TITLE
The influence of swelling on the behaviour of London Clay

AUTHOR
Eduard Viladesau Franquesa

TUTOR
Antoni Gens i Solé

EXTERNAL TUTOR
Matthew R. Coop

ABSTRACT
All natural clays have a structure, defined as the combination of fabric, or particle arrangement, and bonding between particles. Normally, this structure has an enhancing effect on their mechanical properties, albeit in some very rare cases its effect is negative. This natural soil can be disaggregated and mixed with water, and then left to consolidate, so as to produce a "reconstituted" soil, the structure of which is therefore repeatable, standard, and provides a benchmark against which to assess the effect of natural structure on the mechanical properties of the clay; it is found that the enhancing influence of natural structure is different for each clay. Structure can be damaged by compressing the clay to very high confining pressures, or by swelling it to very low confining pressures. In the same way as with the effect of structure varies from clay to clay, the effect of these damaging processes vary also for different clays. Some structures are not affected by swelling or excessive loading, others are so affected that they show the same behaviour as the reconstituted soil, while others have a behaviour in between.

London Clay is a structured, highly overconsolidated clay that outcrops all over the Thames Basin, belonging to the Eocene Epoch and resting on the Thanet Sand Formation and the Lambeth Group, and partially covered by the Bagshot formation. It is the soil present at London's Heathrow airport. For the project of the new Terminal 5 at this airport, extensive excavations and major geotechnical works must be undertaken, which will be left open during long periods of time for schedule reasons. In saturated conditions, this implies that the clay will be unloaded, "swelled", to very low confining pressures. The object of the present work is to assess the influence of this swelling on the structure of London Clay and thus on its mechanical properties. The mechanical properties on which the present work focuses are two of the main design parameters used in geotechnical calculations: the *resistance*, relevant for the Ultimate Limit State, and characterised by the State Boundary Surface of the soil, and the *rigidity*, relevant for the Service Limit State, characterised by the Modulus of Elasticity of the soil.

After a brief introduction to the project of Heathrow Terminal 5, and a geologic characterisation of London Clay, the theoretical concepts necessary for the understanding of clay behaviour and the tools used to quantify the influence of structure have been retraced in the form of a literature review. To implement these concepts and effectively assess the influence of swelling on the behaviour of London Clay, several triaxial tests have been conducted. The Author has performed four tests on samples of London Clay coming from the Heathrow site at the relevant excavation depth; the test procedures used have been thoroughly detailed in the present document. These samples have been swelled isotropically to a mean effective stress of 10 kPa, which represents the process undergone by the clay at the Terminal 5 Site. They have then been recompressed to different confining pressures and from there sheared, both in drained and undrained conditions. This has allowed finding the resistance and the stiffness of the swelled clay. Also, test results of both natural and reconstituted samples have been made available to the Author, which has allowed to compare the State Boundary Surfaces of the three sets of tests (on intact, reconstituted and swelled samples), so as to assess the influence of swelling on resistance; and to compare the stiffnesses of intact and swelled samples, so as to assesss the influence of swelling on rigidity. The conclusions of the work are that although swelling has an effect on the compressive behaviour of London Clay, it does not seem to affect its shearing behaviour, since both natural and swelled State Boundary Surfaces are found to be very similar, and the same trend is observed for the Modulus of Elasticity. Finally, further work is proposed in the form of an extended testing program to allow a complete characterisation of the behaviour of London Clay.