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Soil variability in engineering applications

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Natural geomaterials, as soils and rocks, show spatial variability and heterogeneity of physical and mechanical properties. They can be measured by in field and laboratory testing. The heterogeneity concerns different values of litho-technical parameters pertaining similar lithological units placed close to each other. On the contrary, the variability is inherent to the formation and evolution processes experienced by each geological units (homogeneous geomaterials on average) and captured as a spatial structure of fluctuation of physical property values about their mean trend, e.g. the unit weight, the hydraulic permeability, the friction angle, the cohesion, among others. The preceding spatial variations shall be managed by engineering models to accomplish reliable designing of structures and infrastructures. Materon (1962) introduced the Geostatistics as the most comprehensive tool to manage spatial correlation of parameter measures used in a wide range of earth science applications. In the field of the engineering geology, Vanmarcke (1977) developed the first pioneering attempts to describe and manage the inherent variability in geomaterials although Terzaghi (1943) already highlighted that spatial fluctuations of physical and mechanical parameters used in geotechnical designing cannot be neglected. A few years later, Mandelbrot (1983) and Turcotte (1986) interpreted the internal arrangement of geomaterial according to Fractal Theory. In the same years, Vanmarcke (1983) proposed the Random Field Theory providing mathematical tools to deal with inherent variability of each geological units or stratigraphic succession that can be resembled as one material. In this approach, measurement fluctuations of physical parameters are interpreted through the spatial variability structure consisting in the correlation function and the scale of fluctuation. Fenton and Griffiths (1992) combined random field simulation with the finite element method to produce the Random Finite Element Method (RFEM). This method has been used to investigate the random behavior of soils in the context of a variety of classical geotechnical problems. Afterward, some following studies collected the worldwide variability values of many technical parameters of soils (Phoon and Kulhawy 1999a) and their spatial correlation functions (Phoon and Kulhawy 1999b). In Italy, Cherubini et al. (2007) calculated the spatial variability structure of sandy and clayey soils from the standard cone penetration test readings. The large extent of the worldwide measured spatial variability of soils and rocks heavily affects the reliability of geotechnical designing as well as other uncertainties introduced by testing devices and engineering models. So far, several methods have been provided to deal with the preceding sources of uncertainties in engineering designing models (e.g. First Order Reliability Method, Second Order Reliability Method, Response Surface Method, High Dimensional Model Representation, etc.). Nowadays, the efforts in this field have been focusing on (1) measuring spatial variability of different rocks and soils and (2) developing numerical models that take into account the spatial variability as additional physical variable.

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