Technical Description of Rock Cores for Engineering Purposes

By

Don U. Deere*

Summary — Zusammenfassung — Résumé

Technical Description of Rock Cores. A careful study of rock cores from boreholes can yield valuable information concerning the nature of the in-situ rock mass. The significant geological features are those that influence the homogeneity of the rock mass and include the occurences of (1) surfaces of discontinuity and (2) zones with materials of different hardnesses. Detailed observations of these features should be made and recorded on the boring logs. Complete and accurate descriptions are necessary for rock mechanics studies and for allowing the contractor to appraise the nature of the in-situ rock and to plan and carry out his construction procedure.

Technische Beschreibung von Gesteinsbohrkernen. Eine sorgfältige Untersuchung von Felsbohrproben kann wertvolle Auskunft über die Beschaffenheit von in-situ-Felsmassen liefern. Die wesentlichen geologischen Eigenschaften sind diejenigen, welche die Homogenität der Felsmassen beeinflussen. Sie umfassen das Vorhandensein von (1) Diskontinuitätsflächen und (2) Zonen von Materialien verschiedener Härtegrade. Diese Eigenschaften sollten im Detail beobachtet und im Bohrbericht verzeichnet werden. Vollständige und genaue Beschreibungen sind zur Felsmechanikforschung notwendig und um dem Auftragnehmer die Abschätzung der Felsverfassung in-situ und die Planung und Ausführung des Bauwerkes zu ermöglichen.

La déscription technique des carottes de sondage. Une étude approfondie des carottes de sondage peut fournir des renseignements intérressants sur la nature de la masse rocheuse. Les importantes caractéristiques géologiques sont celles qui influencent l'homogénéité du rocher. Elles comprennent: (1) Les occurences de surfaces de discontinuité et (2) les zones de dureté variables. Les observations détaillées de ces caracteristiques devraient être faites et indiquées dans les rapports de sondage. Les descriptions complètes et précises sont nécessaires pour les études de mécanique des roches et pour permettre à l'entrepreneur de se faire une idée de la nature du rocher "in-situ", de préparer ses procédés de construction et de les exécuter.

Introduction

Rock cores obtained in exploratory drilling are, at best, small and inadequate samples of the in situ rock mass. It ist therefore with considerable apprehension that this paper is presented under the above title because it may appear to assign undue emphasis to the description of the cores. The author would be the first to agree that it is the character of the rock mass as a whole and not just the character of a piece of intact rock core that is of importance in rock engineering.

Valuable information concerning the rock mass, however, can be obtained by critical examination of the cores, providing that the examiner is aware of those geological features that are of significance. Unfortunately — at least within the experience of the author — the rock descriptions given on the boring logs in many engineering and geological reports, and especially in contract documents for con-

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struction, are often woefully inadequate in pointing out the true in situ nature of the rock mass. The information given, oftentimes, consists only of the geologic name of the rock, occasionally supplemented by some vague descriptive term of hardness or soundness.

Emphasis is given in this paper to those geological features which can be observed in rock cores, and which appear to the author to be significant in rock engineering. The significant features include those which have a direct bearing, almost overwhelmingly so, on the homogeneity of the rock mass with respect to (1) variations in hardness, and (2) physical discontinuities. The pertinent features when observed in the rock cores should be carefully described and recorded in the boring logs in such a manner so as to present a factual record containing a minimum of interpretation. From such boring logs interpretations may then be made concerning the character of the rock mass.

In most cases it will not be possible on the basis of the core descriptions alone to satisfactorily describe or classify the rock mass for engineering purposes, although on some small projects this may be possible. In general, additional information will be available from the field, gained during the drilling of the borehole, concerning the rate of drilling, water losses, ground water levels, drill cuttings, color of drilling fluid, and per cent of core recovery. This information should be presented on the field boring log and, along with the boring log of the technical rock core descriptions, should become part of the contract documents. In some cases it may possible to combine the information onto a single log; care should be taken, however, that pertinent information is not excluded for the sake of brevity.

For many projects, in addition to the information gained during the drilling of the borehole, subsequent borehole testing may be warranted in the form of borehole photography, water pressure or grout testing, and seismic or electrical logging. Data from various of the observations as well as from geophysical studies, geological mapping at the surface and in exploratory tunnels and shafts, and in situ physical testing are often necessary for clearly understanding and defining the rock mass characteristics. This paper does not treat of these aspects but limits itself to the one phase of the problem — technical description of the rock cores.

Discontinuities

Physical discontinuities are present in all rock masses in the form of planes or surfaces of separation. Geologically, these discontinuities are recognized as joints, faults, bedding planes, or rock cleavage planes. Terzaghi[1] has referred to such features as mechanical defects of rock. The permeability, shear strength, and deformability of a rock mass are all influenced by the number and kind of discontinuities existing in the mass. Engineering projects involving dam foundations, tunnels, underground chambers, and cut slopes may be adversely affected unless the discontinuities are evaluated and their influence taken into account during design and construction (see, for instance, Terzaghi[1,2], Stini[3], Müller[4,5,6], Pacher[7], Casagrande[8], and John[9]).

A critical examination of rock cores can yield valuable data concerning the occurence and nature of the mechanical defects in the rock mass from which the cores were obtained. The various types of observations that can be made are discussed in the following paragraphs.

Type of Discontinuity

Joints form the most common type of discontinuity and are found in all rock types. Sedimentary rocks contain, in addition, bedding planes which separate the rock into layers. Certain metamorphic rocks, particularly slates, show closely spaced rock cleavage planes. Fractures along which there is evidence of past movement in the form of striations or slickenslides may be recognized as fault planes or surfaces.

In describing the rock core, one of the above geologic names should be given to the discontinuity where possible. In those cases where it is impossible to assign with certainty the correct name, the all-inclusive term fracture* seems applicable.

Spacing of Discontinuities

Of more importance than the naming of the defects is the description of their spacing. In the case of joints, more than one set may be present; if the sets have different orientations it is often possible to distinguish between the sets, and the spacing of the joints in each set should be recorded. It is recognized, of course, that vertical joints would not show up in the core from a borehole drilled vertically. It is for this reason that some inclined boreholes are usually drilled during the course of the exploratory program.

Table 1. Descriptive Terminology for Joint Spacing

Descriptive Term	Spacing of Joints	
	(English)	(Metric)
very close	less than 2 in.	less than 5 cm
close	2 in. — 1 ft	5 cm — 30 cm
moderately close	1 ft — 3 ft	30 cm — 1 m
wide	3 ft — 10 ft	1 m — 3 m
very wide	greater than 10 ft	greater than 3 m

The overall aspect of the closeness of the jointing (and of the cleavage fracturing, schistosity, or foliation of metamorphic rocks) may be given in descriptive terms such as those in Table 2 of John[9]: *very close* (0.5—2 cm); *close* (2—20 cm); *wide* (20—200 cm); and *occasional* (200—1000 cm). The author proposes a somewhat different descriptive terminology for joint spacing which is given in Table 1 in English units and approximate metric equivalents.

Table 2. Descriptive Terminology for Thickness of Bedding Units

Descriptive Term	Thickness of Beds	
	(English)	(Metric)
very thin	less than 2 in.	less than 5 cm
thin	2 in. — 1 ft	5 cm — 30 cm
medium	1 ft — 3 ft	30 cm — 1 m
thick	3 ft — 10 ft	1 m — 3 m
very thick	greater than 10 ft	greater than 3 m

The bedding of sedimentary rocks may be described in terms of the spacing between the bedding planes that are visible planes of weakness. Bedding features in the form of color or textural banding may also be present. This banding should be described and recorded but should be distinguished from the prominent bedding planes. The thickness of the bedding may be given in descriptive terms. There is no general agreement among the geologists as to the terms to be used and the corresponding thicknesses. In Table 2 the author proposes descriptive terminology for use in enginering geology. For convenience the same numerical values have been used as in Table 1.

In describing the rock cores it is advised that the length of the pieces of the core obtained in each coring run be measured and recorded (e. g., 1 pice of 20 cm, 4 pieces of 10—15 cm, and 25 pieces of 2—10 cm, etc.). These lengths are a direct response to the spacing of the joints and fractures and the thickness of the bedding. Unfortunately, they are also influenced by the drilling method and technique. Still, in the author's opinion, they are of sufficient import to warrant describing.

* Obert, Duvall, and Merrill[10] restrict the usuage somewhat in their definition of a fracture: A break in the continuity of a body of rock not attended by a movement on one side or the other and not oriented in a regular system.

Attitude of Discontinuities

The spatial relationship of the planar or near-planar discontinuities are often of major importance on engineering projects involving cut slopes or underground openings in rock. A plane may be described by two components — the strike, or the compass direction of a horizontal line in the plane, and the dip, the angle of inclination of the plane from the horizontal measured normal to the strike direction. In drill cores it is usually possible to measure the dip angle of a discontinuity to within 1 or 2 degrees by means of a protractor. Such measurements should be made and recorded for all planar features visible in the core.

It is quite another matter to determine the strike. Most drill cores are unoriented so it is not possible to determine the strike direction from the cores of a single borehole. If inclined as well as vertical rock cores are available, it is theoretically possible to determine the strike and dip of the planar features. However, because of the complexity of the problem when several joint sets of different attitudes are present, and because of the possibility of changes in attitude from one borehole to another, it is preferable to determine the strike directions by some means other than using the drill cores (borehole photography, geologic mapping at the surface or in inspection shafts and tunnels).

Notwithstanding the fact that the strike directions cannot be determined from the cores, it is still worthwhile to measure the dip angles. The dip angles may be correlated with the spacing (e. g., 20-degree dip joints, 1 per 5—10 cm; 70-degree dip joints, 1 per 40—80 cm, etc.). Oftentimes, it is also possible to note that joints intersect each other and have the same strike. In these cases it is apparent that one is dealing with conjugate sets of joints and not with just one set, even though the dip angles may be similar.

Character of Surfaces and Filling Materials

The behavior in an engineering project of a rock mass traversed by discontinuities is probably more influenced by the character of the joint surfaces and the type of filling material along the discontinuities than by the mere presence of the discontinuities. Therefore in describing rock cores particular attention should be given to those observations regarding the tightness and irregularity of the surfaces as well as to the kind of filling material between or along adjacent surfaces.

Tightness. — The degree of tightness may be sufficiently represented by means of the terms *tight* or *open*. In the former case the rock core pieces on either side of the discontinuity may be fitted together by hand so that no visible void spaces occur and the joint surfaces are in intimate contact. The joint surface may be fresh, unaltered rock, may be altered by discoloration, or may be severely altered to material of soil-like consistency; as long as the above tests holds, the term, tight, may still be applied. Where the above test is not met, the term, open, is used and the ranges in width of the opening should be recorded. It is recognized that what appears to be an open or partially open joint or bedding plane in the rock core actually may have been tight in the field; this may be the case where softer filling materials or alteration products have not been recovered by the coring process. Where this condition is suspected, the interpretative remarks should be included on the boring log (but in parenthesis to distinguish from the factual data recorded).

Irregularity. — The irregularity of the joints or bedding surfaces is of importance in determining, at least in a qualitative fashion, the amount of interlocking in the rock mass and, consequently, the apparent angle of shearing resistance along the surfaces. From rock cores alone the gross features, of course, cannot be determined. Nevertheless, it usually is possible to assign to a surface of discontinuity in a rock core some degree of pläneness (*plane, curved,* or *irregular*), and some degree of smoothness (*slick, smooth,* and *rough*). Corresponding friction coefficients should only be applied following field testing, however.

Filling Material. — The kinds and amounts of filling material along the surfaces are more important in many cases than the planeness or smoothness of the joint surfaces themselves. The filling material may be of secondary origin brought in by ground water, hydrothermal solutions, or even squeezed in by glacial action (Deere and Shaffer[11]). Deere[12] gives an account of a slope failure in weathered granite which was localized by a relict joint along which a thin film of soft, weak manganese dioxide had been deposited by ground water. The filling material may consist of products of alteration of soil-like character derived from the rock by either surface weathering or by hydrothermal action.

Whatever has been the geologic process responsible for the filling, the duty of the examiner of the rock cores is to describe the end results (and not the process) in terms of the character and distribution of the materials present in the cores. Where core recovery is less than 100 per cent and is suspected that softer or weaker materials have been lost in the coring process, the condition may be so stated but in such a manner that the interpretative nature of the statement is clear. The filling or alteration products that are recovered in the core should be described as to thickness, type, and hardness. Soil-like materials may be described in the terms commonly used in soil mechanics, and rock material in a manner similar so that discussed in later sections of this paper. Alteration along joints often produces products which grade irregularly from material with soil-like characteristics near the joint to materials of rock characteristics at greater distances from the joint. These occurrences should be duly recorded.

Lithology and Hardness

Although experience has shown that rocks of a given lithologic type will exhibit a considerable range in hardness, and in other physical properties as well, it is still true that lithology and hardness are related. However, in most engineering projects it can probably be stated that neither of the two is of prime importance in determining the behavior of the rock mass — at least when compared with the influence of the inherent discontinuities of the mass. An exception to this statement is when the hardness of parts of the rock mass departs radically from the average value. Unfortunately, at least within the experience of writer, this is quite often the case and severe design and construction problems may arise as a result.

Illustrative conditions are those encountered with interbedded shales and limestones; with solution-widened and clay-filled joints, fault zones, and bedding planes in limestone terrain; with altered and weakened rocks along faults and shear zones in any type of rock; and with the varied products of weathering in the weathered rock zone where joint-block remnants (often speroidal) of fairly hard rock

are surrounded by soil-like material resulting from advanced weathering and decomposition of the rock adjacent to the joints. Many of these conditions will become apparent during the geological mapping; however, the extent of the conditions can often only be determined by means of boreholes. Consequently, the rock cores should be studied with utmost consideration being given to the detection of significant variations in hardness.

Lithology

Lithologic Description. — The lithologic description of a rock refers to the geologic name given to the rock type on the basis of its mineralogical composition, texture, and in some cases its origin. These factors form the basis for most rock classification schemes. Such names as granite, basalt, sandstone, marble, etc., evolve from such schemes and are generally used and understood by the engineer and geologist alike. Their continued used is certainly recommended along with descriptive terms which give additional information regarding grain size, color, minor constituents, etc.

Textural Description. — From the engineering point of view a textural classification system eventually may prove to be of greater value than the normal mineralogical one. By texture, the author refers to the manner in which the constituent mineral grains are arranged and bound together (the petrographer's *fabric*) rather than reference to grain-size. It is proposed that most rocks can be fitted into one of the following three groups: *interlocking* texture (includes such diverse mineralogical rock types as rock salt, limestone, dolomite, quartzite, basalt, granite, and other related igneous rocks); *cemented* texture (embraces the sandstones, conglomerates, and some limestones and tuffs); and *laminated-foliated* texture. The latter texture includes rocks containing minerals with a preferred orientation such as shales, slates, phyllites, schists, and gneisses; this category obviously would consist of rocks with considerable anisotropy, even in hand specimens. It is recognized that some rocks, granite-gneiss, for instance, would be borderline cases.

Preliminary work done by the author and his students at the University of Illinois indicates that inter-relationships among the various physical properties of intact rock specimens are much more consistent when grouped according to the above textural groups than when undifferentiated or grouped according to normal mineralogical classifications.

Hardness

As has been pointed out by many investigators (Obert, Windes, and Duvall[13]) hardness is an elusive property; a numerical value of hardness is as much a function of the kind of test used as it is a material property. It is not surprising that a number of different types of hardness tests have been developed, some of which measure the resistance to abrasion or scratching, and others the resistance to penetration. The properties of ductility, toughness, strength, and elasticity are involved to one degree or the other in all of the tests. For laboratory study of rocks, the scleroscope rebound hardness and some form of abrasion hardness have been investigated to the greatest extent.

In the routine logging of rock cores it has not been the custom in the past (to the author's knowledge) to check the hardness by anything other than simple means using a knife blade or a geology pick. By such means it is possible to designate the rock hardness by the relative terms of soft, medium, and hard — or other similar terms. Because these words may have different meanings in one organization than they do in another and because the tests are quite arbitrary, there may be considerable lattitude in interpretation. Fortunately, however, in rock engineering it is not the slight difference in degree of hardness from one rock to another that is important but rather the large variations. It therefore appears logical to continue the use of the relative terms of hardness providing that the basis for the terms is given on the boring logs.

It is possible that with further research some portable type of hardness tester (perhaps a small version of the concrete hammer) will be developed which can be used in conjunction with the textural classification system in order to arrive at a meaningful numerical hardness value. Such a hardness value might prove useful as an *index property* and be correlative to other more important physical properties (as the liquidity index of clay or the relative density of sand is used in soil mechanics).

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Some Norwegian Studies and Experiences with Swelling Materials in Rock Gouges

By

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With 8 Figures

Summary — Zusammenfassuug — Résumé

Studies Carried out at the Norwegian Geotechnical Institute on Expansive Materials in Rock Seams. In Norway construction works in rock have increased considerably in the last fifteen years. Consequently fissures and crushing zones filled with clay or clay-like materials are found. These materials may cause difficulties during and after construction, as they in some cases swell, in other cases being exposed to erosion.

It is demonstrated that the occurance of failures in tunnels in many cases can be correlated with the presence of montmorillonite. Some typical case records are given. It is further given a description of some laboratory experiments concerning swelling and swelling pressures.

Conclusionary the importance of recognizing dangerous gouge and taking precautionary measures on the site is stated.

Studien des Norwegischen Geotechnischen Institutes an quellfähigen Materialien in Felsklüften. In den letzten fünfzehn Jahren haben die Felsarbeiten in Norwegen beträchtlich zugenommen. Dabei werden mit Ton oder tonähnlichen Materialien gefüllte Klüfte gefunden. Diese Materialien können während des Bauens oder nachher Schwierigkeiten hervorrufen, da sie in einigen Fällen quellen, in anderen Fällen zu Erosion neigen können.

Diese Arbeit beschreibt, wie oft ein Zusammenhang zwischen Verbrüchen in Tunneln und Vorhandensein des quellenden Minerals Montmorillonit existiert. Einige Beispiele aus der Praxis werden besprochen, sowohl Verbrüche während des Baues als nach mehrjährigem Betrieb.

Weiter werden Laborversuche über Quellung und Quellungsdruck beschrieben und deren Ergebnisse in Diagrammen aufgezeichnet.

Es wird daraus gefolgert, daß es wichtig ist, solche schädliche Kluftfüllungen nachzuweisen und die notwendigen Maßnahmen an Ort und Stelle zu treffen.

Etudes faites par l'Institut Géotechnique Norvégien au sujet des materiaux expansifs dans les fissures des roches. À Norvège les travaux rocher ont profité considérablement pendent les dernières 15 années. Par conséquent on a trouvé des fissures remplies d'argile ou des materiaux ressemblants. Ces materiaux puvent provoquer des difficultés pendent et après la periode de construction, car quelquesfois ils se gonflent, et d'autres fois ils inclinent à l'érosion.

Dans cet article il est démonstré que bien souvant il existe une connexion entre des glissements dans les tunneaux et la présence du mineral expansif montmorillonite. Il est montré quelques cas concrets avec descriptions de glissements dans des tunneaux soit

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Note

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The journal "Geologie und Bauwesen" was terminated with Vol. 28 in order to be continued as "Rock Mechanics and Engineering Geology." The numeration of the new journal starts with Vol. I, No. 1. The issues 2—5 of Vol. 28 of "Geologie und Bauwesen" are already published under the new title of "Rock Mechanics and Engineering Geology," Vol. I, Nos. 1—4.

The subscribers to "Geologie und Bauwesen" will receive "Rock Mechanics and Engineering Geology" instead.

„Felsmechanik und Ingenieurgeologie" Vol. I, No. 1
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