Case Study: Reliability Analysis of a Soil Slope

Stephen Pienaar - 2020-02-28 - 0 Comments - in E01:Generalised slope analysis

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This article presents a case study where the PROKON Generalised Slope Analysis module (SlopBG) was used to
evaluate the reliability of a partially failed soil slope.

The SlopBG module analyses soil slopes using Bishop's Modified Method. The software is capable of finding the critical (minimum factor of safety) slip circle, and performing probabilistic analyses using statistical models for the soil properties. The author has verified[1,2] that the program predicts a factor of safety (FOS) that is within 12% of the "correct" value in most cases, and within 5% of the "correct" value in all cases. It renders conservative values.

Description of the slope

The slope, located in Uganda, comprises saprolitic soils, and consists of a series of 5m high, 4m wide berms, sloped at 1(V):1(H). Sections of the slope failed after heavy rains, raising concern about the stability of the remaining portions.

Deterministic analysis

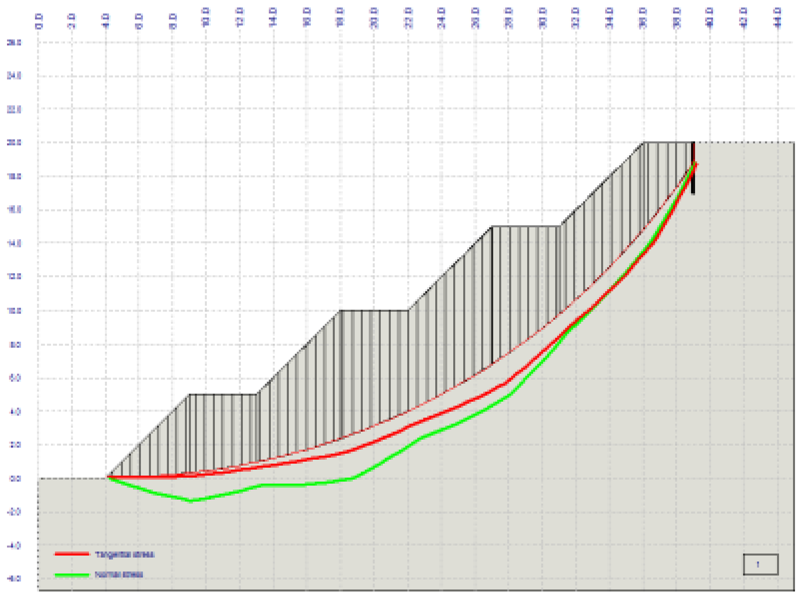
Using results from laboratory testing and back-analysis of previous slope failures, the author was able to derive realistic estimates of the shear strength parameters:

- Cohesion, c = 9.7kPa
- Angle of internal friction, φ = 25.9º

- Density, γ = 18.2kN/m3

To simulate the effect of pore pressures induced after prolonged and heavy rainfall, a pore pressure coefficient r_u = 0.15 was chosen. The highest r_u value observed by the author was 0.3 for an area which exhibited an annual rainfall of some 2m and the in situ material was sandy silt. It was reasoned that, for the slightly more impervious materials which occurred on this site, a value of 0.15 was appropriate and approximates the phreatic surface being located at some 27% of the overburden height above the predicted failure plane.

The author modelled the five-berm configuration in SlopBG. The software determined the slip circle that produced the minimum factor of safety (FOS), and predicted a value of FOS = 1.09. The FOS was not much higher than 1.0 (slope failure) suggesting that variations in the material properties could lead to localised slope failures.



Probabilistic analysis

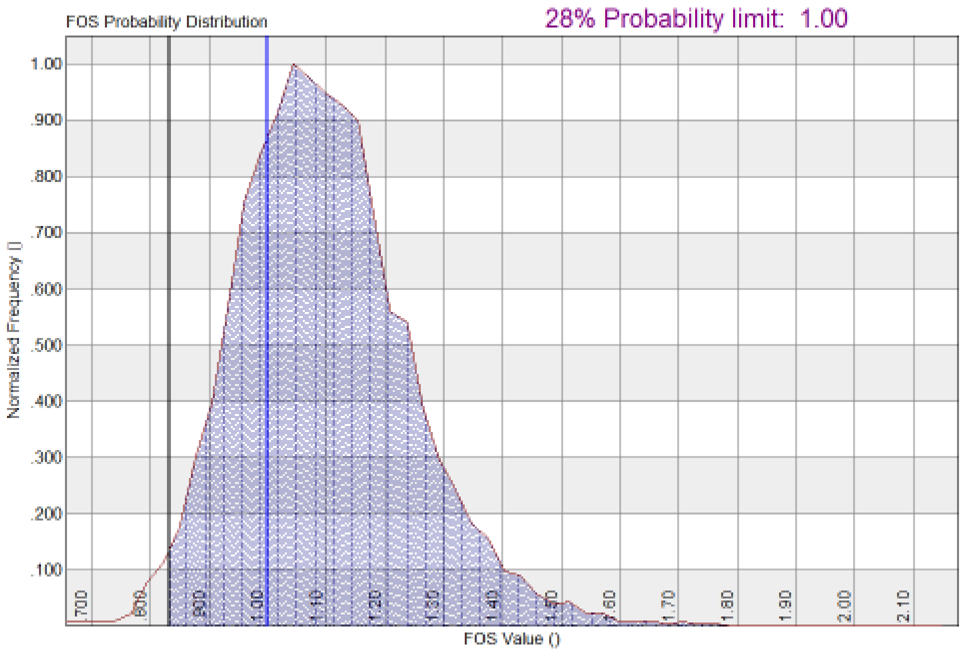
To evaluate the reliability of the slope, the author performed a probabilistic analysis with varying soil properties. For a quantitative measure of reliability, the analysis calculated the probability distribution of the FOS.

The analysis included 10,000 simulations as recommended by Harr[3], and used the following distribution in shear strength parameters:

- Cohesion, c: Log-normal distribution with a coefficient of variation (COV) of 40%.
- Angle of internal friction, φ: A normal distribution with a COV of 10%.
- Density, γ: A normal distribution and COV of 12% based on previous analyses.

The analysis results indicated that the probability that the FOS would be less than 1.0 was 28%. On-site examination of the slope confirmed that this calculated figure was approximately correct.

Given that this reconstructed slope failed after heavy rains in a manner very similar to that as predicted in the computer analysis, it was be surmised that the derived shear strength and moisture parameters were very close to those that existed at the time of the failure.



Conclusion

The author used SlopBG to perform a relatively simple deterministic analysis to determine the minimum FOS slip circle. This was followed by a more rigorous probabilistic analysis that allowed realistic characterisation of slope safety and reliability.

References

1. Lambe TW and Whitman R. V. "Soil Mechanics". Massachusetts Institute of Technology. John Wiley and Sons Inc. 1969.
2. Parrock A. L. "The accuracy of two slope stabi l ity programs, uti l ising Bishop and Sarma's analysis methods" Journal of the South African Institution of Civi l Engineering 42(1) 2000.
3. Harr M.E. "Rel iabi l ity based design in civi l engineering" McGraw Hi l l 1987.

The geotechnical analysis modules in the PROKON suite, including SlopBG, are jointly developed by Prokon Software Consultants and ARQ Consulting Engineers.

Data file

Download the input data file for this case study.