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A Study in Various Techniques, Advances and Issues Used for Rock Masses

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Abstract: *Purpose of this article is to review important parts of rock investigation. However site investigation cost is so less than construction cost but it's role is vital. In this article firstly, we explain Rock mechanics in field such as Geological observations, drilling of the holes, sampling and in situ testing and secondly we're going explain about strength index of rock mass, rock mechanics in laboratory. This article consist of important concept of famous rock mechanics books and article and we hope that be effective and practical for rock mechanics engineers.*

KEYWORDS:*Rock Investigation; Geological Observations; Sampling and in Situ; Strength Index of Rock Mass*

I. Introduction

The proper design of civil engineering structures requires adequate knowledge of subsurface conditions at the sites of the structures and, when structures are to consist of earth or rockfill materials, of subsurface conditions at possible sources of construction materials. Explorations are normally accomplished in a phased sequence as follows (Lowe J,1991):

a) Reconnaissance investigations
b) Explorations for preliminary design
c) Explorations for detailed design
d) Explorations during construction

II. Rock Mechanics in Field

The successful solution of a rock mechanics problem usually depends upon contributions made by the research worker and the practical engineer. In order that the research work should obtain results of practical value, and, having obtained such results, be able to communicate them to the ingenuity and intelligible terms, it is essential that he should remain in constant contact with the field problem. On the other hand, effective cooperation can only be achieved if the practical engineering is familiar with the principal features, the potential and the limitations of the techniques which are available to the rock mechanics research worker. There are Classification of rock masses for practical rock engineering (Hoek E, 1980):

Intact rock: contains neither joints nor hair cracks.
Stratified rock: consists of individual strata with little or no resistance against separation.
Moderately jointed rock: contains joints and hair cracks, but the blocks between joints are locally grown together.
Blocky and seamy rock: consists of chemically intact or almost intact rock fragments which are entirely separated from each other and imperfectly interlocked.
Squeezing rock: slowly advances into the tunnel without perceptible volume increase. minerals or of clay minerals with a low swelling capacity.
Swelling rock: into the tunnel chiefly on account of expansion clay minerals such as montmorillonite.
Crushed rock: chemically intact rock has the character of a crusher run. If most or all of the fragments are as small as fine sand grains and no recementation has taken place.

A. Geological Observation

In the problem involving the behaviour of a large rock mass, the strength and deformation characteristics of the rock material may be of secondary importance compared to the presence of geological discontinuities such as faults or dykes. Hence, a rock slope, in which the material may have excellent mechanical properties, maybe unstable due to the presence of a single or critically oriented fault. Consequently come any rock mechanics investigation in the field should include a geological examination of the site. The type of observations required charges depend upon the nature of the problem being studied in the include the classification of rock types, measurements of frequency in orientation of faults, fissures, cleats or bedding planes and the determination of the extent of weathering.

In order that these geological and observation should be of practical value to the engineer, they should be quantitative rather than qualitative and, where possible, a sufficiently large number measurement should be made to permit statistical evaluation of the results. In addition to the identification of rock types, surface outcrops should be used for the measurement of the inclination (dip) and orientation (dip direction) of structural features such as bedding planes, cleavage and joint planes A great deal of time and energy can be saved if these measurements are carried out with an instrument which is specifically designed for this purpose. Several such instruments are available but one of the most convenient is the compass illustrated in the photograph reproduced opposite. This compass was designed by Professor Clar, West Germany. The folding lid of the compass is placed against the plane to be measured and the target bubble is used to level the body of the instrument. The dip of the plane is indicated on the circular scale at the end of the lid hinge. With the instrument body level, the compass needle clamp is depressed (by the user's thumb in the photograph opposite) and the well-damped needle quickly establishes its magnetic north-south orientation. It is locked in this position by releasing the clamp and a friction clutch in the lid hinge holds the lid in position. The instrument can now be removed from the rock face and the dip and dip direction read off the two scales. This ability to retain the readings after the instrument has been removed from the rock face is important when the compass is being used in difficult positions. Field measurements are usually recorded in a field note book but a portable tape recorder can sometimes provide a very effective means of making field notes.

Figure 1. The Clar geological compass which to measure dip and dip direction of geological planes (John V.S 2006)

III. Determination of the in Situ Properties of Rock

A knowledge of the deformation and strength properties of rock is fundamental to any design of rock structures. Small scale test in the laboratory do not always give results which are representative of the properties of the rock mass. Consequently, the determination of the properties of the rock material on a rock mass in situ is an important aspect of field rock mechanics the importance of the geological survey which should be carried out before a tunnel design is completed and, particularly the importance of obtaining information on the defects in the rock mass.

"From an engineering point of view, a knowledge of the type and intensity of the rock defects may be much more important than the type of rock which will be encountered. Therefore during the survey rock defects should receive special consideration. The geological report should contain a detailed description of the observed defects in geological terms. It should also contain a classification of the defective rock in the tunnel man's terms, such as blocky and seamy, squeezing or swelling rock."(Assakkaf I, 2003)

IV. Core Drilling Tools

an excellent assortment of diamond tools for the exploration and construction industries, including surface set and impregnated bits, reaming shells and casing shoes suitable for most drilling conditions.

Bit: This is the portion of a drill which contacts the rock and disintegrates it. The bit is the essential part of a drill, as it is the part which must engage and disintegrate the rock. In table 1 types of Bits and their's efficiency are explained.

A. Drilling Constrants

Whatever drilling method is used, there are several considerations which must be taken: The amount of energy required to drill is governed by the rock type. Unconsolidated formations such as sand, silt or clay are weak and much easier to drill than consolidated rocks such as anite, basalt or slate which are hard, strong and dense. For hard rocks, cutting tools will need cooling and lubrication. Rock cuttings and debris must be removed. Unconsolidated formations will require support to prevent the hole from collapse.

B. Drilling Methods

The following low-cost, appropriate drilling methods are described and illustrated on the following:

- Percussion drilling
- Hand-auger drilling
- Jetting
- Sludging
- Rotary-percussion drilling
- Rotary drilling with flush

In table 2 types of Drilling method selection and their's efficiency in different rock are explained.

Table 1. Types of Bits in Rock Investigation

Table 1. Drilling-method selection		Percussion drilling	Hand-auger drilling	Jetting	Sludging	Rotary percussion drilling	Rotary drilling with flush
Gravel	Unconsolidated formations	✓?	✖	✖	✖	✓?	✖
Sand		✓?	✓	✓	✓	✓?	✓
Silt		✓?	✓	✓	✓	✓?	✓
Clay		✓ slow	✓	?	✓	✓ slow	✓
Sand with pebbles or boulders		✓?	✖	✖	✖	✓?	✖
Shale	Low to medium-strength formations	✓	✖	✖	✖	✓ slow	✓
Sandstone		✓	✖	✖	✖	✓	✓
Limestone	Medium to high-strength formations	✓ slow	✖	✖	✖	✓	✓ slow
Igneous (granite, basalt)		✓ slow	✖	✖	✖	✓	✖
Metamorphic (slate, gneiss)		✓ v slow	✖	✖	✖	✓	✖
Rock with fractures or voids		✓	✖	✖	✖	✓	✓!
Above water-table		✓	✓	?	✖	✓	✓
Below water-table		✓	?	✓	✓	✓	✓

✓= Suitable drilling method ✓? = Danger of hole collapsing ✓! = Flush must be maintained to continue drilling ? = Possible problems ✖ = Inappropriate method of drilling

C. Core Barrels

Core sample from the rock mass has to be in a state as close to its original condition. Core barrel retains rock core samples from drilling operations. There are three groups of barrels:

Single Tube

Single tube core barrel is most rugged, least expensive and Consists of head section, core recovery tube, reamer shell, cutting bit. Often used as starter when beginning core operations

Double tube

Double tube core barrel is the standard. Outer barrel rotates with cutting bit and Inner barrel is either fixed or swivel type(with bearing) that retains core sample. Core diameters generally range from 21 to 85 mm.

Table 2. Types of Drilling Methods (Nilsen et al 1999)

BIT	Condition of ground
TC (Tungsten carbide)	very soft ground conditions
PCD/TSD (Polycrystalline diamond/thermally Stable polycrystalline diamond)	soft to medium hard; course grained; abrasive; or fractured ground conditions
Surface set	soft to medium hard; course to fine grained; abrasive tonon abrasive; or fractured to competent ground conditions
Impregnated	soft to very hard; course to fine grained; abrasive tono abrasive; or fractured to competent ground conditions

Triple

Good for obtaining core sample in fractured rock and highly weathered rocks. Outer core barrel for initial cut and second barrel to cut and second barrel to cut finer size. Third barrel is to retain cored samples. this core barrel Reduces frictional heat that may damage sample. Table 3 shows Standard diamond drill core sizes .

Table 3. Standard Diamond Drill Core sizes

Designation	AQ	BQ	NQ	NQ2	NX	HQ	PQ
Diameter (mm)	27	36.5	47.6	50.5	54.7	63.5	85

V. Quantitative Indexes of Rock Mass

In addition of strength index of rock mass, there are quantitative indexes of rock mass quality that are very important to predict behavior of rock mass. in this part , we explain 3 quantitative indexes that are useful: RQD, Total Core Recovery and Discontinuity Frequency .(Goodman R, 1989)

A. Deere's Rock Quality Designation (RQD)

In 1964 Deere proposed a quantitative index of rock mass quality based upon core recovery by diamond drilling. RQD described by:

$$\boldsymbol{RQD}(\%) = \mathbf{100} * \frac{\boldsymbol{length of core in pieces > 100mm}}{\boldsymbol{Length of borehole}} \quad (1)$$

The RQD is defined as the percentage of core recovered in intact pieces of 100 mm or more in length in the total length of a borehole. It is normally accepted that the RQD should be determined on a core of at least 50 mm diameter which should have been drilled with double barrel diamond drilling equipment. An RQD value would usually be established for each core run of say 2 meters. the RQD does not take direct account of other factors such as joint orientation. Deere proposed in table 4, the following relationship between the numerical value of RQD and the engineering quality of the rock.

B. Total Core Recovery (CR)

Table 4. Relationship Between the Numerical Value of RQD and Engineering Quality of Rock

RQD	Rock Quality
<25%	Very poor
25–50%	Poor
50–75%	Fair
75–90%	Good
90–100%	Very good

This index described by:

$$CR = \frac{summed \ \ length \ \ of \ \ core \ \ re\,\text{cov}ered}{length \ \ \ drilled} \quad (2)$$

This index depends upon:
1.Quaqlity of the rock mass
2.Stability of lack of vibration in the drig rig
3.Choice of core barrel/skill of the operator.

C. Discontinuity Frequency Total (λ)

Discontinuities and their spacings have important role in rock mass engineering. Discontinuity Frequency is the number of natural discontinuities per meter of core. There are relationships between RQD and λ.

VI. Specimen Preparation

Since most properties testing is carried out on core specimens, the first requirement of a rock mechanics laboratory, in which the mechanical properties of rock are to be studied, is a suitable diamond drilling machine. The most important requirement for such a machine is rigidity and smoothness of operation. Any vibration generated in the machine and transmitted to the diamond core-barrel results in poor quality core which necessitates circumferential grinding Preparation and the ends of the specimen is carried out by cutting the specimen to length by means of a diamond saw and then grinding the ends flat and parallel. This end grinding can be carried out in a number of ways but one of the most convenient methods is illustrated in Figure 1. In this machine, the core is held in an accurately aligned Vee block which is moved slowly across the face of a diamond impregnated cup wheel. (Suping P, 2007)

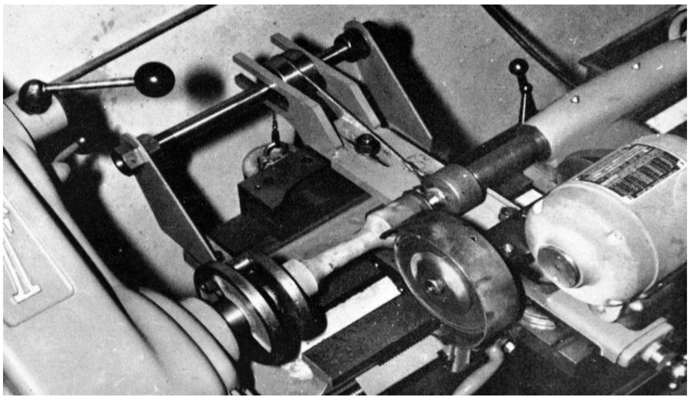

Figure 2. Machine of Rock Specimen Preparation(Hoek. E et al ,1980)

VII. Laboratory Tests in Rock Mass

The mechanical properties of a piece of rock depend on its mineral composition, the arrangement of the mineral grains, and an y cracks that may have been introduced into it during its long geological history by diagenesis or tectonic forces. Consequently, the mechanical properties of rock vary not only between different rock types but also between different specimens of the nominally same rock. Hence, unlike "reproducible" engineering materials such as steels, for which property values can be measured on standard specimens and listed in handbooks, only very rough approximate values of the mechanical properties of a given rock can be estimated from tabulated hand book data. For this reason, laboratory testing necessarily plays a large role in rock mechanics. In this part we describe the basic types of laboratory measurements that are routinely conducted to measure the mechanical properties of rocks. Each particular experimental apparatus and/or procedure subjects the rock specimen to a certain state of stress.(Pells PJN,1998)

A. Point Load Teat (Astm 5731)

In addition to information on the discontinuities in the rock mass, it is also important to obtain estimates of the strength of the intact rock and on the weathering characteristics of this rock. a reasonable estimate of the uniaxial compressive strength of the rock can be obtained by means of the point load test. A piece of core is loaded across its diameter between two hardened steel points. The Point Load Index is given by(John VS, 2006):

$$I_s = \frac{P}{D^2} \quad (3)$$

where P is the load required to break the specimen and D is the diameter of the core. Note that the length of the core piece should be at least 1.5 times the diameter of the core.
The diameter D of the core is expressed in millimeters, an approximate relationship between the point load index Is and the uniaxial compressive strength σ_c is given by

$$\sigma_c = (14 + 0.175D)I_s \quad (4)$$

Because the load required to break a rock core under point load conditions is only about one tenth of that required for failure of a specimen subjected to uniaxial compressive stress, the point load equipment is light and portable and is ideal for use in the field during logging of the core.

B. Uniaxial Compressive Strength Test (ASTM 4543)

The uniaxial compression test is most frequently used strength test for rocks. A right circular cylinder or prism of rock is compressed between two parallel rigid plates, is the oldest and simplest mechanical rock test and continues to be widely used. This test is used to determine the Young's modulus, E, and also the unconfined compressive strength ($q_u = \sigma_u = \sigma_c$). In this test there are Planar ends on NQ size core and Length to width ratio has to be 2 < H/d < 2.5. and uniaxial compressive strength is given by:

$$\sigma_u = \frac{MAX\ \ Force}{\frac{\pi d^2}{4}} \quad (5)$$

In Table 5, Deere and Miller's Classification for intact rock strength is showed.

Table 5. Classification for Intact Rock

Description	Uniaxial Compressive Strength			Examples of rock types
	$\frac{ibf}{in^2}$	$\frac{kgf}{cm^2}$	MPA	
Very low strength	150–3500	10–250	1–25	Chalk, rocksalt
Low strength	3500–7500	250–500	25–50	Coal, siltstone, schist
Medium strength	7500–15000	500–1000	50–100	Sandstone, slate, shale
High strength	15000–30000	1000–2000	100–200	Marble, granite, gneiss
Very high strength	>30000	>2000	>200	Quartzite, dolerite, gabbro, basalt

C. Uniaxial Tensile Test (Astm 2936)

In this test $\sigma_1 = \sigma_2 = 0$ and $\sigma_3 = -\sigma_t$ where σ_t is the uniaxial tensile strength of the specimen. The use of a ball joint on the end of a non-twist cable ensures that the load will be applied along the axis of the specimen with an absence of torsion. Provided that the components are machined with a reasonable degree of precision and that care is taken in bonding the rock specimen into the collars, there will be a minimum of bending in the specimen.(ClaytonCRI, 1995)

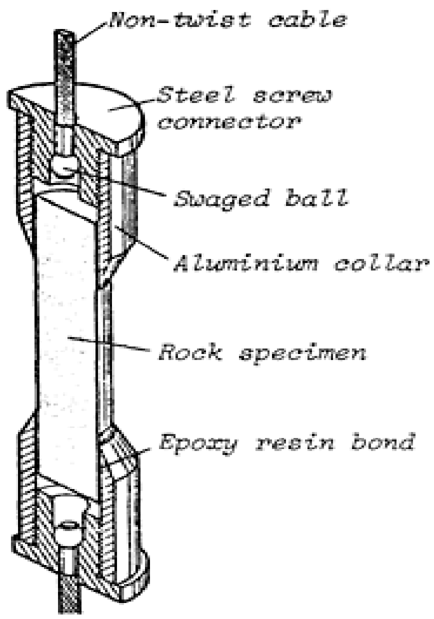

Figure 3. Sample of Uniaxial Tensile Test(Hoek. E et al ,1980)

D. Triaxial Compression-Tensile Tests (ASTM D 2936)

This test is In order to obtain rock fracture data under all the stress conditions of interest. The rubber sleeved "dog-bone" specimen is subjected to hydraulic pressure p which generates radial stresses $\sigma_1 = \sigma_2 = p$ and an axial tensile stress σ_3 which is given by:

$$\sigma_3 = -\frac{p(d_2^2 - d_1^2)}{d_1^2} \quad (6)$$

Figure 3 shows a sample of Triaxial compression-tensile and direction of stress σ_1, σ_3.

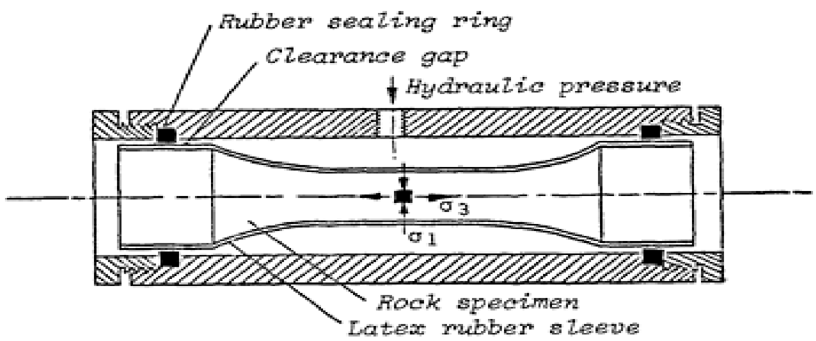

Figure 4. Sample of Triaxial Compression-Tensile Tests(Hoek. E et al ,1980)

E. Brazilian Split-Tension Test (ASTM D 3967)

A discussion on techniques for the determination of rock properties would not be complete without some mention of indirect test methods. These methods aim of providing a simple and convenient test which can be used, in the field if necessary, to give an estimate of some rock property which may be difficult to obtain accurately without elaborate laboratory facilities. One of the best known of such methods is the Brazilian test in which tensile failure is induced in a disc by compressing it across a diameter19, 20. Providing that a certain amount of care is taken in interpreting the results of this test, reasonably accurate estimates of the uniaxial tensile strength of a rock can be obtained. This test is particularly useful for comparative studies on one rock type, e.g. a study of the influence of moisture content upon the uniaxial tensile strength. In such a study, a large number of disc specimens can easily be prepared and tested while profiled tensile specimens of the type discussed in the previous section could only be tested in sport quantities.

A simple test which can be used to determine whether anisotropy exists in a rock involves pressing the ball into the centre of the flat surface of a disc specimen. The disc will split across the diameter and anisotropy can be detected if a preferred failure direction is observed in a number of such tests. The difficulty associated with the interpretation of any indirect test on rock is the fact that the actual stress distribution in the specimen may not be accurately known. In the case of the Brazilian test, the stress distribution and hence the point of fracture initiation can be altered by changing the area over which the load is applied to the edges of the disc.

specimen. If such changes can be induced intentionally under controlled conditions in the laboratory, it is more than likely that they would occur accidentally under field conditions and thereby invalidate the test.(MathierJF,2005)

F. Slake Durability Test (ASTM D 4644)

This test is to Evaluate shalesand weak rocks that may degrade in service environment. Rock fragments of known weight placed in rotating drum apparatus Materials are circulated through wet and dry cycles.

Reweigh rock fragments to determine the Slake Durability Index (SDI). Longevity of the materials for use in construction (fill, backfill, rockfill) Will the rock deterioriate when exposed to the elements, time, freeze-thaw, wet-dry cycles, temperatures, chemicals.

G. Schmidt Hammer

The Schmidt hammer is showed in figure 4, is point perpendicularly and touch the surface of rock. The hammer is released and reading on the hammer is taken If the hammer is point to horizontal and upward, correction is needed to add to the number from the hammer. The correction number is showed in Table 6.

Table 6. Correction Number for Schmidt Hammers

Ebound Number	Vertically Downward	45 Downward	Horizontal	45 Upward	Vertically upward
10	0	-0.8	-	-	-3.2
20	0	-0.9	-8.8	-6.9	-3.4
30	0	-0.8	-7.8	-6.2	-3.1
40	0	-0.7	-6.6	-5.3	-2.7
50	0	-0.6	-5.3	-4.3	-2.2
60	0	-0.4	-4	-3.3	-1.7

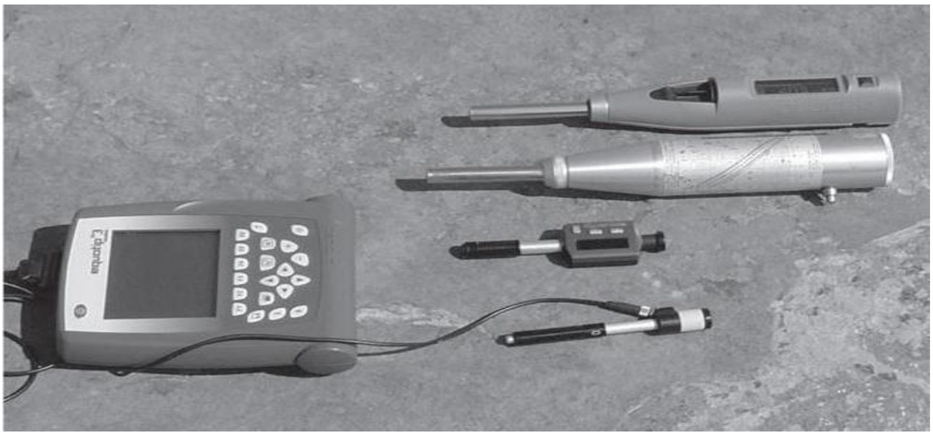

Figure 5. Sample of Schmidt Hammer (Mathier J.F, 2005)

VIII. Conclusions

in this paper we introduced rock mass investigation. Situ and laboratory tests in rock mass are two important parts of rock mass investigation. core drilling tools and methods are expressed, are useful for determination of the In situ properties and quantitative indexes of rock mass.

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