Geophysical Research Abstracts
Vol. 13, EGU2011-7864, 2011
EGU General Assembly 2011

Potentiality of GPR for evaluation of clay content in soils

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The evaluation of clay content in soils is important for many applications in civil engineering as well as in environmental engineering, agriculture and geology. This study is applied to pavement engineering, but proposes a new approach, method and algorithm that can be used also for other purposes. Clay in sub-base or sub-grade reduces bearing capacity of structural layers of pavement. This induces frequently damages and defects that have a severe negative impact on road operability and safety.

Traditionally, the presence of clay in a soil is evaluated in compulsive water content.

In this study we propose a new technique based on Ground Penetrating Radar (GPR) inspection. GPR is yet largely used for pavement engineering applications and this technique could be easily integrated in the existing systems, making the inspection more effective. This method is based on the Rayleigh scattering according to the Fresnel theory: basically the GPR signal, differently as usual, is processed in the frequency domain.

The method has been compared with others to evaluate as it performs.

Ground-coupled Radar antennas were used for GPR analysis. GPR operates with two antennas with central frequencies about 600 and 1600 MHz. Measurements are developed using 4 channels, 2 mono-static and 2 bi-static. The received signal is sampled in the time domain at dt = 7.8125 x 10^{-2}ns.

The experiments have been carried out in laboratory using typical road material adequately compacted in an electrically and hydraulically isolated box. Clay (montmorillonite) has been gradually added from 2% to 30%. GPR inspections have been carried out for any clay content. The GPR signals have been post-processed both in the time and in the frequency domain.

In the time domain, a real consistency of the results was assessed with those expected to arise from the electromagnetic theory, considering the different signals in terms of time delays between pulses reflections, dielectric constant and amplitude. In the second step, the analysis was carried out in the frequency domain, assuming residual water content of dry clay, by virtue of its strong hygroscopic capacity. As expected the scattering produces a non-linear frequency modulation of the electromagnetic signal, where the modulation is a function of water content, therefore, indirectly, of the percentage of clay present in the soil material. The frequency spectra have shown a significant negative correlation between the shift of the value of the peak and the clay content in the road material: indeed the results show a decreasing trend in the value of the peak frequency, with a shift equal to the FFT resolution (0.26 x 10^8 Hz), while the clay content varies from 0 to 30%; further feedback has provided from comparative analysis of spectra, it is possible to evaluate the selective behavior of the clay, compared to specific frequency range. The main benefit of the method is that no preventive calibration process is necessary.