ANALYTICAL PROCEDURES IN THE DESIGN OF UNDERGROUND MINE OPENING OF A PRPOPOSED URANIUM DEPOSIT IN NIGERIA

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ABSTRACT

In this paper the necessary factors to be considered while designing an underground mine opening for a proposed uranium deposit were outlined. Its scope include the assessment of various state of stresses existing in the rock before mine opening and the distribution of stresses at a depth very close to the opening. This eventually will lead to the control of rock failure within the shaft opening and also provide optimum pattern in the design of a mine opening with different diameter of openings for the proposed uranium deposit in Nigeria.

INTRODUCTION

The study of the properties and behavior of rock, the nature of stresses about underground openings and their relation in the design, support of mine workings and induced caving of rock in mine exploitation plays an important role in the overall construction of a mine. Obert et al (1986) stated that all rock at depth is under stress due to the weight of the overlying rock (superincumbent load) and to possible stress of tectonic origins. They went further to add that the pressure of a mine opening induces or redistributes stresses in the rock surrounding the opening, and this rock will fail if the rock stress exceeds the rock strength. Anoshinka (1989) in the study of rock strength in an iron deposit in Rostov, Russia concluded that the problem of designing a stable mine opening reduces by not only the ineffective determination of the maximum stress in rocks surrounding the opening but also the improper determination of the strength of the rock in situ. Borovski (1990) noted that the maximum stresses occur at the boundary of the opening and act tangentially to it. He also deduced that the radial stress at the boundary is zero, and the shear stress is equal to one-half the tangential stress. Panck (1988) on analysis of theory of elasticity found out that the stresses are independent of the elastic moduli of the rock material around a mine opening. Woodruff (1986) study of critical stresses for two basic shapes of mine openings concluded that the peak values of the maximum (tangential) stress acting on a mine opening occur at the midpoints of the top and sides or at corners of the opening. He further pointed out that the stress redistribution about the mine opening is negligible at a distance of one diameter from the edge of the hole.

All the above studies have a place for effective design of underground mine opening of the proposed uranium deposit in Nigeria.

THEORETICAL CONSIDERATIONS

The shape of a cylinder was chosen for the design of the proposed underground mine opening. The state of stresses that were considered were vertical, σ_z, radial σ_r, horizontal σ_θ and tangential σ_{rzr} stresses. The deformations along the vertical and horizontal axis, W and U of the mine opening respectively are defined by these stresses. With these we proceed to solve the problem of axial symmetrical theory of elasticity in the elastic hemisphere of a cylindrical vertical opening of radius R and depth H (fig.1). On the surface opening, external load is absent and at infinity, there is an accommodation of stress that is defined corresponding to the rock mass.

Use is made of two singular integral equations that operate on the assumption that there is continuity in the elastic hemisphere within the zone of the mine opening. These are characterized longitudinally by few vertical and radial stresses on excavating the mine opening. Their intensities P and Q represent a function of countour segment S of meridian cross section. From here it was assumed that the stresses at any point M inside the hole which generate the following stresses (σ_z, σ_r, σ_o, σ_{rzr}) can be calculated if the functions P(S) and Q(S) are known. If Mo represent the value of points inside the mine opening, hence the axial Pz(So)and radial Pr(So) stresses acting on the surface of the mine opening can be calculated through the following equations:

$$P_z(S_o) = P_z^o(S_o) + \quad [P(S)\, fp(S, S_o) + Q(S)\, f_Q(S, S_o)]\, dS \text{............}(1)$$

And

$$P_r(S_o) = P_r^o(S_o) + \quad [P_i(S)\, Fp(S, S_o) + Q(S)\, F_Q(S, S_o)]\, dS \text{..............................}(2)$$

Where,

$P_z^o(S_o) = -\sigma_z^o = \gamma H$; $P_r^o(S_o) = -\tau_{rz}^o = 0$ when $z = H$, $r < R$;

$P_r^o(S_o) = -\sigma_r^o = \lambda\gamma H$; $P_z^o(S_o) = -\tau_{rz}^o = 0$ when $z < H$, $r = R$;

$$\lambda = \frac{\gamma}{1 - \gamma} \text{.........}(3)$$

γ = poisson coefficient

In equation 1 and 2 the functions fp, f_Q, Fp and F_Q determine the influence of the stresses P and Q.

Considering semi contour D_1D_0 in fig 1 evaluate the integral f(S, So)ds to obtain a system of algebraic series where the unknown intensities of P_k and Q_k of the vertical and horizontal stresses lie. These are given as follows:

$$P_k(\sigma_z)^P ik + Q_k(\sigma_z)^Q ik = -\gamma H$$
$$P_k(\tau_{zr})^P ik + Q_k(\tau_{rz})^Q ik = 0 \ (I=1,2,...n) \ \text{...}(4)$$
$$P_k(\tau_{rz})^P ik + Q_k(\tau_{rz})^Q ik = 0$$
$$P_k(\sigma_r)^P ik + Q_k(\sigma_r)^Q ik = \lambda\gamma H \quad (I = m+1, \text{.........} m) \text{ ....}(5)$$

where,

n – common number of parts in the hemisphere D_1D_0

m - number of horizontal parts within the edge of the opening.

Having known the unknown values of P_k and Q_k through equations 3 and 4 we proceed to determine the stress and deformation in every point M inside the hemispherical hole during excavation. This is given by the multiplication of matrix σ and X

$$\sigma_M = \sigma \cdot X \ldots\ldots\ldots\ldots (6)$$

$$\begin{matrix} W_M \\ U_M \\ \sigma = (\sigma_z)_M \\ (\sigma_r)_M \\ (\sigma_\theta)_M \\ (\tau_{rz})_M \end{matrix} \qquad X = \begin{matrix} P_1 \\ Q_1 \\ P_2 \\ Q_2 \\ ! \\ P_n \\ Q_n \end{matrix}$$

$$\begin{matrix} W^P_{M1}, W^Q_{M1}, \ldots\ldots\ldots\ldots W^P_{Mn}, W^Q_{Mn} \\ U^P_{M1}, U^Q_{M1}, \ldots\ldots\ldots\ldots U^P_{Mn}, U^Q_{Mn} \\ (\sigma_z)^P, (\sigma_z)^Q_{M1}, \ldots\ldots (\sigma_z)^P_{Mn}, (\sigma_z)^Q_{Mn} \\ \sigma\ (\sigma_r)^P_{M1}, (\sigma_r)^P_{M1}, \ldots\ldots (\sigma_r)^P_{Mn}, (\sigma_r)^Q_{Mn} \\ (\sigma_\theta)^P_{M1}, (\sigma_\theta)^Q_{M1}, \ldots\ldots (\sigma_\theta)^P_{Mn}, (\sigma_\theta)^Q_{Mn} \\ (\tau_{rz})^P_{M1}, (\tau_{rz})^Q_{M1}, \ldots\ldots (\tau_{rz})^P_{Mn}, (\tau_{rz})^Q_{Mn} \end{matrix}$$

where, W_M, U_M, $(\sigma_z)_M$ etc represent unknown deformation and stress in point M;

and W^Q_{Mn}, W^Q_{Mn} etc represent the deformation and stress per unit value of P_n and Q_n

For effective result in the design of the proposed mine opening use is made of electronic calculating machine of model M-220 which corresponds to the coordinate grid shown in fig.2. The following data were employed to solve the required problem. Proposed diameter chosen were 4m, 6m and 8m; depth of the opening face 300m, tonnage factor of rock encountered 2.5 T/m^3; poisson coefficient, 0.4.

Also the elastic deformation in vertical U and horizontal axis W of the opening were deduced from the equations

2UG and 2GW, where, $G = E / 2(1 + \gamma)$

E is the elastic module constant in kg/cm^2

RESULTS/DISCUSSIONS:

The characteristics of the spatial distribution of stresses σ_z, σ_r and σ_θ for a mine opening of diameter 6m is shown in fig. 3 while the spatial representation of deformation near the face of mine opening with the same diameter is given in fig.4. This signify that if the mine rock is seen as an elastic object it is possible to conclude that at the moment of formation of outcrop of mineral layers around the vicinity of the face of mine opening, there exit stresses and displacement that conform with that shown in figs. 3 and 4. This work also showed that the change in the diameter of the hole has no effect on the spatial behavior of the stresses. It affirms that the spatial characteristics of the stresses solely depend on the region of influence of the rock mass within the mine opening (fig.5). This was explained further, by plotting the graphs of stresses against the distance from the mine face and the axis of mine opening. This is shown in fig.6. From the graph it is seen that on increasing the depth of the shaft the character of stresses in the shaft remain unchanged provided that other geological conditions of the shaft remain constant.

CONCLUSIONS:

For effective design of mine opening there is need to determine the values of stress concentration factor for the shape of the opening required before determining the critical values of boundary stress which will be compared with measured strength properties of the surrounding rock mass.

Tensile stresses are usually more serious than compressive in causing opening failure; peak tensile values occur at the top of openings.

The construction of the underground opening of the proposed uranium deposit require a thorough alignment of the walls of the opening with adequate concrete support to avoid failure during shaft sinking.

REFERENCES:

1. Anoshinka, V., !986. "Design and stability of excavations', Izvestia Journal, Moscow, 165 (4): 30 – 36.

2. Borovski, U., 1990. 'Rock mechanic for underground mining', МГИ Press, Moscow.

3. Obert, L., Duvall, W.I and Merrill, R.H., 1988. 'Rock mechanic and design of structures in rock', Wiley, New York.

4. Panck, L.A. 1988. 'Stresses about mine openings in a homogeneous rock body'., Edwards Bros, Ann Arbor, MI.

5. Woodruff, S.D. 1986. 'Methods of working coal and metal mines', Pergamon Press, N.Y.