Interpolation of sparse dynamic cone penetrometer INDEX using electromagnetic induction DATA on a clayey silt test site at scale 1:1

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Dynamic Cone Penetrometer (DCP) is a widely used method to estimate soil bearing capacity for applications such as road pavement and landing strip design. However, a DCP sounding only provides local information in the form of a penetration per blow index (DCP index). An exhaustive description of a site requires a dense sounding grid and is therefore labor intensive and time-consuming. The present study is part of a larger project aiming to reduce the necessary number of DCP soundings to describe a site of interest and fill in the gaps with geophysical data.

The vertical resolution of any geophysical measurements is admittedly much poorer than that of the DCP but the horizontal resolution can be much better. Geophysical methods are therefore very useful in a geostatistical process aimed at interpolating between DCP soundings. To this end, a 29 m long, 5 m wide and 75 cm deep test site was built near Rouen (France) in 2019 with three zones of different compaction levels. A dense grid of DCP soundings (every 50 cm x 50 cm) was acquired and seismic, electric and electromagnetic geophysical methods were applied on the site. The first successful step in the geostatistical interpolation of DCP soundings was to use the seismic data as the secondary variable, as both methods characterize the mechanical properties of the ground and show a good correlation on the center profile of the test site.

The following step, presented here, is to apply this protocol with electromagnetic induction (EMI) data. Its acquisition is more efficient as it does not require any direct contact with the ground and can be used to generate a 3D volume of the apparent and inverted electrical resistivity in the investigated area. While the EMI methods are sensitive to different physical ground properties, they are dependent on common parameters such as porosity and water content, which are related to the soil bearing capacity.

This process requires a careful processing of the EMI data in order to obtain an electrical resistivity volume as reliable as possible from the quadrature component of the EMI measurements. As the depth of interest is limited to the first meter below ground surface (bgs) and in order to achieve a sufficient resolution both laterally and in depth, a CMD Mini-Explorer 6L that has 6 different offsets between the transmitter and receiver coils (0.20 m, 0.33 m, 0.50 m, 0.72 m, 1.03 m and 1.50 m) was used for data acquisition. The acquisition in the two possible coils orientations, HCP (Horizontal Co-Planar) and VCP (Vertical Co-Planar), means that there are 9 different theoretical depths of investigation (some HCP offsets have the same depth of investigation that larger VCP ones) between 0.15 m and 2.3 m bgs and that an inversion can be confidently envisaged after the data calibration. In our case, the EMI data was calibrated against an electrical resistivity tomography acquired on the center profile of the test site on the same day.

The obtained inverted electrical resistivity volume is then used as the secondary variable in the geostatistical interpolation of the DCP data. All the DCP soundings (almost 500) are first interpolated (ordinary kriging) on their own as a reference. The DCP dataset is then heavily decimated until only a few soundings remain and a co-kriging is applied with the electrical resistivity obtained from the EMI data as auxiliary variable to help fill in the gaps in the sparse DCP data.