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Stability Analysis of Unsaturated Cut Slopes Due to Rainfall Infiltration (Case Study-Khoda Afarin Main Irrigation Canal)

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Extended Abstract

Introduction

The stability of unsaturated slopes during rainfall is an important natural hazard. Past studies have shown that slope failures generally occur during or after rainfall. A review of past studies shows that instability of natural or excavated slopes for infrastructure construction occurs mainly during or after rainfall. Due to rainfall infiltration into unsaturated soil, the apparent cohesion and shear strength provided by matrix suction reduces d, resulting in slope instability. Library studies for this research, revealed that in recent years, extensive studies have been conducted on the rainfall infiltration in unsaturated slopes and their effect on shear strength and stability. But much of the research has been on high-intensity rainfall over a short period of time, however, some instability of slopes occurs during long-term rainfall or after rainfall. In addition to field research and physical modeling, numerical methods have also been developed to solve complex problems of unsaturated soils within the framework of various scientific theories in recent years. In this paper, in addition to considering the results of previous studies, the stability of the excavated soils with multiple berms has been investigated by considering transient fluid-mechanical coupled analysis.

Khodafarinn Irrigation network is one of the largest water resources development projects in northwestern Iran. The length of its main canal is 144 km. According to the topography of the project area, excavations were required to construct the main canal and its structures. The stability of the slopes created by excavation is of great importance for canal construction and operation. One of the critical slopes created along the main canal is in the trench created at the site of the Golmali cut and cover which was selected as a case study.

Methodology

FLAC 2D is one of the most applicable geotechnical software based on the FDM and complex LAC 2D is one of the most applicable geotechnical software based on the FDM and complex geotechnical problems can be modeled by using FISH. The general framework

of the study is that geometrical characteristics and materials parameters of the slope were first extracted using in situ and laboratory tests and then the average monthly rainfall was obtained from the meteorological station statistics. Then, transient fluid-mechanical coupled analysis was prepared for rainfall infiltration and deformation analysis using TPFlow. As a result of the analysis, pore water pressure, degree of saturation and deformation were calculated and according to results, the stability of slope was evaluated by using the shear strength reduction method.

Filter paper test and RETC code were used to extract the SWRC and HCF of unsaturated soil parameters by Van-Genuchten model. Table.1 shows the parameters used in the analysis.

Table 1-Parameters of slope material for numerical analysis

γ_{sat}	G	C	K_s	ϕ	θ_s	θ_r	α	n
KN/m^3	MPa	Pa	m/s	Deg.	-	-	-	-
19.1	100	8340	1.42E-06	27.4	0.453	0.05	1.282	1.585

Based on the available meteorological data, the average annual rainfall and monthly values of rainfall were extracted for the study area. In order to reach initial conditions in terms of water content and degree of saturation, average annual rainfall (288 mm) was applied to the slope for six months. Then, the most critical time limit for performing the task in terms of rainfall was selected from monthly values of rainfall for the 4 critical months (March-June) Fig. 1.

Results and Discussion

Fig. 1 shows the changes in the factor of safety during the four months of rainfall. According to the results, the FOS was 1.72 at the end of the initial condition and after applying four-month rainfalls, it was reduced to less than 1 and as result failure occurs. By finding the trend of its changes, it can be concluded that, when the FOS was reached less than the unit after about 80 days and the slope became unstable. In other words, with the passage of time and the increased rainfall infiltration at higher depths, after about 80 days, the complete slope failure started from the slope claw.

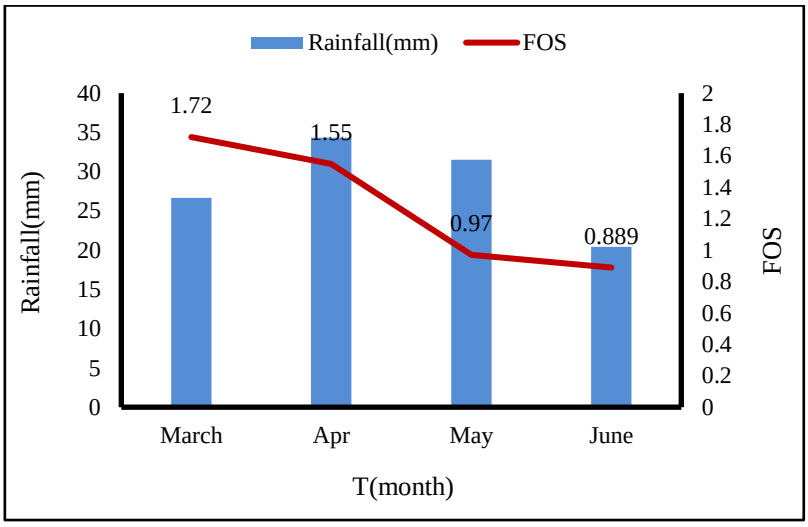

Figure 16- Factor of safety and rainfall history for the 4 month

Conclusions

1) Due to very low permeability and high suction at a low saturation ratio, the behavior of unsaturated excavated slopes in fine-grained soil is relatively complex compared to coarse-grained soil slopes.

2) In fine-grained soil slopes, pore water pressure and degree of saturation increase nonlinearly with increasing rainfall duration. However, the increase rate and the trend of increase was different from studies for high-intensity short duration rainfalls, The increase was faster at the slope surface but with increasing depth, water infiltration rate and consequently changes in pore water pressure will take longer time.

3) The factor of safety decreases with the time of rainfall and after about 80 days, the instability of the slope begins and the reason for its prolongation can be attributed to the low permeability of the slope material. Therefore, for relatively low permeability soil slopes such as those in fine-grained soils, long-duration rainfall is more effective than high-intensity but low-duration rainfall.

4) According to the results of previous studies conducted on high-intensity rainfall on slope stability in fine-grained slopes, high intensity and low duration rainfalls cannot infiltrate due to low permeability of materials and moves in the form of runoff at the slope surface and their stability should be examined for moderate to long-duration rainfall if necessary.

Key Words: FDM, HCF, Pore Water Pressure, RETC, SSR, SWCC, Unsaturated Soil