Determination of Working Support Safety Factor at Great Heads of Mine Water

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ABSTRACT

The method of determining the safety factor of concrete or ferro-concrete linings under the pressure of substantial underwater heads in mine workings is proposed. The method allows one to obtain the lining safety factor at different combinations of load from the rock's own weight and mine water pressure.

The methods of designing monolith concrete and ferro-concrete linings for permanent mine workings undergoing the action of the rock's own weight and water pressure, allowing the presence of a plugged-up rock zone around the working and possible water filtration through that zone and the lining, to be taken into account have been elaborated at Tula State Technical University and described in papers [1, 2].

The technique of designing a monolith lining of the workings of an arbitrary cross-section (with one axis of symmetry) is based upon the solution of the plane contact problem concerning the equilibrium of a double-layer noncircular ring (the inner layer simulates the lining, the outer one simulates the plugged-up rock zone) in a linearly deformable infinite medium, simulating the rock massif. The general designed scheme is given in Figure 1.

The medium S_1, simulating the rock massif is characterised by the deformation modulus E_1 and Poisson ratio ν_1. The outer ring layer S_2 of Δ_1 thickness, the material of which has a deformation modulus E_2 and a Poisson ratio ν_2 simulates the plugged-up rocks zone, the inner layer S_3 of Δ_2 thickness with E_3, ν_3 characteristics simulates the working lining.

The action of rock's own weight and the uniform underground water pressure is simulated by assigning initial stresses resulting from gravitation, and the residual heads filtering through the plugged-up zone and the lining water in fields S_1 and S_2 (Figure 1). Initial stresses are determined in accordance with the standardised document [3] and by applying formulae (i = 1, 2):

$$\sigma_x^{(i)(0)} = -\gamma\,H\exp(-1.3\,l/R_2) - \gamma_w\,H_e\,f_i$$

$$\sigma_y^{(i)(0)} = -\lambda\gamma\,H\exp(-1.3\,l/R_2) - \gamma_w\,H_e\,f_i \qquad \ldots (1)$$

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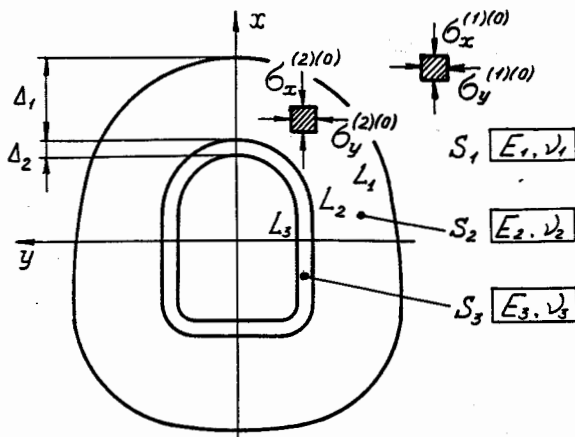
Figure 1. Designed scheme.

where :

γ = rock specific gravity,
H = depth of working,
λ = lateral pressure coefficient in an intact rock massif,
l = distance of the lining being constructed from the working face,
γ_w = water specific gravity,
H_e = underground water level relative to the co-ordinate origin.

$$f_1 = \frac{\dfrac{1}{K_3}\ln\dfrac{R_2}{R_3} + \dfrac{1}{K_2}\ln\dfrac{R_1}{R_2}}{\dfrac{1}{K_3}\ln\dfrac{R_2}{R_3} + \dfrac{1}{K_2}\ln\dfrac{R_1}{R_2} + \dfrac{1}{K_1}\ln\dfrac{R_t}{R_1}}$$

$$f_2 = \frac{\dfrac{1}{K_3}\ln\dfrac{R_2}{R_3}}{\dfrac{1}{K_3}\ln\dfrac{R_2}{R_3} + \dfrac{1}{K_2}\ln\dfrac{R_1}{R_2} + \dfrac{1}{K_1}\ln\dfrac{R_t}{R_1}}$$

... (2)

R_1, R_2 and R_3 are the average radii of the outlines; L_1, L_2 and L_3 correspondingly; K_1, K_2 and K_3 are the coefficients of filtration of the massif, the plugged-up rock's zone and the lining material correspondingly; R_t is the conditional radius of feeding [3].

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Layers of the ring and the medium undergo deformation together, that is conditions of displacements and full stresses vectors continuity are fulfilled upon the L_i (i = 1, 2) lines of contact. The inner outline L_3 is free from loads.

The elasticity theory problem set forth has been solved in papers [1, 2] with the application of the apparatus of the complex variables analytic functions, conformal transformations and complex series [4]. Registration of tough-elastic deformation of rocks may be made on the basis of linear haridatory creepage theory applying the alternative modulii technique [5], according to which rock deformation characteristics being included in the solution of the elasticity theory problem are given in the time functions form.

The described method allows the stresses and inner forces in the lining, namely: the normal σ_ρ^{ex} and shear $\tau_{\rho\theta}^{ex}$ stresses upon the external outline L_2 of the lining cross-section, the normal tangential stresses σ_θ^{ex}, σ_θ^{in} upon the external L_2 and the internal L_3 outlines correspondingly, the N longitudinal forces and the M bending moments to be determined.

Applying strength conditions :

$$- \sigma_{\theta min} \leq R_{\beta c} \quad , \qquad \sigma_{\theta max} \leq R_{\beta t} \quad , \qquad \ldots (3)$$

where $\sigma_{\theta min}$, $\sigma_{\theta max}$ are minimal and maximal normal tangential stresses out of those appearing upon the inner and outer outlines L_3, L_2 (here we assumed the sign "plus" for the tensile stresses if they take place), $R_{\beta c}$, $R_{\beta t}$ are the designed strength of the lining material upon compression and tension correspondingly, the K_s lining safety factor may be determined by the formula:

$$
Ks =
\begin{cases}
\min\left[-\dfrac{R_{\beta\,c}}{\sigma_{\theta\,min}} \, , \, \dfrac{R_{\beta\,t}}{\sigma_{\theta\,max}} \right] & \textit{if tensile stresses appear} \\[4mm]
-\dfrac{R_{\beta\,c}}{\sigma_{\theta\,min}} & \textit{if tensile stresses do not appear}
\end{cases}
\qquad \ldots (4)
$$

A computer programme has been written. Results of designing the lining of an arched form mine working with a 3 m span and a 2.5 m height upon the action of the rock's own weight and underground water pressure are given as illustrated below.

The following input data were assumed: working depth H = 150 m, rock's specific gravity γ = 18.5 kN/m^3, rock lateral pressure coefficient λ = 0.43 distance between constructed lining and working face 1 = 1.4 m, underground water level H = 40 m, water specific gravity γ_w = 10 kN/m^3, plugged-up zone thickness Δ_1 = 2 m, lining thickness Δ_2 = 0.3 m, deformation and filtration characteristics of the massif, plugged-up rocks and the lining material E_1 = 4800 MPa, ν_1 = 0.3, K_1 = 0.19 10^{-5} m/s, E_2 = 9600 MPa, ν_2 = 0.3, K_2 = 0.5 10^{-6} m/s, E_3 = 24000 MPa, ν_3 = 0.2, K_3 = 1.83 10^{-8} m/s correspondingly, conditional radius of feeding [3] R_t = 120 m.

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Results of the design are given in Figure 2 in the form of plots of normal σ_ρ^{ex}, MPa and shear $\tau_{\rho\theta}^{ex}$, MPa stresses upon the external outline of the lining cross-section (Figure 2a), normal tangential stresses upon external σ_θ^{ex}, MPa and internal σ_θ^{in}, MPa outlines (Figure 2b), longitudinal forces N, kN and bending moments M, kN.m in the lining (Figure 2c).
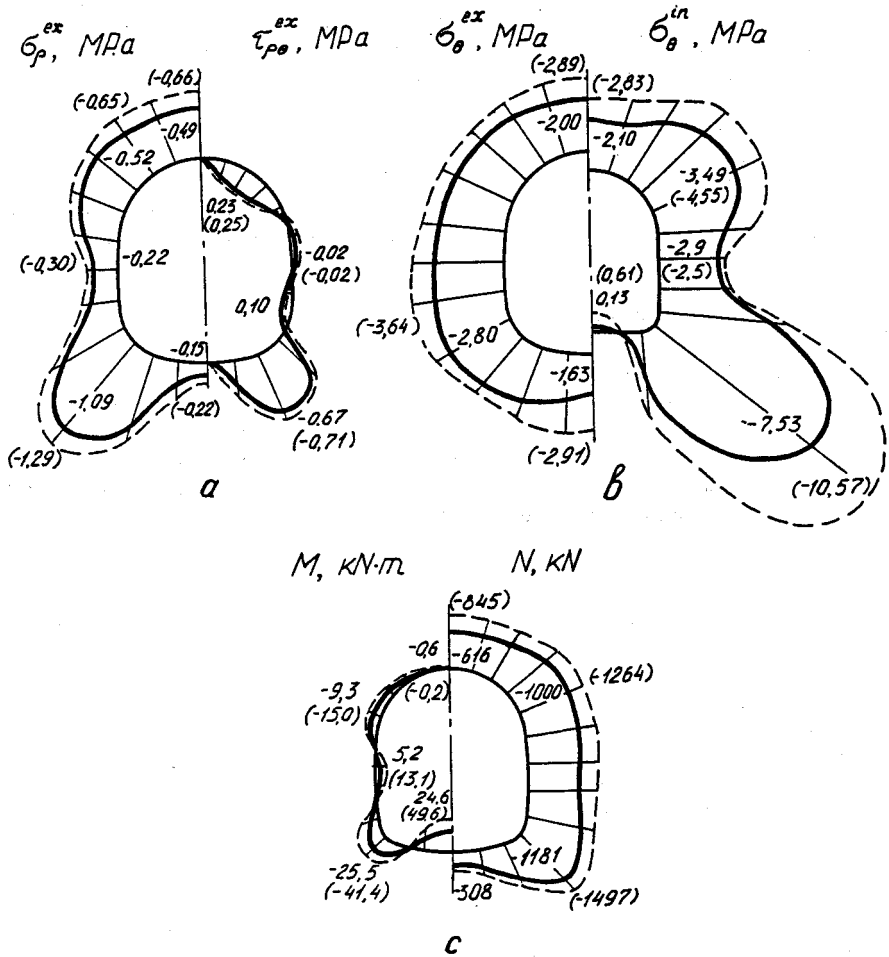

Figure 2. Plots of stresses and internal forces in the lining.

For comparison plots of the same stresses and forces (numerical values are given in brackets) in the lining constructed without the plugged-up curtain are shown in dotted lines.

Calculations have shown the safety factor for considered lining at the presence of plugged-up zone to be $K_s = 1.2$, and without that zone to be $K_s = 0.85$. Therefore, in the

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considered case the lining without a plugged-up zone does not possess the necessary bearing capacity and the presence of a plugged-up rocks zone results in an increase in the lining safety factor.

REFERENCES

1. Fotieva, N.N. and Sammal, A.S. Design of the closed monolithic lining with the rock strengthening taken into account. Proc. of the 9th Plenary Scientific Session of the Int. Bureau of Strata Mechanics. Rotterdam, pp. 163-167 (1986).

2. Fotieva, N.N., Bulychev, N.S. and Sammal, A.S. Design of mine working monolith lining upon the action of underground waters. Proc. of the 4th Int. Mine Water Assoc. Congr. Vol. 2, pp. 31-51 (1991).

3. Manual in Designing Underground Mine Working and Lining Construction. Moscow, Stroyizdat, 272 pp. (1983).

4. Muschelishvili, N.I. Some basic problems of the mathematical elasticity theory. Moscow, Nauka, 708 pp. (1966).

5. Amusin, B.Z. and Linkov, A.M. On the application of the variable modulus method for solution of one class of linear heridatory creeping problems. Proc. of the USSR Acad. of Sci. Mech. of a Solid Body. Vol. 6, pp. 162-166 (1974).