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MINE WORKINGS STABILITY AND ROCK-MASSES DEFORMABILITY

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ABSTRACT: In different mines, workings are exposed to stressed rock masses, which excite their deformation in time. In a generalized form, rocks and rock masses around workings with their deformation characteristics as a stressed background with a complexity of influential factors, are represented. Using the simplified rock masses loading index (RLI) and the deformability parameters, according to the theory of "Critical Depths" for galleries, the intervals of their stability in time are presented. Examples of mining levels, rock mass classifications and different mining workings stability attended in them are described. A way of simplified calculations for the used support systems design, is also exposed.
In an abridged form, some large underground cavity problems of deformations in time, for exploitation workings deformability in chromite mining, illustrates the wide spectrum of the calculation method.

1. INTRODUCTION

Problems of workings stability are closely linked with rock masses deformability, which depends on variety of natural, technical and technological factors.
By a generalization of the last thirty years mining practice at the main ore and coal mines in Albania, many practical and theoretical conclusions are drawn with regard to the development of non-elastic deformations around underground workings. Technical and technological changes are applied, and some new methodological solutions in engineering design of support systems are used due to the increase of rock masses deformability by the growth of mining depth.

2. DEFORMABILITY OF ROCK MASSES AND STABILITY PROBLEMS.

As it is exposed in another Congress paper, a close analysis of the underground workings is associated with a different theoretical treatment using the Critical Depths Method (Sauku, 1992).
It is concluded that there exists a direct relationship between rock masses deformability (u), Rock Loading Index (RLI^H/cTsh), rock plasticity parameter (kpi), rock masses pressures (q), and support resistance (p_s). Such a connection is expressed by

$$u = K\left(\frac{q}{p_s}\right)\ln\left(\frac{\gamma H}{p_s}\right),\ \text{cm}$$

where

$$K = \left(\frac{100}{\gamma}\right)k_{pl}\,E \qquad \textbf{and the value}$$

$$E = e^{\frac{\left[\frac{2\gamma H}{\sigma_c}-1\right]}{2}};$$

a_c - uniaxial rock compression strength;
Y - rock masses density, kN/m^3;
H - mining depth from the surface, m;
q, p_s, O_c, in kPa.
For normal conditions of mine workings the values must be $p_s > q$. At the deformable support construction (yielding arches, etc.) it is often developed $p_s = q$. So it means that there are developed maximal normal deformations in an environment with normal rock pressures q. In such conditions u^ values are

u = K\n

and the deformable zone reaches its maximal arch stability height b^ (in meters), so is
<7=Y*max>kPa
The pressure fields (q) are as in Fig. 1.

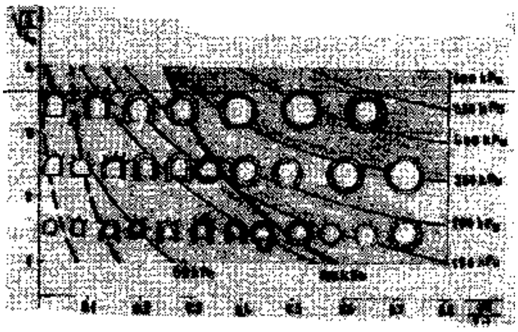

Fig.l Detailed representation of "q" values in four pressure fields of horizontal workings with a cross section area S=4-64m^2, S_0=4m^2.

In normal pressure fields, the presence of a mean rock masses fracturation nf=2 (fractures per meter) as a common phenomenon, is also taken into consideration. On the other hand, it is observed that the fracturation change is 0.5-5 fractures per linear meter, and it varies the rock pressure fields and the respective rock masses deformability. Such a variation may be calculated and represented. A design solution for the case in point is summarized by Fig.2.

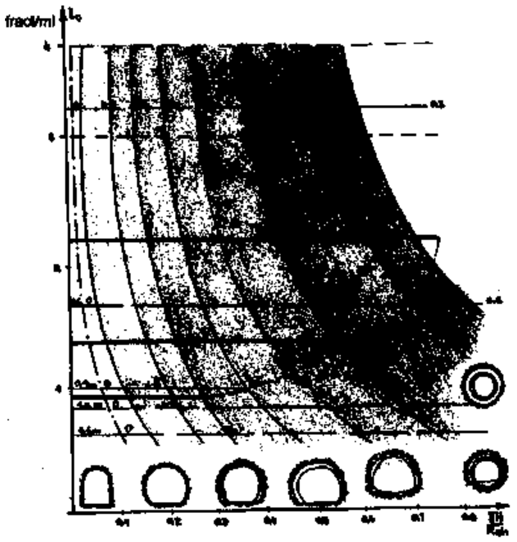

Fig.2 General representation of rock pressure fields for a mine object advancing in rock masses with different fracturation nf.

3. SELF SUPPORT CALCULATIONS FOR DESIGN OPERATIONS

A serious problem in mining is the working face stability during the first days of the advancing excavation. Safety rules after blasting and during loading operations constrain a safe working place, which depends on the self-support time of rocks around. Such a problem is treated exclusively for working faces in weak (soft)rocks. In great depths, the rocks deformability is higher and falling blocks from the roof and the sides endanger both normal work and the workers.

Deformation in time analysis helps to seclude the temporary stability caused by the self-support time. Deformations in time are characterized by the prolongation of the deformation in time, and the variable deformation speed and acceleration.

Setting on the evolution formula, deformations in time are described by

$$u_t = u_{max}\left(1 - e^{-zt}\right)$$

In the same way, we can describe the arch top raising in time (b_t):

$$b_t = b_{max}\left(1 - e^{-zt}\right)$$

where $z = z_0\, k_{pl} \frac{\gamma H}{\sigma_c}$, $z_0 = 1$ for t in months.

Considering $b_t = 0.99 b_{max}$ a limit value for an agreeable stabilization, the stabilization time T fixed is definitely

$$T = \ln\frac{100}{z}$$

Such a rule is also valid for deformation calculation at short time intervals (Sauku, 1995).

Considering that the first falling structural block is from the central part of the working roof with height value h_s=0.4-0.5m and the height value for the roof fall to take place must be h_s=bt, is calculated as T, the self-support time (TS) for each individual case of advancing mine working or tunnel.

To precise the rock masses stability for each mining level (RLI=const.) and also for a support system, a more agreeable working arch shape in different RLI situation is needed.

Respective examples are represented at Fig.3 and Fig.4.

Practically, from the geometrical dimensions point of view three types of arches are used, namely : very low (height ho=B/5), low (h_0=B/3) and normal half-circle arch (ho=B/2).

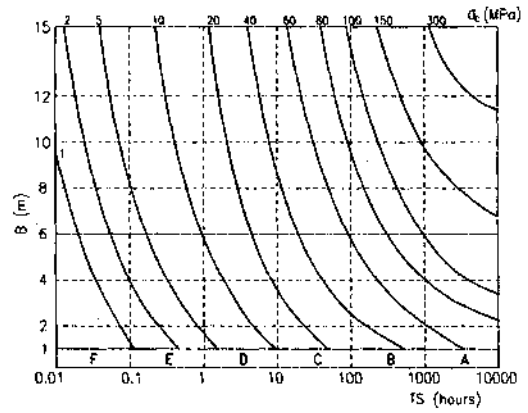

Fig.3 Rock masses classification for a given level and working widths 1-15 m: A-Very high stability, B- High stability, C- Normal stability, D- Low stability, E- Instability, F- High instability.

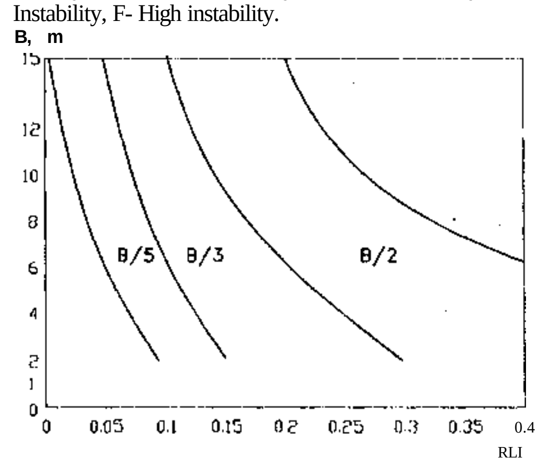

Fig. 4 Effective arch raising fields for horizontal workings: B/5 - Very low arches, B/3 Low arches, and B/2 - Normal half-circle arches used also for shotcrete and concrete lining.

4. SIMPLIFIED CALCULATIONS FOR MINE WORKINGS SUPPORT DESIGN.

During the analysis, I have come out with some simplified formula for timber and steal sets, bolting, and different shotcrete and concrete lining design. Each of them is connected with RLI parameter, free space width of the working, the quality of the support material, and the supporting technology. As an example, a formula for thickness of the shotcrete and concrete lining in horizontal workings and in vertical shafts, is:

$$d_0 = k_0\left(\frac{\sigma_m}{\sigma_u} B \frac{\gamma H}{2\sigma_c}\right)^{0.6} \text{ in cm;}$$

where do - thickness of lining, cm;

a_m = 16 MPa, lower quality class of concrete used in underground constructions,

σ_u - used quality of concrete or shotcrete, MPa;

B - free space width, in mm;

ko - connecting value for the used material and technology (k_0=0.33-0.75). Such a calculation is illustrated by Fig. 5.

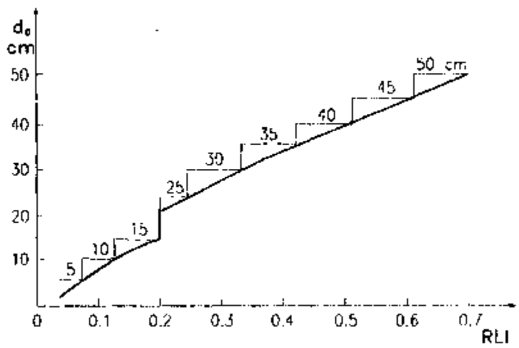

Fig. 5 "do" growth diagram by RLI for shotcrete and torcrete linings of a given working's cross section.

5. STABILITY AND DEFORMABILITY OF LARGE UNDERGROUND CAVITIES

We can evaluate the possible deformability of mining rooms and other exploitation cavities by using a similar calculating method.

a)

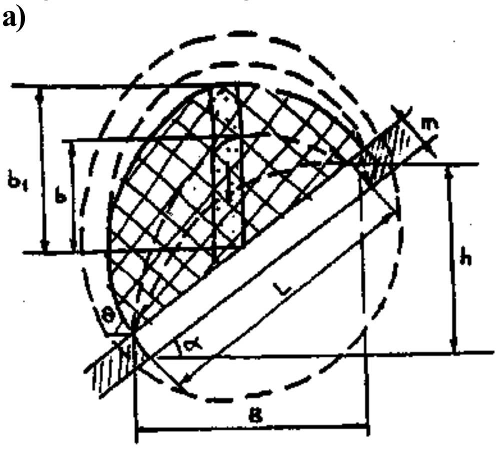

Fig.6 a) Calculation scheme.

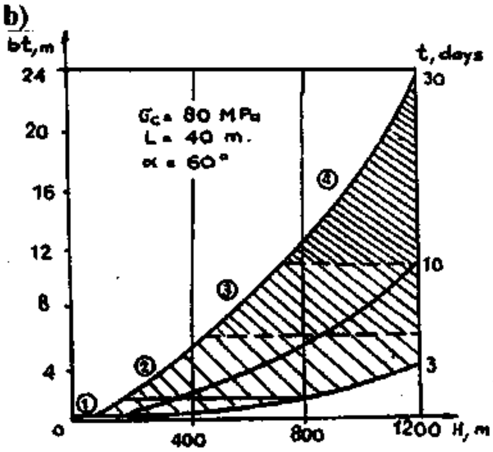

Fig.6 b) Probable deformations in cavities without support: 1- Disjointed individual structural blocks falling, 2- Structural blocks falling, 3- Movement of tectonic blocks, 4- Profound rock masses discharge.

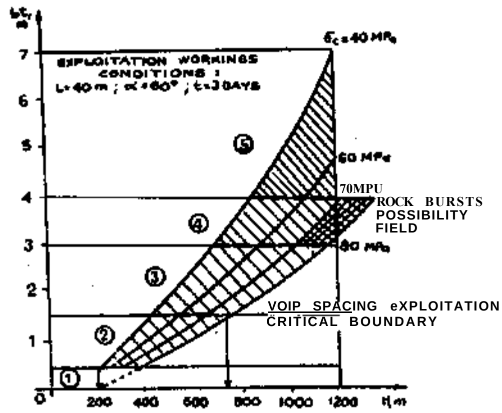

Fig. 7. Rock masses movement situations (mobility zones):
1- Full quiet zone (RLR0.13);
2- Relatively quiet (RLI = 0.13-0.25);
3- Visibly movable (RLI = 0.25-0.4);
4- Rapidly movable (RLI = 0.4-0. 5);
5- Vigorously movable (RLI>0.5).

By a special procedure used for mining in chromite mines, using data for cavities and rock masses around them, as RLI, tectonic and ordinary fracturations, k_pi index etc., their possible deformability in time is calculated in different level depths (Fig. 6) and probable phenomena display (Fig. 7) are predicted.

Bulqiza chromite mine has also many ore bodies with a variable layer dipping. Analysing dip influence, for different dip angles are obtained deformation changes as in Fig.8.

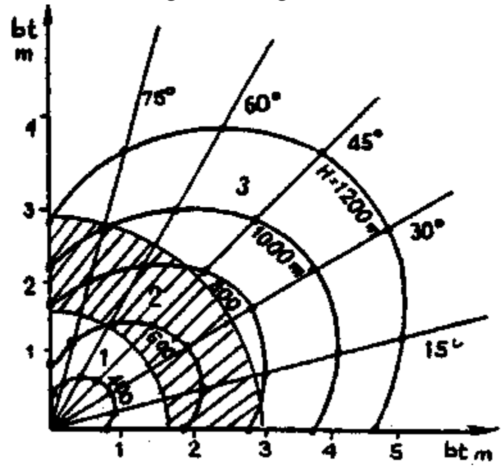

Fig.8 Development of b_t by depths H, for rocks c_c=80MPa, t=10 days and garanted stability: 1- Without support systems; 2- with reinforcing bolts; 3- with filling.

By calculations, it may also be predicted the increase of the ore quality loss within the exploitation space, by rock blocks falling from roof or wall sides mixing with ore. An example is summarized in Fig.9.

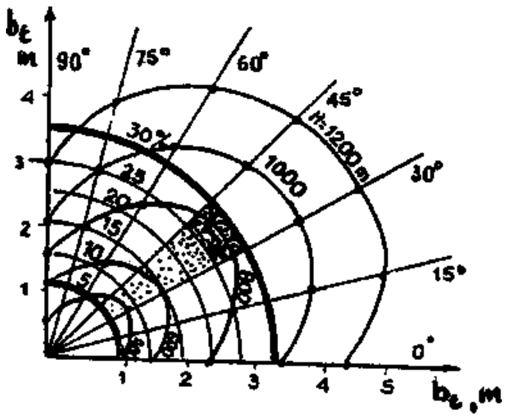

Fig.9. Possible increase of the quality loss by the depth of exploitation without guaranteed rock stability. Loss values are in percentage (%) of initial quality.

CONCLUSIONS

1. Calculation method analysis of workings deformability is a verified one by observations in situ and by different supporting brake downs in mining and tunneling.

2. Many graphical representations are from realized scientific studies and projects for mining activities and prospects of tunneling (Qafe Thana).
3. The success of the calculating method depends on the conception of the rock masses strength, which want a complex analysis of different natural, technical and technological intervening factors, by the author used.

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