NONTRADITIONAL APPROACH TO DEFINITION OF ROCK STABILITY PARAMETERS OF NEAR-CONTOUR ZONE OF UNDERGROUND WORKING, DEEP AND SUPERDEEP BOREHOLES

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The review of works devoted to the stability theory application in the rock mechanics to analysis of rock state near deep and superdeep boreholes is given and method for determing stability parameters of deep spherical cavity in the conditions of minimum information about opening massif.

1. Studying spatial (three dimensional) body equilibrium stability problems conformably to geomechanics problems including problems of rock stability near deep and superdeep boreholes (deep geomechanics) forms the new rapidly developing field of the deformable solid mechanics (or rock mechanics). This new direction of investigations - the stability in rock mechanics (SRM) appeared as a matter of fact on a junction of two fields of knowledge with the deformable solid mechanics (the nonlinear mechanics of continuum) and the rock mechanics is successfully developing more than twenty years in the Kazakh National Academy of Sciences. In the papers (Alimzhanov M.T., 1982,1990 a) the rather complete review of works on spatial bodies equilibrium stability problems conformably to geomechanics problems is given. From the references it is evident that Kazakhstan researches have a priority in this field of knowledge. The investigations carried out recently (Alimzhanov M.T., 1990,1992) showed that the fundamental propositions of the SRM theory allow to come to a solution of highly important problem namely the prevention of accidents and complications connected with the loss of rock equilibrium stability near deep boreholes. It is known that the variant: near-Caspian West Kazakhstan boreing enterprises suffer damage about hundreds millions roubles annually because of these accidents and complications.

When calculating a deep borehole wall stability till our times the traditional approach (Alomzhanov M.T., 1990 b,1992 a) is used which based on the evaluation of a near-wall zone rock durability. In this case the concepts "durability" and "stability" of borehole walls are identified (though these concepts have different sences in the deformable solid mechanics).

However from the results of researches (Alimzhanov M.T.,1989, 1990,1992, Alimzhanov M.T. and Semenychev G.A., 1989,1990, 1991,1992) it is follows that the only correct approach to solving this class problems is nontraditional approach based on evaluation of elastic - plastic equilibrium stability of rock near a borehole following from the propositions of SRM theory.

This approach allows to obtain a number of new results. Thus, in the work (Alimzhanov M.T., 1990 b) from point of view of SRM theory which basis is given in the paper (Alimzhanov M.T., 1982) a problem of mining pressure control when drilling deep boreholes is considered. As is generally known the applyied bore-solutions exert enormous influence on drilling deep and superdeep boreholes to designed depth. The bore-solutions must first of all to prevent from the process of the loss of equilibrium stability of borehole wall rock bringing to borehole narrowing (change of dimensions and form of section) screes, collapses. Now there is a number of formulae for calculating a bore-solution density. However, all these formulae were obtained from point of view of borehole wall durability ensuring and at times overstated results which differ each other greatly. In the work the new concept was introduces with "optimum bore-solution density (minimum allowable)" which ensures the stability of deep borehole walls. The method for determing this optimum density was given too proceeding from the SRM theory. It is shown that the Coulomb-Mohr's condition can be used for a description of mechanical processes around a borehole in a massif of sand-clay sediments where different complications occur very often. Thus the new scientific direction-SRM theory can be used in the new field of knowledge namely in the deep drilling science (deep geomechanics).

In the paper (Alimzhanov M.T.,1992 b) the function of cohesion coefficient heterogeneity was introduced.

This function takes into account the heterogeneity of rock properties in the nonlinear deformation zone (NDZ) owing to the forming micro and macrocracks and bore-solution weakening influence on rock near a borehole.

Plane problem about strained deformed state (SDS) and the loss of equilibrium stability of rock near borehole was considered too.

Spatial axially symmetrical form of the loss of equilibrium stability of rock near a borehole was considered in the paper (Alimzhanov M.T., 1989, 1992 a).

In the work (Alimzhanov M.T.,1992 c) an experimental-analytical method was proposed. This method allows to carry out an express- analysis of rock state near a deep borehole with minimum information about opening massif.

The influence of physical-mechanical characteristics of sediment and drilling depth on optimum bore-solution density was

studied in the work (Alimzhanov M.T., and Semenychev G.A., 1990 a)

In the paper (Alimzhanov M.T. and Semenychev G.A., 1990 b) the differential equation system was given. This system allows to determine perturbation components both in NDZ and in elastic deformation region and to solve the problem about plane equilibrium buckling of rock near deep boreholes drilled in a thickness of fragility destroyed rock was considered in the work (Alimzhanov M.T. and Semenychev G.A., 1990c). Here the Coulomb-Mohr's condition was taken as the condition of rock change in nonlinear deforming state. In the works (Alimzhanov M.T. and Semenychev G.A., 1989, Semenychev G.A., 1991) for described mechanical processes in sediment around a borehole the elastic-plastic model of noncompressable medium was used. This medium submits to the theory of small elastic-plastic deformations with extendable strengthening. However for lack of reliable experimental data about sediment parameters entering in the correlation between deformations and strains, the formulae obtained in the work (Alimzhanov M.T., 1990b) were used. By these formulae the program was formed and calculation was carried out on the computer. The influence of physical-mechanical characteristics of sediment and boring depth on the stability of deep borehole walls was given in the tables.

In the work (Alimzhanov M.T. and Semenychev G.A., 1992) the ideas stated on the paper (Alimzhanov M.T., 1990b) were developed and were applied in practice (to concrete conditions of building deep boreholes in Caspian cavity). The experimental examining the method of determination of rock stability near a borehole was made in the boreholes on an area Elemeth-2 and Elemeth-4 (district Otrau). The calculation data were given in tables.

The research fulfiled in (Alimzhanov M.T., 1992d) showed that the critical radius of NDZ around a borehole decreases with rise in drilling depth, but the optimum value (minimum allowable) of bore-solution density ensuring the stability of borehole walls increases. But this optimum density is substantially smaller than density maintaining borehole wall durability. Such regularity is appeared when considering as a plane form of stability loss (Alimzhanov M.T., 1990d) as a spatial axially symmetrical form of stability of rock equilibrium near a borehole (Alimzhanov M.T., 1989).

In the work (Alimzhanov M.T., 1992e) on the basis of SRM theory concepts, the analysis of variation of parameters of durability and stability of borehole walls with rise in drilling depth was given. For the stability state of borehole walls it is necessary that the NDZ boundary do not go out of limits of the axially symmetrical surface described by the critical radius of NDZ, i.e. this boundary must be inside the "stability jug" as it is called. The walking of NDZ boundary beyound the "jug" leads to the processes of the equilibrium stability loss of rock near a borehole and as a result every possible complications described in the paper (Alimzhanov M.T., 1990b) occurs. It is obtained the formula for determing a typical depth corresponding to the base of the "stability jug". Below this depth the conditions of durability and stability of borehole walls coinside. The numerical examples are given.

The report (Alimzhanov M.T., et al.,1992) is devoted to non-traditional approach to solving problem of preventing the complications connected with loss of rock equilibrium stability in deep boreholes.

In the paper (Alimzhanov A.M., 1993 a) it is studied influence forces and bore-solution weakening influence on elastic-plastic state of rock near a deep borehole. The influence of these factors on value and configuration of elastic-plastic boundary is given in tables.

One of the perspective direction of wall stability rise of deep boreholes and borehole hermetic capacity relative to permeable layers is controlable colmatation.

In the paper (Alimzhanov A.M.,1993 b) SDS of rock near a deep borehole is defined with taking into account colmatated screen. It is shown that colmatated screen allows not only to raise near-wall zone durability of a deep borehole but also to reduce essentially bore-solution density.

Thus, nontraditional approach to analysis of rock state near a borehole allows to introduce a new concepts in science about deep drilling, i.e. to develope a technique for determing practically important nontraditional parameters connecting with rock stability near a deep boreholes and method for determing stability parameters of deep spherical cavity in the conditions of minimum information about opening massif. For example, these parameters are optimum (minimum allowable) bore-solution density (Alimzhanov M.T.,1990, 1992), "stability jug" for ensuring rock stability near a borehole it is necessary that NDZ near a borehole did not go out the jug limits (Alimzhanov M.T.,1992e) etc. This approach allows to give practic trend to investigation, in another words, to substantiate and to specify existent methods and to develop new (nontraditional) ones for determing quantitative indices of the processes studied.

Thus, in the work (Alimzhanov M.T.,1993) the new nontraditional method for determing stability parameters of a deep extensive horizontal working in the conditions of minimum information about opening massif is given. Further it is proposed the analogous method for determing the stability parameters of a deep spherical cavity in the same conditions of minimum information about opening massif.

2. The methods based on experimental-theoretical approach to researching rock mechanics problems were called as experimental-analytical (Alimzhanov M.T.,1993).

These methods allowed to define a nonlinear deformable state of rock massif around cleaning workings when working off coal strata. It should be noted that experimental-analytical method based only on the traditional analytical solutions following from elastic or elastic-plastic equilibrium of rock massif can be used not always.

Combination of non-traditional analytic solutions (Alimzhanov M.T.,1982) following from the proposition of SRM theory and experimental methods giving any information about concrete mechanic processes near underground cavities, opens new possibilities in the rock mechanics (Alimzhanov M.T.,1993). These possibilities are connected first of all with calculating SDS and stability of near-contour zone rock in the condition of minimum information about opening massif.

The possibilities of nontraditional approach to analysing rock state near deep and superdeep boreholes are described in the works (Alimzhanov M.T.,1990,1992).

On the basis of the nontraditional experimental-analytic approach we will consider the method for defining the stability parameters of deep spherical cavity used for placing machine and pumping stations, storing useful minerals etc. Let, on the some depth h from daily surface the deep spherical cavity with radius R_0 is created. On the cavity contour uniform distributed load P acts it is reaction of timbering.

We will suppose that durability properties of rock both of NDZ and of elastic deformation region are described by rectilinear rounding of Mohr's circles.

$$|\tau_n| = (\sigma_n + H)\,tg\varphi, \quad \sigma_\varphi = \frac{1+\sin\varphi}{2}(\sigma_\rho + \sigma_\theta) + H\sin\varphi, \quad (1)$$

the parameter H for non-destroyed intact rock (elastic deformation region) will be equal:

$$H = \frac{\sigma_c}{\alpha_2}, \quad (2)$$

where $\alpha_2 = 2\sin\varphi/(1-\sin\varphi)$, φ is an angle of inner friction of rock, σ_c is durability of rock relative to pressing, and for the rock in NDZ

$$H = K\,ctg\varphi, \quad (3)$$

where K is coefficient of rock cohesion in this zone.

We suppose that from results of nature investigations with the help of dynamometers the normal component value of contact pressure on a timbering P was defined. With the help of ultrasonic investigating near-contour massif (Alimzhanov M.T.,1993 the dimensionless boundary β_0 of NDZ was found.

Using the analytic solution of problem on SDS and rock stability of near-contour zone (Alimzhanov M.T.,1984) and experirimental research data P and ρ_0 we will found the durability of rock relative to pressing σ_c^M and displacement module G^M of massif near considered cavity by the formulae:

$$\sigma_c^M = \frac{1}{2}\left[3\gamma h + (1+2\alpha_1)K\,ctg\varphi - (1+2\alpha_1)(P+K\,ctg\varphi)\rho_0^{2\alpha_2}\right], \qquad (4)$$

$$G^M = \left[(2\alpha_1-1)\rho_0^{2\alpha_1+1} - (2\alpha_1+1)(1-A)\rho_0^{2\alpha_1-1} - \frac{(1+\alpha_1)(2\alpha_1+1)}{3\alpha_1} + 1\right], \qquad (5)$$

$$\text{where } A = \frac{\alpha_2}{B}\left(\frac{3\gamma h - 2\sigma_c^M}{2\alpha_1+1} + K\,ctg\varphi\right), \quad B = \sigma_c^M + \alpha_2\gamma h.$$

It have been defined in experiments that angles of inner friction for weakened rock and untouched rock are practically coinsided. Therefore we can suppose that these angles have equal values in piece as well as in rock massif. The values of durability (σ_c^M) and deformation (G^M) characteristics in rock massif near spherical cavity on the depth having defined by the formulae (4) and (5) one can forecast value of the least contact pressure on a timbering P_* on the deeper horizons in the conditions of the minimum information about opening massif. This value is defined by the formula:

$$P_* = \left[\frac{3\gamma h}{2\alpha_1+1} + K\,ctg\varphi\right]\rho_*^{-2\alpha_2} - K\,ctg\varphi, \qquad (6)$$

where ρ_* is found from transcendental equation

$$\frac{\alpha_1}{2\alpha_1+1}\rho_*^{2\alpha_1+1} - \frac{\alpha_1(1-A)}{2\alpha_1-1}\rho_*^{2\alpha_1-1} - \frac{A(1+\alpha_1)}{3(2\alpha_1-1)} + \frac{2\alpha_1}{4\alpha_1^2-1} - C = 0, \qquad (7)$$

where $C = \frac{G^M}{B}$.

Let us consider an example. Let on the depth 800m in thickness of argillaceous schists a spherical cavity with radius $R_0 = 4\,m$ is built. The mean value of data from dynamometers placed between rock and timbering on the cavity surface is $P = 11{,}5\ t/m^2$. The mean distance of boundary of NDZ from working contour is equal to 5m then dimensionless boundary on NDZ will be

$$\rho_0 = (R_0 + 5m)/R_0 = (4+5)/4 = 2{,}25.$$

Assuming an angle of inner friction $\varphi = 25°$ for argillaceous schista and $K = 10\,t/m^2$ we will found the values of σ_c^M and G^M for thickness of argillaceous schists near this cavity by the formulae (4) and (5). These values are given in table.

Further using obtained values we found the least contact pressure P by the formulae (6) and (7). With this value P stability of the cavity maintains already on the depths h=1000m, ..., 1500m.

TABLE

CALCULATION OF ROCK STABILITY PARAMETERS NEAR DEEP SPHERICAL CAVITY

h,mm	P, t/m^2	ρ_0	σ_c^M, t/m^2	G^M, t/m^2	Note
800	11,50	2,25	2027	498712	Initial data
900	24,72	2,23	2027	498712	Stability parameters of deep spherical cavity
1000	38,70	2,21			
1100	53,40	2,18			
1200	68,74	2,16			
1300	84,78	2,14			
1400	101,30	2,12			

The value of P are given in the table too. The merit of new proposed method for founding parameters of rock stability in near-contour zone in comparison with existing ones is that these parameters are defined by experimental data (by readings of dynamometers and data of ultrasonic investigation) which reflect well, real deforming rock massif in concrete mine-geological conditions without specific investigating a kern in laboratory.

Thus combination of analytic solution following from SRM theory with readings of dynamometers and systematic ultrasonic control of near-contour massif is one of the progressive directions for creating methods for geomechanics basing stability parameters of deep underground cavity in the conditions of minimum information about opening massif.

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