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Research Paper

Prediction of embankment performance using numerical analyses – Practitioner's approach

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ABSTRACT

A 3 m high embankment with prefabricated vertical drains was constructed over Ballina clay. It has been thoroughly instrumented for monitoring over three years after construction. Based on the data available at the site, the authors undertook Class A predictions of embankment performance using two approaches: a simple 1D consolidation analysis and a sophisticated large strain finite element analysis (FEA) using Soft Soil Creep (SSC) model. Class C predictions were then conducted using the SSC model in FEA, with and without large strain. It is demonstrated that the SSC model can give satisfactory results when large strain FEA was used.

1. Introduction

This paper presents comparisons of measured settlements, soil layer compressions, pore pressures and horizontal displacements at the Ballina trial embankment with those of Class A predictions using two soil models: a simple 1D consolidation analysis with Mesri type creep model (Hypothesis A) preferred by engineering practitioners due to its simplicity; and a sophisticated large strain finite element analysis (FEA) using elastic viscoplastic Soft Soil Creep model (Hypothesis B) that is mostly endorsed by academia. The merits and limitations of these two prediction approaches are outlined and improvements to the predictive capability are discussed in the subsequent Class C predictions. A reflection on whether the complex reality of foundation soils can or cannot be captured by the complexity of the adopted soil model is provided in the conclusions section.

2. Background

The 3 m high embankment was constructed in 2013 over Ballina clay treated with prefabricated vertical drains (PVD). The embankment was thoroughly instrumented including vibrating wire piezometers, settlement plates, extensometers, horizontal profile gauges and borehole inclinometers to monitor the performance of the foundation soils during progressive filling and three years of subsequent consolidation.

With reference to Fig. 1, the soil stratigraphy comprises generally a thin layer of soft to firm alluvial sandy silt near the ground surface, followed by very soft estuarine silt/clay, over firm sandy clay transitioning to clayey sand, and underlain by medium dense sand and stiff Pleistocene clay. Initial pore water pressures from all vibrating wire piezometers (VWP) at the site indicated that the groundwater table varied between RL −0.1 m and RL +0.1 m prior to embankment construction. For the present settlement prediction analysis, a groundwater level of RL 0 was adopted. With the original ground surface level typically at about RL 0.3 to RL 0.5, the groundwater table was about 0.4 m below the original ground surface. There were fluctuations in groundwater level since the completion of embankment filling. The influence of groundwater level variation on predictions is discussed in Section 6 of this paper.

3. Adopted parameters in class A prediction

3.1. Stress history and undrained shear strength

As discussed in Pineda et al. [1], Constant Rate of Strain (CRS) tests on high quality piston-sampled Ballina clay were conducted at a displacement rate of 0.004 mm/min. The preconsolidation stress, σ'_p estimated from these tests are higher than that when tested at a slower displacement rate, but no important changes in the shape of the compressibility curves are expected. To correct for the strain rate effect, the approach of Watabe et al. [2] was adopted in which a correction factor of 0.84 was applied to the σ'_p values. Fig. 2a shows the σ'_p profile assessed from CRS tests, as well as from conventional oedometer tests. While the σ'_p of the CRS are higher than that of the oedometer tests, good

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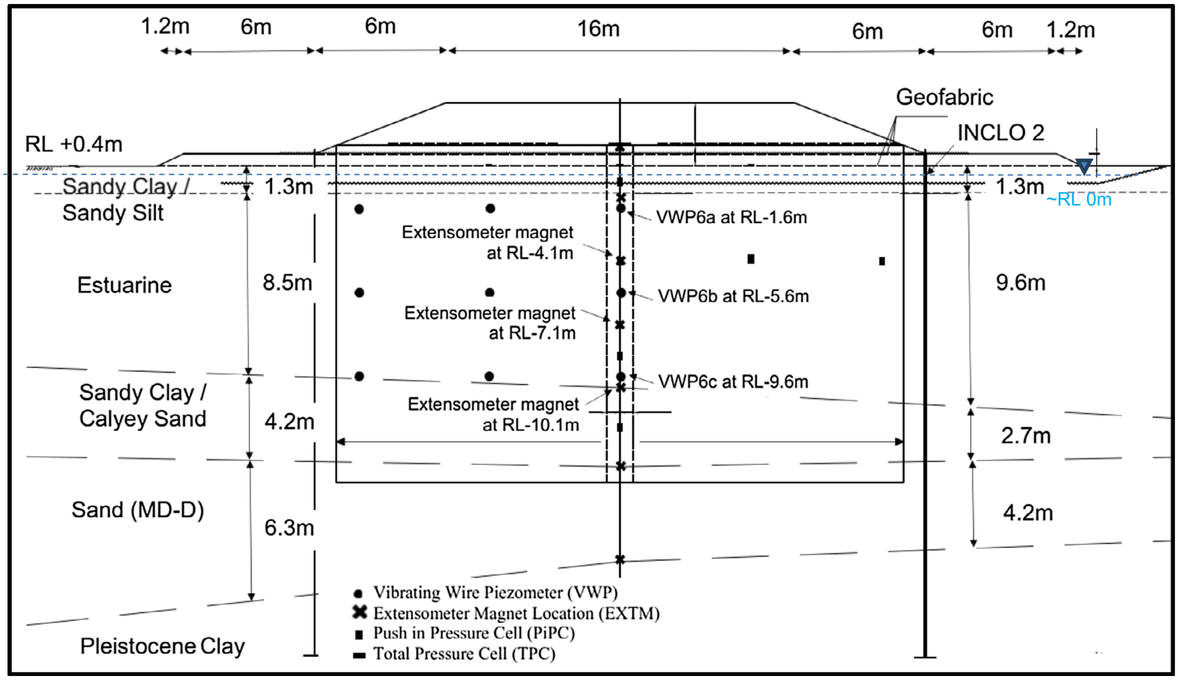

Fig. 1. Geotechnical section of the instrumented trial embankment.

agreement is indicated after σ'_p of the CRS results are corrected for the strain rate effect by applying a reduction factor of 0.84. Also shown in Fig. 2a is the in-situ vertical effective stress, σ'_v with RL which was calculated based on the adopted groundwater level outlined in Section 2, in conjunction with the bulk unit weights obtained from laboratory test results. The over-consolidation ratio, OCR calculated based on σ'_p/σ'_v, is shown in Fig. 2b. Fig. 2c shows the strain rate corrected OCR from all available CRS tests, along with the adopted OCR profile for Class A prediction.

Given the high quality of the samples and the CRS tests, it is considered appropriate to place greater emphasis on the CRS test data for the derivation of σ'_p and OCR as outlined above than the inferred OCR from other testing such as the in-situ piezocone (CPTu) test results. Furthermore, by utilising the strain rate corrected OCR values obtained from the CRS tests and the undrained shear strength, S_u, measured from field vane tests (FVT) and the CPTu, a site specific S_u–OCR correlation can be established with great confidence as follows.

Jamiolkowski et al. [3] and Ladd [4] indicated that the variation in S_u/σ'_v with OCR can be approximated by the SHANSEP equation

$$S_u/\sigma'_v = S \times \mathrm{OCR}^m \tag{1}$$

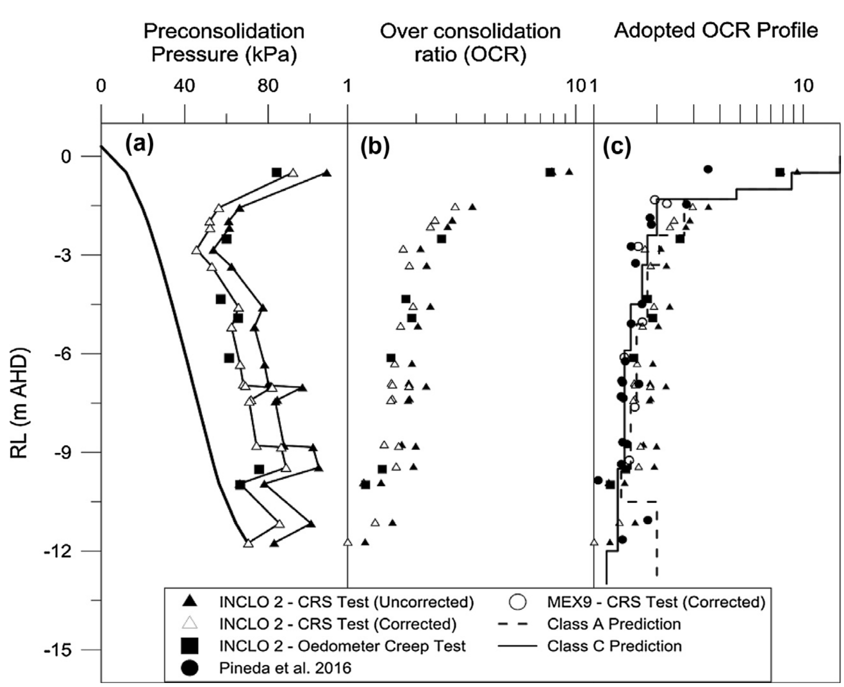

Fig. 2. Profiles of (a) σ'_p, (b) OCR, and (c) adopted OCR.