JOINT TRANSPORTATION RESEARCH PROGRAM

Principal Investigator: Rodrigo Salgado, Purdue University, rodrigo@purdue.edu, 765.494.5030

Program Office: jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp

Sponsor: Indiana Department of Transportation, 765.463.1521

SPR-3375 2013

Implementation of Limit States and Load Resistance Design of Slopes

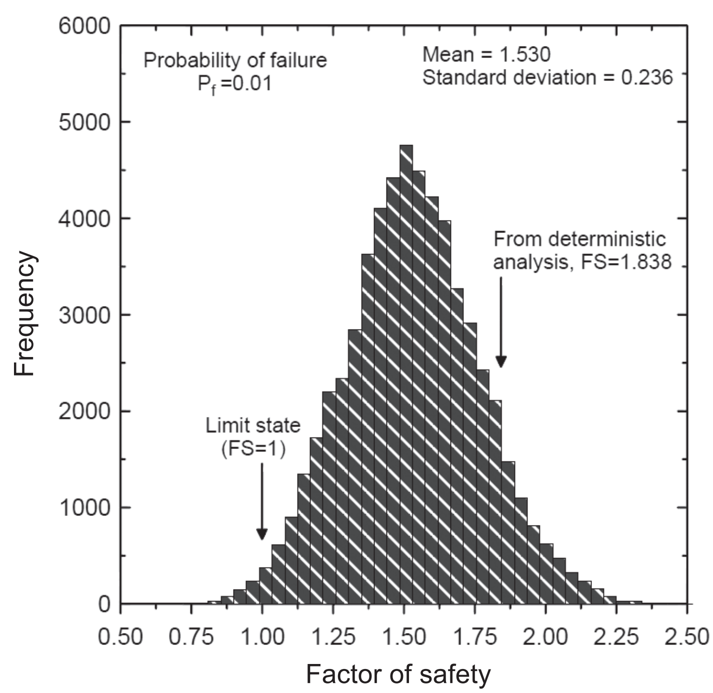
Introduction

A logical framework is developed for load and resistance factor design (LRFD) of slopes based on reliability analysis. LRFD of slopes with resistance factors developed in this manner ensures that a target probability of slope failure is not exceeded. Three different target probabilities of failure (0.0001, 0.001, and 0.01) are considered in this report. The ultimate limit state for slope stability (formation of a slip surface and considerable movement along this slip surface) is defined using the Bishop simplified method with a factor of safety equal to unity. Gaussian random field theory is used to generate random realizations of the slope with values of strength and unit weight at any given point of the slope that differ from their mean by a random amount. A slope stability analysis is then performed for each slope realization to find the most critical slip surface and the corresponding driving and resisting moments. The probability of slope failure is calculated by counting the number of slope realizations for which the factor of safety did not exceed 1 and dividing that number by the total number of realizations. The mean of the soil parameters is adjusted and this process repeated until the calculated probability of failure is equal to the target probability of failure. Optimal resistance and load factors are obtained by dividing the resisting and driving moments corresponding to the most probable ultimate limit state by the nominal values of resisting and driving moments. The main goal of this study was to provide specific values of resistance and load factors to implement in limit states and load resistance design of slopes in the context of transportation infrastructure. This report introduces the concept of load and resistance factors, the target probability of failure for slopes, and the ultimate limit state equation. It then presents a detailed algorithm for resistance factor calculation by using reliability analysis. Six slope stability cases provided by INDOT are examined in order to illustrate the LRFD procedure and validate the recommended resistance and load factors.

Findings

The main goal of this study was to provide more specific guidance on values of resistance factors to implement in load and resistance factor design of slopes, with specific illustrations.

The effect of slope geometry was investigated. It was shown that, when realistic values of COV and scale of fluctuation of the soil properties were assumed (values close to those of set D), the resulting resistance factor values did not depend strongly on slope geometry, suggesting that the rigorous reliability analysis algorithm



proposed in the present study can be used effectively to produce load and resistance factors for use in design of slopes.

The LRFD methodology was used to check the stability of a total of six slope cases (cases A through F) provided by INDOT. The short-term (undrained) properties of soil were used to analyze all cases. For all the adopted target probabilities of failure, there were strong linear correlations between the ratio *Rf* of factored resistance to factored load and *FS*.

Based on this study, the recommended resistance factors RF^* adjusted with respect to the proposed load factors LF^* (LF^*_{DL} = 1.0 and LF^*_{LL} = 1.2) are 0.75, 0.70, and 0.65 for $P_{f,T}$ of 0.01 (1%), 0.001 (0.1%), and 0.0001 (0.01%), for undrained slopes respectively.

Implementation

INDOT should start using the load and resistance factors proposed in this research project in slope stability checks in INDOT projects. As confidence in the application develops, greater reliance on this very economical method of checking slope stability will follow. Research opportunities for improvement of these factors should be pursued.

Recommended Citation

Salgado, R., S. I. Woo, F. S. Tehrani, Y. Zhang, and M. Prezzi. *Implementation of Limit States and Load Resistance Design of Slopes*. Publication FHWA/IN/JTRP-2013/23. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2013. doi: 10.5703/1288284315225.

View the full text of this technical report here: http://dx.doi.org/10.5703/1288284315225

Published reports of the Joint Transportation Research Program are available at http://docs.lib.purdue.edu/jtrp/.