

Two new methods for the determination of hydraulic fracture apertures in fractured-rock aquifers[†]

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Abstract

Fracture apertures play a significant role in groundwater systems. For proper groundwater quantity and contamination management, fractures have to be properly characterised. However, due to their complexity, fracture characterisation is one of the main challenges for hydrogeologists all over the world. This is particularly important in South Africa, where aquifers are predominantly fractured. Two new methods have been developed to determine inclined and horizontal fracture apertures in fractured-rock aquifers. The first is a water-balance method, the slug-tracer (ST) test:

- The slug-tracer (ST) test

$$[b = (r^2 / R^2) \Delta h]$$

and the second is a tracer-detection method, comprising the NAPL entry pressure (NEP) test and the NAPL injection pressure (NIP) test:

- The NAPL entry pressure (NEP) test

$$[b = \frac{1}{2P_e} (r \rho g h)]$$

- The NAPL injection pressure (NIP) test

$$[b = \frac{1}{2P_e} (\rho g V / 2 \pi r)] \text{ and } [b = \frac{1}{4P_e} (M g) / m]$$

These mathematical formulations were developed from laboratory experimentation using transparent Perspex parallel plate physical models and 27 apertures of 0.008 mm to 6 mm, created by using aluminium foil and thickness gauges between 20 mm thick clamped Perspex plates. The ST test uses a slug to which is added NaCl as tracer (50 mg to 300 mg/l). An EC meter is used to detect breakthrough in the observation boreholes.

The NEP test uses an NAPL (sunflower oil) hydraulic head and transducers to determine the entry pressure. Using these mathematical formulae, fracture apertures are then determined for horizontal and inclined apertures. The NIP test uses the entry pressure (by injection), recorded by transducers of an NAPL (sunflower oil) and its volume or mass to determine the fracture aperture for horizontal and inclined fractures. Results from smooth and rough (buffed to 10 x 20 μ) fracture surfaces gave accuracies of 96 to 98% for aperture determinations of 26 apertures from 0.04 to 6 mm.

Keywords: direct measurement of fracture aperture, fractured-rock aquifers