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Effective stress law for the permeability of a limestone: experimental study and microstructural modelling

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The variation of the permeability of a rock with changes of total stress and pore pressure has a great interest in rock mechanics, reservoir engineering and geophysics. If a single variable can be defined as a linear combination of the total stress and the pore pressure to express the variations of the permeability, then we can say that the permeability follows an effective stress law. The effective stress law for the permeability of a limestone is studied experimentally by performing permeability tests in a triaxial cell with different conditions of confining pressure σ and pore pressure p_f. A power law is proposed for the variation of the permeability with the effective stress (σ'=σ-$n_k p_f$). The permeability effective stress coefficient n_k increases linearly with the differential pressure and is greater than one as soon the differential pressure exceeds few bars. This means the effect of the pore pressure change on the variation of the permeability is more important than the effect of a change of the confining pressure.

On the basis of microscopic observations of the microstructure of the rock, a conceptual pore-shell model is proposed to explain these experimental observations. It is shown that the important factor is the ratio of the different bulk moduli of the various constituents of the rock. This ratio is studied experimentally by performing microhardness tests. The proposed pore-shell model which results in a permeability effective stress coefficient which is greater than one is compatible with the results of the performed permeability tests.

References

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