MINING ENGINEERING

B.TECH

LAB MANUAL

ROCK MECHANICS

LIST OF EXPERIMENTS

EXPERIMENT: 01

AIM: Preparation of rock sample for testing in laboratory.

Materials & Equipment:

1. Diamond saw
2. Raw rock core
3. Grinder
4. Caliper, ruler
5. Craftsman lathe
6. Magic pen

THEORY:

In Mining operations we mainly deal with hard rocks with different physico-Mechanical properties. Rock is a complex engineering material that can vary greatly as a function of lithology, stress history, weathering, moisture content and chemistry, and other natural geologic processes. All reasonable efforts shall be made to prepare a specimen in accordance with this practice and for the intended test procedure. These practices specify procedures for laboratory rock core test specimen preparation of rock core from drill core and block samples for strength and deformation testing.

The dimensional, shape, and surface tolerances of rock core specimens are important for determining rock properties of intact specimens. All these dimensions must be according to the standards recommended by ISRM. The moisture condition and the original physical condition of the specimen at the time of the sample preparation can have a significant effect upon the strength and deformation characteristics of the rock. Good practice generally dictates that laboratory tests be made upon specimens representative of field conditions. Thus, it follows that the field moisture condition and physical conditions of the specimen should be preserved until the time of the test.

PROCEDURE:

1. Each student will select one kind of rock and cut 5 samples. The ratio of length/ diameter should be at least 2.0
2. Grind both ends until they become parallel to within the 0.003 inches. Check it using the craftsman lathe.
3. Grind both ends of the specimen so that it will be near vertical to the axis of the specimen within 0.001 radian.
4. Mark the roll number and specimen number using magic pen.

A Typical cylindrical Rock Sample:

EXPERIMENT: 02

AIM: Methods for determination of Compressive strength, Tensile strength, Shear strength and triaxial strength of rock.

Materials & Equipment:

1. Universal Testing Machine.
2. Shear box.
3. Rock Samples.

THEORY:

Rock strength is measured by laboratory testing. Strengths are very different depending on the stress field applied to the rock. All rocks and soils are very much stronger in compression than in tension.

The two common laboratory tests to determine the compressive strength of rock are:

- Uniaxial Compression Test - A cylindrical rock core is loaded axially until it fails.
- Triaxial Compression Test - A cylindrical rock core is placed in a cell, subjected to all around (confining) pressure by hydraulic oil acting through a thin impermeable membrane, and loaded axially to failure.

There are a variety of tests to determine the tensile strength of rock:

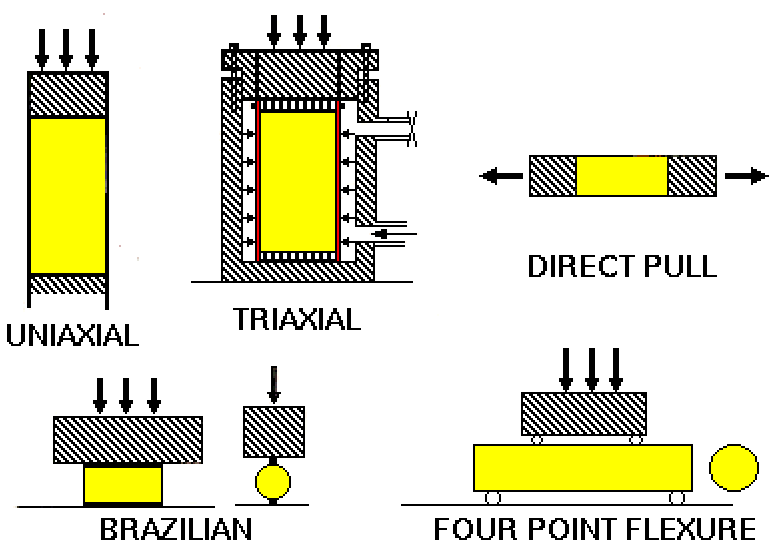
- Direct Pull Test - A cylindrical rock core sample is anchored at both ends and stretched.
- Brazilian Test - A relatively thin disk is load across the diameter until it splits.
- Beam Flexure Test - A thin slab of rock is loaded vertically when supported at three or four points along its length.

The portable field shear box is used to directly measure the shear resistance of joint surfaces. The shear-box provides information on the shear strength and shear stiffness of jointed rock masses.

PROCEDURE:

1. For compression testing core sample (a cylinder) is subjected to a loading arrangement in Universal Testing Machine. At failure point the load is noted down and strength is calculated out.
2. For tensile test, Brazilian arrangement is preferred. Again the core sample (a disc) is subjected to UTM arrangement and strength is calculated out at the failure point reading.
3. For shear test; a Shear Box is used. . A block with a natural fracture is cemented into a split-box mould with the fracture surfaces in contact. When the cement or plaster is cured, normal and shear loads are applied using hydraulic jacks. The displacement is measured with a dial-gauge.

- **Typical sections from different Testing Machines;**



EXPERIMENT: 03

AIM: Study and determination of Porosity of rock.

Materials & Equipment:

1. A rock specimen.
2. Weighing scale.

THEORY:

Porosity is the percentage of void space in a **rock**. It is defined as the ratio of the volume of the voids or pore space divided by the total volume. For most rocks, porosity varies from less than 1% to 40%.

$$n = \frac{V_{\text{pore space}}}{V_{\text{total}}}$$

The porosity of a rock depends on many factors, including the rock type and how the grains of a rock are arranged. For example, crystalline rock such as granite has a very low porosity (<1%) since the only pore spaces are the tiny, long, thin cracks between the individual mineral grains. Sandstones, typically, have much higher porosities (10–35%) because the individual sand or mineral grains don't fit together closely, allowing larger pore spaces. The porosities of the rocks measured vary from 2% to more than 30%. Much of this variation is due to lithology of rock.

Bulk-volume measurement technique**:**

This technique utilizes the Archimedes' principle of mass displacement. The laboratory measurements, using this technique, are very accurate.

PROCEDURE:

1. The core sample is first saturated with a wetting fluid and then the core weight is determined (the core may be coated with paraffin).

2. The sample is then submerged in the same fluid and its submerged weight is measured.
3. The bulk volume is the difference between the two weights divided by the density of the fluid.
4. The bulk volume can be determined also by the volume of the displaced fluid.

   Fluids that are normally used are:
   - water which can easily be evaporated afterwards,
   - Mercury which normally does not enter the pore space in a core sample due to its non-wetting capability and its large interfacial energy against air.

Calculation part:

Void space = Bulk volume- Core volume

Porosity of rock sample = Void space ÷ Bulk volume.

EXPERIMENT: 04

AIM: Study and determination of Abrasivity of rock**.**

Materials & Equipment:

1. Rock sample.
2. CERCHAR Apparatus.
3. Sets of stylus.

THEORY:

Rock Abrasivity plays an important role in characterizing a rock material for excavation purposes. Abrasion can be defined as the wearing or tearing away of particles from the surface, i.e. it is a process causing removal or displacement of material at a solid surface, which will lead to wear, especially on tools that are used in mining, drilling, and tunneling applications. The CERCHAR Abrasivity Test is a method to determine an index called CERCHAR Abrasivity Index (CAI) for the rock's Abrasivity.

The testing principle is based on a steel pin with defined geometry and hardness that scratches the surface of a rough rock sample over a distance of 10 mm under a static load of 70 N. The Cerchar-Abrasivity-Index (CAI) is then calculated from the measured diameter of the resulting wear flat on the pin:

$$\mathbf{CAI = 10 \times D \div \mathit{C}}$$

Where; CAI = Cerchar-Abrasivity-Index

D = diameter of sample wear flat (mm)

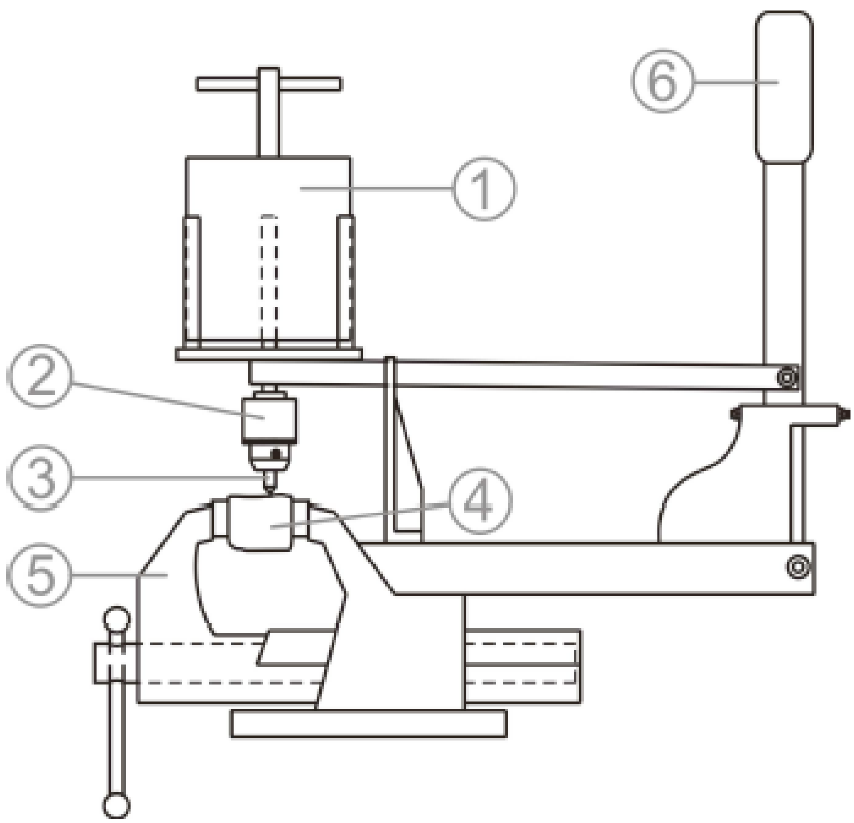
C=unit correction factor (c=1 mm)

PROCEDURE:

1. Prior to a test, the stylus should be inspected under a microscope. The apparatus should be checked for proper functionality.
2. The sample should be clamped firmly in the vice while observing the desired scratching direction.

3. The stylus should be carefully lowered onto the rock surface to avoid any damage to the tip of the stylus.
4. The stylus should be positioned so it is vertical and perpendicular to the rock surface.
5. During the test there should be constant contact between the stylus and the rock surface. Otherwise, there is likely to be an erroneous result.
6. A minimum of five test replications must be made on the rock surface, each time by a new or re-sharpened stylus.

A typical CERCHAR Apparatus.



EXPERIMENT: 05

AIM: Study of strength indices of rock.

Materials & Equipment:

1. Rock samples.
2. Volumometer
3. PSI apparatus.
4. Point load strength test machine
5. A 100 mm scale attached with the loading frame
6. Pressure gauge (Capacity 25 kN or 50 kN)

THEORY:

A wide array of index tests has been evolved over the past three decades to evaluate the strength and deformation behavior of coal and rocks, both in intact specimens and in the rock mass. Such empirical strength measurement techniques offer much potential for wider use in routine measurements as they offer significant benefits in terms of cost-effectiveness, skill and manpower requirements. Amongst the various empirical indices in use, the Protodyakonov Index and the Point Load Index (Broach and Franklin, 1972) are marked by their simplicity of determination vis-a-vis other strength tests proposed to date. To be of use and realistic in application, the data obtained from these tests must ultimately be related to some fundamental strength parameter of rock.

PROCEDURE:

Protodyakonov strength index test:

1. For Protodyakonov strength index test which is generally carried out in case of coal, samples each weighing 50-70 gm, in the form of irregular coal pieces of 10-14 mm in size were crushed individually in a hollow cylinder of 76 mm internal diameter by a free-falling weight of 2.4 Kg five times from a height of 0.6 m. The fines so produced, of size below 500 microns, were combined and the height of the fines column measured in a volumometer of 23 mm diameter. The index (I_f) was calculated by the following formula:

$$PSI = 20\times N \times M \div H$$

Where: PSI- Protodyakonov strength index
N- No. of samples
M- No. of impacts
H- Height of fine material in volumometer

five determinations are carried out for each coal sample and the mean value reported as the Protodyakonov Index.

Point load test

1. The diametral test is conducted on rock core sample. Minimum of 10 test specimens are required to find out the average value of point load strength index.
2. This test can be conducted on the core specimens which are completely dry or after soaking it for 7 days.
3. Measure the total length (**l**) and diameter (**d**) of the core specimen. Specimen of **l/d=1.5**, are considered to be suitable for this test.
4. Place the specimen horizontally between two platens in such a way that the distance between the contact point and the nearest free end (**L**) is at least 0.75times the diameter of the core (**d**).
5. Measure the distance between two platen contact points (**D**) with the help of the scale attached with the loading frame. (Note-In case of diametral test, the diameter of the core (**d**) and the distance between two platens (**D**) will be same)
6. Apply load to the core specimen such that failure occur within 10-60 sec. record the failure load ‘**P**‘.

Point load strength index (I_s) = $(P*1000)/D^2$ Mpa

Where **P** is breaking load in kN

D is the distance between platens in mm

EXPERIMENT: 06

AIM: Study of Modulus of elasticity and Poisson's ratio.

Materials & Equipment:

1. Testing machine.
2. Dial gauge.

THEORY:

The modulus of elasticity (also known as the elastic modulus, the tensile modulus, or Young's modulus) is a number that measures an object or substance's resistance to being deformed elastically (i.e., non-permanently) when a force is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region.

Compressive stress = $\frac{P}{A}$

Axial strain = $\frac{dL}{L}$

Modulus of elasticity = $\frac{\text{Compressive stress}}{\text{Axial strain}}$

Poisson's ratio is the ratio of transverse contraction strain to longitudinal extension strain in the direction of stretching force.

Diametral strain = $\frac{dD}{D}$

Poisson' ratio = $-\frac{\text{Diametral strain}}{\text{Axial strain}}$

PROCEDURE:

1. The diameter of the specimen shall be recorded to the nearest 0.1mm by taking two perpendicular measurements at three different heights of the cylinder. The height of the cylinder shall be determined to the nearest 0.1mm.
2. The load on the specimen shall be applied continuously at a constant stress rate between 0.5 and 1Mpa/sec.
3. The axial load and the axial and diametrical deformation shall be recorded at evenly spaced load intervals during the test. At least ten readings should be taken over the full load range until failure occurs. For this purpose the loading must be interrupted to take the measurements, these interruptions of the test shall be as short as possible.

EXPERIMENT: 07

AIM: Study of Slake durability of rock.

Materials & Equipment:

1. Standard slake durability testing equipment as specified by ISRM.
2. Oven capable to maintain a temperature of 105 C (+/-5C) for a period of at least 12 hours.
3. Balance capable to determine the mass of the drum plus sample to an accuracy of 0.5g.

THEORY:

This test is intended to assess the resistance offered by a rock sample to weakening and disintegration when subjected to cycles of drying and wetting. The ISRM standard is based on two cycles of drying and wetting. Four or five cycles of drying and wetting are recommended when evaluating rocks of higher durability. The slake durability index is expressed as the percentage ratio of the final dry sample mass to the initial dry sample mass.

PROCEDURE:

1. A representative sample is selected, consisting of ten lumps of rock, each with a mass of 40 to 60grams, to give a total sample of 450 to 550 grams. The maximum grain size of the rock should not be larger than 3 mm. Lumps should be as good as possible rounded in form and corners should be rounded during preparation of the sample.
2. The sample is placed in a clean drum and is dried to constant mass at a temperature of 105°C, usually requiring 2 to 6 hours in the oven. The mass (A) of the drum plus the sample is recorded with an accuracy of 0.1 g. The sample is then tested after cooling.
3. The lid of the drum is replaced; the drum is mounted in the trough and coupled to the motor.

4. The trough is filled with slaking fluid (usually tap water at 20°C) to a level 20 mm below the drum axis, and the drum rotated for 200 revolutions during a period of 10 minutes +/- 0.5 minutes.
5. The drum is removed from the trough, the lid removed from the drum, and the drum plus retained portion of the sample is dried to constant mass at 105°C. The mass B_1 of the drum plus retained portion of the sample is recorded after cooling with an accuracy of 0.1 g.
6. Steps (c) to (e) are repeated and the mass B of the drum plus retained portion of the sample after another 200 revolutions is recorded.
7. The drum is brushed clean and its mass D is recorded with an accuracy of 0.1 g.

Calculation:

$$\text{Slake Durability Index} = \frac{B-D}{A-D}$$

EXPERIMENT: 08

AIM: Study of Shear strength, consistency, consolidation and compaction of soil.

Materials & Equipment:

1. Soil sample.

THEORY:

Shear strength is a term used in soil mechanics to describe the magnitude of the shear stress that a soil can sustain. The shear resistance of soil is a result of friction and interlocking of particles, and possibly cementation or bonding at particle contacts. The shear strength of soil depends on the effective stress, the drainage conditions, density of the particles, the rate of strain, and the direction of the strain.

Soil consistency is the strength with which soil materials are held together or the resistance of soils to deformation and rupture. Soil consistency is measured for wet, moist and dry soil samples. Soil consistency is the resistance of a soil at various moisture contents to mechanical stresses or manipulations. It is commonly measured by feeling and manipulating the soil by hand or by pulling a tillage instrument through it. Consistency of a soil sample changes with the amount of water present.

Consolidation is a process by which soils decrease in volume. Consolidation is any process which involves a decrease in water content of saturated soil without replacement of water by air." In general it is the process in which reduction in volume takes place by expulsion of water under long term static loads. It occurs when stress is applied to a soil that causes the soil particles to pack together more tightly, therefore reducing its bulk volume. When this occurs in a soil that is saturated with water, water will be squeezed out of the soil. The magnitude of consolidation can be predicted by many different methods. In the Classical Method, developed by Terzaghi, soils are tested with an oedometer test to determine their compression index. This can be used to predict the amount of consolidation.

Compaction is defined as the process of increasing the unit weight of soil by forcing the soil solids into a dense state and reducing the air voids. So compaction is basically a phenomenon in which the expulsion of air takes place. So compaction is defined as the process of increasing the unit weight of soil solids by forcing them into a dense state by applying a mechanical energy and reducing air voids.

The purpose of compaction is that it reduces compressibility; increases shear strength and reduce permeability. The basic purpose of compacting earth fields such as earth dams and embankments particularly highway embankments and railway embankments and canal is to produce a soil mass that will satisfy two basic criteria; one is the reduction in settlement and increase in shear strength.

EXPERIMENT: 09

AIM: Determination of in situ stresses in rock.

Materials & Equipment:

1. Flat jack testing machine.
2. Calibration mechanism.

THEORY:

Flat jack testing can determine the engineering properties of existing structures for structural evaluation. This method is also used to determine the in situ stress and compressive strength of masonry structures. A flat jack is a hydraulic load cell manufactured to be very thin, for insertion into a typical mortar joint into which a slot has been formed. When pressurized, the flat jack exerts stress on the surrounding masonry and by measuring surface deformations; information on the existing state of stress as well as the stiffness and strength of masonry can be obtained. This method directly measures the actual state of compressive stress present within the masonry and is useful for determining stress gradients present within a masonry wall or column. Prior to forming a flat jack slot, the distance between gauge points on opposite sides of the slot location is measured. After the slot is cut, compressive stress present within the structure forces the slot to close slightly. Flat jacks are then placed in the slot and pressurized to restore the slot back to its original position. The pressure required to restore the gauge points to their original position, modified by the flat jack calibration constant, provides a measure of the state of compressive stress normal to the slot.
The measurement consists of two distinct phases:
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a. Cutting a slot (preferably by a diamond saw)
b. Insertion of a flat jack into the slot and pressurization until compensation (re-establishing the deformation stage prior to saw cutting)

The in-situ stress is evaluated using the following equation

$$\sigma_m = \rho.k_m.k_a$$

Where;
σ_m = in-situ stress component to be determined,
ρ = restoration pressure in flat jack at full compensation
k_m = flat jack calibration factor
k_a = proportion of area of flat jack to area of slot.

The double flat-jack test was created to determine on-site the behavior curves of materials and, therefore, to estimate its elastic modulus and, through other relations established in the literature, the load capacity. This test is usually preceded by a simple flat-jack test. Then, a second cut, parallel to the first one, is made above the previous one where a second flat-jack is inserted. The two flat-jacks are connected to the same hydraulic pump that ensures the same pressure in both jacks. A set of displacement transducers is placed between the two flat-jacks to monitor the displacements for the different levels of pressure installed in the flat-jacks.

PROCEDURE:

1. Prior to forming a flat jack slot, the distance between gauge points on opposite sides of the slot location is measured.
2. After the slot is cut, compressive stress present within the structure forces the slot to close slightly.
3. Flat jacks are then placed in the slot and pressurized to restore the slot back to its original position.
4. The pressure required to restore the gauge points to their original position, modified by the flat jack calibration constant, provides a measure of the state of compressive stress normal to the slot.