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Geo-Risk 2017

Impact of Spatial Variability, Probabilistic Site Characterization, and Geohazards





Edited by

Jinsong Huang, Ph.D.
Gordon A. Fenton, Ph.D., P.Eng.
Limin Zhang, Ph.D.
D. V. Griffiths, Ph.D., P.E., D.GE

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Limin Zhang, Ph.D.
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Preface

Interest and use of probabilistic methods and risk assessment tools in geotechnical engineering has grown rapidly in recent years. The natural variability of soil and rock properties, combined with a frequent lack of high quality site data, makes a probabilistic approach to geotechnical design a logical and scientific way of managing both technical and economic risk. The burgeoning field of geotechnical risk assessment is evidenced by numerous publications, textbooks, dedicated journals and sessions at general geotechnical conferences. Risk assessments are increasingly becoming a requirement in many large engineering construction projects. Probabilistic methods are also recognized in design codes as a way of delivering reasonable load and resistance factors (LRFD) to target allowable risk levels in geotechnical design.

This Geotechnical Special Publication (GSP), coming out of the *Geo-Risk 2017* specialty conference held in Denver, Colorado from June 4-7, 2017, presents contributions in sessions: 1) Impact of Spatial Variability and Site Characterization, and 2) Geohazards.

These contributions to the use of geostatistics and probabilistic methods to model the spatial variability of the ground, to characterize geotechnical sites and to assess the risk of geohazards are very timely, and will provide a valuable and lasting reference for practitioners and academics alike.

The editors would like to thank all of the members of ASCE Geo Institute's Technical Committee on Risk Assessment and Management and the Engineering Practice of Risk Assessment and Management Committee (TC304) of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE) for their ongoing support.

All the papers in this GSP went through a rigorous review process. The contributions of the reviewers are much appreciated.

The Editors

Jinsong Huang, Ph.D., M.ASCE, University of Newcastle, NSW, Australia

Gordon A. Fenton, Ph.D., P.Eng., FEIC, FCAE, M.ASCE, Dalhousie University, Halifax, Canada

Limin Zhang, Ph.D., F.ASCE, Hong Kong University of Science and Technology, PR China

D.V. Griffiths, Ph.D., P.E., D.GE, F.ASCE, Colorado School of Mines, Golden, CO, USA

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Calibration of Factors of Safety for Slope Stability of Dikes

Willem Kanning, Ph.D.[1]; Ana Teixeira, Ph.D.[2]; Mark van der Krogt[3]; Katerina Rippi[4]; Timo Schweckendiek, Ph.D.[5]; and Bianca Hardeman[6]

[1]Dept. of Dike Safety, Deltares, P.O. Box 177, 2600 MH Delft, The Netherlands; Dept. of Hydraulic Engineering, Delft Univ. of Technology. E-mail: Wim.Kanning@deltares.nl
[2]Dept. of Dike Safety, Deltares, P.O. Box 177, 2600 MH Delft, The Netherlands. E-mail: Ana.Teixeira@deltares.nl
[3]Dept. of Dike Safety, Deltares, P.O. Box 177, 2600 MH Delft, The Netherlands. E-mail: Mark.vanderKrogt@deltares.nl
[4]Dept. of Dike Safety, Deltares, P.O. Box 177, 2600 MH Delft, The Netherlands. E-mail: Katerina.Rippi@deltares.nl
[5]Dept. of Dike Safety, Deltares, P.O. Box 177, 2600 MH Delft, The Netherlands; Dept. of Hydraulic Engineering, Delft Univ. of Technology, The Netherlands. E-mail: Timo.Schweckendiek@deltares.nl
[6]Rijkswaterstaat WVL, Flood Defense Dept., P.O. Box 2232, 3500 GE Utrecht, The Netherlands. E-mail: Bianca.Hardeman@rws.nl

Abstract

Dikes in the Netherlands are by law required to comply with predefined safety standards. The goal of this paper is to derive the safety format and the required factor of safety for the inner slope (landside slope) instability failure mode. The first step is to derive the required target reliability for a cross-section. The second step is to derive a safety format in which all uncertain variables in the slope stability computation are identified and accounted for by sufficiently safe parameters estimates. The third step is to derive the relation between target reliability and required Factor of Safety. This is done by evaluating 48 test cases. For each test case, the Factor of Safety is computed based on the safety format, as well the corresponding reliability index. This paper shows how to derive a required Factor of Safety based on a predefined target reliability. However, the spread in this relationship is significant. Hence, a full probabilistic analysis would lead to more accurate slope stability assessments.

INTRODUCTION

Dikes in the Netherlands are by law required to comply with predefined safety standards, which will be defined in terms of target failure probabilities from 2017 onwards. These safety standards are translated into assessment rules for the various failure modes to comply with. Within the Dutch WBI (‘Wettelijk Beoordelings Instrumentarium’) program, new dike assessment rules are being developed. These rules allow for both a probabilistic and semi-probabilistic (based on

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partial safety factors) assessments (Slomp et al. 2016). In order to obtain consistency between probabilistic and semi-probabilistic assessments, and for the failure modes to comply with the target reliability, the semi-probabilistic assessment methods have to be calibrated for each failure mode.

Slope instability of the inner slope (landside slope) is one of the main failure modes for dikes. Slope instability of the inner slope occurs when flood stages (referred to as outside water level in this paper) cause increased pore water pressures in and below the dike. This can occur in combination with increased pore water pressures due to precipitation. This results in reduced effective stresses and ultimately sliding of the inner slope (on the protected side). The resistance with respect to slope stability is typically assessed in terms of a Factor of Safety (F_s) that is a ratio of resisting and driving forces; where the slope is considered stable in cases F_s is larger than 1. The goal of this paper is to derive the safety format and the required Factor of Safety for the failure mode for slope stability of the inner slope a function of a target reliability requirement. For more details about this so-called calibration, please refer to Kanning et al. (2016). This paper first discusses probabilistic slope stability computations, after which the calibration procedure is elaborated: the target reliability, safety format and finally the calibrated safety factors.

PROBABILISTIC SLOPE STABILITY

This section discusses probabilistic slope stability computations.

Material model. The material model for Dutch slope stability assessment within WBI for low permeability materials (clay, peat) is based on Critical State Soil Mechanics (CSSM; Schofield and Wroth, 1968), and specifically the SHANSEP implementation (Ladd and Foott, 1974). Within this model, the undrained shear strength along the slip circle can be computed by eqn. [1]:

$$s_u = \sigma'_{v,i} \cdot S \cdot OCR^{\,m} \quad \text{with} \quad OCR = \sigma'_{vy} / \sigma'_{v,i} \quad \text{and} \quad \sigma'_{vy} = \sigma'_{v,i} + POP \qquad [1]$$

Herein, s_u is the undrained shear strength [kN/m^2], $\sigma'_{v,i}$ the in-situ effective vertical stress [kN/m^2], S the undrained shear strength ratio (normally consolidated) [-], OCR the Over-Consolidation Ratio [-], m the strength increase exponent [-], σ'_{vy} the vertical yield stress [kN/m^2], and POP the pre-overburden pressure [kN/m^2]. For higher permeability layers (sand), the drained material model based on an effective friction angle is used. The application of CSSM to Dutch dikes on a nationwide scale is new, and hence there is limited experience with the application of the method to real cases.

Limit Equilibrium Modeling of slope stability. In order to find the slip circle with the minimum Factor of Safety, F_s, limit equilibrium modeling is used. More specifically, the Uplift-Van method is used (Deltares, 2016). This method is similar to Bishop's method of slices but

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