Performance of horizontal and chimney drainage in stability of retaining wall of earthen slopes

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Abstract

Due to heavy rainfall, underground water level and pore water pressure increase each year, which can cause failure of the earthen slopes. Retaining wall is one of the main structures that is used to increase the earthen slopes stability. In the present study, the stability of earthen slopes relative to the critical hydrological cases was simulated by Slope/w software and the pore pressure behind the retaining walls over 10 meter height which causes to instability was simulated using Seep/w software. The studied parameters are: precipitation intensity, soil type, position and the diameter of drainage. Also the kind of drainage has been considered as a variable parameter and horizontal and chimney drainages were used. Results showed that for fine grained soils with intensive rains condition, using of one horizontal drainage could not provide the stability of retaining wall. While in the same conditions, for coarse grained soils, the retaining wall will be stable by using of one horizontal drainage and drainage will be able to discharge all of the excess water behind the retaining wall. Also the chimney drainage system provided the best results and the stability of the retaining wall did not face any danger under the worst circumstances. For overturning moment and water pore pressure behind the wall, linear and non-linear regression relations were produced in dimensionless form. The accuracy of the regression relations were proper and the acceptable results could be expected.

KEYWORDS

Drainage system, Pore water pressure, Heavy rainfall, Soil slope, Stability.

1- Introduction

Due to heavy rainfall, ground water level and pore water pressure increases each year, which can cause failure of the earthen slopes. This type of failure and sliding can have economic losses and lives fatalities, thus design of retaining walls is very necessary, especially when precipitation will occur. The retaining walls are used for soils preserving on the slopes. Presence of heavy rainfall cause to increase ground water level and pore water pressure. Due to pore water pressure increasing, the soil shear resistance reduces and failure risk increases. Drainage systems releases the water behind of the retaining walls and are used to pore water pressure control.

Stanton [1] reported good performance for horizontal drainage on high slopes retaining walls. Au and Pong [2] in their study investigated retaining walls with 8-10 m height. Definition of correct and usual pattern for water moving through drainage systems was the main goal of that study. Blake et al. [3] simulated a retaining wall to predict the pore water pressure due to heavy rainfall. Beckmann and Loher [4] used drainage systems instead of weep hole in the retaining walls.

Due to lack of usable results for designing and construction of retaining walls drainage systems, providing designing criteria are very important. In this study, the performance of chimney and horizontal drainage systems in pore water pressure control and soil maintenance on the slope, will be studied.

2- SEEP/W and SLOPE/W

Under steady state groundwater flow conditions, these are expressed as the Laplace's equation, a second-order partial differential equation, which describes the potential flow fields [5]. In this study, Laplace's equation is solved numerically using Seep/w (2007)[6]. The software code Slope/w uses limit equilibrium analysis method for slope stability analysis (Geo-Slope 2007). Bishop's modified method, Junbu's simplified method, Spencer's method, Morgenstern-Price's method can be used for slope stability analysis in this numerical code [7].

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3- Study materials

In this study, an assumed retaining wall with 10 m height was investigated. Three types of soil included: clay, silt and silt loam were used behind of the retaining wall. Figure 1 shows the studied retaining wall and study parameters and Table 1 shows the values of the studied parameters.

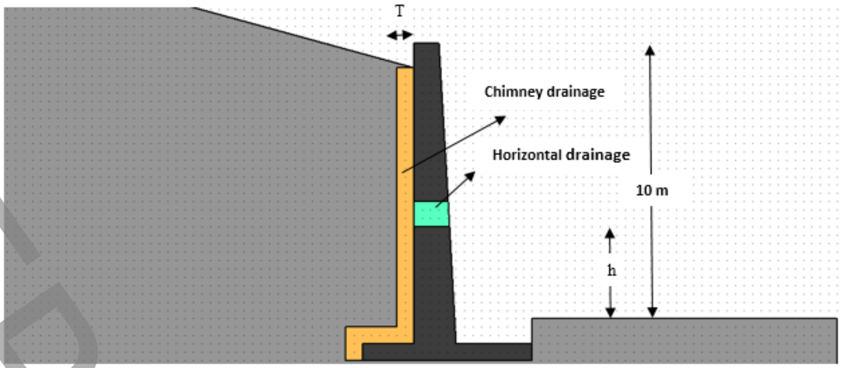

Figure 1. The retaining wall with 10 m height including horizontal and chimney drainage

Table 1. The values of used parameters in models

Parameter	Corresponding values
Horizontal drainage distance from wall bottom (h)	0, 2, 4, 6, 8 (m)
Chimney drainage thickness (T)	10, 20, 30, 40, 50 (cm)
Precipitation intensity (P)	5 and 15 mm/h

Using mentioned effective parameters, the retaining wall was simulated by the SEEP/W and pore water pressure was generated. Then the simulated retaining walls were used to assessment of retaining walls safety factors by SLOPE/W.

4- Results and discussion

Figure 2(a) shows the slope failure after 15 mm precipitation without drainage system and Figure 2(b) shows the slope stability due to horizontal drainage at the bottom of the retaining wall. The results showed that precipitation intense is most effective parameter between used parameters. After 2 days precipitation with an intensity of 5 mm/h, soli slopes entered force due to pore water pressure was 7.09 KN. In this case, 15 mm precipitation caused to increasing entered force up to 75.39 KN. The rate of stability torque to overturn torque for 5 mm/h precipitation was 19.27 and the slope was stable. This rate for 15 mm/h precipitation was 0.86 and the slope was unstable. In other case, for investigation of the effect of soil properties, the model with horizontal drainage at the wall bottom was used. The silt has higher hydraulic conductivity in comparison with clay and silt loam. So drainage capacity of silt is more than others and this causes to generate less pore water pressure. Figure 3 shows the values of entered force and overturn torque on the studied soils.

Figure 2 (a). Soil slope status after precipitation without drainage system

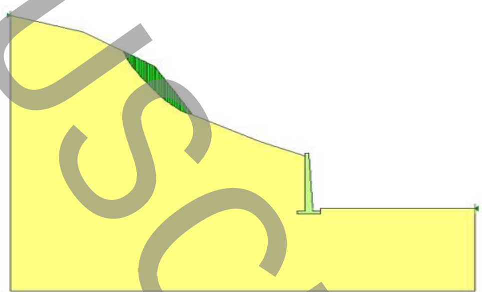

Figure 2 (b). Soil slope status after precipitation using horizontal drainage

For investigation of drainage system position, the horizontal drainage distance from the wall bottom varied between 0 to 8 m. According to the results, when the drainage located near the wall bottom, its performance was better than its performance in high positions on the wall. For fine grained soils with intensive rains condition, using of one horizontal drainage could not provide the stability of retaining wall. While in the same conditions, for coarse grained soils, the retaining wall will be stable by using of one horizontal drainage and drainage will be able to discharge all of the excess water behind the retaining wall.

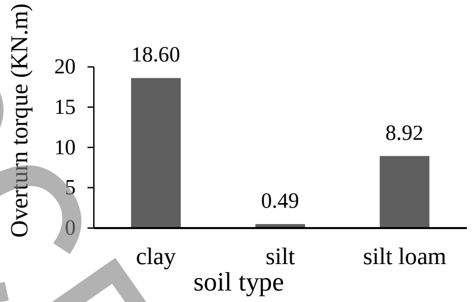

Figure 3(a). The overturn torque due to 5 mm/h precipitation for retaining wall with horizontal drainage at h=0

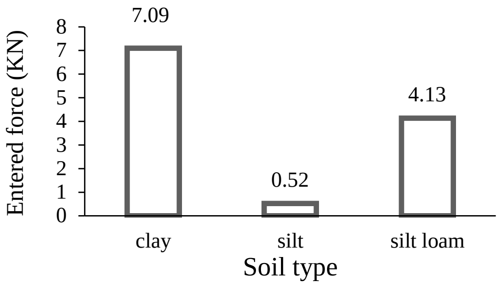

Figure 3(b). The effect of soil materials on the entered force

The regression analysis was used to present equations for entered force and torques rate calculation. Tables 2 and 3 shows presented equations for calculation of dimensionless entered force (F) and the rate of overturn torque to the resistance torque (M / M'). In presented equations, h is the drainage elevation from the wall bottom, H is the wall height, P is the rainfall intensity and K is the hydraulic conductivity. Performance Index (EF), R^2 and root mean square error (RMSE) were used to comparison of equation results. Based on the mentioned factors, results showed presented equations could have acceptable results and can be used in retaining wall designing.

Table 2. Nonlinear regression equations for entered force calculation for studied soils

Soil type	Presented equations	R^2	R	RMSE	EF
Clay	$\frac{F}{M} = -0.273 + 0.756\frac{h}{H} + 0.37\frac{P}{K}$	0.966	0.98	0.06	0.96
Silt	$\frac{F}{M} = -0.143 + 0.675\frac{h}{H} + 0.236\frac{P}{K}$	0.944	0.97	0.04	0.94
Silt Loam	$\frac{F}{M} = -0.251 + 0.756\frac{h}{H} + 0.352\frac{P}{K}$	0.967	0.98	0.05	0.96

Table 3. Linear regression equations derived from torques rates analysis

Soil type	Presented equations	R^2	R	RMSE	EF
Clay	$\frac{M}{\acute{M}} = -0.419 + 0.696\frac{h}{H} + 0.556\frac{P}{K}$	0.95	0.97	0.11	0.95
Silt	$\frac{M}{\acute{M}} = -0.197 + 0.701\frac{h}{H} + 0.264\frac{P}{K}$	0.87	0.93	0.07	0.87
Silt Loam	$\frac{M}{\acute{M}} = -0.381 + 0.746\frac{h}{H} + 0.513\frac{P}{K}$	0.95	0.97	0.08	0.95

5- Conclusion

In this study, the performance of chimney and horizontal drainage systems in pore water pressure control and soil maintenance on the slope, were studied. According to the results, precipitation intensity was the most effective parameter between mentioned parameters. About the location of horizontal drainage on the retaining wall, results showed when drainage system is located in lower elevations on the wall, this systems can be more effective.

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