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TOPICS

A. Physical and mechanical properties of rocks and structural characteristics of the massif.
B. Investigation of the stress condition and strain state of the rock mass.
C. Geomechanical provision of mining and civil engineering.
D. Mine surveying geodetic and geophysical methods used in geomechanics
E. Geomechanical state of explosive and seismic impacts.
F. Environment protection in mining and construction activities.
G. Education and qualification.

IMPACT OF SOME PHYSICAL - MECHANICAL AND STRUCTURAL CHARACTERISTICS OF SLOPE STABILITY

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ABSTRACT
This paper give description of some influential parameters of slope stability.
In mining works, we every time need to have caution on safety of mining slopes, intentionally to have safety on work and don't have interruption of works process in excavation of minerals. Also during construction of motorways or roads, in cases when if necessary to open the track through of any hill or to her side, when need to work side slopes of roads, living the safety benches with certain dimensions, is very responsible to do the analyses of the environment through which the track of road passes.

INTRODUCTION

The slope sustainability is an important engineering issue due to the economic impact on mining and construction companies. Slides can be extremely costly and can have tragic consequences on people and machinery. The slopes with big angel are conductive to the economy of mining with surface exploitation, and the slopes with small angle favor sustainability.
The compromise between these two directions almost always results in some sliding of slopes in large surface exploitation mines. In construction works which are slopes during the excavation of roads the slide of slopes can't be tolerated due to the danger of public safety.
The main purpose of the sustainability analysis is to verify the stability of the slope in order to gain the necessary safety and functionality both of the projected and natural slopes in the rock masses. Given the specific discontinuous character of the rock masses, the manifestations of instability can be manifested in different forms.

Slopes can be classified on many ways, e.g. Soils slopes or Rocks slopes. Although the description of the fundamental characteristics of these two divisions such as physical laws is the same, the methods of their analysis are generally different. Of course, broken rocky slopes are categorized on the soil slopes, so it can't always be a clear distinction between these two categories and should be considered for choosing the most appropriate method of analysis. Slopes can also be classified according to the expected manner of slide, for example, displacement or rotation. Slide rocky slopes with great stamina often at the beginning are rigid bodies with a tendency for translational movements (parallel with slope), while slopes composed of soils with little resistance often begin to slide as a rigid body that tend to torque. Continuous slides result mainly in the breakdown of the sliding massif in any case.

The slide may arise as a result of natural changes in the geological environment of the slope (change of underground water regime, erosion, earthquake action), or as e result of human activity. When the soil massif of the slope can't provide the balance of forces acting on it, the sliding occurs. The area of massif which is included by the sliding is called the sliding body. When sliding of the slope appears, it is clear that it is a lack or weakness of the shear stability on the slippery surface in order to maintain the sliding body equilibrium.

Appears of instability on slopes of roads, surface mines, deposits and another geotechnical objects is common, although they are designed with allowed safety factor. The response to these phenomena should be sought in the analysis of parameters and many natural and technical factors influencing the safety factor that by accurate analysis of these parameters and factors we come to the choice of the appropriate safety factor.

1.0 IMPACT OF THE PHYSICAL - MECHANICAL CARACTERISTICS IN THE SLOPE STABILITY

In terms of physical and mechanical characteristics of the rocky massif or soil, have a great impact on the stability of slopes.

Their impact lies in it because they determine the stability of the material to slippage, which affect the reduction of the safety factor or the contrary in the increase of the safety factor.

1.1 GEOLOGICAL DISCONTINUITIES

The stability of rock slopes is significantly influenced by the structural discontinuity in the rock in which the slope is excavated. A discontinuity is a plane or surface that marks a change in physical or chemical characteristics in a soil or rock mass. A discontinuity can be in the form of a bedding plane, schistosity, foliation, joint, cleavage, fracture, fissure, crack, or fault plane.

This discontinuity controls the type of failure which may occur in a rock slope. The properties of discontinuities such as orientation, persistence, roughness and infilling are play important role in the stability of jointed rock slope.

Discontinuities may occur multiple times with broadly the same mechanical characteristics in a discontinuity set, or may be a single discontinuity. It makes a soil or rock mass anisotropic. The orientation of a major geological discontinuity relative to an engineering structure also controls the possibility of unstable conditions. The mutual orientation of discontinuities determines the shape of the individual blocks. Orientation of a discontinuity can be defined by its dip (maximum inclination to the horizontal) and dip direction (direction of the horizontal trace of the line of dip, measured clockwise from north). The strike is at right angles to the dip direction, and the relationship between the strike and the dip direction is illustrated in Figure 1. Figure 2a explain the possibility if plane failure at lower value of dip angle with respect of slope angle however, as the dip angle of discontinuity increase and become sub parallel to the slope angle the slope become relatively stable (figure 1b). However further increase in dip angle in discontinuity make is liable to undergo toppling failure (figure 1c).

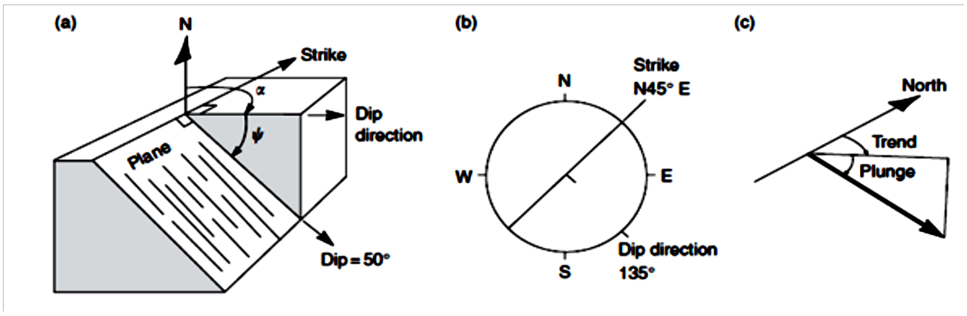


Figure 1: Terminology defining discontinuity orientation (a) isometric view of plane (dip and dip direction, (b) plan view of plane (c) isometric view of line (plunge and trend).

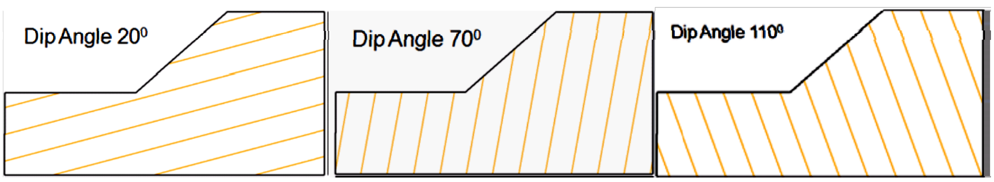


Figure 2. Dip angle of material

Figure (2a-c) illustrates the effect of discontinuity orientation on the types of slope failure A Jointed rock exhibits a higher permeability and, reduced shear strength along the planes of discontinuity apart from increased deformability and negligible tensile strength in directions normal to those planes. The degree of fracturing of a rock mass is controlled by the number of joint in a given direction. A rock mass containing more joints is also considered as more fractured.

The spacing of adjacent joints largely controls the size of individual blocks controlling the mode of failure. A close spacing of joints gives low cohesion of rock mass and responsible for circular or even flow failure. It also influences the rock mass permeability. Persistence of discontinuities defines, together with spacing, the size of blocks that can slide from the face (figure 3). Furthermore, a small area of intact rock between low persistence discontinuities can have a positive influence on stability because the strength of the rock will often be much higher than the shear stress acting in the slope.

Roughness of joint surface is a measure of the inherent unevenness and waviness of the surface of discontinuity relative to its mean plane. The friction angle of a rough surface comprises two components the friction of the rock material (φ), and interlocking produced by the irregularities of the surface (i).

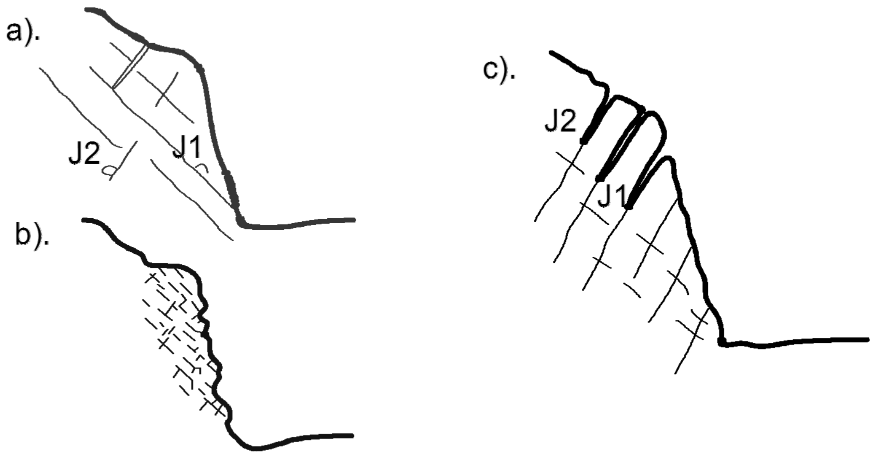


Figure 3: Effects of persistence on slope stability

1.2 EFFECT OF WATER

The effect of water on the slope can be considered into two fold. One is ground water or aquifer below the surface that generates pore water pressure and the other is rainwater infiltration that seeps through surface and flows along the slope generating water pressure. It is related to the surrounding precipitation levels, topography, nearby water masses, and the geo-hydrological characteristics of the rock mass (Sjöberg, 1999).

In medium to hard rock, water occupying the fractures within the rock mass can significantly reduce the stability of a rock slope. Water pressure acting within a discontinuity reduces the effective normal stress acting on the plane, thus reducing the shear strength along that plane. If a load is applied at the top of a slope, the pore pressure increases. Such a load can lead to immediate failure of the slope if it exceeds its shear strength of slope. Water filling in discontinuities can result in lowering of stability condition for natural or artificial slopes. Figure 4 shows a rock blocking resting on an inclined plane and separated from the upper part of the slope by a sub vertical discontinuity plane. The water applies horizontal and vertical pressure along the discontinuities. The uplift force U is also developed due to water at the surface between the block and its base.

The water pressure increases linearly with depth down to the intersection of the sub vertical plane with the base and linearly decreases from the intersection point to the lower edge of the block in contact with the surface where the water pressure is zero (Gaine, 1992).

Addition of water from rainfall and snow melt adds weight to the slope. In addition to it ground water also exists nearly everywhere beneath the earth surface. Such water fills the pore spaces between the grains or fractures in the rock.

Such water can seep into discontinuity present in the rock mass replacing the air in the pore space thus increasing the weight of the soil. It leads to increase in effective stress resulting into failure of the slope. Figure 5 depicts the effect of water content in the rock mass on factor of safety of the slope found on the different slope angles. It depicts for an increase in slope angle from 60^{o} to 80^{o}, the factor of safety of the slope under dry rock mass conditions reduces from value of 2 about 1. Whereas, under the saturated rock mass conditions increase in the slope angle makes it unstable when value exceed 70°.

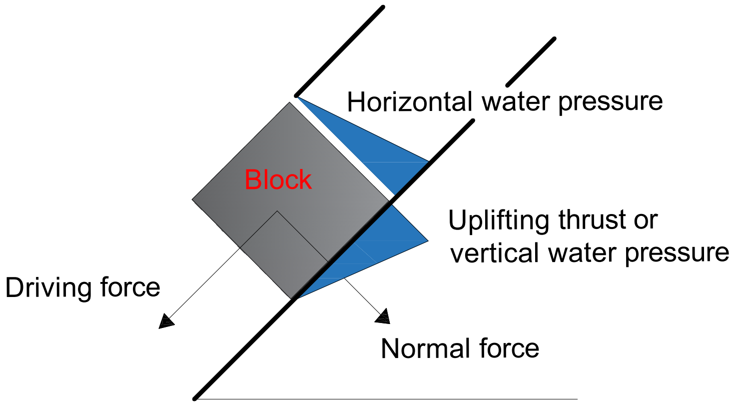


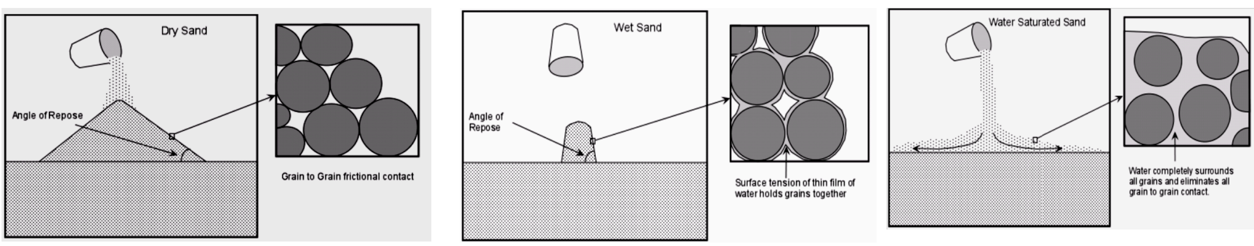
Figure 4: Diagram of water pressure acting on a block

In soil and mine waste dump in surface mines, if the unconsolidated material is dry or non-saturated, an increase in load compress the air in the pore spaces thus compacting the mass and bringing grains or rock fragments closer together which increase its shear strength. However, when a rock mass is saturated, an increase in external pressure leads to an increase in the pore pressure, as water is relatively incompressible.

This increase in pore pressure has a buoying effect, and can be enough to support the weight of the overlying rock mass, thereby reducing friction and the shear strength.

Unconsolidated sediments behave in different ways depending on whether they are dry or wet (Terzaghi, 1943). Dry Unconsolidated grain from a pile with a slope angle control by the angle of repose (figure 5a) which generally varies between 30-37°. In contrast to this, a slightly wet unconsolidated material exhibits a very high angle of repose because surface tension between water and the grains tends to hold the grains in their places (figure 5b).

This is due to capillary attraction resulting into surface tension which holds the wet material together as a cohesive mass. However, when the material is saturated with water the angle of repose reduces substantially (figure 5c). This is because the water gets in between the grains eliminating grain to grain frictional contacts.



a. b. c.

Figure 5: Effect of water content in unconsolidated grain of piles.

1.3 GEOTECHNICAL PROPERTIES OF MATERIAL

The important geotechnical properties affecting stability of a slope are shear strength of material, particle size distribution, density, permeability, moisture content, plasticity and angle of repose. The strength of rock mass is a very important factor that affects the stability of slopes. It is a function of strain rate, drainage condition during shear, effective stresses acting on the soil prior to shear, the stress history of the soil, stress path, and any changes in water content and density that may occur over time. It consists of cohesion and friction angle of material.

Friction is a resisting force between two surfaces. Cohesion results from a bonding between the surfaces of particles. It is dependent upon many factors, including material properties, magnitude and direction of the applied force and the rate of application, drainage conditions in the mass, and the magnitude of the confining pressure.

The relationship between the peak shear strength τ and the normal stress σ can be represented by the Mohr-Coulomb equation (figure 7):

$\tau = c + \sigma tan\phi$

where c is the cohesive strength and ϕ is the angle of friction.

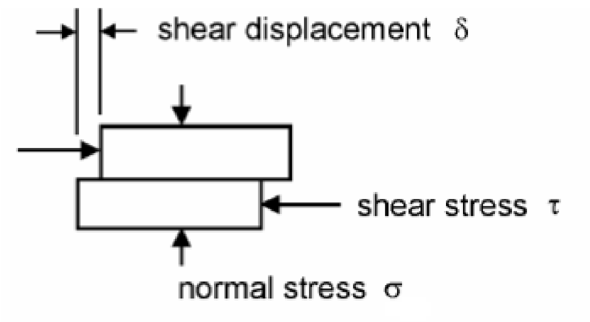


Figure 6: Shear testing of discontinuities or between two plane

The shear strength of Patton's saw-tooth specimens (figure 8) can be represented by:

$\tau = \sigma \tan(\phi + i)$, Where ϕ is the basic friction angle of the surface and i is the angle of the saw-tooth face.

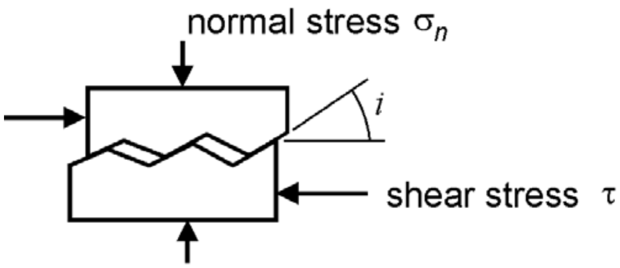


Figure 7: Patton's experiment on the shear strength of saw-tooth specimens.

Materials that are coarse or have a rough texture have greater opposing frictional forces or shear strength to resist the movement. However, unconsolidated materials such as sediment and soil that have no strong cementing material or interlocking crystal structure is far less stable than hard rock. Rate of loading, degree of compaction and moisture content of the rock mass also affect its slope stability.

Density is also important factor in slope stability. However, its effect is more in mine waste dumps where it is a function of the manner of deposition, gradation, and loading history. A relatively small increase in density can increase the shear strength of waste dump, but it also increases the stresses due to gravity loading.

Permeability of the soil or waste material affects seepage pattern and water levels in the slope. This, in turn, can affects shear resistance of the material depending on the size and shapes of the particles, degree of compaction and the gradation of soil and its density (Campbell, 1975 and Aubeny and Lytton, 2004).

Angle of repose of loose material is influenced by the size and shape of its particles. Smooth, rounded particles have a lower angle of repose than rough, angular particles. Coarse fragments can maintain a greater slope than fine fragments.

2.0 SLOPES STABILITY

The main factor for to destroying slopes stability is change of geometrical forms, partial or local excavation forming e new slope. When changed the slopes form, also changed the state of tensions and in different rocks zones having new deformations. When new tensions appear then causing the critical deformations, they coming how result of changed and deformation of slope geometrical form, complete or in some their partial. The change in the physical and mechanical properties of rock masses is often the cause of the slope instability. Change in depth due to freezing and melting etc., creates new conditions in the state of massive rock masses and leads to slope instability.

The long-term process of changing the state of tensions and the state of deformation under equal conditions in which the mass of the rock can be found can lead to slope instability. There are overloading and deformations in some parts of the mass of rocks that reduce the stability of the slope as a whole.

The tension release process near the newly created slope creates a new disruption and a weakening of the mass of the rock. The stability condition of each slope is to have a balance between the external acting forces and the internal resistance of the slope stability.

2.1 CONDITIONS FOR STABILITY OF SLOPES

Solution to the stability of the slopes of soils or rocky environments, based on known forces and deformation sites, determines the gradient of slope change and provides an estimate of its degree of stability.

This means that the state of tension and deformation caused by the change in the state of tension. This in turn requires that, apart from formulating the equilibrium equation, to formulate an equation between tensions and deformation relationships (behavior of the material under load).

The reaction of rock under pressure can be described briefly below:

- Loads and discharges to the rocks apply equally, these equations consist of tensions between tension and tensions and should also be formulated in relation to increasing tension and deformation,
- With the appearance of the sloping ground on the rock masses, the connection between tension and deformation as a whole, should depend on the time,
- The ratio of tension and deformation is not linear, nor for small deformations and large distortions there is an area where they grow despite the tension drop,
- The relationship between tension and deformation for rock masses must cover the properties of heterogeneity, anisotropy and non-interpretation,
- Existence of natural tensions, which cannot easily be measured, makes it difficult to determine the appropriate state of the tension in the rock mass.

From the above, we can conclude that the tension and deformation connection, which includes all the aforementioned phenomena, is not enough to be practically used. Therefore, approximate methods are used which are based on the simplification of some of the applied rock mechanics laws.

2.1.1 Basic Equilibrium Conditions

The slope stability in the rocks is determined by slippage resistance and pressure. For incoherent rocks, resistance to cutting depends only on friction ($\varphi \neq 0$, $c=0$). Resistance of cracked rocks is characterized by an unknown angle of internal friction and unknown cohesion ($\varphi \neq 0$, $c \neq 0$). While the resistance of strong rocks that has a high cohesion depends largely on the power of cohesion.

Below are the equilibrium conditions for non-coherent rocks and coherent rocks.

- **Non – coherent rocks**

We take the slope surface AB (Figure.8.), which is built from incoherent rocks, in this lies a solid particle. The weight of this is "W", angle of slope is "i" and the internal friction angle is "φ".

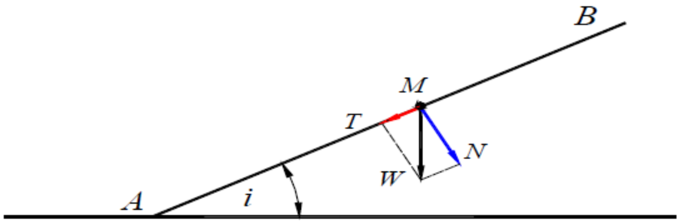


Figure 8. Condition for the balance of a solid particle

Normal component "N" and tangential component "T" of pressure, by weight "W" is:
$N = W \cos i$
$T = W \sin i$
The force "T" tends to move the particle along the slope. But in this counteracts the friction force:
$T' = f N$
This affects in parallel with the slope surface AB.
The equilibrium condition will be achieved if:
$T = T'$
Where T' is equal to the product of friction coefficient and normal pressure:
$T' = f N$
For equilibrium is necessary: $W \sin i - f W \cos i = 0$
Where is: $tgi = f,\ tg\varphi = f$
Then is: $i = \varphi$

From here it is seen that border of the slopes gradient angle on the non – coherent rocks is equal to the internal friction angle. If the internal friction angle on the non-coherent rock is equal to the natural angle then the slope gradient angle in the non-coherent rocks equals the gradient of the slope and does not depend on the slope height.

- **Coherent rocks**

Similarly, in the previous case, with N we show normal strength and with T tangential component of the pressure vector W on point M.

The tangential trend that operates at the given point will be equal to T = Ntgi, and resistance to slipping: $S = N\, tg\varphi + c$
The state of the border equilibrium will be T = S or $N\, tg\, i = N\, tg\varphi + c$
This is the condition for the border equilibrium of slope for rocks, depend on internal friction angle dhe on cohesion.

2.3 TYPES OF ROCK SLOPE FAILURE

Slope failures are major natural hazards that occur in many areas throughout the world. Slopes expose two or more free surfaces because of geometry. Plane, wedge, toppling, rockfall and rotational (circular/non-circular) types of failure are common in slopes (Figure 9). The first four are more predominant in rock slopes and are primarily controlled by the orientation and the spacing of discontinuities planes with respect to the slope face. The pattern of the discontinuities may be comprised of a single discontinuity, or a pair of discontinuities that intersect each other, or a combination of multiple discontinuities that are linked together to form a failure mode. Circular and non circular failure occurs in soil, mine dump, heavily jointed or fractured rock mass and very weak rock. The types of slope failure are primarily controlled by material properties, water content and foundation strength.

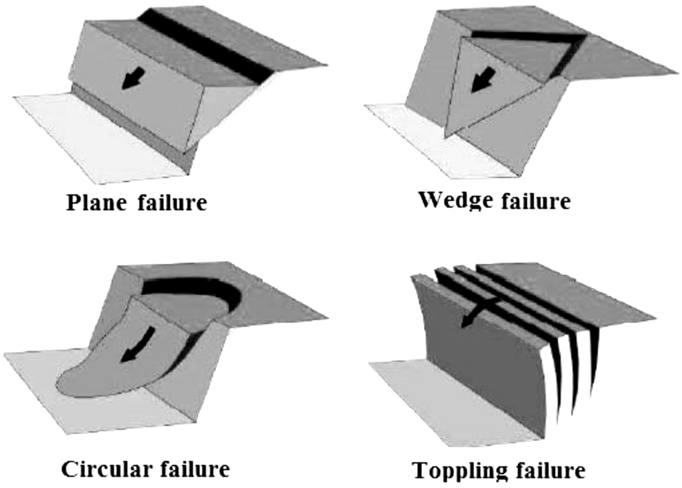


Fig.9. Type of slope failure

2.4 FACTORS AFFECTING SLOPE FAILURE

Slope failure occurs when the downward movements of material due to gravity and shear stresses exceeds the shear strength. Therefore, factors that tend to increase the shear stresses or decrease the shear strength increase the chances of failure of a slope.

Different processes can lead to reduction in the shear strengths of rock mass. Increased pore pressure, cracking, swelling, decomposition of clayey rock fills, creep under sustained loads, leaching, strain softening, weathering and cyclic loading are common factors that decrease the shear strength of rock mass. In contract to this the shear stress in rock mass may increase due to additional loads at the top of the slope and increase in water pressure in cracks at the top of the slope, increase in soil weight 3 due to increased water content, excavation at the bottom of the slope and seismic effects.

In addition to these reasons factor contributing in failure of slope are properties of rock mass, (slope geometry), state of stress, temperature and erosion. The factors affecting in slope failure have been shown in Table 1. and important factors have been described in this chapter.

Tab.1. The factors affecting in slope failure

Sr. No	Name of the parameters and properties	Details
1	Geological Discontinuities	Fault, Joint, bedding plane,
2	Water	Ground water, drainage pattern, rainfall, permeability, aquifer
3	Strength	Shear strength, compressive strength, tensile strength
4	Geotechnical parameters	Gran size, moisture content, Waterberg limit, etc.
5	Method of construction	Shovel, dumper, BWE or combination
6	Dynamic forces	Blasting, Seismic activity
7	Geometry of slope	Height and angle of slope, bench height and angle,

CONCLUSION

When we calculating the stability of the slope by some methods, we need to know the physical and mechanical characteristics of the slope forming material, which are determined by laboratory analysis.

During the work on mineral exploitation or in the opening of roads, it is imperative to have safety at work and not be jeopardized by the possible contusion of any part of the slope or the whole slope, also if we are dealing with the opening of roads, then it is imperative that we have secure slopes and not have the opportunity of defeat, because if it comes to the contusion, then the traffic participants will be jeopardized, where this would end with fatality. To make the construction of these slopes with the utmost security, it is necessary:

1. Determine in a fair and accurate manner the physical and mechanical properties of the material from which the slope is composed. So, be determined more accurately: the angle of internal friction "φ", the cohesion "c" and the volume weight "γ".
2. Forces which tend to disturb stability must to be smaller than the forces which maintain the stability (resistance forces).
3. The angle of benches must to be smaller and the width of benches must to be the greater, where on this occasion the general angle of the slope will be reduced, which will influence the increase of the security factor. Increased the width of benches it also increases the security of the risk of breaking the pieces from the stairs above and their fall down, whereby these pieces will be stopped in the security zone and will be prevented from falling below them.
4. The height of the bench must to be lower, on this occasion will increase the number of benches and security squares, it will also affect the reduction of the general angle of the slope and the increase of the security factor.
5. Must to taking away the atmospheric waters and dry the slope, because by doing these actions, we will influence the increase of the resistance forces and also the increase of the security factor.

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