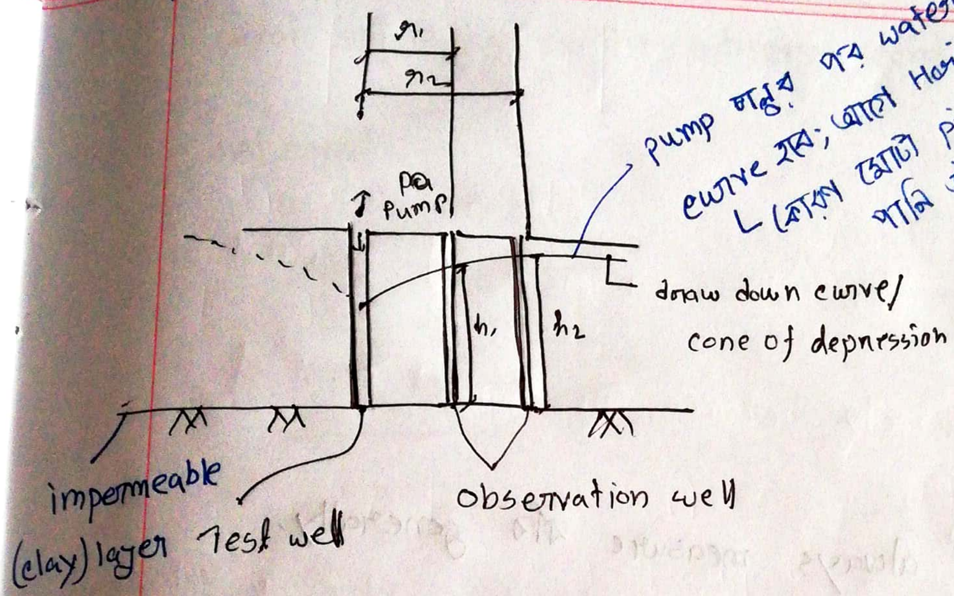
Ans.

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

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

25/6/19

Lec-08



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

$$q = kiA =$$

$$k.\frac{dh}{dr}2\pi rh$$

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

ear^n 2·7 বই এ

$$k =$$

expensive এই method.

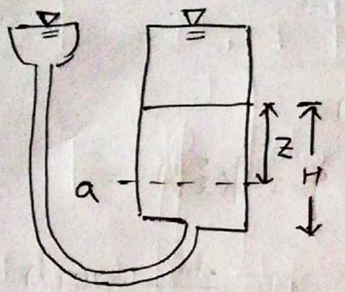
যেখানে অনেক depth এ ~~measure করে~~)

[illegible] suppose deep tubewell বসানো হবে।

clay থেকে পানি extract করা যাবে না।

মোটা sand layer এ গেলে 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 → Aquefar(?) → porous formation বই.

Stress in soil:



ছাব ৰই ৯->

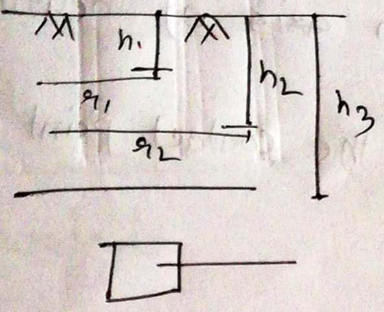
Stress at a point always measure কৰি generally.

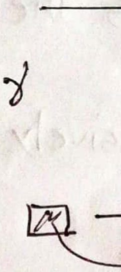
The total stress at a point on a mass of a saturated soil is composed of 2 part ->

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

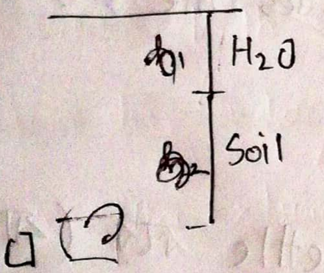
-> it acts in equal magnitude in all direction (F.M. ৰ Hydrostatic pressure)

Total stress is the stress contributing by overlying material.





এখানে stress
হবে γh.



~~$\gamma_w \times h_1$~~ heigl
$+$
~~$\gamma_s \times h_2$~~
= ~~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. →

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

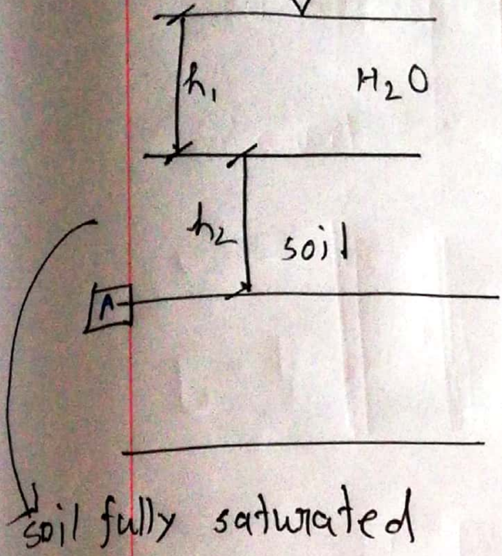
$$\bar{p} = p - u_w$$

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

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.



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)

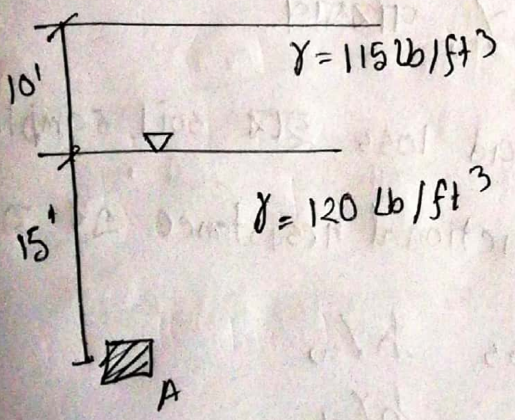
effective stress $p_A - u_A$ =

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

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

$$= \boxed{\gamma' h_2}$$

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



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

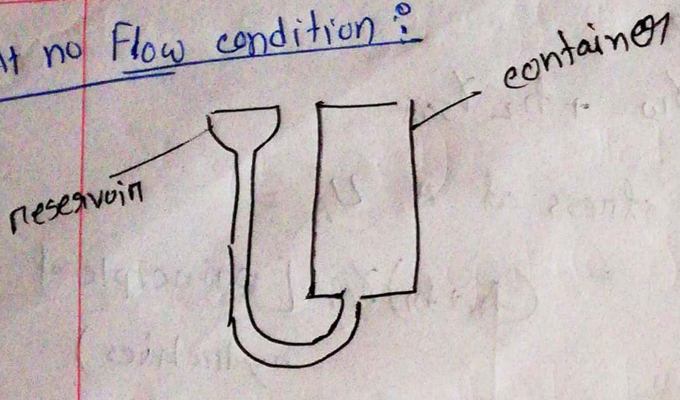
$u_A = \underset{\text{যতদূর পানি আছে}}{15} \times \gamma_w (62.4) = 936$

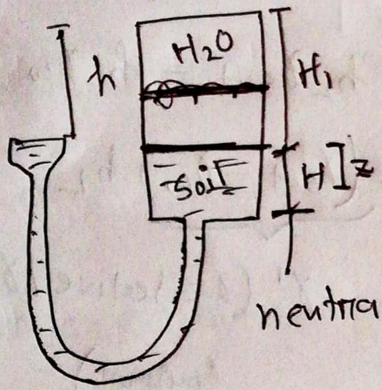
$\bar{p} = p_A - u_A = 2014$ /

$\boxed{115\times10} + (120-62.4)\times 15 = \bar{p}$

পানি নাই উপরে soil এর contn

At no Flow condition :





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

neutral stress কমে যাবে $\overset{\cancel{H_1\gamma_w + \gamma_s}}{h\gamma_w}$

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 ~~H0~~ loss $h\gamma_w$

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

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

Totat stress same থাকবে।

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

$$\boxed{= i z \gamma_w}$$

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

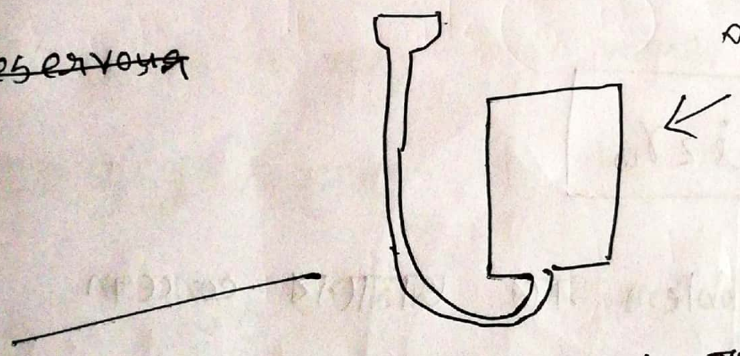
(z depth এ)

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

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

direction of flow ছিল downward এই case এ

~~reservoir~~



পানি reservoir থেকে container এ flow করে

এই case এ upward momement 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 → critical hydraulic gradient → যেখানে effective stress 0 হবে (upward flow তে)।

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

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

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 comple-tely looses it's strength, co-efficient of permeability reaches a very high value, severe edgitation (জলের মত বুদবুদ) occurs of the cohesionless soil.

e → 0·5 ~ 0·9

0·7 – mean value ধরলে i_c approa-ches unity.

i_c এর value (0·9 ~ 1)

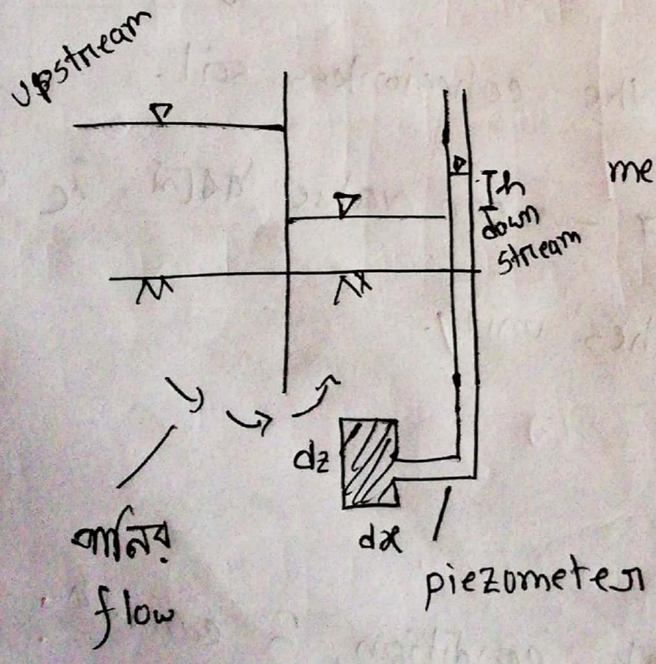
In water to exist quick condition, 2 cond^{tn}:

① effective stress must be 0

② frictional resistance ~~$\propto$~~ 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.

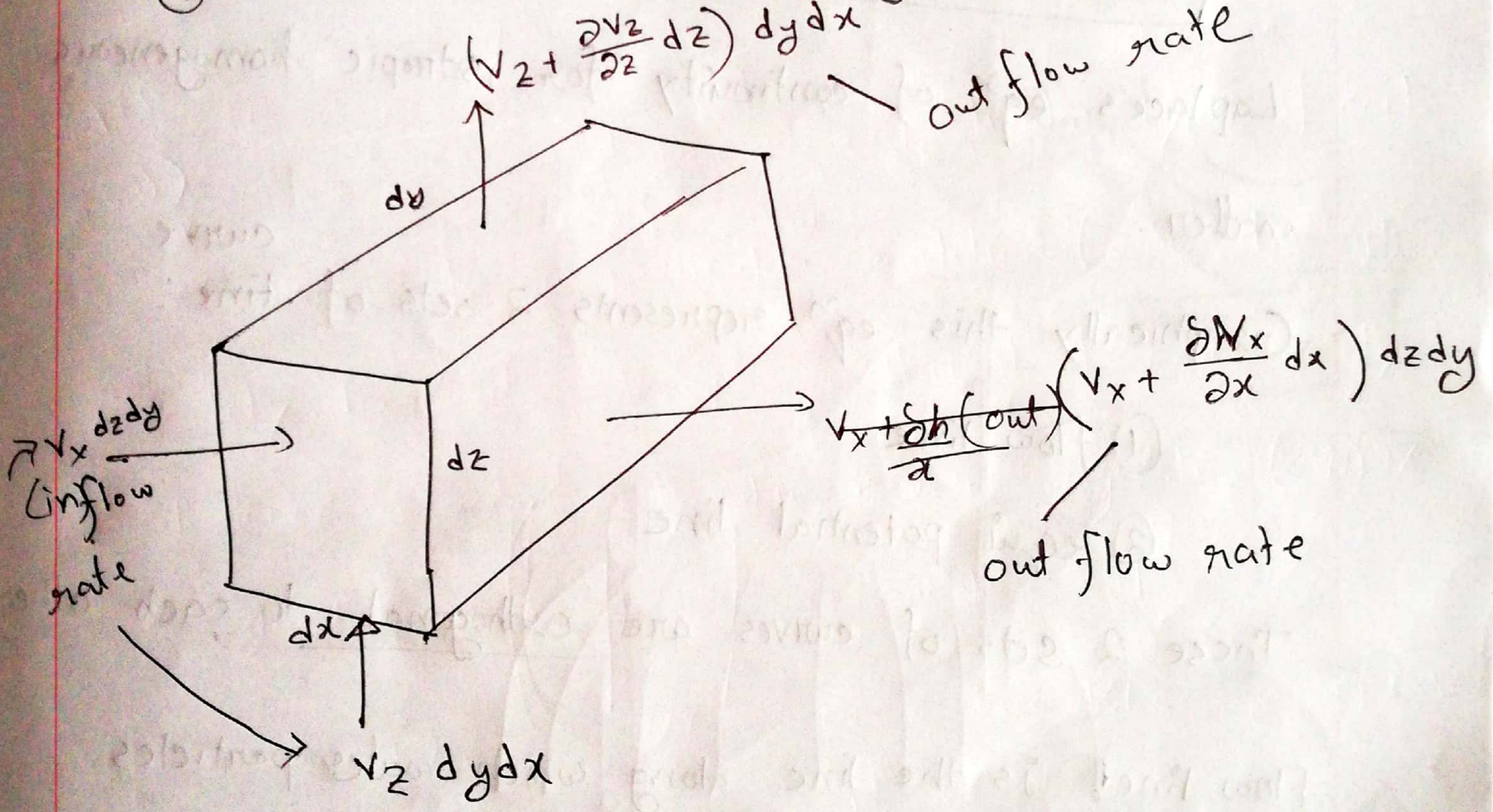
Assumption:

① Soil is fully saturated

② Darcy's principal applicable

③ Steady state condⁿ (no volume change)

④ ~~Medem~~ Material must be homogeneous and isotropic.



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

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

$$\therefore \frac{\partial v_x}{\partial x} + \frac{\partial v_z}{\partial z} = 0$$

$v_x = ki$

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

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.

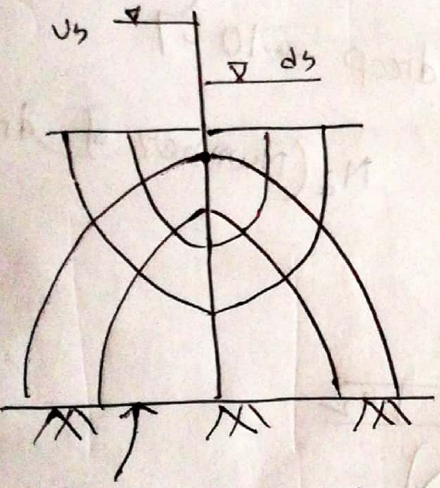
Flow line: is the line along which water particles moves from upstream to downstream

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

1/7/19

Lec-10

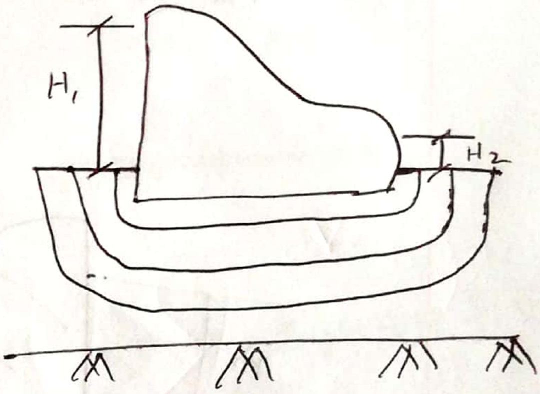
The region bounded ~~by 2~~ between 2 successive / adjacent line is called flow channel. And the element bounded by 2 adjacent flow line and 2 adjacent equipotential line is called flow element.



impermeable layer/

clay layer

sheet dam

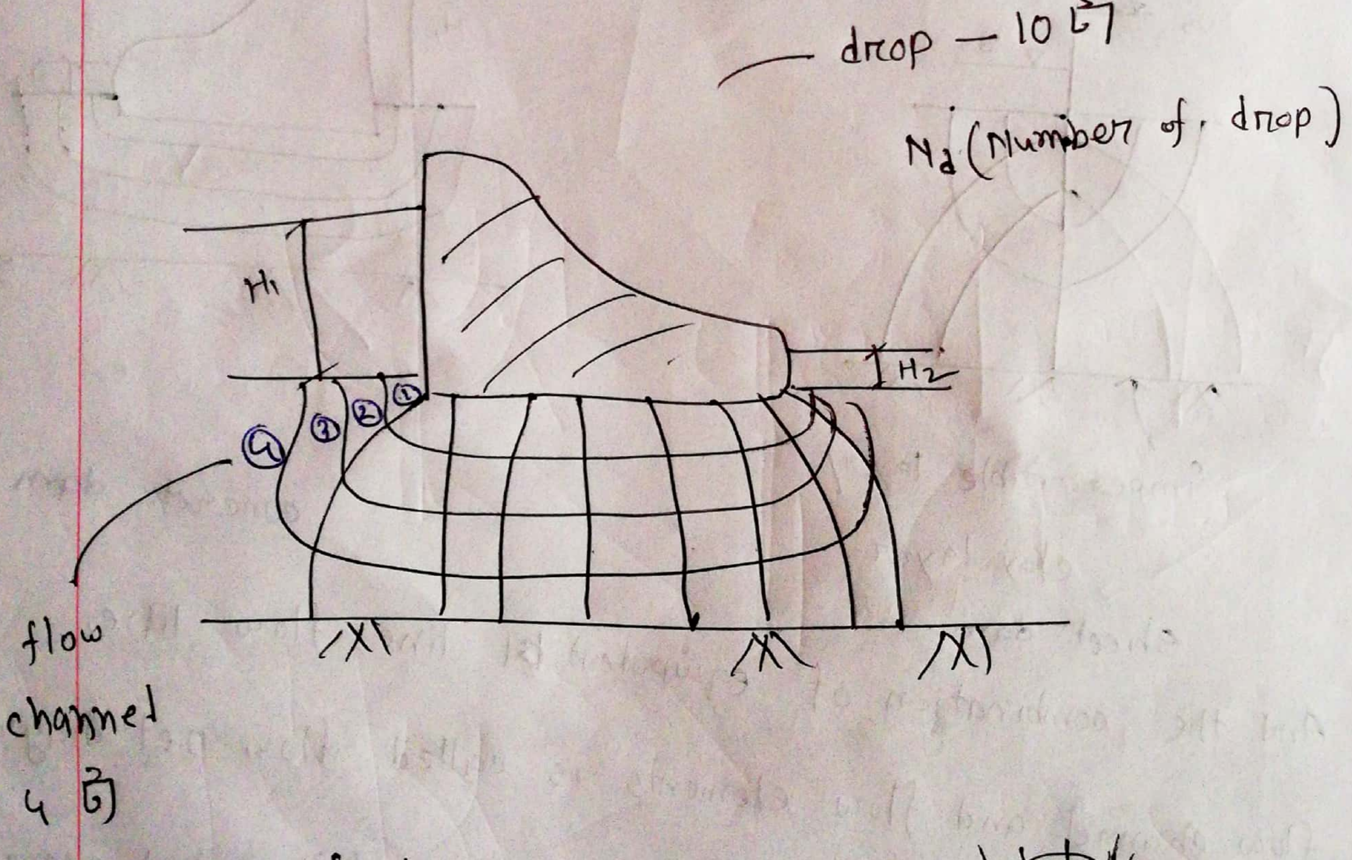


concrete dam

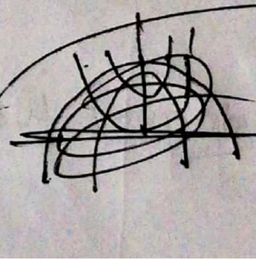
And the combination of equipotential line, flow line, flow channel and flow elements is called flow net diagram. Using this, we can calculate seepage loss (flow that occurs from upstrem to downstream). We can also compute the effective stress and pore water pressure in the entire domain (flow net diagram)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

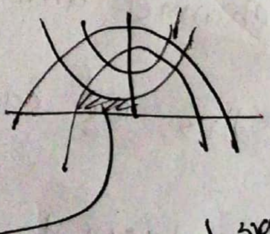
Flow Net diagram কিভাবে draw করব:

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



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

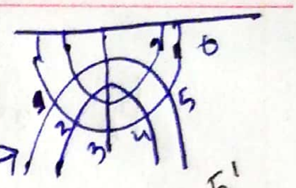




এই channel square না, fraction আসবে; না

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

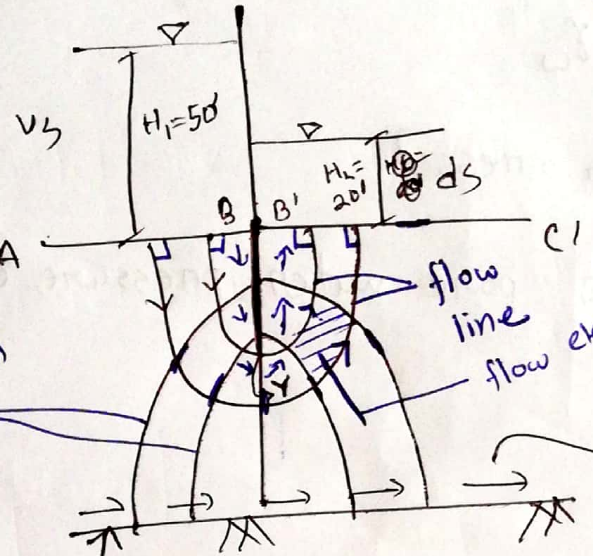
পানি flow করে যেতে 30' loss



6টা drop (Head loss)

1টা drop = 5'

$\gamma = 130$ #/ft³



B'C' equipotential line

AB' ও line

~~B'Y → flow line~~

$N_d = 6$

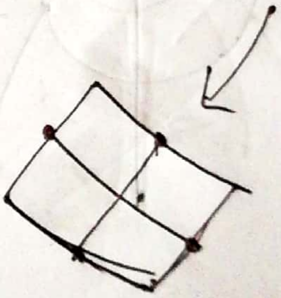
$H = H_1 - H_2$

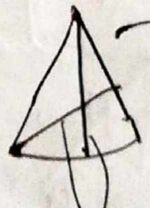
$= 30 = H$

$\boxed{\frac{H}{N_d}}$

xm এ (2-4)টা flow line draw

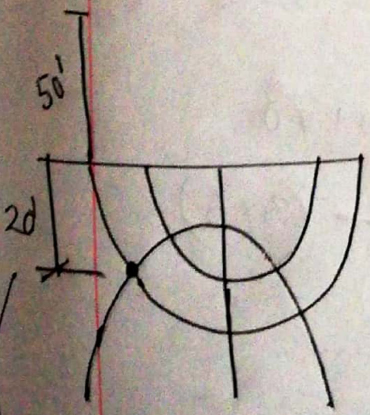
flow element curvilinear square হবে





এ রকম আসমান

এই দুই length অসমান



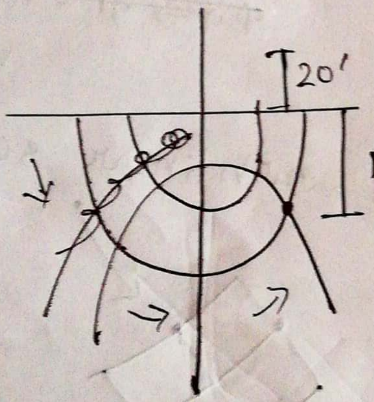
এখানে piezometer বসালে 70' পাওয়ার কথা। 5' drop এর জন্য 65' পাবো।

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

$U_A = (70-5)\gamma_w$

effective ~~pressur~~ stress?

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



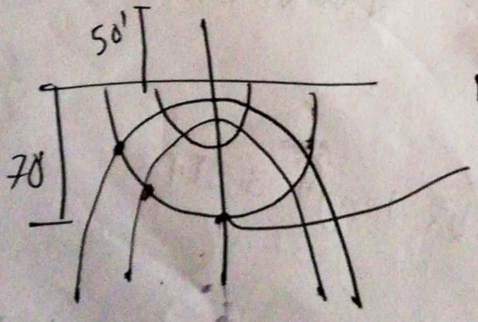
$\gamma_B = 43\gamma_w$

$(20+18+5)$ → এখানে (+)ve হবে

downstream এ

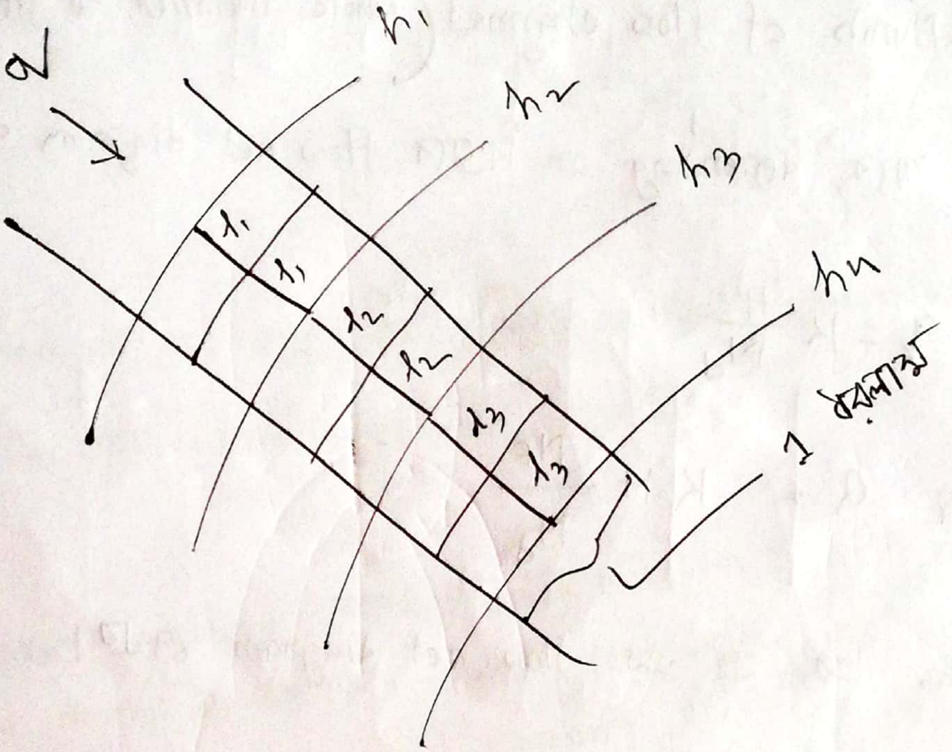
নিয়েছি

upstream এ করলে (−)ve হবে।



No flow condn এ 50+70

flow তে ⇒ 120 − (3×5)



$q = kiA$

যে পানি এই channel

দিয়ে ঢুকবে, সেটাই বের হবে;

no flow across the channel.

$h_1 - h_2 = \text{drop}$

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

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

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

[সব drop এর মান সমান

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

Scanned by CamScanner

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 দেখো।

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

2/7/19

Lec – 11

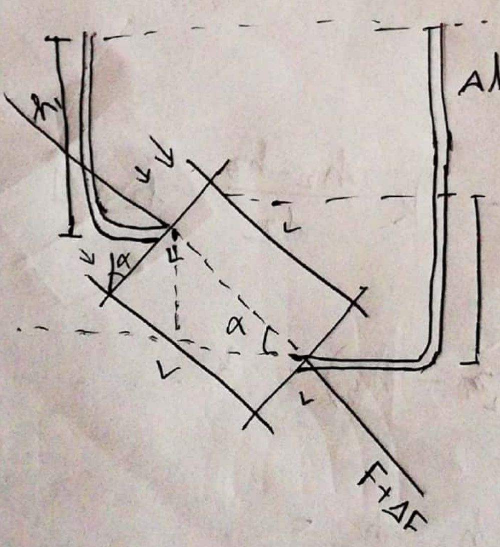
বই ⇒

γ_{sat}

~~$l \times \Delta x$~~

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

self weight downward কাজ করবে



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

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

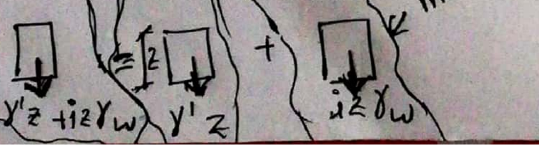
$h_2 = h_1 + L\sin\alpha - ~~\Delta h~~ \Delta h$

⇓

$\Delta F =$

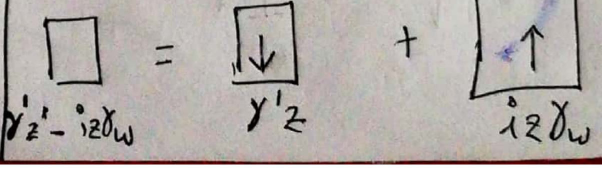
Flow through a inclined flow element

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



upward movement

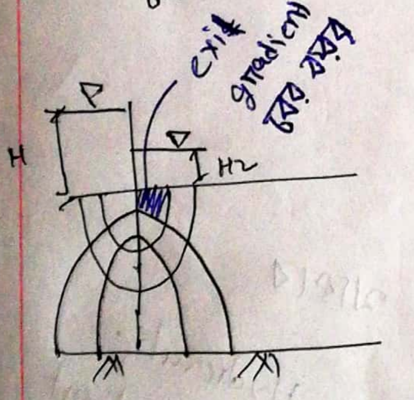
$p' = \gamma' z - iz\gamma_w$

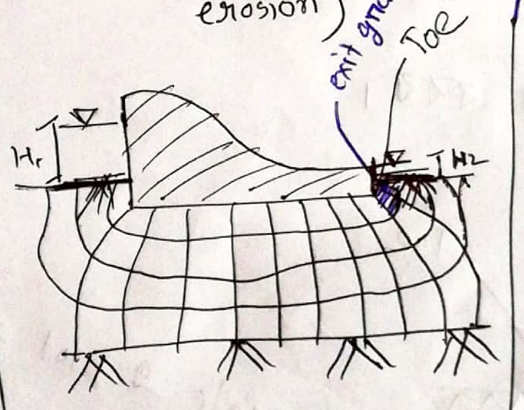


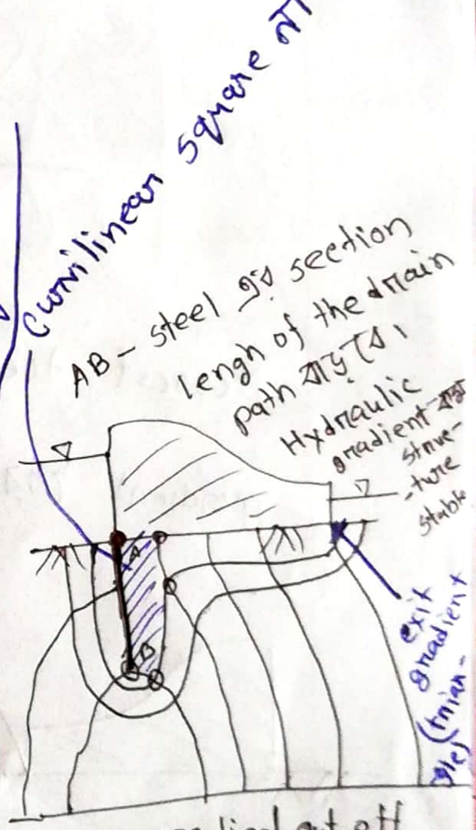
Hydraulic gradient বেশি হলে prob ⇒
upward এর flow বেশি হলে quick condn হবে soil এ; soil সরিয়ে ফেলবে। তাই river bed এ upward movement quick sand condn হতে পারে।

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

check the stability করলে → Quick condn 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 মাত্রের জন্য seepage loss?

width দেওয়া না থাকলে unit.

$N_F = 4$

$N_d = 11$

$H = H_1 - H_2$

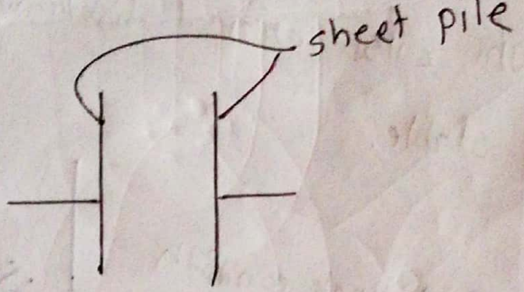
A B vertical cut off

দুটো vertical cut off?

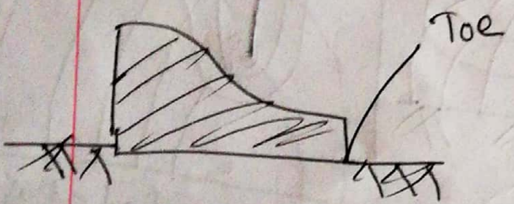
কেমন হবে দেখব

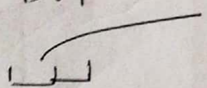
$$i_{cr} = \frac{\gamma'}{\gamma_w} = \frac{G_s - 1}{1+e} \approx \boxed{0.9 \text{ to } 1.1}$$ যদি না দেয়া থাকে

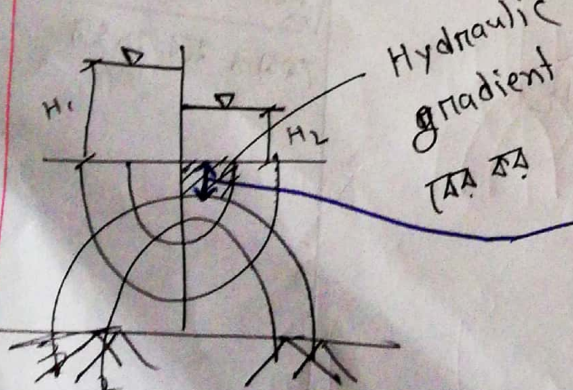
[illegible]



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







$$\overbrace{\dfrac{\dfrac{H_1 - H_2}{N_d}}{l}}^{\text{Hydraulic gradient}}$$

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

F.S. → Harza ~~বইতে~~ বলেছে 3 দিতে হবে।

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

Flow through inclined এর continue →

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

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

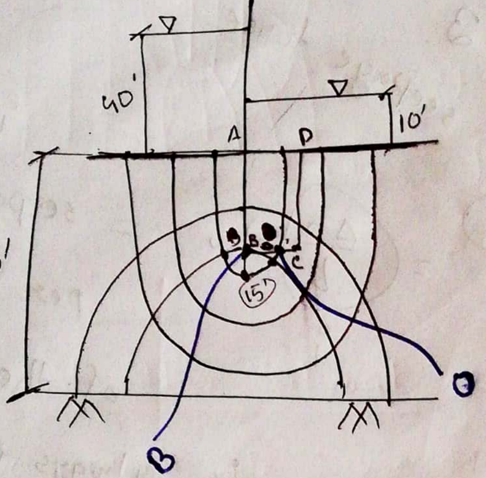
it acts along the direction of flow

$$\overset{i_z\gamma_w}{\boxed{iz\gamma_w}} \Rightarrow \text{seepage pressure}$$

$A \cdot iz\gamma_w \Rightarrow$ seepage force

$$\frac{\cancel{A}\cdot i\cancel{z}\gamma_w}{\cancel{A}\cdot\cancel{z}} = \text{〃 〃 per unit volume} = i\gamma_w$$

#



Ө, $N_F = 3 \cdot 6$

$H = 30'$

$N_d = 6$

$K = ?$ — দেয়া থাকবে

q বের করব

stability check কর।

নদীর fine siltty sand এ highly susceptable to quick condition

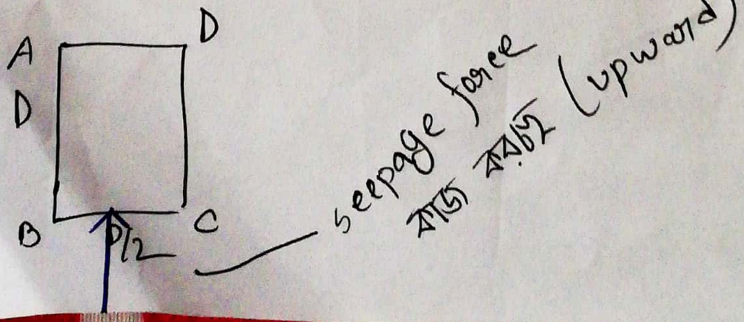
clay তে quick condⁿ arise করে না কেন ? → Ques.

AB = D BC = D/2

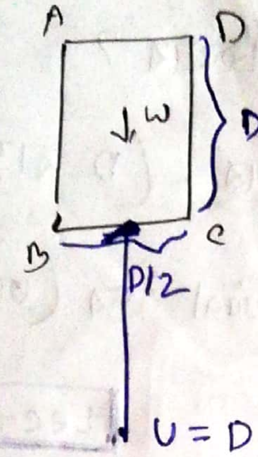
ABCD area ~~অ~~ এর soil কে protect করাতে পারলে

(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

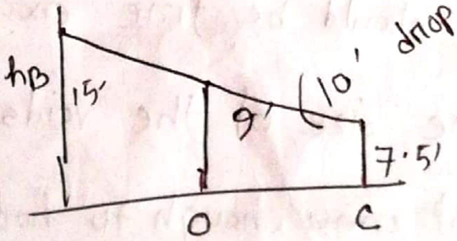
$$U = \underbrace{D \times \frac{D}{2} \times 1}_{volume} \times \underbrace{i\gamma_w}_{seepage\ F\ per\ unit\ volume}$$

soil এর ভিতর দিয়ে যাওয়ার time এ frictional loss উপরে

১টা drop 5'

$h_B = 15'$

(drop এ loss হওয়ার পর



(10' drop এর পর একটু উপরে c point 60 হওয়ায় 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 → havg

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

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

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 materia

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 $$\boxed{\frac{\overset{\text{filter mat.}}{D_{15}(F)}}{\underset{\text{Base mat.}}{D_{85}(B)}} \leq 4 \text{ to } 5}$$

1971 এ হয়েছে

Condition 2 " " " " $\frac{D_{15}(F)}{D_{85}(B)} \geq 4$ to 5

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

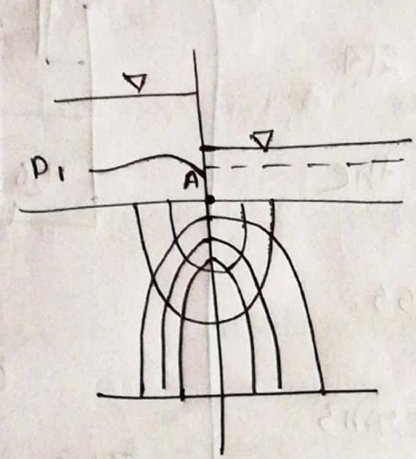
① To avoid movement of the particles of protected soil (Base soil).

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

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

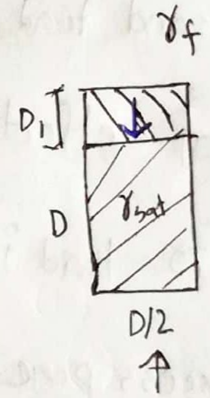
cont.
(পরের 1 pg পরে)

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 $\frac{D_{15}(F)}{D_{15}(B)} > 4$.



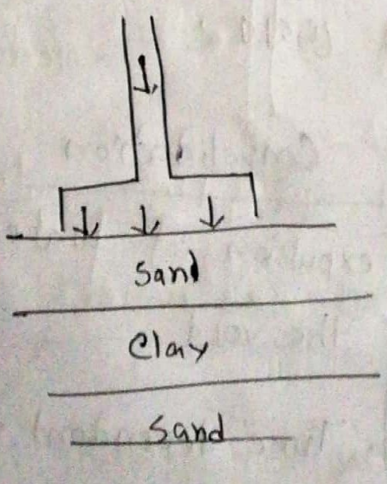
$F_s = ?$ বের করব

AB = D



next class এ ct (মঙ্গলবার)

Capilary rising soil:



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

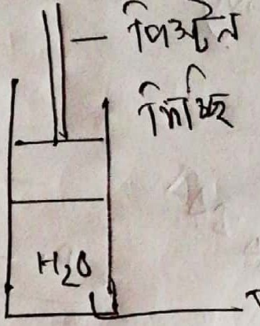
sand এর coeff. permeability clay " " " এর চেয়ে 10^8 গুণ বেশি।

Sand layer এ load আসলে

পানি সব বের হয়ে যাচ্ছে। Normal stress অল্প একটু হয়ে নাই, সব 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 দেখাব।

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

হব ,, ,, - এর theory

Tarzaki 1 dimensional consolidation theory

1D কারণ পানি শুধু vertical direction এ বের হবে।

Oedometer/ Consolidometer:

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

3/4" – 1" → thickness

Oedometer .

এর ভিতরে sample নিয়ে consolidation test করব।

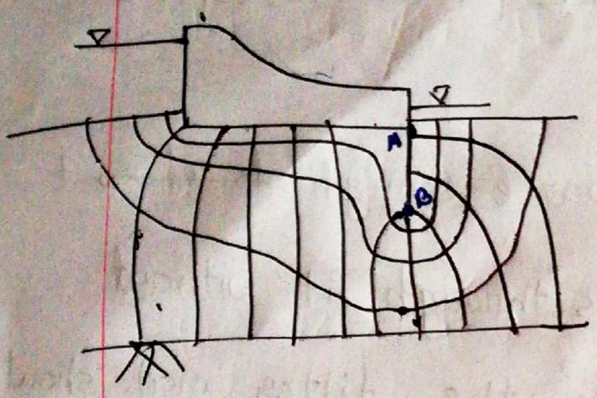
Settlement criteria controlling factor → structure এর (90% time)

(Consolidation থেকে পাবো।

Lec - 13

9/7/19

downstream এ cut of দিলে length of drainage বেড়ে গেল



NF = 3.4

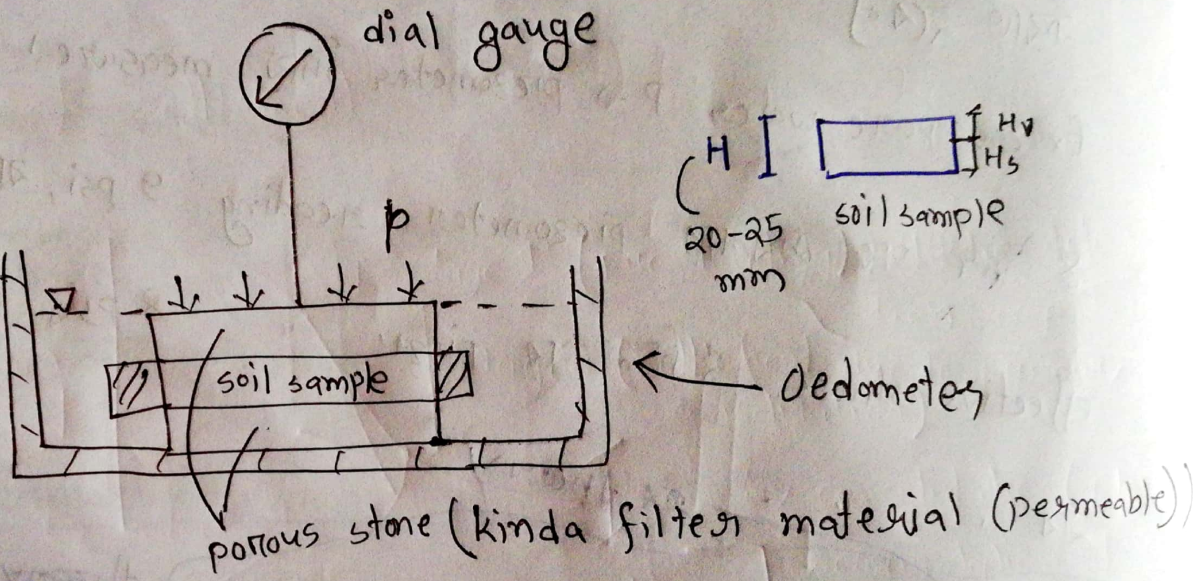
Nd = 11

Hydraulic structure এর width বাড়ালেও length বাড়বে (but expensi

Filter material → Quick condtⁿ যাতে arise না করে তা ensure করবে।

Consolidation থেকে যাবে।

Lec-13
9/7/19



যে depth এ consolidation characteristic দরকার সেই

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~~ kPa

normal " – 5-10 kPa

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

করে। 24 hour রাখা হয় ~~এই~~ 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, 2min, 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 যে ঘন্টাই হয়

reading নিয়ে আবার load increment করা হয়।

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

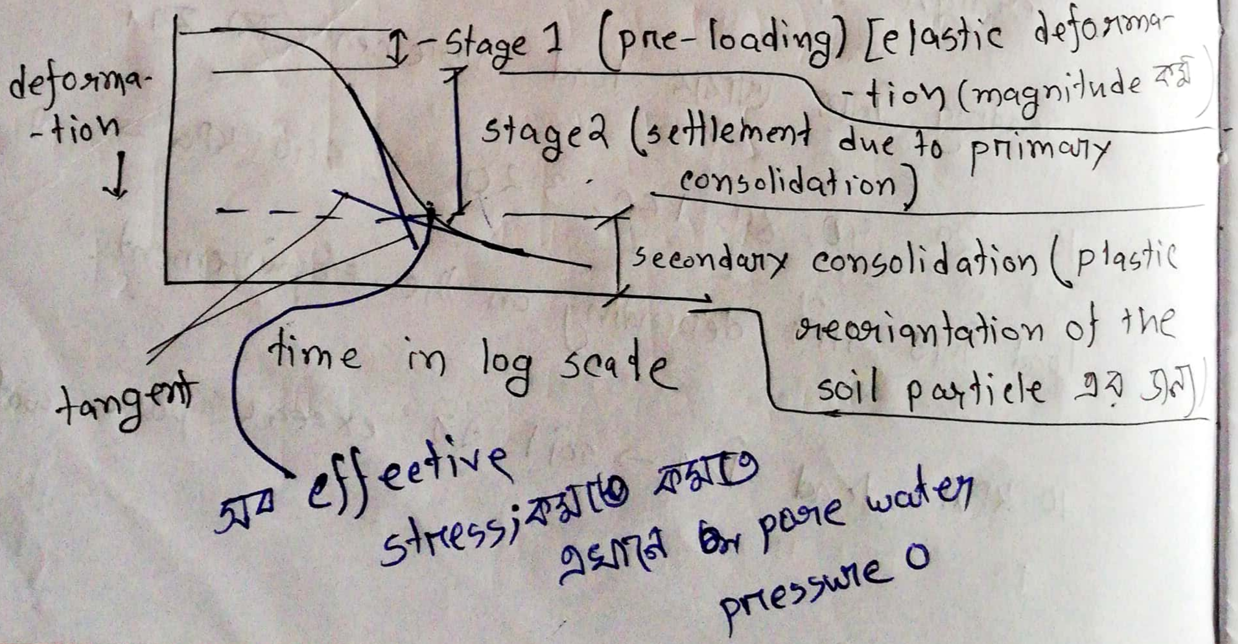
load দিতে পারি depending on the requirement.

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 [illegible]~~ suppose 8 kPa হল → (মানে 8 kPa effective stress এ convert হল) → 24 hr পরেও যদি সেইম reading ~~change না~~ না পাই আর dial gauge এর তাহলে বলতে পারব যে load দিয়েছি তা fully converted to effective stress.

এটা consolidation settlement ~~assoct~~ / ~~consolidation~~ settlemeng related with primary consolidation.

3 types of settlement



secondary consolidation → soil এ organic matter থাকলে excess pore water pressure ~~কমে~~ যাওয়ার পরেও
0 হয়
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 বুঝব।

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

weight of soil

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

cross-section area

$H = H_s + H_v$

২. $H_v = H - H_s$

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

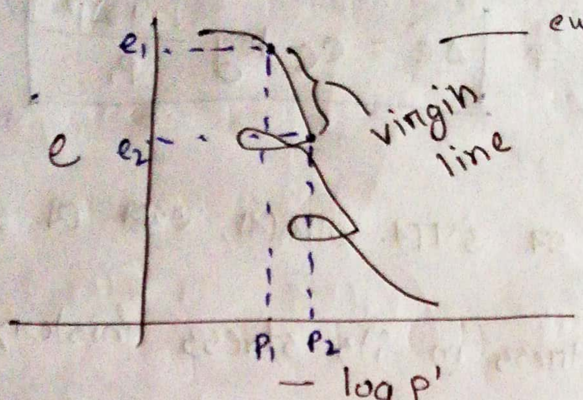
next load 20 kPa, এ 10 kPa]

$$p_2 = \overset{10\,kPa}{\boxed{p_1}} + \boxed{\Delta P}$$ আরো 10 kPa 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।

অনেক loading থাকলে এই graph



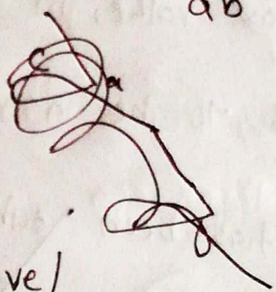
— curve এর slope compression index (C_c) (virgin line এর slope)

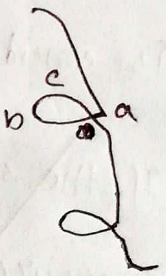
$$C_c \doteq \frac{\Delta e / e_1 - e_2}{\log(\frac{p_2}{p_1})\beta}$$

$$p_2 \doteq p_1 + \Delta p$$

follow করে.

1st এ curve টা concave downward. Then straight line, – virgin line। ~~ঠিক~~ 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 বইয়ের 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)~~

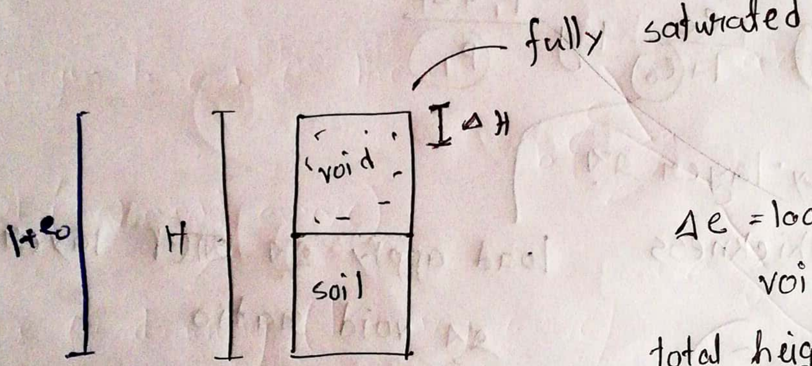
The soil whose present overburden P is less than that which the soil experienced in the past and the past max pressure is called Pre-consolidation Pressure; denoted by (Pc) [like পাহাড় কেটে ফেললাম, তার নিচের soil; এই soil অনেক stiff.

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

$OCR > 1 \rightarrow$ [OC]

OCR যত বেশি, degrees of over consolidation তত বেশি।



Δe = load এর জন্য change in void ratio

total height $= 1 + e_0$

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

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

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

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

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

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

lab test থেকে বের করব

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

ঐ clay এর test করব তার height

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

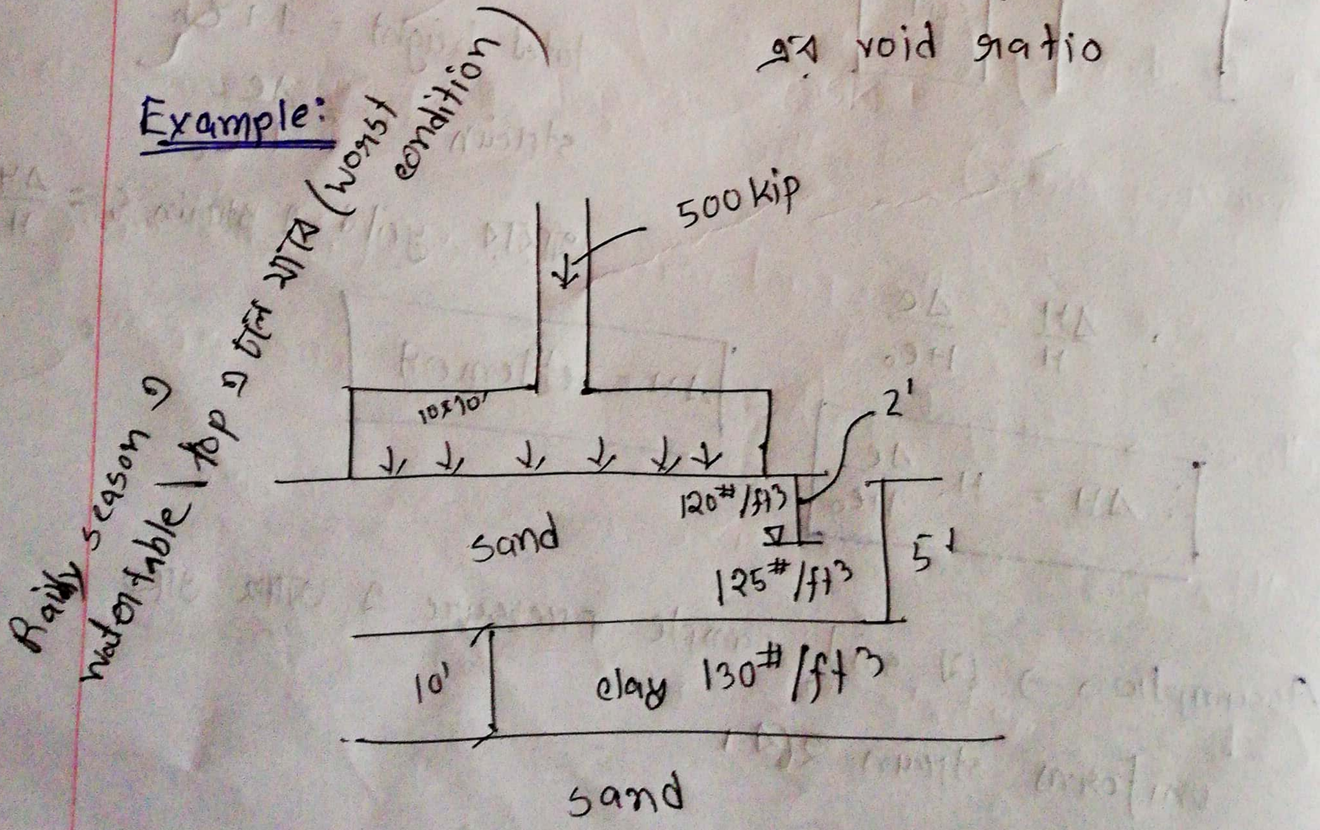
ΔP আর C_c বের করতে হলে e – log P curve থেকে,

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

clay layer এর thickness

load apply এর আগে layer এর void ratio

Example:



$\underbrace{e_0,\ P,\ \Delta P,\ C_c}$ লাগবে $H = 10'$ জানা

↓

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

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

75 ksf

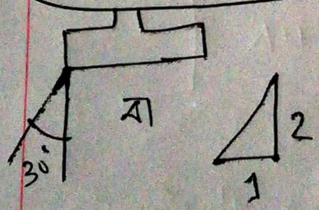
প্রতি layer এ moisture content ~~দেয়া~~ দেয়া থাকলে, like clay layer এ $\omega = 30\%$ তাহলে

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

NC এর জন্য $C_c = 0.009(LL - 10)$

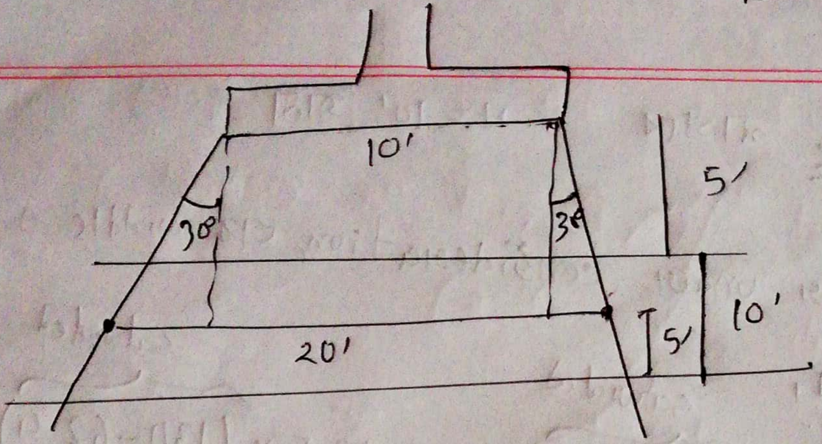
(accurate হবে না, curve থেকে নিলে accurate পাবো।

emperical (যদি C_c দেয়া না থাকে)



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

~~120×~~



30° angle এ load spread হয়ে clay তে যেয়ে 20'

span হবে।

ΔP = ~~5ksf~~ 1.25 ksf

$C_c \approx$ '21 — '35 (soft clay তে normally)

Footing এর size change করে (rectangle/circular) এর

জন্য কিভাবে হবে dispersion দেখব।