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Interaction between geological and geotechnical investigations of a sandstone residual soil

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Abstract

This paper discusses results of geological and geotechnical investigations carried out on a residual soil originated from the weathering of a southern Brazil sandstone, the Botucatu formation. Triaxial compression tests with local strain measurement were used for the evaluating stiffness and strength parameters of this soil. Its microstructure was investigated using both optical and scanning electron microscopy. Important differences observed in relation to the expected geomechanical behaviour of structured soils are explained by considering details of soil fabric shown by these microscopy analyses.

Keywords: Residual soil; Sandstone; Triaxial compression test; Microstructure

1. Introduction

From a geotechnical point of view, the presence of microstructure in soils has been considered a relevant research subject since the classical work of Leroueil and Vaughan (1990). In that work, the authors highlighted some important characteristics of the geotechnical behaviour of structured soils and showed that these characteristics are quite common in many natural soils. Based on such concepts, research into transitional soil/rock materials has intensified in the last two decades (Cuccovillo and Coop, 1997). The presence of microstructure has been identified even in freshly deposited clays (Burland, 1990) and sands (Schmertmann, 1991).

In this relatively new area of knowledge, both geotechnical and geological concepts are essential in order to build a common basis for understanding and modelling the behaviour of structured soils. Considering the similar geomechanical behaviour shown by some types of structured soils—as pointed out by

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Leroueil and Vaughan (1990)—it is important to recognise the different behaviours that can result from differences in soil microstructure. In this paper, both geological history and microscopy analysis were taken into account to explain some peculiarities observed in the geomechanical behaviour of a residual soil classified as a structured sand. According to Barton (1993), transitional soil/rock behaviour is better understood in clayey materials than in sandy materials due to the relative facility with which undisturbed samples of clays can be obtained from boreholes. Despite this difficulty, Barton (1993) observed that both interlocking and cementing can bring cohesion to sands in a sand/sandstone transition during a lithification process. On the other hand, Dobereiner and de Freitas (1986) showed that a structured sand can result either from incipient consolidation of a freshly deposited sand or from a weathering process acting on a sandstone. The residual soil described in this paper derives from the weathering of a southern Brazilian sandstone called the Botucatu Formation. Although this material has been classified as a soil, the original layered structure of the parent rock is still quite visible. Its behaviour during geomechanical tests, especially its stiffness and strength characteristics, is better understood by taking into account some geological factors. Emphasis is given in this paper on the description of some petrologic aspects of this residual soil and its relation to observed stiffness and strength characteristics.

2. The Botucatu sandstone

The Botucatu sandstone is present across a wide area of South America. This sandstone is of eolian origin and was deposited under desertic conditions over an area of 1.5 million km^2. It consists of a superposition of paleodunes with typical cross-bedding stratification. These sedimentary rocks are present in most of Southern Brazil and are covered by thick Cretaceous basaltic flows of the Paraná Basin. In some places, the Botucatu sandstone is more than 100 m thick (Scherer, 2000). This sandstone is found not only below the basaltic flows but is also found between flows, being related to the Lower Cretaceous period. Erosive processes acting intensely on the border of these flows exposed the Botucatu sandstone along a comparatively narrow east–west strip of land located about 30 km north of Porto Alegre, Brazil. An extensive investigation of the geology of Botucatu sandstone was conducted by Scherer (2000). The author identified the original process of formation of dune bodies by an association with observed stratigraphic patterns. The natural stratigraphy of Botucatu sandstone was related to wind direction, wind intensity, age and the consequent movement of dune bodies. According to Scherer (2000), the Botucatu sandstone preserves its original structure intact. It is one of the most representative formations originated by an eolian sedimentation deposition process.

A significant difference can be found between geological and geotechnical terminologies used to describe the residual soil of Botucatu sandstone (here denoted as BRS soil). From a geological point of view, since this material preserves the original fabric through depths of tens of metres, it is called a rock. On the other hand, from a geotechnical point of view, this material is called a soil (C horizon) due to its low strength, as it is easily excavated by hand. Different from most tropical residual soils, in which original features of the parent rock, like fabric and cementation, are preserved only within a comparatively narrow C horizon that marks the transition between soil and rock, BRS soils are remarkable for showing very thick C horizons. The B horizon is about 3 m thick, and the A horizon only about 0.5 m thick. This contrasts with local residual soils originated from the weathering of basalt, which usually present a very thick B horizon and a comparatively narrow C horizon. It also contrasts with local residual soils of granite, which are often less than 3 m thick. The thick C horizon observed in BRS soils is explained by its porous fabric, which has a medium hydraulic conductivity (k>10^{-7}m/s). The consequent good drainage is responsible for making the Botucatu formation one of the largest aquifers of the world. However, weathering of this sandstone did not act so efficiently as to form a thick B horizon (as in residual soils of basalt), probably due to the quartzitic nature of its clasts. At the Vila Scharlau site, about 20 km north of Porto Alegre, the BRS soil (C horizon), with its clearly visible original fabric, is over 30 m thick. This paper shows results of triaxial compression tests performed on samples taken from the C horizon at this site (Martins, 1994, 2001) and also from another site, denoted as RS239 and located about 10 km from Vila