CALCULATION OF SUSTAINING SYSTEM WITH SUPPORT ANCHORS BASED ON THE AREA OF NOT ELASTIC DEFORMATIONS FROM AROUND UNDERGROUND EXCAVATIONS

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Abstract: *Theoretical and Experimental Research on geo-mechanical processes that occur in the execution of underground excavations show that by strengthening the rock with sustaining anchored makes possible the increasing its resistance at shear and traction stress, with forming and involvement of consolidated area, very shortly after completion in taking over the stresses. As a particular expression of its specific work regime, the interaction mechanism in "anchor-rock" system, accepted by most specialists, must be properly elucidated and evaluated, constituting the main argument in the parameters and opportunity calculation of the use of anchored sustaining for different and various conditions and rocks type. In this case, the design of anchored sustaining depends on many factors, depending upon, the technical literature provides a series of hypothesis that seek to characterize the work regime and the calculation of parameters for this type of sustaining, one of which is the hypothesis of non elastic deformation area or of its influence over the secondary status for stress-strain, based on the assumption that the anchors are creating the consolidation of rocks, modifying, in a positive sense, the new created secondary status the stress with their installation, fact that is the subject of this paper.*

Key words: *anchor, massive rock, interaction mechanism, secondary status of stress-strain.*

1.INTRODUCTION

Currently, technical literature presents three hypotheses by which it seeks to characterize the work regime of anchored sustaining, namely [1], [2], [3]:

a - Hypothesis of suspension, where the cracked and disrupted rocks from the area of non elastic deformations are suspended through anchors to the undisturbed massive. In this case, the calculation of anchored sustaining parameters is made by taking into consideration the action of own weight of the

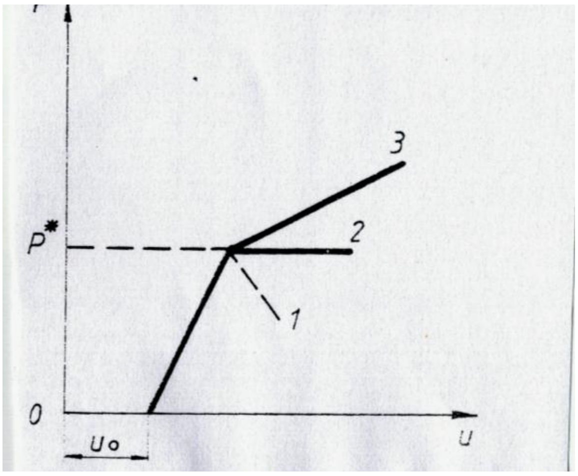
b - The hypothesis of sustaining that considers that the anchors link the rock layers with the result of forming a bearing construction. The calculation, in this case, is made also on the principle of given burdens;

c - The hypothesis of elastic deformation zone or of the influence on the secondary state of stress-strain based on the consideration that the anchors are creating a consolidation of rocks, changing in positive sense the secondary new created state once they are installed.

As object of study and analysis of the present work, according to the latter hypothesis were

suspended rocks;
displacement (Pu)", which can characterize the work regime of different anchor systems (Picture 1): a - anchors, which, once reaching the limit load P *, the lock / link comes out of service losing their work capacity; b - continuous resistance anchors, which upon reaching the limit load P *, their links practically move with no change in load; c -

found three dependencies "load -
anchors of pushing - consolidation. Of practical interest is the third hypothesis, that support meaning the approach of sustaining calculation based on the involvement and influence of the anchor on the secondary state of stress-strain in rock massive, around underground excavations.



Picture 1: The characteristic of work regime of various way of anchorage depending the load - displacement: 1 punctiform anchor; 2 continuous resistance anchor; 3 push – consolidation anchors

The literature dedicated to this calculation method evaluates only the pre-stressing forces of anchored sustaining, without taking into account the forces occurring in the process of interaction mechanism "massive rock - anchors - time". The calculation method that is shown below, gives the possibility to evaluate such forces, the success of approached method for solving the problem is based on the including of some factors with important role in ensuring the stability - reliability of underground excavations, as well as rock strength and deformation characteristics, time and place of sustaining installation, execution method of excavations, the anchors characteristics.

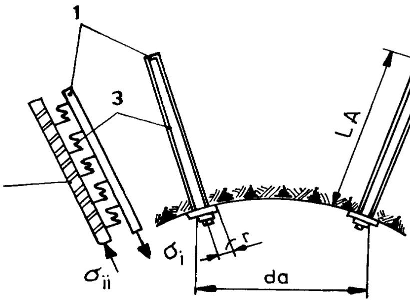
2.ELABORATION OF MAIN SYSTEM OF EQUATIONS

The problem of interaction of massive rock- anchor (Picture 2) must be solved considering [1], [2], [4]:

● massive rock as a linear medium unfavorably, ponderable affected by an excavation;

● anchor bears longitudinal deformations, its action on the massive being replaced with a state of stress σ_i at the two ends of it, balanced by a surface stress state distributed hole surface.

For the calculation is considered, in a section of the excavation system "n" anchors as: length of anchors - L_A; distance between anchors in the section studied - d_A; distance between sections - a_s.



Picture 2 Construction and calculation scheme of anchored sustaining:
1 - anchor rod; 2 massive rock; 3 connection material between the anchor and the massive

In this case, the expression of stress state σ_{ii} of anchor "i" from the studied section, depending on the u_i movements suffered by the anchor, has the form:

$$\sigma_{ii} = \lambda_L \cdot \frac{U_i^P + U_i}{S_{ta}} \text{, N/mm} \qquad (1)$$

where:

λ_L – the longitudinal rigidity of the anchor.

$$\lambda_L = \frac{E_a \cdot S_{ta}}{L_A} \text{, mm} \qquad (2)$$

S_{ta} – cross-sectional area of the anchor rod;

U_i^P – anchor displacement resulted from its pre-stressing;

E_a –the elasticity modulus of anchor rod material performance.

Deformation of rock massive around excavation (ε) is determined by the relation:

$$\varepsilon = \varepsilon^N - \varepsilon^a \text{, mm} \qquad (3)$$

where:

ε^N –the deformation of massive around unsustained excavation;

ε^a – the deformation of massive due to the anchors action:

As consequence, the rock massive displacements corresponding anchor "i" will be: $U_i = U_i^N - U_i^a$, mm (4)

in which:

U_i^N - displacements of unsustained underground excavations;

U_i^a - displacements produced by the anchor action.

Corresponding to the theory of linear deformability of the massive, we can write the relation:

$$U_i^a = \sum_{k=1}^{n} \sigma_k \cdot \delta_{ik} \text{, mm} \qquad (5)$$

Where:

δ_{ik} – coefficients reflecting the influence that σ_k stresses create in the massive as following of rocks displacements that occur in anchor "i".

On the basis of (1) and (5) we obtain: $U_i^a =$

$$\sum_{k=1}^{n} \lambda_L (U_k^N + U_k) \cdot \delta_{ik} \text{, i = 1,2,3...n} \qquad (6)$$

Assessing the relation (4), we get finally to the system of equations of unknown displacements, system that is of matrix type namely:

$$[K]\{U\} = \{U^N\} - \lambda_L \{U^P\} \qquad (7)$$

δ_{ik} coefficients, which express the influence of anchors in neighboring sections also, not only in the considered section, can be determined according to the relation:

$$\delta_{ik} = \frac{1-\mu^2}{E} \cdot \left[\frac{3 - 4\cdot\mu}{8\cdot(1-\mu^2)} + 1 \right] \cdot \left(\frac{1}{d_{(A)ik}} - \frac{1}{\sqrt{d^2_{(A)ik} + L^2_A}} \right) \qquad (8)$$

3.EVALUATION OF ROCKS CREEP

The experimental research reveals that in son situations, the stresses in anchors grow over tin on the installation sustaining regime ar finds applicability in the rocks creep arour underground excavations. In this case, tl solving of rock creep involvement in stres strain state of the massif can be achieved on the principles of heredity theor i.e. by replacing the elastic constants E and with creep operators E_t and μ_t, of type [2], [4

$$E\cdot\left[f(t)-\int_{\tau o}^{t} f(\tau)\cdot L(t,\tau)\cdot\delta_\tau\right] \qquad (9)$$

and in other cases fall. Such a phenomenon depend

In the case when the anchors are mount right to the cutting edge and, as a result the cre history of the system begins after the anchoring, t U_i^N (t) component will be as follows:

$$U_i^N(t)$$

$$\frac{\gamma_a\cdot H\cdot d_a}{4\cdot G_t}\cdot\frac{L_A}{1+L_A}\cdot\left\{1+\xi-(1-\xi)\left[(3-4\cdot\mu_t)-\frac{1}{1+L_A}-\frac{1}{(1+L_A)^2}\right]\cos\left(\frac{4\pi}{n}\right)\right\} \qquad (10)$$

Where the operators G_t and $(1+\mu_t)$ $\frac{3-4\cdot\mu_t}{E_t}$ are have the form of:

$$G_t = 2\cdot\frac{1+\mu}{E}\ [1+\left[1+\frac{3\cdot\beta}{1+\mu}\cdot\exists_\alpha(o)\right]\exists_\alpha(o)] \qquad (11)$$

$$(1+\mu\cdot t)\cdot\frac{3-4\mu_t}{E_t}=\frac{(1+\mu)(3-4\mu)}{E_t}\left[1+\beta\cdot\frac{(1-2\mu)}{(1-\mu)\cdot(3-4\mu)}\cdot\exists_\alpha+\frac{3\cdot\beta\cdot\exists_\alpha(o)}{2\cdot(1+\mu)\cdot(3-4\mu)}\right] \qquad (12)$$

where: $\exists_\alpha(o)=\frac{t^{1-\alpha}}{\Gamma(2-\alpha)}$ and $\beta = \delta_\Gamma\,(1-\alpha)$, and $\Gamma(1-\alpha)$ and $\Gamma(2-\alpha)$ represent the "gamma" function; α, β, δ are the creep parameters of the rock.

Considering the simultaneous installation of anchors, the system is according to relation (7), with the evaluation of time operators, it can be written as follows:

$$[K(t)]\{U\} = \{U^N\}[1+f(t)-\lambda_L]\ \{U^P\}[1+\varphi(t)] \qquad (13)$$

where:

f(t), φ (t) – creep functions (φ(t)= 0 and f(t) = 0);

K(t) – the system matrix whose elements depends on the time ([k(t)] = [k].

Solving equation (13), for the set the values of t, it is obtained the history stress-strain state of the anchoring system. Thus, if during the anchors mounting is $t_{ma} \neq 0$, it means that they are mounted after a certain period from the uncovering of rock, then the relation will be the following:

$$[K(t)]\{U\} = \{U^N\}[(1+f(t)+t_{ma})-f(t_{ma})-\lambda_L]\{U^P\}[1+\varphi(t)] \qquad (14)$$

On the other hand, evaluating the distance from the anchors mounting place to face of mining excavation work, and the time of their entry into service, the relation becomes of the form:

$$[K(t)]\{U\} = \{U^N\}[(1-\psi(Z_{ma})+f(t)+t_{ma})-f(t_{ma})-\lambda_L]\{U^P\}[1+\varphi(t)] \qquad (15)$$

For different conditions of mounting the sustaining, by combining the values of Z_{ma} ucceeded to explain the right side of system, as shown in Table 1

Table 1 Explanation of equations system of the unknown movements for different anchoring conditions

No.	**Description of anchoring conditions**	**Parameter values**		**Equation system** [K(t)] {U}=
		T ma	**Z ma**	
1.	Immediately mounting after the rock unveiling, directly in edge of excavation	0	0	$\{U^N\}[1-\psi(o) + f(t) - \lambda_L]\ \{U^P\}[1-\varphi^*(t)]$ (16)
2.	Anchors mounting at some distance from the cutting edge, where the occurred elastic deformations are complete	t_{ma}	Z_e	$\{U^N\}[f(t-t_{ma}) - f(t_{ma}) - \lambda_L]\ \{U^P\}[1-\varphi^*(t)]$ (17)
3.	Anchors mounting after t_{stab}. Meaning at Z_e distance	t^*_{stab}	Z_e	$-\lambda_L\ \{U^P\}[1-\varphi^*(t)]$ (18)

$*t_{stab}$. and $\varphi^*(t)$ are determined by the creep behavior of rocks where excavation is done

Analysis of expressions from the right side of the system depending on the place and time of anchors mounting, confirms the practical results, namely that the most effective applied anchoring method is to the excavation edge.

The dimensioning calculation presented has a general character and it can be applied to determine the parameters for all types of anchors, making it easier, on the other hand, the approach of designing the anchored sustaining by elucidating the interaction of sustaining system with the surrounding rock massive of underground excavation, the determination of the forces that occur in the anchors, as well as predicting secondary stress-strain state of sustained rock massif, together with the evaluation of stability degree the of the rocks and respectively of the excavation.

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