STRESS-DEFORMATION DISTRIBUTION ANALYSIS OF UNDERGROUND STORAGE CAVERNS IN SALT DEPOSITS

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ABSTRACT

Experimental evidence from triaxial compressive tests carried out with salt specimens, indicates that the mechanical response of rock salt is characterized by substantial strain hardening and an ability to mobilize a post-failure residual strength.

On this basis, a constitutive model is proposed capable of describing such behaviour, while being simple enough to allow its use in the assessment of the stability of solution mined salt caverns.

The complete characterization of the mechanical response of rock salt under quasi-static loading conditions is recognized by identifying the following three distinct parts in the stress-strain curve of salt when subjected to triaxial compressive testing :

Part I : Salt behaves linearly as long as the differential stress $\sigma_1-\sigma_3$ remains below the yield limit σ_y, and its deformational response is entirely characterized by its elastic constants.

Part II : When $\sigma_1-\sigma_3$ is greater than σ_y the material's resistance to deformation always increases with increasing deformation and the relationship between axial strain ε_1 and $\sigma_1-\sigma_3$ is expressed by the following non-linear strain hardening law:

$$\sigma_1-\sigma_3 = \frac{\varepsilon_1}{a + b\,\varepsilon_1}$$

where a and b are material constants. This phase, which extends until $\sigma_1-\sigma_3$ reaches the material's peak strength σ_p, is accompanied by a slight increase in volumetric strain.

Part III : The material here exhibits a sudden drop in strength to the residual σ_r once peak strength σ_p has been attained. Furthermore ε_1 increases indefinitely while the differential stress, equal to σ_r, remains constant and the volumetric changes are nearly zero.

To demonstrate the application of the proposed constitutive model, a stability analysis is presented for internally pressurized spherical and cylindrical salt caverns, giving analytical expressions for the distribution of tangential and radial stress components as well as the radii of the yield and fracture zones.

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