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STABILITY ANALYSIS OF THE SARCHESHMEH PSEUDOWEDGE FAILURE

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ABSTRACT: The Sarcheshmeh pit studies have clearly shown, once again, the dominant role of discontinuities on the stability of rock slopes.The objective of this paper is to attract the attentions of open pit designer to the effect of local features and their relation to the geometrical form of the pit, which should be examined before any pit design. A simplified method of estimation of safety factor and of the evolution of the safety factor as a function of the Sarcheshmeh pseudowedge height is presented. This type of rupture affects the slope stability of the Sarcheshmeh porphyry copper open pit mine at scale of some benches.

1. INTRODUCTION

The Sarcheshmeh porphyry copper-molybdenum deposit is located in southern Iran, at 30 degree N lat., 56 degree E long. It is currently the largest open pit mine in Iran. The ore body contains 1,200 Mt. of ore with average sulfide of 0.7% copper and approximately 0.03% molybdenum.

This paper examines the importance of engineering geology and rock mechanics parameters in the design of aslope.
Generally the slope design may be strongly influenced by the engineering geology and the rock mechanics parameters of the slope forming materials. A clear understanding of the structural geology, engineering geology and the historical tectonic is essential to assess the behavior of the slope. The slope design requires identification and assessment of all possible slope failure mechanisms with respect to proposed slope geometry.
The frequency, shear strength, orientation, spacing and continuity of discontinuities determine the failure mechanism which controls the stability.
At Sarcheshmeh mine, major structural features such as faults, dikes will have different relative attitudes to the faces of the various walls. Joint fabric may homogenous throughout the mine, but the difference in geometry relative to the various slope faces again might make it necessary to have more than one design sector. Major features, such as faults or dikes, often occur in only one wall, clearly it needs a distinctive design.

2. GEOLOGICAL SETTING

In term of fracturing, the ore porphyry such as Sarcheshmeh, is one of the more complex geological environment. The Sarcheshmeh deposit is related to the Late Tertiary granodioritic stock which intruded the early Tertiary volcanics. The deposit was intruded by intra-mineralisation and post

mineralisation dikes and intrusives (Shahabpour, 1982).
The original subcircular Sarcheshmeh porphyry stock exhibits an east-west elongation due to dilation by the dike swarm, which strike is predominantly NNW. The highest grade hypogene zone occurs as an annular ring in altered andésite around the periphery of the Sarcheshmeh stock, (Waterman et al., 1975).

3. MODES OF INSTABILITY

Wedge failures may occur where at least two discontinuities intersect, and that intersection is undercut by the slope.
Wedge stability analysis is a standard procedure when designing cut slopes or assessing the performance of natural slopes in rock.
The well-known analysis for tetrahedral wedge formed by two joints and the slope is used to first develop a simplified analysis procedure and associated diagrams. The procedure is associated with the case where sliding occurs along the line of intersection and includes different slope geometries and water conditions. The two joint planes can have different values of friction angle and cohesion, as well as different water pressures.

In spite of the wedge failure, the Sarcheshmeh pseudowedge was subjected to a special investigation.
The Sarcheshmeh pseudowedge instability at 2600m elevation in the west design sectors which form a zone of large loose blocks in the slope. Fig. 1, involves combination of a fault and major joints in the heavily jointed and altered andésite. Groundwater along the fault appears to have contributed to the failures.
In order to establish the safety factor of the this kind of failure the following parameters are considered:

- the fault has a strike of S15E and a dip of 45° to the NE. The faults contain thick clay gouge material. From the shear strength data a friction angle of 20° and a cohesion of 14 kPa are used .

-the major joints having the strike of S70E and the dip of 75° to 85° to the NE. Almost all the major joint surfaces were iron stained, which means they are open to weathering agents down to the base. For the major joint a friction angle of 40° and a cohesion of 50 kPa were chosen as the starting point for the analysis.
-in this area, the crest has the strike S50E, the combination of discontinuity with the crest orientation in this sector of the mine leads to the slope instability. So considering the geometry of the pit, the stability of this sector can be controlled by the orientation of the crest.

From early in the mine life 12.5m high benches were excavated at spacing of 12.5m crest to crest with a theoretical bench angle of 65° and berm width of 9.17m. Actually, because of the undercutting action of the Sarcheshmeh pseudowedge which reduces the width of the berm, sliding failure in upper benches are induced in a retrogressive process.

4. MECHANISMS INVOLVED IN PSEUDOWEDGE FAILURE

Valuable information is obtained on actual modes of instability by examining slides. Sometimes expected modes are confirmed. Often slides, like the Sarchehmeh pseudowedge, do not conform exactly to the simple models used in conventional methods that described before. Analysis for this type of failure is carried out assuming that the potential failure block is triangular or prismatic shape and completely isolated from surrounding rock, as shown in Fig. 2.

The "Sarcheshmeh pseudowedge" failures occur where a discontinuity does not daylight into the slope face. So, sliding on the discontinuity requires crushing, deformation or shearing of the rock substance at the toe of the slope, between the discontinuity and the slope face at the toe. This mechanism is effective due to the high degree of alteration and splitting of the* rock material. This type of failure cannot be analysed with the conventional method.
From a consideration of the geometry of failures in the field there are five possible failure mechanisms:

1- Failure by undercuting of rocks
2-Failure by horizontal stress, perpendicular to free face
3- Bearing capacity failure
4-Sliding along a plane in the basal rock
5-Failure induced by tension crack water pressures.

All these mechanisms can occur, but most have played mainly a minor role, also, various mechanisms would have operated together,

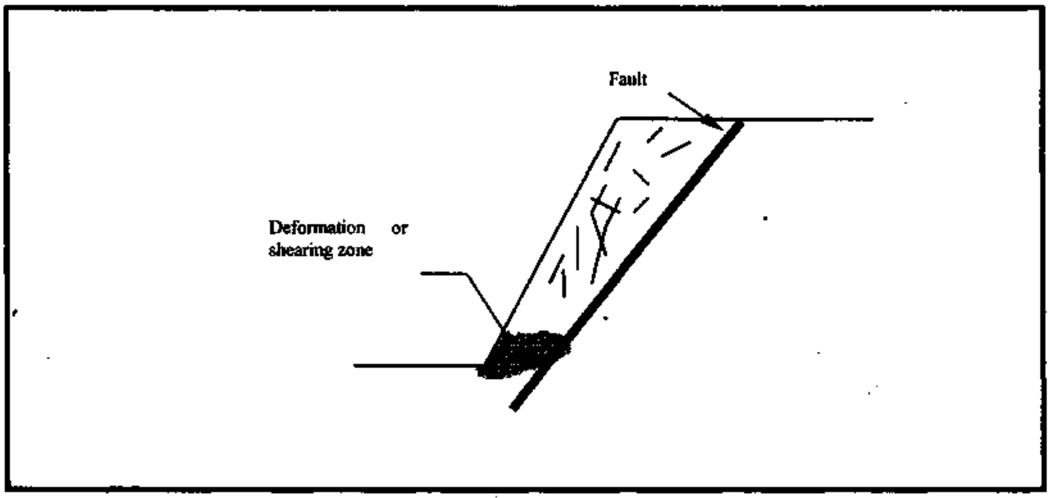

Fig. 1. The fault does not daylight into the slope face in the heavily jointed and altered andésite, requiring crushing at the bottom point of the wedge to permit movement.

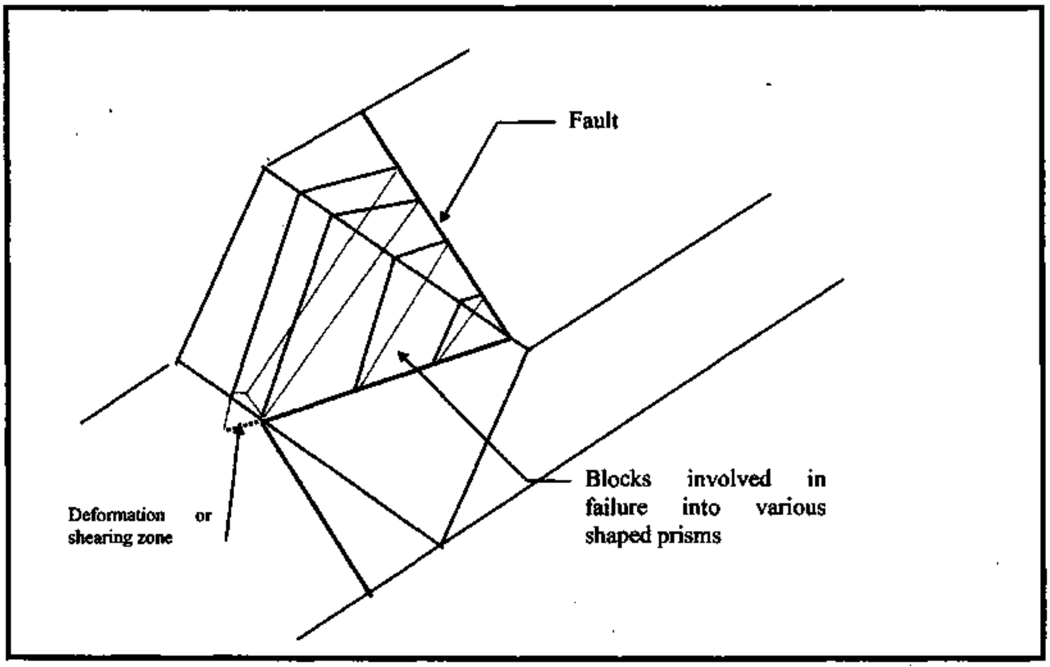

Fig. 2. A typical situation where a discontinuity dose not daylight into the slope face. Sliding on the discontinuity requires crushing or shearing of the rock substance between the discontinuity and the slope face at the toe.

The gradual movements are indicative of progressive failures which may be accelerated by water pressure or blast vibration.

In consequence of the alternating strength and weathering characteristics of the rocks, undercutting is commonly observed there is a distinct time delay between heavy rainfall and failure this time delay varies greatly from merely a day ör so up to several months.

The scale of progressive failures ranges from small blocks or somewhat blocks up to large failures of the escarpment itself where hundreds of tonnes of rock are involved. The progressive failures were bounded by the vertical orthogonal joints.
This type of progressive failures shows the importance of creep and the large variation in mechanical properties in weathered rocks.

The basal rock exhibits a number of vertical and horizontal and sub horizontal joints which become less dominant back from the free face. It is likely that there is a gradation in the degree of weathering inwards from the free face in the basal rocks, there is not to say that no weathering of the rock
Field observations of failures have shown the existence of the completely weathered to moderately weathered zones.
Many of these features cannot be considered in a conventional limit equilibrium analysis, specifically, neither progressive failure nor creep deformations can be taken into account. The intensity and continuity of jointing, and the extent of basal weathering and undercutting, determine the size of the blocks involved in failure. When the joints are orthogonally oriented they tend to break the rock mass into various shaped prisms.
Considering the five possible failure mechanisms, the pseudowedge failure can be analysed as follow:

The whole volume of wedge failure, "V", can be divided into two volumes of "V|" (A]1A_2 A'ıI'A'a) and "V_2" (OA',rA'$_2$) as shown in Fig. 3, (Çan T., 1995).

The volumes of "V]" and "V_2" separated by an assumed discontinuity inclined at small angle of "oil" to the horizontal, cut cross the volume "V". The net force acting on this discontinuity due to the volume "V_3" *(A\YA'$_2$E)*.
The volumes of "V!" and "V_2" separated by an assumed discontinuity inclined at small angle of "cii" to the horizontal, cut cross the volume "V".

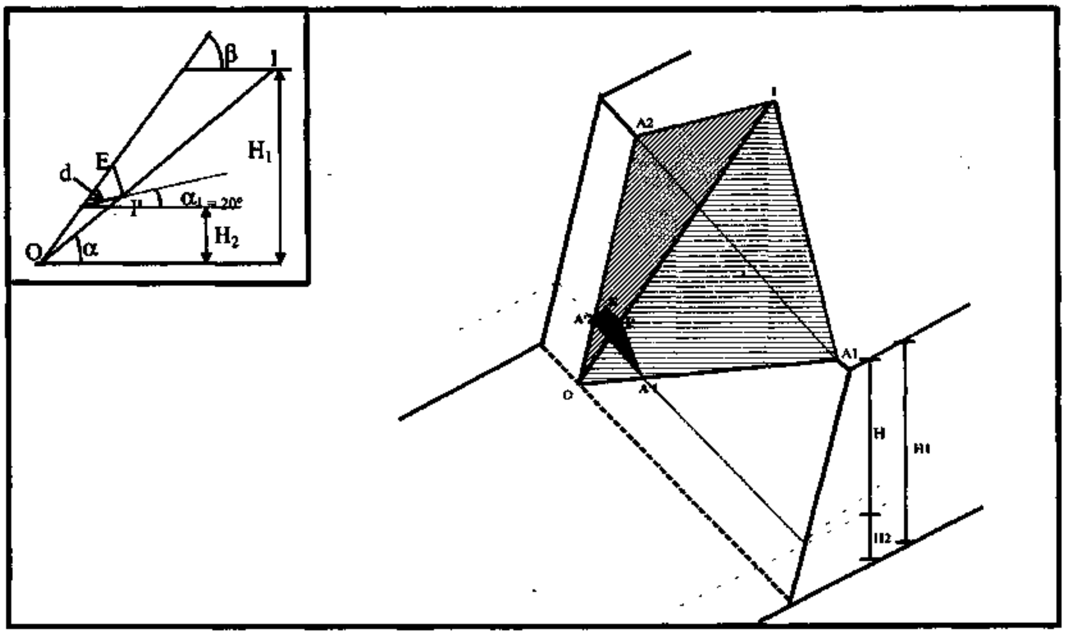

Fig. 3. Geometrical features for the Sarcheshmeh pseudowedge stability analysis.

The horizontal distance between free face and the line of intersection is considered as "d".
It is considered that, for estimating the strength properties of that assume discontinuity, the modified empirical criterion of Hoek-Brown (Hoek et al., 1992) for heavily jointed rock masses is used. Based on this criterion the values of cohesion and friction angle, for the altered andésite rock masses for different height of the Sarcheshmeh pseudowedge are calculated.

If the shear strength of both the sliding surfaces of volume "V![11] and the distance "d" are exceeded simultaneously, the toe of the bench kick out and the volume "Vy* will slide down.

By considering oil = 20° and different combinations of "d", height of pseudowedge and different strength properties for the volume "V2", Fig. 4 can be derived. These results can be applied to this particular slope problem.

The analysis method described may be used to develop comparative plots for different pseudowedge heights. Increase in bench height, increase the potential for sliding.

The force due to gravity and strength properties along the basal volume "Vi" are calculated. Thus the net force acting on the volume "Vj" is computed to determine whether the pseudowedge is stable, or if it could fail by sliding. The force of gravity is considered to be acting on thé boundaries of failure block.

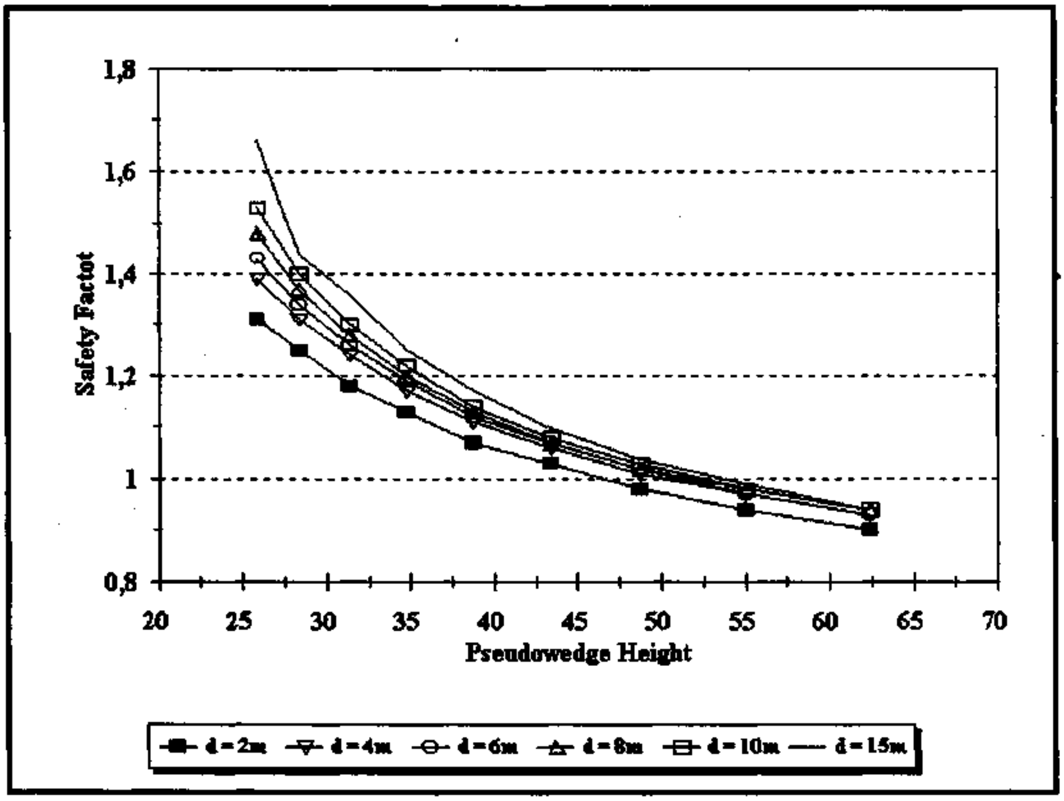

Fig 4. Evolution of the safety factor vs. the Sarcheshmeh pseudowedge height.

CONCLUSION

It can be concluded that:

1. the object of the case study is to illustrate using a realistic example, the influence of pit geometry on the design of an open pit project.

2. the Sarcheshmeh pit studies have clearly shown, once again, the dominant role of jointing on the stability of rock slopes.

3. time dependence phenomena such as alteration, weathering, blasting and creep obviously play an important role in this progressive failure process but for the Sarcheshmeh pseudowedge the geometrical shape of the interlocking blocks within the failing mass also plays a part in this process.

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