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Clay content significantly influences the mechanical behavior of soils, thereby playing an important role in many fields of applications such as civil engineering, geology and agriculture. In the area of pavement engineering, clay content in structural bearing courses of pavement frequently causes damages and defects, such as transversal and longitudinal cracks, or other faults. The main consequence is a lowering of both the road safety and operability, with the number of expected accidents increasing.

In this study, ground-penetrating radar (GPR) laboratory tests were carried out to predict the clay amount in pavement structural layers under different clay and moisture conditions. GPR data processing is performed using two different methods. The first method is based on the Fresnel theory and focuses on the Rayleigh scattering of the radar waves. The approach is based on a different scattering of the various components of the frequency spectrum, mostly depending on both the soil texture and variation in soil moisture content. For the application of this method, we used a pulse radar with ground-coupled, 500 MHz centre-frequency antennas in a common offset, bistatic configuration. The transmitter and receiver were linked by optic fiber electronic modules.

The second method is based on full-waveform inversion of the ultra wideband radar data. In particular, a specific radar-antenna electromagnetic model is used to filter out antenna effects and antenna-medium interactions from the raw radar data and retrieve the response of the soil only, expressed in terms of a layered medium Green's function. To estimate the medium geometrical and electrical values, an optimization inverse problem is formulated.

For the application of that second method, we used a vector network analyzer (VNA) as continuous-wave stepped-frequency radar system to acquire data in the 500-3000 MHz frequency range. A doubled-ridged broadband horn antenna operating in far-field conditions was used as transmitter and receiver, and was connected to the radar using a high-quality coaxial cable.

Typical road materials for subgrade and sub-base courses were used. In particular, three types of soils classified, respectively, as A1,A2,A3 by AASHTO were used and adequately compacted in electrically and hydraulically isolated boxes. A copper sheet was laid at the bottom of the experimental boxes to control the bottom boundary conditions in the electromagnetic model. Basically, two significant cases were considered for each soil type, taking into account the 0% and the 25% by weight of bentonite clay, respectively. Water was gradually added and GPR measurements were carried out for all moisture steps until the maximum saturation level was reached.

Concerning the Rayleigh scattering method, analyses show a high consistency of the results with respect to our expectations. A negative correlation between the shift of the frequency spectrum peaks and the clay amount was demonstrated, by virtue of its strong hygroscopic properties. Similarly, the full-waveform inversion technique allowed to measure reliable electric parameters. Generally, different responses (e.g. electric conductivity and permittivity) of the 0% clay-member cases compared to those of the analogous clayey soil samples highlight the large potentiality of both methods for the detection of clay.