FEM Analysis of Highway Embankment Slope Erosion

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Abstract: A two dimensional FEM model was used to simulate the slope the failure of an embankment due to loss of soil at the toe due to erosion. The factor of safety against slope failure reduced with the amount of soil loss. The predicted failures by the FEM model was similar to that was observed in the field.

1 Introduction

Soil erosion process involves the dislodging, and transporting of soil particles by external forces. Soil particles are dislodged from the slopes of embankments by the impact of rain (which lifts and shifts particles), overland flow of water, and surface wave action due to standing water. The control or modification of these forces is the primary aim of erosion control planning and design (Duncan et al, 2005). Based on Davis et al (2003), large wave height and deep draw downs which cause sever fluidization at the toe causing erosion, and leading to the slope failures. In this study a finite element (FEM) analysis was used for a preliminary evaluation of existing slope failures along a highway embankment in Houston, Texas.

2 Objectives

The objective was to study the effects of toe erosion by wave action on a highway embankment slope using the finite element analysis.

3 Description of the Project

The highway embankment was constructed to have four lanes of highways across a lake. After several years in service, there were several minor slope failures (3-4 ft in height), and one major slope failure in the embankment where slope was protected by sand bags (Fig.1). The slope of the embankment was 3:1 (horizontal to vertical). The soil was silty soil.

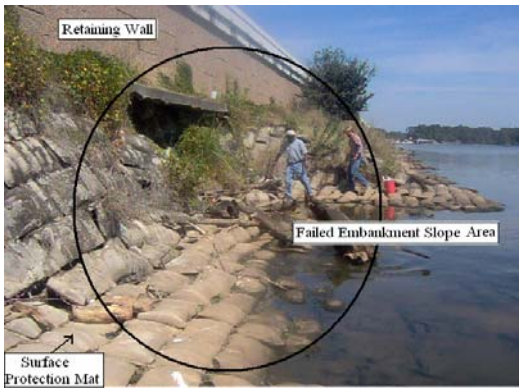

Fig.1. Embankment failure due to loss of fine particle by wave action

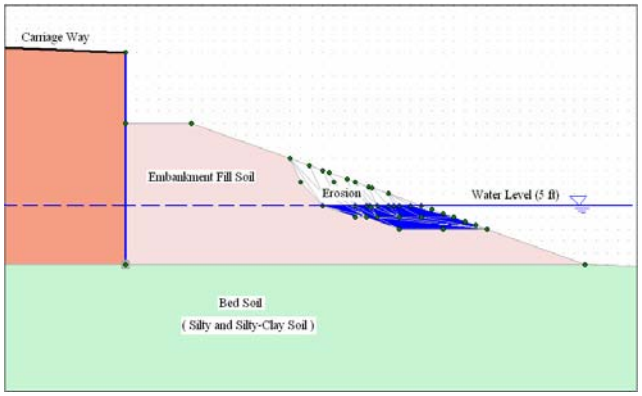

Fig. 2. FEM model for the slope failure Analysis

Due to the continued shallow surface wave action, near the water-embankment interface, the embankment had undergone severe erosion. Because of this, the slope started to fail slowly and undermine the retaining wall.

4 Finite Element Analysis

This field problem was simulated using a commercially available finite element program, PLAXIS. As shown in the Fig.2, the embankment was modeled simulating the existing field conditions. According to the soil type, which was identified using the collected field sample, and with best engineering judgment, the properties of embankment soils were assumed. Using the finite element model the possible slope failures and corresponding factor of safety (FOS) were determined with increasing amount of soil erosion (Fig 4). This was simulated in the FEM model by removing the soil elements according to a selected pattern.

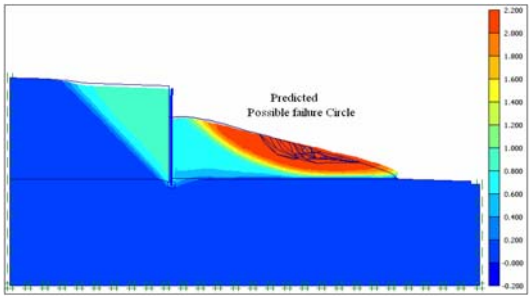

Fig. 3. Predicted failure surface with higher soil erosion by wave action

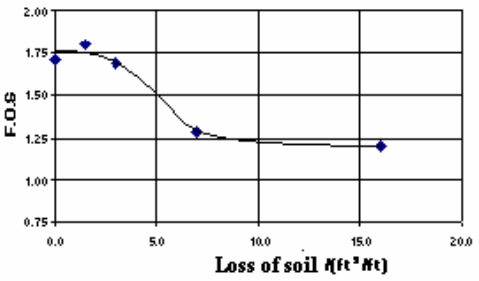

Fig. 4. Variation of F.O.S with loss of soil materials from the embankment

5 Results and Analysis

The reduction of F.O.S with loss of soil was determined for the field configuration. The relationship was non-linear.

6 Conclusions

A two dimensional finite element model was used to investigate the embankment slope failure. The soil loss (volume/length) was related to the factor of safety.

7 Acknowledgement

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References

1. Duncan, J.M and Wright, S.G., (2005), Soil Strength and Slope Stability, John Wiley & Sons, Inc. New Jersey.
2. Davis, M., Köhler, H.J., Schwab, R., and Koenders, M.A., (2003), Hydraulic Failure and soil-structure deformation due to wave and draw down loading. Proc ASCE 3rd International Coastal Structures Conference. Portland Oregon USA; 924-934