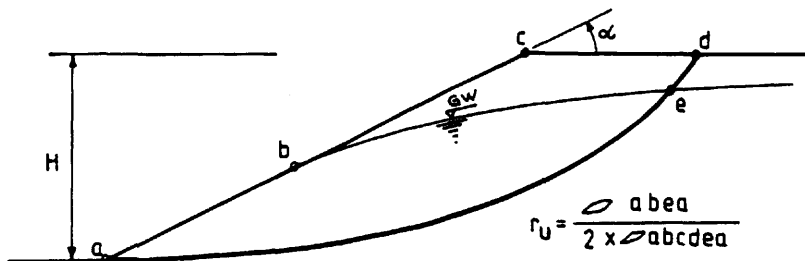


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It has long been recognised that the most important factor which is tending to produce the movement of stable and unstable open pit slope is high water table, e.g. high pore pressure ratio above slip surface. Figures 1 to 3 present three conditions under which pore water pressure causes instability of the open pit mine slopes. The effect of water pressure is to create an uplift force on the potential failure surface and thus reduce the resistance along the slip surface. To eliminate that factor it is necessary to eliminate water pore pressure by adequate drainage. By drainage or adequate removal of water from soil mass, the pore pressure regime can be reduced in its capacity to produce instability of open pit slopes.



BASIC CONSIDERATIONS OF WATER PRESSURE IN OPEN PIT SLOPE

In all open pit slopes stability problems it is necessary to determine the pore water pressure from a prescribed phreatic surface. Phreatic surface in the open pit slope area is not constant and it depends on different factors. In order to include the effects of

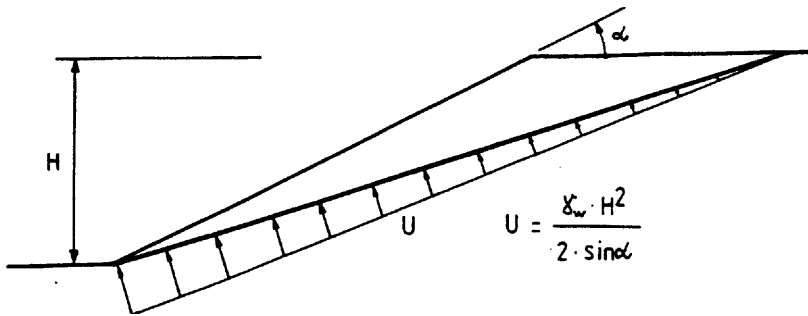


Figure 2. Open pit slope with groundwater, case 2.

pore pressure in stability analysis we use the pore pressure ratio r_u . The pore pressure ratio is defined as ratio between the total upward force due to water pressure and the total downward force due to the weight or overburden pressure⁽²⁾. According to the Archimedes' principle, the upward force is equal to the weight of water displaced or the volume of sliding mass under water multiplied by the unit weight of water, The downward force is equal to the weight of sliding mass. The pore pressure ratio can be determined by:

$$r_u = \frac{\text{Volume of sliding mass under water} \times \text{Unit weight of water}}{\text{Volume of sliding mass} \times \text{Unit weight of soil}}$$

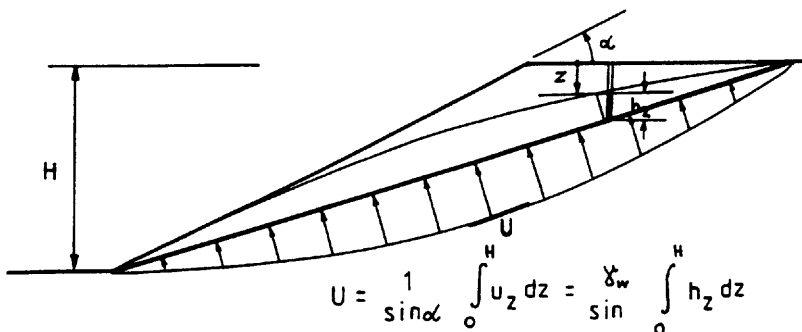


Figure 3. Open pit slope with groundwater, case 3.

In all the simplified method of stability analysis, the pore pressure ratio is used to reduce the effective stress along the failure surface by a factor of $(1 - r_u)$

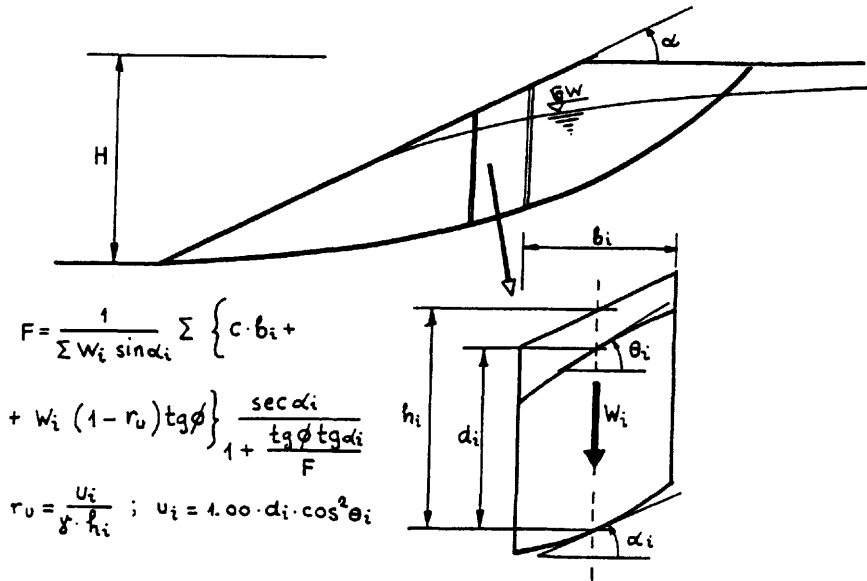


Figure 4. Bishop's method of slope stability analysis

This definition of pore pressure ratio is different from that proposed by Bishop and Morgenstern⁽⁵⁾, who defined the pore pressure ratio as: $r_u = u / (\gamma h)$, where u , γ , h are as on Figure 4. From that equation the pore pressure along the failure plane at the bottom of the sliding mass is $r_u \gamma h$, or neutral force within a horizontal distance, dx , is $r_u \gamma h \sec \alpha \, dx$, or

$$u = r_u \left(\int h \, dx \right) \sec \alpha .$$

METHODS USED TO DETERMINE GROUNDWATER IN OPEN PIT SLOPES

In general, we can use three methods to analyse the groundwater situation in open pit slope can be used:

1. The classical method of water pore pressure, described for assumed phreatic level,
2. Field water pressure readings from piezometers' levels,
3. Fitting theoretical solutions to the real or possible water pressure situation for isotropic or anisotropic water flow.

The presence of water in the open pit slope and its influences on slope stability can be as shown in Figure 5:

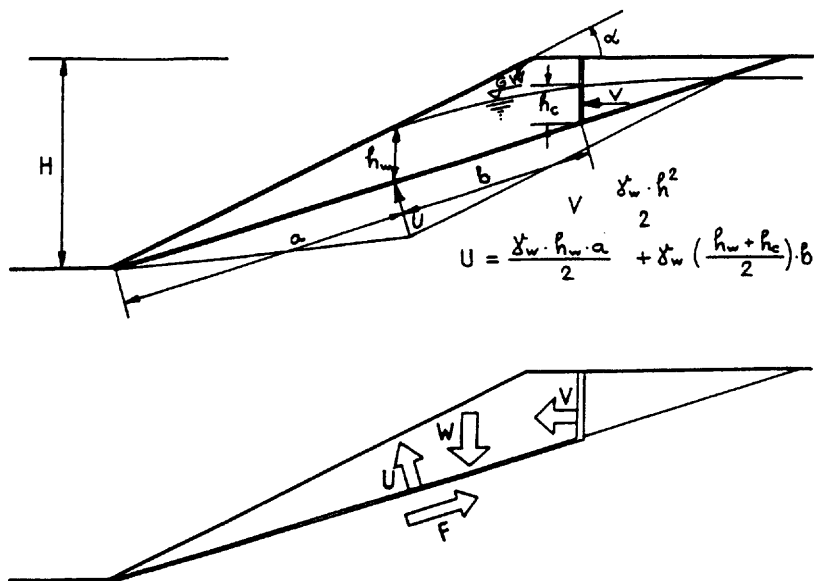


Figure 5. General aspect of water influence on slope stability

1. Water pressure which reduce the shearing strength of soil or rock material along the potential failure surface, (force F),
2. Water pressure as an uplift force along the failure surface, (force U),
3. Water pressure in tension cracks, (force V).

Consideration must be given to water pressure distribution in all three cases, and upon that the failure risks in stability analysis must be based, (Figure 5). In mining practice the only possibility open to the slope designer is to consider a number of realistic extremes in an attempt to bracket the range of possible factors of safety and to assess the sensitivity of the slope to variations in groundwater conditions⁽¹⁾.

GROUNDWATER CONDITIONS IN MINING PRACTICE

In order to assist the mine planning engineers in designing open pit operations by SIKULJE coal mine, BRACAN bauxite mine and SMREKA iron mine in the former YUGOSLAVIA, an analysis was carried out.

Stability of north slope of Sikulje open pit strongly depend on water table drowdown from pumped boreholes (Figure 6).

Planning and designing the stability of west slope of Bracan bauxite open pit is very difficult problem. Geological mapping and shear testing of discontinuities of clay-limestone contact provide a useful guide to the possible failure. Influence of groundwater level can be controlled by mining operations to permit the factor of safety to be determined with a reasonable degree of confidence (Figure 7).

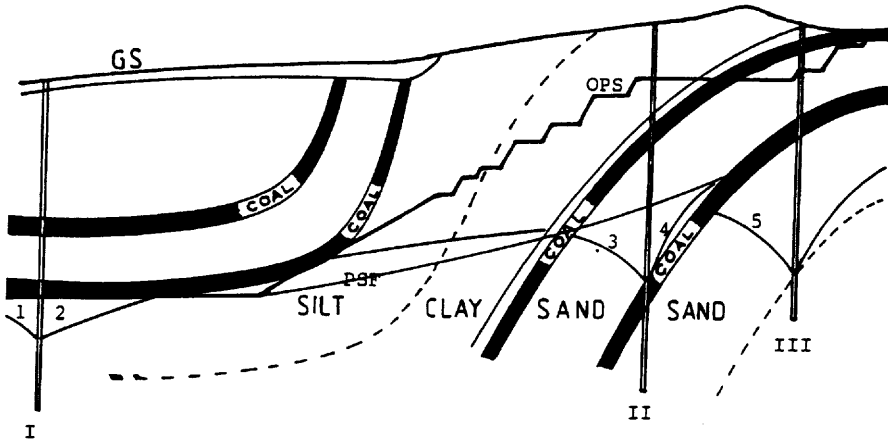


Figure 6. Section of a typical slope in open pit Sikulje, Yugoslavia 1 - 5 Position of phreatic level below the potential failure surface, I,II,III - Pumped borehole OPS - Open pit slope in some time PFS - Potential failure surface

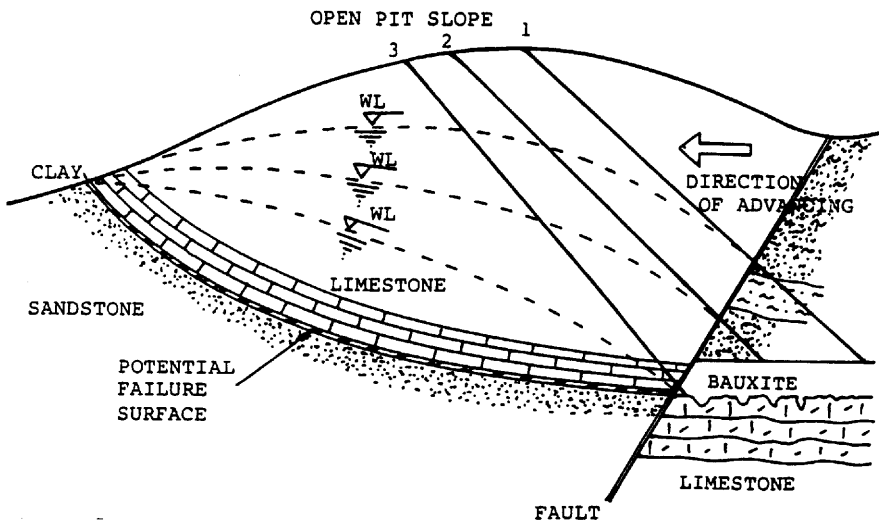


Figure 7. Section of typical slope in open pit Bracan

About 10 million cubic meters of rock material is permanently being moved on the north slope of the Smreka iron open pit, (Figure 8). For the last six-years-period it was calculated that the water pore pressure, r_u , had an enormous influence on the surface

displacement velocity, v_{ave} (cm/day), as it is presented in Table 1 for the measuring points stabilized close to, or on the, J profile (Figure 9).

Table 1

Water pore pressure ru	Slop displacement velocity v_{ave} (cm/day)
0	0
0.1	1
0.2	2
0.3	4
0.4	6
0.5	10
0.6	over 10

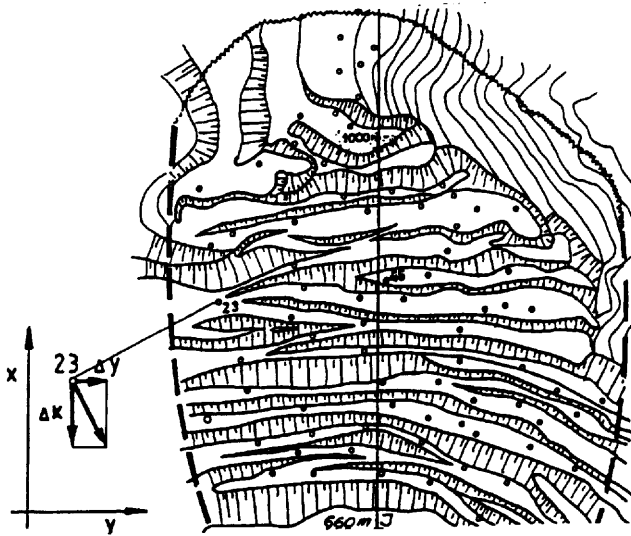


Figure 8. Unstable area of Smreka open pit

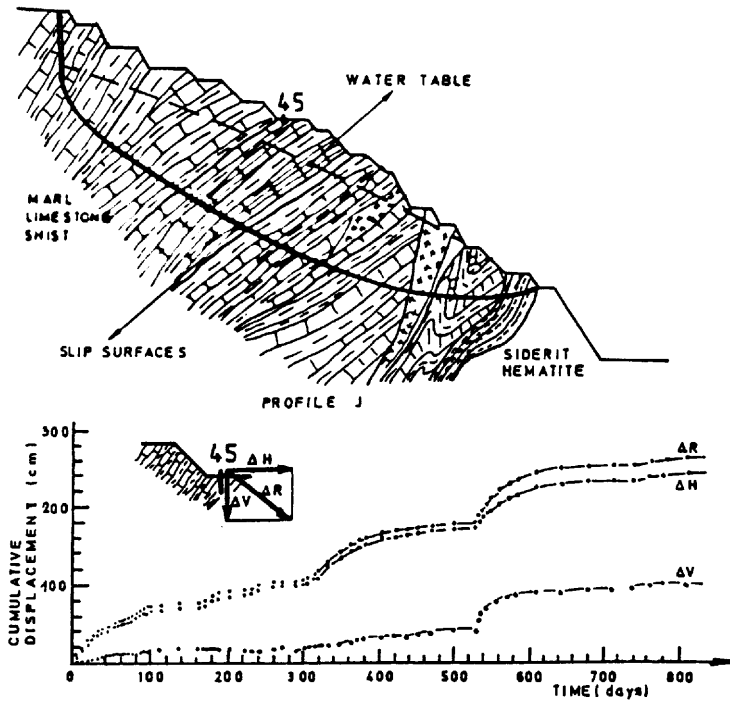


Figure 9. Profile J from Figure 8 and one typical diagram of point displacement in time

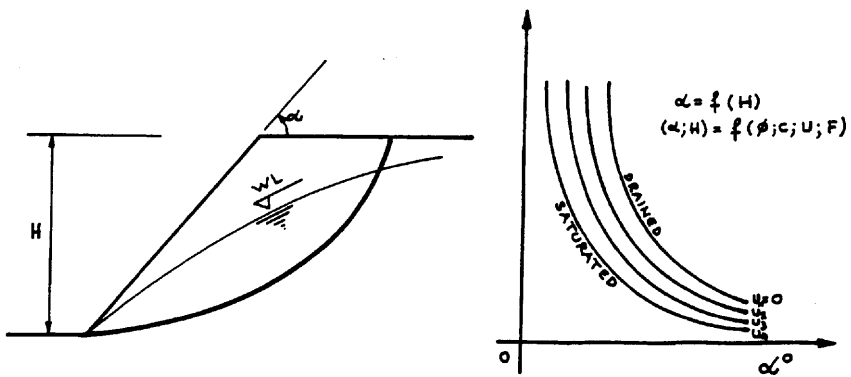


Figure 10. General conclusion of pore pressure influence on slope stability

For slope stability and average velocity (v_{ave}) water pore pressure was calculated from water levels above the failure plane. Water levels were measured by piezometers and at the same time surface displacement velocity was measured each days.

CONCLUSION

Water pressure due to groundwater presence has a great influence on the open pit slope stability and for that reason the risk of slope instability is dependent on water level in the slope. Factor of safety could be reduced from 1.3 to 1.0 if the water level increases. In all cases in open pit mining practice more than 40 % of slope instability risks depend on groundwater conditions in the slope. To prevent slope failure, effective drainage system can be installed, and other factors can remain unchanged. The importance of controlling water surface in open pit slope is emphasized. In general, increasing the open pit slope angle and decreasing the failure risks, is directly proportional to effective drainage system.

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