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Finite element modelling of a deep excavation in Boston Blue Clay

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Abstract

The work investigates the behaviour of a deep excavation that forms part of a wide basement located in Boston, Massachusetts, USA. The glacial marine clay deposit is modelled with a kinematic hardening model for structured soils, its reduced bubble model version and the well-known Modified Cam Clay model. The aim of the work is to assess the effects of the added features of the advanced model, such as small-strain stiffness, structure degradation and anisotropy, on the numerical prediction of the overall behaviour of the excavation. The first part of the paper provides a brief description of the site conditions, ground profile and construction sequences for the case study under consideration. Then, the soil model calibration process using experimental undrained triaxial, self-boring pressuremeter and constant rate of strain consolidation tests is discussed. Finally, the comparison of the predicted wall deflection and ground settlements profiles with observed movements is presented.

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Keywords: Excavations; constitutive models; finite element method; diaphragm wall; instrumentation

1. Introduction

The limited availability of land for construction in both developed and developing regions of the world has seen an increase in urban regeneration projects as well as construction of various types of infrastructure such as deep basements, subways and service tunnels. For a safely and timely completion of deep excavations, the use of appropriate retaining walls and bracing systems is usually required to minimise excessive ground movements. Successful control

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of movements during excavation works is often as imperative as assurance against collapse. As a consequence, limiting values of deformation should be carefully prescribed in accordance to the serviceability limit state. The techniques available to evaluate the wall deflections and ground settlements include either semi-empirical methods, derived from the interpolation of published data sets [e.g. 1,2] or analytical and numerical methods such as finite element (FE) analyses [e.g. 3-5].

The paper investigates the performance of a deep basement excavation located in Boston using an advanced constitutive model for natural clays formulated within the framework of kinematic hardening plasticity [6] and implemented in a finite element software [7]. The modelling framework adopted in this work is focused on the effects of the soil constitutive assumptions on the numerical predictions by starting with the well-known Modified Cam Clay model and consequently adding advanced modelling features such as stress-history dependency, anisotropy and structure.

2. Description of the case study

The case study investigated in this work is a 14.6m deep, 100m wide basement excavation above which four buildings up to eight storeys will form the Allston Science Complex at Harvard University, Boston, Massachusetts, USA. The construction site is located off Western Avenue in Allston, as indicated in Figure 1. In-situ investigations included standard penetration (SPT), cone penetration (CPTU) and seismic cone penetration (SCPT) tests, self-boring pressuremeter (SBPT) and field vane testing. The location of the different in-situ explorations is reported in Figure 1. SPT and field vane tests were undertaken in the boreholes together with associated sampling. The groundwater table was encountered at 2.0m below ground surface with a hydrostatic pore pressure increasing with depth, as measured by vibrating wire piezometers installed in some of the boreholes (Fig. 1). Laboratory testing consisted of K_0-consolidated undrained triaxial tests in both compression (CK_0UTC) and extension (CK_0UTE), direct shear tests (DSS), unconsolidated undrained triaxial tests, Atterberg limits and moisture contents. The geological sequence, confirmed by the site investigations, included successive strata of made ground, alluvium deposits (occasionally including organic peat material), sandy gravel, the Boston Blue Clay (BBC) marine clay, glacial till and the Cambridge argillite bedrock. According to the available geological and geotechnical data, the geotechnical model adopted in this study was composed by a first 2m thick layer of made ground (L_1) followed by a 4m stratum of fluvial sands (L_2), a 26m deep BBC deposit (L_3) overlaying 8 meters of glacial till (L_4) resting on the Cambridge argillite bedrock. The BBC deposit was divided in an upper overconsolidated (OC) 19m thick layer and a lower normally consolidated (NC) 7m thick layer.

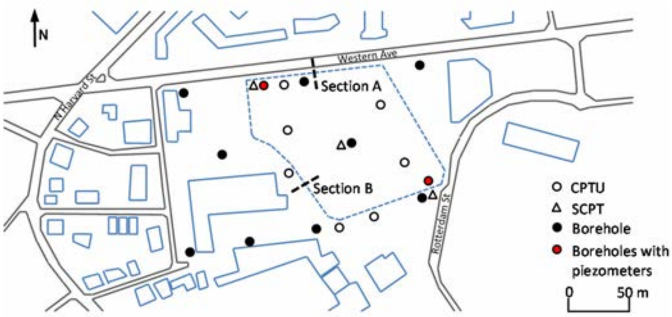

Fig. 1. Allston Science Complex, Boston, USA and location of in-situ tests.

Two different types of retaining wall were adopted in the project: a diaphragm wall (or reinforced concrete slurry wall) was used for the sections where a significant cantilever condition was required above the top tieback level (Section A), while a soldier pile tremie concrete (SPTC) slurry wall was proposed for those sections where the top tieback level was in relative proximity to the ground surface (Section B). The schematic plan view of the two Sections A and B is reported in Figure 1. The total depth of excavation was varying between 13m and 17m and the walls were