THE OPPORTUNITY OF THE USE OF ANCHORED SUPPORTS AT THE UNDERGROUND EXCAVATIONS

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Abstract: *As an objective requirement of the a confinement of the application domain of the metallic support presently used for the execution of underground excavations, it results from the non-correlation of the symmetric construction of the support system having an irregular behaviour of the vector of maximum pressure, and on economic considerations, generated by increased costs of metal and production costs of laminated profiles, by the application of the suppliers of additional enhancement treatments, it becomes more and more necessary to introduce and generalise anchored supports for the consolidation of rocks. The paper analyses the possibility to generalise anchored supports for the execution of underground excavations, as well as the particularities of this kind of support system and its interaction with the surrounding rock, the purpose being to fundament the choice of this rock consolidation procedure.*

Key words: *underground excavation, traction tension, expansion bond, cement mortar, rock massif, support interaction*

1. Introduction

Analysed considering the reliability and safety criteria, the theoretical and experimental researches carried out during the past years prove that for difficult placement conditions of the underground excavations, the metallic supports are irregularly kept under stress with increased intensities. Therefore, they lose their bearing capacity after a relatively short period of time after having been installed, due to the local tensions forming in certain spots on the outline of the work, tensions which exceed the limited flow frequency of execution steels. It is therefore considered that the deformation of the support is generated not only by the burden of the rock massif, but especially by the discordance of the construction of the support system used to the direction of which the pressure vector has a maximum value. It is also known that the classical usual metallic support, with an elastic-sliding operation, considering its construction may carry only vertical loads generated by the vertical pressure of the ceiling, for limited convergences of the rock of 150-200 mm. In the case in which the lateral pressure manifests itself with intensity, and the ratio $P_x/P_y > 1$, the metallic props give in, due to their bearing capacity and their limited reaction to the load of the rock massif, with all the unfavourable consequences regarding the optimum operation of the support. Consequently, considering the present economic crisis, during which the iron and steel plants are reducing their activity of producing support laminated profiles, for the insurance of the stability of underground excavations, internationally they are oriented to introducing and generalising anchored supports for the consolidation of rocks, aspect which is imposed more and more profound in the practice of underground constructions in our country as well.

2. Appreciations regarding the effect of stress on the rocks surrounding the underground excavations

As the result of the theoretical and experimental researches on the geomechanical processes show it the most intense rock movements around the underground excavations are produced after the excavation activity and the advance of the face. The rocks with increased mechanical resistances may ensure a new balance, based on their self-bearing capacity, while the rocks with medium and reduced resistances, such as sediments, undergo an active movement process which is finalised through the deformation of the entire profile of the excavation (Figure 1) consequently this kind of rock needs to be supported.

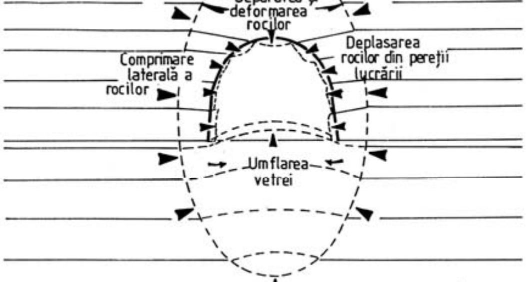

Figure 1 *The effect of stress on the rock surrounding the underground excavations*

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The classical usual support, such as the metallic sliding one, with a symmetric construction and installation of the composing elements, is designed to bear the maximum loads which come down preponderantly from the ceiling of the excavation and, consequently, by asymmetric distribution of the state of tension on the outline of the work, the present system no longer corresponds to the given requirements [1],[2],[3],[4].

Therefore, the conditions of non-uniform manifestation of the underground pressure, when the lateral stress (Pp_1 , Pp_2) of the excavation records values which exceed the vertical ones (P_t), results in accentuated deformations of the pillars with the loss of balance of the "rock-support" system and the decrease of the stability of the work (Figure 2).

The same non-uniform deformation aspect is recorded in the case of rigid arch bricks masonry supports as well, respectively monolith concrete or pre-fabricates, which, although have superior bearing capacities, following the asymmetric stress manifested on the outline of the excavations and the non-corresponding filling degree of the voids in the back, both in the walls and in the ceiling (Figure 3).

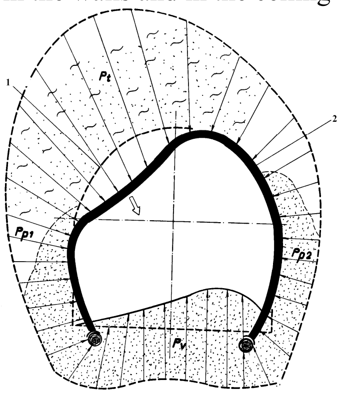

Figure 2 *The irregular deformation of the mine work supported with metallic reinforcements, considering the taking over of maximum stress from the wall next to the layer: **1**-initial profile; **2**-profile resulted after the stabilisation of the stress*

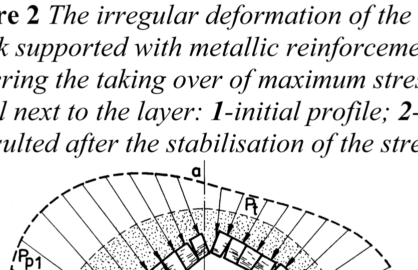

Figure 3 *Asymmetric stress and deformation mode of the mine opening works supported by masonry with arch bricks (case P_t < Pp_1, Pp_2)*

As a consequence of the incorrelation between the construction of the present classical supports and the direction in which the maximum pressure vector manifest itself, the theoretical and experimental researches of the geomechanical processes have highlighted the need to orient the actions to benefit to a maximum of the bearing surface of rocks in taking over the stress, by consolidating them with the help of anchored supports. Consequently, the increase of the resistance of rocks to the shearing and traction stress becomes possible, with the formation and the implication of the consolidated area, at a very short period of time in taking over the pressures. this type of mechanism of the interaction in the "anchor-rock" system is accepted by most of the specialists in the field, constituting the main argument regarding the anchored support for various kinds of rocks.

Considering this context, most of the countries with experience in this field observe the diversification and extension of system of anchoring the rocks, phenomenon appreciated as one of the most important realisations in the technique and technology of mine works supports during the post-war period. The increasing interest manifested by the mining industry of the Western Europe, USA, Australia, South Africa, and others, towards the anchored supports, results mainly from the economic situations of mines and the efforts which are undertaken to make the extraction activities of useful mineral substances more efficient.

In order to give examples concerning the interest manifested in the field of anchored supports it is highlighted that in England, the year 2000 meant coming back to its senses, namely using this kind of support for the execution of over 238 km of underground mines, representing 78% of the total network system of opening and preparing, made for the coal mining industry, effectively contributing to reducing the exploitation expenses by 2.5 from the initial situation. Also, during the past 10 years, the coal sector of the USA used 100 million differently constructed anchors per year, while in South Africa over 65% of underground mines are supported by anchors based on the principle of friction with the surrounding rock.

3. Particularities of anchored supports and their interaction with the surrounding rock

The option of using the anchored support is practically exemplified by its following extremely important particularities, namely [3], [4]:

a – consolidates the rock, forming an increased bearing pillar which is involved in staking over the pressure (Figure 4)

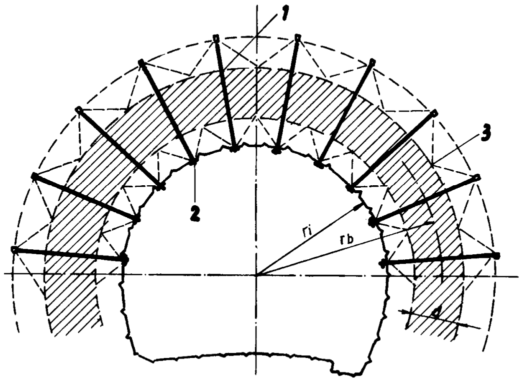

Figure 4 *The creation of the consolidated rock pillar: **1**-metalli anchor (anchoring rod); **2**-pretensioning plate; **3**-consolidated rock pillar; **d**-the thickness of the consolidated rock pillar*

b – develops forces in different spots on the outline of the excavations, which through their action generate the redistribution of tensions and limit the rock deformation process (Figure 5).

c – creates a consolidated arch which amplifies the resistance of rocks and ensures their stability in the conditions of increased traction tensions which are developed within the walls of the excavation (Figure 6).

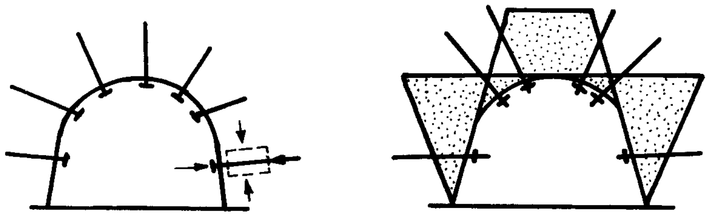

Figure 5 *The influence of the anchored support when developing the additional consolidation forces on the outline of the excavation*

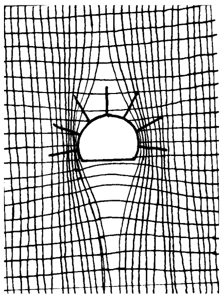

Figure 6 *Redistribution and concentration of traction tensions in the walls of the mine work*

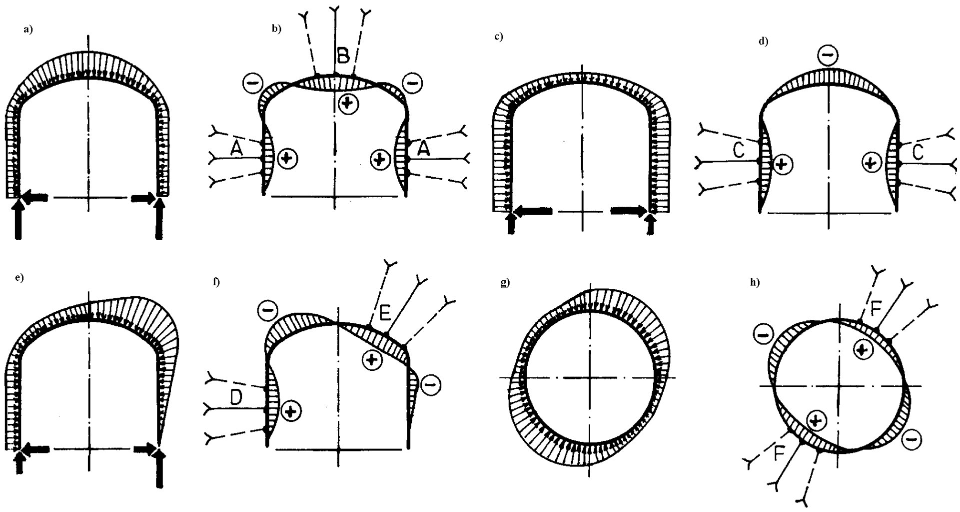

Figure 7 *The formation areas of the maximum arching momentums around the underground excavations for different types of profiles and their loads: **a, b**–the case of the arched profile and the maximum load of the ceiling; **c, d**–the case of the arched profile and the maximum load of the walls; **e, f**–the case of the arched profile and the asymmetric load of the from the ceiling; **g, h**–the case of the circular profile and the maximum vertical load (ceiling and floor)*

The basic principle in placing and using the anchors needs to be represented by the knowledge of the place where the maximum arching momentums are formed, the proportion of which is recorded to be 90% of the total of the main tensions. Consequently, if the actual metallic supports take over most of the loads only from the ceiling of the mine work (Figure 7a), then the maximum arching momentums will be created corresponding to graphical representation in Figure 7b

Therefore, in the action area of the maximum momentums A and B, the most intense rock movements and deformations are observed, scenario in which the placement of the anchors in these areas becomes rational, namely in the ceiling and the wall of the work. The installation of anchors in the walls ensure not only the decrease of the deformations but also decrease of the maximum arching momentums which manifest within the support pillars, favouring the formation and development of additional internal forces which improve the interaction of the “rock-support” system, taking part in the increase and insurance of the stability of the mine work.

On the other hand, during the experimental researches carried out on site confirmed that the installation of the anchors only in the lateral walls of the mine work, where the largest movements and deformations of rocks take place, it is observed a more uniform distribution of tensions on the entire outline and also a decrease of the effort of traction. Therefore, when the rock movement in the wall is predominant, with the development of lateral pressures (Figure 7c), the anchors need to be installed in spot C (Figure 7d). In the case of galleries found under the influence of the coal face, exposed asymmetrically to the stress of the vector of maximum pressure (Figure 7e), the representation of the maximum arching momentums indicates correctly the spot to install the anchors, respectively spots D and E (Figure 7f), namely the efficiency of the obtained stabilisation to be maximum, with a reduced consumption of materials.

For the circular profiles of the mine work, which also bear the asymmetric stress of the pressure (Figure 7g) is rational to place the anchors in spots F (Figure 7h), namely on those sectors on the outline of the work where the deformation tendency of the rocks is going to reach the maximum value.

d – influences the stress regime which is formed during the rock excavation process, which is favourably modified. Therefore, the laboratory experimental researches, carried out through photoelastic methods, have shown a comparative situation between an unsupported ceiling excavation and the models supported by anchors (Figure 8a, b and c).

In the first case (Figure 8a) the stress is focused in the middle of the opening, making the ceiling to expand and to deform. In the model presented in Figure 8b there is a contact-point anchor fixed and therefore the stress is spread around the rod which compresses the area between the two fixing points keeping the ceiling horizontally during the exploitation period of the work. For the model presented in Figure 8c, the anchor fixed integrally redistributes the compression stress around the rod, with favourable stabilisation influences of the rocks of the ceiling. Based on the obtained results it is emphasised that in the case of anchored sections the surface of the rocks is being supported with a normal effort the maximum value of which is found in front of the rods and the support plates, while the minimum value situated in the middle of the interval between two anchors. Around the anchoring rods, the form of the force lines is presented in Figure 9.

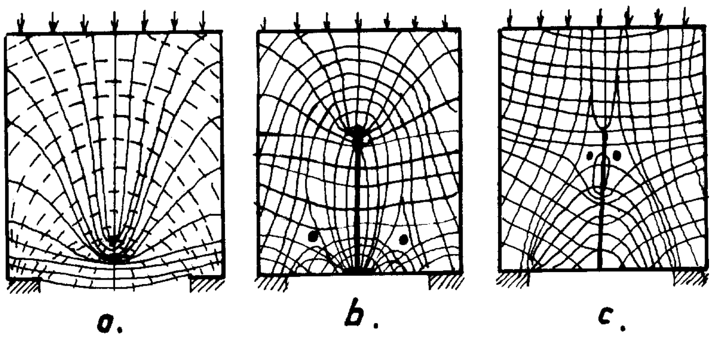

Figure 8 *The representation of efforts considering the ceiling of an excavation: **a**–the case of an unsupported ceiling; **b**–supported ceiling by contact-point anchors; **c**–ceiling supported by plug anchors on its entire length*

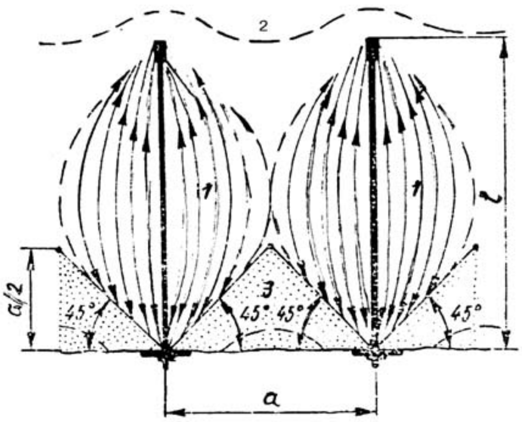

Figure 9 *The repartition of force lines in the package of anchored rocks;* ***1****–the force lines area;* ***2****–the balanced rocks area;* ***3****–uncompressed area*

The rock package is compressed with the value of the force of closure of the rod of its axle which decreases gradually, as it goes further away from the place where the anchor was installed. Therefore, between the rods of the anchors there is an uncompressed area, extending towards the surface of the work, representing a form of cones with the generator tilted at 45° and the height a/2.

The influence of the anchors on the tensions of the massif is conditioned by time as well. As the period of time spend between the excavation to the anchorage is smaller, the rocks expand less and the effect of the anchors is better. When the rocks already record an expansion process, the anchors present only a limited action, increasing their resistance to shearing.

e – compared to the traditional supports, the consolidation of the rock using anchors ensures a more efficient balance in the "rock-support" system, explained by the formation of the consolidate pillar and involving the anchored support in taking over the pressure in a short period of time from its installation (Figure 10).

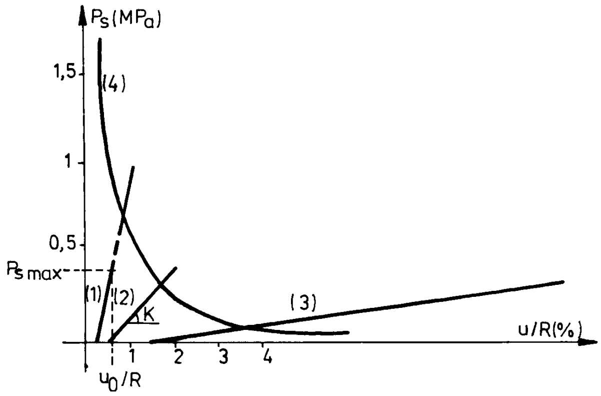

Figure 10 *The role of the consolidation in the interaction "support-rock": U_o – the deformation of the rock around the underground excavation; R-the radius of the minework*

Based on the presented graph, it is observed that for average values of stress, i.e. 0.4 MPa (40 t/m^2), the working characteristic of the concrete or arch brick rigid support (Curve 1) indicates that this type of support suffers total deformation, their characteristic curve being unable to intersect the deformation curve of the rocks around the underground excavation (Curve 4).

In the case of anchored supports (Curve 2), the consolidated rock pillar is formed with an increased bearing capacity and a characteristic almost identical (Curve 1), but, which, due to a higher value of the developed bearing capacity, ensures the corresponding balance with the rock massif.

In the case of elastic supports comprised by the sliding reinforcements, the characteristic working curve (Curve 3) intersects the relaxation curve of the rock after a relatively large interval of time, but for larger deformations of the rock, respectively repeated sliding of elements and reduced values of stress, case in which the balance of the support with the rock and the stability of the mine work are produced for large reductions of the profile of the excavation, the conditions of efficiency not being fully meet.

4. Conclusions

The options for choosing a support adequate to the conditions with a diversified manifestation of the loads around the underground excavation, along with the need to allocate reduced material and labour expenses, they shall also consider the value of the bearing surface of the surrounding rock, possible to realise by the reinforcing them with the help anchored supports.

Corresponding to the constructive and operational characteristics of this type of support, as application steps underground it is imposed to perform the wholes, radial on the outline of the excavation, followed by the implant of the anchoring rods and the installation of the pre-tensioning plates, immediately after unveiling the rocks, disposing them in distant layers on the direction of the work depending on the type of rock met and the type of anchoring system used.

Considering the difficult geomechanical conditions, the anchored support may be associated with concrete supports, having as purpose the protection of the rocks against alteration, which are designed in 2-3 succesive layers with a 2-5cm thickness, above the metallic net foreseen for bandaging.

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