Fluid flow and fracturing in weakly cemented porous media: an insight into the underlying mechanisms

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Fluid flow and fracturing in porous media are the underlying mechanisms of many applications in the fields of energy geomechanics, hydrogeology and groundwater hydrology. The characteristics of the fluid flow vary depending on the physical and mechanical properties of the porous medium and the composition and viscosity of the injected fluid. These parameters are chosen depending on the target of each application (whether fracture or uniform replacement of pore fluids - infiltration) and the depth of the operation (soil/rock) [1].

Many operations take place in weakly-cemented and poorly-consolidated sands which represent the host rock for a large portion of active aquifers and oil and gas reservoirs. These materials have much higher porosity and permeability compared to strong rocks, hence, their behaviour under fluid injection conditions is very different and largely unexplored [2].

Since coring of such formations is problematic due to large costs and destruction of cementation, synthetic materials of known mechanical and hydraulic properties were generated to perform fluid flow injection experiments [1], [3]. The method used to prepare the specimens was microbially induced carbonate precipitation (MICP), a bio-cementation technique that builds calcium carbonate around silica particles [4].

Specimens of various cementation levels, and hence various combinations of permeability, porosity and strength were tested in a fracture capture apparatus capable of reproducing field conditions.

The experimental behaviour was then examined (i.e., infiltration/fracturing response, fracturing patterns and behaviour) and critical concepts from the field of advanced geomechanics, which have been neglected in numerical studies, such as enhanced permeability, infiltration, flow type, insitu stresses and the elastoplastic behaviour of the material itself are considered to understand the experimental results.

First, dimensional analysis is performed to reveal the role of permeability, flow rate and stress anisotropy in the fluid flow in weakly cemented porous media and then the concept of brittleness index (BI) and cavity expansion theory is applied to the findings [5].

Results show that the fluid flow properties are dominant in fluid flow experiments in such weakly cemented and highly porous media, while the effects of stress levels and anisotropy are also of great importance as the stress dependent brittleness indices provided better fits. Finally, conventional fracture initiation criteria have been proved inadequate in interpreting the findings as the results are better described by the pressure limits derived from the cavity expansion theory.

References

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