METALLIC SUPPORT WITH REINFORCED ELEMENTS FOR THE EXECUTION OF UNDERGROUND EXCAVATIONS FOUND IN DIFFICULT GEO-MECHANICAL CONDITIONS

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Abstract
The execution of underground mines, namely the works carried out for the opening of the mine and for the preparation of the coal deposit which is the raw material used by heating power plants to create conventional energy, is carried out for different geo-mechanical conditions of the location, beginning with the light ones, with the existence of fixed rocks on the outline to more difficult ones characterised by the presence of unstable rocks and a high degree of changeability in time. For such difficult conditions of the location of the underground mining the present common metallic support built from simple metallic elements used temporarily in an elastic-sliding regime no longer represents an efficient solution both from a technical and economical point of view, being exposed during the enhancement of the loads on the outline of the excavation for accentuated stress and deformation, favouring the sensitively high increase of material and man-hours consumption, exaggerated expenses required for mining / maintenance works during their entire life span. Considering the increase of the efficiency of the support activity of the underground mine in such difficult geo-mechanical conditions, a new metallic support is described hereinafter based on doubling its basic elements. The main operation principle of the new metallic support consists of a temporary behaviour in a first step, when its operation is an elastic-sliding operation followed by a final behaviour when the operation of the support is final, operation obtained by ending the sliding movement of the basic elements and aligning them with the metallic reinforcements.
Key words: *metallic support construction, bearing capacity, interaction mechanism, rock deformation, metallic reinforcements, laminated profiles, attachment flange, operational characteristic of the support relaxation curve of the rock*

1. Introduction

Within the actual construction presented, the metallic sliding support, used 80% of the cases when carrying out underground excavations, respectively mine galleries, is composed of metallic elements (beam and the 2 props) made of laminated profiles with different shapes of the transversal section and weight per meter belonging to the same reduced class, to average, respectively up to 24 Kg/m, which overlap with openings between the shoulders (the case of the old national made laminated profiles) or without openings by connecting them completely (the case of imported laminated profiles). Depending on the geo-mechanical conditions of the location of the underground excavation, the metallic support employed, for which the connection of the elements (beam and the props) is made with the use of attachment flanges, involves the placement of the frames / reinforcements supports at distances up to 1.0 m. Considering the case of difficult sites, with excessive pressures on the outline of the mine work where the geo-mechanics of the massif is affected by the presence of rocks which have a reduced resistance and a high degree of alterability and instability in time at the action of disturbing agents, with a view to take over the stress and ensure the stability of the excavation, this classic support lacking heavy laminated profiles depending on weight (weights higher than 25 kg/m of profile), implies the placement of metallic reinforcement at reduced distances of minimum 0.3 m, influencing the exaggerated increase consumption of materials, man-hours and maintenance costs.

Following the non-correlation of the actual technological excavation requirements and considering the technical-economic efficiency criterion that regards the lack of application for such difficult geo-mechanical areas for the placement of heavy laminated profiles, the finding of a new adequate construction for the support, respectively a support with reinforced elements, is required, based on the increase of the bearing capacity of the metallic reinforcements manufactured for the presently used laminated

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profiles as long as the connection is made at the level of the basic metallic elements of the metallic resistance reinforcements.

2. The construction of the support with reinforced elements

Considering its constructive form and size, the new support construction may be adapted for the execution of underground excavations from simple profiles to double or triple ones, which may be open at the base – the case of GSM, GDM, and GTM profiles or closed circular type profiles – the case of profiles foreseen with bedstone elements such as GSM_V, GDM_V, and GTM_V, respectively the simple circular profile GSIM or the double circular profile GDIM.

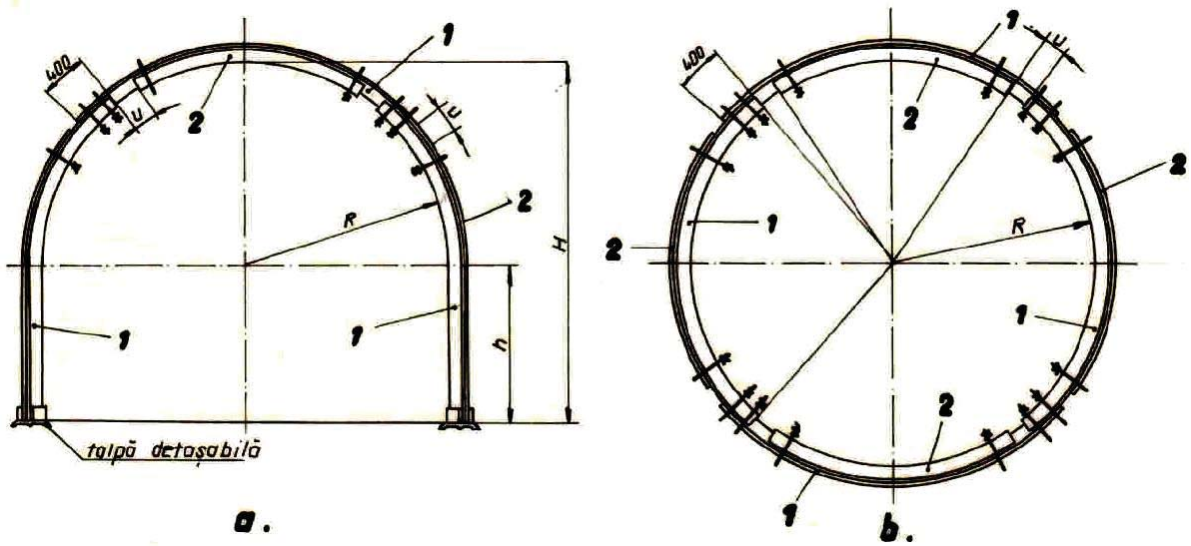

Fig.1 *Double construction metallic support reinforcements:*
a – GDM profile (straight walls and arched roof); b – circular profile; 1 – main supporting elements (base); 2 – metallic support reinforcements; u – the sliding length of the elements

The new support construction presented in Figure 1 a and b implies the use of base metallic elements made of laminated profiles usually used for mine galleries, the connection of which is made without any space between the shoulders at the level of the collar (for the Bulgarian THN 21 laminate and the "U" type Polish flanges), which are foreseen with resistance reinforcements executed from the same type of laminate attached to the base elements with attachment flanges which has the form of a demountable construction assembly [4], [5].

By using this new type of supporting construction, the increase with over 50% of the actual bearing capacity is foreseen in the conditions of a controlled sliding and stiffening of the elements by carrying out the connection between the head of the elements and that of the resistance reinforcements. Therefore, the dimensioning and the use of the exact length for the resistance reinforcements is made considering the dual interaction mechanism i.e. "massif – support" in order to ensure the sliding race of the base metallic elements during the operation of the construction within the elastic-sliding field and the start of the rigid operation regime during which the bearing capacity records its maximum values

The connection and attachment of the main supporting elements is made over distances of 400 mm, with the help of a new type of flanges which shall be used as well for the connection/attachment of the reinforcements to the base.

3. The interaction between different types of supports and the surrounding rock

In order to explain the operating principle of the reinforced support, Figure 2 exemplifies the classic principle of the interaction between the support and the surrounding rock, taking into consideration different types of behaviour in the non-elastic field. [1], [2].

This representation of the classic interaction mechanism highlights the fact that the expansion of the rock and the development of the non-elastic area reduces on one hand the load on the support, load which decrease as the radius of the area increases, and on the other hand leads to the reduction of the resistance of the rock [2], [3], [4].

Considering the obtained results, the hypothesis according to which an area of non-elastic deformities is formed around the horizontal mine work is therefore confirmed, area which is strictly dependent on the geo-mechanical characteristics of the surrounding rock, as well as

on the expansion phenomenon as a result of the breaking of the rocks respectively the appearance of fissures and crushed rocks in the immediate vicinity of the outline of the mine work.

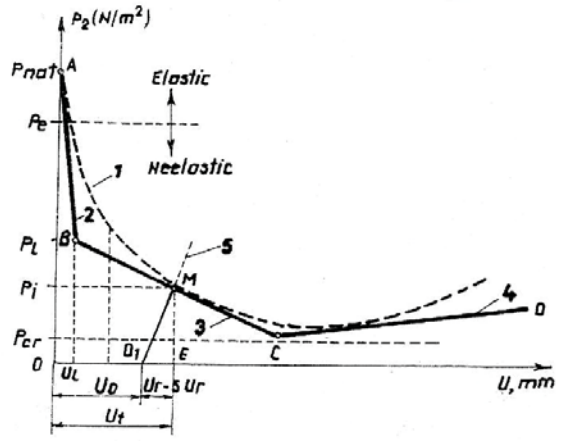

Fig.2 *The classic interaction mechanism between the massif and the support system: **1**-the relaxation curve of the rock; **2**-the elastic behaviour of the rock; **3**-the elastic-plastic behaviour; **4**-the plastic-rigid behaviour; **5**-the characteristic curve of the support; OD_1-the theoretic radial movement; M – the balance point between the rock and the support*

Following the influence of the support (curve 5 from the diagram) on the displacement of the rocks on the outline of the mine work (curve 1) highlights the fact the installation of the support determines the reduction of the deformations (u), but in the same time the increase of the load on the outline (p). In time, the deformations increase to the limit of elasticity of the used support. Thus in order to ensure a better stability of the work the mechanism of the interaction between the support and the rock involves running through two distinct steps:

- Step I, when the behaviour of the support needs to be elastic, and the displacement of the rocks to occur in certain limits of the stresses on the outline of the mine work, together with the assurance of their reduction and redistribution;
- Step II, when the behaviour of the support needs to be a rigid one in order to allow the reduction of the movement assuring therefore the normal functionality of the mine work together with an increased bearing capacity.

The conditions of an adequate interaction within the "rock-support" system are not completely met by either the presently used supports or by the elastic sliding type of supports, the operation of which is exclusively temporary, or by the rigid supports made of bricks or prefabricate reinforced concrete characterised by a definitive operation.

Therefore, considering the metallic sliding supports the applicability of which records a value of over 80% for the execution of horizontal mine works in Jiu Valley, the mechanism of the interaction is partially carried out, this type of support ensuring an almost continuous slide and a relatively limited bearing capacity (120 – 170 kN), depending on the type of laminate used for the execution and the characteristics of the steel used.

Considering the classic metallic structures, the bringing to a halt the deformation of the rocks on the outline of the excavation, carried out in difficult geo-mechanical conditions with the achievement of the balance between the operating characteristic of the support and of the rock for load and stress values equal at least to the superior bearing capacity of the used metallic support, might be possible through the introduction and application of heavy laminated profiles due to their weight for the manufacture of metallic support elements (figure 3), belonging to the TH series profiles (44, 46). This could thus bring forward the significant increase of the consumption of raw materials and man hours for the execution and installation of the support, with highly increased expenses which are not economically justified for the present excavation conditions [1], [5].

In the case of definitive supports, the situation becomes more critical through their completely rigid behaviour, this type of support encourages the intensification of much larger strains on the outline of the mine work without any movement of the rocks and respectively their reduction and redistribution. In such cases, the increase and intensification of the strains on the outline of the mine work, exceeding the resistance to breaking of the construction material produces therefore the destruction of the support, for the rehabilitation of which high consumptions of materials and man hours are necessary, which increased expenses compared to those required for a metallic sliding support.

One ideal support solution for the execution of the underground excavations in difficult geo-mechanical conditions would be the one where the installation in first step of a temporary support made of simple construction metallic reinforcements, and after a certain time interval pre-established taking into account a series of technical and technological parameters of the excavation as well as of the support and of the rocks met on site, the rigid support should be applied. In this case as well, the application of this solution, which uses combined supports, requires an increased period of maintaining the underground excavation in service (over 15 years) besides important initial costs for the application of the support, generated by the consumption of materials and extremely increased man-hours.

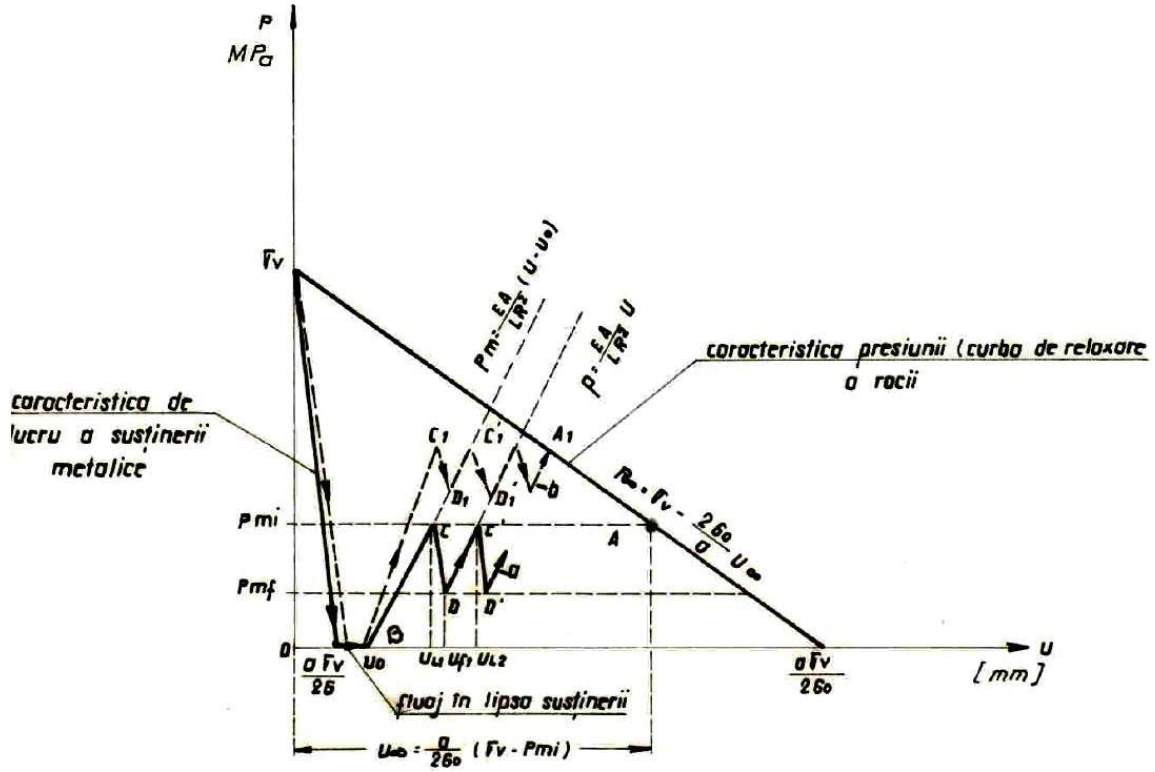

Fig.3 *The diagram for the rock-support interaction considering the temporary operation: a –the working characteristic of the metallic support in the usual actual construction; b-the working characteristic of the metallic support built from superior laminated profiles according to weight; B – contact spot between the support and the rock; BC –the pre-tensioning interval (loading) of the support; CD – the sliding interval (discharge) of the support; A, A_1 – balance points in the rock-support system (A- the case of the actual metallic support; A_1 – the case of the superior bearing support made of heavy laminated profiles)*

4. Working characteristics of the support with reinforced elements

In order to eliminate the constructive and functions inconveniences met in the case of usual classic supports, the researches were directed to find at the level of the support, such as the elastic metallic support as well as the rigid concrete or masonry support, modular solutions which award the possibility to retrieve the level of the same type of support two operation modes, namely an elastic one (elasto-plastic) occurring in a first step, followed by a rigid operation mode.

All these in mind, at the level of the definitive rigid masonry or prefabricated concrete elements support, the solution using drilled bricks placed on the extra-back of the basic support, in order to be sacrificed (destroyed) during the deformation of the rocks, until the stress is reduced to maximum values equal to the minimum bearing capacity of the basic support.

Considering the same interaction principles with the surrounding rock, at the level of the elastic-sliding metallic support, in order to assign the support and the operation in a rigid mode, the reinforced elements were therefore conceived. Therefore, together with the initial role of elastic operation of the support given by the cyclic charge and discharge through the sliding of the basic elements the support also has the role of rigid operation once all the elements are butt joined with the resistance reinforcements. The operation of the reinforced support and the highlight of the two steps and working modes is presented graphically in figure 4 [3], [4].

According to the interaction diagram it is therefore noticed that the reinforced elements the working characteristic of which is represented considering **curve c** on the diagram and which have a superior bearing capacity compared to the actual present support (**curve a**), similar to the support from heavy laminated profiles (reinforced) according to weight (**curve b**) ensure the balance with the massif in the contact point A_2 with the relaxation curve of the rock, point which is situated at a superior level and corresponds to a superior rock pressure which is equal with the bearing capacity of the support, for a deformation of the rock and respectively sliding of the support (**u**) with more reduced values compared to the classic usually used support.

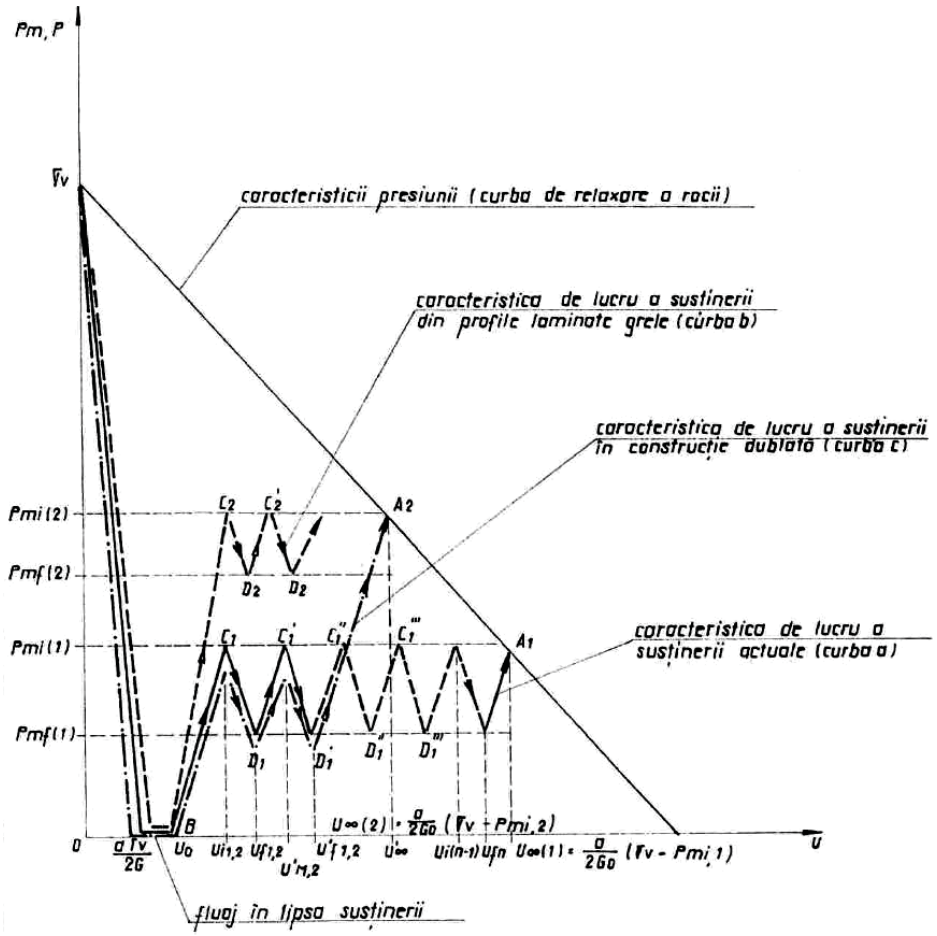

Fig. 4 *Graficul de interacțiune rocă – susținere metalică: A_1, A_2 – puncte de echilibru între susținere și masivul de rocă (rigidizarea susținerii); C,D – puncte limită de pretensionare (încărcare) și, respectiv de descărcare prin culisare ale susținerii la nivel de ciclu; P_{mi}, P_{mf} - presiunile inițială și, respectiv finală exercitate de rocă (portanța susținerii); (u) –deformarea rocii.*

One of the characteristics of the new support construction with reinforced elements is the prognosis of the sliding of the basic elements and the stiffening of the support anticipating how a controlled bearing capacity of the support might be obtained considering the specific conditions of the location of the mine galleries, the type of material used for the execution and the type and dimensions of the profiles used for the galleries.

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