SAFETY IN OPENCAST MINING WITH SPECIAL REFERENCE TO SLOPE STABILITY

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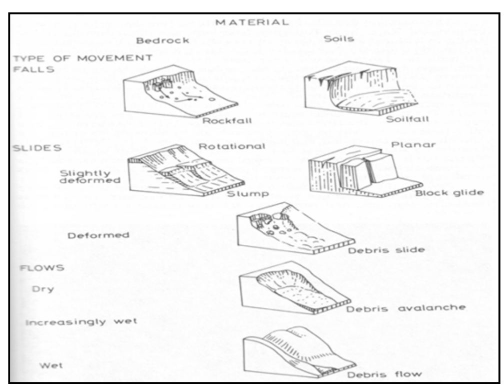
CONTROLLING FACTORS

- *Strength*
- *RQD*
- *Joint features*
- *Ground water*
- *In-situ stress*

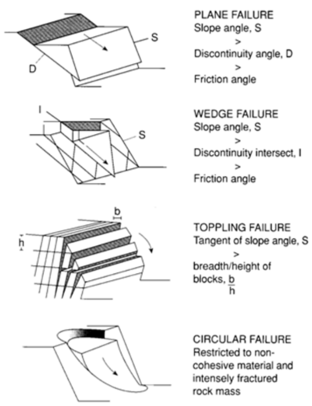
- *Weathering*
- *Orientation*
- *Induced stresses*
- *Blasting*
- *Slope profile*

BASIC ISSUES

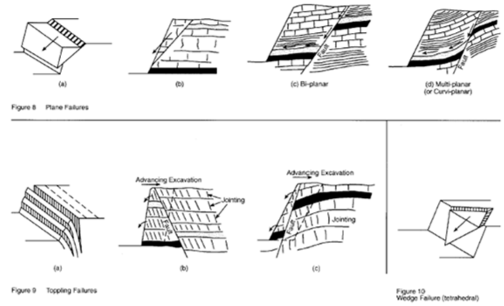
- When is a slope not stable?
- Slope stability is based on the interplay between two types of forces: <u>Driving</u> forces and <u>Resisting</u> forces.
- Driving forces promote downslope movement of material.
- Resisting forces deter movement.
- When driving forces overcome resisting forces, the slope is unstable and results in FAILURE.
- The main TRIGGERING/driving force in most SLOPE movements is WATER.
- The main resisting force is the material's shear strength.

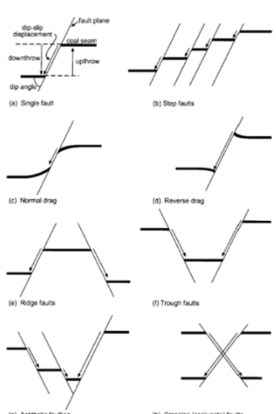


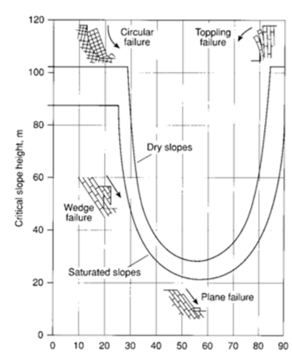
Typical failures in soil



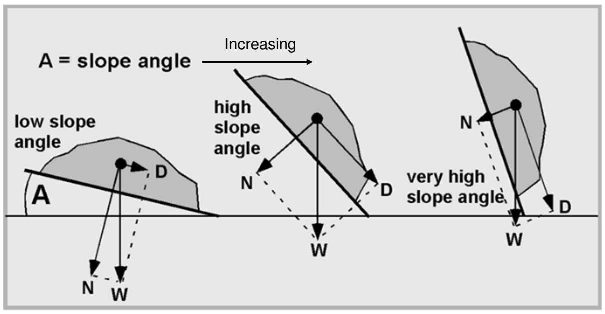
Failure type related to discontinuity geometry and friction strength





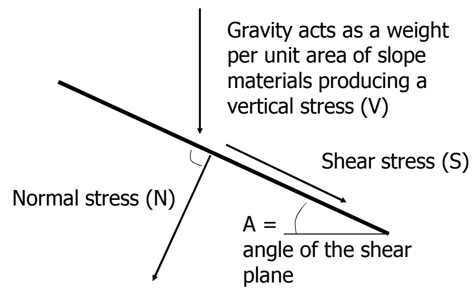


Critical height of vertical rock slopes related to fracture geometry and wetness



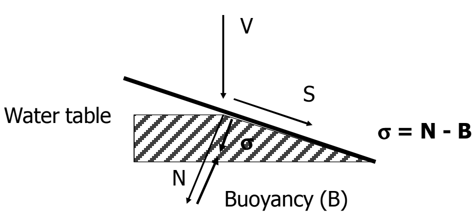
Factors that Influence Slope Stability

Effects of gravity on slopes



The vertical stress (V) can be resolved into two components acting at right angles to each other (S) and (N). The relative size of (N) and (S) depends on A

Effect of Water



Water-filled slopes have positive pore water pressures which give buoyancy to overlying material, acting in opposition to normal stress thus producing a smaller effective normal stress (σ)

Safety Factor (SF)

The ratio of resisting forces to driving forces:

$$SF = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

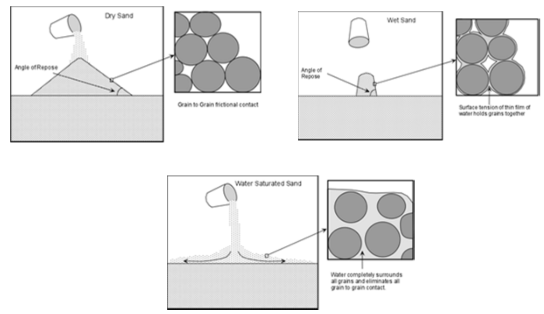
If SF > 1 then SAFE

If SF < 1 then UNSAFE

Atterberg Limits

- Plasticity – related to water content and how the material reacts to loads
  - LL –liquid limit - water content above which soil acts as liquid
  - PL – plastic limit - water content below which soil does not deform plastically (governed by clay content)
- If water is removed, but all the voids remain filled the mixture will deform under its own weight. The boundary between the two states is called the *liquid limit.*
- With further reduction in water the material shifts to a plastic state. An external force (load) is needed to deform the material. *Plastic limit* is the smallest water content at which a soil is plastic.

Role of Water



<u>Factor of safety</u>

$$\text{Factor of safety (FOS)} = \frac{\textbf{shear strength}}{\textbf{shear stress}}$$

$$= \frac{C + \sigma . \text{Tan}\ \phi}{S}$$

FOS > 1.2 the slope is stable,

< 1 the slope is actively unstable,

=1 - 1.2 the slope is conditionally stable.

RECOMMENDATIONS

It is necessary that the dip amount and dip direction of prominent faults be determined. Such information will help in better planning of mine workings.

In addition to this, geo-technical mapping be carried out periodically to ascertain the new exposures and the impact of structural features on slope stability. To avoid sliding along the fault plane, the benches may be laid in such a way that they don't strike parallel to the strike of fault.

The water, especially the water pressure inside the slope significantly reduces the available shear strength and plays a critical role in determining the stability of slopes. Effective drainage measures are thus necessary to avoid or minimize water-induced instabilities.

External loading on the top of slope in the form of overburden dumps be avoided, as such situations adversely affects the stress equilibrium inside the slope. The overburden dumps should be preferable placed in the decoaled areas or away from the mine boundary.

CONCLUSIONS & RECOMMENDATIONS

Reasons for Instability

- ✓**Dead load in the form of overburden dump**
- ✓**Steeper overall slope angle in soil formation**
- ✓**Presence of developed workings with yielding of pillars/parting**
- ✓**Unfavourable orientation and proximity of faults with vis-a-vis the mine workings**
- ✓**Ingress of rain water, built up of water pressure & reduction of shear strength**
- ✓**Change in strata within the failure zone**

Suggestions

- ✓**Appropriate slope angle & benching in soil ad rock strata**
- ✓**Systematic monitoring of tension cracks & slope movement**
- ✓**Effective drainage measures**
- ✓**External loading on the slope be avoided**

Control Measures

- Flattening the slope
- Benching the slope
- Drainage pipes and trenches
- Sealing cracks to reduce infiltration
- Rock or earth buttresses
- Retaining walls
- Revegetation