

Probabilistic analysis of stability of earth slopes

Analyse probabiliste de la stabilité des talus en terre

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SYNOPSIS A probabilistic method for the analysis of stability of slopes is presented. Determination of the probability of failure anywhere along the slope axis involves two steps. The first step concerns determination of the probability of occurrence of a potentially unstable zone, i.e., an area where the conventional factor of safety is less than unity. It is demonstrated that a real failure can only occur within such area. The second step involves evaluation of the probability that a real failure occurs, assuming the presence of a potentially unstable zone. In this step the effects of the finite width of a real failure mode must be taken into account. A procedure is suggested for updating the estimate of the probability of failure, if it is observed or may be assumed that certain states of loading actually have occurred and did not involve failure.

INTRODUCTION

There has been a continuous development of probability based methods for computational analysis of reliability of earth slopes during the past decade. In the earliest publications attention was restricted to a probabilistic treatment of the conventional analysis of stability in a cross sectional plane of the slope (Yu & Kraft 1970, Cornell 1972, Alonso 1975, Tang Tsesoni & Ang 1976). Key feature of these analyses is that natural variability of shearing strength of soil and uncertainty, originating from limited sampling and testing defects, leads to uncertainty about the actual value of the factor of safety. The probability of failure of the slope was considered to equal the probability that the factor of safety is less than unity. Either only the most critical slip circle or a more or less representative set of potential slip circles was considered, taking into account decay of mutual correlation (Moris Catalan & Cornell 1976). A basically three dimensional failure mode has been examined in a probabilistic context by Vanmarcke (1977). He considered a rigid cylinder of finite width in the along slope direction. His analysis accounts for "end section" contributions to the failure resisting moment. Combination of the effects of these contributions, on the one hand, and the effect of "averaging" of shearing strength variations along the slip surface, on the other hand, yields a so called critical width of the failure mode for which the corresponding probability of occurrence takes a maximum. The analysis, according to Vanmarcke, thus predicts the probability of failure as well as the most probable width of the failure area.

The analysis presented here adopts Vanmarcke's fundamental concept of modeling spatial variations of the soil's shearing strength as a random process, as well as his concept of a "finite width" failure mode. It differs from his analysis in the sense that this width is not pre-assigned to some critical value. Instead, it is taken to be equal to the expected width of the zone where the conventional factor of safety is less than unity, the so called potentially unstable zone. It is demonstrated that a real failure mode, if it occurs, necessarily coincides exactly with such a zone. Whether or not a real failure actually occurs, depends on the "end section" contributions to the failure resisting moment. The analysis yields estimates of the probability that a failure occurs and

the expected width of the failure mode. The adopted analytical description enabled a further development, which would otherwise have been cumbersome. A kind of Bayesian procedure could be designed, by which it is possible to update estimates of the probability of failure based on observation of the history of survival of the slope.

DESCRIPTION OF THE FAILURE MODE

The failure mode adopted here consists of a cylindrical failure surface, which extends over a finite width L in the along slope direction (Figure 1). Analysis of equilibrium of failure generating (overturning) moment and failure resisting moments predicts failure if

$$\int_L M_r = 2M_o < \int_L M_R \quad (1)$$

Here M_r denotes local failure resisting moment due to mobilized friction along the (potential) failure surface, M_o the "end section" contribution to the failure resisting moment and M_o the local overturning moment.



Figure 1. Definition of failure mode

From equation 1 it is found that existence of a real failure mode necessarily implies existence of a potentially unstable zone. Figure 2 indicates a potentially unstable zone of width L . Now consider the possibility that a real failure occurs, and its width is less than L (Figure 2a). The part of the potentially unstable zone complementary to the failure mode would be excluded from failure. However, comparison of failure causing and failure resisting moments, acting on this part of the zone indicate its instability, since

Stability Analysis Of Earth Slopes

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A decorative graphic consisting of a light blue horizontal bar with a rounded right end, and a red circular shape partially visible behind it.

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Stability Analysis of Earth Slopes Y.H. Huang, 2012-12-06 During the past several years I have been engaged in applied research related to the stability analysis of slopes This research was supported by the Institute for Mining and Minerals Research University of Kentucky in response to the Surface Mining Control and Reclamation Act of 1977 which requires stability analysis for refuse dams hollow fills and spoil banks created by surface mining The results of the research have been published in several journals and reports and also presented in a number of short courses Both the simplified and the computerized methods of stability analysis as developed from this research have been widely used by practicing engineers throughout Kentucky for the application of mining permits The large number of out of state participants in the short courses indicates that the methods developed have widespread applications This book is a practical treatise on the stability analysis of earth slopes Special emphasis is placed on the utility and application of stability formulas charts and computer programs developed recently by the author for the analysis of human created slopes These analyses can be used for the design of new slopes and the assessment of remedial measures on existing slopes To make the book more complete as a treatise on slope stability analysis other methods of stability analysis in addition to those developed by the author are briefly discussed It is hoped that this book will be a useful reference class room text and users manual for people interested in learning about stability analysis

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Foundation Engineering Handbook Hsai-Yang Fang, 2013-06-29 More than ten years have passed since the first edition was published During that period there have been a substantial number of changes in geotechnical engineering especially in the applications of foundation engineering As the world population increases more land is needed and many soil deposits previously deemed unsuitable for residential housing or other construction projects are now being used Such areas include problematic soil regions mining subsidence areas and sanitary landfills To overcome the problems associated with these natural or man made soil deposits new and improved methods of analysis design and implementation are needed in foundation construction As society develops and living standards rise tall buildings transportation facilities and industrial complexes are increasingly being built Because of the heavy design loads and the complicated environments the traditional design concepts construction materials methods and equipment also need improvement Further recent energy and material

shortages have caused additional burdens on the engineering profession and brought about the need to seek alternative or cost saving methods for foundation design and construction

Slope Stability Analysis and Stabilization Y. M. Cheng, C. K. Lau, 2014-05-22 Includes Recommendations for Analysis Design Practice Design Charts Tables and More Using a unified approach to address a medley of engineering and construction problems Slope Stability Analysis and Stabilization New Methods and Insight Second Edition provides helpful practical advice and design resources for the practicing engineer This text

Geotechnical Engineering Handbook Braja M. Das, 2011 The Geotechnical Engineering Handbook brings together essential information related to the evaluation of engineering properties of soils design of foundations such as spread footings mat foundations piles and drilled shafts and fundamental principles of analyzing the stability of slopes and embankments retaining walls and other earth retaining structures The Handbook also covers soil dynamics and foundation vibration to analyze the behavior of foundations subjected to cyclic vertical sliding and rocking excitations and topics addressed in some detail include environmental geotechnology and foundations for railroad beds

Probabilistic Seismic Stability Analysis of Earth Slopes Rensselaer Polytechnic Institute, D. A-Grivas, J. D. Howland, National Science Foundation (U.S.), 1980

Procedures for Design of Earth Slopes Using LRFD J. Erik Loehr, 2006

Geotechnical Slope Analysis Robin Chowdhury, Phil Flentje, Gautam Bhattacharya, 2009-11-18 Freshly updated and extended version of Slope Analysis Chowdhury Elsevier 1978 This reference book gives a complete overview of the developments in slope engineering in the last 30 years Its multi disciplinary critical approach and the chapters devoted to seismic effects and probabilistic approaches and reliability analyses reflect the distinctive style of the original Subjects discussed are the understanding of slope performance mechanisms of instability requirements for modeling and analysis and new techniques for observation and modeling Special attention is paid to the relation with the increasing frequency and consequences of natural and man made hazards Strategies and methods for assessing landslide susceptibility hazard and risk are also explored Moreover the relevance of geotechnical analysis of slopes in the context of climate change scenarios is discussed All theory is supported by numerous examples A wonderful book on Slope Stability recommended as a reference book to those who are associated with the geotechnical engineering profession undergraduates post graduates and consulting engineers Prof Devendra Narain Singh Indian Inst of Technology Mumbai India I have yet to see a book that excels the range and depth of Geotechnical Slope Analysis I have failed to find a topic which is not covered and that makes the book almost a single window outlet for the whole range of readership from students to experts and from theoreticians to practicing engineers Prof R K Bhandari New Delhi India

Geotechnical Engineering A.V. & Venkatramaiah, 2000

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Landslides and Engineered Slopes. Experience, Theory and Practice Stefano Aversa, Leonardo Cascini, Luciano Picarelli, Claudio Scavia, 2018-04-17 Landslides and Engineered Slopes Experience Theory and Practice contains the invited lectures and all papers presented at the 12th International Symposium on Landslides Naples Italy 12 19 June 2016 The book aims to emphasize the relationship between landslides and other natural hazards Hence three of the main sessions focus on Volcanic induced landslides Earthquake induced landslides and Weather induced landslides respectively while the fourth main session deals with Human induced landslides Some papers presented in a special session devoted to Subareal and submarine landslide processes and hazard and in a Young Session complete the books Landslides and Engineered Slopes Experience Theory and Practice underlines the importance of the classic approach of modern science which moves from experience to theory as the basic instrument to study landslides Experience is the key to understand the natural phenomena focusing on all the factors that play a major role Theory is the instrument to manage the data provided by experience following a mathematical approach this allows not only to clarify the nature and the deep causes of phenomena but mostly to predict future and if required manage similar events Practical benefits from the results of theory to protect people and man made works Landslides and Engineered Slopes Experience Theory and Practice is useful to scientists and practitioners working in the areas of rock and soil mechanics geotechnical engineering engineering geology and geology

Rock Slope Engineering Evert Hoek, Jonathan D. Bray, 1981-06-30 This classic handbook deals with the geotechnical problems of rock slope design It has been written for the non specialist mining or civil engineer with worked examples design charts coverage of more detailed analytical methods and of the collection and interpretation of geological and groundwater information and tests for the mechanical properties of rock

Soft Soil Engineering A.K.L. Kwong, C.K. Lau, C.F. Lee, C.W.W. Ng, P.L.R. Pang, J.-H. Yin, Z.Q. Yue, 2001-01-01 This volume contains seven keynote lectures and over 100 technical contributions by scientists researchers engineers and students from more than 25 countries and regions worldwide on the subject of soft soil engineering

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