Journal of Engineering and Applied Sciences 12 (5): 1097-1101, 2017
ISSN: 1816-949X


# New Approach to Contact Pressures Determination Provided to Layer Soil by the Basis of Lining One Row Shield Section

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**Abstract:** During the attachment of a highwall mining in the process of a lining section thrust the collapse of a culm contact layer and the roughness of the soil as well as the local introduction of foundations takes place. The current state standard of Russia, establishing the basic parameters and general technical requirements for mechanical linings only the average pressure on a layer soil is regulated. However as practice shows the focus on medium pressures does not correspond to the real operation conditions for mechanical linings and the standard needs a serious adjustment in this respect. The method is offered which provides the calculation of contact pressures on a layer soil, provided by a foundation beam along the length of a lining single-row shield section, taking into account not only the efforts of hydraulic props but also the efforts in rear fence levers.

**Key words:** Lining section, thrust, layer soil, hydraulic prop, foundation beam, contact pressures, rear fence levers

## INTRODUCTION

During the underground excavation of coal at long highwall minings one of the essential technology elements is the attachment of a face space by a mechanized lining and the management of rock pressure. At that during the thrust of mechanized lining sections the deformation of a culm contact layer and soil roughness as well as the local introduction of foundations or lining section plowing Δ takes place (Fig. 1). In this case the resistance R of the lining is being decreased.

**Formulation of research problems:** Traditionally a working resistance of a mechanized lining section is determined according to the Equation (Horin,1988) during its presesing into the ground ($P_c^!$):

$$P_C^! = K\frac{P_C\sigma_{BD}}{\sigma_k},\ kH \quad (1)$$

where:

$$P_C = P_L\cdot t = Q_{kp}\cdot t \quad (2)$$

lining section resistance, kH

Where:

- t = Lining section placement step (m)
- K = 0.67 = The coefficient which takes into account an uneven nature of contact stresses under a lining section foundation
- $\sigma_{BD}$ = Soil resistance value to indentation (MPa)

$$\sigma_k = P_c/S_{ocH}$$

The average surface pressure of a lining section base on a layer soil (MPa). Here: $S_{ocH}$, the area of lining section foundation ($m^2$). At that the study by Jacobi (1987) and Korovkin (1990) determined that during the thrust of lining sections the tips of rigid structure foundations make a high pressure on a layer soil and are pressed into it. Consequently, the Eq. 1 focus on the average specific base pressure of a lining section on a layer soil $\sigma_к$ does not correspond to its real value. It should be noted that the current state standard of Russia which establishes the basic parameters and general technical requirements for mechanized linings (Gost, 2003), regulates only mean pressure on a layer soil-up to 2.0 MPa for soft rocks and above 2.0 MPa for the solid rocks of a soil. However, as practice shows, the focus on medium pressures does not correspond to the real conditions of mechanized linings operation and the standard needs a serious adjustment in this regard.

As a rule, the hydraulic stands $2P_1$ on the foundations consisting of 2 beams and the levers of a hinged system $2T_1$ and $2T_2$ (Fig. 1) are located along a beam and along its axis. Each of the beams of a two beam foundation is a resilient beam, deformable along the length from the action of rack concentrated loads and 2 arms attached to its longitudinal axis.

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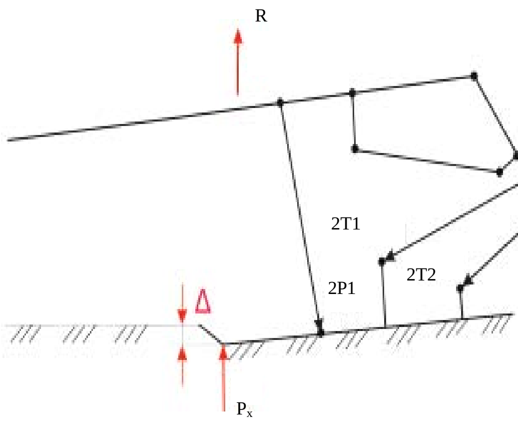


Fig. 1: Lining section burying in a layer soil

A direct soil layer is considered as a homogeneous elastic medium, characterized by an elastic modulus and poisson's ratio. This approach is adopted according to the study results of mechanized lining section interaction with rock walls, carried out in Russia and in Germany (Jacobi, 1987). The role of a mechanized lining section foundation (a beam) is in the distribution of concentrated forces on soil. These forces are provided by struts and rear fence levers with a section thrust and the manifestation of an active rock pressure.

The beam of a lining study foundation is regarded as a thin elastic beam. It does not take into account the friction force between a beam and a soil. Florin and Zhemochkin showed in their studies that the effect of friction between a beam base and a ground (soil) has little effect on the distribution of stresses along a beam sole. Mehrian studied the stress distribution of a shell and plate under different type of loading (Nowruzpour Mehrian *et al*., 2013 a,b, 2014, 2015; Mehrian and Mehrian, 2015; Vaziri *et al*., 2015).

It should be noted that the weight component of a lining section gravity is several tens of times less than the sum of forces acting on a section base so it can be neglected. The mathematical model developed in provides the calculations of contact pressures provided to the ground by the bases of shield type sections, only from the vertical components of hydraulic prop forces, excluding the efforts performed by the arms of a rear fence four links $2T_1$ and $2T_2$ which are attached to the goaf side of a foundation.

The calculations determined that the efforts in arms make 20-50% from the efforts of hydraulic props. Thus they significantly influence the value and the distribution of contact pressure real values along the foundation length of a lining shield study and should be taken into account during the determination of specifications for a mechanized shield lining (Turuk, 2004).

The objectives of the study were formulated in order to develop the method for contact pressures determination provided to a layer soil by the base of a lining one row shield section composed of 2 beams:

- The analysis of existing methods for contact pressure determination provided to a layer soil by lining section bases
- The modeling of engineering structures by I.A. Simvulidi method

**Theoretical studies:** During the method development the operating experience of mechanized shield linings (Mehrian and Mehrian, 2015; Nowruzpour Mehrian *et al*., 2013a, b, 2014; Vaziri *et al*., 2015; Turuk, 2004) was taken into account, we observed the positions of foundations for lining sections during their shift and spreading out.

The practice of mechanized linings operation both in Russia and abroad showed that single-row sections with the bases consisting of two beams are most common, so the calculation of contact pressures will be produced in relation to this scheme of a shield lining. At that in order to determine the contact pressures on soil by lining section bases let's use the plane problem of elasticity theory, i.e., a planar deformation (Nowruzpour Mehrian *et al*., 2013a, b, 2014).

The design scheme for contact pressure determination provided to a layer soil by each foundation beam of a single-row shield section of a lining is presented on Fig. 2. The reaction of a layer soil on a foundation beam in the theory of elasticity is taken in the following form (I.A. Simvulidi method) (Schumacher and Kim, 2013):

$$P_x = a_0 + \frac{2a_1}{L}\cdot\left(x-\frac{L}{2}\right)+\frac{4a_2}{L^2}\cdot\left(x-\frac{L}{2}\right)^2+\frac{8a_3}{L^3}\cdot\left(x-\frac{L}{2}\right)^3, \text{N m}^{-2}(\text{MPa}) \quad (3)$$

Where:

x = The distance to the point where the value
$P_x$ = Is determined to a downhole end of a foundation beam
$a_0$-$a_3$ = The parameters whose values depend on the hardness of a foundation beam, its length, the module of a foundation beam deformation, load character, deformation characteristics of a layer soil

It should be noted that layer soil reaction is determined by a foundation beam width unit. Since, a

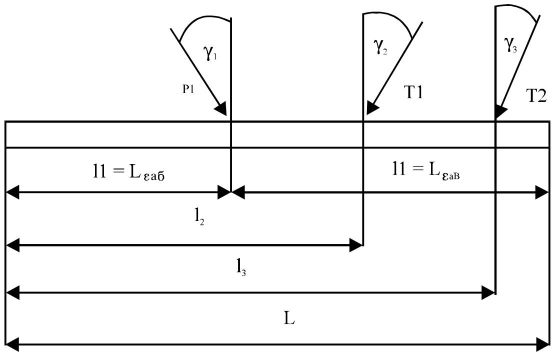


Fig. 2: The design scheme for contact pressure determination on a layer soil, provided by the foundation beam of a lining single-row shield section; $P_1$ = Rack reinforcement (kN); $T_1$ and $T_2$ = The force of a front and a rear arm, respectively (kN); $\gamma_1$ = The angle between a rack axis and a perpendicular to a beam base, grades; $\gamma_2$ and $\gamma_3$ = The angles between the axes of a front and a rear arm and a perpendicular to the beam of the base, respectively, grades; $l_1$-$l_3$ = The distance from a downhole edge to the application point P1, T1 and T2, respectively (m); L= The beam length of a foundation (m)

beam is influenced by concentrated forces only, the values $a_0$, $a_1$, $a_2$ and $a_3$ are determined according to the following Eq. 4:

$$
\begin{aligned}
a_0 &= \frac{(8252-34\cdot\alpha)\cdot\left(\frac{\Sigma P}{L\cdot b}\right)-13440\cdot B_1\cdot\alpha}{13440+29\cdot\alpha}\,\mathrm{Nm^{-2}}\\
a_1 &= 3\cdot\frac{(1280-\alpha)\frac{1}{L\cdot b}\cdot[2\Sigma P\cdot\beta_{31}-\Sigma P]-8\cdot N\cdot\alpha}{2048+\alpha}\,\mathrm{Nm^{-2}}\\
a_2 &= 3\cdot\frac{(5188+63\cdot\alpha)\cdot\left(\frac{\Sigma P}{L\cdot b}\right)+13440 B_1\cdot\alpha}{13440+29\alpha}\,\mathrm{Nm^{-2}}\\
a_3 &= 10\cdot\frac{(384+\alpha)\cdot\frac{1}{L\cdot b}[2\Sigma P\beta_{31}-\Sigma P]+4\cdot N\cdot\alpha}{2048+\alpha}\,\mathrm{Nm^{-2}}
\end{aligned} \tag{4}
$$

Where:

$\Sigma P$ = $P_1 \cdot \cos\gamma_1 + T_1 \cdot \cos\gamma_2 + T_2 \cdot \cos\gamma_3$ (N)

$\alpha$ = Flexibility indicator

Depending on the young modulus E for a foundation beam material and the layer soil $E_0$, Poisson's ratio of the soil material $\mu_0$, the length L, the width b and the inertia moment of a foundation beam section $J_{poperech}$ are calculated as follows:

$$
\alpha = \frac{1}{1-\mu_0^2}\cdot\frac{\pi\cdot E_0\cdot b\cdot L^3}{E\cdot J_{poperech}} \tag{5}
$$

The values $\mu_0$ and $E_0$ are taken according to reference literature or determined experimentally (Gersevanov, 1934; Turuk, 2014). The values of auxiliary members N and $B_1$ are determined by the following Equation (Gersevanov, 1934; Turuk, 2014):

$$
N = \frac{1}{L\cdot b}\left\{\begin{bmatrix}\Gamma_0^{\beta_{31}=0.5}\cdot P_1\cdot\cos\gamma_1+\Gamma_0^{\beta_{32}=0.5}\cdot T_1\cdot\cos\gamma_2+\\ \Gamma_0^{\beta_{33}=0.5}\cdot T_2\cdot\cos\gamma_3\end{bmatrix}-\begin{bmatrix}P\cdot\cos\gamma_1(1-\beta_{31})+T_1\cdot\cos\gamma_2(1-\beta_{32})+\\ T_2\cdot\cos\gamma_3(1-\beta_{33})\end{bmatrix}\right\},\ \mathrm{N\,m^{-2}} \tag{6}
$$

$$
\begin{aligned}
B_1 = \frac{1}{48L\cdot b}\cdot\{&2\cdot[P_1\cdot\cos\gamma_1(1-\beta_{31})^4+T_1\cdot\cos\gamma_2(1-\beta_{32})^4+\\
&T_2\cdot\cos\gamma_3(1-\beta_{33})^4]-[P_1\cdot\cos\gamma_1(1-\beta_{31})+\\
&T_1\cdot\cos\gamma_2(1-\beta_{32})+T_2\cdot\cos\gamma_3(1-\beta_{33})]-W,\mathrm{N\,m^{-2}}
\end{aligned} \tag{7}
$$

Here, W is an additional member which is determined according to Eq. 8:

$$
W = \frac{1}{6L\cdot b}\cdot\begin{bmatrix}\Gamma_0^{\beta_{31}=0.5}\cdot P_1\cdot\cos\gamma_1(0.5-\beta_{31})^3+\\ \Gamma_0^{\beta_{32}=0.5}\cdot T_1\cdot\cos\gamma_2(0.5-\beta_{32})^3+\\ \Gamma_0^{\beta_{33}=0.5}\cdot T_2\cdot\cos\gamma_3(0.5-\beta_{33})^3\end{bmatrix},\mathrm{N\,m^{-2}} \tag{8}
$$

where: $\Gamma_0^{\beta_{31}=0,5}$ -Gersevanov's two-way breaker and $\beta_{31} = l_1/L$; $\beta_{32} = l_2/L$; $\beta_{33} = l_3/L$ Gersevanov's two-way breaker is the feature that for all values of the argument between its certain 2 values is equal to unity and is equal to zero outside of these limits, i.e., a two-way breaker is equal to the difference between 2 one way breakers. A unilateral breaker (Gersevanov, 1934; Turuk, 2014) is a function that experiences a break at a certain value of an argument, namely: at all values of an argument less than the specified one, it is equal to zero for all values of an argument, more than that it is equal to unity and at the argument value equal to a specified one the function is equal to half.

Therefore, if the force P is applied to the left portion of a foundation beam, i.e. $\beta_3 < 0.5$, then $\Gamma_0^{\beta_3=0.5}=1$; if the force P is applied in the middle of a foundation beam, i.e., $\beta_3 = 0.5$, then $\Gamma_0^{\beta_3=0.5}=0.5$ and if the force P is applied to the right portion of the foundation beam, i.e., $\beta_3>0.5$, then $\Gamma_0^{\beta_3=0.5}=0$. As Eq. 6 and 7 were obtained for the beam with the width equal to one meter, its actual width must be considered during the calculation of a foundation beam.

## RESULTS AND DISCUSSION

Thus knowing the force of the rack $P_1$ of a front and a rear arm $T_1$, $T_2$ and section parameters let's determine the contact pressures on a layer soil according to the presented Eq. 3-8, provided by a foundation beam of a mechanized lining single-row shield section. Figure 3 shows the graphs of contact pressures on a layer soil provided by base beams of single row shield sections of KMPS, M137S and CS lining, resulting from the implementation of this developed method.

The analysis of the graphs shows that the contact pressures on the downhole and goaf portion ends depend significantly on the ratio of their sizes. Thus, with respect to a downhole length of a base to the length of a goaf part less than one $L_{заб}/L_{заВ}<1$ (KMPS and 1137S) the contact pressures on a downhole end of a base make 3.41 Mpa and 2.85 MPa, respectively and on the goaf end of a base they make 1.5 MPa and 1.9 MPa. At the ratio $L_{заб}/L_{заВ}>1$ (KS) the contact pressures on the downhole end of a base make 2.26 MPa and on the goaf end of a base they make 2.64 MPa. An important conclusion follows from this: the KS lining sections are able to work on the layers with weaker soils than the sections of M137S and KMPS linings.

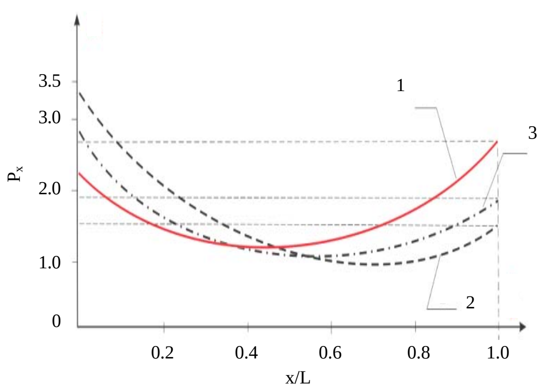


Fig. 3: The graps of contact pressures provided to a layer soil by the foundation beams of single row shield sections of KS, KMPS, M137S, linings depending on a base length: 1-KS linen sections-$l_{tooth}/l_{time}$ = 1170/975 mm); 2-KMPS linen sections-$l_{tooth}/l_{time}$ = 1000/1420 mm); 3-1137S linen sections-$l_{tooth}/l_{time}$ = 980/1240 mm)

## CONCLUSION

The developed approach to the contact pressure determination presented on a layer soil by base beams of a linen single row shield section will allow to improve the existing mechanized facilities to create new and implement the choice of a mechanized lining, ensuring its effective operation in certain geological conditions. The selection of a lining type and base parameters according to a pressure criterion on a layer soil should be made not by an average value as provided by GOST R52152-2003 but by the contact pressure at the end of a base bottom hole.

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