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BULGARIEN EXPERIENCE WITH FRICTIONAL ROCK BOLTING IN MINES AND TUNNELS

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ABSTRACT: In die present paper a laboratory and practical experience with factional pipe anchor TFA in Bulgaria invented is discussed. An improvement in the strength and deformation properties of rock mass is defined. A comparative analysis is made for determining the difference between reinforcing effects of factional pipe anchor and expansion shell rock bolts.

1.INTRODUCTION

The development of mine extraction industry in Bulgaria from 1950 to 1985 created favorable conditions for entering in the branch variety of technical and technological innovations. The extensive utilization of rockbolting in underground mining started in the period 1950 - 1960. Over 12 types of different rock bolt patterns were created and tested with acceleration, because of heavy mining and geological environment at the region of the Balkan Peninsula. Rock mass properties were studied to establish where the different types of rock bolts have revealed the highest reinforcing effect. For the needs of underground mining and tunneling self-made rock bolt patterns of all known directions of rock bolt development have been created and offered for application. The development started with application of expansion wedge or shell rock bolts mainly in ore extraction and partially in coal mines, then so called grouted resin or cement rock bolts were developed mostly for the need of the tunneling and at the end of 70's Bulgarian structure of frictional pipe anchor called TFA was invented, tested and offered for utilization. In the next years and at this moment frictional pipe anchor TFA replaced almost completely the rest type of rock bolts in ore and coal mines and gradually got into the tunnel construction. One of the reasons stimulating own developments lies in a closed economical system to the 1989, known with limited access to the modem west technologies and equipment

As a result of this comprehensive investigations, a high quantity of date and experience about the action of different type of rock bolts İn a specific mining conditions at region of Balcan are collected.

First of all, experience gained on the application of frictional pipe anchor TFA is discussed in this paper. Some comparative studies with conventional rock bolts were implemented to get a more clear idea about reinforcing effect of TFA.

2. GENERAL PRINCIPLES

The suggested conception is based on the assumption for confining to the minimum of natural arch forming around mine opening. Such a model corresponds better to frictional pipe anchor, counteracting the this arch forming by contact with rock over the whole length of anchor and by tangential stresses. Suspention effect (suspention of soft to hard rock), as well as so called clamping effect described more detailed in (Panek et al.,1973) are of no use because of the lack of pre tension anchor stresses. Rockbolting in time and appropriate distribution of bolts create a condition, rock mass surrounding the opening to be considered as a monolith with improved stress and strain properties.

When an underground opening is made the in situ stresses are distributed, resulting in deformation of rock mass surrounding the opening. The magnitude of these stress changes and strata movements depend on initial in situ stress, physico-mechanical and geological properties of rock and opening geometry. These stress changes and strata movements around zirkulär opening are idealized in Fig. I (Nikolaev et al., 1985).

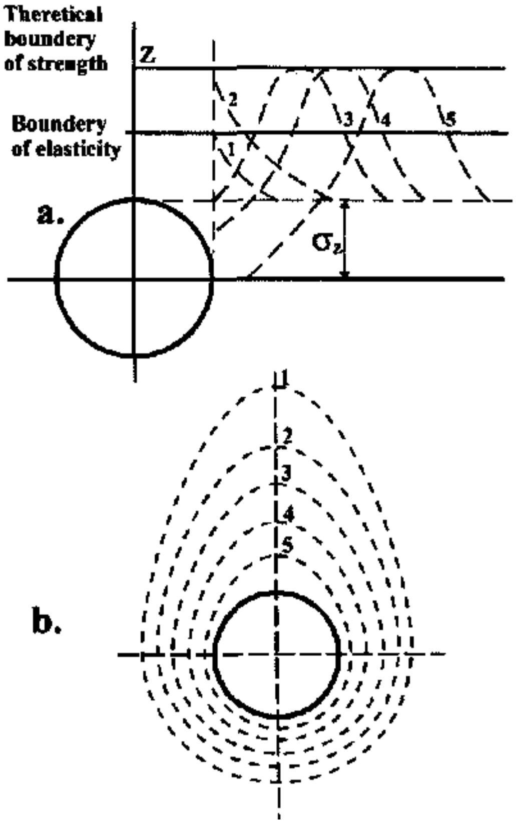

Fig. 1. Stress distribution around the opening
a. Stages of stress distribution
b. Zone of stresses around the opening

The curve of increased stresses 1 indicates, that around the opening a zone with increased stresses being the highest at the counter of opening is formed. However the distribution of stresses goes on and the zone with increased stresses is extended and get into the rock mass. Maximum stresses are also moved away from the surface of opening. In the next stage of the rock pressure development stresses decrease from the line of maximum pressure towards the counter of the opening and at the free surface of opening, they are almost equal to the geostatic pressure a* before driving the opening.

The process of stress distribution continuous and close to the counter of opening, a zone with lower stresses than the geostatic pressure arises. In this stage, fissure forming around the opening begins.

Depending on the physicc-mechanical properties of rock and maximum stresses, rock pressure development could be stopped at first (curve 1), second or fifth stage(curves 2 to 5). The third and forth stages expresses temporary (of short duration) state of rock pressure development.

Rock bolting takes a part completely still at first stage of stress distribution, if it has been implemented immediately after opening advance.

Rock bolting, as well as all the rest types of support have for an object not to restore completely the disturbed equilibrium of rock mass being due to the driving of opening, but have to offset this part of stresses only, which exceeds the rock strength in a zone with optimum magnitude and distance from surface of the opening. In this way the equilibrium would be achieved with minimum number of support elements.

With rock bolting at some distance in the rock mass, a rock arch with increased load bearing capacity is formed, serving as an additional support.

The zones, arising in the time of stress distribution are characterized with different state stresses of causing a different movement. Passing deformation processes decrease with entering in the rock mass. The development of deformation processes begins immediately after opening advance and continuous to the forming of stable equilibrium, i.e. forming a natural arch around the opening.

If deformation processes are considered in a certain moment of their development, each point of the rock mass surrounding the opening has been undergone some deformation and has the possibility to implement an additional deformation. Each point has a potential possibility to implement certain deformation to the establishing the state of equilibrium. The magnitude of this potential possibility depends on the point distance to the counter of opening, decreasing moving away from it.

Connecting the zones with different potential deformations, rock bolts contributes to reducing the difference between them and strives to equalize the possible deformations of the points at counter of opening with these of points He at the inside end of the anchor. In this way anchor support confines the development of deformations around mine opening and causes a state of equilibrium at much earlier stage of rock pressure development, reducing the natural arch to the minimum.

Analytical expression of this reinforcing effect for the purpose of finding the quantitative relationships for the need of design is still on the unsatisfied level. That's why the first results for reinforcing effect by the application of frictional pipe anchor TFA were obtained by simply laboratory studies on the models.

If an element of rock mass unsupported by anchors is found at the condition close to uni-axial pressure, it is characterized by ultimate strength <Ji. Assigning by frictional anchors different magnitudes of confining pressure Ao"3, it could be increased substantially the magnitude of principal stress of failure d* (so called effective stress). The magnitude of rock reinforcing in supported by

anchors zone of rock mass can be given by the following reinforcement factor:

$$RF = \sigma_1{}^*/\sigma_1 \qquad (1)$$

Beginning with the Coulomb failure criterion

$$\sigma_1 = 2C\text{tg}\alpha + \sigma_3\text{tg}^2\alpha \qquad (2)$$

the effective cohesion C* can be obtained as a function of confining pressure AO3 supplied by the reinforcement.

Applying the further developed by (Grasso et al., 1989) effective cohesion concept, the effective cohesion can be expressed, as

$$C^* = C + (\Delta\sigma_3/2)\text{tg}\alpha \qquad (3)$$

Starting with eq.(1) and introducing C*, reinforcement factor is given by

$$RF = 1 + (\Delta\sigma_3/C)\text{tg}\alpha \qquad (4)$$

Where $\Delta\sigma_3 = \eta P_a n_a$; $\alpha = 45^\circ + (\varphi/2)$; P_a = initial load bearing capacity of the rock bolts; η = factor of P_a increasing with time for frictional pipe anchor TFA; n_a = density of anchor distribution; φ = internal angle of friction.

With varying the length and the density of anchor distribution, it is easy to achieve RF = 2 (Parushev, 1986), which implies double improvement of strength parameters of reinforced rock mass. Even those comperatively good reinforcement factor obtained in laboratory condition, could not explain the high reinforcing effect, resulting by practical application of TFA. This effect is expressed particularly strong in the soft rocks, as it can be seen in the following practical studies.

3. ANALISIS OF PRACTICAL STUDIES

Widely application of frictional pipe anchor TFA In underground mines and recently in tunnel construction verified the expected positive results for traditional anchoring rocks. The basic principal of frictional pipe anchor and high reinforcement factor in the laboratory tests obtained were used as a background for studying die frictional rock bolting in a heavier mining and geological environment, typical for coal mines in Bulgaria. For this purpose, sections of longwall openings were selected in which studies with conventional rock bolts have been already carried out

These studies enable to be made a comparison between the reinforcing effects of the both type of anchors for the strata properties of coal field of Bobov dol.

The selected sections of opening were driven along the seam at a depth of 150 m below surface. The coal seam is of thickness 2,5 to 3 m. The host rocks are marlstones with slowly expressed bedding and thickness in the roof of 40 to 50m. The uni-axial strength of marlstone is of 23 MPa. The dimensions of the opening cross section are as follows: 3.5 m width and 3 m height. The roof of opening was supported by 4 anchors in row with 0,3 x 0,2 m wood header and space between rows of 0,8 m. The anchor bolts are of length 1,8 m and inclination 60° towards a horizontal level.

Long term observations are carried out for defining the influence of the both type of anchor supports on the deformation parameters of bolted rocks. They involved regular measurements of the displacements of rock from the roof to the opening in the course of one year. The displacement of the rocks are measured by the traditional mine surveying methods, because of the typical for coal field high displacements from 1 to over 10 cm.

The measured values of roof rock displacement were subjected to correlation analyses. Five types of approximations corresponding to 5 different models of rock deformation response were tested by appropriate software for pc. The exponential dependence between deformation and time proved to be the most suitable, characterizing the clear Theological character of rock deformation.

The function has a following logaritmic type:

$$\text{Log}U_{f,s} = A_{f,s} + B_{f,s}t + C_{f,s}t^2 \qquad (5)$$

Where $V\{_s$ = displacement of rocks from the roof anchored by friction, respectively expansion shell rock bolts; t = time in days; Af_s, Bf_s, Cr_s = coefficients for friction, respectively expansion shell rock bolts.

In Table 1 are summarized the coefficients for the three functions Uf, U_s and the ratio (Uf/U_s).

The in situ measured results give the opportunity for defining the relative alteration of deformation indexes for the both type of rock bolts.

Table 1.

Coeff. for	U_f	u_s	u_f/u_5
A	0.084	0,826	0.724
B	3.69x10'J	4.76x10'J	1.07x10°
C	-5.16x10-°	-10.2x10-°	-5.07x10"°

In Fig.2 is illustrated a graphical representation of U for the both type of rock bolting.

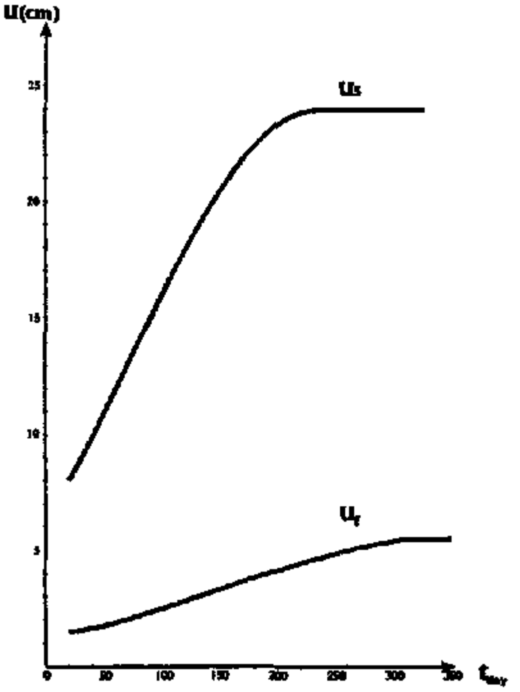

Fig.2. Altering the deformation of anchoring rock with time.

As it can be seen from Fig. 2 the stabilisation of rock mass with expansion shell rock bolts takes place much earlier, but with 3 times higher value of rock displacement. It should be also outlined that during the time of rock stabilization with expansion rock bolts, they needed to be retensioned several times. The first retensioning was carried out 24 hours after their installation. In contrast to the expansion rock bolts, the frictional pipe anchor TFA did not need any care during the whole time of rock stabilization.

Fig,3 shows the graphical relationships between relative deformations and time.

Curve 1 shows the alteration of ratio
U_f/U_s during the stabilisation for the studied section of opening. Curve 2 indicates the velocity of alteration of the relative deformation.

The appearance of curve 1 shows an increasing of ratio to 6.3 times to the advantage of frictional pipe anchors, then the ratio begins a progressive decrease and became equal to 3 by the stabilization of rock mass.

In ore extraction, a room roof rock bolting is an effective application of frictional pipe anchor TFA in the room and pillar mining. Anchors serve for maintaining the safety working space during the preparation and extraction of ore.

The results of analytical investigations for determining the required anchor length are given graphically in Fig.4 for the two type of anchors, expansion shell and rock bolts, in mine Bor, Yugoslavia. The present study is based on the method proposed by (Ershanov et al., 1981).

The mining and technological conditions of ore extraction are as follows: depth of mining H = 300 m; density of rock $y = 26$ kN/m$^{?}$; rock mass rating RMR = 65 and roof span of room L = 25 m.

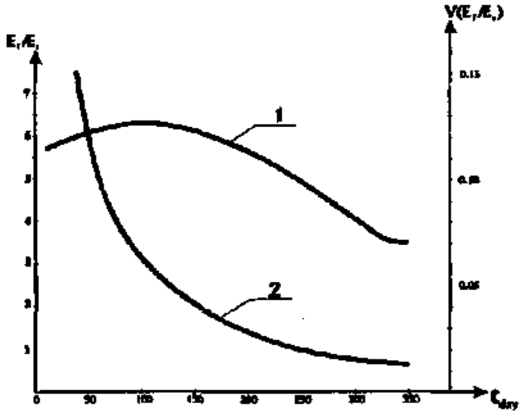

Fig.3. Alteration of deformation ratio with time

It is evident from the figure that anchor length of the both type of rock bolts is different depending on the space to the pillar, i.e. the anchor length ls increased with moving away from the pillar. In virtually, the roof rock bolting of room is implemented by maximum anchor length calculated for technological reasons. As it follows from the graphical relationships of the both type of rock bolts, length of 2,6 m is used by expansion bolts and of length 2 m by frictional anchors. From the graphic of Al_a it can be seen that costs for anchoring and hole drilling are reduced of about 32% by frictional rock bolting. The smaller length of frictional anchors is explained by the higher resistance of TFA to the tangential stresses, whose importance is increased by large excavations.

Frictional pipe anchor TFA have been applied in tunneling for a short time and there is not still a sufficient quantity of date for analytical assessment. Nevertheless they proved to be unique technique for realizing by the two concrete technological decisions.

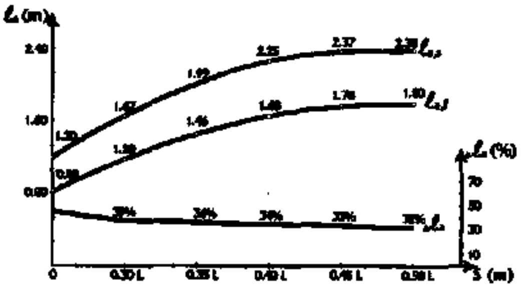

Fig.4. Relationship between length of rock bolts and space to the room pillar.

In one case, they were used successfully for additional enlarging the cross sections of old tunnels in rail way network. Through the lining of tunnel or after its removal, the disturbed or weathered rocks are supported by frictional anchors of length 2,40 m. In this way, further work under free rock surface is maintained safety. Cross section enlarging is implemented by blasting to the depth of 1,20 m. Blast holes are drilled between rock bolts. After blasting and removing the rock to the depth of blast holes, the rest part of anchor length prevents rock failure of unblasted rock mass. Safety conditions are provided for further construction of the new tunnel lining. This enlarging of tunnel cross section is possible due to the less sensibility of frictional pipe anchor to the blast action. The frictional anchors preserve sufficient load bearing capacity to provide safety of support after blasting.

An other case of frictional rock bolting in tunneling is the utilization of anchors as a temporary and permanent support simultaneously in technological cycle of tunnel construction.

In former technology, the construction of tunnel included application of conventional grouted rock bolts as a permanent support and solution injection through die additionally drilled holes between anchors.

With the introduction of frictional pipe anchor TFA, the necessity of injection hole fall off. Anchors TFA provide sufficient load bearing capacity soon after their installation and they serve as a temporary support initially. After passing the deformation processes due to die stress distribution, cement solution is injected through the anchors. The injected cement solution fill up the joints crossed by the anchor, on one hand and coat the pipe body of anchor outside and inside, on the other hand In this way, pipe anchor is protected by two layers against corrosion and turned in to the permanent support. The falling off the additional injection holes leads to the significant reducing in cost for tunnel construction.

4. CONCLUSION

Both the laboratory and in situ studies reveal that reinforcement with frictional pipe anchors affected substantially the strength and deformation characteristics of soft rocks. From comparative studies, one can see that with frictional pipe anchor TFA, the stabilization of rock mass was achieved by three times less displacements of the roof rock. Furthermore the expansion shell anchors need to be retensioned several times before rock stabilisation.

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