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Advances to the Modelling of Variably Saturated Fracture Flow using the Geotechnical Centrifuge in South Africa

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Geotechnical centrifuge modelling has developed into an important physical modelling tool due to its ability to replicate natural stress conditions in a reduced-scale model, allowing for many complex interaction problems to be investigated. Most complex numerical models are only mathematical approximations of reality. Unlike constitutive models, no assumptions need to be made and an actual physical event can be observed in the centrifuge, making it a unique physical modelling technique [1]. Centrifuge modelling of soil behaviour has received much more attention than the modelling of rock masses. Consequently, the available literature that deals with fluid flow through a rock mass is scarce and limited to transport studies and petroleum industry research. In this instance a valid centrifuge model allows one to directly measure or observe the influence that different fracture properties will have on fluid flow. This research therefore aims at assessing the use of centrifuge modelling in answering practical geotechnical problems associated with rock masses and variably saturated fracture flow.

The cubic law is employed for quantifying flow through discrete fractures and relates the estimated hydraulic conductivity to the cube of the fracture aperture, provided that the fracture is clean, smooth, parallel and completely saturated. The first experiment was constructed to test unsaturated flow in the smooth parallel plate model for a horizontal fracture and a vertical fracture, under an intermittent as well as continuous seepage influxes. The parallel plate model was thereafter extended to include an orthogonal fracture intersection in order to validate the findings to theory on unsaturated flow at fracture intersections. Furthermore, the influence of inclination of the fracture and subsequent intersections were also explored in the centrifuge.

Results presented here show that similar flow regimes described in literature (e.g. film and droplet flow as presented in Indraratna and Ranjith [2]) are observed at increased gravitational acceleration, which supports the geotechnical centrifuge as a valid method in answering practical problems associated with variably saturated flow. However, the research has also underlined the existing issues with using the cubic law to quantify flow through rock fractures as these fairly basic conceptual tests, aiming to directly mimic the smooth parallel plates model, cannot duplicate the basic assumptions of the cubic law. Therefore, its use in numerical models should also then be queried. The results observed of flow at fracture intersections contradicts literature (e.g. Ji et al [3]) and highlight the impact gravity-driven flow has on the movement of fluid at orthogonal intersection with a wide aperture. However, when inclined, significant flow into the lateral fracture was observed at the intersections.

Findings from this research can be used to construct and test valid geotechnical problems associated with variably saturated rock masses using the centrifuge. These include, but are not limited to: the stability of building basements; civil engineering tunnels; large rock caverns; water seepage into road cuts and the stability thereof.

References:

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