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Theoretical Approach on Open pit Dump Slope Stability

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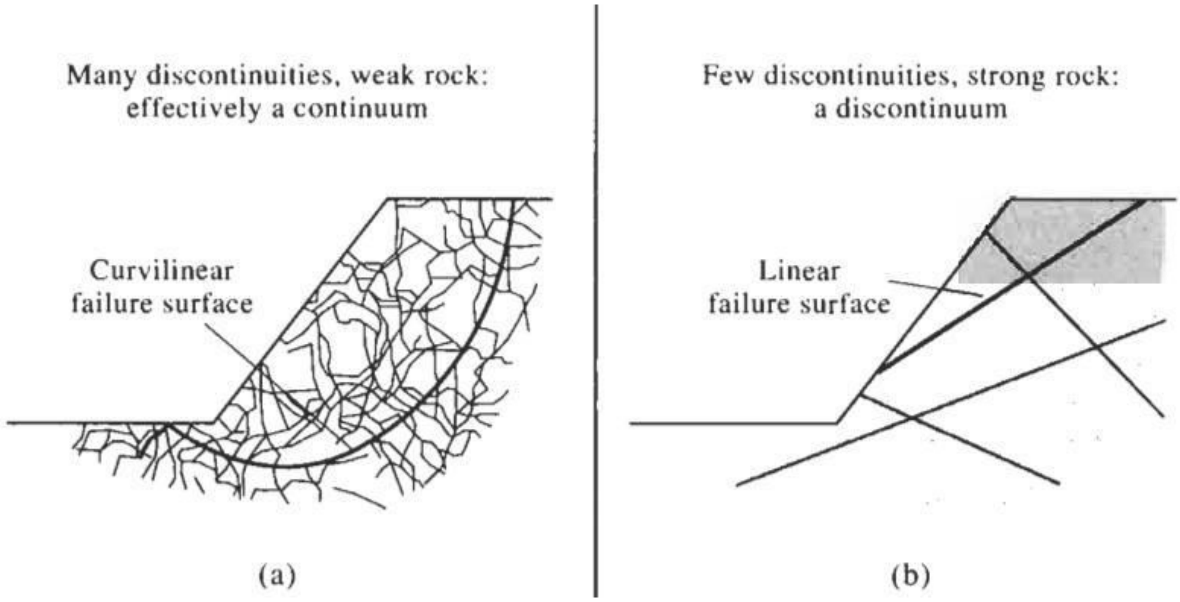
ABSTRACT :
Stability of slopes is an important engineering topic because of economic impact on mining and civil enterprises. Failures may be costly in the extreme and have tragic personal consequences .
Steep slopes are favorable to the economics of surface mines, while low slope angles favor stability. The trade-off between these two trends almost always results in some slope failures in large, open pit mines. In civil works such as highway cuts, slope failures cannot be tolerated because of the threat to public safety.
An opencast mine in which we have stabilized benches we can produce profitable production with avoiding disasters which may happened due to slope failure.
Hence, the study of slope stability of benches is required.This paper present a case study of dump slope stability of Makardhokra – II open cast mine of western coalfieldlimited. This mine spread over the area of 289.0 hectares. Dump slope instability is the prime concern ofproposed mine site. Depth of Black Cotton Soil is extended up to a depth of 20m from the natural ground level.To assess the stability of the OBD slope, samples of dump material were collected from benches of OBD slope.Geotechnical parameters of dump material were evaluated mainly for black cotton soil and white soil. From thegeotechnical and geometrical parameters, numerical models were created in software GEO5 for stabilityanalysis and calculation of FoS. GEO5 worked on the Limit Equilibrium Method. The optimal and economicalsolution for dump slope management and for safety analysis, Geo5 software is used by considering threemethods namely Bishop Method, Fellenius method and Spencer method. To check the suitability ofimprovement the stability of the OBD slope, cantilever wall of 2.75m and 3.0m with variation of backfillingfrom the inner face of the wall at distance of 0, 0.5m, 1m and 1.5m were evaluated through LEM. Feasibility ofgabion wall for improvement of the stability of OBD was also checked. FoS was calculated by varying the slopeangle of dump and replacement of black cotton soil with white soil. It is seen that as the angle of the slopeincreases then FoS decreases. Provision of gabbion wall and replacing black cotton soil of dump with white soilindicate the improved value of Fos. Because of restriction of land, feasibility of construction of retaining wallprovision is discarded. Provision of cantilever wall and gabion wall increase the FoS of OBD slope. From costanalysis, cost of provision of cantilever wall is about 70% more than const of provision of gabion wall.

Gabionwall proposed to be economical, suitable, easily workable and sustainable method for stability of OBD slope ofMakardhokra – II open cast mine.

INTRODUCTION :
In the history of rock mechanics and rock engineering, more attention has been paid to slope instability considerations than any other topic, and this topic remains one of the most important today. Let us discuss about slope instability mechanism.

SLOPE INSTABILITY :
In below figure , there are two slope failure mechanisms. Figure a illustrates slope instability when the rock is behaving as an equivalent continuum; Figure b illustrates slope instability when the rock is behaving as a discontinuum. One of our first considerations must be to identify the basic mechanisms of slope instability. The sketches in Figure also highlight the CHILE versus DIANE nature of the rock.



Slope failure mechanisms in (a)a continuum and (b) a discontinuum.

This can be remembered by two acronyms: CHILE and DIANE.
1.1 CHILE :
A*Continuous, Homogeneous, Isotropic and Linearly- Elastic* **(CHILE)** material is one that is most commonly assumed for the purposes of modelling. Traditional stress analysis techniques are formulated in terms of these four attributes, simply for necessity andor convenience for obtaining closed form solutions. In the past, limited computational techniques precluded any more sophisticated analysis. Nowadays, however, especially in consulting and research organizations, there are computer codes available which will routinely deal with violation of any of these traditional assumptions. This leads directly to the second acronym.
1.2 DIANE :
A *Discontinuous, Inhomogeneous, Anisotropic, Non-Elastic* **(DIANE)**rock is the material with which the engineer has to deal." We should therefore consider the significance of the difference between the CHILE material being modelled and the DIANE rock being engineered,and the likely error arising from the direct application of a model based on a CHILE material. Alternatively, the specific attributes of the DIANE rock can be modelled.

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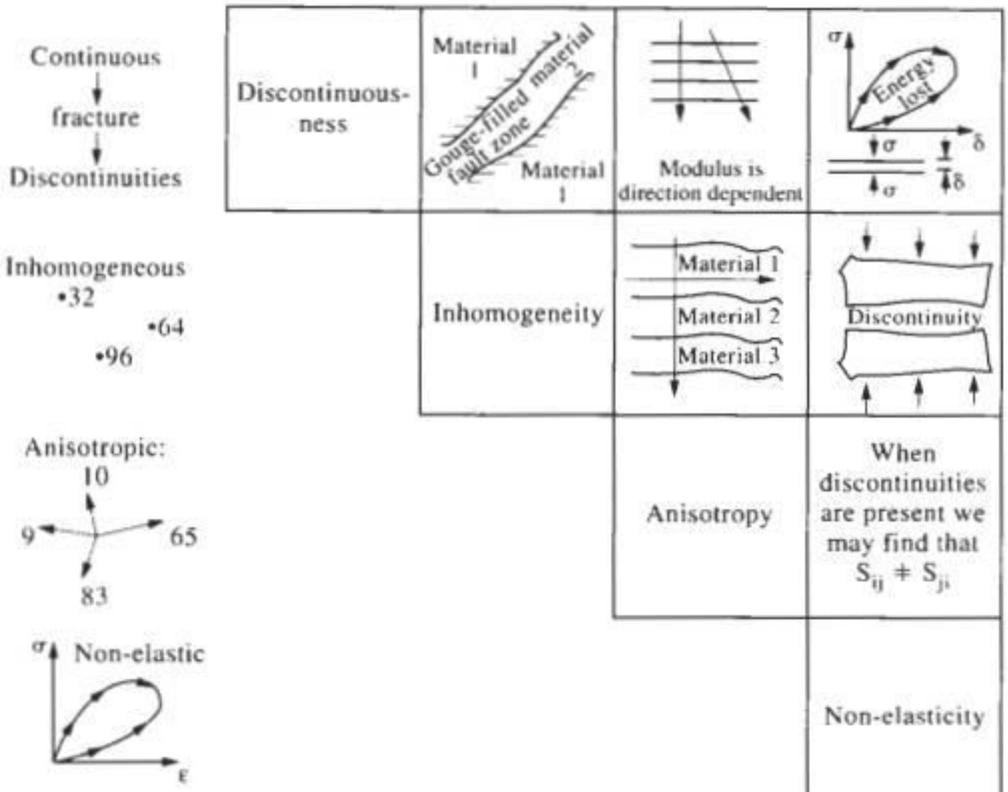
Superb examples of the latter procedure are the development of block theory and the use of distinct element techniques in numerical analysis.we can also give simple definations to all the terms in above two acronyms as below :
CHILE : Continuous, Homogeneous, Isotropic, Linearly Elastic(a model material)
DIANE : Discontinuous, Inhomogeneous, Anisotropic, and Not Elastic(rock in reality)
Continuous : is mechanically continuous; there can be variations in the mechanical property values but there are no mechanical breaks.

Discontinuous : does contain mechanical breaks having effectively zero tensile strength.
Homogeneous : has the same property values at all locations.
Inhomogeneous (or heterogeneous) : has different property values at different locations.
Anisotropic has different property values in different directions. Linearly Elastic the stress-strain curve is a line with a constant slope, all strains are instantaneous, and all energy can be recovered. Isotropic has the same property values in different directions.



Connections between the attributes discontinuousness, inhomogeneity, anisotropy and non-elasticity.

2. SLOPE STABILITY ANALYSIS

Slopes may be classified in a number of ways, for example, as rock slopes or soil slopes. While description of the two share fundamental features such as physical laws, methods of analysis are generally different. Of course, weathered rock slopes grade into soil slopes, so there may not always be a clear distinction between the two and some consideration must be given to the most appropriate analysis method. Slopes may also be classified according to an expected mode of failure, say, by translation or rotation. High strength rock slope failures initially are often rigid-body like translational motions, while low strength soil slopes often

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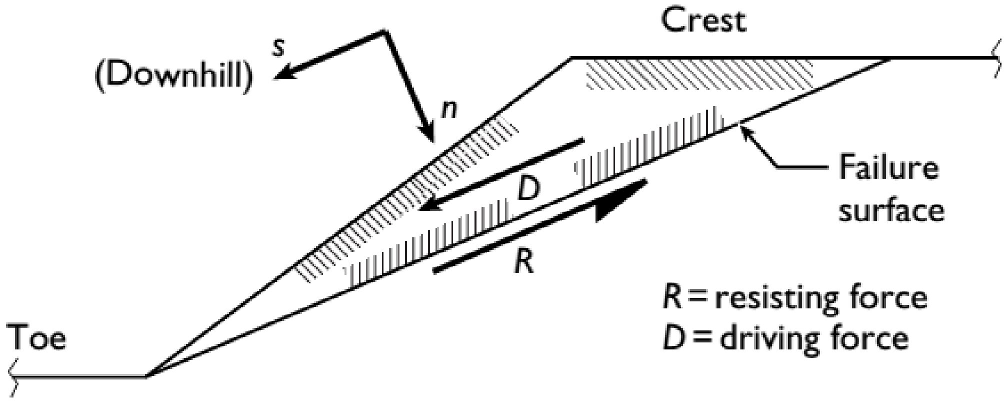
begin to fail in rigid-body like rotations. Continued failure generally results in disintegration of the slide mass in any case.
A primary objective of slope stability analysis is estimation of a factor of safety for the considered slope and slide mass. An intuitive formulation of a safety factor appropriate to translational sliding is the ratio of resisting to driving forces acting parallel to the direction of translation as shown in Figure Thus, for translational slides

2.1 FACTOR OF SAFETY :

FACTOR OF SAFETY =(resisting force)/(driving force) :
In this regard, a sign convention is needed that determines whether a force is driving or resisting. The convention is simple: forces that act downhill in the direction of the potential slide are driving forces; uphill forces are resisting. Forces directed uphill should not be subtracted from downhill driving forces, nor should downhill forces reduce resisting forces. Otherwise a different value of safety factor results. Normal forces acting into the slope are also positive.



Resisting and driving forces during translational slope failure.

The reason for this uphill–downhill force convention and safety factor definition is associated with slide mass motion or acceleration. Motion impends if the resultant of external forces is greater than zero. In this case, according to Newton's second law of motion, $F = \dot{P} = ma;$
where F, dP/dt, m, and a are resultant of external forces, time rate of change of linear momentum, slide mass, and acceleration of the slide mass center, respectively. The resultant of external forces may be decomposed into downhill and uphill forces based on the sign convention adopted in the safety factor formula, that is, $F = D-R$. With this decomposition and the expression for safety factor, one has for acceleration $D(1 - \mathrm{FS}) = ma;$
Clearly, a safety factor less than one indicates a positive, downhill acceleration. A safety factor greater than one indicates a negative acceleration that for a slide mass at rest is physically meaningless; the slide mass would remain at rest. If the slide mass were moving downhill, then a negative acceleration would indicate a reduction in velocity. Conceivably, a slide mass could be moving uphill after gaining momentum from a previous downhill motion. However, the factor of safety concept is not intended for *slide dynamics*; such questions are better addressed directly through Newton's second law.
The factor of safety defined here is a *global* factor of safety in contrast to a *local* factor of safety (FS) that is defined as the ratio of strength to stress at a point. A local factor of safety less than one indicates the elastic limit may be exceeded, yielding, and failure ensue, at the

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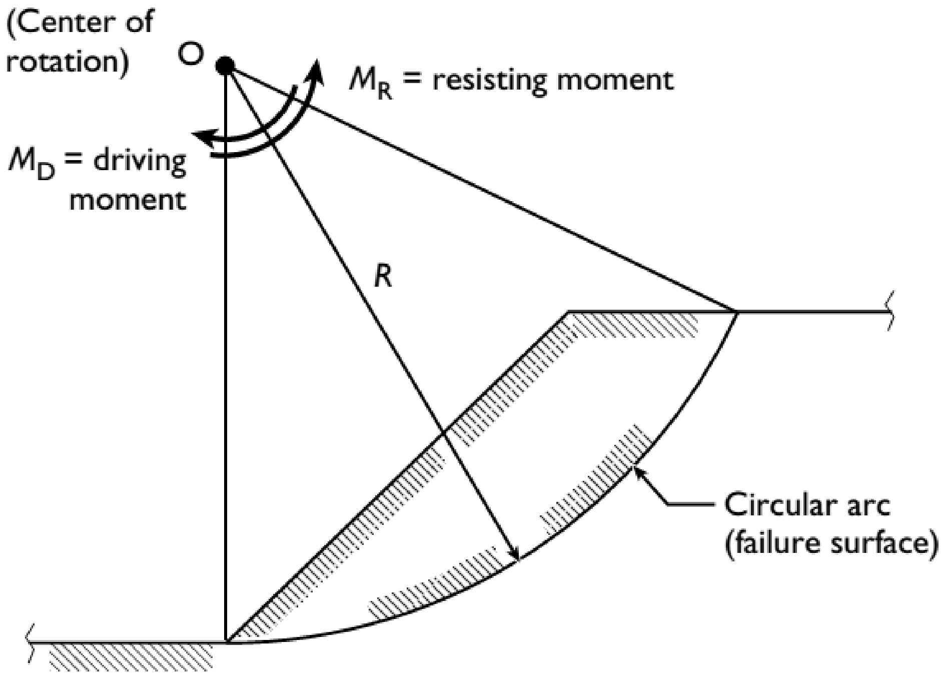
considered *point*. A global safety factor less than one implies yielding and failure over an extended failure surface and is indicative of *collapse*.



Resisting and driving moments during conventional rotational slope failure.
In the case of rotational sliding, as shown in above figure
FACTOR OF SAFETY =(Mr)/(Md);
Md(1-FS)=M;

where *M*, *M*r, *M*d are resultant of external moments, time rate of change of angular momentum, resisting moment total, and driving moment total, respectively. A partition of external moments into driving and resisting moments that depends on direction of action is made in the equation of motion. Resisting moments are then eliminated from the equation of motion using the safety factor definition. Again, a safety factor less than one indicates potential angular acceleration of the slide mass from rest, while a safety factor greater than one indicates stability.
There are always two choices for improving a factor of safety
(1) increase resistance or
(2) decrease driving forces or moments.
Slope stability problem is greatest problem faced by the open pit mining industry. The scale of slope stability problem is divided in to
two types :

2.2 Gross stability problem:

It refer to large volumes of materials which come down the slopes due to large rotational type of shear failure and it involves deeply weathered rock and soil.
2.3 Local stability problem:
This problem which refers to much smaller volume of material and
these type of failure effect one or two benches at a time due to shear plane jointing, slope erosion due to surface drainage.

Aim of slope stability

1.To understand the development and form of natural and manmade slopes and the processes responsible for different features.

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2.To assess the stability of slopes under short-term (often during construction) and long-term conditions.
3.To assess the possibility of slope failure involving natural or existing engineered slopes.
4. To analyze slope stability and to understand failure mechanisms and the influence of environmental factors.
5. To enable the redesign of failed slopes and the planning and design of preventive and remedial measures, where necessary.
6. To study the effect of seismic loadings on slopes and embarkments.

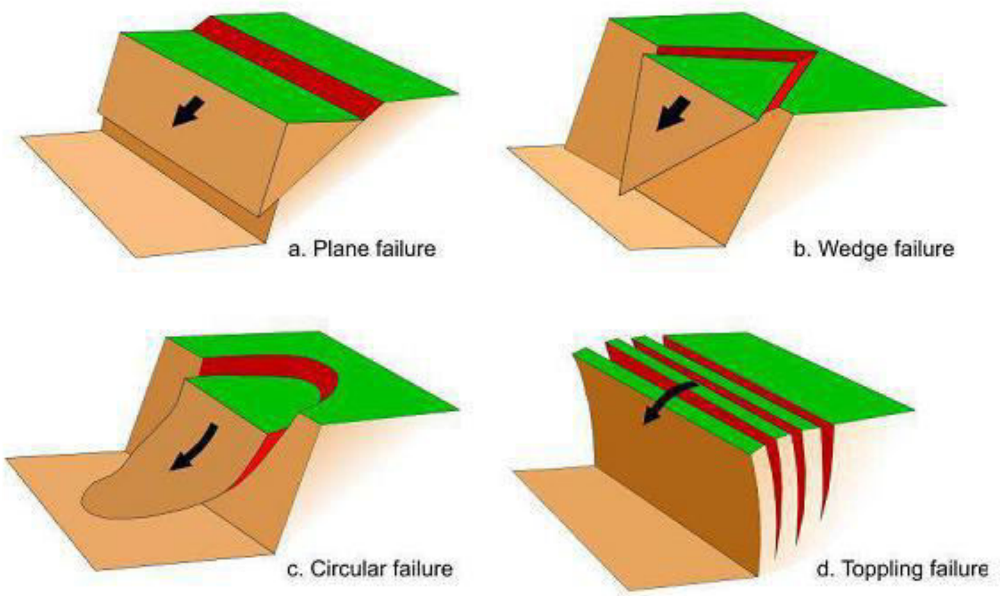
3. TYPES OF ROCK SLOPE FAILURES

3.1.1 Failure in Earth and Rock mass

1. Plane Failure
2. Wedge Failure
3. Circular Failure
4. Toppling Failure
5. Rock fall

3.1.2 Failure in Earth, rock fill and spoil dumps and Embankments :

1. Circular
2. Non-circular semi-infinite slope
3. Multiple block plane wedge
4. Log spiral (bearing capacity of foundations)
5 .Flow slides and Mud flow
6. Cracking
7. Gulling
8. Erosion
9. Slide or Slump



Types of failures

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Over burden dump

Stability Analysis

Stability of dump slope without retaining wall was analyzed using limit equilibrium method with the help of the
Geo5 software. Numerical models created to evaluate the slope stability of dump without and with retaining
wall. Variation of Factor of safety with respect to various slope angle is calculated in case of a) Natural slope
without any retaining wall and partial replacement of white soil to black cotton soil b) Cantilever Retaining wall and c) Gabion wall as retaining wall. Factor of safety has been calculated by software using three methods
namely Bishop Method, Fellenius method and Spencer method. The results and its analysis are shown below.

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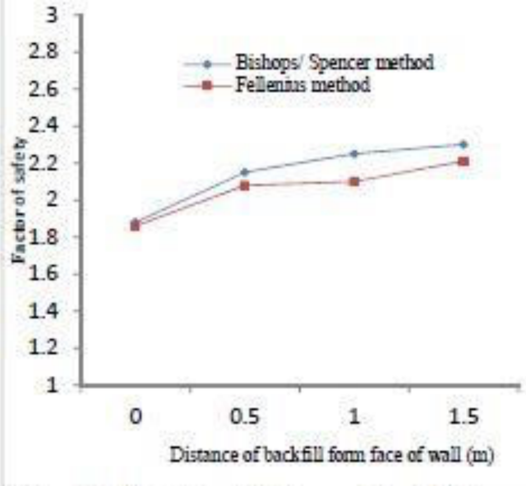
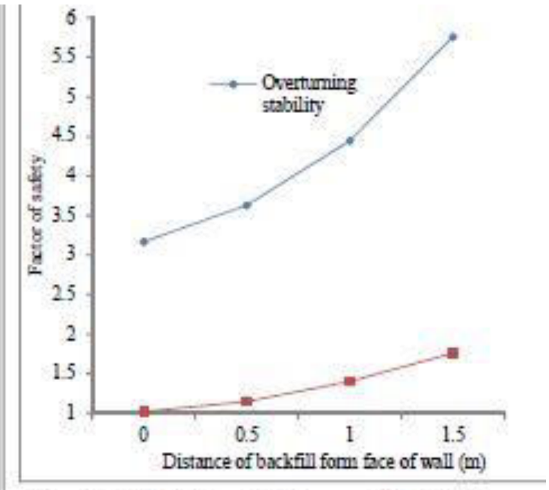
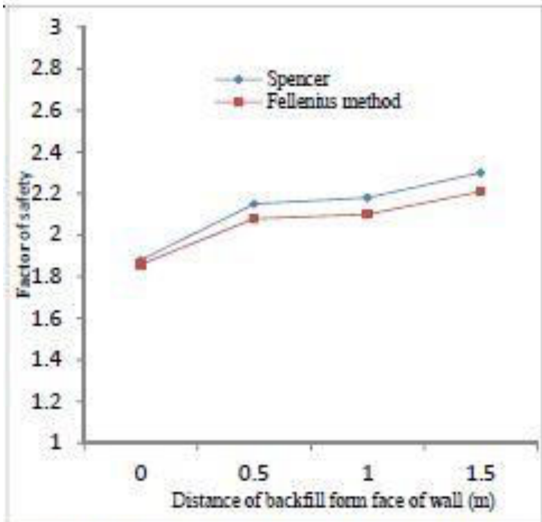


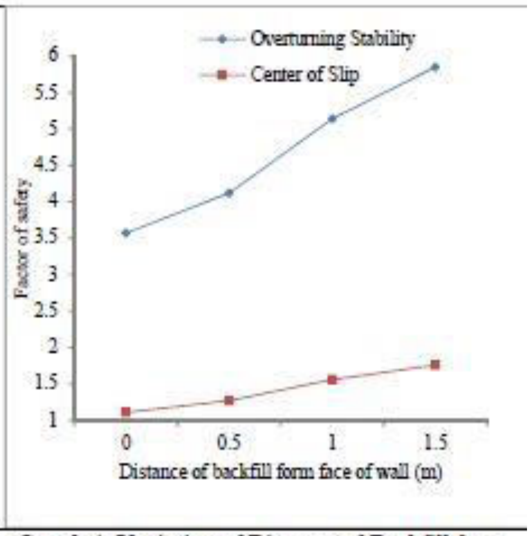
Graph 1: Variation of Distance of Backfill from Face Cantilever Wall for 3m Height with FoS



Graph 2: Variation of Distance of Backfill from Face Cantilever Wall for 3m Height with FoS for Center of Slip and Overturning Stability



Graph 3: Variation of Distance of Backfill from Face Cantilever Wall for 2.75 m Height with FoS



Graph 4: Variation of Distance of Backfill from Face Cantilever Wall for 2.75 m Height with FoS for Center of Slip and Overturning Stability

Conclusion

The following conclusions can be drawn from the work done:

1. As the flattering of slope is safe and considered to the economical solution due to filling of dump fromthe site is used in above case, but not suggested to use due to restricted space is available over the site.
2. As the construction of 2.75 m cantilever retaining wall shows fare results but the construction cost ofsuch wall comes out to be 43.05 lakhs (Calculated as per CSR 2016-17)
3. The other alternative for the stability of slope is gabion wall; the cost of Gabion wall comes out to be24.96 lakhs. (Calculated as per CSR 2016-17). This makes the gabion wall method more economical.The cost of Cantilever wall is nearly around 70% higher than the cost Gabion wall.
4. Gabion wall also has some other advantages like it can be removed and reused if needed. As the minelife is very less, it is generally advisable to use temporary construction Moreover as the mine is notpermanent; gabion wall is more advisable for temporary construction.

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Gabion wall doesn't allowdeveloping hydrostatic pressure and pore water pressure is easily dissipated in this case.

5. Construction of Gabion wall is very fast, On other side cantilever wall is very expensive, requires moreconstruction time, skilful workmanship and it is a permanent kind of structure. Whereas Gabionconstruction is very eco friendly as it allows the growth of vegetation.

6. As the existing soil available is the Umrer region is black cotton soil which is subjected to swelling inrainy season which leads to increase in earth pressure due to increase in unit weight. Also the soil issubjected to pore water pressure. The use of Gabion wall provided drainage to disperse the pressure ofwater flowing through backfill soil which also allows good natural drainage. Therefore, it is suggestedto use Gabions for the stability of dump

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