JHARKHAND Rai University
RANCHI

MINING ENGINEERING LAB MANUAL

ROCK MECHANICS (B.TECH)

SEMESTER IV

LIST OF EXPERIMENTS

EXPERIMENT: 01

AIM: Sample Preparation for various rock testing in laboratory.

Materials & Equipment:

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

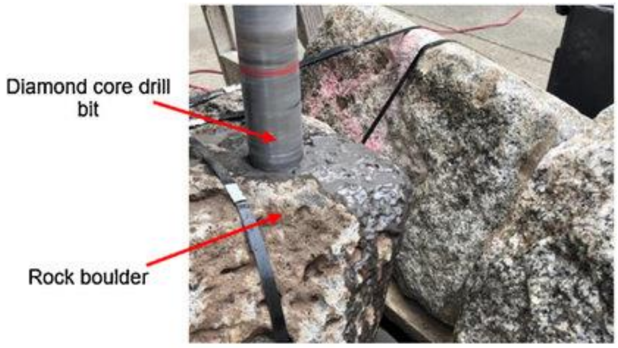
THEORY:

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)

(b)

Cylindrical Rock Sample

Fig : Cylindrical Sample Preparation Machine

EXPERIMENT: 02

AIM: To determine RQD & SCR for bore hole logs.

Scope:

• The Los Angeles (L.A.) abrasion test is a common test method used to indicate aggregate toughness and abrasion characteristics.
• Resistance to abrasion is usually measured so that the feasibility of the materials for manufacturing, stockpiling production placing and compaction can be estimated
• Lower the abrasion value more resistant will be the material against abrasion.

Materials & Equipment:

- Core boxes
- Core of NX size (54.7 mm in diameter)
- Measuring scale

Theory

Rock Quality Designation:

The percentage of intact core pieces longer than 100 mm in the total length of core." The core should be at least NX size (54.7 mm in diameter). The RQD was developed by Deere in 1963 to provide a quantitative estimate of rock mass quality from drill core.RQD measure jointing and fracturing in rock which is indirectly measure of stresses in rock.

$$\text{RQD} = \frac{\sum \text{Length of core pieces} > 10 \text{ cm length}}{\text{Total length of core run}} \times 100$$

Limitations:

RQD is directional, but due to its definition it is more sensitive to the hole or line direction than joint spacing or fracture frequency measurements. For a particular section, RQD has variable values depending upon direction of run.

Another drawback is that the RQD gives no information of the core pieces <10cm excluded, i.e. it does not matter whether the discarded pieces are carth-like materials or fresh rock pieces up to 10cm length.

Volumetric joint count (JV):

Jv is defined as the number of joints intersecting a volume of one m³. When no core is available but discontinuity traces are visible in surface exposures or exploration, the RQD may be estimated from the number of discontinuities per unit volume. The suggested relationship for clay-free rock masses is:

RQD-115-3.3 Jv

Where Jv is the sum of the number of joints per unit volume

Classification Table:

From the RQD index the rock mass can be classified as follows:

RQD	ROCK MASS QUALITY
<25%	**Very good**
25-50%	**Poor**
50-75%	**Fair**
75-90%	**Good**
90-100%	**Excellent**

Table rock mass quality

Solid Core Recovery:

It is defined as the percentage ratio of solid core recovery to the total length of the core run. Solid core: Solid core is defined as the core with at least one full diameter measured along the core axis between the natural discontinuities. By this definition core that contains a single set of inclined discontinuities would have an SCR of 100%. Where there are two or more sets of non-parallel sets of discontinuities sections, they are not considered as solid cores. SCR Sum of solid core plecesx100 Total core run

Fracture Index (FI): The minimum, maximum and average spacing of natural discontinuities in mm, measured along the core axis. Measured over core lengths of uniform characteristics not over the core runs. The boundaries between different zones correspond to boundaries between zones with different structural and discontinuity details. The detailed core logs a min thickness of Im has been chosen to distinguish between zones of different characteristics.

Total Core Recovery (TCR): It is the total length of the core recovered expressed as a percentage of the core run length

$$\text{TCR} = \frac{\text{Sum of core pieces}}{\text{Total core run length}} \times 100$$

Observations & Calculations:

Box No.36

Sr. No	Total length (inches)	Depth (feet)	Dip angle in degree	Type Of discontinuity	Cumulative length greater than 4 inch	SCR inches
		1420.166				
1	6.12	1420.729	12	Natural	6.12	6.8
2	9.10	1421.530	25	Natural	15.22	9.10
3	19	1423.161	27	Induced	34.22	19.4
4	9.2	1423.921	20	Induced	43.62	8.6
5	4.12	1424.286	30	Induced	47.74	3.9
6	3.2	1424.539	20	Induced	-	3.16
7	5.16	1424.997	20	Natural	52.9	5.8
8	6.14	1425.564	20	Natural	59.04	6.8
9	7.5	1426.173	26	Natural	66.54	7.3
10	14.1	1427.392	43	Natural	80.64	14.4
11	2.4	1427.569	26	Natural	-	1.16
12	2.4	1427.746	25	Induced	-	1.16
13	17.4	1429.183	28	Natural	98.04	16.9
14	9.9	1429.980	31	Natural	107.94	9.9
15	10.11	1430.870	20	Natural	118.05	10.4
16	2.15	1431.078	15	Natural	-	2.7
17	7.6	1431.693	27	Induced	125.65	7.2
18	8.10	1432.374	18	Induced	133.75	8.8
19	9.12	1433.224	20	Induced	142.87	9.4
20	12.13	1434.292	45	Induced	155	12.5
21	5.18	1434.755	25	Natural	160.18	5.0

Total Core Run 280 inches - 23.3 ft

For ROD:
RQD= [(cumulative length greater than 4)+(Total core number) ×100%
RQD=87.5%
For TCR:
TCR = [(Total length) (Total core number)]×100%
TCR-92.39%
For SCR:
SCR-[(Total scr) (Total core number)]×100%
SCR-91.6%
Result: On the basis of RQD we find this rock body is Good.

✡ **Box No. 5**

Sr. No	Total length (inches)	Depth (feet)	Dip angle in degree	Type Of discontinuity	Cumulative length greater than 4 inch	SCR inches
		722				
1	1.5	722.125	20	Natural	--	1.25
2	15	723.25	20	Natural	15	14.5
3	6	723.757	25	Induced	21	5.37
4	10.37	724.614	20	Natural	31.37	9.68
5	2.75	724.843	10	Induced	-	2.62
6	2.37	725.04	10	Induced	-	2.15
7	1.75	725.186	10	Induced	-	1.37
8	4	725.52	50	Natural	35.35	-
9	2.5	725.728	20	Natural	-	2.5
10	14.37	726.925	20	Natural	49.74	13.88
11	14.25	728.113	26	Natural	63.99	13.75
12	10.25	728.967	20	Induced	74.24	9.75
13	4.37	729.331	30	Natural	78.61	3.62
14	2	729.498	20	Natural	-	1.37
15	15	730.498	30	Natural	93.61	14.5
16	27.5	732.79	20	Induced	121.11	26.75
17	3.25	733.06	30	Induced	-	2.37
18	2.37	733.258	20	Natural	-	2
19	5	733.675	20	Natural	126.11	4.75
20	9	734.425	20	Natural	135.11	8.62
21	9	735.175	35	Natural	144.11	8.65
22	7	735.758	20	Natural	151.11	6.25
23	4.75	736.570	20	Induced	155.86	4.12
24	2.75	736.800	10	Natural	-	1.88
25	2.25	736.987	10	Induced	-	2.12
26	6.12	737.497	30	Induced	161.98	5.62
27	12	738.497	70	Natural	173.98	8.88

Total Core Run 226 inches 18.83ft
For ROD:
RQD-[(cumulative length greater than 4)+(Total core number) x100% RQD-87.38%
For TCR:
TCR=[(Total length)+(Total core number)]×100% TCR-98.76%
For SCR:
SCR = [(Total SCR) + (Total core number)]×100% SCR-88.02%
Result: On the basis of RQD we find this rock body is Good.

Precautions:
Fractures induced by handling or the drilling process should not be counted (the pieces broken by such fractures should be fitted together and their total length measured) and the pieces counted should be "hard and sound".
• Depth of total core run and location should be mention on box.
• Principal joints direction and tunnel drive direction should be consider setting direction of core run.

EXPERIMENT: 03

AIM: To determine of Point Load Index of rock.

Materials & Equipment:

1. Rock samples.
2. Point load strength test machine
3. 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:

Point load test

1. The diametric 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**).

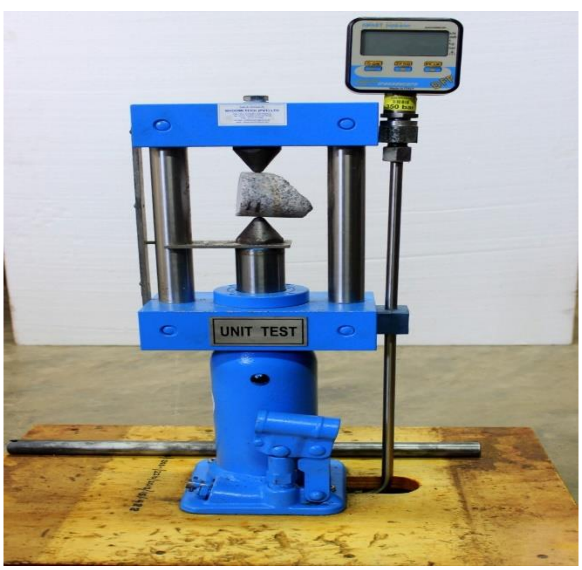
5. Measure the distance between two platen contact points (**D**) with the help of the scale attached with the loading frame. (Note-In case of diametric test, the diameter of the core (**d**) and the distance between two platens (**D**) will be same)
6. Apply load to the core specimen such that failure occur within 10-60 sec. record the failure load ‘**P**‘.

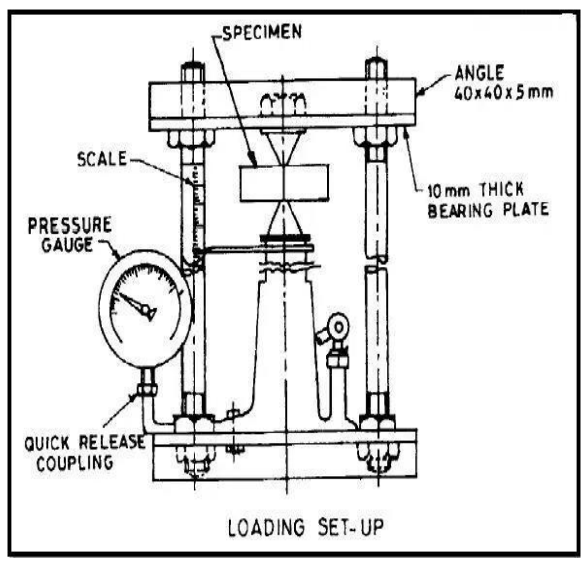
Observation Table

Sl no.	Load (KN)	Diameter of sample (cm)
1		
2		
3		
4		

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





Point Load Index Testing Apparatus

EXPERIMENT: 04

AIM: To determine Uniaxial Compressive strength of rock.

Materials & Equipment:

1. Universal Testing Machine.
2. 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.

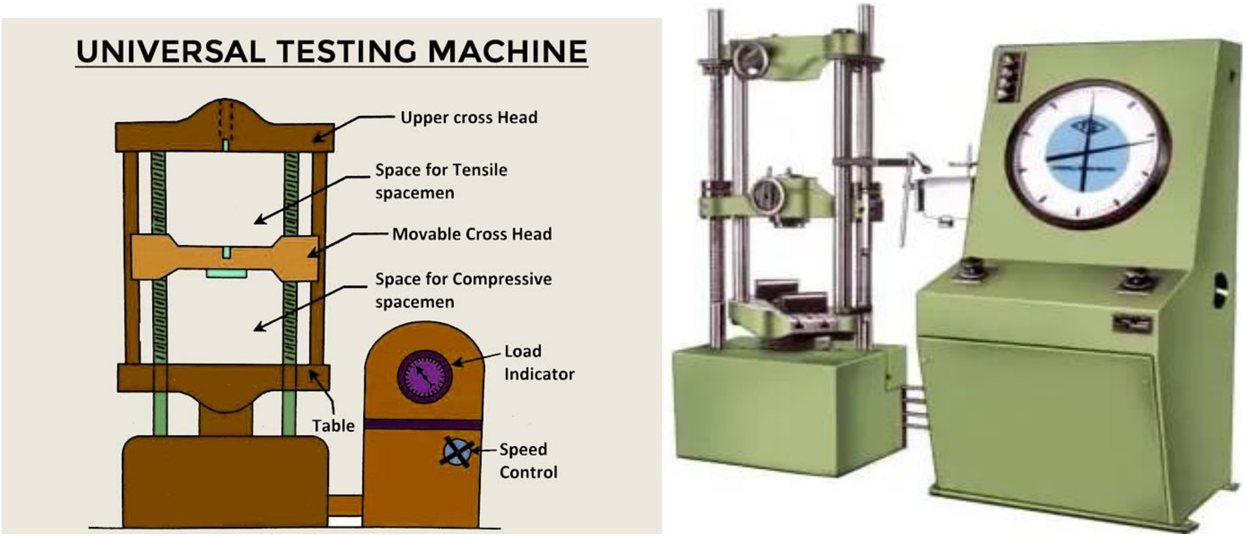
The two common laboratory tests to determine the compressive strength of rock are:

- 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.

Sl No.	Load (KN)	Diameter of sample (cm)

PROCEDURE:

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.



Universal Testing Machine

EXPERIMENT: 05

AIM: To determine indirect tensile strength of rock (Brazilian Test).

Materials & Equipment:

1. Universal Testing Machine.
2. 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.

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.

Sl No.	Load (KN)	Diameter of sample (cm)

PROCEDURE:

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. For Brazilian Test a relatively thin disk is load across the diameter until it splits. At failure point the load is noted down and strength is calculated out.

Brazilian Testing Apparatus

EXPERIMENT: 06

AIM: To determine of shear strength of rock.

Materials & Equipment:

1. Shear box.
2. 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 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:

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.

Shear Test Apparatus

EXPERIMENT: 07

AIM: To determine the Protodyakonov strength index of rock.

Materials & Equipment:

1. Rock samples.
2. Volumometer
3. PSI apparatus.
4. A 100 mm scale attached with the loading frame
5. 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:

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:

$$PSI = \frac{20\times NxM}{H}$$

Where: PSI- Protodyakonov strength index

N- No. of samples

M- No. of impacts or blows

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.

Weight of Sample taken	No. of Sample (N)	No. of Impacts(M)	Height of fine material in volumometer (H)

Protodyaknov strength Apparatus

EXPERIMENT: 08

AIM: To determine the specific gravity of rock using pycnometer.

Theory and Application: Specific gravity of rock is the ratio of weight, in air of a given volume; of dry solids to the weight of equal volume of water at 4ºC. Specific gravity of grains gives the property of the formation of soil mass and is independent of particle size. Specific gravity of is used in calculating void ratio, porosity and degree of saturation, by knowing moisture content and density. The value of specific gravity helps in identifying and classifying the type.

Apparatus:

1. Pycnometer
2. 450 mm sieve
3. Weighing balance
4. Oven
5. Glass rod
6. Distilled water

Procedure:

1. Dry the pycnometer and weigh it with its cap. (W1)
2. Take about 200gm of oven dried rock powder passing through 4.75mm sieve into the pycnometer and weigh again (W2).
3. Add sufficient de-aired water to cover the rock powder and screw on the cap.
4. Shake the pycnometer well and remove entrapped air if any.
5. After the air has been removed, fill the pycnometer with water completely.
6. Thoroughly dry the pycnometer from outside and weigh it (W3).
7. Clean the pycnometer by washing thoroughly.
8. Fill the cleaned pycnometer completely with water up to its top with cap screw on.
9. Weigh the pycnometer after drying it on the outside thoroughly (W4).
10. Repeat the procedure for three samples and obtain the average value of specific gravity.

Observations and Calculations:

Determine the specific gravity of rock sample (G) using the following equation

$$\mathbf{(W2 - W1)\ G = (W2 - W1) - (W3 - W4)}$$

Where

W1 = Empty weight of pycnometer.

W2 = Weight of pycnometer + oven dry rock

W3 = Weight of pycnometer + oven dry rock+ water

W4 = Weight of pycnometer + water

Observation for Specific Gravity Determination:

Sample Number

W1 in gms

W2 in gms

W3 in gms

W4 in gms 1

Specific Gravity G 2 3

Result:

Average specific gravity of rock (G) =