Changes in Rock Pressure Manifestations
When Working Pre-Wetted Coal Seams*

(VDC 622.83 and 622.333)

V. I. Murashov and Ya. G. Shliomovich

VostNI Institute for Safety in Mines, Kemerovo

Translated from Fiziko-Tekhnicheskie Problemy Razrabotki Poleznykh Iskopaemykh, No. 5,
pp. 20-28, September-October, 1965

Original article submitted May 13, 1965

Pre-wetting of the solid coal is now widely employed in underground mines, the water usually being pumped in via long boreholes; this method has numerous advantages over other wetting methods.

The moisture taken up by the coal causes a marked change in its properties [1], which inevitably leads to a difference between the rock pressure phenomena occurring during the working of pre-wetted seams and those observed in nonwetted seams under similar conditions. Two questions are of particular practical interest, namely stress distribution in the solid coal ahead of the mine workings, and the behavior of the surrounding rock within the supported waste area.

In our theoretical examination of these questions we used Barenblatt and Khristianovich's solution of the problem of stress distribution in the solid coal during extraction operations [2]. We also studied Kuznetsov's papers [3, 4], which give a closer examination of this problem.

In [2] \( x_0 \) is the fictitious position of the working face, found by solving the problem of the stresses in a dense elastic space with a semi-infinite slit in which a rigid coal wedge is driven; \( x_* \) is the position of the face, allowing for the fact that the adjacent coal is in a plastic state; \( x_{**} \) is the position of the maximal abutment pressure, allowing for the plastic zone (without this zone the coal near the working face would be subjected to an infinite load).

Thus, ahead of the working there is a plastic zone of length \( l = x_{**} - x_* \), and an elastic zone \( (x > x_{**}) \). The stresses in the elastic region [3] are

\[
\sigma = \frac{1}{2} \frac{hE}{\pi (1-\nu) H} \left( x_{**} - l \right), \quad (x < x_{**}).
\]

Here

\[
x_{**} = \frac{hE}{\pi (1-\nu) H},
\]

where \( h \) is the half-thickness of the seam; \( E \) is the modulus of elasticity for the roof rocks; \( \nu \) is Poisson's ratio for the roof rocks; and \( \gamma H \) is the initial stress at a working depth \( H \).

If we assume that in the plastic state the intensity of the tangential stresses in the coal is constant and equal to \( K \), the law of stress distribution in the face zone will take the form

\[
F(x) = -\tau_y = K \left( \frac{\pi}{2} + \frac{x-x_*}{h} \right), \quad (x_* \leq x \leq x_{**} + l).
\]

This law was derived by the authors of [2] using the known Prandtl solution, which gives the stress in an infinite plastic slab compressed between two rigid plates. Kuznetsov employed the conditions of plasticity of the coal in the form

\[ \tau_{\text{max}} = K + \sigma_n + \tan \rho, \]

where \( \tau_{\text{max}} \) is the maximum tangential stress, \( \sigma_n \) the mean normal stress, and \( \rho \) the angle of internal friction of coal.

He obtained a more complicated law for stress distribution, which will be disregarded here.

To determine the boundaries \( x_0 \) and length \( l \) of the plastic zone, we have the following equations [4]:

\[
F(x_0 + l) = \gamma H \sqrt{\frac{x_0 + l}{x_0 + l - x_0}} \int_{x_0}^{x_0 + l} F(x) \, dx = \gamma H x_0 \left[ \sqrt{\frac{x_0 + l}{x_0}} \left( \frac{x_0 + l}{x_0} - 1 \right) \right] \]

\[
+ \ln \left( \sqrt{\frac{x_0 + l}{x_0}} - 1 + \sqrt{\frac{x_0 + l}{x_0}} \right) \quad (4) \]

The first equation expresses the fact that in the section \( x = x_0 + 1 \), the vertical load in the plastic zone is equal to the load in this section in the absence of roof deformations and with the working face located at the fictitious point \( x_0 \) in the section; the second equation expresses the fact that the total roof load in the plastic zone is equal to the fictitious load (3) in the sector from \( x = x_0 \) to \( x = x_0 + 1 \).

We shall use these results to determine the effect of seam wetting and the consequent changes in the coal's mechanical properties on the length of the plastic zone and on the stress concentration in the abutment pressure zone.

To simplify the calculations we will employ a law of stress distribution in the plastic zone in the form (3), and thus write Eq. (4) as

\[
K \left( \frac{\pi}{2} + \frac{l}{h} \right) = \gamma H \sqrt{\frac{x_0 + l}{x_0 + l - x_0}} \int_{x_0}^{x_0 + l} F(x) \, dx = \gamma H x_0 \left[ \sqrt{\frac{x_0 + l}{x_0}} \left( \frac{x_0 + l}{x_0} - 1 \right) \right] \]

\[
+ \ln \left( \sqrt{\frac{x_0 + l}{x_0}} - 1 + \sqrt{\frac{x_0 + l}{x_0}} \right) \quad (5) \]

Let \( K / \gamma H = K' \); \( l / h = \bar{l} \); and \( \sigma_{\text{max}} / \gamma H = K_k \). We then obtain the stress concentration coefficient from Eq. (3), putting \( x = x_0 + l \),

\[
K_k = \bar{K} \left( \frac{\pi}{2} + \bar{l} \right) \quad (6) \]

Assuming that \( x_0 / h = \bar{x}_0 \), after simple operations we obtain the following equation for determining \( K_k \) from (5):

\[
\ln \frac{K_k + 1}{K_k - 1} = \frac{1}{K_k x_0} K_k^2 - 2 \frac{K_k}{K_k^2 - 1} - \frac{\pi^2 \bar{K}}{4 x_0} \quad (7) \]

Equation (7) is a transcendental equation and will be solved graphically. Finding the concentration coefficient we determine the length of the plastic zone (relative to the seam's half-thickness):

\[
\bar{l} = \frac{K_k}{\bar{K}} \frac{\pi}{2} \quad (8) \]

The value \( \bar{x}_0 = x_0 / h \) is found from the expression obtained from the first equation of (5):

\[
\frac{\bar{x}_0 + \bar{l}}{x_0} = \frac{K_k^2}{K_k^2 - 1} \quad (9)\]