Rock Failure Mechanisms: Explained and Illustrated

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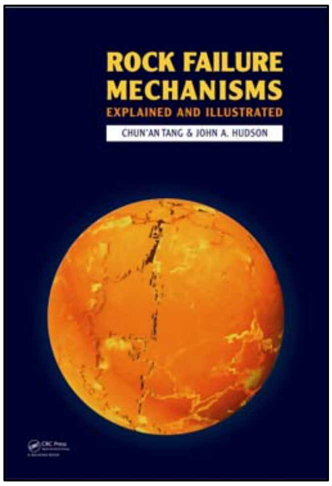

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INTRODUCTION

The subject of rock failure has been studied in a co-ordinated way since the 1960s. The way in which rock fails can be studied by examination of natural rock formations that have been stressed and strained over geological time, by laboratory experiments on rock samples, through *in situ* experiments, and by observing the results of rock excavation and loading during engineering construction. In this book, rock failure mechanisms are illustrated and explained.

Over the years, there have been three main developmental phases supporting rock engineering design: analysis based on elasticity theory; the use of rock mass classification systems; and computer modelling. The elasticity theory approach is useful because it enables the stresses around circular and elliptical holes to be determined, although the approach is most useful for deep excavations where the rock behaviour is essentially elastic. Rock mass classification is also useful because the variety of factors affecting rock behaviour can be accommodated in a mathematical expression, thus providing an index value for rock quality. Computer modelling started as a method of displaying analytical results and extending the analyses to more complex situations. However, in the last two decades, computer modelling has advanced by leaps and bounds so that it is now, not only the design tool of choice for rock engineering, but is also a research tool in its own right for exploring rock failure mechanisms. For example, a comprehensive knowledge of the state of stress throughout the micro-structure of a rock specimen or throughout a fractured rock mass several kilometres in size cannot be established by direct laboratory or *in situ* measurements but it can be studied through computer modelling using numerical techniques. For this reason, to illustrate rock failure mechanisms, many of the diagrams in this book are the output from numerical simulations. By many comparisons with the behaviour of real rocks, there is the confidence that these simulations do indeed represent real rock failure behaviour.

When engineering on or in rock masses, one may wish to avoid failure (e.g. when excavating a cavern to host the turbines in a hydro-electric project) or one may wish to cause failure (e.g. in the block caving method of mining when a large rock block is undercut and breaks up as it descends). In both cases, wishing to avoid or to cause rock failure, it is important to understand the rock failure mechanisms and the many factors that can affect the mode of rock failure, in particular the nature of the applied stress state and the nature of the rock. The applied stress can be in the form of tension, compression or shear, and various combinations of these. The rock itself is generally discontinuous, inhomogeneous and anisotropic and occurs on a multiplicity of scales. This means that rock failure can be manifested in many ways. In the book mainly brittle rock failure is considered.

The authors' intention in writing this book has been to provide an overview of the physical manifestations of rock failure in the variety of circumstances that can occur. Accordingly, the Chapters follow the logic of an overall introduction explaining the geological background and engineering failure, then direct loading in tension, compression and shear, the effects of inhomogeneity, anisotropy, multiple loading and time dependency, the effects of water and heat flow, engineering projects, and finally the two concluding Chapters on 3-D modelling and concluding remarks. Five of the individual chapters are somewhat longer than the others because of the importance of their subject matter: Chapter 3 on indirect tension, Chapter 4 on uniaxial compression, Chapter 6 on the effect of rock heterogeneity, Chapter 10 on the coalescence of fractures and Chapter 19 on particle breakage.

Photographs and computer simulation outputs are included to explain and illustrate the rock failure mechanisms. It has not been the intention to provide detailed mathematical expressions characterising rock failure in the different circumstances, but rather to present illustrative examples of the rock failure mechanisms so that the overall spectrum of rock failure can be appreciated by all those concerned, including clients, consulting engineers, contractors, students, lecturers and researchers.

BRIEF TABLE OF CONTENTS

The mechanical behavior of rock material under the biaxial and triaxial conditions is beneficial to explore the failure mechanism of rock engineering. Sagong et al. [12] conducted the biaxial compression test on specimens with different orientations (30Â°, 45Â°, and 60Â°). They discovered that tensile crack initiation and propagation plays a dominant role at a small joint dip angle.Â The phenomena were explained in terms of the restraint effect of confining pressure on the lateral deformation of the specimens. According to Mohrâ€"Coulomb failure criterion, the deviatoric stress. () will increase when the confining pressure. 4.2.3.3 Stress distribution and failure-. induced stress redistribution . 68 4.3 Rock failure modes in uniaxial compression .Â 11.3.2 Influence of stress wave amplitude on the. fracture process and failure pattern . 186 12 Rock failure and water flow . 189 12.1 Introduction . 189 12.2 Rock failure under hydraulic pressure . In this book we explain and illustrate rock failure mechanisms. The subject of rock failure has been studied in a co-ordinated way since the 1960s: the International Society for Rock Mechanics was founded in 1962 and the first issue of the International Journal for Rock Mechanics and Mining Sciences was published in 1964.Â Computer modelling started as a method of displaying analytical results and extending the analyses to more complex situations. However, in the last two decades, computer modelling has advanced by leaps and bounds so that it is now, not only the design tool of choice for rock engineering, but is also a research tool in its own right for exploring rock failure mechanisms. It subsquently deals in detail with explaining, simulating and illustrating rock failure in laboratory and field. The concluding chapter discusses coupled modelling and the anticipated future directions for this type of computer simulation. An appendix describing the RFPA numerical model (Rock Failure Process Analysis program) is also included. In this book, rock failure mechanisms are illustrated and explained. Over the years, there have been three main developmental phases supporting rock engineering design: analysis based on elasticity theory; the use of rock mass classification systems; and computer modelling. The elasticity theory approach is useful because it enables the stresses around circular and elliptical holes to be determined, although the approach is most useful for deep excavations where the rock behaviour is essentially elastic.