HANDBOOK ON

MECHANICAL PROPERTIES OF ROCKS

VOLUME I

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HANDBOOK ON MECHANICAL PROPERTIES OF ROCKS

– Testing Techniques and Results –

Volume I

by

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FOREWORD

Like a sculpturer, a construction engineer must know best his material with which or in which he has to work.

The rock, as a construction material, is the most complicated and most difficult to describe and define with which an engineer has ever to deal with and still it is the most commonly used building material. We have built in it and over it right from our appearance on the earth and still it is the material about which we know the least. It is absolutely necessary to understand it and control it so that the tragedies of Vajont, Malpasset, Langarone do not repeat themselves.

The problems of excavation and construction in rock, whether for mining of deeper or poorer quality minerals or for underground storage reservoirs, deep foundations, water storage dams or high speed transportation facilities, have become more complicated and wide spread requiring more stringent economic controls, technical planning and designs requiring an exact knowledge of the behaviour of immediate rock in particular and the surrounding rock in general.

The need for a handbook or a reference book containing an overall view of the material properties as well as the behaviour of the geologic-body and the methods to determine it had long been felt. This aspect of the field of rock science has grown so big that not many can keep an overall view of it. Therefore, this book by these authors who have spent considerable energy in describing the behaviour of the rock material and rock masses, is all the more welcomed. This work containing a rich review will be useful in determining the safety and economic viability of construction work in rock; an aspect in which there is nothing more important than the knowledge of the rock behaviour.

With satisfaction one could state that the book contains not only the mechanical properties of the rock substance in small hand specimens but also that of the composite rock mass which is built out of an assembly of such elements. The details of the important methods of investigation described in the book and the analyses of the results obtained are important for a man in practice.

Without approving any premature standardisation of the methods of testing, it is hoped that this treatise will particularly give an impulse to the various attempts of rock mass classification and the unification of the understanding of the testing techniques.

It is for this purpose I wish this book a wide dissemination.

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Preface

The knowledge of mechanical properties of rocks is essential in any rock mechanics investigations connected either with mining, tunnelling, drilling, blasting, cutting or crushing. After predicting the state of stress, strain or stored energy from the analysis of loads or forces being applied to the rocks, the behaviour, i.e., fracture, flow, or simply deformation of the rock can be estimated from these mechanical properties.

The mechanical properties of a rock depend primarily on its mineral composition and constitution, i.e., its structural and textural features. They also depend upon the condition it is in when tested (e.g., temperature, water content).

In reviewing the factors which influence the mechanical properties, it is helpful to work progressively from the scale of the single mineral to that of the rock mass. The properties of a single mineral are a function of its chemical composition, lattice structure (which determines glide systems), and lattice defects such as vacancies and dislocations. They also depend on its orientation relative to the applied stress field and on the mode of load application.

In bulk specimens of intact rock the mechanical properties depend not only on the properties of the individual minerals, but also upon the way in which the minerals are assembled. The relevant information is given by a full petrographic description, which includes the mineral composition of crystals, grains, cementing materials and alteration products and also the structure and texture, including size, shape, distribution and orientation of crystals, grains, pores and cracks. The degree of isotropy or anisotropy is also important and varies with the size of the body of rock under consideration. For example, in schist, gneiss, and other foliated rocks, the constitutive properties vary with direction even at the microscopic scale, and to the extent that the mechanical properties even of a small specimen are affected. However, in sedimentary rocks, which are generally laminated, the rock within a lamina may be relatively isotropic, whereas, at a scale that includes the separation between lamina, the same rock may be relatively anisotropic. On the other hand, other rocks may be strongly anisotropic even within very thin sheets. Primary anisotropy, brought about by preferential orientation during crystallisation, or by recrystallisation during sedimentation or metamorphic processes, may be distinguished from secondary anisotropy, brought about by geologic deformation of the rock.

The rock mass contains planes of weakness that affect its mechanical properties, making it mechanically anisotropic.* These planes of weakness may be joints, faults, fractures, partings between beds, or in bedded or laminated rock, layers of lower strength rock. The mechanical properties of a rock mass depend upon the following factors:

1. The mechanical properties of the individual elements constituting the system.
2. The sliding characteristics of the planes of weakness.
3. The configuration of the system with respect to the directions of loading.
4. The operating stress field.

The size or scale of the rock body that is being considered is an important factor in deciding the testing program for the determination of the mechanical properties of rock. From an engineering standpoint, if bodies of rock are being considered at a macroscopic scale, planes of weakness generally are not a point of concern. Operations such as crushing, grinding, and drilling occur at this scale. However, at a megascopic scale, e.g., in the excavation of large underground openings, in large open pit mines, planes of weakness generally dominate the failure process. This conclusion is borne out by the observation that the larger part of fracture surfaces created by underground or slope failures occurs on planes of weakness rather than through fresh rock.

Virtually all data on the mechanical properties of rock have been obtained from tests at a macroscopic scale, i.e., on specimens of rock, hand size or larger, but specifically below a size that would include planes of weakness of geological origin, e.g., joints, bedding planes, etc.

As yet, data are meager on the mechanical properties of large bodies of rock, i.e., from tests at a megascopic scale. The requirement for this information has been realised for some time, but the problems of preparing in situ test specimens and developing equipment for applying loads of the required magnitude have been slow in materialising. Several investigators have studied the effects of mechanical defects such as joints and bedding by testing

* This anisotropy is in addition to that due to mineral fabric (schistosity, etc.) that may be present both on macroscopic and megascopic scales.

specimens containing either real or simulated planes of weakness in the laboratory.

Various testing techniques (both laboratory and in situ) have been developed for the determination of mechanical properties and the results obtained are often dependent on many factors.

Probably because of the relative importance of this subject, a large amount of literature is available from a great number of papers scattered over many engineering and scientific periodicals and texts, and the proceedings of several conferences and symposia on the subject of rock mechanics, rock pressure, mining, etc.

The purpose of this handbook is to present a detailed treatment of the subject from the widely scattered literature in a simple, clear and logical form.

Volume 1 contains five chapters and an appendix dealing with 1. Specimen preparation for laboratory tests; 2. Compressive strength of rock; 3. Tensile strength of rock; 4. Shear strength of rock; 5. Strength of rock under triaxial and biaxial stresses; and Stiff testing machines. Volume 2 would contain Static and Dynamic elastic constants of rock, Rheological properties of rock, Mechanical behaviour of jointed rock, Large scale testing of rocks, Classification of rock and Miscellaneous properties of rocks (for details see Contents in this book).

It is hoped that this handbook will serve students, research workers, designers, practising engineers and members of the teaching staff in equal measure in the fields of mining engineering, civil engineering, geological engineering and petroleum engineering.

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CONTENTS

Volume II

CHAPTER 1

Specimen Preparation for Laboratory Tests

1.1. Introduction

Proper sampling of the rock mass and preparation of specimens require considerable care and effort. The samples collected must truly represent the parent body. The preparation of specimens takes up much of the time allocated for tests. Often the results are widely scattered. This poses the problem as to how many specimens are required for the test. These various points are dealt with in this chapter.

1.2. Sampling

Sampling should be proper because the samples collected must truly represent the rock mass, the properties of which are to be determined. Rock masses, in general, are non-homogeneous and the properties of the samples taken from one portion of the rock mass may be altogether different from those taken at another location.

The averages calculated from test results would be affected if certain portions of the deposit are not sampled. This leads to the important conclusion that samples should be collected from all portions of the deposit.

To ensure proper sampling, lithological studies of the deposit are made and regions which differ markedly in their mineral composition, nature of the cementing material, texture and degree of alteration are marked on the cross-section of the deposit. Very often, changes in the colour of the mineral, reflectivity and bands help in delineating these regions on the spot by visual examination.