CHAPTER ONE

INTRODUCTION

1.1 GENERAL

Studies on well-instrumented embankments constructed over soft soils indicate that they suffer excessive creep deformations. Most of the soft soil deposits undergo very large delayed settlements long time after completion of earth structures (e.g., Le Flumet dam, Fodil et al. 1997). The conventional design approaches consider consolidation effects however, do not consider the creep deformational behaviour that plays a vital role on the long-term performance of geotechnical structures. Finite element numerical models available in the literature based on the classical elastoplastic formulation are also not adequate for capturing such long-term time dependent behaviour. The magnitude of this problem has thus necessitated the development of advanced elasto-viscoplastic numerical models so as to address the creep behaviour of embankments constructed over soft soils and to predict the behaviour characteristics accurately with time.

Full-scale embankment case analyses presented in the literature do not have long term time dependent field data for few years. In addition, these case analyses are test/trial embankments, which are lot different from the real embankments that evolve complex design, instrumentation and monitoring, complicated loading history and ill defined boundary conditions. Noted exception being the Tarsuit Island in Canada, Yin and Zhu, 1999. However, finite element analyses conducted on this real embankment case history did not consider the long-term prediction of multiple characteristics such as vertical and horizontal deformations, excess pore pressures and reinforcement strains simultaneously in a single analysis. The main objective of this thesis is to predict all the behaviour characteristics of a real embankment accurately in a single analysis and Leneghans approach embankment, which has six years long-term field measurements was chosen for this purpose.

Leneghans approach embankment was constructed with prefabricated vertical drains (PVDs) over a soft compressible clay deposit, Newcastle. The embankment was instrumented with pneumatic piezometers, horizontal profile gauges, settlement plates and vertical borehole inclinometers. Paralink 200 M, which is made from polyester strap formed as a flexible geogrid was used as reinforcement and it was instrumented with LVDTs that mounted on clamps. The field performance shows that the embankment probably manifests sufficient creep. A numerical model was developed to perform fully coupled large deformation elasto-viscoplastic Biot consolidation analysis with creep material behaviour for the foundation soil using six noded linear strain triangular elements and the predicted behaviour is compared with the field measurements of the Leneghans embankment. Sensitivity analyses were also carried out based on uncertainties involved in the determination of parameters and a parametric study was conducted to determine the effect of secondary consolidation on the end of primary settlement of this embankment.

1.2 OUTLINE OF THE THESIS

Various elasto-viscoplastic constitutive soil models proposed by numerous researchers are critically reviewed in chapter 2. The finite element numerical models available for the analysis of reinforced embankments constructed over soft soils and their shortcomings are also discussed. The modeling of vertical drains and the related challenges are discussed and the choice of models used in this thesis is also briefly described in this chapter.

The mathematical description of elasto-viscoplastic models based on creep (Kutter and Sathialingam, 1992) and rate (Adachi and Oka, 1982) formulations and the implementation of creep model with required modifications to the finite element code to obtain a numerical solution are briefly presented in chapter 3. This chapter also describes the finite element solution algorithm for fully coupled large deformation Biot consolidation analysis and its implementation into the finite element code and also the modeling of prefabricated vertical drains (PVDs) in the plane strain conditions.

The procedures to determine the parameters of the creep model are discussed in chapter 4 and the predictive capability of the creep model of known and desirable behaviour pattern is studied through various numerical examples. The verification of matching procedure in PVD modeling via unit cell analyses for elastoplastic and creep models to a multi layered soil is also reported for a case study in this chapter.

Finite element analyses of Sackville test embankment are reported in chapter 5 adopting three different constitutive material behaviours to the foundation soil based on creep, rate and elastoplastic formulations. Details of the selection/determination of material parameters/properties and the variations of vertical and horizontal deformations, excess pore pressures and geotextile strains with time and the sequence of construction obtained from the finite element analyses are discussed in comparison with field observations in this chapter.

The instrumentation and field performance of the geosynthetic reinforced approach embankment constructed at Leneghan, Newcastle has been described in chapter 6. The site conditions and soil profile, the embankment construction, the instrumentation details, the description of PVDs and reinforcement and the details of construction sequence are also described in this chapter.

Chapter 7 described the finite element analyses of Leneghans embankment adopting elasto-viscoplastic creep material to the foundation soil. The determination and selection of foundation soil properties, embankment fill and reinforcement properties via field and laboratory tests and the modelling of vertical drains are described. The predicted behaviour obtained from the finite element analyses are discussed in comparison with the field measurements in this chapter.

Limited sensitivity analyses performed on Leneghans embankment are presented in chapter 8 in comparison with the field measurements and the benchmark analysis results reported in chapter 7.

Chapter 9 presents the conclusions drawn form the work reported in the previous chapters and recommendations for future work.

Appendix A presents the detailed mathematical description of the creep model described in this thesis.