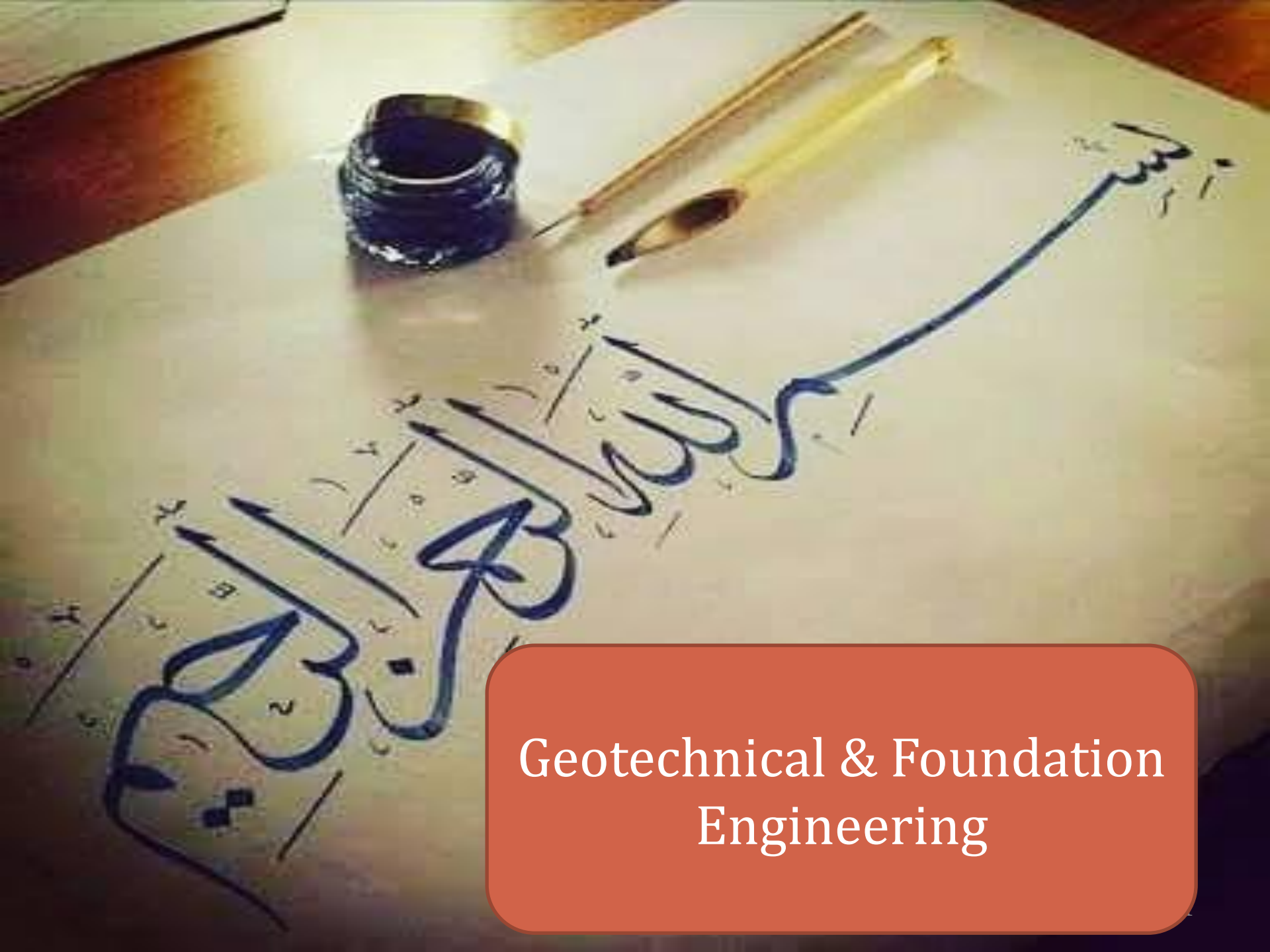


Geotechnical & Foundation Engineering

Slope Stability

S

STABILITY OF SLOPES

Slope

An exposed ground surface that stands at an angle with the horizontal is called an unrestrained slope.

2

Slope Stability

S

TYPES OF SLOPES

A) w.r.t. Method of Construction

1. Natural Slopes
2. Man-made / Engineered Slopes

Embankments, earthen dams, river dikes, excavation trenches, etc.

Natural Slope

Engineered Slope

3

Slope Stability

S

TYPES OF SLOPES

B) w.r.t. Extents

1. Infinite Slopes

   Having constant slope of infinite extent, e.g. long slope of a mountain face.

2. Finite Slopes

   Slopes of limited heights and extents, e.g. typical man-made slopes

Infinite Slope

Finite Slope

4

Slope Stability

S

TYPES OF SLOPES

C) w.r.t. Slope Material

1. Cohesionless
2. Cohesive

Cohesionless

Cohesive

5

Slope Stability

S

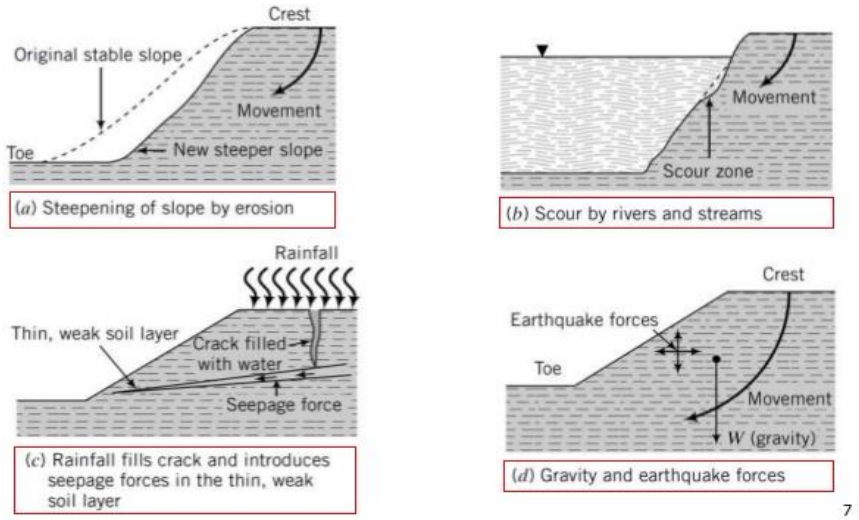
STABILITY OF SLOPES

A slope is said to be stable if it meets a prescribed need for a fixed period of time with a suitable safety factor (FOS).

Slope Stability

S

CAUSES OF SLOPE FAILURE



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Slope Stability

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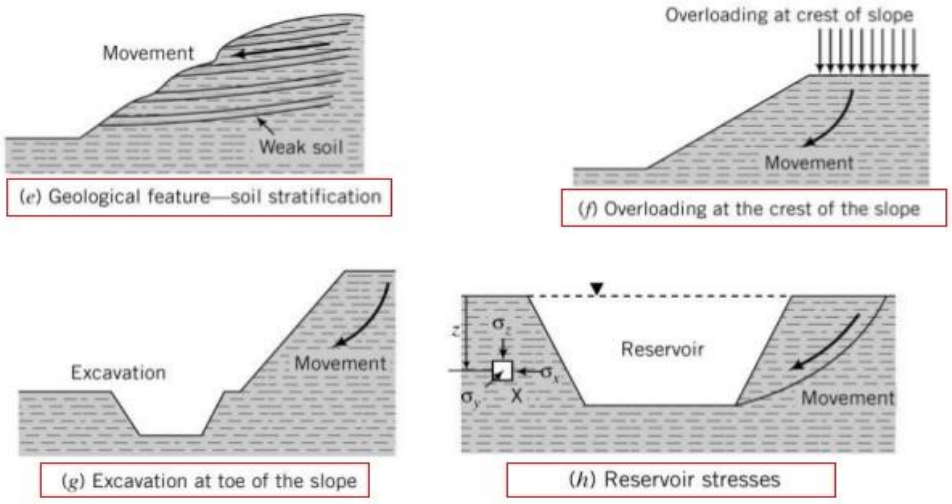
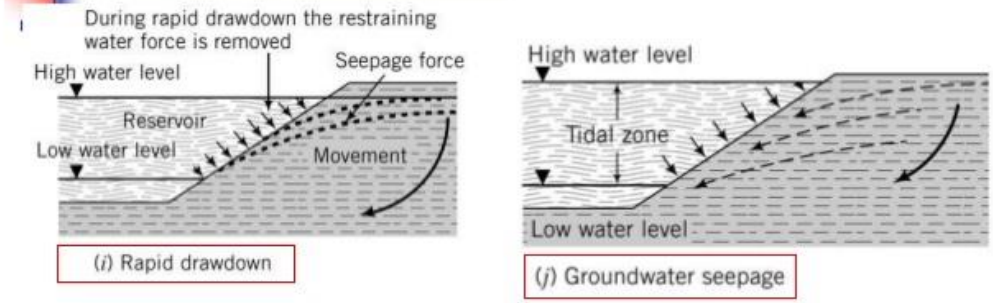
CAUSES OF SLOPE FAILURE



Slope Stability

S

CAUSES OF SLOPE FAILURE



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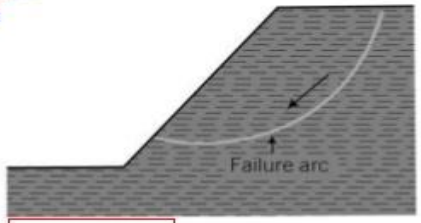
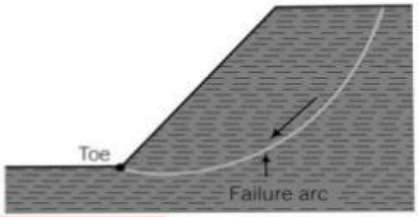
Slope Stability

S

TYPES/MODES OF SLOPE FAILURE



(d) Slope slide



(c) Toe slide

Toe Failure

- Failure surface passing through toe of slope
- Material of slope is homogeneous
- Relatively steep slope angles

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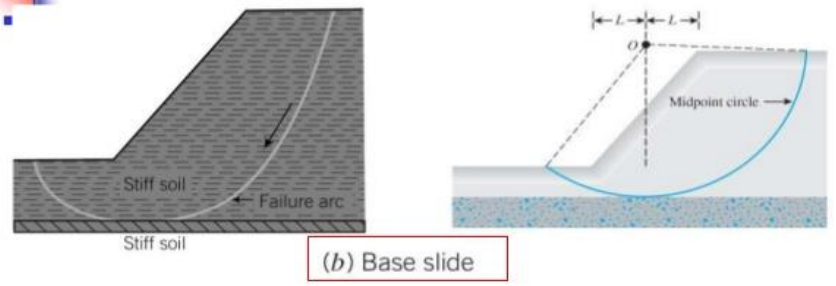
Slope Stability

S

TYPES/MODES OF SLOPE FAILURE



(*b*) Base slide

Base Failure

- ❑ Failure surface passing through foundation
- ❑ Foundation soil somehow weaker than slope material
- ❑ Relatively gentle slopes

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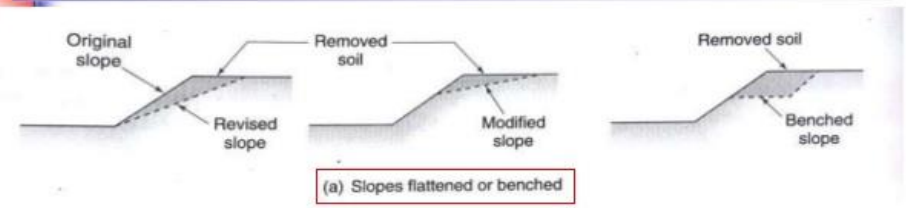
Slope Stability

S

SLOPE STABILIZING MEASURES



(a) Slopes flattened or benched

(b) Berm provided at toe (weight increases the resistance to sliding)

(c) Protection against erosion provided at toe

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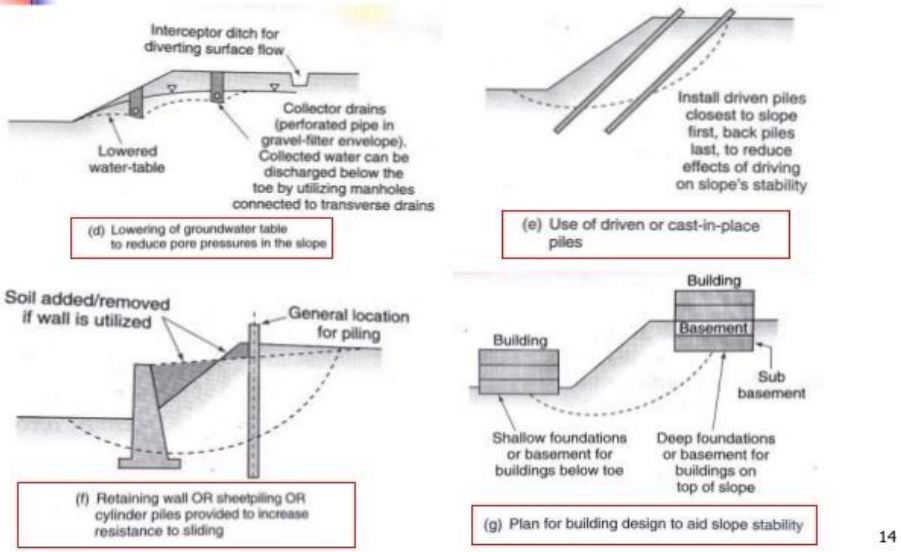
Slope Stability

S

SLOPE STABILIZING MEASURES



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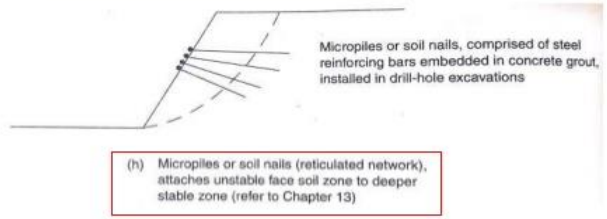
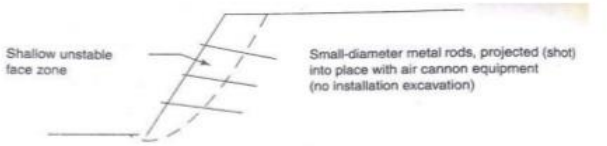
Slope Stability

S

SLOPE STABILIZING MEASURES



(h) Micropiles or soil nails (reticulated network), attaches unstable face soil zone to deeper stable zone (refer to Chapter 13)



(i) Launched soils nails reinforce unstable face zone and attach to deeper stable zone (method limited to stabilizing shallow face zones); see Chapter 17

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Slope Stability

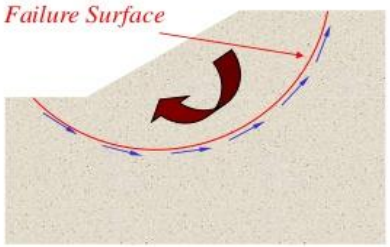
S

LIMIT EQUILIBRIUM ANALYSIS

- Most common *quantitative* measure of slope stability
- Stability of slope expressed in terms of *factor of safety just before failure*

$$FOS = \frac{Resisting\ Force}{Disturbing\ Force}$$

$$FOS = \frac{Available\ Shear\ Strength\ of\ Soil}{Applied\ Shear\ Stress}$$



$FOS < 1 \rightarrow$ *Failure*

$FOS = 1 \rightarrow$ *Verge of failure/Just stable*

$FOS > 1 \rightarrow$ *Stable*

Typical design criterion for stable slope; FOS > 1.5

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Slope Stability

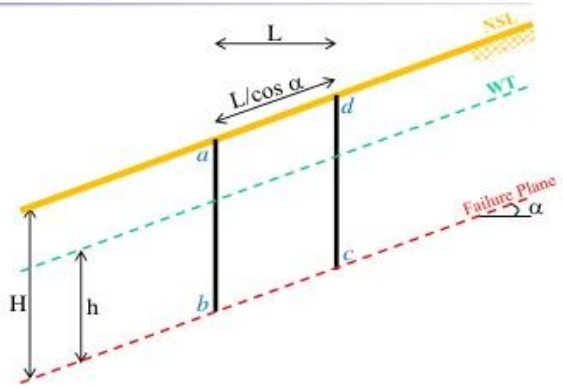
S

SLOPE STABILITY ANALYSIS

Infinite Slope

Assumptions:

1. *Slope face* is planar and of infinite extent
2. *Failure surface* is ‖ to slope face
3. *Water surface* is ‖ to slope face



$$FOS = \frac{Available\ Shear\ Strength\ of\ Soil}{Applied\ Shear\ Stress}$$

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Slope Stability

S

SLOPE STABILITY ANALYSIS

Infinite Slope

Case-A: c-ϕ Soil (c>0; ϕ>0)

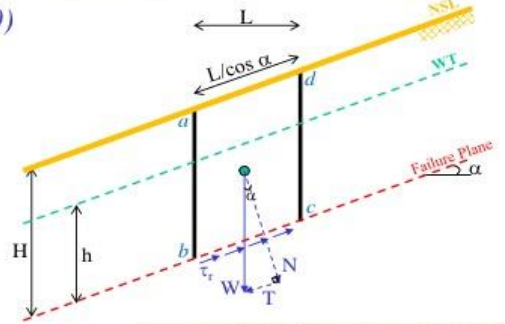
$$W = \gamma HL$$

$$N = W\cos\alpha = \gamma HL\cos\alpha$$

$$T = W\sin\alpha = \gamma HL\sin\alpha$$

Available Shear Strength of Soil (τ_r)

$$\tau_r = c' + \sigma_n' \cdot \tan\varphi'$$



$$FOS = \frac{\text{Available Shear Strength of Soil}}{\text{Applied Shear Stress}}$$

Normal stress on the failure plane

$$\sigma_n = \frac{N}{(L/\cos\alpha)(1)} = \frac{\gamma HL\cos\alpha}{(L/\cos\alpha)(1)} = \gamma H\cos^2\alpha$$

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Slope Stability

S

SLOPE STABILITY ANALYSIS

Infinite Slope

Case-A: c-ϕ Soil (c>0; ϕ>0)

Available Shear Strength of Soil (τ_r)

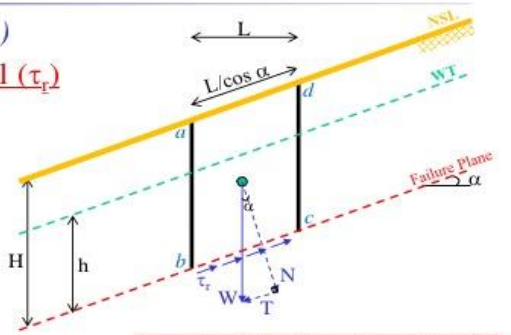
$$\tau_r = c' + \gamma H cos^2\alpha \cdot \tan\phi'$$

Applied Shear Stress (τ)

$$\tau = \frac{T}{(L/\cos\alpha)(1)}$$

$$\tau = \frac{\gamma HL \sin\alpha}{(L/\cos\alpha)(1)}$$

$$\tau = \gamma H \sin\alpha \cos\alpha$$



Factor of Safety (FOS) ⇒

$$FOS = \frac{c' + \gamma H cos^2\alpha \cdot \tan\phi'}{\gamma H \sin\alpha \cos\alpha}$$

Without considering the effect of WT

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Slope Stability

S

SLOPE STABILITY ANALYSIS

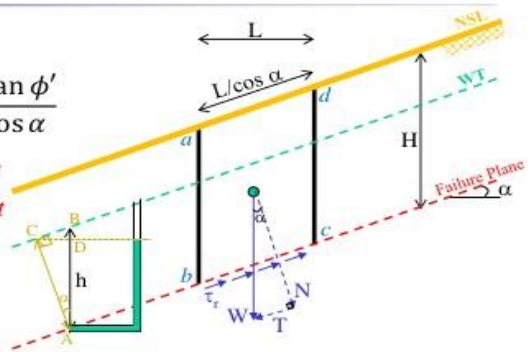
Infinite Slope

Case-A: c-ϕ Soil (c>0; ϕ>0)

Considering presence of WT

$$FOS = \frac{c' + \sigma_n' \cdot \tan\phi'}{\gamma H \sin\alpha \cos\alpha}$$

- *c' & ϕ'; effective strength parameters*
- Obtained through *drained triaxial test*



$$\sigma_n = \gamma H \cos^2\alpha \qquad \sigma_n' = \sigma_n - u$$

$$AB = h$$
$$AC = h\cos\alpha$$
$$AD = h_w = AC\cos\alpha = h\cos^2\alpha$$

Pore water pressure, u

$$u = \gamma_w h_w$$
$$h_w = AD = h\cos^2\alpha$$
$$u = \gamma_w h \cos^2\alpha$$

$$FOS = \frac{c' + (\gamma H - \gamma_w h) \cdot \cos^2\alpha \tan\phi'}{\gamma H \sin\alpha \cos\alpha}$$

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Thank you