CURRENT CHALLENGES OF GEOTECHNICAL MECHANICS

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The milestones in geotechnical mechanics research conducted at the N. S. Polyakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine are listed. Solutions to the deep-mining challenges faced by the institute as a leading research institution in the industry are outlined. The basic results on the subject achieved by the institute over the years of its existence are summarized.

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The 60s of the past century witnessed a constantly increasing depth of mining, both underground and opencast, in the major mining regions of Ukraine: Donbass and Krivbass. The drastically deteriorated mining conditions posed several tasks: control of rock pressure, heat, and gas and development of new means of haulage and transport at deep opencast, etc., which meant a lot of research work.

Besides developments in mining engineering and rock mechanics, of great significance is geotechnical mechanics, which studies natural and man-induced processes in the Earth’s crust.

Research on certain aspects of the said problem was conducted at the Department for Ore Mining Problems of the Institute of Electrodynamics, Academy of Sciences of the Ukrainian Soviet Socialist Republic (AS UkrSSR). This department was the basis for the establishment of the Dnepropetrovsk Branch of the Institute of Mechanics, AS UkrSSR, in 1964 and then the Institute of Geotechnical Mechanics (IGTM), National Academy of Sciences of Ukraine (NASU), in 1967.

Orders of the State Science-and-Technology Committee of the Council of Ministers of the USSR and the Presidium of the Academy of Sciences of the UkrSSR made the IGTM responsible for resolving deep-mining problems, for coordination, areas, and status of research in the field, and for putting scientific developments into practice at deep underground and opencast mines.

To perform these tasks, the IGTM launched an extensive research program on rock mechanics with the intent of studying the mechanical characteristics, engineering properties, and composition of rocks and their behavior under various conditions and at different depths. This had the effect of establishing patterns of the rheological behavior of rock and evaluating some associated parameters. New methods were developed to determine the stress–strain state of a rock mass and to predict rock pressure at great depths. Theoretical and experimental investigations helped to develop recommendations on mine layout, ground support, and maintenance of development and permanent workings and shaft stations at deep mines of Donbass and Western Donbass [16–18, 67, 75, 76].

Several ultrasonic devices, such as ShUP-1, ShIEMS, ShIS-1, and PPU [86], have been developed for in-mine analysis of the stress state, fracture, and mechanical properties of rock.
Of special importance were studies intended to prevent outbursts of coal, rock, and gas in deep mines of Donbass. The first of the studies were concerned with rock and gas outbursts in driving drifts along sandstones.

To lay a theoretical basis for outburst prediction and prevention, experts from some institutes of the Ukrainian Academy of Sciences were engaged in development of an outburst theory. Among them were scientists from the Institute of Mechanics such as Academician A. N. Guz, Corresponding Member L. P. Khoroshun, Doctors of Physics and Mathematics I. Yu. Babich, Yu. N. Podil’chuk, V. N. Chekhov, and others.

Over a relatively short period, the research yielded the following important results:

Outburst-hazard indices of sandstones were identified and outburst conditions were modeled, which made it possible to develop a region-specific method to predict rock outbursts based on prospecting data. The method allows outburst-hazard assessment of sandstones within an industrial geological region and a series of or individual mine fields with the purpose of selecting (in mine design) the most stable and least outburst-prone rocks for driving permanent and development mine workings [36, 37, 84].

The energy parameters of stressed gas-saturated outburst-prone sandstones were determined in view of stored potential energy and work done to break up and displace rocks during outbursts.

Analytic relations were derived to describe the stress–strain state of a rock mass subject to a blast shock, the mechanical properties of rocks, and the size and depth of a mine working, which made it possible to clarify the mechanism of rock outbursts.

A technique of abating the effect of blasts on a stressed rock mass was developed and tested. The use of this technique made it possible to reduce the outburst frequency by a factor of 1.5 to 2 and the amount of displaced rock by a factor of 3 to 4 [17, 19, 28, 39, 51].

A technique of blast-free machine drivage through outburst-prone rock, which prevents outbursts, was justified theoretically.

Self-destruction of stressed rocks at the mine face during blast-free drivage was discovered and the possibility to control this process was theoretically justified. The State Committee for Inventions and Discoveries of the USSR recognized these results a scientific discovery by issuing Discovery Certificate No. 337 in 1987 [40, 41, 59].

Industrial testing of blast-free drivage through outburst-prone sandstones, conducted in our country for the first time, promoted creation of several heading machines (Yasinovatets-2, Soyuz-19, and Soyuz-19U), which improved the safety of mining operations and increased the sinking rate.

A method to prevent sandstone and gas outbursts by extracting adjacent coal seams in advance of mining was developed. This method was included in Safety Rules (1973) and in collected methods approved by the Ministry of Coal Industry of the USSR.

The integrated mine studies conducted by the Institute of Geotechnical Mechanics and other institutes underlie the development of a mathematical model to describe the drainage effect of an undermined seam, which reduces outburst hazard. The model accounts for the displacement of sandstone and the dependence of its stress–strain state and gas content on the mechanical properties [1, 42, 48, 83].

Along with development of safe and reliable methods of reducing the risk of sandstone outburst in deep coalmines of Donbass, much effort was undertaken to improve the stability of the Donbass gypsum mines.

The strength analysis of rock outcrops in room-and-pillar mining was placed on a theoretical footing, and analytic problems were solved to determine rock stresses near mine workings. Techniques of combined breaking and machine excavation of gypsum were developed, which made it possible to exclude the adverse effect of blasts on pillars and roof and to improve the environmental situation.

A method to evaluate the room-and-pillar parameters for faulted gypsum deposits was developed. It considerably improved the stability of mine workings.

Geomechanical principles of underground gypsum mining and goaf maintenance were established [58, 77, 78].

Later, the research was extended to perfect room-and-pillar mining methods for nonmetallic minerals in other regions. B. M. Usachenko, V. G. Perepelitsa, and S. B. Vakarchuk achieved great results in this field and were awarded the Dinnik Prize of the Academy of Sciences of Ukraine in 1999.

It should be noted that the stability of mine workings within virgin and disturbed rock masses was analyzed in [10, 23–27, 42, 80, 88, 89] in linearized formulation in the context of the stability of the equilibrium state of these rock masses. In particular, the three-dimensional linearized theory of stability with the assumption of small and finite subcritical strains was first used in [10, 24] to formulate and find approaches to solve such problems. A three-dimensional theory of stability of mine