On the Scope of Geomechanics

by

N. A. TSYTOVICH, Dr.Sc. (Eng.)

Professor and Head, Department of Bases and Foundations, Kuibyshev Civil Engineering Institute, Moscow, USSR

SYNOPSIS. Geomechanics is presented in this paper as a new branch of science, and previously stated views of the author are expanded. Geomechanics is defined as the science that deals with the mechanical processes (in the wide sense of this conception) that take place in the earth's crust due to both natural factors (gravitational and temperature fields, hydrodynamic pressures, seismic effects, etc.) and the influence of human activities (high dam construction and high-rise buildings, the continuous pumping-out of ground water, petroleum and gas over large areas, etc.).

Geomechanics is essential for solving certain problems in general geology (tectonics, stratigraphy, etc.), as well as for the quantitative evaluation of the effect of heavy capital construction on the top layers of the earth's crust and of the economic development of new extensive territories.

A new trend, followed more and more often in recent years, is to unite soil and rock mechanics into a single general branch of science called geomechanics.

It should be pointed out, however, that geomechanics is a much wider branch of science than it is generally considered to be at the present time. As far back as 1963, the author of the present paper, in a speech made during a session of the USSR Academy of Sciences, indicated that in addition to the two abovementioned branches, the concept of geomechanics should also cover global and regional geodynamics of the Earth's crust, also the mechanics of organic masses and the dynamics of the lithification of loose rock deposits.

Geomechanics should be defined as the science which deals with the mechanical processes that take place in the Earth's crust and are due both to natural factors (gravitational field, hydrodynamic pressures, seismic effects, etc.) and to the influence of human activities (high dam construction, building up of extensive territories, pumping out ground water over long periods, ect.) It is quite timely, therefore, to outline and establish the scope of geomechanics- this new wide-range branch of science that is being developed today at the boundaries of general geology (tectonics, stratigraphy, lithology, etc.), engineering sciences (theories of elasticity, plasticity and creep, theory of plastic-viscous flow, etc.), making use of up-to-date mathematical apparatus and fine techniques in physical experiments. Along with geophysics and geochemistry, geomechanics should be employed in general and engineering geology to enable their problems to be more successfully solved, including problems related to the erection of structures, especially huge hydrotechnical structures or ones of great height with heavy loads on the area under construction.

The construction of up-to-date high dams (several hundred metres high), spanning natural canyons and even whole valleys; the construction of huge reservoirs and storage lakes; the building up of extensive territories and the prolonged pumping of subsoil waters are all on such a grand scale, that they substantially affect the mechanical processes occurring in the upper layers of the Earth's crust. Consequently, they must be taken into account in construction operations.

The foregoing is exemplified by the curves in Fig.1, obtained by E.V.Kalinin (Ref.2). These curves are isolines of the

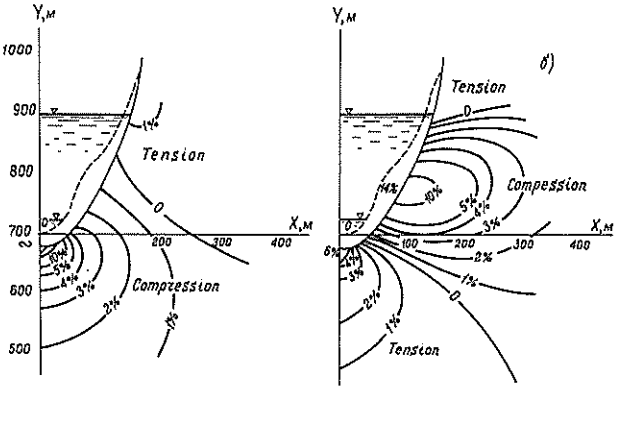

Fig.1 Variations in normal stresses: (a) in horizontal and (b) in vertical planes of the rock in the slope and base of a valley after filling the storage lake.

changes in the normal stresses of the rock in the slope and base of a deep valley after filling the storage lake. These isolines refer to the horizontal (Fig.1a) and vertical (Fig.1b) planes. They show the complexity of the stressed state and the possibility of localized disturbances of stability in the valley's slopes since the stress in the slopes has increased by more than 10 per cent. This example was solved by an electronic computer as a plane problem of elasticity theory for a semi-infinite region bounded by a parabolic contour. Use was made of Cauchy-type integrals and conformal mapping (Academician N.I.Muskhelishvili).

Many problems in geomechanics concerning the stability of natural slopes of rock were investigated by Professor A.Nadai and others (Ref.3,4).

An interesting theoretical solution of the plane problem of the stressed state of a rock massif, with a wide class of curvilinear boundaries and subject to a gravitational field, was obtained in the closed form by Z.G.Ter-Martirosyan and J.M.Akhpatelov (Ref.5). This solution is based on the method of complex variables, taking the mass forces into account.

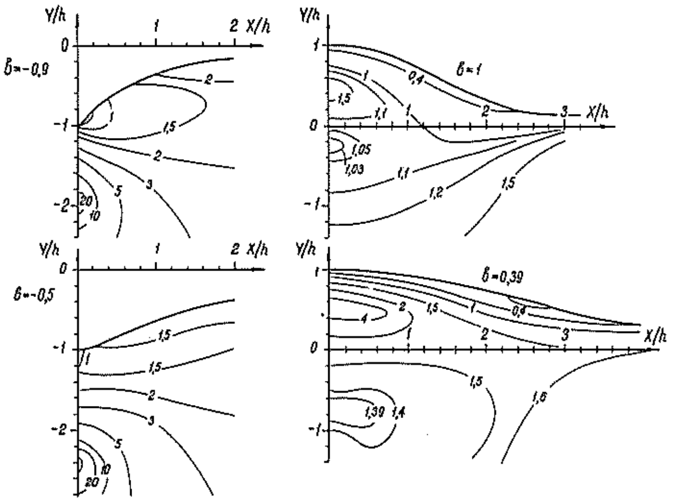

Fig.2 Isolines of the variation in the coefficient of stability of valley slopes of various configurations, subject to a gravitational field

An example is given in Fig.2 which shows the results of computer calculations according to the obtained closed solution. Shown are isolines of the coefficient of stability $\eta = \frac{\tau_{lim}}{\tau}$ where τ_{lim} is the limit shear stress and τ is the actual stress, in slopes of various configurations (as the parameter b of configuration varies from -0.9 to +1.0) for canyons and valleys. The corresponding data are: slope height h=100m, cohesion c= 0.2 kgf per cm^2, angle of internal friction φ=15° the coefficient of lateral pressure K=0.8 and unit weight of the rock γ=1.9 g/cm^3.

It should be noted that with a stability coefficient $\eta \leq 1$, the rock will be in an unstable state since undamped plastic-viscous flow may be set up in the rock.

Another factor that becomes of prime importance is the nonuniform settlement of the earth's surface in building up big cities as a result of the compaction of weak clayey soils and especially due to the increase in soil weight as the subsoil water level is lowered. Thus, very large settlements (up to several metres) are observed on the territory of the city of Tokyo, Japan. This is described in a work by I.V.Garmanov, et al (Ref. 1).

During his participation in the VII International Conference on Soil Mechanics and Foundation Engineering (Mexico, 1969), the author became acquainted with the results of long-term observations of the settlements on the territory of Mexico City. According to this data, from 1900 (when observation began with reliable bench marks, established on rock outside of the city) the settlement of the territory has reached seven metres. This has been caused by regular pumping of subsoil water, lowering its level over a considerable part of the city's territory and leading to substantial compaction of the overmoistened clayey soil (volcanic ash).

The foregoing questions have already outgrown their treatment as localized problems of soil and rock mechanics, and should be dealt with as problems of geomechanics.

Geomechanics should include the following branches:

1. Global and regional geomechanics of which the first deals with purely geological problems on a global scale (continental drift, problems in tectonics, etc.), and the second refers to the above-mentioned general engineering problems that arise in large-scale construction.

2. Mechanics of massive-crystalline rock, which is of vital importance both for hydrotechnical construction, and for building high, heavy structures, erected on rock.

3. Mechanics of multiphase soil masses, a knowledge of which is essential for stable construction of all kinds of structures on sandy and clayey soils.

4. Mechanics of organomineral and organic masses (silts, peats, sapropels, etc.) whose problems require correct solutions as otherwise stable and firm construction is impossible on weak clayey, silty and peaty soils which are widespread in the flood plains of large rivers, especially in their deltas, as well as certain locations on sea coasts and shallow water areas.

5. Dynamics of the lithification of loose deposits, which is necessary to assess the processes of compaction, diagenesis, epigenesis, etc., up to metamorphism with the formation of new rock.

All the foregoing branches of geomechanics should be studied as an integrated system. comprehensively related to one another, taking account of the instability of the properties of rock, soils and organic masses, and making full use of the advances in related branches of science: theories of elasticity, plasticity, creep, plastoviscous flow, as well as data from physical-chemistry, etc.

The author is of the opinion that this new branch of knowledge-geomechanics-should be developed within the above-mentioned scope. Geomechanics, in this aspect, is absolutely necessary, both for general geology and for the evaluation of the geological engineering conditions for erecting various structures with the aim of fully ensuring their strength and stability.

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