

# Rock Slope Engineering

Revised third edition

**Evert Hoek**

D.Sc(Eng)

Principal, Golder Associates,  
224 W 8th Avenue, Vancouver, B.C., Canada

and

**John Bray**

Ph.D(Eng)

Reader in Rock Mechanics, Imperial College  
of Science and Technology, London, UK



Published for the  
INSTITUTION OF MINING AND METALLURGY  
by



**E & FN SPON**

An Imprint of Chapman & Hall

London · Weinheim · New York · Tokyo · Melbourne · Madras

Published by E & FN Spon, an imprint of Chapman & Hall,  
2-6 Boundary Row, London SE1 8HN, UK

---

Chapman & Hall, 2-6 Boundary Row, London SE1 8HN, UK

Chapman & Hall GmbH, Pappelallee 3, 69469 Weinheim, Germany

Chapman & Hall USA., 115 Fifth Avenue, New York, NY 10003, USA

Chapman & Hall Japan, ITP-Japan, Kyowa Building, 3F, 2-2-1 Hirakawacho,  
Chiyoda-ku, Tokyo 102, Japan

Chapman & Hall Australia, 102 Dodds Street, South Melbourne, Victoria 3205,  
Australia

Chapman & Hall India, R. Seshadri, 32 Second Main Road, CIT East, Madras  
600 035, India

---

First edition 1974

Revised second edition 1977

revised third edition 1981

Reprinted 1991, 1994 (twice), 1996

© THE INSTITUTION OF MINING AND METALLURGY and  
E. Hoek and J.W. Bray

Printed and bound in Great Britain at the University Press, Cambridge

ISBN 0 419 16010 8

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the UK Copyright Designs and Patents Act, 1988, this publication may not be reproduced, stored, or transmitted, in any form or by any means, without the prior permission in writing of the publishers, or in the case of reprographic reproduction only in accordance with the terms of the licences issued by the Copyright Licensing Agency in the UK, or in accordance with the terms of licences issued by the appropriate Reproduction Rights Organization outside the UK. Enquiries concerning reproduction outside the terms stated here should be sent to the publishers at the London address printed on this page.

The publisher makes no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability for any errors or omissions that may be made.

A Catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data available

#### Special regulations for readers in the USA

This publication has been registered with the Copyright Clearance Centre Inc. (CCC), Salem, Massachusetts. Information can be obtained from the CCC about conditions under which photocopies of parts of this publication may be made in the USA. All other copyright questions, including photocopying outside the USA should be referred to the publisher.

*Rock Slope Engineering* is made available at the lowest possible cost to ensure that it is readily available to practicing engineers. Neither the authors nor the organisations for which they work receive any royalties from the sale of this book.



## CONTENTS

|   | Page |
|---|------|
| Chapter 6: Groundwater flow; permeability and pressure                  | 127  |
| Groundwater flow in rock masses   | 128  |
| Flow nets   | 134  |
| Field measurement of permeability                                       | 136  |
| Measurement of water pressure   | 143  |
| General comments  | 146  |
| Chapter 6 references  | 148  |
| Chapter 7: Plane failure  | 150  |
| General conditions for plane failure                                    | 150  |
| Plane failure analysis  | 150  |
| Graphical analysis of stability   | 157  |
| Influence of groundwater on stability                                   | 159  |
| Critical tension crack depth  | 161  |
| The tension crack as an indicator of instability                        | 164  |
| Critical failure plane inclination                                      | 165  |
| Influence of under-cutting the toe of a slope                           | 166  |
| Reinforcement of a slope  | 166  |
| Analysis of failure on a rough plane                                    | 167  |
| Practical example No. 1   | 168  |
| Practical example No. 2   | 174  |
| Practical example No. 3   | 179  |
| Practical example No. 4   | 190  |
| Practical example No. 5   | 196  |
| Chapter 7 references  | 198  |
| Chapter 8: Wedge failure  | 199  |
| Definition of wedge geometry  | 202  |
| Analysis of wedge failure   | 202  |
| Wedge analysis including cohesion and water pressure                    | 203  |
| Wedge stability charts for friction only                                | 209  |
| Practical example of wedge analysis                                     | 210  |
| Chapter 8 references  | 224  |
| Chapter 9: Circular failure   | 226  |
| Conditions for circular failure   | 226  |
| Derivation of circular failure charts                                   | 228  |
| Groundwater flow assumptions  | 229  |
| Production of circular flow charts                                      | 230  |
| Use of the circular failure charts                                      | 230  |
| Location of critical failure circle and tension crack                   | 239  |
| Practical example No. 1   | 242  |
| Practical example No. 2   | 243  |
| Practical example No. 3   | 244  |
| Bishop's and Janbu's methods of slices                                  | 247  |
| Chapter 9 references  | 254  |
| Chapter 10: Toppling failure  | 257  |
| Types of toppling failure   | 257  |
| Secondary toppling modes  | 259  |
| Analysis of toppling failure  | 259  |
| Factor of safety for limiting equilibrium analysis of toppling failures | 269  |
| General comments on toppling failure                                    | 269  |
| Chapter 10 references   | 270  |

## CONTENTS

|   | Page |
|---|------|
| Chapter 11: Blasting                                      | 271  |
| Production blasting                                       | 271  |
| Production blasting design                                | 282  |
| Evaluation of a blast                                     | 288  |
| Modification of blasting methods                          | 290  |
| Blasting damage and its control                           | 291  |
| Special blasting techniques for improving slope stability | 301  |
| Chapter 11 references                                     | 307  |
| Chapter 12: Miscellaneous topics                          | 309  |
| Influence of slope curvature upon stability               | 309  |
| Slope de-pressurisation                                   | 313  |
| Surface protection of slopes                              | 317  |
| Control of rockfalls                                      | 321  |
| Monitoring and interpretation of slope displacements      | 323  |
| A look into the future                                    | 326  |
| Chapter 12 references                                     | 330  |
| Appendix 1: Analysis of laboratory strength test data     | 333  |
| Appendix 2: Wedge solution for rapid computation          | 337  |
| Appendix 3: Factor of safety for reinforced rock slopes   | 352  |
| Appendix 4: Conversion factors                            | 355  |
| Index   | 356  |