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Influence of Variations in Precipitation at Pore water Pressure Causing Surface Layer Failure of Naturally Undulated Slope of the Nau Kilo at Narayangadh-Mugling Road, Central Nepal

Samyog Khanal[1,*] and Ranjan Kumar Dahal[2]

[1]Kajaria Ramesh Tiles Ltd., Team Venture Building, 3rd floor, Sinamangal, Kathmandu, Nepal
[2]Central Department of Geology, Tribhuvan University, Kathmandu Nepal

(*Corresponding E-mail: samyogkhanal2017@gmail.com)*

Abstract: This work focuses on the naturally undulated slope with topographic failures, their flow direction, and the discharge of hill slope seepage, to recognize the pore water pressure variations phenomenon in connection with slope failures in the hollows. A small naturally undulated slope containing a topographic hollow, with six failures caused by rainfall events from 2001 to 2023, was chosen for this research work. The precipitation date of July 31 2003 was used for seepage and slope stability modelling in the GeoStudio environment. A threshold relationship between the topographic hollow area and maximum pore water pressure was prepared for the 24-hour maximum rainfall data and its 5, 10, 25, 50, and 100-year return period. Each return period rainfall event is normalized into a 24-hour event using daily rainfall of 6 min length with potential seepage face applied for the simulations. Furthermore, a threshold relation between the study's topographic hollow area and maximum pore water pressure indicates that a hollow of 100 sq. m area can develop maximum pore water pressure of 6.94 kPa as indicated by 24-hour maximum rainfall data.

Keywords: ***Hillslope Hydrology, Threshold for shallow failure, Pore water pressure.***

Introduction

The intense rainfall reduces the shear strength of the soil by gradually increasing pore water pressure, which leads to the instability of the slope Setyawan et al. (2021). Thus, the seepage and slope stability model is applied in naturally undulated slopes to recognize possible processes leading to slope failure and to provide proper guidance leading to the mitigation measures Acharya et al. (2016). Seepage modeling is the process of examining the flow of moisture in and out of the soil and dealing with the evolution of pore water pressure within the soil.

Methodology

The field investigation was done to gather the length/width of slope failure zones, soil thickness, and soil permeability. A dynamic cone penetration test was done to determine the thickness of the soil in the research area. For the permeability of the soil in-situ permeability test was done in the study area. Disturbed soil sampling was collected due to the impossible of

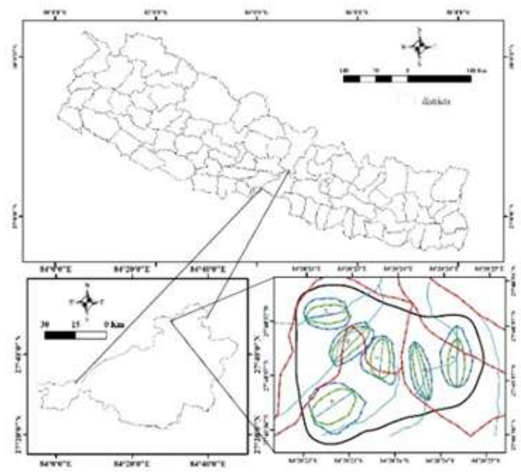

Figure 1, Location map of the study area.

undisturbed sampling in the field. An overall field survey was conducted to determine the area of the failure, soil thickness, and permeability of the soil. A series of laboratory work was performed to obtain definitive information on the soil properties.

Based on the flow direction map of the study area slopes were chosen for the modeling and evaluation of the stability of the area. The flow direction map shows the most unstable area on the flow line of the subsurface water in the naturally undulated slope. The most critical part of the slopes was chosen which represents the entire geometry of the study area. The slope was a natural slope with average slope angles ranging from 31 to 62 degrees. The required geotechnical parameters for the modeling were obtained from both field tests and laboratory tests. The slope profile was extracted with the help of Arc Map 10.8, Google Earth Pro, and DEM of the area. In the research area, six slope failures were studied. Named as A, B, C, D, E, and F as indicated in Figure 2. All slope failures were facing toward the northeast direction, recognized in the topographic map using the flow direction map. For the seepage and slope stability analysis, all six failure slopes of the naturally undulated slope were chosen for further work.

Results and Conclusion

The coupled seepage and slope stability modeling for all six failed slopes were prepared with the help of the flow direction map using the digital elevation model (DEM) of the study area. For the soil thickness, data topographic break point in the slopes was chosen. All profile sequences were discretized into the mesh of triangle elements of 0.25 m. The number of nodes was 223, 216, 164, 208, 144, and 143, whereas the number of mesh elements was 295, 297, 236, 291, 214, and 216 for slope profiles A, B, C, D, E, and F, respectively. The main input parameters used were the soil water characteristic curve (SWCC) function and the soil permeability curve (SPC) function. The slope was simulated using the maximum accumulated rainfall record in 24 hr. at Narayani at Devghat station between 2001 to 2003 A.D. The maximum 24-hour rainfall was discovered on July 31of 2003. For the slope stability analysis seepage simulated in SEEP/W is directly linked to SLOPE/W.

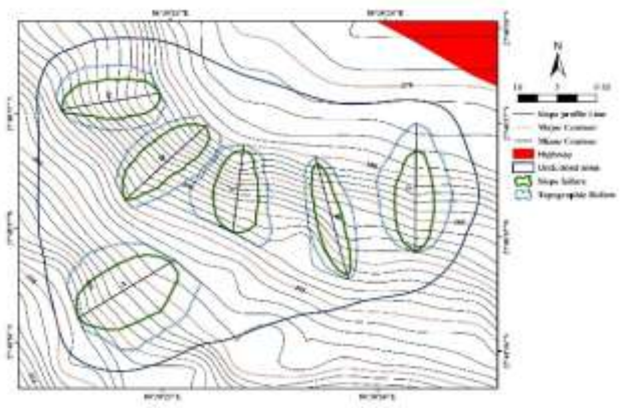

Figure 1, Naturally undulated slope with six failures.

For further simulations, different return periods of the 24-hour maximum rainfall of 31 July 2003 were considered. The hydraulic function employed in the previous simulation was used using the 5 years return period of rainfall. The Gumbell technique was used to compute the return period. The variation of pore water pressure with the topographic hollow area is shown in Figure 2 for a 5-year return period. Using the area of the topographic hollow and the maximum pore water pressure data recorded, a threshold relation between the maximum pore water pressure and the topographic hollow area was established.

The empirical relation between the maximum discharge of hillslope seepage and the topographic hollow area presented in this study for 24 h maximum rainfall data and their 5, 10, 25, 50, and 100 years return period as in Table 1. The variation in the pore water pressure is increased with increase in the rainfall long durations and low for the short period rainfall events as shown by analysis result as shown in Figure 3. Larger the naturally undulated slope, the greater the hillslope seepage as indicated by the maximum porewater pressure measured in the lower elevation part of the slope.

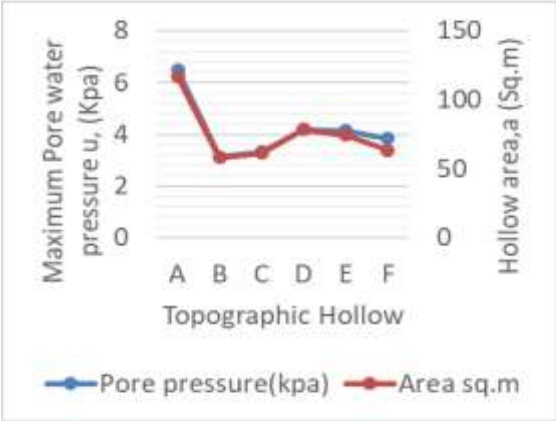

Figure 2, Variation of maximum pore water pressure with topographic hollow area for different return periods.

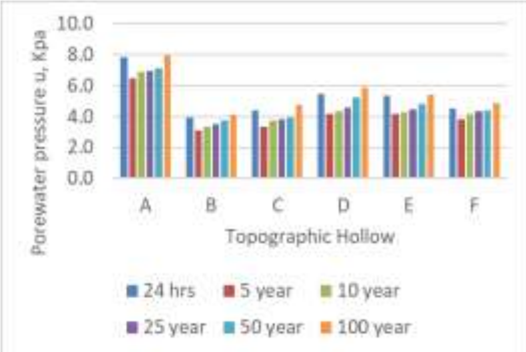

Figure 3, Pore water pressure and topographic hollow area threshold cure for slope failures for 5-year return period.

Table 1, Maximum Porewater pressure- topographic hollow area threshold equations for slope failure for different period of time. where u= Maximum Pore water pressure u, (kPa), a = Topographic hollow area, (sq.m)

Time	Threshold equation
24 hrs max	$u = 0.09*a^{0.9413}$
5-year return	$u = 0.0564*a^{0.9956}$
10-year return	$u = 0.0768*a^{0.9398}$
25-year return	$u= 0.092*a^{0.9063}$
50-year return	$u = 0.0985*a^{0.9029}$
100-year return	$u = 0.1279*a^{0.8708}$

References

Acharya K. P., Bhandary N. P., Dahal R. K. and Yatabe, R. (2016). Seepage and slope stability modelling of rainfall-induced slope failures in topographic hollows. Geomatics, Natural Hazards and Risk, 7(2), 721-746.

Setyawan A., Alina A., Suprapto, D., Gernowo, R., Suseno, J. E. and Hadiyanto, H. (2021). Analysis slope stability based on physical properties in Cepoko Village, Indonesia. Cogent Engineering, 8(1), 1940637.