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A. A. BARYAKH *(Mining Institute of the Ural Branch of the Russian Academy of Sciences, Perm, Russia)*
V. A. ASANOV *(Perm National Research Polytechnic University, Perm, Russia)*
N. A. SAMODELKINA *(Mining Institute of the Ural Branch of the Russian Academy of Sciences, Perm, Russia)*
I. L. PANKOV *(Mining Institute of the Ural Branch of the Russian Academy of Sciences, Perm, Russia)*
E. A. TELEGINA *(Mining Institute of the Ural Branch of the Russian Academy of Sciences, Perm, Russia)*

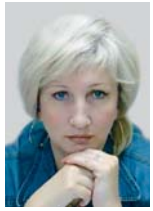
GEOMECHANICAL PROVISION OF PROTECTION OF POTASSIUM MINES FROM FLOODING*

A. A. BARYAKH, Director, Professor, Doctor of Engineering Sciences

V. A. ASANOV, Professor, Doctor of Engineering Sciences

N. A. SAMODELKINA, Leading Scientific Fellow, Candidate of Engineering Sciences

I. L. PANKOV, Assistant Professor, Candidate of Engineering Sciences



E. A. TELEGINA, Senior Scientific Fellow, Candidate of Engineering Sciences

The main feature of underground mining method at potassium and salt deposits is protection of mining operations from penetration of fresh waters. It can be achieved via usage of chamber working system that should provide solidity of above-laying waterproof rock pack, named also in mining practice as waterproof stratum (WPS). The main components of geomechanical provision of protection of potassium mines from flooding, including presenting definitions of mechanical parameters of salt rocks for different loading conditions, natural tool measurements, mine-surveying observations on land surface deformation, results of geophysical investigations are observed. This information makes parametric base of theoretical analysis of the processes of WPS deformation and destruction. It is shown that quality of geomechanical provision of safety of mining operations at potassium mines and of their protection from flooding is directly connected with usage of up-to-date methods of mathematical simulation of stress-strain state of mining technical objects and with completeness of usage during realization of total complex of experimental data - laboratorial, nature instrumental and geophisical ones.

Key words: *underground mining of potassium salts, salt rocks, waterproof stratum, stresses, cracks, deformations, shrinkage of land surface, mathematical simulation, criteria of crack propagation, measurements, geophysics.*

Russia takes one of the leading places in the world in production of potassium chloride. All volume of mining of potassium salt in Russia currently is concentrated at the Verkhnekamsky deposit of potassium salt (VKDPS), that is the second in the world by prospected resources — more than 3.8 milliard tons.

Principal problem of underground mining of potassium salt if reliable waterproofing of the rock bundle, named in mining practice water-protected rock mass (WPRM). It is located between the roof of the upper mined seam and the bottom of the first lower water-bearing horizon. In case of disturbing of continuity of WPRM fresh or weak-mineralized water dissolve rock-salt and erode the cracks. It leads to increase of water inflow with possible flood of the mine. In order to avoid above mentioned situation room-and-pillar system of mining, as a rule, is used at potassium and salt mines. In this case above-lain rock massif is supported by the regular inter-chamber pillars.

Geo-mechanical ensuring of safety of mining (on the base of experimental and theoretical methods and approaches) takes the important place in conditions of constant threat of flood of potassium mines. Mathematical simulation is efficient modern tool for study of geo-mechanical processes. It permits to examine mining-technical objects with complicated spatial configuration in three-dimensional arrangement; to include in calculation synthesized multi-level models describing behavior of the natural and technogeneous elements of the rock massif under the load; to analyse in detail deformation and destruction of the constructions in the time. In its turn, active development of mathematical simulation increases demands of parametric providing of geo-mechanical calculations that are based on the laboratory and field experiments.

Traditional laboratory mechanical testing of rock-salt is carried out in conditions of single-axial compression of the small samples (few centimeters). Shear and volume (stabilometrical) testing of the rock is carried out more seldom. Tension testing of the rock is the single one. Meanwhile shear and tension determine the criterions of forming of the centers of technogeneous disturbing in the rock massif. As a result, they determine localization of

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irreversible deformations. New testing equipment has appeared today. It permits to realize different controlled conditions of complex loading and opens qualitatively new possibilities of construction of appointed correlations of the rock mechanics and working up of criterions of the rock destruction. New equipment is intended for testing of the samples with sizes to tens of centimeters. It permits to estimate the scale effect with more substantiated transition from the properties, obtained for the samples, to corresponding parameters of the massif. On the base of representative tasting it has been determined [1] influence of the scale factor (size of the samples) on strength of rock-salt under single-axial and volumetric compression (Fig. 1). With increase of size of the sample from 30 to 100 mm it takes place increase of compression strength conditioned by granular structure of the rock. Presence of 30 and more grains (in average) within the contour of cross-section of the sample leads to some stabilization of compression strength. Further increase of size of the sample (more than 200 mm) leads to decrease of compression strength. It is conditioned by dominating influence of texture features of structure of the rock-salt — lamination and presence of the thin clay inter-layers.

Field instrumental measurements always were and are one of the principal elements of study, often independent, of state of the rock massif. Priority here often is given to determination of the rock properties in the massif, to measurement of the strains, to study of deformation processes in mining workings and moving of the earth's surface. For all this intercommunication of the field experiments and theoretical analysis often is restricted by estimation of mechanical properties of the rock in the massif and by comparison of results of calculation with the data of measurements. Undoubtedly, it is important aspect of geo-mechanical investigations since it permits in some measure to catty out parameter adjustment of mathematical models. But point character of the field observations, their fulfillment at rock reveal do not ensure full-weight realization of above-mentioned approach.

Application of results of the field measurements as parametric data for mathematic models is the preferable approach. For example, diagram of increase of settling of the earth's surface may be used as the base for forming of reologic models of the worked massif. Mathematic working of the models permits to estimate reologic parameters of the worked rock mass [2]. Obtained reologic model is relatively simple. It is realized easily within the bounds of modification of the known method of variable in the time modules of deformation in the complex spatial arrangements [3]. At the same time concordance of calculated and real distribution of the surface of settling is the certain evidence of adequate estimation of strained-deformed state (SPS) of the worked massif by the method of mathematical simulation (Fig. 2).

Significant prospects of application of experimental data in theoretic calculations are connected with geophysics [4, 5]. Geophysical investigations give indirect estimations of state of the rock massifs. But, in contrast to instrumental methods, they ensure spatial distribution of measured parameters. Thus, spatial location of the wave anomalies in the worked massif is determined on the

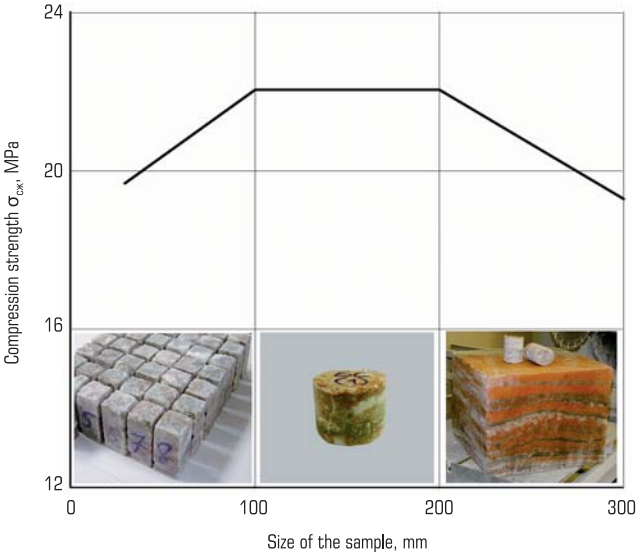


Fig. 1. Dependence of compression strength of rack-salt on the size of the tested samples

base of seismic prospecting. Anomalies are interpreted as the zones with decreased mechanical properties of the rock conditioned by technogeneous disturbing. At the same time within the bounds of elastic-plastic interpretation of the fields of localization of plastic deformations in the worked massif they are interpreted, in physical meaning, as the zones of forming of technogeneous fissures. This conformity permits to carry out adjusting of geo-mechanical model by integration method on the base of data of seismic prospecting.

At the first stage of geo-mechanical calculations, taking into account the whole complex of mining-geological (features of structure, character of bedding of the seams and so on) and mining-technical (number of worked seams, parameters of mining system, order of extraction, usage of stowing of empty space and so on) factors, it is estimated the zones of development of plastic deformations in the worked massif. Results of mathematical

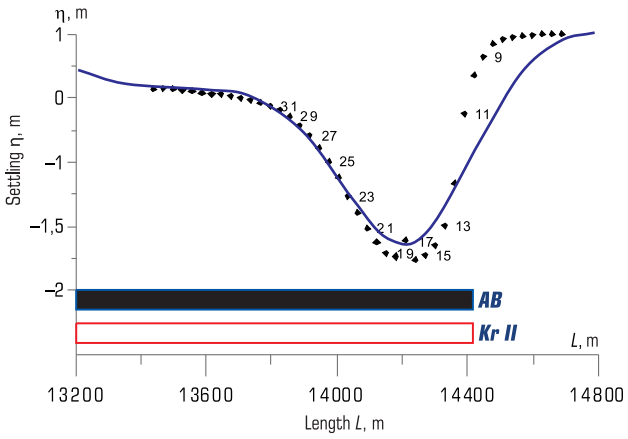


Fig. 2. Calculated (line) and real (points) of settling of the earth's surface under mining of silvinite seams KrII and AB

simulation are compared with the data of seismic prospecting, in particular, with information about location of the marked geophysical anomalies. In case of their disparity it is changed strength characteristics of the rock and calculations are repeated. Final stage of integration cycle is selection of strength characteristics of the rock-salt that ensure spatial conformity (by lateral and vertical axis) of the zones of plastic deformations and marked wave anomalies. Realization of above mentioned approach permits the to determine degree of decrease of mechanical properties of the rock and to obtain qualitative estimation of disturbing of continuity of WPRM under influence of mining directly in process of calculation (Fig. 3).

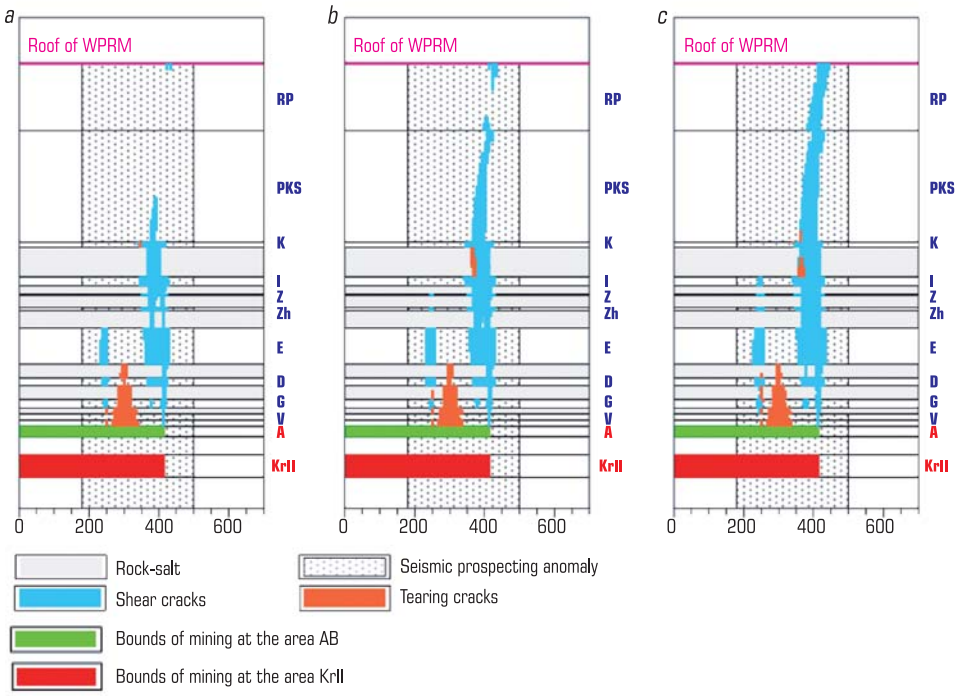
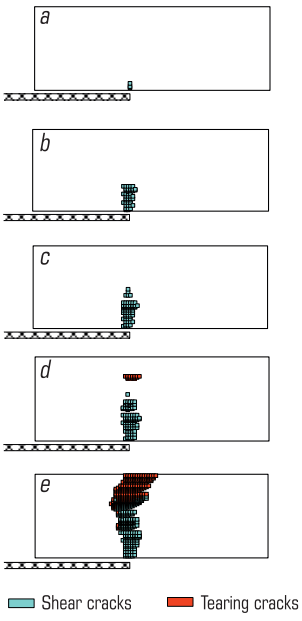


Fig. 3. Forming of the zones of technogeneous disturbing in the seams of WPRM within the bounds of chosen seismic prospecting anomaly with decrease of strength of the rock 1.1 times (*a*), 1.15 times (*b*), 1.2 times (*c*)

Substantiation of adequate criterions of safe working of WPRM is one of problematic part of geo-mechanical ensuring of protection of potassium mines against of flood. Study of disturbing of continuity of WPRM in course of its deformation is based on synthesis of experimental investigations and detailed mathematical simulation. Fulfillment, within the bounds of experimental approaches, of some analogue of physical simulation is the perspective direction. Thus, analysis of conditions of deformation of the border parts of WPRM shows that in case of physical simulation the curve of the hard fastened slab-beam corresponds most adequately to above-mentioned processes. On the base of results of experimental investigations of one-layered and multi-layered slab-beams it has been obtained dependence of maximum flexure, at the moment of forming of the main fissure, on thickness of the slabs and it has been determined character of change of relative flexure (ratio of absolute maximum flexure to length of the slab-beam) depending on ratio of length of the slab-beam to its thickness. Obtained in course of physical simulations qualitative estimates [6] have permitted, on the base of calculated experiments, to calibrate criterions of destruction (forming of the fissures) of the slab-beams under flexure and to use the criterions for estimation of possibility of destruction of continuity of WPRM in real conditions of its deformation [7].

On the base of results of multi-variant mathematical simulation it has been found principal features of destruction of continuity of WPRM. Destruction of the seams of rack-salt begins from forming of shear cracks in lower part of WPRM. In course of increase of deformations it takes place relatively slow development of the zone of shear fissuring upward along the section of WPRM. Tearing cracks appear in the upper part in case of significant settling of the earth's surface and develop from top to bottom of WPRM. After forming of tearing cracks it takes place sufficiently quick destruction of WPRM (Fig. 4). In case of gentle moulds of moving destruction of the seams of rock-salt realizes only in case of considerable settling of the earth's surface. In this situation shear cracks (over the edge of the empty space) and tearing cracks are formed almost simultaneously in the roof of WPRM. With increase of settling of the surface it is realized inversion mechanism of development of the cracks: shear cracks increase upwards and tearing cracks — from the top to bottom.



Numerical experiments have shown that destruction

Fig. 4. Dynamics of disturbing of continuity of WPRM with increase of settling of the Earth's surface, m:
a — 1.4; *b* — 2.8; *c* — 3.4; *d* — 4.6

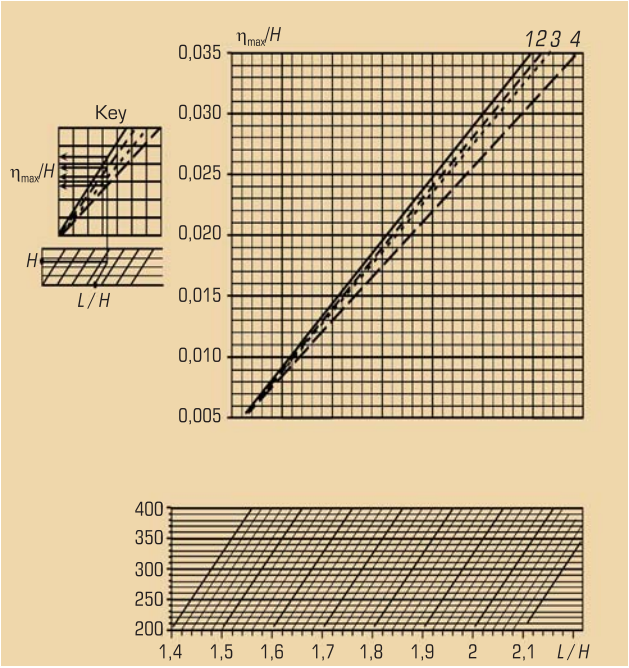


Fig. 5. Nomogram for definition of critical meaning of relative value of settling ($\eta_н/H$), corresponding to total disturbing of WPRM (*1*); partial, when thickness of non-disturbed layers of WPRM is 10 meters (*2*) and 20 meters (*3*); beginning of intensive disturbing (*4*) depending on depth of mining *H* and relative length of the edge zone of the mould of moving *L*

of the seams of rack-salt of WPRM, within the bounds of quantitative estimates, is connected with difference of maximum settling of adjacent zones and different parameters of mining, relative length of edge of the mould of moving and depth of mining. On the base of found appropriateness it has been offered engineering criterions for ensuring of the safe conditions of extraction of WPRM [7] based on regulation of sum thickness of non-disturbed seams of rack-salt and maximum settling, on barring of forming of the tearing cracks (Fig. 5).

Thus, modern effective geo-mechanical providing of safe mining at potassium mines, protection of the last ones against of flood are directly conditioned by application of the methods of mathematical simulation SPS of mining-technical objects and by completeness of usage for their realization of the whole complex of experimental data — laboratory, field instrumental and geophysical.

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Baryakh Alexander Abramovich,
e-mail: bar@mi-perm.ru
Asanov Vladimir Andreevich,
e-mail: emil-ava@mi-perm.ru
Samodelkina Nadezda Anatolievna,
e-mail: samodelkina@mi-perm.ru
Pankov Ivan Leonidovich,
Phone.: +7 (342) 219-80-19
Telegina Elena Alexandrovna,
e-mail: Elena.T@mi-perm.ru