Witold Paleczek

THE RELATION BETWEEN THE RADIUS OF THE MAIN INFLUENCE RANGE AND THE OVERBURDEN STRATUM RIGIDITY

The aim of this analysis is to confirm the existence of the relationship between the values of the terrain and rock mass distortion index and the mechanical properties of rock. The rock mass model is here considered a multilayer medium meeting all the conditions of a stochastic medium introduced by J. Litwiniszyn. The medium of such a kind is well described by the applied theory of W. Budryk-S. Knothe [1-3]. In the model subjected to analysis each layer is characterized by its thickness, occurrence depth and empirical rigidity index of the μ_i layer. The definition of the proposed stratum rigidity index remains an open question since it is an empirical index analyzed here (to put it simply) as a function of two variables [3]. The variables are the uniaxial rock compressive strength R_c and the rock softening index $M = R_{cn}/R_c$. Possessing all the data from geological sections a rock mass may be described in terms of its rock strength (as a parameter regarding rock material) or rock stratum rigidity (as a geometrical rock mass parameter). The above mentioned characteristics may constitute especially in the case of an intact rock mass a basis for a further forecast of the influence of underground mining not effected yet. In such cases the average value of rock mass rigidity $\mathrm{tg}\beta \cong 2$ [1-3] is usually taken for analysis. It would be unthinkable not to mention here the factors that influence rock strength such as the deposition depth, geothermal gradient, rock pressure, layer order, saturation gradient, degree of tectonic engagement, and many more. Thus, as more and more adequate data is obtained, the proposed function may be expressed as a function of more than just two variables by finding a mutual correlation between the mentioned factors, provided that the factors can be described in the form of exact numerical discrete data (within an appropriate range) [1].

1. Factual basis of the issue

In the proposed and analyzed model the following assumptions have been made:

– rock mass influence function is in its shape similar to the resultant from the loose material model analyzed by J. Litwiniszyn and the rock mass model assumed in the W. Budryk-S. Knothe theory,
– meeting in the model the requirements (postulates) in accordance with [1: p. 196]: transitivity, convergence, homogeneity, superposition, non-negative result,
– rock mass undisturbed by previous mining,
– rock mass and bedded deposit probed with test bore-holes,
– multilayer rock mass model with diversified depth and compactness of each strata (without taking into consideration the degree of tectonic involvement since the value has not been sufficiently well described in numerical terms),
– ground settlement coefficient a (within the range between 0 and 1) corresponding with the percentage degree of unfilled void after exploitation,
– correlating the influence function on the basis of the empirical (scale) stratum rigidity index.

The scale stratum rigidity index applied in the model of the values assumed in the analysis has been expressed using an empirical formula as a function of two variables: the uniaxial rock compressive strength R_c and the rock softening index $M = R_{cn}/R_c$. The function model has been expressed using the approximate formula [3]:

$$\mu = \frac{\xi_0}{\xi_1 + \xi_2 \cdot \exp\left(\xi_3 \cdot \frac{R_{cn}}{R_1}\right) - \xi_4 \cdot \exp\left(\xi_5 \cdot \frac{R_{cn}}{R_c}\right)} \tag{1}$$

in which the estimated values of the ξ_i parameters have been respectively assumed:

$$\xi_0 = 1,\ \xi_1 = 2,\ \xi_2 = \frac{4}{5},\ \xi_3 = -\frac{1}{50},\ \xi_4 = \frac{3}{5},\ \xi_5 = \frac{1}{2}$$

and individual symbols stand for:
R_c - uniaxial rock compressive strength; $R_c > 0$ [MN/m^2];
R_1 - unitary strength [$R_1 = 1$ MN/m^2];
R_{cn} - uniaxial rock compressive strength in a saturated state [MN/m^2].

It is worth pointing out that the values R_c of the floor and roof samples of the same layer differ considerably whereas it happens that rock strength tests are conducted on samples removed from one place in a massif only. R_c values differ considerably despite identical geological names of rock.

In the projected multilayer model (overburden) consisting of n layers the radius of the main influence range can be expressed using the formula [3]:

$$r = r_n = \sum_{i=1}^{i=n} r(z_i;\mu_i) - \sum_{i=2}^{i=n} r(z_i;\mu_{i-1}) \quad \text{for} \quad i = 1,2,3,\ldots,n \tag{2}$$

in which:

z_i - deposition depth of i-layer, where z_0 corresponds to the terrain surface.

The radius r corresponding to an individual layer z has been expressed using the formula:

$$r = \mu \cdot \left[(1-a) \cdot \sqrt{\left(\frac{H}{1+\frac{a}{\chi}} \right)^2 - \left(z - \frac{a \cdot H}{a+\chi} \right)^2} + a \cdot (H - z) \right] \tag{3}$$

in which:

$\chi = \sqrt{1 - 2 \cdot a + 2 \cdot a^2}$,

H - exploitation depth,

a - percentage degree of unfilled void after exploitation.

2. Analyzed computational variants

In the analysis presented there are examined combinations of the layer L_i rigidity index in rock mass at a constant layer thickness with an assumption that the overlying rock consists of three layers L_1, L_2, L_3 of geological material (sedimentary rock) of the following thicknesses: $L_1 = 70$ [m], $L_2 = 130$ [m], $L_3 = 250$ [m], hence the deposition depth of the floor forecast for mining: $H = L_1 + L_2 + L_3 = 450$ [m]. All the possible combinations of the overburden arrangement are examined and expressed in the following variants (for calculations the value $a = 0{,}5$ has been assumed).

Variant I:

Combination of the rigidity stratum index starting from the surface:

$$L_1 \Rightarrow \mu_1 = 0.5;\ L_2 \Rightarrow \mu_2 = 0.75;\ L_3 \Rightarrow \mu_3 = 1$$

thus

$$r_I = r_{11}(z_1 = 0; \mu_1 = 0.5) + r_{22}(z_2 = 70; \mu_2 = 0.75) + r_{33}(z_3 = 130; \mu_3 = 1) - [r_{21}(z_2 = 70; \mu_1 = 0.5) + \\ + r_{32}(z_3 = 130; \mu_2 = 0.75)] \cong 308 \text{ [m]}$$

and

$$\mathrm{tg}\beta_I = \frac{H}{r_I} \cong 1.46$$

Variant II:

Combination of the rigidity stratum index starting from the surface:

$$L_1 \Rightarrow \mu_1 = 0.5\,;\; L_2 \Rightarrow \mu_2 = 1\,;\; L_3 \Rightarrow \mu_3 = 0.75$$

thus

$$r_{II} = r_{11}(z_1 = 0; \mu_1 = 0.5) + r_{22}(z_2 = 70; \mu_2 = 1) + r_{33}(z_3 = 130; \mu_3 = 0.75) - [r_{21}(z_2 = 70; \mu_1 = 0.5) + \\ + r_{32}(z_3 = 130; \mu_2 = 1)] \cong 241\,[\mathrm{m}]$$

and

$$\mathrm{tg}\beta_{II} = \frac{H}{r_{II}} \cong 1.87$$

Variant III:

Combination of the rigidity stratum index starting from the surface:

$$L_1 \Rightarrow \mu_1 = 0.75\,;\; L_2 \Rightarrow \mu_2 = 0{,}5\,;\; L_3 \Rightarrow \mu_3 = 1$$

thus

$$r_{III} = r_{11}(z_1 = 0; \mu_1 = 0.75) + r_{22}(z_2 = 70; \mu_2 = 0.5) + r_{33}(z_3 = 130; \mu_3 = 1) \\ - [r_{21}(z_2 = 70; \mu_1 = 0.75) + r_{32}(z_3 = 130; \mu_2 = 0.5)] \cong 306\ [\mathrm{m}]$$

and

$$\mathrm{tg}\beta_{III} = \frac{H}{r_{III}} \cong 1.47$$

Variant IV:

Combination of the rigidity stratum index starting from the surface:

$$L_1 \Rightarrow \mu_1 = 0.75\,;\; L_2 \Rightarrow \mu_2 = 1\,;\; L_3 \Rightarrow \mu_3 = 0.5$$

thus

$$r_{IV} = r_{11}(z_1 = 0; \mu_1 = 0.75) + r_{22}(z_2 = 70; \mu_2 = 1) + r_{33}(z_3 = 130; \mu_3 = 0.5) \\ - [r_{21}(z_2 = 70; \mu_1 = 0.75) + r_{32}(z_3 = 130; \mu_2 = 1)] \cong 171\ [\mathrm{m}]$$

and

$$\mathrm{tg}\beta_{IV} = \frac{H}{r_{IV}} \cong 2.63$$

Variant V:

Combination of the rigidity stratum index starting from the surface:

$$L_1 \Rightarrow \mu_1 = 1;\ L_2 \Rightarrow \mu_2 = 0.75;\ L_3 \Rightarrow \mu_3 = 0.5$$

thus

$$r_V = r_{11}(z_1 = 0; \mu_1 = 1) + r_{22}(z_2 = 70; \mu_2 = 0.75) + r_{33}(z_3 = 130; \mu_3 = 0.5) - [r_{21}(z_2 = 70; \mu_1 = 1) + \\ + r_{32}(z_3 = 130; \mu_2 = 0.75)] \cong 169\ \text{[m]}$$

and

$$\text{tg}\beta_V = \frac{H}{r_V} \cong 2.66$$

Variant VI:

Combination of the rigidity layer index starting from the surface:

$$L_1 \Rightarrow \mu_1 = 1;\ L_2 \Rightarrow \mu_2 = 0.5;\ L_3 \Rightarrow \mu_3 = 0.75$$

thus

$$r_{VI} = r_{11}(z_1 = 0; \mu_1 = 1) + r_{22}(z_2 = 70; \mu_2 = 0.5) + r_{33}(z_3 = 130; \mu_3 = 0.75) - [r_{21}(z_2 = 70; \mu_1 = 1) + \\ + r_{32}(z_3 = 130; \mu_2 = 0.5)] \cong 236\ \text{[m]}$$

and

$$\text{tg}\beta_{VI} = \frac{H}{r_{VI}} \cong 1.91$$

For the sake of monitoring the presented analysis has been also carried out with use of the finite element method assuming rock mass layers in a disc arrangement. The results from FEM confirm with good approximation the results obtained from variants I-VI [3].

Conclusions

It appears from the carried out analysis that having assumed in calculations, for example, value $\text{tg}\beta \cong 2$ for average overburden conditions (applying analogies of the stratum depth and type of rock in the overburden) we may expect the value of this parameter within the range: $1.46 \le \text{tg}\beta \le 2.66$. It is worth mentioning that the values $\text{tg}\beta$ assumed in forecasts are often used for determining the limits of protecting pillars. Assuming in the deformation forecast the value $\text{tg}\beta$ resulting from the observation of the depression of the appearing troughs (most often troughs in a transient state) it is rather debatable to use the term forecast since in that case we rather deal with the analysis of an existing state. The presented results of the analysis may constitute a ground for setting the direction for further research regarding the relations between the surface distortion coefficient and the mechanical properties of rock.

References

[1] Ochrona powierzchni przed szkodami górniczymi, praca zbiorowa pod redakcją M. Boreckiego, Wydawnictwo Śląsk, Katowice 1980.

[2] Knothe S., Prognozowanie wpływów eksploatacji górniczej, Wydawnictwo Śląsk, Cieszyn 1984.

[3] Paleczek W., Metoda określania wielkości i zasięgu deformacji powierzchni terenu powodowanych podziemną eksploatacją złóż z uwzględnieniem własności geomechanicznych skał górotworu, Studia z Zakresu Inżynierii nr 58, Instytut Podstawowych Problemów Techniki, Komitet Inżynierii Lądowej i Wodnej, Polska Akademia Nauk, Warszawa 2007.

Abstract

This is an analysis of the influence of the changes in the overburden rigidity on the alteration of the radius of the main influence range and the changes of the main influence range angle in a rock mass as parameters of the theory of forecasting the influence of mining on the surface and rock mass. The results obtained justify the view that in order to forecast the value of the terrain and rock mass distortion index, computational models that encompass the relations resulting from the mechanical properties of rocks such as uniaxial compressive strength R_c can be applied.

Streszczenie

Przedstawiono analizę wpływu zmian sztywności warstw nadkładu na zmiany promienia zasięgu wpływów głównych oraz na zmiany kąta zasięgu wpływów głównych w górotworze jako parametrów teorii prognozowania wpływów eksploatacji górniczej na powierzchnię i górotwór. Otrzymane wyniki uzasadniają pogląd, że w celu prognozowania wartości wskaźników deformacji terenu i górotworu można zalecać modele obliczeniowe, które ujmują związki wynikające z mechanicznych własności skał, jak na przykład wytrzymałość doraźna na jednoosiowe ściskanie R_c.