Détermination dans les forages de l'élasticité des sols à l'aide de sondes

BARON Ludovic; October 11, 2001

Supervisor: Prof Dominique Chapellier, Institut de Géophysique

Biot, in 1956, described the fully coupled motion of mechanical waves in saturated porous media. The required inputs for this model are, among other : mechanical properties of the soil matrix, porosity, and matrix density. Thus, Biot equations, by accommodating any possibilities of test conditions, including in situ and laboratory ones, are ideal to determine skeletal bulk properties from P- and S- wave velocities. In order to find porosity and matrix density, a set of samples were collected in boreholes. Clay and sand for quaternary and marls and sandstone for tertiary formations essentially constitute lithologies. Bulk density, porosity and matrix density laboratory tests were performed on these samples. A general trend can be observed : an increase of gamma-gamma probe intensity corresponds to a decrease of laboratory bulk density and a decrease of the neutron probe intensity corresponds to an increase of porosity.
A root mean square approach has been performed in order to calibrate the probes but the computed matrix density is scattered due to errors on porosity determination. A neural network has then been trained with in situ probe data and laboratory test. Results for densities and porosities are similar to those with the root mean square approach but due to the fact that the information of the two tools has been treated simultaneously the computed matrix density is more accurate. This calibration procedure, valid for any geotechnical borehole conditions, is empirical but gives sufficient accuracy to allow us the computation of elasticity parameters of soils. For both nuclear probes, relationships are tool dependant but scaling methodologies are available for other probes.
In soils, as S-wave velocity is less than P-wave velocity in water, shear refracted wave cannot be generated at the interface between fluid and formation by an emission of classical P-wave in the borehole. Consequently, polarized P-wave is generated in order to produce a pressure at a point of the borehole and a depression at an opposite point. This flexural mode generates S-waves in the formation. Horizontal field is then recorded at two constant offsets above the emitter, leading to the shear wave velocity. Full-waveform sonic has also been recorded, P-wave velocity profile are computed from first arrivals.
P- and S-waves vertical seismic profile have been performed with hydrophones and horizontal geophones. Subtraction of two opposite horizontal shoots on S records allows keeping only opposite phase signals propagating at shear wave velocity. Further, the combination of logging information and vertical seismic profile optimises the velocities determination.
Once all the parameters are known, computation of the shear and compressibility modulus profile can be made, using the specific frequency of the wave, leading to the description of the soil elastic behaviour at short and long term.