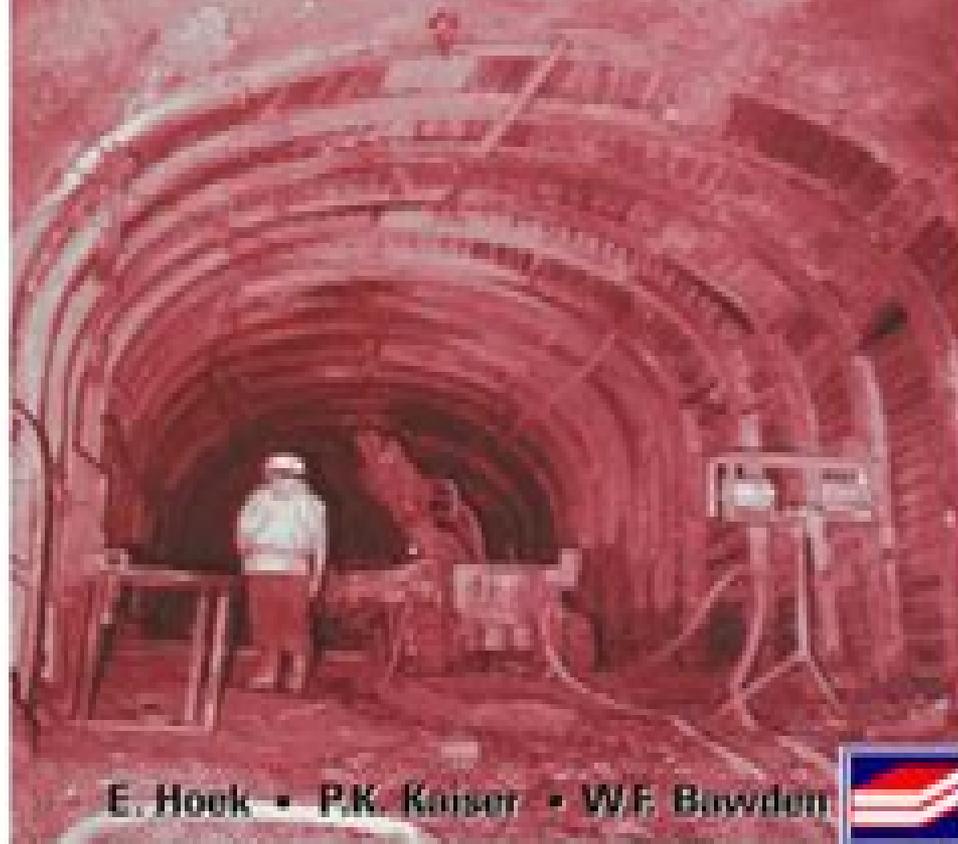


# Support of Underground Excavations in Hard Rock



E. Hook • P.K. Kaiser • W.F. Bowden



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**W. A. Hustrulid, Richard L. Bullock**



## Support Of Underground Excavations In Hard Rock:

**Support of Underground Excavations in Hard Rock** E. Hoek,P.K. Kaiser,W.F. Bawden,2000-01-01 The safe and economical construction of tunnels mines and other subterranean works depends on the correct choice of support systems to ensure that the excavations are stable These support systems should be matched to the characteristics of the rock mass and the excavation techniques adopted This expansive text explores the design of rockbolts dowels cable bolts and shotcrete for underground excavations in hard rock and covers key topics including rock mass classification systems and support design for overstressed rock

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Support of Underground Excavations in Hard Rock consultant expert mohamed taha,2021-02-02 Table of ContentsPreface vForeword vii1 An overview of rock support design 11 1 Introduction 11 2 Stages in mine development 1 1 2 1 Exploration and preliminary design 3 1 2 2 Mine design 3 1 2 3 Early years of mining 4 1 2 4 Later years of mining 71 3 Support design 72 Assessing acceptable risks in design 82 1 Introduction 82 2 Factor of safety 92 3 Sensitivity studies 102 4 The application of probability to design 102 5 Probability of failure 162 6 Problems to which probability cannot be applied 183 Evaluation of engineering geology data 203 1 Introduction 203 2 Engineering geological data collection 203 3 Structural geological terms 213 4 Structural geological data collection 223 5 Structural geological data presentation 233 6 Geological data analysis 244 Rock mass classification 274 1 Introduction 274 2 Engineering rock mass classification 27 4 2 1 Terzaghi s rock mass classification 28 4 2 2 Classifications involving stand up time 29 4 2 3 Rock quality designation index RQD 30 4 2 4 Rock structure rating RSR 314 3 Geomechanics classification 344 4 Modifications to RMR for mining 384 5 Rock tunnelling quality index Q 394 6 Using rock mass classification systems 454 7 Estimation of in situ deformation modulus 475 Shear strength of discontinuities 515 1 Introduction 515 2 Shear strength of planar surfaces 51ii Support of underground excavations in hard rock5 3 Shear strength of rough surfaces 52 5 3 1 Field estimates of JRC 53 5 3 2 Field estimates of JCS 54 5 3 3 Influence of scale on JRC and JCS 555 4 Shear strength of filled discontinuities 565 5 Influence of water pressure 575 6 Instantaneous cohesion and friction 576 Analysis of structurally controlled instability 616 1 Introduction 616 2 Identification of potential wedges 616 3 Support to control wedge failure 65 6 3 1 Rock bolting wedges

*The Design and Support of Underground Excavations in Deep-level, Hard-rock Mines* John W. Wilson,1971

Underground Mining Methods W. A. Hustrulid,Richard L. Bullock,2001 Reflecting

the highly international and diverse nature of the industry a series of mining case studies covers the commodity range from iron ore to diamonds as extracted by operations located in all corners of the world Industry experts have contributed 77 chapters

Proceedings of the 6th International Conference on Rehabilitation and Maintenance in Civil Engineering—Volume 2 Stefanus A. Kristiawan, Keh-Chyuan Tsai, Mohamed Shahin, Abdul Rahman Mohd Sam, Pham Dinh Hai, 2025-07-07 This book presents selected papers from the 6th International Conference on Rehabilitation and Maintenance in Civil Engineering 6th ICRMCE on July 4 5 2024 at Mataram Indonesia The papers cover topics related to developing and maintaining a sustainable built environment to mitigate the environmental impacts of human activities and create a healthier and more resilient future This is achieved through infrastructure development and maintenance issues from various perspectives and is brought together under the theme of policy design construction rehabilitation and maintenance for a sustainable built environment Readers will gain a deeper understanding of how to identify and solve issues related to infrastructure design construction use and maintenance toward realizing a sustainable built environment by tapping into various fields expertise within civil engineering such as material structural geotechnical transportation water resources and construction management

*Tunnel Lining Design Guide* British Tunnelling Society, Institution of Civil Engineers (Great Britain), 2004 Of geotechnical and geophysical properties 160 10 3 4 Design of tunnel linings 1 61 10 4 Instrumentation of the CTRL North Downs Tunnel 164 10 5 References 165 Appendix I Abbreviations and symbols 166 Appendix 2 Risk management 168 A21 Introduction 168 A2 2 Scope 168 A23 Risk register 169 A21 1 When to use the risk register 169 A2 32 What is it 169 A2 3 3 Assessment process 169 A2 3 4 Key steps 169 A2 3 5 Risk assessment qualitative or quantitative 171 A2 3 6 Remaining risk 175 A2 4 References 17

**Rock Mechanics for Natural Resources and Infrastructure Development - Invited Lectures** Sérgio da Fontoura, Ricardo Rocca, José Mendoza, 2019-09-03 Rock Mechanics for Natural Resources and Infrastructure Development Invited Lectures contains the Invited and Keynote Lectures and the prestigious ISRM Award Lectures the Leopold Muller Award Lecture by professor Peter K Kaiser and the Manuel Rocha Award Lecture by Dr Quinghua Lei as presented at the 14th ISRM International Congress ISRM 2019 Foz do Iguaçu Brazil 13 19 September 2019 Starting in 1966 in Lisbon Portugal the International Society for Rock Mechanics and Rock Engineering ISRM holds its Congress every four years where relevant themes related to rock mechanics and rock engineering are discussed This volume covers topics ranging from fundamental research in rock mechanics laboratory and experimental field studies to petroleum mining and civil engineering applications and is a must read for academics engineers and students involved in rock mechanics and engineering

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*Rock Mechanics for Natural Resources and Infrastructure Development - Full Papers* Sergio A.B.

Fontoura, Ricardo Rocca, José Mendoza, 2019-09-03 Rock Mechanics for Natural Resources and Infrastructure Development contains the proceedings of the 14th ISRM International Congress ISRM 2019 Foz do Iguaçu Brazil 13-19 September 2019. Starting in 1966 in Lisbon Portugal the International Society for Rock Mechanics and Rock Engineering ISRM holds its Congress every four years. At this 14th occasion the Congress brings together researchers, professors, engineers and students around contemporary themes relevant to rock mechanics and rock engineering. Rock Mechanics for Natural Resources and Infrastructure Development contains 7 Keynote Lectures and 449 papers in ten chapters covering topics ranging from fundamental research in rock mechanics laboratory and experimental field studies and petroleum mining and civil engineering applications. Also included are the prestigious ISRM Award Lectures: the Leopold Muller Award Lecture by professor Peter K Kaiser and the Manuel Rocha Award Lecture by Dr Quinghua Lei. Rock Mechanics for Natural Resources and Infrastructure Development is a must read for academics, engineers and students involved in rock mechanics and engineering. Proceedings in Earth and Geosciences Volume 6. The Proceedings in Earth and Geosciences series contains proceedings of peer reviewed international conferences dealing in earth and geosciences. The main topics covered by the series include geotechnical engineering, underground construction, mining, rock mechanics, soil mechanics and hydrogeology.

**Technical Manual for Design and Construction of Road Tunnels--civil Elements**, 2010. The increased use of underground space for transportation systems and the increasing complexity and constraints of constructing and maintaining above ground transportation infrastructure have prompted the need to develop this technical manual. This FHWA manual is intended to be a single source technical manual providing guidelines for planning, design, construction and rehabilitation of road tunnels and encompasses various types of road tunnels. Part IX **Geotechnical Design for Sublevel Open Stopping**

Ernesto Villaescusa, 2014-04-01. Presenting topics according to the conventional process used by most mining houses, this book covers the design and operation of sublevel open stopping. Summarizing state of the art practices encountered during his 25 years of experience, the author discusses increases in sublevel spacing, improvements in slot rising and rock mass characterization as well as methodologies to design open spans and pillars, rock reinforcement and fill masses. He also addresses in situ stress concentration minimization, dilution control, action plans and techniques to back analyze and optimize stope wall performance. **Engineering Rock Mass Classification**

R K Goel, Bhawani Singh, 2011-08-09. Rock mass classification methods are commonly used at the preliminary design stages of a construction project when there is very little information. It forms the bases for design and estimation of the required amount and type of rock support and groundwater control measures. Encompassing nearly all aspects of rock mass classifications in detail, **Civil Engineering Rock Mass Classification: Tunnelling, Foundations and Landsides** provides construction engineers and managers with extensive practical knowledge which is time tested in the projects in Himalaya and other parts of the world in complex geological conditions. Rock mass classification is an essential element of feasibility studies for any near surface construction project prior to any

excavation or disturbances made to earth Written by an author team with over 50 years of experience in some of the most difficult mining regions of the world Civil Engineering Rock Mass Classification Tunnelling Foundations and Landsides provides construction engineers construction managers and mining engineers with the tools and methods to gather geotechnical data either from rock cuts drifts or core and process the information for subsequent analysis The goal is to use effective mapping techniques to obtain data can be used as input for any of the established rock classification systems The book covers all of the commonly used classification methods including Barton's Q and Q systems Bieniawski's RMR Laubscher's MRMR and Hoek's and GSI systems With this book in hand engineers will be able to gather geotechnical data either from rock cuts drifts or core and process the information for subsequent analysis Rich with international case studies and worked out equations the focus of the book is on the practical gathering information for purposes of analysis and design Identify the most significant parameters influencing the behaviour of a rock mass Divide a particular rock mass formulation into groups of similar behaviour rock mass classes of varying quality Provide a basis of understanding the characteristics of each rock mass class Relate the experience of rock conditions at one site to the conditions and experience encountered at others Derive quantitative data and guidelines for engineering design Provide common basis for communication between engineers and geologists

**Computer Methods and Advances in Geomechanics** Chandra S. Desai,2001 *KWIC Index of Rock Mechanics Literature* J P Jenkins,E. T. Brown,2016-06-03 KWIC Index of Rock Mechanics Literature Part 2 1969 1976 is an index of subjects in rock mechanics The KWIC keyword in context index is produced by cyclic permutation of significant words in the title of the publication The text covers materials in rock mechanics and geomechanics published around the 70s The book will be of great use to students researchers and practitioners of geological sciences

Ground Characterization and Structural Analyses for Tunnel Design Benjamín Celada,Z.T. Bieniawski,2019-08-06 This practical and design oriented book focuses on ground characterization and structural calculation as part of the active structural design methodology With a focus on rock tunnelling it offers a comprehensive rather than a topic based perspective deriving sound tunnel design criteria and methods from basic principles Ground characterization includes excavations site investigation and in situ stress determination culminating in geotechnical classifications The book then deals with various construction methods and their appropriate calculations which range from constitutive models for the stress strain behaviour of an excavation and tunnel support elements to a full stress strain analysis methodology The heavily practical approach of the book draws on the authors twenty years of tunnelling experience in Spain and South America It will help any young or established professional who wants to develop a career in the underground field across both civil engineering and geology As it incorporates the very fundamentals of tunneling design it can be used as a support for tunneling courses or as a textbook for master's and PhD courses Benjamín Celada was Chief Tunnel Engineer at Hunosa and Potasas de Navarra S A before founding Geocontrol S A He has also worked for twenty years as Professor of Underground Works at the Polytechnic Mining University in Madrid

Spain Z T Bieniawski directed the Rock Mechanics Department of the Council for Scientific and Industrial Research in Pretoria then taught at the Pennsylvania State University for twenty years North American Tunneling 2004 Levent Ozdemir,2004-04-01 This publication includes papers from the North American Tunneling 2004 conference sponsored by the American Underground Construction Association The theme of the conference is Underground Construction the Sensible Solution to Urban Problems to reflect the increasing importance of locating urban facilities in the United States underground for enhanced security to build critical infrastructure where it is needed and to improve the function of urban areas The papers are grouped in four major themes Management of Underground Projects Public Policy and Underground Projects Advances in Technology Case Studies Trials Tribulation and Triumphs in Tunneling This work should benefit everyone involved in any aspect of infrastructure tunneling and underground construction Rock Mechanics and Rock Engineering: From the Past to the Future Reşat Ulusay,2016-11-18 Rock Mechanics and Rock Engineering From the Past to the Future contains the contributions presented at EUROCK2016 the 2016 International Symposium of the International Society for Rock Mechanics ISRM 2016 rg p Cappadocia Region Turkey 29 31 August 2016 The contributions cover almost all aspects of rock mechanics and rock engineering from theories to engineering practices emphasizing the future direction of rock engineering technologies The 204 accepted papers and eight keynote papers are grouped into several main sections Fundamental rock mechanics Rock properties and experimental rock mechanics Analytical and numerical methods in rock engineering Stability of slopes in civil and mining engineering Design methodologies and analysis Rock dynamics rock mechanics and rock engineering at historical sites and monuments Underground excavations in civil and mining engineering Coupled processes in rock mass for underground storage and waste disposal Rock mass characterization Petroleum geomechanics Carbon dioxide sequestration Instrumentation monitoring in rock engineering and back analysis Risk management and the 2016 Rocha Medal Lecture and the 2016 Franklin Lecture Rock Mechanics and Rock Engineering From the Past to the Future will be of interest to researchers and professionals involved in the various branches of rock mechanics and rock engineering EUROCK 2016 organized by the Turkish National Society for Rock Mechanics is a continuation of the successful series of ISRM symposia in Europe which began in 1992 in Chester UK **Blasting Technology for Underground Hard Rock Mining** Vivek Kumar Himanshu,A. K. Mishra,M. P. Roy,P. K. Singh,2023-05-30 This book presents the principles and practices of rock blasting for underground hard rock mining It covers a theoretical background of the rock blasting technology and comprehensive case studies on different stages of rock blasting for underground metalliferous mining It includes the discussions on burn cut face blasting pattern slot raise excavation methodology and ring blasting methods It further discusses different practical challenges associated with underground blasting viz ore dilution ground vibration wall instability etc and their possible solutions The book also covers the recent advancements in methodologies to predict blasting outcomes and instrumentations for monitoring rock blasting operations The book is a

useful reference for rock blasting practitioners mining engineers professionals and researchers It is also a valuable reference for undergraduate and postgraduate students **Mine Planning and Equipment Selection 2000** T.N.

Michalakopoulos,2018-05-08 This text looks at mine planning and equipment and covers topics such as design and planning of surface and underground mines geotechnical stability in surface and underground mines and mining and the environment

**Rock Mechanics for Resources, Energy and Environment** Marek Kwasniewski,Dariusz Lydzba,2013-09-11 The emphasis in Rock Mechanics for Resources Energy and Environment is on the application of rock mechanics to the extraction of natural resources securing energy supplies and protecting the environment surrounding rock that is subject to engineering activities The book will be of interest to rock mechanics researchers as well as to professionals who are involved in the various branches of rock engineering

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In a world inundated with displays and the cacophony of quick conversation, the profound power and psychological resonance of verbal art often fade into obscurity, eclipsed by the regular assault of noise and distractions. Yet, situated within the musical pages of **Support Of Underground Excavations In Hard Rock**, a captivating perform of literary beauty that impulses with raw thoughts, lies an wonderful trip waiting to be embarked upon. Published by way of a virtuoso wordsmith, that mesmerizing opus courses readers on a mental odyssey, delicately revealing the latent possible and profound affect stuck within the intricate internet of language. Within the heart-wrenching expanse with this evocative analysis, we will embark upon an introspective exploration of the book is central themes, dissect its interesting writing style, and immerse ourselves in the indelible impression it leaves upon the depths of readers souls.

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