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Viscoelastic-plastic constitutive relationship of swelling soft rock and modified generalized Kelvin creep model

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Swelling soft rocks will exhibit strong dilation and softening due to water immersion of which it is, generally, a time-dependent deformation in relation with humidity distribution. It is hard to describe this kind of creep property by means of the existing rheological model. Therefore, in this paper, A new model is presented by a modified generalized Kelvin element in series with a plastic cell introduced on the assumption that the material corresponds to Mohr-Coulomb criterion as well as corresponding plastic flow rule after yielding.

The generalized Kelvin model (Three Parameters Solid Model) is modified by introducing the **swelling coefficient** α depending on rocks attribute and **viscosity attenuation coefficient** ξ to consider the humidity factor based on the humidity field theory. According to the theory, there are three main processes as the swelling rock subjected to wetting which like that of the thermal behavior of materials: the humidity transport within swelling rocks triggers the change of humidity field; the change of humidity field lead to the dilation and softening, then by which the change of stress and displacement fields are exhibited.

The new model can simulate the viscoelastic-plastic deviation characteristics and the elastic-plastic volume behavior under different humidity condition. The corresponding viscoelastic-plastic constitutive relation is deduced, and the solution method of model parameters is given. The rheological model is redeveloped by FLAC 3D to simulate the creep characteristic of swelling soft rock in humidity field and the creep parameters under different water content were fitted by the experimental data. The results demonstrate that the experimental curves are in good agreement with the theoretical curves based on the new model. The modified generalized Kelvin creep model can not only reflect the two kinds of creep characteristic of swelling soft rock under humidity field-the deformation is relatively faster at first and gradually tends to be stable after a period of time at low stress loading while it gradually transforms into unstable creep at high stress loading-but also the different creep curves of swelling soft rock under different water content.

Key words: generalized Kelvin model; humidity field theory; Mohr-Coulomb; viscoelastic-plastic; swelling soft rock