P-wave velocity variation in water-saturated sand from shallow seismic refraction

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Recent advances in equipment, sound sources, and computer interpretation techniques have made the seismic refraction methods highly effective and economical for petroleum, mineral, engineering, and to a limited extent, groundwater modelling applications. Direct values of desired interval velocities in subsurface formations can be determined from geometrically ordered first arrival refraction times. The reliability of seismic lithology mapping lies in accurate velocity determination and correct formation identification from a wide range of velocities derived. A problem arises in subsurface mapping of shallow alluvium in Malaysia from the current assignment and interpretation of velocities to various degrees of water saturation in the sands and gravel. Dry sand and soil cover are usually described by a low velocity between 330-500 ms^{-1}, while Young Alluvium and sand filled paleochannals, the later, as prominent targets for placer tin prospecting are assigned a range of velocities between 1600 to 1900 ms^{-1}. Notice however that the velocity of sound wave in water is 1500 ms^{-1}. We are tempted to ask whether the delineation of the Young Alluvium and Transitional Zone, based on refraction velocities, is not an exercise in mapping the ground water-table instead. In the absence of borehold control, water saturated sands can have similar refraction velocities.

The purpose of this study is to examine the variation of P-wave velocity in water saturated sands from velocities derived by shallow seismic refraction. Data was collected from 2 selected wholly sand-filled sites in Penang, with known depth of water table, through the wet and dry seasons. The Gassmann's equation is used next to model and calibrate the effects of water saturation on velocity in this clastic media.

Results of this study indicate that on the contrary, P-wave velocity in porous sand decreases slightly with water saturation. This continues until it is nearly fully saturated when the velocity takes a five-fold increase. We obtained in Balik Pulau and Teluk Kumbar, Penang, values between 340-360 ms^{-1} in 'dry sand' with estimated 10-20% water saturation, and, 1600-1800 ms^{-1} in fully saturated sands with 40% calculated porosity. Velocity measurements derived from shallow seismic refraction methods can only identify 'alluvium' sands to the extent whether it is 'dry' or fully saturated; it is difficult to determine intermediate saturation values. This attribute provides a useful basis for groundwater mapping. Our study suggests the velocity change as due to fully saturated sands demarcated by the level of the water-table only.

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