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Permeability-porosity relationship for compaction of a low-permeability creeping material : Experimental evaluation using a single transient test

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It is well-known that there is no unique permeability-porosity relationship that can be applied to all porous materials. For a given evolution process that changes both permeability and porosity of a porous material, for example elastic or plastic compaction, microcracking or chemical alteration, it is usually assumed that there is an empirical relationship in the form of a power-law or exponential relationship between these parameters. The coefficients of these empirical relationships depend strongly on the properties of the material and of the evolution process. For the case of the power-law permeability-porosity relationship, a review of the literature shows that the exponent of this relation may be integer or non-integer, constant or variable, and the reported values of exponent vary between 1.1 and 25.4 for different materials and evolution processes, but no clear correlation between the exponenet and the petrophysical properties could be found. This wide variability of the permeability-porosity relationship highlights the necessity of experimental evaluation of this relationship for each material and evolution process.

An experimental method is presented for the evaluation of a permeability-porosity relationship in a low-permeability porous material using the results of a single transient test. This method accounts for both elastic and non-elastic deformations of the sample during the test and is applied to a hardened class G oil well cement paste. An initial hydrostatic undrained loading is applied to the sample which generates an excess pore pressure, related to the applied hydrostatic stress by the Skempton coefficient of the material. The generated excess pore pressure is then released at one end of the sample while monitoring the pore pressure at the other end and the radial strain in the middle of the sample during the dissipation of the pore pressure. These measurements are back analysed using a finite-difference numerical scheme to evaluate the permeability and its evolution with porosity change. The stress-dependent character of the poroelastic parameters of the hardened cement paste (Ghabezloo et al., 2008) and also the creep of the material during the test add some particular aspects to the back-analysis, which makes this problem different from the classical solutions of transient permeability evaluation tests. The effect of creep of the sample during the test on the measured pore pressure and volume change is taken into account in the analysis. This approach permits to calibrate a power law permeability-porosity relationship for the tested hardened cement paste and also two parameters of a viscoelastic model for the creep of the material. The porosity sensitivity exponent of the power-law is evaluated equal to 11 and is shown to be mostly independent of the stress level and of the creep strains.

The proposed method can be applied to different low permeability porous materials and for the case of non-creeping materials, the same type of analysis can be used to calibrate either a permeability-porosity or a permeability-effective stress relationship for the compaction of the tested material using a single transient test.

References:

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