Rock Slope Engineering 1

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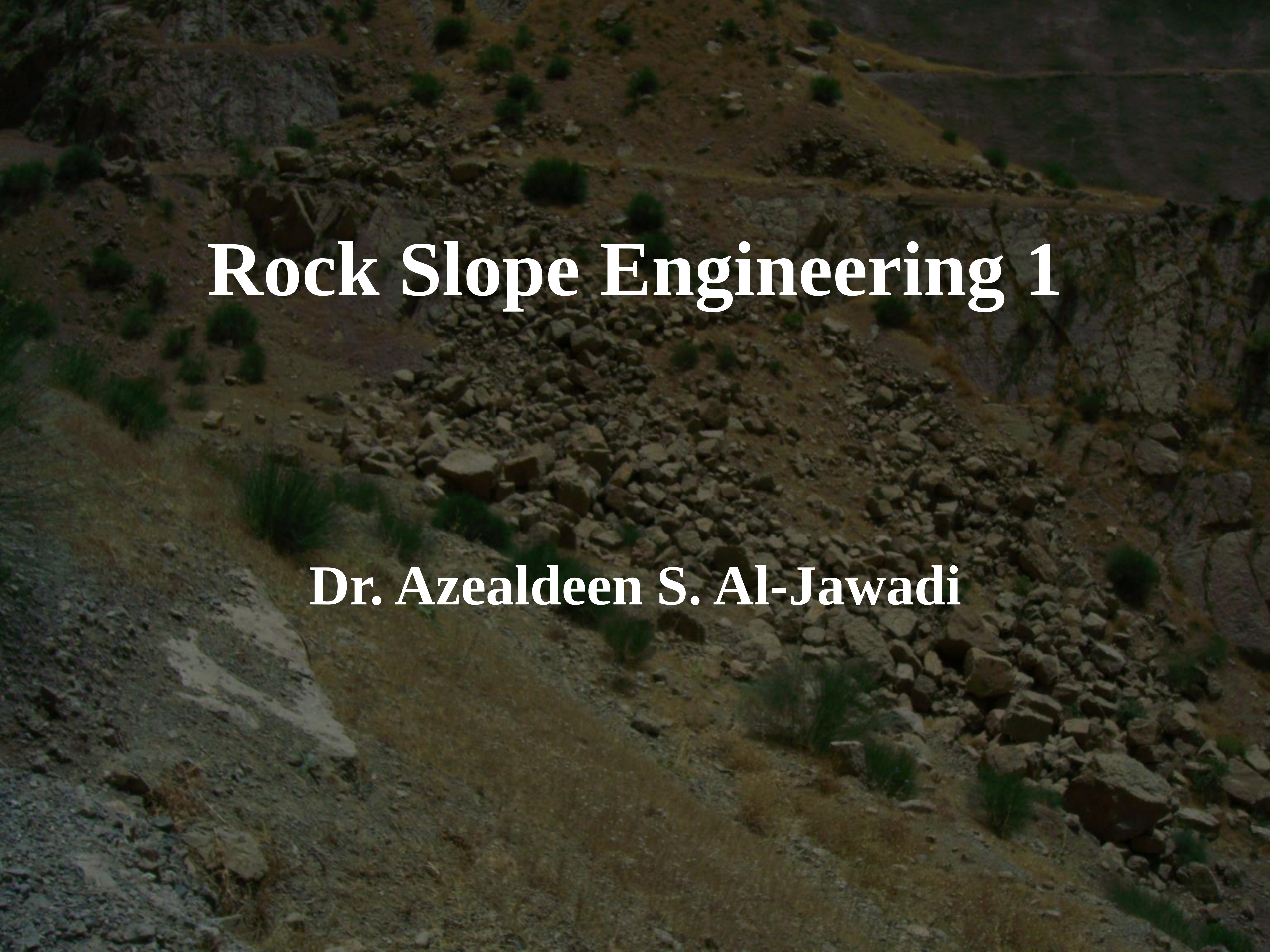
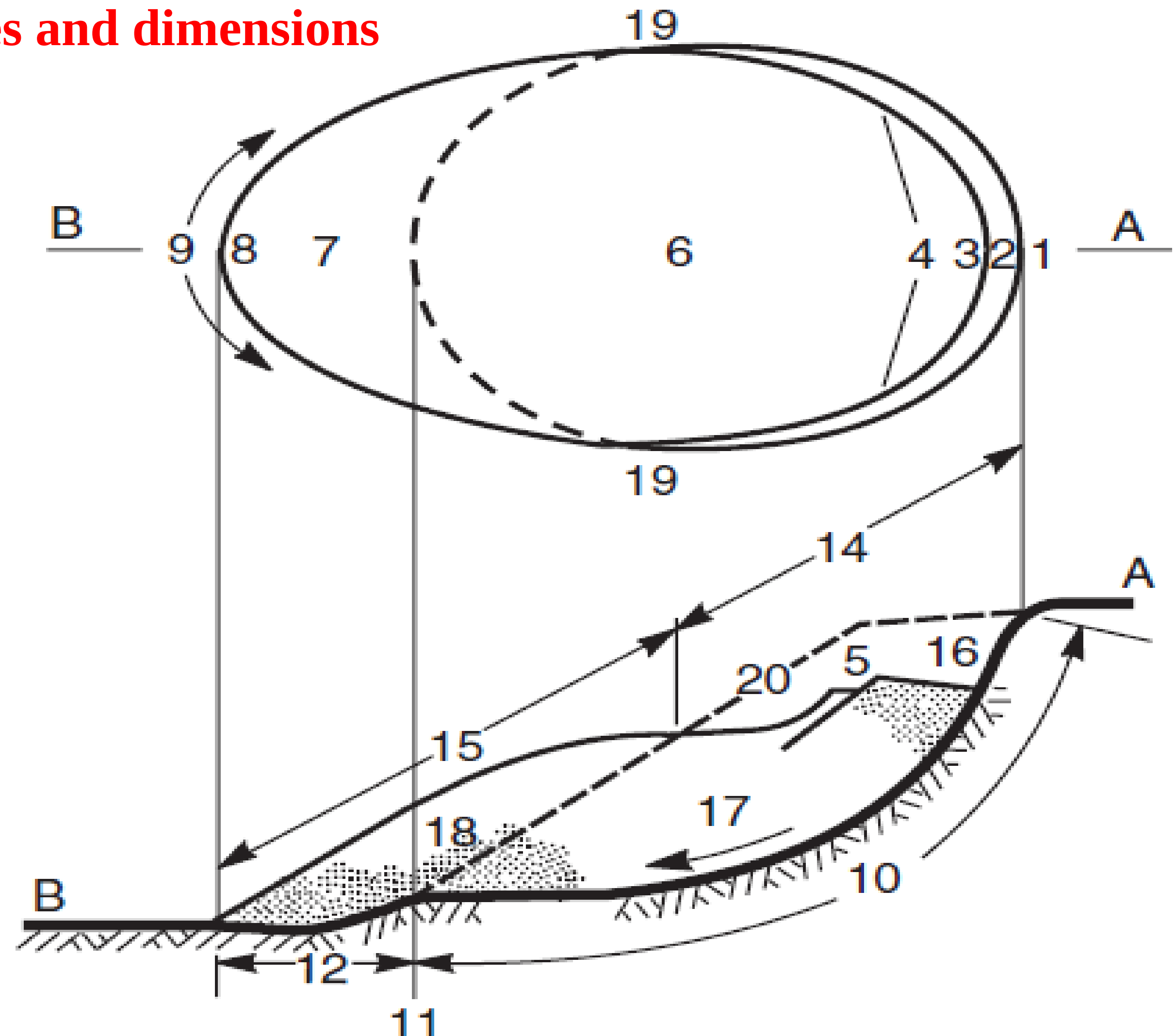



scarp

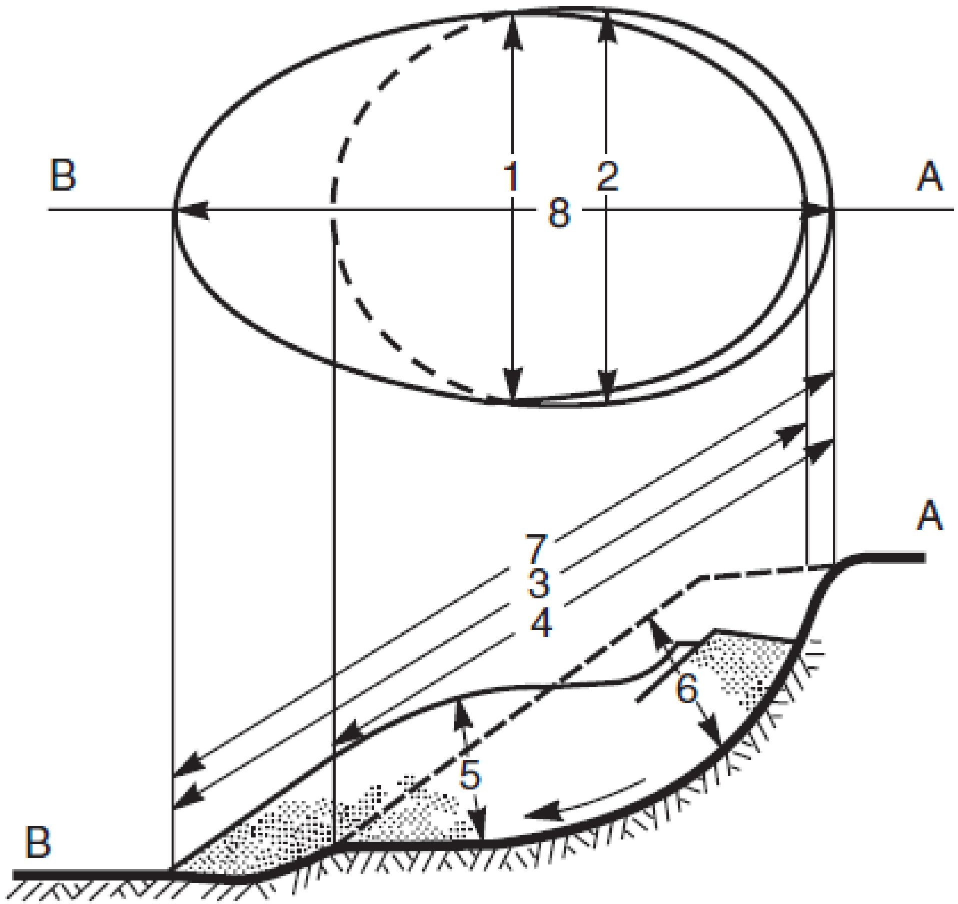
U

Slope features and dimensions



10	Surface of [illegible]	Surface that forms (or that has formed) lower boundary of [illegible]
[illegible]	[illegible]	[illegible]

Slope features and dimensions



8	Length of center line,	Distance from crown to tip of landslide through
6 / 5	Depth of surface / Depth of displaced	Maximum depth of surface of rupture below original ground [illegible]
[illegible]	[illegible]	[illegible]
	mass, [illegible] Lr	[illegible] length, Lr

Summary of design methods

If the shear force (displacing force) is greater than the shear strength of the rock (resisting force) on this surface, then the slope will be unstable.

Instability could take the form of displacement that may or may not be tolerable, or the slope may collapse either suddenly or progressively.

The definition of instability will depend on the application.

Expression of the slope stability

(a) *Factor of safety*, *FS*—Stability quantified by limit equilibrium of the slope, which is stable if FS > 1.

(b) *Strain*—Failure defined by onset of strains great enough to prevent safe operation of the slope, or that the rate of movement exceeds the rate of mining in an open pit.

(c) *Probability of failure*—Stability quantified by probability distribution of difference between resisting and displacing forces, which are each expressed as probability distributions.

(d) *LRFD (load and resistance factor design)*— Stability defined by the factored resistance being greater than or equal to the sum of the factored loads.

Failure type	*Category*	*Safety factor*
Shearing	Earthworks	1.3–1.5
	Earth retaining structures, excavations	1.5–2.0
	Foundations	2–3

Upper values: loads and service conditions,

Lower values: maximum loads and the worst expected geological conditions.

probabilistic design methods 5% probability of failure Risk & Consequence

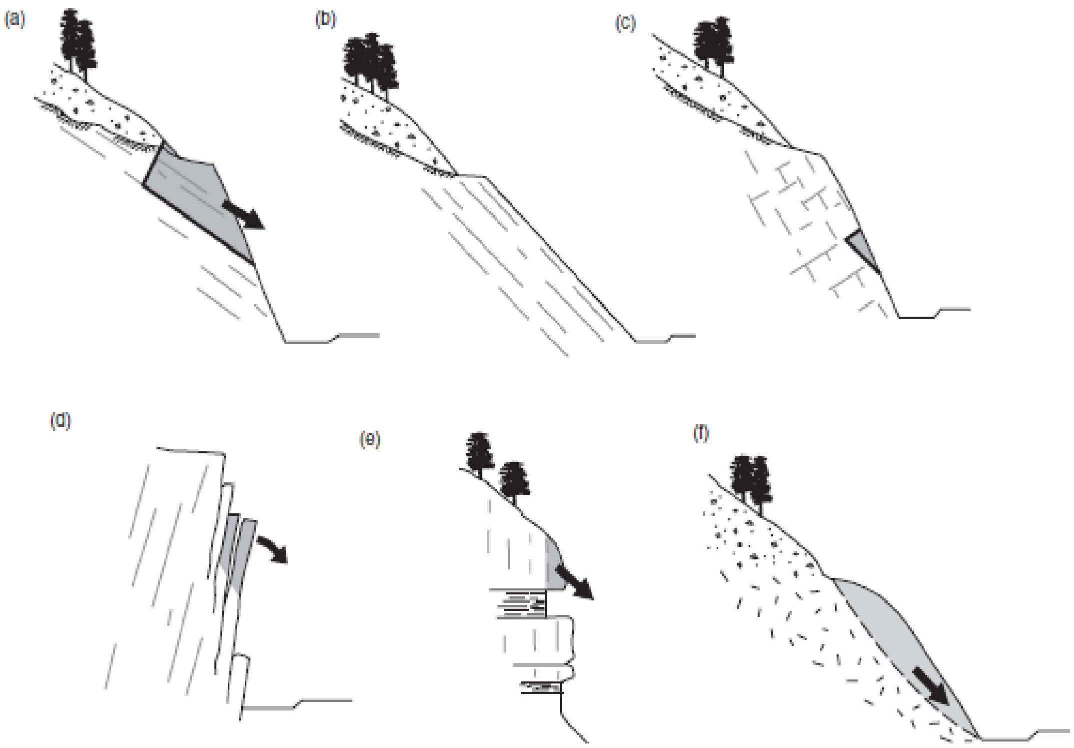
The calculation of strain in slopes is the most recent advance in slope design.

numerical analysis discontinuities geological conditions

Conditions

- A limited drilling program and extensive mechanical breakage or core loss.
- Absence of rock outcrops, and there is no history of local stability conditions.
- Inability to obtain undisturbed samples.
- Absence of information on ground water conditions.
- Uncertainty in failure mechanisms, plane type failures can be analyzed with considerable confidence, while the detailed mechanism of toppling failures is less well understood.
- Concern regarding the quality of construction, including materials, inspection and weather conditions.
- The consequence of instability.

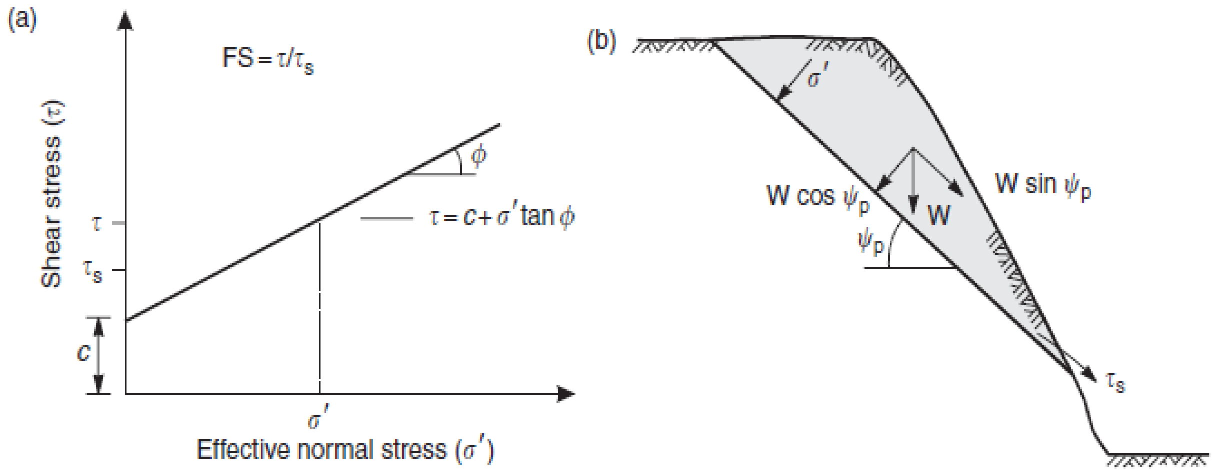
1. Limit equilibrium analysis



Influence of geological conditions on stability of rock cuts: (a) potentially unstable—discontinuities "daylight" in face; (b) stable slope—face excavated parallel to discontinuities; (c) stable slope—discontinuities dip into face; (d) toppling failure of thin beds dipping steeply into face; (e) weathering of shale beds undercuts strong sandstone beds to form overhangs; (f) potentially shallow circular failure in closely fractured, weak rock.

For all shear type failures, the rock can be assumed to be a Mohr–Coulomb material in which the shear strength is expressed in terms of the cohesion c and friction angle $\boldsymbol{\varphi}$. For a sliding surface on which there is effective normal stress $\boldsymbol{\sigma}$ acting, the shear strength $\boldsymbol{\tau}$ developed on this surface is given by

$$\boldsymbol{\tau} = c + \boldsymbol{\sigma}' \tan \boldsymbol{\varphi} \quad (1.1)$$



The effective normal stress is the difference between the stress due to the weight of the rock lying above the sliding plane and the uplift due to any water pressure acting on this surface.

$$\text{Normal stress, } \sigma = \frac{W \cos \psi_p}{A} \quad \text{and}$$

$$\text{shear stress, } \tau_s = \frac{W \sin \psi_p}{A} \qquad (1.2)$$

$$\tau = c + \frac{W \cos \psi_p \tan \phi}{A} \qquad (1.3)$$

or

$$\text{driving force} \quad \tau_s A = W \sin \psi_p \quad \text{and}$$

$$\text{resisting forces} \quad \tau A = cA + W \cos \psi_p \tan \phi \qquad (1.4)$$

The stability of the block in Figure 2(b) can be quantified by the ratio of the resisting and driving forces, which is termed the factor of safety, FS. Therefore, the expression for the factor of safety is

$$FS = \frac{\text{resisting forces}}{\text{driving forces}} \tag{1.5}$$

$$FS = \frac{cA + W \cos \psi_p \tan \phi}{W \sin \psi_p} \tag{1.6}$$

The displacing shear stress $\boldsymbol{\tau}_s$ and the resisting shear stress $\boldsymbol{\tau}$ defined by equations (1.4) are plotted on Figure 2(a). On Figure 2(a) it is shown that the resisting stress exceeds the displacing stress, so the factor of safety is greater than one and the slope is stable. If the sliding surface is clean and contains no infilling then the cohesion is likely to be zero and equation (1.6) reduces to

$$FS = \frac{\cos \psi_p \cdot \tan \phi}{\sin \psi_p} \tag{1.7}$$

or

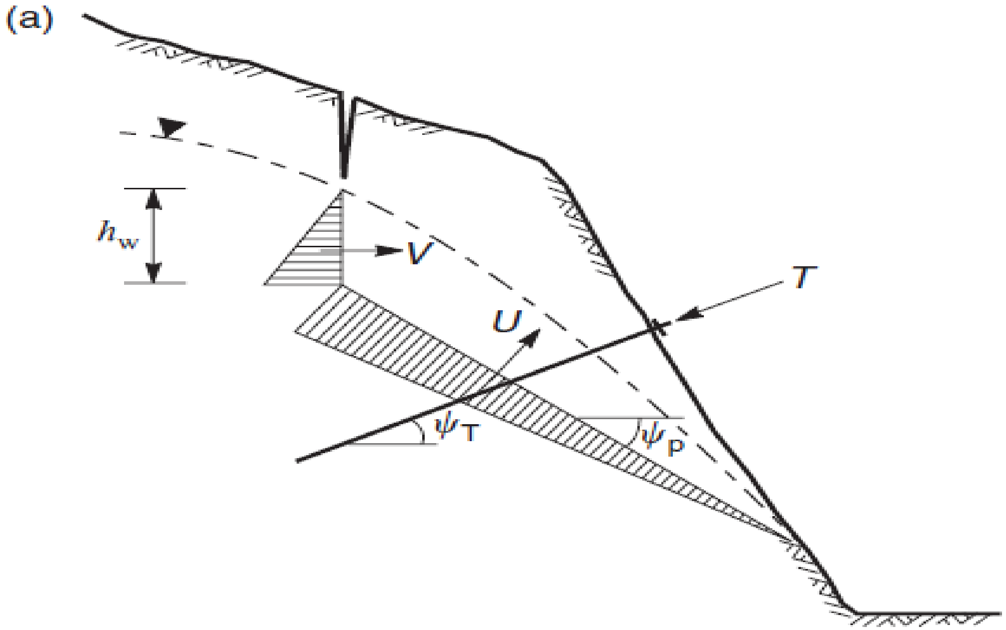
$$FS = 1 \quad \text{when } \psi_p = \phi \tag{1.8}$$

The stability is independent of the size of the sliding block

limiting equilibrium

the driving forces are exactly equal to the resisting forces and the factor of safety is equal to 1.0

limit equilibrium analysis



wide range of conditions water forces acting external reinforcing

water forces acting $p = \gamma_w h_w$ (1.9) the maximum pressure, p at the base of the tension crack and the upper end of the sliding surface

the water forces acting in the tension crack, V, and on the sliding plane, U

$$V = \frac{1}{2}\gamma_w h_w^2 \quad \text{and} \quad U = \frac{1}{2}\gamma_w h_w A \qquad (1.10)$$

factor of safety

$$FS = \frac{cA + (W\cos\psi_p - U - V\sin\psi_p)\tan\phi}{W\sin\psi_p + V\cos\psi_p} \qquad (1.11)$$

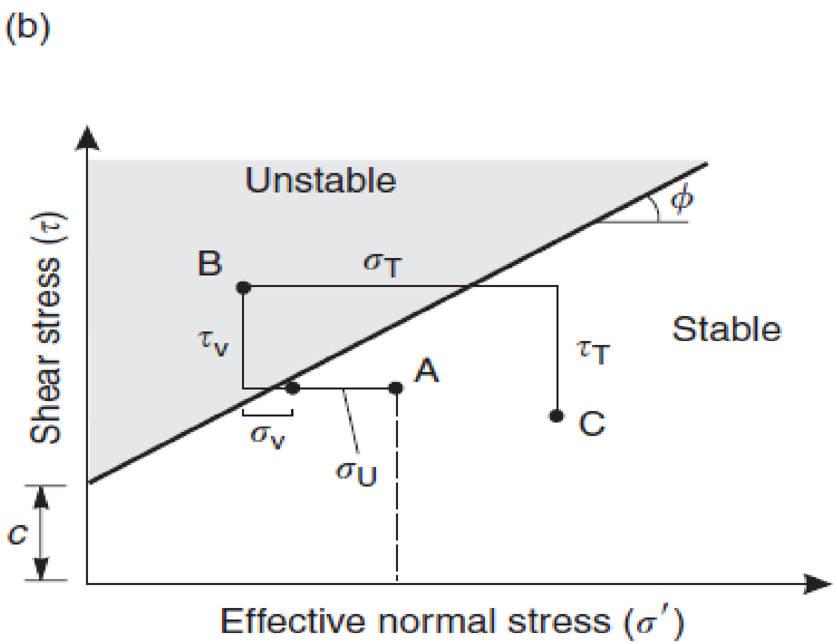
external reinforcing

Normal force $NT = T \sin(\psi T + \psi p)$ and

Shear force $ST = T \cos(\psi T + \psi p)$ (1.12)

factor of safety

$$FS = \frac{cA + (W\cos\psi_p - U - V\sin\psi_p + T\sin(\psi_T + \psi_p))\tan\phi}{W\sin\psi_p + V\cos\psi_p - T\cos(\psi_T + \psi_p)} \quad (1.13)$$

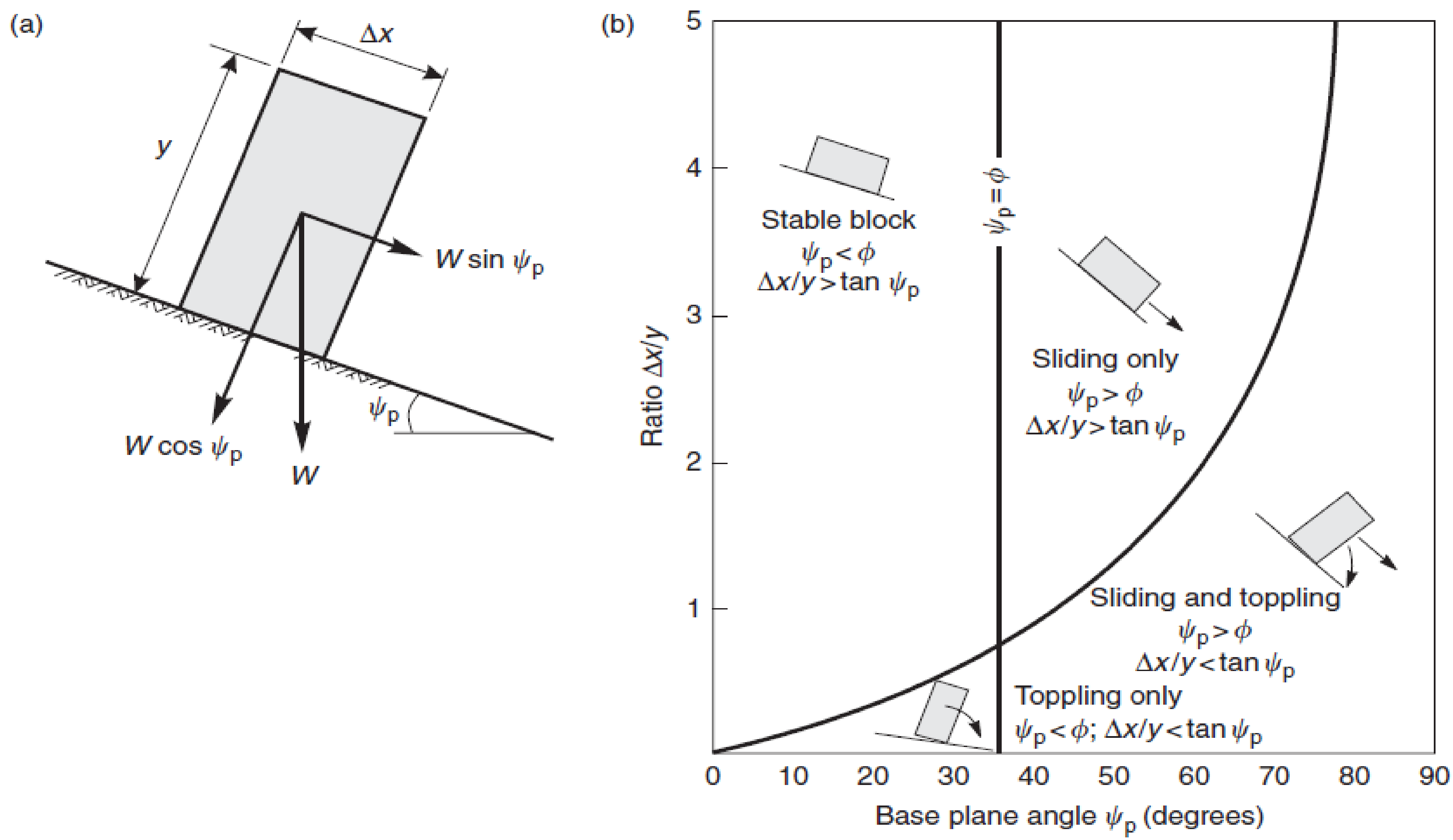


the optimum dip angle for the bolts, that is, the dip that produces the greatest factor of safety for a given rock anchor force is

$$\psi T_{(opt)} = (\varphi - \psi_p) \text{ or } \varphi = \psi_p + \psi T_{(opt)} \quad (1.14)$$

versatile method that can be applied to a wide range of conditions

all the forces are assumed to act through the center of gravity of the block



the conditions that differentiate stable, sliding and toppling blocks in relation to the width Δx and height y of the block, the dip **ψ**p of the plane on which it lies and the friction angle **ϕ** of this surface. Sliding blocks are analyzed either as plane or wedge failures

Thanks for your Attention