Evaluation of the Geomechanical Performance of Compacted Kaolin Utilizing Unsaturated Constitutive Model of Soils

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Extended Abstract

Introduction

Expansive soils contain clay minerals such as compacted kaolin which are widespread in nature. Displacements of this type of soils are associated with matric suction and degree of saturation. To determine the in-situ characteristics, necessary measures may be required to deal with the possible failure related to this type of soil. Different constitutive models of unsaturated soils have been considered the subject of many recent researchers (Sheng et al. 2004; Wheeler et al. 2003; Nuth and Laloui 2008; Zhang and Lytton 2009 a, b 2012). However, those constitutive models are generally complicated that are not properly implemented in computer programs for practical applications. The Barcelona Basic Model (BBM) is one of the geomechanical constitutive models to capture the elastoplastic behavior of unsaturated soils.

Material and analysis methods

In this paper, the Barcelona Basic Model (BBM) has been implemented in a finite difference-based computer program to simulate the behavior of unsaturated soils due to the wetting process. Using this type of soil for embankment will result in more long-term settlement problems depending on the climate and movement of the wetting surface during post-

construction and wetting cycles. In the present study, the BBM implementation was verified using analytical solutions in the literature, and then the verified model was used to simulate the response of a compacted fill embankment under complete saturation and wetting induced conditions. Numerical simulations were conducted for the self-weight, complete saturation and suction variations. BBM parameters were chosen from Alonso (1990) research works. As it was expected, numerical analyses indicate that a considerable amount of total and differential settlements can develop at the top surface of the embankment. It should be mentioned that the BBM is implemented into FLAC 2D extending a defined module for modified Cam Clay (MCC) and has been set up an analytical solution for suction-dependent stress and strain (i.e. total stress minus air pressure: $\sigma_t - \sigma_a$) in unsaturated soil medium. Also, results of the centrifuge model from Zheng et al. 2013 were utilized to simulate the matric suction response of a model constructed incrementally with clay minerals as a fill embankment. Stress paths are produced for two cases including BBM together with considering the over-consolidation ratio (OCR) and compared with experimental results from Alonso (1990). Then, the effect of pre-consolidation and over-consolidation ratio are investigated and the results are presented. In the next step, a modification to the BBM constitutive model equation is proposed and results from BBM and OCR-induced BBM implementation in FLAC are compared with the previous research data. Finally, the application of modified BBM was applied to deep soil mixing (DSM) columns as one of the ground improvement methods in an unsaturated medium.

Results and discussion

In this study, the embankment with lower initial suction is expected to undergo a greater amount of self-weight settlement. However, these amounts are not as greater as the settlements obtained from the two recent cases of experimental studies and BBM prediction in FLAC. In a case study, for the suction amount of 200 kPa, surface settlement after full saturation would be 80 mm more than the same situation in the suction of 100 kPa. According to Rao et al. (1988), the initial stress state is measured

as the corrected swell pressure from a constant volume type from an odometer test. DSM columns with different lengths and various spacings were simulated in a numerical program using BBM equations to obtain the settlements more accurately for the unsaturated condition. Settlement control analyses in finite-difference programming indicate better performance by utilizing the over-consolidation ratio in the yield function equation of the BBM namely suction increase (SI).

Conclusion

The numerical results illustrate a significant impact of the suction value on the vertical displacement of the embankment containing kaolin mineral clay. However, matric suction potential should be assigned in the design process of embankments constructed with mineral clays in an unsaturated medium. Investigating on the theoretical and experimental researches on unsaturated conditions indicate the over-consolidation ratio plays an effective role in the mechanical and hydromechanical behavior of these types of soils. Thus, a correction is performed on the yield function of the Barcelona Basic Model (BBM) and coded in a finite difference-based program. The numerical results of the vertical displacement demonstrate a better agreement with reality. As a result of this research, finite difference codes with BBM modification can be applied to the problems associated with earthen structures dealt with unsaturated soil such as DSM-treated columns.

Keywords: Compacted kaolin, Barcelona basic constitutive model, Unsaturated soil, Deep soil mixing, Over-consolidation ratio, Stress path

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