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***Engineering Rock Mechanics—An Introduction to the Principles*: Hudson, J.A. and Harrison, J.P. 1997. Pergamon, Elsevier, New York. 444 pp., ISBN 0-08-041912-7. Price: hardcover US$104.**

Engineering Rock Mechanics describes the discipline based on mechanics that is used to design structures built on or in rock masses. The rock mass is the aggregate material composed of the intact rock material, the intervening fractures, faults, and bedding planes (collectively referred to in rock engineering as "discontinuities"), and the groundwater and in-situ stress conditions. The intact rock material is what we learn to identify in undergraduate geology classes. Fracture sets that divide the rock mass are treated in structural geology classes, while explicit consideration of groundwater and stress state may be deferred to other classes. The study of rock masses from an engineering perspective deals by necessity with all these elements in as quantitative a fashion as practicable.

Whereas rock has been used as an engineering material for millennia, only in the past several decades has it gained independent status—on par with glass, steel, concrete, ceramics, and composites—as a material with special characteristics and design requirements. The construction of hydroelectric power plants, deep underground mines, huge open-pit mines, and storage facilities for petroleum reserves or high-level radioactive waste, as well as environmental issues such as groundwater recharge and tracking of contaminant plumes, all require a sound knowledge of rock-mass mechanics. In apparent contrast to these practical applications, the understanding of natural geologic structures, and the causative deformation processes, of interest to structural geologists and geodynamicists also depend critically on rock mechanics. The basic physics common to both disciplines are the same despite differences in terminology or professional motivation. This book provides a useful, though concise, exposition of much of this shared material.

Including the introduction, the book is divided into 20 chapters, followed by a reference list, two appendices, and an index. These chapters take the reader from a description of what engineering rock mechanics is, through chapters dealing with stress, strain, rock properties and their measurement, discontinuities, various rock-mass properties such as permeability and anisotropy, and into a series of chapters that discuss important applications such as excavation, slope stability, and support design (wall and roof reinforcement). The appendices provide ancillary material on stress, strain, and stereonet methods. The book is intended as a resource for engineers or others who work in rock mechanics and/or rock engineering, and as a textbook for either introductory or advanced teaching in rock mechanics.

Chapters 1 and 2 (Introduction and Geological Setting) define the subject of rock mechanics and give a very brief historical account of its development and major attributes. Photographs of jointed outcrops, fractured core, and quarries provide examples of rock as an engineering material. Important terms and concepts, such as intact rock, rock mass, and the geometrical configuration of fractures in the rock mass (called the "rock structure" in the book) are highlighted. Chapter 3 (Stress) presents a somewhat cursory outline of stress, using a matrix-based formulation. Many of the points raised in the nine-page long treatment would be useful for structural geologists, including "why study stress," "the difference between a scalar, vector, and tensor," "normal and shear stress components," "stress as a point property," properties of the stress matrix, and principal stresses. The material is best extracted from this brief chapter by a reader with some exposure to matrices and linear algebra although only the results, and not the derivations, are presented. The gory details of stress equations that are really necessary for an understanding of this chapter's material are given in Appendix A (discussed below).

Chapter 4 provides a clear introduction to in situ stress. After briefly relating the rationale for understanding and measuring in situ stress—from an engineering standpoint—a concise discussion of stress determination methods is presented. The flatjack, hydraulic fracturing, and the USBM and CSIRO overcoring devices are described succinctly and qualitatively. The discussion moves on to vertical and horizontal stress components and their presentation as a worldwide dataset. The Hoek and Brown method for presenting the data, plotting the average horizontal stress over the vertical stress against depth, is quite useful and revealing but may be new for geologists conversant with strength envelopes. A glossary of selected terms follows the chapter.

A short sketch of strain follows in Chapter 5. Here, finite strain is described first, using a few very simple examples and diagrams. The important attribute of path-dependent strain is noted up-front. Infinitesimal strain is presented next, followed by the strain tensor (in matrix form) and its linkage to the stress matrix through the compliance matrix, which is developed for the interesting and useful cases of orthotropic, transversely isotropic, and isotropic materials. Details of strain equations and conventions are deferred to Appendix A.

The rock mechanics part of the book begins with Chapter 6 (Intact rock). Here the concept of intact rock is defined, followed by a cursory yet readable description of the complete stress–strain curve for rock. Elastic parameters such as Young's modulus (both tangent and secant) are defined and some of the mechanisms that underlie rock deformation—such as closing or opening of microcracks in test samples—are noted. The unconfined compressive strength is defined without the usual recourse to a Mohr diagram. The importance of testing machine stiffness on laboratory results is described in some detail. Other factors that can influence laboratory-scale intact-rock properties including size, shape, end effects, loading conditions, and moisture content (pore water pressure) are presented. Useful terms such as strain hardening or softening and creep are defined. This material is pertinent background for structural geologists looking for a quick and relatively painless entry to the field and intricacies of rock-mechanical testing. The chapter concludes with a brief overview of peak-strength failure criteria including Mohr–Coulomb, Griffith, and Hoek–Brown.

Chapter 7 begins the material on Discontinuities. As noted by the authors, "...discontinuities can be the single most important factor governing the deformability, strength and permeability of the rock mass ... it is the existence of discontinuities in a rock mass that makes rock mechanics a unique subject". As used in the book, a discontinuity is defined as any separation in the rock continuum having effectively zero tensile strength, and it is used without any genetic connotation, to include, for example, structures such as joints, faults, and stylolites. Following some nice photographs of jointed outcrops, the Chapter follows the standard rock-engineering approach of statistical characterization of discontinuities. Topics such as discontinuity frequency and spacing, RQD (rock quality designation, a measure of fracture spacing), and probability functions are presented. The role of discontinuities in modulating the stiffness and strength of an outcrop is touched on at the end of the chapter.

Important aspects of rock-mass mechanics are considered in Chapters 8, 9, and 10. Following a brief explanation of the concept of the rock mass (Chapter 8), the effect of fracture sets on the hydraulic properties of this composite material is considered in Chapter 9. Basic concepts and definitions are laid out, with the treatment focused on fluid flow through fractures. The effect of scale on fluid flow properties is briefly considered. In Chapter 10 the basic elements of anisotropy and inhomogeneity of rock masses are presented concisely.

Techniques used by rock engineers to measure the strengths of rock mass components are presented in Chapter 11. The Schmidt hammer and point-load tests are documented as ways of assessing the mechanical index properties of the intact rock material. Simple experimental methods for measuring the shear strength of discontinuities, and of the entire rock mass, are then presented. The material then flows to rock mass classification systems in Chapter 12, where the major systems in current use (RMR and Q-system) are developed. Stand-up time for unsupported underground openings in fractured rock masses and the related deformation modulus are presented as applications of the classification systems, along with suggestions for further development. The time-dependency and creep of rock masses is considered in Chapter 13 with a brief introduction to inelastic behavior from a macroscopic (rheologic) viewpoint.

A suite of topics of interest to rock engineering follows, including separate chapters on rock mechanics interactions, excavation and blasting, stabilization and support, slope stability, design of surface excavations, and design of underground excavations (Chapters 19 and 20). The stereographic projection is used extensively as a quick and reliable tool to assess block kinematics such as toppling or sliding toward an exposed cliff face.

Appendix A, which follows the reference list, provides a compact summary of the basic equations for stress and for strain, using both matrices and trigonometry. Several worked examples illustrate the equations and the Mohr diagrams. Appendix B walks the reader through basic operations on the stereonet. An index completes the book.

In general the book is a useful summary of rock mechanics as applied to rock engineering. The treatment is more of an overview than an in-depth exposé, however. This approach makes the book both rewardingly streamlined for an advanced reader yet frustrating by its lack of supporting data and sources. A reader new to the topic may similarly learn much from the general concepts presented yet be unable to develop the depth of understanding needed to thoroughly digest and utilize the material. The inclusion of worked example and homework problems throughout the chapters would greatly facilitate the use of the book as a text in college and university level classes.

Concepts are illustrated either with photographs of rocks or with original line drawings. Although the quality of the artwork and photographic reproduction is high, the short figure captions are largely insufficient to do justice to the important concepts contained in the figures, making it more difficult for the less experienced reader to fully grasp the figures' significance.

Throughout the book (e.g. Chapter 2, p. 28) the authors associate brittle deformation (jointing) with high strain rates and ductile deformation (folding) with slow rates. This interpretation of joints, once prevalent in the geologic literature, has been revised and superceded since the 1980s (e.g. Pollard and Aydin, 1988). Similarly, the description of geologic discontinuities may seem overly simplistic to the structural geologist, as much more is known about fractures and faults than is even hinted at in the book.

However, the discerning reader will note the elegant simplicity and sharp focus in considering discontinuities by their effect on the mechanical response of the rock mass. The useful definitions given in the chapter-ending glossaries should probably not be construed as comprehensive, however, given a somewhat simplified usage. While the authors are not geologists, the differences in definition illuminate the rather wide, and unnecessary, gulf that still exists between structural geology and rock mechanics.

A more comprehensive index (currently less than 4.5 pages for a 444-page volume) would improve the book. I found that many important terms that were highlighted in the chapters (e.g. Section 5.5, the elastic compliance matrix) were not linked to entries in the index. Placing the references before the appendices and index made it more difficult to locate the pages than if the index were located at the end.

Engineering Rock Mechanics fills a useful niche as a relatively painless introduction to applied rock mechanics. While it may be lacking in the level of detail presented, engineers and geologists should appreciate the uncluttered exposition of major concepts. The book would be a worthwhile supplement for courses in geotechnical engineering and structural geology.

Reference

Pollard, D.D., Aydin, A., 1988. Progress in understanding jointing during the past century. Geological Society of America Bulletin 100, 1181–1204.

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