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DETERMINATION OF SEISMIC BEARING CAPACITY AND FAILURE MECHANISMS FOR SHALLOWS PLACED ADJACENT TO SLOPES

Mojtaba MOUSAVI
M.Sc. Student of Geotechnical Engineering, Department of Civil Engineering, Qom University of Technology, Iran
mousavi.mojtaba@rocketmail.com
Morteza JIRYAEI
Assistant Professor of Geotechnical Engineering, Department of Civil Engineering, Qom University of Technology, Iran
jiiriay@qut.ac.ir
Aydin YARI ILKHCHI
M.Sc. Student of Geotechnical Engineering, Istanbul Technical University, Istanbul, Turkey
ilkhchii16 @itu.edu.tr
Zeynab MAHDAVI
M.Sc. Graduate of Earthquake Engineering, Semnan University, Semnan, Iran
mahdavi.z@gmail.com

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In this paper, an analytical method is developed for calculating ultimate bearing capacity of foundations adjacent to slopes. This subject is highly dependent on the slope geometry and soil properties. Seismic forces are applied to the soil mass, soil surcharge and foundation by pseudo-static forces. In this study, a rigorous assessment of the seismic bearing capacity is performed using an upper-bound limit state plasticity framework known as discontinuity layout optimization (DLO), which makes few prior assumptions concerning the failure geometry. The results show that soil properties, slope configuration, and pseudostatic seismic loading all influence the realized failure mechanism and associated bearing capacity. The use of bearing capacity coefficients that fit within the conventional superposition method may underestimate limit loads when the underlying soil provides a relative increase in resistance but may greatly overestimate bearing capacity when the self-weight of the soil is destabilizing in nature. A set of design charts using direct computational methods for a variety of geometric, geotechnical and seismic conditions is provided.

The main objective of this technical note is to explore the influence of horizontal pseudostatic seismic coefficients on the failure mechanism and the ultimate load for footings located near slopes. The suitability of bearing capacity factors compatible with the superposition method for analyzing the capacity of footings near slopes subject to seismic conditions is discussed. Finally, a set of design charts is presented.

Outline of Proposed Analysis

The discontinuity layout optimization (DLO) procedure (Smith and Gilbert, 2007) implemented in the LimitState: GEO v3.4 software (LimitState, 2013) was adopted for this study. DLO is an efficient tool for directly obtaining upper-bound collapse loads and critical failure mechanisms. An advantage of this method is that it works without assuming the failure mode a priori. The bearing capacity of shallow foundations on slopes under static conditions has successfully been assessed by Leshchinsky (2015), Leshchinsky and Xie (2017) and Zhou et al. (2018) using the DLO procedure. Figure 1 shows a schematic of the model used in this study. A weightless, rigid strip footing of width B was placed adjacent to the slope crest with a slope angle β and a slope height H. The seismic stability of these systems was conventionally analyzed using pseudostatic conditions, and seismicity was incorporated through a horizontal pseudostatic acceleration coefficient kh applied to both the soil and the footing. The interface between the rigid footing and the soil was assumed to be rough. A brief comparison of the DLO procedure was made against seismic bearing capacity factors available from the prior literature, considering a footing placed on a slope with $\beta = 15°$ and $\varphi = 40°$, as shown in Figure 2. The differences between the DLO results and those from the lower-bound limit analysis of Kumar and Chakraborty (2013) are typically within 4.0%, demonstrating that the DLO procedure provides a reasonable evaluation of bearing capacity factors.

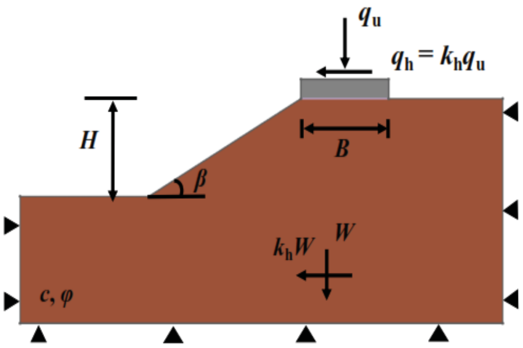
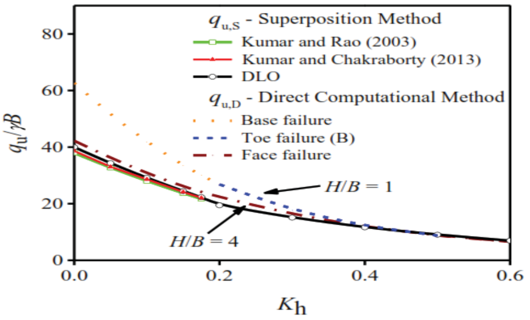


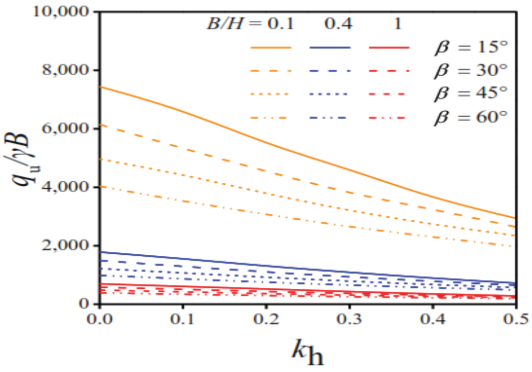
Figure 1. Schematic of the model.



(a) $\beta = 30°, \varphi = 40°$

Figure 2. Comparison between the ultimate seismic.

As shown in Figure 4, for higher kh values (e.g., kh = 0.45 in Figure 4) result in a deepened slope failure where the shear surface extends beyond the outer edge of the footing, and the observed bearing capacity decreases greatly.



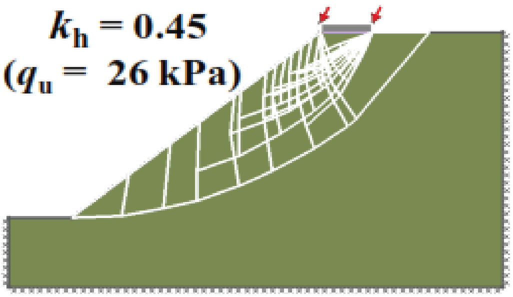


Figure 3. Design charts for normalized.

Figure 4. Transition of failure mechanisms.

In Figure 3, the results, presented in terms of the normalized bearing capacity qu/γB, were established for slope angles (β) of 15°, 30°, 45°, and 60° and B/H ratios of 0.1, 0.4, and 1. Ns values of 2, 10, and ∞ (indicating cohesionless soil) were considered for the bearing capacity of the footings adjacent to the slope face. For large Ns values (i.e., 10 and ∞), limited results are presented because the slopes are inherently unstable under many conditions. Additionally, the ultimate load decreases as the slope angle β increases, and it increases with the soil strength (particularly for large friction angles). Conversely, slopes with large friction angles are also the most sensitive to changes in kh.

REFERENCES

Amini Chakraborty, D., and Kumar, J. (2015). Seismic bearing capacity of shallow embedded foundations on a sloping ground surface. *International Journal of Geomechanics*. *15*(1), 04014035.

Kumar, J., and Chakraborty, D. (2013). Seismic bearing capacity of foundations on cohesionless slopes. *J. Geotech. Geoenviron. Eng.*, *139*(11), 1986-1993.

Leshchinsky, B. (2015). Bearing capacity of footings placed adjacent to c′-φ′ slopes. *Journal of Geotechnical and Geoenvironmental Engineering*, *141*(6), 04015022.