CIV E 354
GEOTECHNICAL ENGINEERING II

-CLASS NOTES-

by

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Note: This set of notes contains numerous spaces to be filled in during lectures

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CIV E 354: GEOTECHNICAL ENGINEERING II

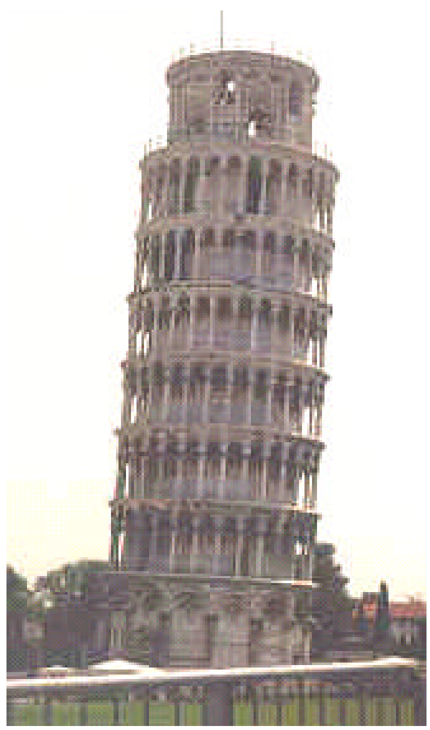
1 – INTRODUCTION

Geotechnical Problems	Review of Soil Mechanics (Chapter 3):
Design Philosophy (21-1)	Effective stresses,
Design Loads (2.1)	Shear strength: drained and undrained,
	Mohr circle

“The most important thing is to keep the most important thing the most important thing”

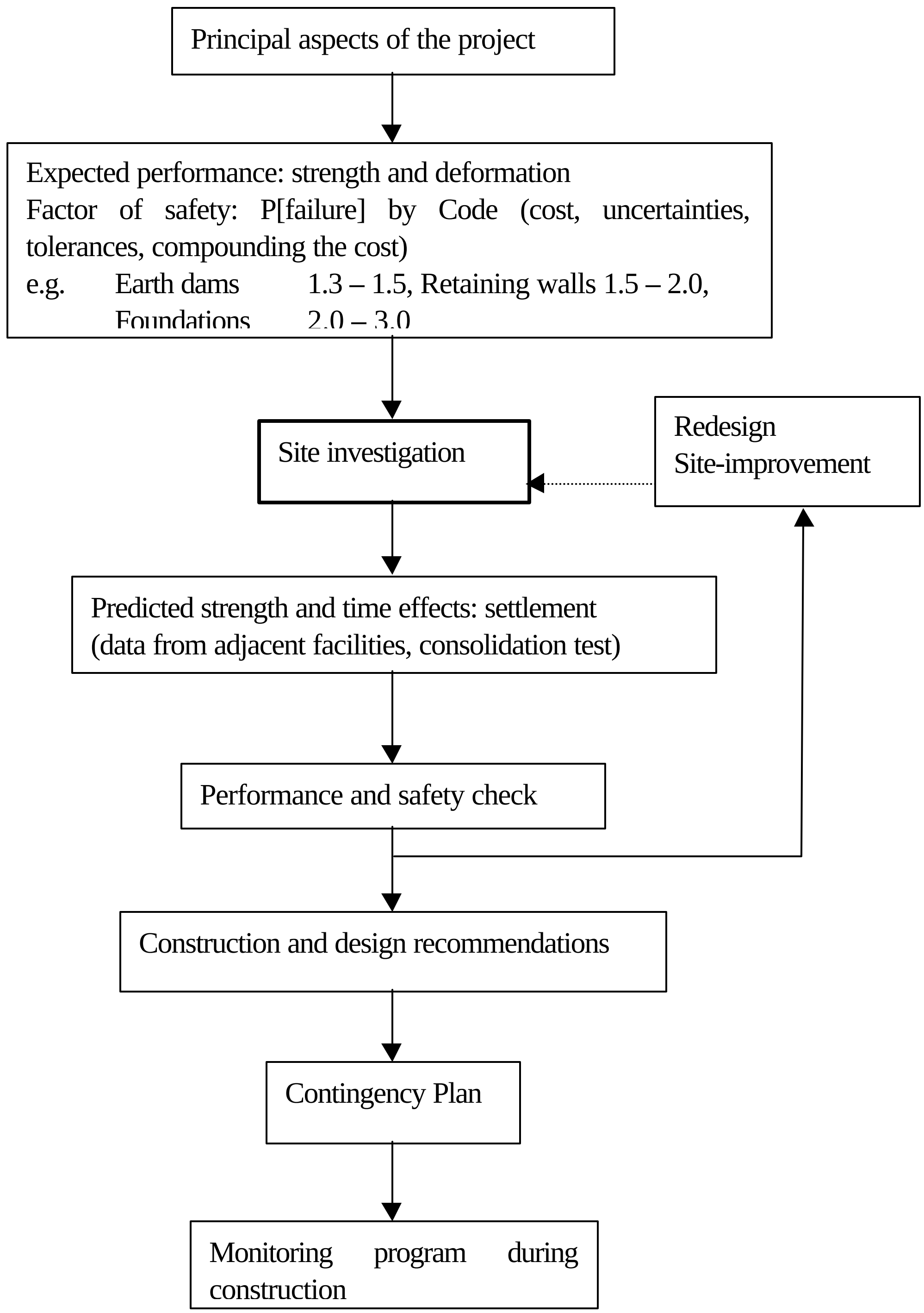
“A structure is not stronger than its connections”

Foundations transmit all the structural loads to the underlain soils. The foundation engineer must be multi-disciplinary and have knowledge of Geotechnical Engineering, Structural Engineering and Construction Engineering.



…and we can save 1000 Lira by not conducting soil studies!

1.1 Geotechnical problems



1.2 Design philosophy

Since the behaviour of soils is quite complex, most of our analysis and design methods include a mixture of rational and empirical techniques. The **success** of a geotechnical engineer relays on his solutions to practical design problems based on his **understanding** of the strengths and limitations of this mix of rationalism and empiricism (CE 353). A successful structure will fulfill the following performance requirements:

- Strength
- Serviceability
- Constructibility
- Economy.

Settlement

- Connection with existing structures
- Utility lines
- Surface drainage
- Access
- Aesthetics.

In spite of uncertainties in analysis and design, the society expects engineers to develop economical, timely, and reliable designs. The factor of safety (F.S.) is based on required reliability (i.e. the acceptable probability of failure), consequences of failure, uncertainties in soil properties and applied loads, construction tolerances (design and as-built dimensions), ignorance of true behaviour, cost-benefit ratio of additional conservatism in the design. Therefore, the factor of safety is used to compensate for uncertainties.

We use the factor of safety:

F.S.= Strength / Load (deterministic method)

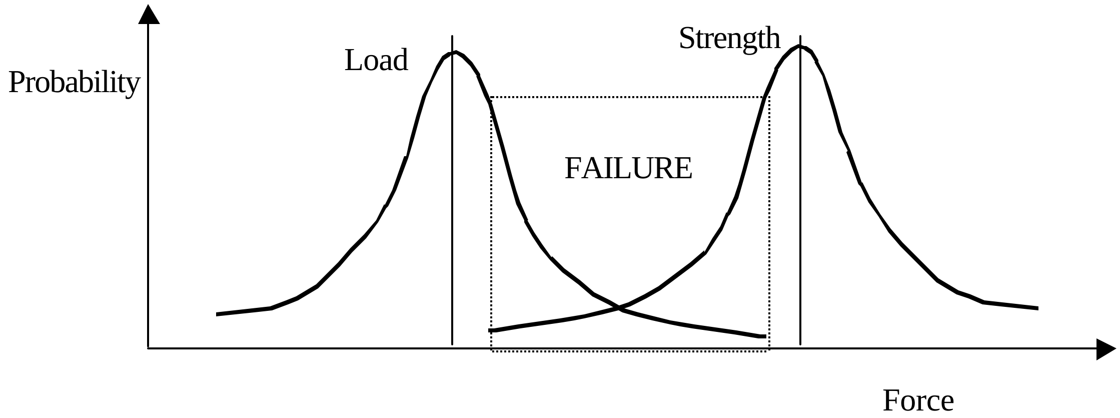
In Geotechnical Engineering there are two main approaches for design:

- Working stress design or allowable stress design (WSD, ASD): forces from working conditions

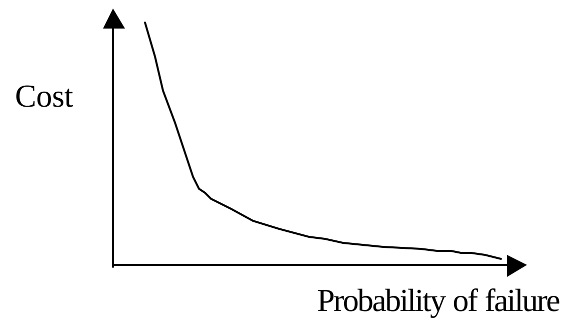
- Limit state design or load and resistance factor design (ULS, LRFD): forces from maximum loads

$$P_u = \gamma_1 P_D + \gamma_2 P_D + \ldots$$

$$P_u \leq \phi P_n$$



$$P[\text{ failure }] = P[L > S] = \sum P[S = So] P[L > So]$$



1.3 Design loads

$$D$$

$$D + L + F + H + T + (L_r \text{ or } S \text{ or } R)$$

$$0.75[D + L + (L_r \text{ or } S \text{ or } R) + (W \text{ or } E)]$$

$$0.75[D + (W \text{ or } E)]$$

where:

D:	dead loads;	W:	wind loads
L:	live loads;	T:	self-straining loads;
S:	snow loads;	I:	impact loads;
R:	rain loads;	SF:	stream flow loads;
H:	earth pressure loads;	ICE:	ice loads;
F:	fluid loads;	CF:	centrifugal loads; and,
E:	earthquake loads;	BF:	braking loads.

1.4 Review of soil mechanics

1.4.1 Total and effective stresses

$$\sigma' = \sigma_T - u$$

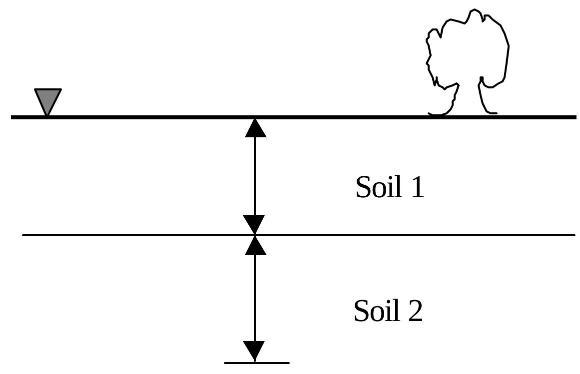
<u>Example 1.1</u>

Soil 1: H= 5m, γ_T =16 kN/m^3, ϕ'=30^o , c'= 15 kPa

Soil 2: H= 7m γ_T =19 kN/m^3 and ϕ'=35^o

Compute the total and effective stresses at the soil 2 – bedrock interface.

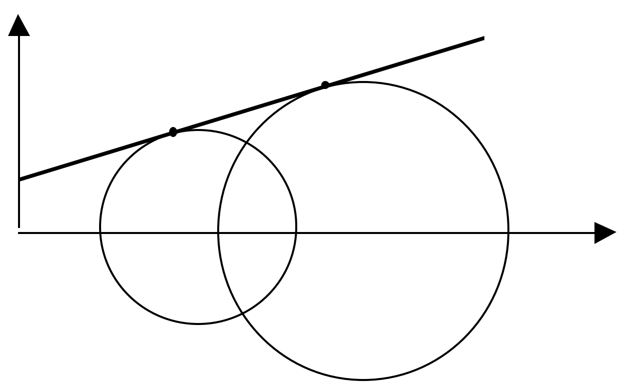
What is the water content of soil 2 if the in-situ void ratio is 0.60?



1.4.2 Drained (τ_f) and undrained shear strength (τ_f)

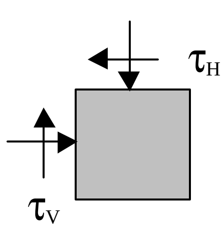
Drained shear strength:

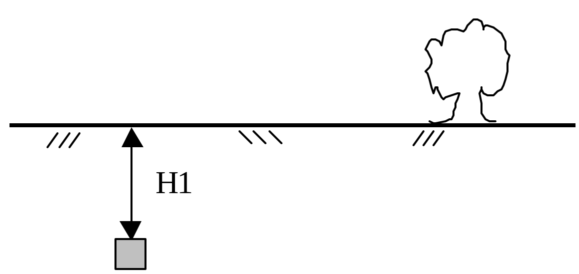
$$\tau_f = c' + \sigma'_n \tan(\phi')$$



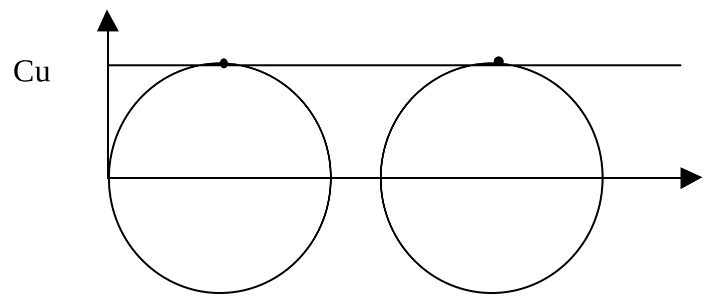
<u>Example 1.2:</u>

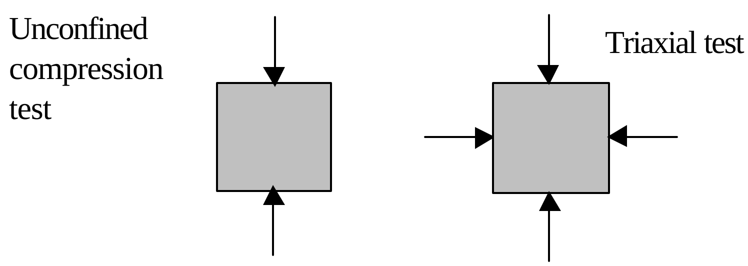
Compute the maximum shear stresses that can be applied on a vertical or horizontal plane at depth H.





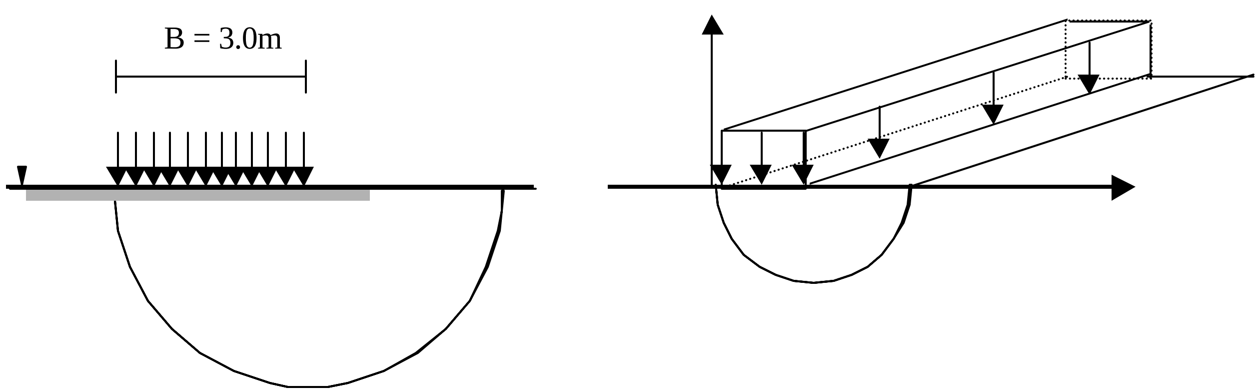
Undrained shear strength: $\tau_f = Cu$



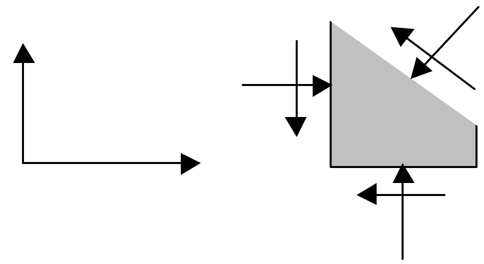


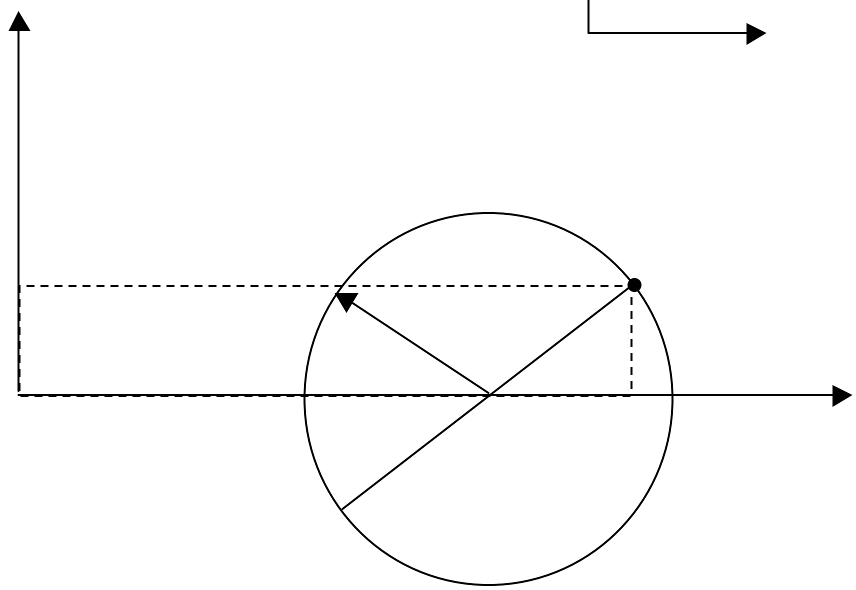
Example 1.3:

Compute the maximum load “q” for a strip footing on clay for fast loading. Cu= 80 kPa.



1.4.3 Mohr Circle: Graphical representation of the state of stress at any direction, at a given point





Characteristics of Mohr circle:

1- A change of an angle θ in the element represents an angle 2θ in the circle

2- Principal stresses σ_1 and σ_3 → Null shear stress

3- Radius and centre of the circle:

From principal stresses $R = \dfrac{\sigma_1 - \sigma_2}{2}$ $C = \dfrac{\sigma_1 + \sigma_2}{2}$

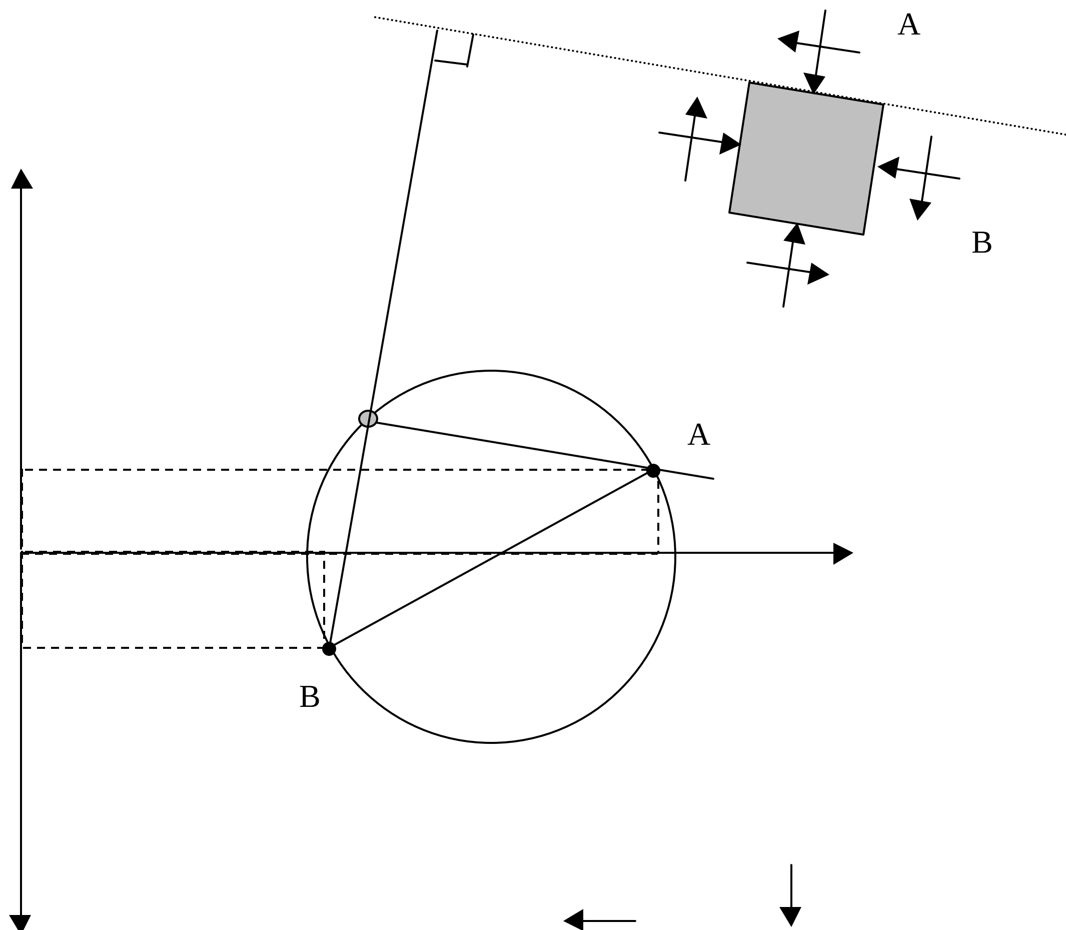
From non-principal stresses $R = \sqrt{\left(\dfrac{\sigma_Y - \sigma_X}{2}\right)^2 + \tau_{YX}^2}$ $C = \dfrac{\sigma_X + \sigma_Y}{2}$

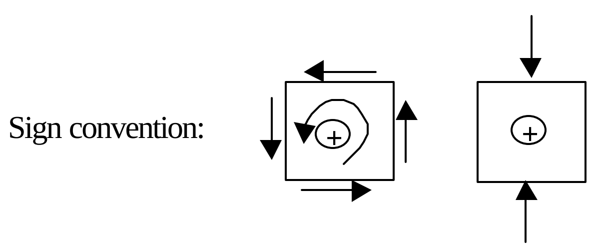
4- The resultant stress at any plane is given by

$$\sigma_R = \sqrt{(\sigma_N)^2 + (\tau_N)^2} =$$

5- The maximum shear stress is equal to the radius of the circle. Maximum shear stress acts on planes at 45^o with respect to principal stresses.

1- Stresses at any given orientation → Pole or origin of planes. Locate any given state of stresses (σ, τ) on the Mohr circle (Point A). Draw a line parallel to the plane on which the stresses (σ, τ) are acting at Point A and extend this plane until intersects again the circle (Point P). The intersection of this plane with the Mohr circle (Point P) defines the pole. This procedure can be used with any known state of stresses and the same pole should be obtained.



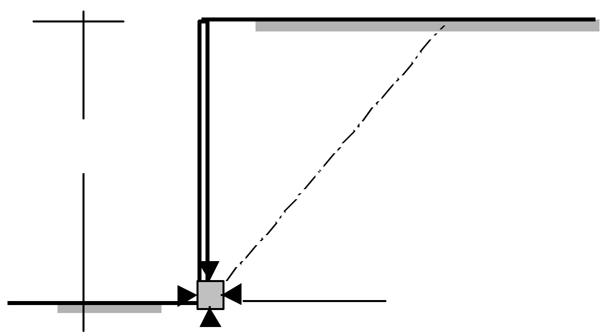


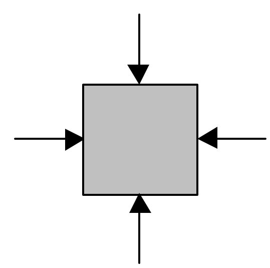
Example 1.4:

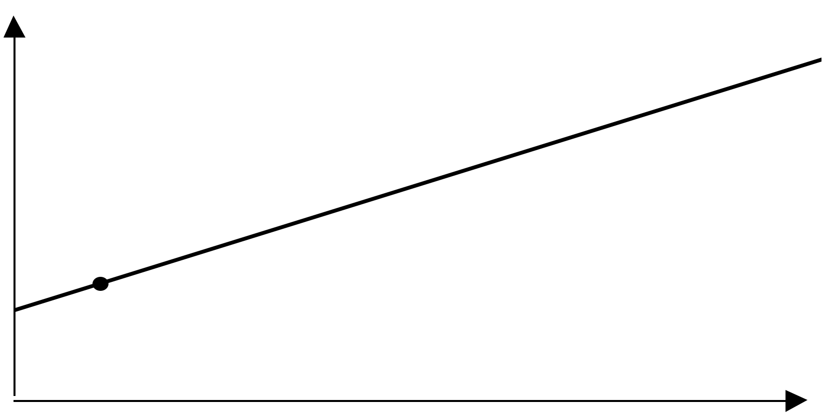
For a triaxial test, σ_1 = 10 kPa and σ_2 = 5 kPa. Find the normal and shear stresses in a plane inclined +30° with respect to the horizontal.

Example 1.5:

Find the maximum height H for an open-cut excavation on Soil 1.
Soil 1: γ_T =16 kN/m^3, ϕ'=30^o , c'= 15 kPa







Review Formula Sheet

$$G_s = \frac{\rho_s}{\rho_w} \qquad e = \frac{Vv}{Vs} \qquad n = \frac{Vv}{V} \qquad \omega = \frac{Ww}{Ws} \qquad S = \frac{Vw}{Vv} \qquad S = \frac{\omega G_s}{e} \qquad A = \frac{V_a}{V}$$

$\gamma_w = 9.81\ \text{kN/m}^3$

$$\rho_T = (1+\omega)\rho_d \qquad \rho_T = \frac{(1+\omega)}{(1+e)} G_s \rho_w \qquad \rho_d = \frac{G_s(1-A)}{(1+\omega G_s)}\rho_w \qquad dd \propto \left[\frac{D\,T}{v^2\,n}\right]^{1/2}$$

$Cu = D_{60}/D_{10}$ $\qquad$ $Cc = (D_{30})^2/(D_{10}\,D_{60})$

$Cu \geq 6$ $\qquad$ $1 \leq Cc \leq 3$ (SW)

$Cu \geq 4$ $\qquad$ $1 \leq Cc \leq 3$ (GW)

$$q = k\ i\ A \qquad i = \frac{\Delta h_T}{\Delta s} \qquad i_c = \frac{\gamma_T - \gamma_w}{\gamma_w}$$

$q = k\ h_{T(\text{st-last})}\ (N_f/N_d)$

$h_T = h_p + h_e$

$$FS = \frac{\textit{Strength}}{\textit{Load}} \qquad \sigma' = \sigma_T - u \qquad \tau_f = c' + \sigma'_n \tan(\phi') \qquad C_V = \frac{0.196 d^2}{t_{50}}$$

S_O= Surface/Mass
Sphere
Area=$4\pi R^2$
Volume=$4/3 * \pi R^3$

$$u = \sum_{m=0}^{\infty} \frac{2u_0}{M} \sin\left(\frac{Mz}{d}\right) e^{-M^2 T_v} \qquad S_\infty = \frac{\Delta e}{1+e_0} H \qquad S_I = \frac{qB}{E}\mu_0\,\mu_1 \qquad I_z = \frac{\varepsilon_z E}{q}$$

$$M = \frac{\pi}{2}(2m+1) \qquad S_\infty = \frac{C\ \log\left(\frac{\sigma'_2}{\sigma'_1}\right)}{1+e_0} H$$

$I_z\left(\frac{B}{2}\right) = 0.6 \quad I_z(2B) = 0.0$

$I_z(B) = 0.6 \quad I_z(4B) = 0.0$

$$K_A = \tan^2\left(45 - \frac{\phi'}{2}\right) \qquad K_P = \tan^2\left(45 + \frac{\phi'}{2}\right)$$

$$\sigma'_H = K_A \sigma'_V - 2c'\sqrt{K_A} \qquad \sigma'_H = K_P \sigma'_V + 2c'\sqrt{K_P}$$

$$T_v = \frac{\pi \bar{U}^2}{4} \qquad \bar{U} < 0.6$$

$$T_v = -0.933 \log(1-\bar{U}) - 0.085 \qquad \bar{U} > 0.6$$

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

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

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

$$K_o = 1 - \sin(\phi') \qquad C = \frac{\sigma_1 + \sigma_2}{2} \qquad R = \frac{\sigma_1 - \sigma_2}{2} \qquad a' = c'\cos\phi'$$

$$K_{oc} = K_o^{OCR}\ OCR^{\sin\phi'} \qquad C = \frac{\sigma_X + \sigma_Y}{2} \qquad R = \sqrt{\left(\frac{\sigma_Y - \sigma_X}{2}\right)^2 + \tau_{YX}^2} \qquad \tan\alpha' = \sin\phi'$$