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Frequency-dependent streaming potential of porous media: Experimental measurement of Ottawa sand, Lochaline sand and quartz glass beads

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High quality frequency-dependent streaming potential coefficient measurements have been made upon Ottawa sand, Lochaline sand and glass bead packs using a new apparatus that is based on an electro-magnetic drive. The apparatus operates in the range 1 Hz to 1 kHz with samples of 25.4mm diameter up to 150 mm long. The results have been analysed using theoretical models that are either (i) based upon vibrational mechanics, (ii) treat the geological material as a bundle of capillary tubes, or (iii) treat the material as a porous medium. In each case we have considered the real and imaginary parts of the complex streaming potential coefficient as well as its magnitude. It is clear from the results that the complex streaming potential coefficient does not follow a Debye-type behaviour, differing from the Debye-type behaviour most markedly for frequencies above the transition frequency. The best fit to all the data was provided by the Pride (1994) model and its simplification by Walker and Glover (2010), which is satisfying as this model was conceived for porous media rather than capillary tube bundles. Theory predicts that the transition frequency is related to the inverse square of the effective pore radius. Values for the transition frequency were derived from each of the models for each sample and were found to be in good agreement with those expected from the independently measured effective pore radius of each material. The fit to the Pride model for all four samples was also found to be consistent with the independently measured steady-state permeability, while the value of the streaming potential coefficient in the low-frequency limit was found to be in good agreement with steady-state streaming potential coefficient data measured using a steady-state streaming potential rig as well as the corpus of steady-state determinations for quartz-based samples existing in the literature.