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SLOPE STABILITY ANALYSIS OF AN OPEN PIT MINE BY NUMERICAL MODELLING

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Abstract - *Stability of opencast mine slopes is significantly influenced by the presence of geological disturbances like faults, joints, unconformities and some other manmade mistakes. In this paper the analysis of slope stability for the ultimate pit slope is indicated by assuming factor of safety 1 as equilibrium. The factor of safety for the slopes of 40 degrees and above is getting less than one without consideration of the faults. However, the presence of fault decreases the safety factor below 1 for the sure. Based on the numerical model analysis, it is concluded that bench failures are likely to occur because of varying of bench parameters. Hence, it is recommended to drag the boundary of the mine to cover the fault (if present), and maintain the overall slope angle not more than forty degrees.*

Key Words: *Slope, Overall slope angle, Numerical modelling, Pit, factor of Safety*

1.INTRODUCTION

The main problem in open pit mines is Slope stability and in a large-scale open pit mining operations it is a matter of concern for the mine management to establish safety throughout the life of the mines. From geotechnical data, the rock quality is assessed, and from this the physio mechanical properties of rock mass are estimated. Using these properties stability of the slopes is evaluated from empirical, analytical and numerical techniques.

In homogenous ground conditions, the factor of safety can be determined for predefined failure modes by limit equilibrium method. Some design charts are available for plane, wedge, circular modes of failure (Hoek & Bray, 1981), and for toppling failure (Coquet & Tenon, 1985; Zana, 1983). These charts are useful to analyze only simple types of predetermined failures, but not for determining the slope angle which depends on the rock mass stability. So, there is a need to design charts and guidelines to determine slope angles for different slope heights in various rock mass conditions, which can be readily used by the practicing engineer.

The slope stability parameters in open pit mines with different mining conditions were studied. Analysis was carried out using numerical methods, and the results compared with the empirical methods. Based on these studies, design charts and guidelines are prepared for determining slope angles under different geminin conditions.

1.1 Objectives

- To understand the stability of slopes in the presence of geological discontinuities such as folds, faults, joints in opencast mine,
- To design safe slope angles for ultimate pit depth of an open pit mine

2. SLIDE V (7)

Slide software is a powerful tool for numerical modelling of slope stability analysis and it was used for finding out factor of safety and stability of different structures like opencast bench slopes, earth dams, etcetera.

3. FACTORS AFFECTING THE STABILITY OF A SLOPE

- Geometry of the slope
- Geological structure
- Lithology
- Ground water
- Time
- Dynamic Forces
- Cohesion
- Old workings
- Angle of internal friction

4. TYPES OF SLOPE FAILURE:

There are 4 types of slope failures. They are:

1. **Plane Failure:** Sliding of rock mass along single discontinuity plane is called plane failure.
2. **Wedge Failure:** Wedge failure occurs when rock mass slide along two intersecting discontinuity planes, forming a wedge-shaped block.
3. **Circular Failure:** The circular failure occurs in arc like structure. Mostly circular failure occurs in dumps.
4. **Toppling Failure:** Toppling failure occurs when number

of regularly spaced discontinuity set present in a bench. The toppling failure again classified based on mode of failure.

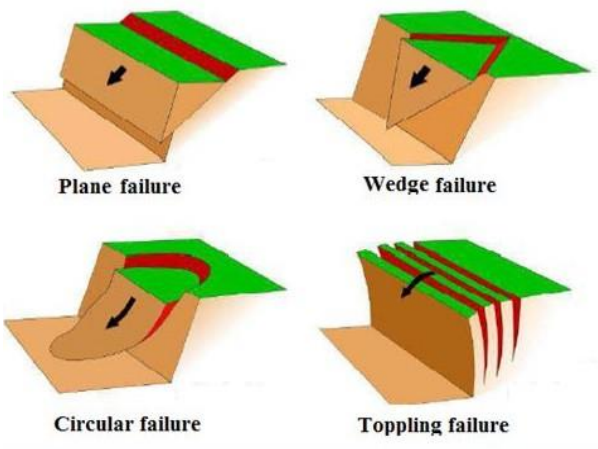

Fig- 1 Modes of slope failures

5. ANALYSIS & REVIEW

Here we are going to analyze the slopes in three different cases i.e., angle varying, height varying and varying of both angle and height of the bench.

- **Angle varying:** Here in this case, we put the height of bench constant and observing the behavior of the bench slope at varying slope angles. The observations are made at height 10m and angle of slope ranging from 30 deg to 40 deg. Due to high slope angle the bench leads to failure and the safety factor goes below 1.0. Table 1 shows the safety factor of slopes with varying bench slope angles.

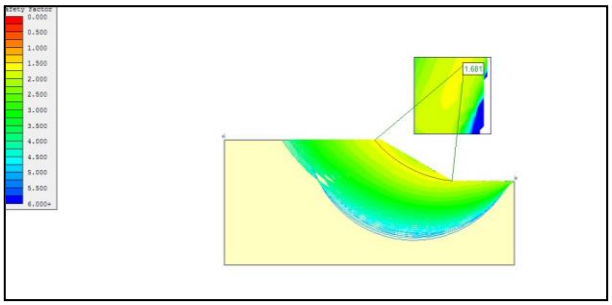

Fig- 2 Analysis result for bench slope angle 30° & bench height 10m. (initial position)

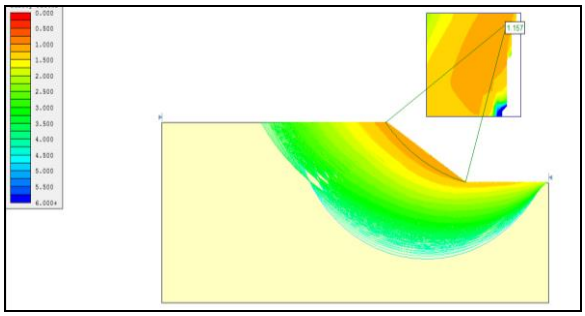

Fig- 3 Analysis result for bench height 10m. & slope angle at 35°

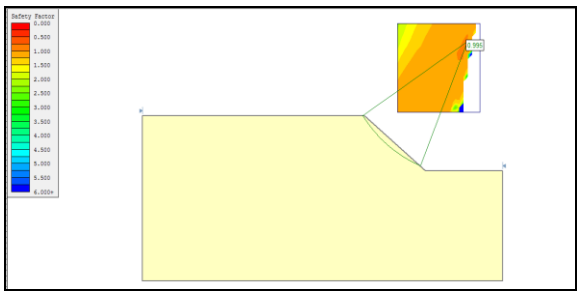

Fig- 4 Analysis result for bench height 10m & slope angle 40º

Table -1: Safety factors of slopes with varying slope angles

Slope angle	Factor of safety
30	1.681
35	1.157
40	0.995

- **Height varying:** Due to more height, the bench leads to failure or instability and the safety factor goes below 1.0. Therefore, the analysis of slope stability conducted here is, bench height ranging from 10 to 25m. Here in this case (bench height 25m) the factor of safety of bench slope observed as 1.02 which means the bench height beyond this may cause instability and sliding of slope.

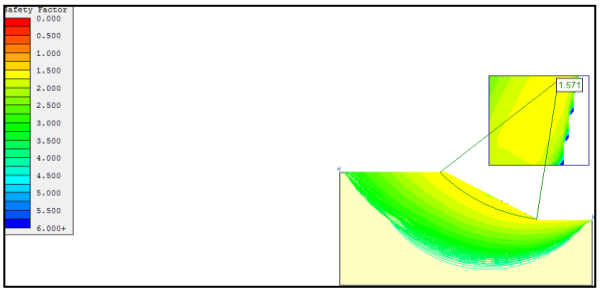

Fig- 5 Analysis result for bench at a height of 10m.

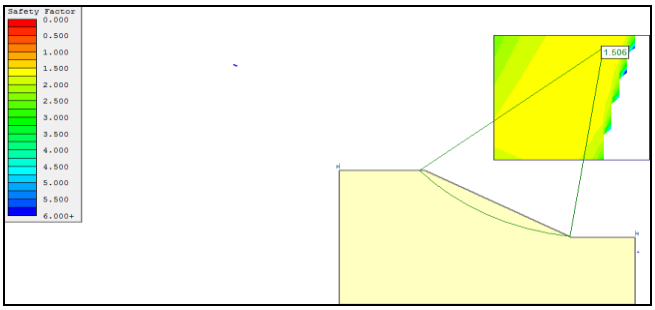

Fig- 6 Analysis result for bench at a height of 20m

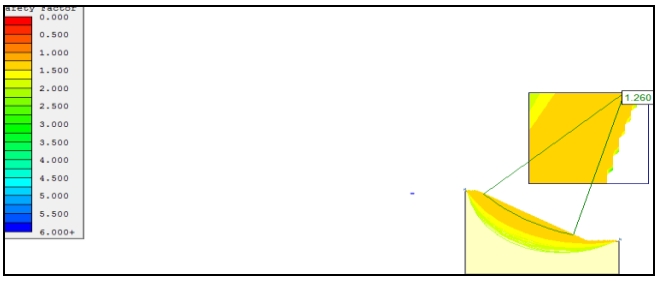

Fig- 7 Analysis result for bench at a height of 25m

Table -2 Safety factor of bench with Varying bench height

Bench height	Factor of safety
10	1.681
15	1.571
20	1.506
25	1.02

- **Height and angle varying:** If we put high slope angle and more height for opencast benches it may assist in less capital requirement but more maintenance is required and also due to the same factor of safety will be less than 1.0 and tends to failure of bench. Therefore, the analysis of slope stability is conducted here bench slope angle & bench height ranging from 30 to 40 degrees & 10 to 20m respectively. When the slope angle reached 40 deg and height 20 m. the factor of safety of the bench become less than one and tends to failure. The table 4.3 shows the factor of safety of the slopes at varying slope angle and bench height.

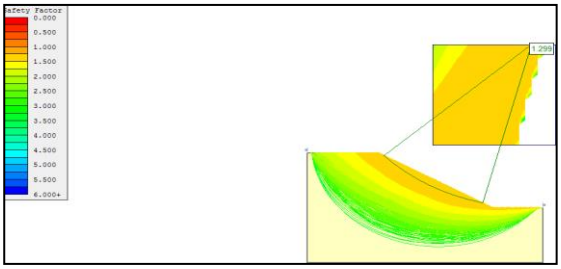

Fig- 8 Analysis results for bench height 15m. & slope angle 35 deg.

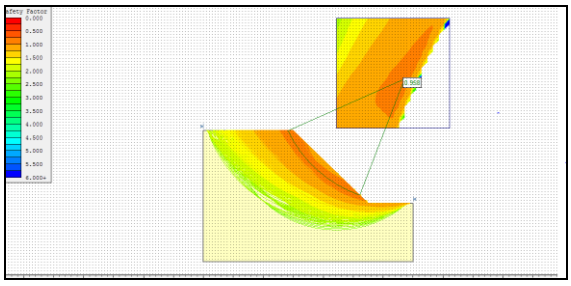

Fig -9 Analysis results for bench height 15m. & slope angle 35°

Table -3 Safety factor of bench at various angles & height

Slope angle	Bench height	Factor of safety
30	10	1.681
35	15	1.299
40	20	0.981

6. CONCLUSIONS

In the above (case-1) angle varying the bench is failing at a slope angle of 40° and its factor of safety is less than 1(0.995). Generally, the bench slope angle is 30° in initial conditions. The bench is stable up to a slope angle of bench is 40°. If it is exceeding, the bench become unstable.

In the (case-2) height varying the bench is fail at a height of 25 meters and its factor of safety is less than 1 Generally the bench height is 10 meters in initial conditions. The bench is stable up to 25 meters of bench height. Whenever it exceeds, the bench become unstable (safety factor is less than 1).

In the (case-3) both angle and height varying the bench is fail at an angle of slope 40° and height 20 meters and its factor of safety is less than 1. Generally, the bench parameters are 10-meter height and 30° slope angle in initial conditions. The bench becomes unstable due to gradual increasing of height and slope angle. The bench becomes to fail at a slope angle of 40° and height 20 meters. So the bench parameters should not exceed slope angle 40° and height 20 meters when the conditions are similar.

Based on above numerical model analysis, the bench failures are likely to occur because varying height or angle or both and depends on rock properties. So,it is strongly recommended to put the height and slope of the bench below 40 deg and 25m. respectively.

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