SLOPE STABILITY ANALYSIS OF UNSATURATED SOILS

By

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ABSTRACT

The most common type of natural soils on the earth's surface is the unsaturated state. This type of soils can be found in arid and semi-arid regions and may cause severe problems to several existing structures worldwide. Moreover, the unsaturated soils are often handled in civil engineering applications. Examples of these earthworks are roads, dams, embankments and vertical cuts. In Egypt, many projects, as well as road cuts and embankments, are mostly made of unsaturated soils. In addition, the need to construct in new areas, for instance the case of multi-basement stories in Cairo outlets, requires vertical cuts in unsaturated soil which may lead to slope failures. Therefore, this thesis attempts to investigate the real causes behind this problem and explore analytical solutions for it. This may help geotechnical engineers to build bridges of understanding of this serious problem.

Unsaturated slope failures may be attributed to a number of factors, such as decrease of initial suction, surface infiltration, rainfall, evaporation or combinations of these factors. Hence, this analytical study is performed for examination of the effect of the initial suction, rainfall and evaporation on the stability of unsaturated slopes. Herein, the main purpose of this research is to study the stability of unsaturated slopes taking into consideration the effect of suction, rainfall and evaporation. In addition, the thesis presents a conceptual methodology to study the effect of climate exposure and embankment compaction on the stability of slopes.

The computer software (GeoStudio, 1991-2004) is used to model the unsaturated soil slopes. The stability analysis using GeoStudio is based on the limit equilibrium methods. In modified Mohr-Coulomb failure criterion, the effect of suction is considered in the analysis. In addition, the artificial neural network technique using MATLAB program is adopted for studying the stability of vertical cut.

It is shown that the variation of initial suction, infiltration rate and evaporation rate has a significant effect on the stability of unsaturated soil slopes. Furthermore, the climate exposure and compaction have a considerable effect on the stability of slopes. Proposed simplified charts and empirical equations are powerful tools for the analysis of unsaturated vertical cuts.

Many areas where further work is required are identified. In particular, there is a need to perform a numerical analysis for the unsaturated soil slopes to investigate the deformations and displacements associated with the effect of suction change on unsaturated slopes.

THESIS OUTLINE

This thesis is prepared in six chapters. Chapter 1 presents the background, the aims of the study and this section.

Chapter 2 presents a general literature review; it can be divided into three main parts: The first shows the basic concepts and fundamental aspects of unsaturated soil mechanics and its properties, such as, the vadose zone, soil suction, soil water characteristic curve (SWCC), hydraulic conductivity, thermal conductivity, and shear strength. The second part of this chapter presents detailed study of slope stability analysis in unsaturated soils; also it presents studies performed on unsaturated slopes. Finally, the third part presents the artificial neural network and its fundamentals.

Chapter 3 presents the methodology and research strategy and it illustrates the geometry slope models and soil properties. This chapter also introduces the plan of studying each of the effect of initial suction, infiltration and evaporation on slope stability.

Chapter 4 presents the analysis, results and discussion of this research. Where, many parametric studies are conducted for slope model 1 and slope model 2 under the effect of initial suction, infiltration and evaporation.

Chapter 5 introduces proposed methodology for climate exposure and effect of compaction on the analysis of unsaturated slopes.

Chapter 6 presents development of stability charts for preliminary analysis and empirical analysis equations for vertical cuts based on neural network modelling. Finally, the conclusions drawn from this research and the recommendations for potential future studies are presented in Chapter 7.