C.W.

Theory important

Sat Sun Mon ☑Tue Wed Thu Fri

Yasin Sir L-1

Date: 30 04 19

References
1. Principles of foundation engg - BM Dash.
2. Physical and Geotechnical Properties of soil - Bowels
3. Coduto
4. Peck and Hanson

- Soil investigation techniques
  Planning and reporting
- Rafts and piles
- Slope stability analysis

Site exploration and characterization

In geotechnical engg. properties of subsoil unique. In other cases, specified properties are available. or decided by engineers.

Soil strength parameter, c, φ, q_u (Direct shear, Unconfined Compression)

Settlement, C_c, C_r, OCR

*BD, alluvial soil, heterogenous, recent deposit.

Soil cannot be specified, we must what we have.

* Purpose/Significance
Should be tested/explored

No place for imagination.

⊛ Explanation of each point reqd.

1. Nature → type: boulder-gravel-clay/cohesion/
   thickness, depth, organic mat ↑ q_u < 10~15 kPa
   consistency: stiff, soft (clay)
   loose, dense (sand)
   ↓
   SPT 40~50

2. Assess the suitability:

CE → 4^n upto 200m for high rise/bridge.

Geologist → deeper

Agriculture: few meters.

Type and height of structure determines depth of exploration.

3. Topsoil → weathered zone
Solid crust → bedrock.
slope north to south in BD
Fault movement, tectonic activity. for important structure (Padma bridge, nuclear power plant)
Bearing level/stratum
Scouring depth with high velocity, washes away bed material (Padma - 60m)

Position of soft clay layer

4. GWT : Fluctuation. Permanent level
Depth increases → settlement, liquefaction.
- Variation harms wooden foundation.

5. foundation problems:
Soil may loose shear strength + pore pressure buildup.
↓
Collapse
Expansion,

6. Type of foundation:
Pile, raft, mat.

7. Ground improvement.
When forced to use bad soil.

8. Soil sample, tests. → design parameter
Canal, leachate pond (impermeable layer), embankment
↓ permeability
↓ c, φ.

9. Constrauction method:

Basements increase depth to cut.

Dewatering if GWL intercepts.

Shore protection for structures nearby.

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Steps in soil investigation program

1. Planning
2. Field work
3. Lab work
4. Reporting : Sub soil investigation report

Planning

1. Project assessment
   - type, location, approx dimension
     building, powerplant, dam, tunnel.
   - rough idea of load per floor
     settlement limit ~ concrete structure - low $\frac{1}{2}$"
     steel " - high

* info from related organization (LGED/PWD)

LGED local road - low
highway - high
airfield - very low

   - topography (ditch, marsh, river, previous structure)
   - previous development (3 story to 10 story)

2. Literature search (General)
   LGED
   Bangladesh geological survey / USGS

* Not all data are reqd in every project
Padma bridge and Nuclear plant : Geological info for high cost and safety.

Ground water : PWD, WASA (relevant to settlement)

Groundwater extraction causes top layer effective stress to increase and boyancy to decrease → consolidation and settlement

3. Reconaissance:
সরেজমিনে
general topography - canal, marsh
shrinkage crack in dry season
→embankment failure as rainwater enters through cracks.
stratification through previous excavatio
high water mark (flood level)
vegetation.
info of adjacent building (foundation)

Site Geology.
filled up channel
Satellite image for shift in channel for 10 - 20 years
(SPARRSO) - Padma bridge.
Seismic potential
Difference in plain, hilly, marshy areas.
Earthquake: nearby faults, return period
Great Brahmaputra earthquake - 100 year return period
Gravity slope followed by rivers, break in that indicates fault. Sylhet, Tongi
for 100 story building in Purbachal.

9. Field work
1Boring de
Boring depth: Minimum influence zone depending on type and load of structure.
Bed rock can be found $\frac{1}{2}$ - 1 km down
Stress due to imposed load decreases with depth (Newmark chart)

Thumb rule: 1:2 dispersion.

D_2: $\frac{\Delta\sigma}{\sigma_z'} = 0.05$ $\left(\Delta\sigma\ \frac{1}{20}\text{th}\right)$

Depth determined from experience or empirical equation.

Steel can take higher differential settlement.

$D_1 = 0.1q \geq 30\text{ ft}$

Boring spacing:

Close spacing for dam.

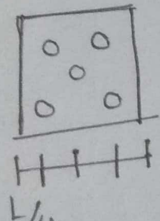
Airport runway: 10 km

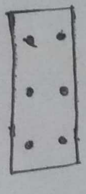
Sparse in case of road

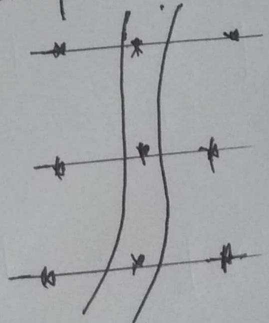
For large projects, at first sparse, grid pattern boring for preliminary design producing general picture.

Boring location:

depends on plot shape.







(Boring may be done crosswise)

If structure exact location is known, boring should be done there.

Borehole location for bridge depends on scour depth.

আগে কিছু জায়গায় deep boring. uniform layer পাওয়া গেলে cost বাঁচে কারণ অন্য জায়গায় shallow boring.

* Soil investigation is very important for safe structure.

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Exploratory Borings

Techniques and Equipments

Boring methods

- Process
- Applicability
- Limitation
- Advantages

Auger method:

Hand auger: not for sandy soil
highly disturbed.

Machine operated: helix এর গায়ে soil লেগে থাকবে,
Solid stem / Hollow stem
↓
Undisturbed soil
(Auger remains, removing the front bit and pushing a sampler through the hollow pipe)

70-100 mm hole enough to collect samples for consolidation, unconfined compression, direct shear.

Wash boring:

Sharp cutter in front. Fall from a height. Then torque applied.
Water pumped into the loose soil which is forced upward with the soil. Water circulation.
Suitable for soft alluvial deposit (BD). manpower বেশি
4500/- for 30m
Easy to carry.
Drill তুলে SPT or undisturbed sample
↓
(disturbed sample)

Rotary drilling

Relatively hard soil As wash boring.

Percussion drilling:

machine operated. unlike wash boring. only disturbed sample due to pounding.

Bore-log

D1, 2, ... Disturbed samples

Description - symbol - D1 - SPT.

* Mentioned if layer changes in the middle.

SPT: 140 pound hammer from 2.5′ on drill. 6″ penetrate করাতে কত blow?

প্রথম column ignore. কারণ top 6″ is disturbed due to boring.

Existing GL, elevation বসালে homogeneity, discontinuity বোঝা যায়।

Staggered boring
Geological profile. for ~~de~~ foundation design.
Individual footing - relative settlement due to relative density.
footing depth.
Ground improvement, if reqd.
Gasfield layout

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Observation of Water Table

High hydraulic conductivity – after borehole stabilization, chan
(Highly permeable)

Impermeable – water will not stabilize.

rain/heat may affect open water

Piezometer.

ভিতরে ছোট dia standpipe: দ্রুত stabilize

Impermeable layer to prevent water entering into borehole.

Electric transducer = auto record water level.

Silty soil: Vorslev method

3 # equal time interval

* 3 টা point পাওয়া যাবে। Average line draw করতে হবে।

Also piezometer may be used.

Soil sampling:

Disturbed - Boring, SPT-N

Undisturbed

Wash boring করলে পানি mix করলে constituent change হয়ে যায়। Sample হয়না।

SPT থেকে disturbed sample.

6" penetrate করতে যত blow লাগে – SPT-N

Test~ attachment বার বার change করতে হয়।

SPT তে pipe এর নিচে Split Spoon Sampler. Hollow pipe এ sample উঠে আসে। Ingredent same, but compressed.

* Undisturbed allowed for all tests.

Split Spoon Sampler

Driving shoe ক্ষুরের দিকে dia কম, পরে dia বেশি সমান থাকলে friction length বাড়ায় অনেক বেশি resistance আসত। এখান কম dia'র resistance continue করবে।

Ball joint Other end solid থাকলে আগে পানি ঢুকে জায়গা দখল করে soil ঢুকতে পারবনা।

Other end open হলে উপরে পানির কলাম soil কে নিচে ফেলে দিবে। Ball works as a lock.

Suction

Shelby tube.

Soft to moderate stiff ~ BD

Ball joint - 7-8m depth sampling. Vacuum.

Parameters.

Annular area ratio < 10%.

For large A_r, soil will be compressed.

Crimping ratio. $C_r < 1\%$ (Variable internal dia)

*Advantages and disadvantages

@W.

1st class after vacation
L 1-5

L-5

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Sampling of Cohesionless soil
Spring core catcher tube and cap.
Sand cannot drop as springs close.
Very fine sand /pebble may not be recovered.

Piston sampler:
For very soft soil. 2 tubes. Piston is connected. After boring. Inside piston is pushed down. Fixed piston stays in place. Because of fixed piston, no water or air cannot remain inside. Sample cannot drop due to suction.
Fixed piston prevents swelling of soft soil

Hand carved sample:
Tube then plate. Undisturbed sample at shallow depth.

Lecture-5

Field Tests:

DPL : Dynamic penetration light
medium
heavy
super heavy

SPT is the most common. Others are conducted depending on project.

Standard Penetration Test
Too many error sources.
Hammer height is important for energy transmission.
Manually controlled means height varies.
Rope এর প্যাঁচ friction control করে। ($2\frac{1}{2}$ turns)

Correction

Ideally, hammer energy should be transmitted completely.

$$\left(\frac{E_A}{E_{in}}\right)_{max} = 1$$

Convert accordingly. Different for different countries.

Empirical relationship of SPT and soil properties.

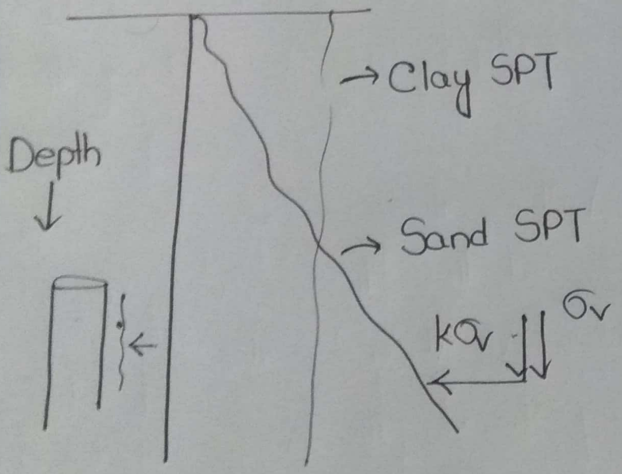
Interpretation depends on type of soil, not only on N.

SPT~OCR

Straight line in semilog paper.

OCR from consolidation test.

Cohesionless soil



Sand SPT increases due to friction → normal stress → overburden pressure.

Clay SPT remains same.

SPT ~ Relative Density

N_f - field SPT is accompanied with σ_v'

SPT is done on Silty soil under GWT. Water level lowers due to fast pulling out of drill rod. 'Boiling' occurs due to hydraulic head.

Compressibility → check moisture content along with SPT.

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L-6

Date: 22 06 '19

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Design N- values

একটা footing এর নিচে কতটুকু influence zone?

উপরে $\frac{B}{2}$, নিচে 2B পর্যন্ত B = width of footing.

Pile এর জন্য ~ Avg N

N'_{70} ~ 70% of driving energy to be transmitted.

Lecture-6

Cone Penetration

Dutch CPT / Static PT. No borehole reqd. Pushed.

Steady rate.

Measured: Cone resistance $\left(\frac{F}{10 cm^2}\right)$

Frictional resistance:

$f_c = \underset{= q_s}{f_s}$ = Side friction (better to denote as f_s)

Piezocone - CPTU - Clay

Seated = pressed in position.

$q_T = q_c + f_s$ (Add in force unit
Stress cannot be added)

Mechanical

Electric: Continuous recording.

Depending on soil softness, equipment accordingly.

CPT graph Indicates soil profiles.

Advantages:

Can detect thin layer (SPT cannot)

Preliminary work in large projects

Faram Sir

Disadvantages:

Automated operation is not 100% accurate.

Human judgment reqd.

Pore pressure cannot be zero (minm γh)

Wheel mounted so difficult to move.

CPT correlations:

Relative density Semilog এ straight line.

Angle of internal friction.

Friction ratio (Soil type) N_f = SPT-field value.

$C_u = \frac{q_u}{2}$ = undrained cohesion.

Preconsolidation pressure, OCR

* কীভাবে related, Graph type $\to$ semilog/log, কোন factor এর উপর কোন parameter dependent ~ মনে রাখতে হবে)

Pressuremeter test

We want soil to expand laterally.

Guard cell prevents vertical expansion.

Supplied liquid/gas indicates the increased volume.

Points of inflection - two.

P_ℓ = limit pressure. Volume will continue to increase.

Soil yields.

$V_m = \frac{V_0 + V_f}{2}$

Pressuremeter modulus E_p (Slope of volumetric strain vs pressure)

Crosscheck with CPT & SPT correlations

Vane shear Test

Hand vane : on sample

soft soil only. sand এ vane shear test

λ = correction factor.

C_u ↑ stiffer ↑ λ ↓

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L-7
Date: 25/06/19

Geophysical Exploration
1 Seismic refraction survey
2 Cross hole seismic "
3 Resistivity survey

| Relatively new technology

Applicability: Large area, Megaprojects (10 acre and +)
Rapid
Validation reqd. (Casualty হয়)

↓ Precision scale different

* There is small scale applicability.
* Image interpretation can be flawed 1 in 100 or 1 in 1000.

Seismic Refraction Survey
S-wave - Shear wave
P-wave - Compression and Expansion.
P-wave depends on soil stiffness.
Velocity of P wave depends on soil stiffness.

Mechanism
Transducer: mili/nano second recorder.
যতগুলা layer within 5-10 m range ততগুলা straight line

$$\text{Slope} = \frac{1}{\text{Velocity}} = \frac{\text{Time}}{\text{Distance}}.$$

পূর্ণ অভ্যন্তরীণ প্রতিফলন

যত stiff medium তত E↑ v↑
Water এর নিচে থাকলে incorrect velocity. | Limitation.

Cross-hole seismic survey:
Old buildings cannot be removed for exploration.
যেই depth এ measure করাছি ওই S-wave ওই layer এর info.
Related to shear modulus.
Layers can be identified by time profiling (change in time)

Electrical Resistivity Survey

Mechanism:

Wenner method

একই line চারটে 1 m electrode, same gap.

Voltage drop

d is adjusted for multiple values.

Multiple layer হলে segmented straightline.

Old utility lines can be located. (Maps নাই থাকলে)

Soft pocket within mat foundation may cause building to tilt. To save boring cost, survey.

Subsoil exploration report

Arbitration if it is neglected.

Preview: Slope stability.

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L-8

Date: 29/06/19

SLOPE STABILITY

Slope:

Not horizontal. 'Unrestrained'. Fortified - not.

Natural: Mountain, Bank

Manmade: Road embankment.

How do they fail?

Large magnitude.

Macro stability of slope

Micro stability also possible (পাহাড় থেকে মাটি কাটা)

Natural failure. Inclined component of gravity.

Liquid will flow but soil has shear strength.

Causes:

39. পানি ঢুকলে, WLevel বাড়বে।

Particle to partice stress field changes.

Phenomena Governing Stability of Slope:

Water lowers stability

Pore water pressure ↑ effective stress/strength ↓

Horizontal seepage imposes additional force.

Lubrication between two layers - sliding.

Liquefaction: Earthquake. behaves as liquid.

Factor of Safety:

Shear stress ≤ Shear strength.

Shear strength এর সমান হলেই ~~factor~~ failure শুরু।

Type of soil can predict potential surfaces.
Trial and error matching stress-strength of each surface.

$FS = \frac{\text{Strength}}{\text{Developed stress}}$

Mohr-Coulomb Failure Criterion.

Cohesion = glue effect

φ = depends on normal stress how much resistance will develop.

FS >1 must

For permanent slope $FS \geq 1.5$

F_c and F_φ $\quad F_c = F_\varphi$ (always)

$\frac{c}{C_d} = \frac{\tan\varphi}{\tan\varphi_d}$ (Not precise, but within reasonable range)

1. Limit equilibrium method
2. Stress analysis method (লাগবেনা)

Impending failure:

Plane ~ Shear stress = Shear Strength

Curved ~ Moment (Rotational failure about a point)

Infinite slope and semi-infinite soil mass.

AB pottentially failure surface, abcd paralelopipet

Force imbalance by freebody diagram.

Stability of infinite slope without seepage

Assumption. Side forces are equal and colinear
(No need to consider this)

Assume, homogenous soil,

$$\tau = \frac{T_a}{A} = \frac{\gamma L H \sin\beta}{L/\cos\beta} = \gamma H \sin\beta \cos\beta$$

$$\sigma = \gamma H \cos^2\beta$$

$$\tau_d = c_d + \sigma \tan\varphi_d$$

$$c_d = \frac{c}{FS_c}$$

$$\tan\varphi_d = \frac{\tan\varphi}{FS_\varphi}$$

How does c, φ, β affect FS?

Apparent cohesion if sand is wet, but mostly $c=0$

For sand,

$$F_s = \frac{\tan\varphi}{\tan\beta}$$ [H has no effect on FS]

$\beta < \varphi$ যতক্ষণ steep angle এ রাস্তা যাবেনা।

$\varphi = 0$, saturated clay/undrained situation.

$$FS = \frac{c}{\gamma H \cos^2\beta \tan\beta}$$ [H is important here]

That is why mountains are made of rock/granular material

At critical condition,

$$F_s = 1 \Rightarrow H_{cr} = \frac{c}{\gamma \cos^2\beta \tan\beta}$$

Date :

Stability of Infinite Slope with Seepage,

$\gamma = \gamma_{sat}$

$\sigma = \sigma' + u$

$$F_S = \frac{c}{\gamma_{sat} H \cos^2\beta \tan\beta} + \frac{\gamma'}{\gamma_{sat}} \frac{\tan\phi}{\tan\beta}$$

since, $\gamma_{sat} > \gamma'$ $\left[\frac{\gamma'}{\gamma_{sat}} \approx 0.5\right]$

F_S decreases.

Slope fails in rainy season

Disturbed slope causes high seepage as bare

Lower surface runoff.

Examples:

Not only slope but also excavation.

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L-8

Date: 02/07/19 Y

Finite Slopes

In real life, slopes are finite with limited height.

Shallow failure: Top surface. Toe failure Base failure	Single/Curved/Multistep Plain.

Analysis

ABC block, Weight, ~~Friction~~ resistance, Normal force.
reaction

At impending condition, Weight component = Resistance.

Resistance development due to cohesion and normal force (friction)

$\tau = \tau_d$ (developed)

যে plane এ c_d minimum সেখানে fail করবে।

$$\frac{\partial c_d}{\partial \theta} = 0 \quad (\theta = \theta_{critical})$$

$$\frac{\beta + \varphi_d}{2} = \theta_{critical} < \beta = (\text{slope angle})$$

To determine Factor of Safety, start with φ, FS_φ then FS_c.

$FS_\varphi = FS_c$ (or else revise φ)

Maximum height of slope/depth of cut for a particular factor of safety. Design problem, H_{cr}

Steeper slope may fail, then decrease β (milder)

Example 13.3

$c = 600\ \text{lb/ft}^2,\ \varphi = 15^\circ$

$c_d = 200\ \text{lb/ft}^2,\ \varphi = 5.1^\circ$ (FS = 3)

$H_{cr} = 23',\ \beta = 45^\circ$

Slopes with water in the crack (tensile)

Soil variation. Insufficient soil investigation warrents higher slope. FS = 3

Temporary slope FS = 1.5

Dry season: Shrinkage crack.

Rainy season: Water infiltrates crack.

FS decreases. Extra pressure affects failure block.

Disturbing force ↑

Bouyancy decreases normal force ↓

Crack depth is important.

Crack vertical, Water pressure works perpendicular to crack.

X can be determined from graph/design pad.

Disturbing force W, U

Resisting force, $R = \underset{\substack{\downarrow \\ \text{Area}}}{cX} + \underbrace{(W\cos\theta - U_1\sin\theta - U_2)}_{\sigma}\tan\varphi$

Q. Find point C for protection against excess loading.

Considerations:

1. BC may have load on them. as trucks (shoulder) rest on shoulder. Should assume distributed load on BC.

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L-810

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Date: 08/07/19

Finite slope: Circular Failure Surface

Homogenous clay, $\varphi = 0$ (Undrained condition)

$\tau_f = c_u$

Drained condition এ $c - \varphi$ হয়ে যাবে।

Fast loading - direct shear - c_u

W_2 moment কমায় দিবে।

* Use design pad.

Limiting condition এর আগ পর্যন্ত $c_d = c_u$ develop করবে gradually.

$M_R = c_d (\overset{\frown}{AED})(1)(r) = c r^2 \theta$

$F_c = \frac{c_u}{c_d} =$ [Change β accordingly]

For a single centre, all options need not be analyzed.

Critical circles - minm of minm.

$\beta > 53°$ Toe circle

$\beta < 53°$ Toe/Midpoint/Slope (Depends on D = Depth of hard layer from top)

$D \geq 1.2H$ হলে Midpoint circle, $D = 1.2H$ toe, $D \leq 1H$ slope

$m = \frac{c_d}{\gamma H}$ = stability number

$m = \frac{\gamma H}{c_d}$ = stability factor

Q Maximum depth with FS = 3

$FS \rightarrow c_u \rightarrow c_d \rightarrow m \rightarrow \beta \rightarrow H$

* কত load পর্যন্ত safe তা বের করতে হবে।

Rana plaza crash due to overloading

To locale the centre, use graphs.

$n = \frac{\text{Horizontal distance}}{\text{Vertical distance}}$

Top horizontal distance reqd to impose restriction.

Examples 13.4

Example 13.5

$\beta = 75^\circ$

Maxm depth - limiting condition - $c_u = c_d$ — FS = 1.

Example 13.6

Mass procedure:

© $\varphi > 0^\circ$.

Normal force is ignored.

N~~of~~ and R — combined indeed.

↑ Resultant

W. Design chart.

$F_c \neq F_\varphi$ (Revise φ)

Example 13.8

Critical height ⟹ FS = 1, $c_u = c_d$,

For any other height, c_d, φ_d haven't reached c_u, φ.

Trial and error. $\varphi \leq 20^\circ$

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Sat | Sun | [✓ Mon] | Tues | Wed | Thurs | Fri

CT: July last week

L-11

Date: 0~~8~~9/07/19

Ordinary Method of Slices

পাহাড়ধ্বস। Manmade disaster. Sand-hill will get saturated and fail.

আগের method গুলো ছিল mass procedure considering blocks.

Assumption: 1. Pore water pressure zero
Water table way below.

Freebody diagram.

ΣF_x, ΣM এ কোন effect ফেলবেনা। Resistance remains. W, T_R, N_R. Resultantant vertically upward হতে হবে। ΔL

A - Factored.
Normal surface area.

σ = Normal stress on normal surface area.

(Hogmogencus soil, else, ~~plastic~~ . . .). holders; ~~be~~depends.

1. Point maker modelling to holders;

Effrective Stress Analyis-

~~e~~ ∵ summation
summation

FS কমবে overall. Void space এ পানি ঢুকে উঠলে

Example 13.9

Design sheet এ ছবি। Arbitrary centre.

~~প~~পরীক্ষায় 5 slice.

Width (দশমিকের পর দরকার নাই)

Height (Avg height)

Centre থেকে line টেনে radial line connect করতে হবে। α. Vertically clockwise negative. Resisting

and disturbing moment.
We are considering segmental straight line.
অথবা inclined length scale দিয়ে বের করা যায়।
$W = b \times h \times \gamma$
This is for one centre. এরকম আরো centre (dome) নিয়ে critical FS and critical surface বের করতে হবে।

C.W

CT- 21 July (Method of Slices) L-12

Date: 18/07/19

Bishop's Simplified Method of Slices

Ordinary method of slices is too conservative.

Ordinary method of slices is too conservative

If calculated FS < field FS (conservative)

calculated FS (say 1.25) > field FS (say 0.9) (may fail)

→ Implication of conservative

Design becomes uneconomic to some extent

We must not use method that overestimates FS.

Gone are the days of thumbrule | Analysis should estimate field FS closely.

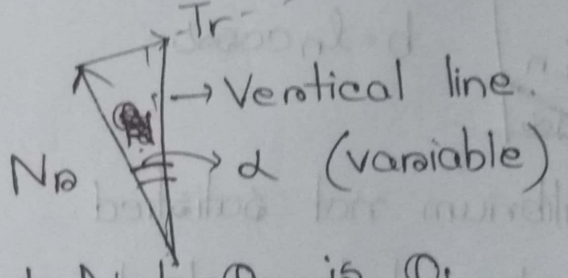
Ordinary method assumption: Side forces are equal in magnititude and colinear. Completely balances

But Bishop considers them to some extent

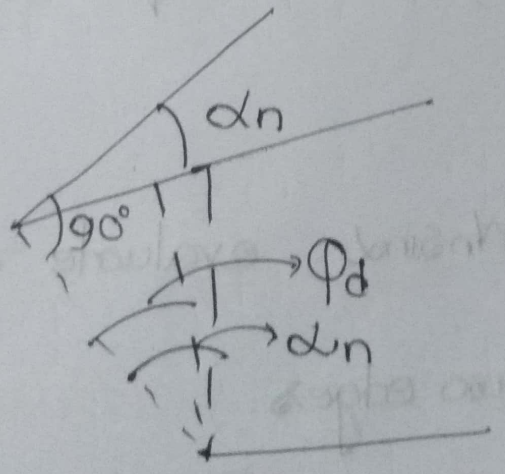
Developed friction factor. $\tan\varphi_d$

T_r inclined. ΔP horizontal, $\Delta T, W$ - vertical

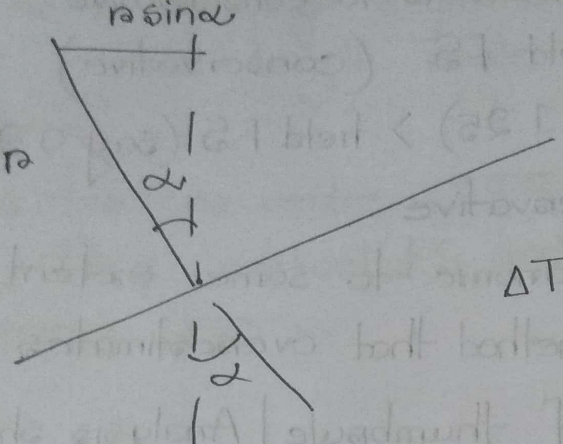
$N_r \perp T_r$ 90°



Angle btn N_r and $N_r \tan\varphi_d$ is φ_d.



Moment Equilibrium:

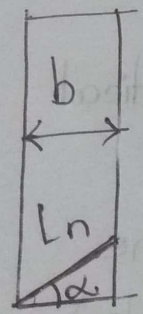


ΔT also ignored.

ΔP, ΔT ignored.

Equation of F_s becomes implicit equation. Use
$\overset{\downarrow}{\text{Transcendental}}$

Numerical methods. Trial and Error



$b = l_n \cos\alpha$.

Force equilibrium not satisfied.

Slide width doesnot have to be equal.

Example 13.9

c, tanφ constant

$\frac{b}{m_\alpha}$, $\frac{W_n}{m_\alpha}$, $W_n \sin\alpha$ evaluate করা লাগবে।

*Avg ht of two edges.

চাঁদা না থাকলে α বের করতে trigonometry use.

Math এ $\frac{b_n}{m_\alpha}$ column নাই। Add করতে হবে।

*Comment: Analysis have to revised ~~us~~ considering lower FS. [যদি FS=2 ধরে finally 1.60 আসে, কিন্তু revise করে দেখানোর দরকার নাই]

Computer ব্যবহার করলেও limit equilibrium দিয়ে check.

Layered soil: Affect W calculation. Ordinary method applicable.

c, φ avg করা যেতে পারে অথবা layer এর area বের করে করা যায়।

C.W.

Syllabus: ✓

L-13

Date: 16/07/19

Ordinary method of slices

- Considering wt at great depth
- Considering pore pressure.

Weight component reduced due to buoyancy force

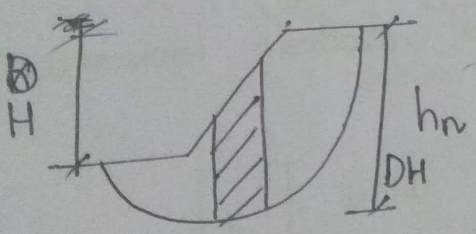
For bangladesh, rain should be considered as a big factor

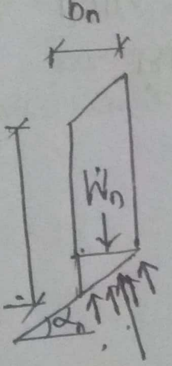
Bracing system: Horizontal I-joist and Shore pile.

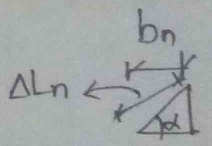
Contractor delay may cause damage to road and utilities lines. ~ if slope fails.

Bishop's method of slices doesnot consider wt

Modified eqn:







$u = \gamma_w h_n$

u perpendicular to surface area (inclined)

To develop chart, non-dimension equation.

r = non dimension parameter

= avg ht of slice.

$F_s = \frac{1}{a} \times \sum (b - c r_u)$

= m − ~~ru~~ n ru

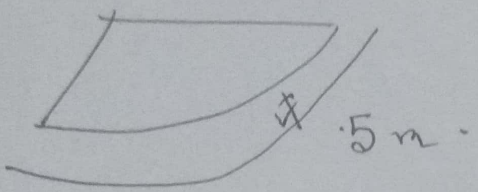
r_u differs from slice to slices For, different slices cs. (Exam)

Ru assume to be 1.

Top এ seepage নাই।

BD riverbank = 0.7

Toe surfcee:



Example

নিচের –

Critical ~~FS.~~ FS. =

Interporation = আগের উপরের দিয়ে check.

C.W

CT- 30 July

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Date : 20/07/19

* ~~Mutiple Beam.~~

~~টেবিল দেয়া থাকবে।~~

Morgerinstern method of slices for rapid drawdown curve

বাংলাদেশে বৃষ্টি না হলেও catchment India তে থাকায় নদীতে পানি বেড়ে যায়। কয়েকদিনের মধ্যে Rapid drawdown.

Low permeability - Seepage pressure - Critical.

Large fluctuation in water level - flash flood -

Flood protection embankment.

Polder = এলাকার চারপাশে বাঁধ দেয়া যেন ভিতরে dry থাকে।

$\gamma_{sat} = 2\gamma_{water}$

Graphs :

Example :

$c/\gamma H$ = Stability number

$\tan\beta$

L/H

$\rightarrow F_s$

* Interpolate করা যাবে। $\left(\frac{C}{\gamma H} \text{ or } \beta\right)$

Spencer's solution for stability of simple slope with seepage

Bishop's method only takes into account moment equilibrium. Spencer considered all inter-slice forces.

Trial and Error/Graph এঁকে Fs বের করা যায়।

r_u = non-dimensional pore pressure parameter.

Example 13.11.

Fluctuation of Fs of slopes in clay embankment on saturated clay

Shear stress becomes constant

Pore pressure dissipates.

At final height ~ minm er Fs ~ at the time of construction.

To prevent this, stage loading or ground improvement.

C.W.

Question pattern will change.

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Date: 23/07/19

Deep Foundation on Sand

General discussion on pile foundation.

Classification according to depth

1. Shallow:
    - Strip: Wall
    - Individual
    - Combined
    - Mat / Raft

2. Deep:
    - Pile, Caisson, Well foundation

1. $D_f/B \le 2\sim4$ (Not a stringent defn)

* Types of foundation

* Applicability (Load and soil condition)

Bridges + River adjacent structure = Unsupported height + Scour depth.

For Padma bridge, scour depth 60m, pile 120 m.

For transmission tower, significant lateral load, shallow foundation will be uplifted.

Raft and Mat has different design principle.

↓

Structure load < ~~Soil load~~ Displaced soil weight

5-6 তলার জন্যও 15-20m depth boring

Structure type.

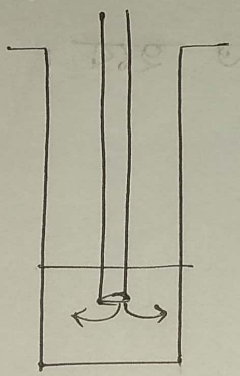
Khulna = compressive soil.

Foram Sir

Bored pile = 16" dia

*Types of Deep foundation
- Material (RCC /steel)
- Construction/Installation Process.
  - ~bored
  - ~ driven pile (steel, hollow)

Steel: Hollow ; driven (River Jetty: Easy to transport steel)
RCC: bored/precast. Tremie pipe. (May be prestressed)



Tremie pipe will always be under concrete surface.
- Segregation
- Mix with soil and water.

PHC = Prestressed Hollow Concrete pile

Dia = 1200mm
Wall thickness = 150 - 250 mm.
78 MPa./11000 psi
Strength /Longevity high
Cost less
Steel corroded /eaten by coral in marine environment

Driven pile based on type of driving) mechanism.

* Advantages and Limitation of driven + bored pile
equipment + heating, Splicing

*Quality Control / Assurance

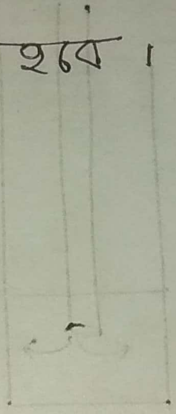
Pile load test

Soil investigation এর পরেই test pile এর উপর static and dynamic load test অথবা পরে Service pile test (1-2%) but rectifying measures are not much available. তখন building story এর limit.

Pile integrity test

Non destructive. Soundwave.

Tender এ mentioned থাকতে হবে।



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C.W

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Factor of Safety

Justification by load sharing

Methods of Determining Ultimate Load Bearing Capacity

Single pile.

1. Soil and theoretical variation may be 2-3 times for the same zone.

3. Field test: relatively accurate, reliable.

For high rise building, field test must be done to verify the equations.

Pile construction এর পরে spacing (3dia), symmetry break করে pile বাড়ানো যাবেনা। (eccentricity).

Load tests are costly and lengthy (2-3 months)

But safety and economy must be prioritized

In the capacity equations, plane strain assumed. but in real life piles are 3D. Only shape factors are applied to compensate.

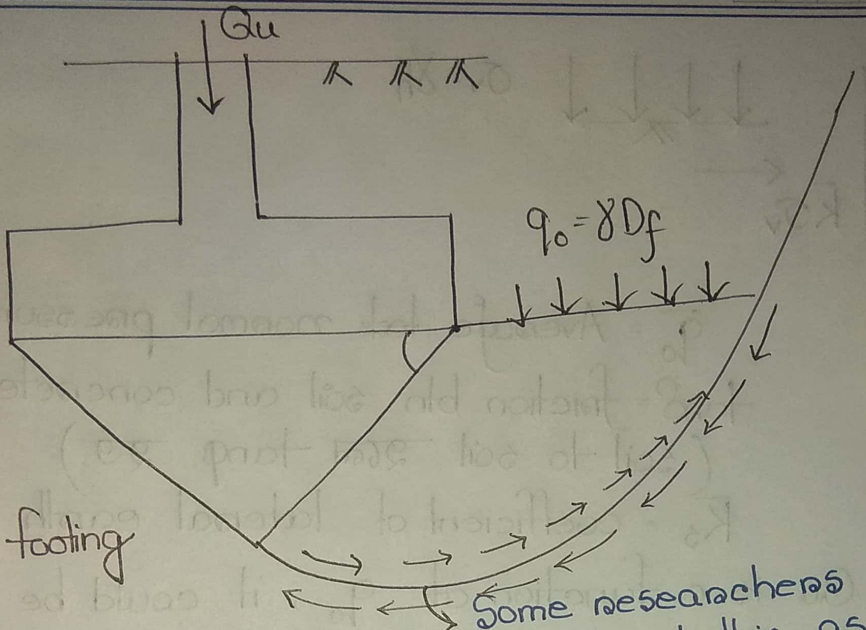
General Theory for Ultimate Bearing Capacity

For soil, deformation is very high at failure.

$$\overline{Q_u} = Q_u + W_p = Q_b + Q_f + W_p$$

$$Q_b = \left(CN_c + q_0 N_q + \frac{1}{2}\gamma B N_\gamma\right) A_b$$

Why N_c, N_q and N_γ values differs in different method?



* For footing

Some researchers considered this as parabolic / circle + straight line / logspiral. Hence, the difference in N_c, N_q, N_γ

* For piles.

Different failure pattern than footing. different q_o

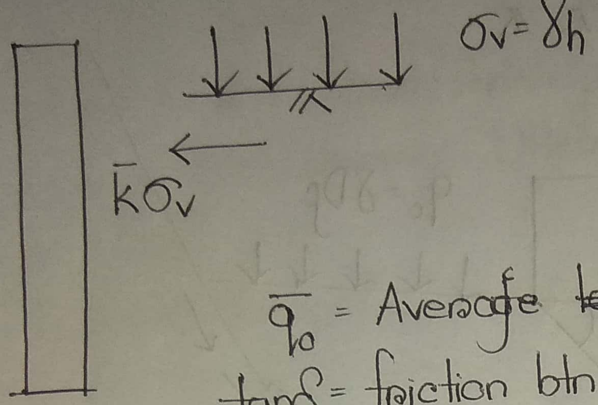
$cN_c = 0$ [Cohesionless]

$\frac{1}{2}\gamma B N_\gamma \approx$ negligible [Pile dia = B very small]
[Safer as Qu is smaller]

$Q_u = q_o N_q A_b + A\bar{q}_o \bar{K}_s \tan\delta$

Soil friction parameter = $\tan\phi$

Friction force = Friction factor x Normal force.

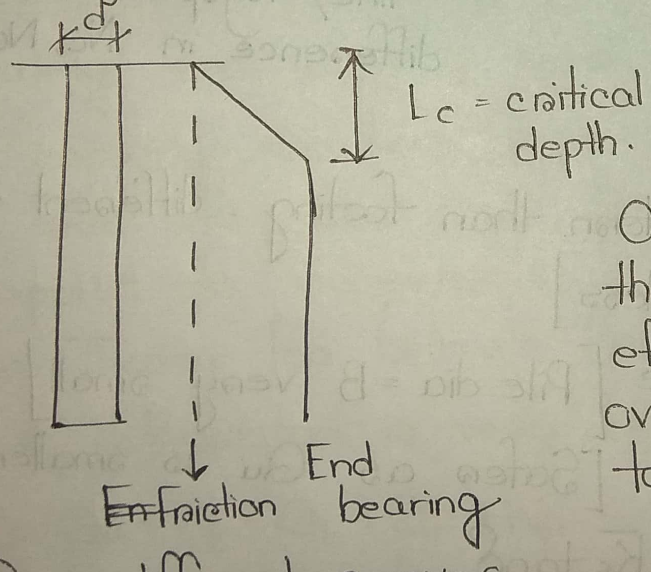


$\bar{q}_o$ = Average ~~lat~~ normal pressure.

$\tan\delta$ = friction btn soil and concrete.
(soil to soil হলে $\tan\varphi$ হয়)

$\bar{K}_s$ = coefficient of lateral earth pressure.

Since Qu is a function of q_o, it could be expected that D_f ↑, Qu ↑ But in reality that doesnot happen after a certain depth.



Only in granular soil, there is an 'arching' effect which causes overburden pressure to not increase.

Nq from different curves.

φ can be assumed if not given (according to $\frac{L_c}{d}$)

C.W

Ref: Murthy (3rd Ed)

L-18

Sat Sun Mon Tues Wed Thurs Fri

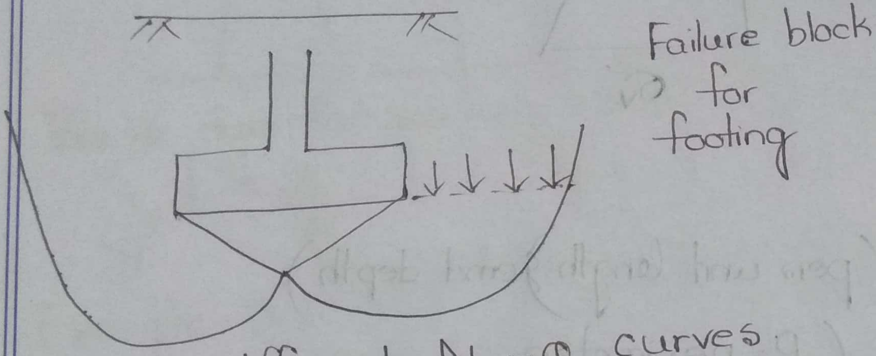
Date : 24/08/19

Chapter 8 : Deep Foundation

For cohesionless soil, $Q = q_0 N_q A_b$ [c=0]

$N_q = f(\varphi)$

Nq will be different for pile than footing as failure block will be different.



11 টা different Nq − φ curves

Maybe ~~dif~~ dependent on $\frac{L_c}{d} = \frac{\text{Length of pile}}{\text{Dia of pile}}$.

Nq varies wildly

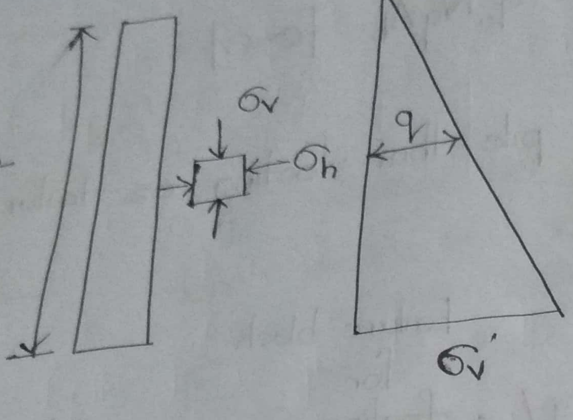
Maxm base resistance = 11000 kN/m² [Based on experimental findings]

*Theoretically এর চেয়ে বেশি আসলে maxm নিতে হবে।

$F = N.f$

$= N \tan\delta$ [Soil to concrete, δ = Angle of wall friction]

$= N \tan\varphi$ [Soil to soil]



$\sigma_v = \bar{q}$

$\sigma_h = k\bar{q} = N$

$F = k\bar{q} \tan\delta$ (per unit length } and depth)

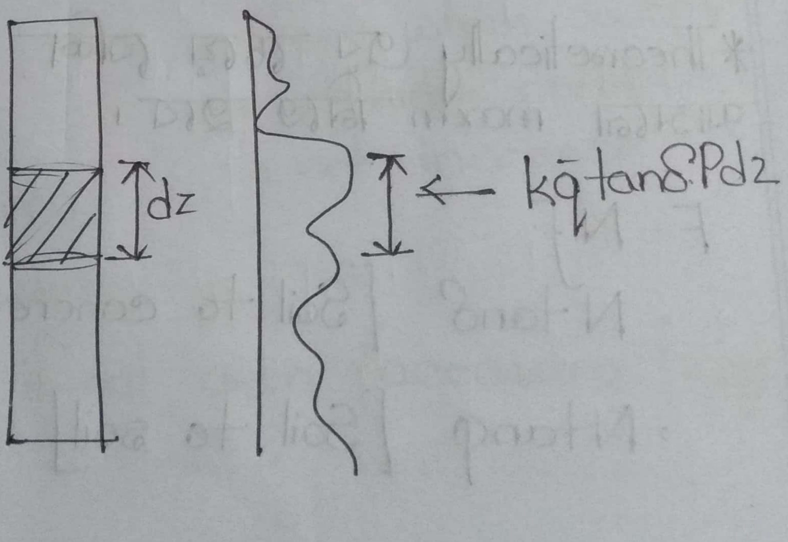
$F = Pk\bar{q} \tan\delta$ (P = perimeter
(per unit depth) Triangular σ_v কে ঘুরিয়ে আনতে হবে)

$Q_f = \int_0^L Pkq \tan\delta$ ~~dt~~ dz

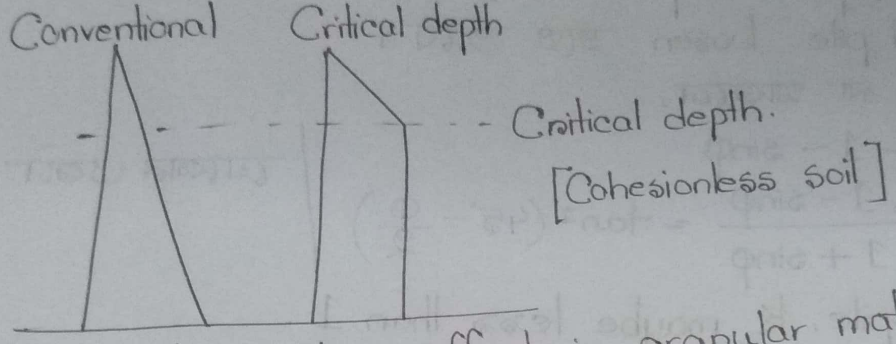
Non-homogenous soil

$\sigma_v = \gamma' h$

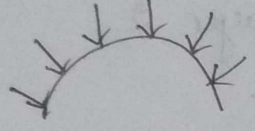
(Since, $\gamma' < \gamma$,
Saturated অবস্থায়
capacity কম থাকে)



Overburden pressure doesnot increase linearly with depth of embedment after a certain critical depth.



This is due to arching effect in granular material.



Example 9.1

FS = 3 [Minm 2.5]

Assume depending on soil homogeneity and confidence in determination of properties FS can be taken as 4.

* বইয়ে ভুল $Q = A_b q_b$ হবে।

$q_o' = 9 \times 7.4 + 4 \times 11.2$ হবে

d = dia (circular)

= smallest dimension/eqv dia (rectangular)

φ from Table 3.6. Interpolate না করলেও হবে। যেহেতু base resistance, bottom layer φ লাগবে। Limiting value 11000 নিব।

$\bar{q}$ = Avg pressure = $\frac{0 + 9 \times 7.4}{2}$

$\overline{K}$ depends on compaction:

Driven pile: compacted হতে থাকে

Bored pile: loosen হতে হবে।

* Table না থাকলে,

$K_o = 1 - \sin\phi$

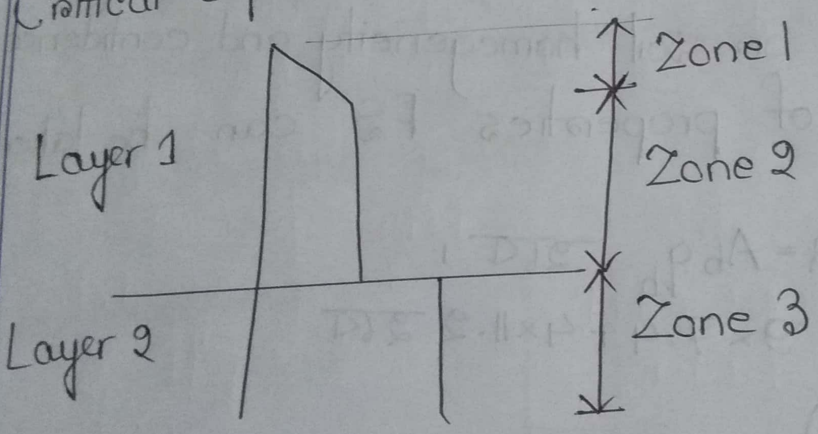
$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \tan^2(45^\circ - \frac{\phi}{2})$ | যেকোন একটা

Bored pile, K maybe less than 1.

$\overline{q}_2$ = Avg pressure at midpoint of layer 2.

Limiting value for friction 110 kN/m².

Critical depth consider করলে, 3 components

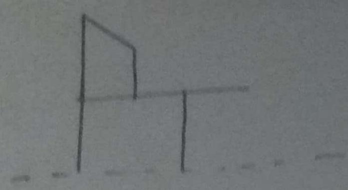


CW

L-19

Date: 27/08/19

Example 9.2



√β-method (For cohesionless soil)

$$Q_f = \int_0^L p \bar{q}_0 \bar{K}_s \tan\delta \, dz$$

For a given soil and pile material, β constant.

$$\sqrt{\beta} = \bar{K}_s \tan\delta$$

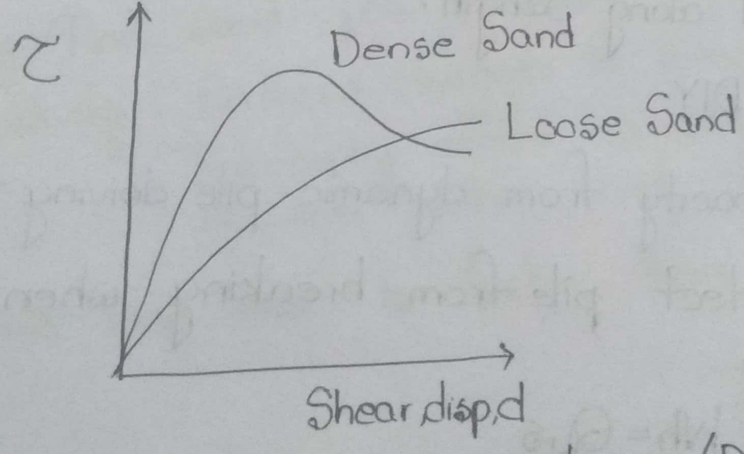
Poulus's curve will give greater friction than meyerhof
So, meyerhof should be used when conservative.

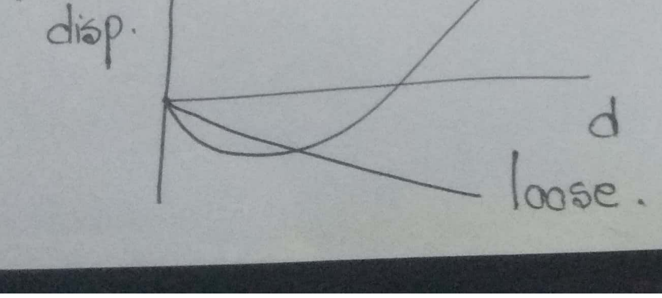
Boring friction < Driven pile.
↓
When holes are made, soil becomes loose.

$\varphi = 0.75\varphi_1 + 10^\circ$ [driven] ~ becomes compact while driving

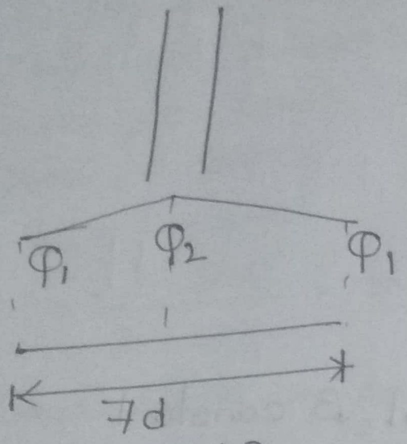
$\varphi = \varphi_1 - 3^\circ$ [bored] ~ becomes loose while boring

যত দূরে যাব φ কমবে।





(Dilatancy – Volm বাড়ে কারণ একটা particle আরেকটার উপরে উঠে যায়)



$\phi_2 = \frac{\phi_1 + 40}{2}$ ϕ_1 from test

Insitu $\phi = \sqrt{20N_{cor}} + 15^\circ$ (For sand)

* Example 9.1, 2 তে ϕ modify করা হয়নাই।

Bearing capacity of piles in granular soils based on SPT-N

Unit sensitive.

N = SPT near end bearing zone

$\overline{N}$ = avg SPT along length.

Example 9.3 DIY

Pile bearing capacity from dynamic pile driving formula.

Pile cap: to protect pile from breaking when driving.

Ideal condition, $Wh = Q_u s$

Energy loss.

Hiley formula

η_h = hammer efficiency.

$\varepsilon = \frac{\sigma}{E}$

$\Delta L = \varepsilon L$

$= \frac{\sigma}{E} L$

$= \frac{P}{AE} L$

C_r = coefficient of restitution

$= \frac{\text{velocity after collision}}{\text{" before "}}$

Engineering News Formula

$Q_a = \frac{Wh}{6(s+c)}$ $\underline{F.S = 6}$

Applicability is important

VIP Comments on dynamic formulae

Silty / Fine sand – pore pressure – liquefaction.

Sensitivity : Reduced strength in remoulded clay.
Thixotrophy effect causes to regain strength within some time.

Dynamic load test is faster than static load test.

L-20

C.W

Date: 21/08/19

Pile Load Test

Driven pile – Driving record থাকলেও PLT করা যায়।
Different loading arrangement vertical/uplift/horizontal
Load বেশি resist করতে পারলে uneconomic.
" কম " " " ভাঙতে হবে।
Test pile test purpose এ construct করা হয়।
Pile হয়ে যাওয়ার পর test করতে চাইলে
service/working pile.
PLT for bored pile requires 3-4 months.
But design revision is also difficult due to
influence (3-5d) zone and group action.
So, design should be on conservative side.

Loading

Cement bag filled with sand on platform which is on girder than pile. Hydraulic jacking.

Certain eccentricity. Load 1.5× desired load to prevent uplift of platform.

Reference beam is used. It should remain static. Sufficiently long and away from pile command area

Magnetic attachments to measure settlement

For high load: Brick wall as supports.
or Anchor ~~wall~~ piles – tension

Active resistance < Passive
Tension pull Compression

Loading Method

SM
QM
CRP
SC
| Different load settlement curves
Fo.

SM: (বেশি করা যায়)

Design load from theoretical capacity.

Reading each 5 minute until 0.25 mm/h. or 2 hr.

Loading - unloading - reloading

25% 25% 50% — 10%

2h 1h 20 min 20 min :

(design load) (failure load)

বেশি load দিলে কাত হয়ে পড়তে পারে, so pre-planning reqd

QM:

5 min loading, 2.5 min loading,

CRP:

Settlement ~ 0.05 in/min, 2-3 in

Limitation: ① Run length of jack
② If service pile, it will become useless } 2-3"

SC:

Cyclic loading

A silo where loading - unloading is unimportant SC is done.

Dynamic load test is also done along with SM.

Perpetual Pavement

Traditional lifetime = 10-15 years, then maintenance.

In BD, মিঠিচুর উন্নয়ন। Huge deviation from standards.

Perpetual ~ lifetime 50 years with routine maintenance.
~ no capital intensive redesign required.
~ costly initial development.

Full-depth pavement ~ binders in all layers

Tension zone: ~ bottom layer tension. Migrates to top. Req's high elastic range. Fatigue resistant. High amount and high quality binders.

Compression zone: ~ নিচে strong foundation. উপরে compression layer

Abrasion zone ~ Surface will take wheel wear and tear.

[Q. Conceptual Figure important]

Considerations:

Compression members are perpetual. But pure compression members are hard to make.

Arch = pure compression member.
= after installing keystone, pressure only increases stability

Though factor of ignorance was high in ancient structures

Roads have continuous support, it should be stable.

Soil properties vary both horizontally and vertically. Hard to achieve uniform construction. Staggering density.

Solid Foundation: Uniform support, no density stagger.
Carried earth, homogenous then proper compaction
(6" layers = lift thickness)
To maintain fine superelevation ⟶ smart compactor
(formula 1 racing track)
Drum in drum – impact – vibration – can gauge reaction
Now-a-days ~ oscillation instead of vibration (vertical)
~ to preserve any area, less disturbance

Solid foundation will resist vertical movement and goes horizontal. that is why, edge confinement

MTV = material transfer vehicle.

Thermal imaging with geo-coordinates. Density যেখানে কম, temperature segregation. Cold binder will not take compaction.

When truck carries material, open top becomes colder and crusty.

MTV: before dumping on road, mix with infrared pug mill. Also continuous eir rotation prevents agg separation.

HMA cannot be reheated, bitumin will liquify and segregate.

Smart paver ~ continuous feedback with gps antenna

Polymer modified binder ~ waste tyre
~ improves extreme temperature performance.
~ good for BD – deters water due to ~~high &~~ large coating thickness.

C.W

Ref: Sharma, Prakash L-21

Sat Sun Mon Tues Wed Thurs Fri

Date: 03/09/19

Lecture-6

Interpretation of Pile Load Test Data

Objective: Failure Load
Allowable load
Settlement (Dial gauge, outs reference beam outside influence zone of pile)
Failure pattern

Load settlement curve, showing failure pattern.
We want gradual/progressive failure, not sharp.

1. Davisson's method
Unit important <u>inch</u>
Quick maintained load test
For OA line, $\Delta = \frac{PL}{AE}$, BC limit line can be drawn before test. We can only test upto the limit for service pile.

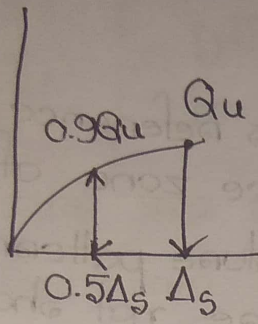
2. Chin's method:
Δ/Q vs Δ (linear scale)
Slope $= c_1 =$ Ton^{-1}, Failure load $= \frac{1}{c_1}$ Ton.
QM and SM.
Limitation: constant time increments.

3. De Beers method
Load vs settlement (Log scale)
Two straight lines (limitation)

4. Brinch Hansens 90% criterion.
Linear

Qult

So, 90% Load at 50% deformation



CRP

5. Brinch Hansens 80% criteria.

$\frac{\sqrt{\Delta}}{Q\cancel{ult}}$ vs Δ

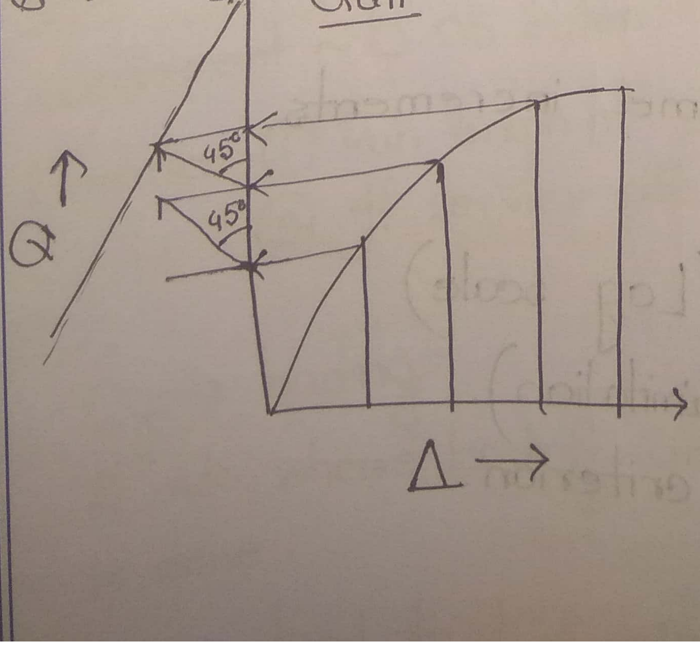
0 থেকে আঁকার দরকার নাই।

$$\frac{\sqrt{\Delta}}{Q} = C_1\Delta + C_2$$

$$Qult = \frac{1}{2\sqrt{C_1C_2}} \quad (\text{DIY})$$

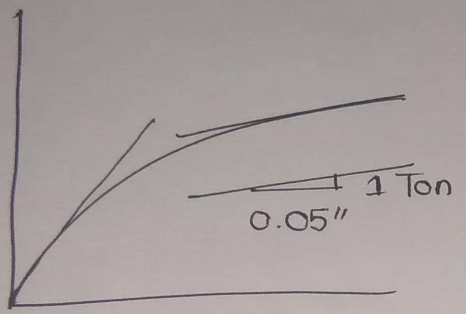
SM, QM

6. Mazurkiewiez



Failure load, 80% criterion method same.
Limits: Not all points fall in straight line.

7. Fuller and Hoy's
Slope = 0.05 inch/ton. QM, long pile.



→ Draw this then move to match tangent parallel.

8. Butler and Hoys method:
Rebound or initial tangent.

9. Vander veens method:
Trial failure load (In scale)
Until straight line.

Differential 12 mm

Allowable settlement বিবেচনায় নিতে হবে, 25mm।

* Find pile failure, Qult determination in BNBC
Justify the above methods.

L-22

Date : 07/09/19

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Pile Group

Most of the time: group pile

Isobar = Same pressure line

Influence zones are created which reduces group pile capacity — to prevent that adequate spacing reqd.

If the pile causes displaced soil to be compacted then closer piles can be installed. Driven pile in sandy soil.

Cast in situ installation doesnot impact the pile beside, so smaller spacing can be allowed.

Minimum spacing 3d – (Soft alluvial deposit + Friction pile)
2.5d – (end bearing pile)
2d – (compaction pile)

Fig 11.2 : Pile arrangements:
Building – (7,8,9)
Symmetric about both axes
Difficult to modify

Pile Group Efficiency:

$$E_g = \frac{Q_{gu}}{\Sigma Q_u}$$

100% means single and group piles have the same capacity.

Sand

4 and 9 pile groups. 2d, 3d, 4d, 6d. Effect of pile cap.

Maxm efficiency at 3-4d.

Spacing এর বেশি দিলে block effect হয়না।

Pile no বেশি দিলে efficiency কমে

Spacing depends on column to column spacing.

Loose sand এ pile drive করা হলে $E_g > 1$ (Compaction)

Dense sand এ pile drive করা হয়না। Dilation occurs

Bored pile in sand

General loosening of soil.

Soil yield করবে -

$E_g < 1$

$E_g = 1$ (if optimum spacing maintained)

Preview: Settlement

Settlement in sand ~Vertical ~Lateral

We cannot measure group capacity as load test is done on single pile.

Settlement is not linear.

Models can be erratic.

Group factor, $F_g > 1$

$S_g > S$

$B/d \uparrow \; F_g \uparrow \; S_g \uparrow$

Settlement cannot be allowed more than 1"

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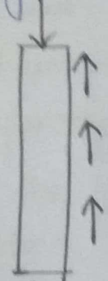
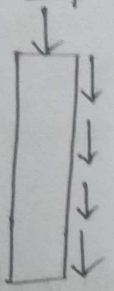
Fig 11.3: Group Efficiency vs Spacing

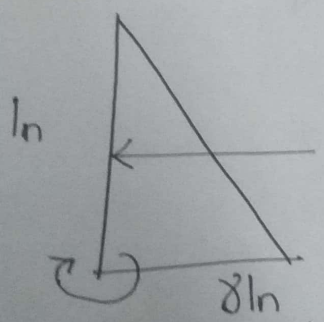
Negative Friction



Usually



Soil itself is moving downward (soft, fill normally consolidated, recent deposit)



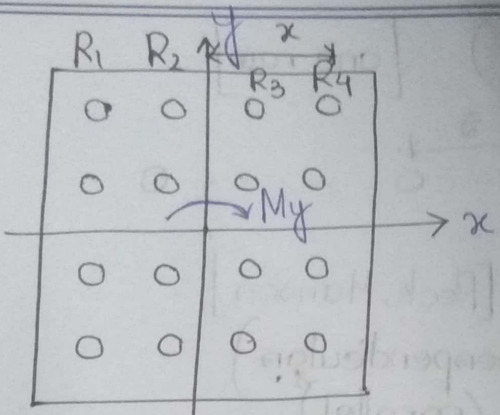
$\frac{1}{2}k\gamma l_n^2 \tan\delta$

$F = \frac{1}{2}pk\gamma l_n^2 \tan\delta$

$F_{ng} = s l_n P_g + \underline{\gamma l_n A_g}$
↳ Soil to soil friction

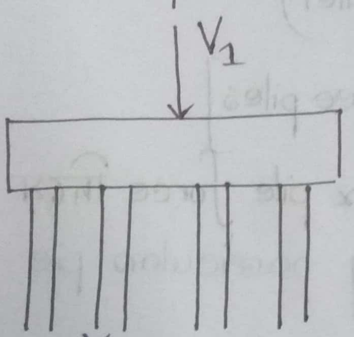
$F_{ng} = nF_i$

Take maximum

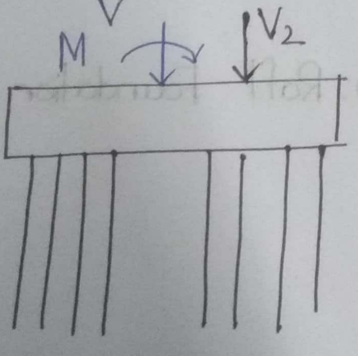


$$R_n = \frac{V}{n} \pm \frac{M_y x}{\sum x^2} \pm \frac{M_x y}{\sum y^2}$$

$$M = 4R_1 x_1 + 4R_2 x_2 + 4R_3 x_3 + 4R_4 x_4 = \frac{4R_1}{x_1}\left[x_1^2 + x_2^2 + x_3^2 + x_4^2\right]$$

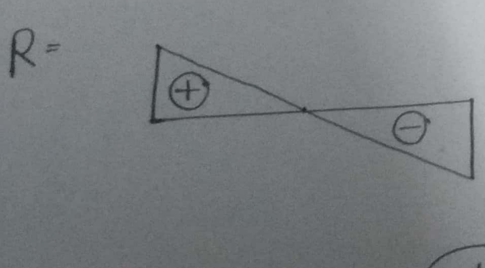


$\frac{V_1}{n}$ (V_1 cg and pile group cg coincide)

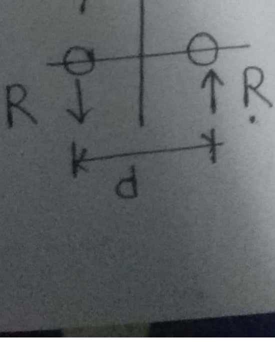


$V_2 = V + M$

Moment from
- eccentric loading
- horizontal loading
(Wind, Transmission tower)

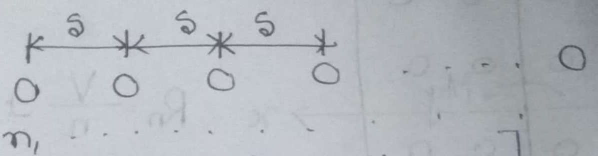


As pile cap is rigid, reaction can be assumed to be linear.



$M = Rd$

$\sum x^2 = \frac{S^2}{12} n_1 (n_1^2 - 1)$ [one row]



Example: Bridge pier [Peck, Hanson]

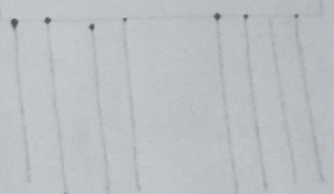
Horizontally = Wind (perpendicular)
Traction (parallel)

$x = 9'$
$y = 10.5'$ [Corner এর piles]

Tension যেন না আসে। Max pile force দিয়ে design.

Q. Find pile force for any particular pile single pile.

Preview: Raft Foundation



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Raft Foundation

Ref: Chapter 18 (Peck, Hanson, 2nd Ed)

Like a combined footing. Shallow foundation.

Why are rafts chosen?

~ Basement [Although costlier than pile]

~ Individual footings overlap and cover half the area.

~ Underground space required due to height restriction (road width, ~~analysis~~ airport)

Footing on clay:

$q_d' = cN_c + \gamma D_f$

$q_d = q_d' - \gamma D_f$ [Overburden pressure থেকে কত অতিরিক্ত load নিতে পারবে।]

$= cN_c$

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

$q_{safe} = \frac{q_d}{3} = \frac{q_u N_c}{6}$
allowable

$N_c = f\left(\frac{D_f}{B}\right)$

L-∞ ↗

Figure 18.3 for q_{allow} vs q_u [FS = 3, continuous footing]

For square and rectangular footing, multiply shape factor.

To determine pressure from column load,

$q_{net} = \frac{Q}{A} - \gamma D_f = q_b - \gamma D_f$

$F = \frac{cN_c}{q_b - \gamma D_f}$ $\left[\frac{\text{Theory}}{\text{Field}}\right]$

To F ↑ q_b ↓ A ↑

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Year: 2019
Subject: PPCM

Raft foundation পুরো plot ধরে থাকে। তাই A বাড়ানো যায়না। তাই D_f বাড়াতে হবে।

$F = \infty = \frac{cN_c}{0}$

$q_b - \gamma D_f = 0$

$q_b = \gamma D_f$

Fully compensated foundation. as if floating in soil medium [Archimedes]

Anticipated load থেকে বেশি আসলে F দ্রুত কমে থাকে।

Example:

$q_b, D_f, = 20.5'$

Available depth for basement $= 20.5 + 3 - 5' - 1.5'$

$\downarrow$ PL to EGL $\downarrow$ Raft thickness $\downarrow$ Slab thick

$= 16.5'$ [One or 2 basement 8.5']

For F = 3

Assume, $\frac{D_f}{B} = 0.1$ to determine N_c

$\downarrow$ (Assume less than 20.5')

$F = 3 = \frac{cN_c}{q_b - \gamma D_f}$ [Use this equation or use the chart]

$d_f = \frac{q_b - q_a}{\gamma}$ [q_a from chart]

Determine F for any particular depth.

Chart use করা যাবেনা।

q_b 25% and 50% increase করলে F কত কমবে?

$\downarrow$

in % [non linear]

Effect of increase in load on factor of safety

Fully compensated foundation - y axis আটকাবে.

Preview: Raft Foundation on Sand.

C.W.

L 25

Date: 18/09/19.

Raft foundation On Sand

$q_d' = \frac{1}{2} B\gamma N_\gamma + \gamma D_f N_q$

$q_d = q_d' - \gamma D_f = \frac{1}{2} B\gamma N_\gamma + \gamma D_f (N_q - 1)$

N_γ, N_q dependent on φ

B = smaller dimension

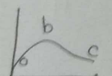
$q_d = \left\{\frac{1}{2} \gamma N_\gamma + \frac{\gamma D_f}{B} (N_q - 1)\right\} B$ Design Eqn.

$q_a = \frac{q_d}{F}$

Chart given for F = 3

Horizontal cutoff from settlement consideration (1")

Raft allowable settlement = 2" [Large rigid object]



same settlement curve.

Dry condition. Water table deep.

N correction required.

Overburden pressure to be calculated.

Raft may tilt where soil is heterogenous/large variability.

Bearing capacity doesnot gover in shallow soil. 52' Fan > Mountain.

~~52N~~

N Corrected equaling ~~[illegible]~~ ~~Md~~ Makes at home.

Bored notbook.

~~Dewarda~~ ~~[illegible]~~ [illegible]।

Dewater

পানি

fail

One tr

Why

$q_u = 0.1$

$q_u = 0.$

পানি জমলে বা seepge হলে ভারবহনশক্তি fail করে।

One trick.

Why not 8'-?

$q_u = 0.11N$ (1")

$q_u = 0.22N$ (2")