

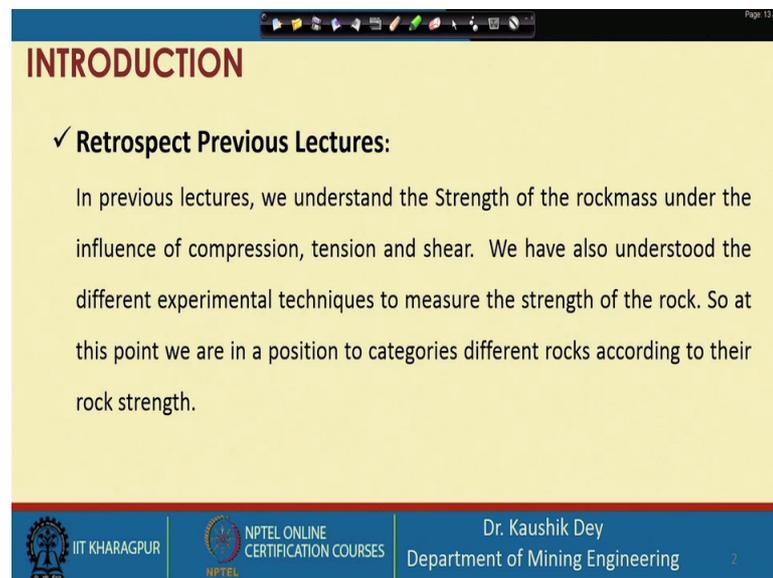
Drilling and Blasting Technology
Prof. Kaushik Dey
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Indian Institute of Technology, Kharagpur

Lecture – 07
Rock Properties & Testing-2

Let me welcome all of you to the Drilling and Blasting course. This is the second lecture on the Rock Properties and Testing, where we will discuss about the how the different rock properties can be measured, and how the they are influencing the drilling operation while we are carrying out it in a rock.

So, like every class let us retrospect what we have studied so far. In our previous lecture we understood the strength of the rock mass under the influence of compression tension and shear. So, we have understood their measurement procedure, we have understood how they are influencing.

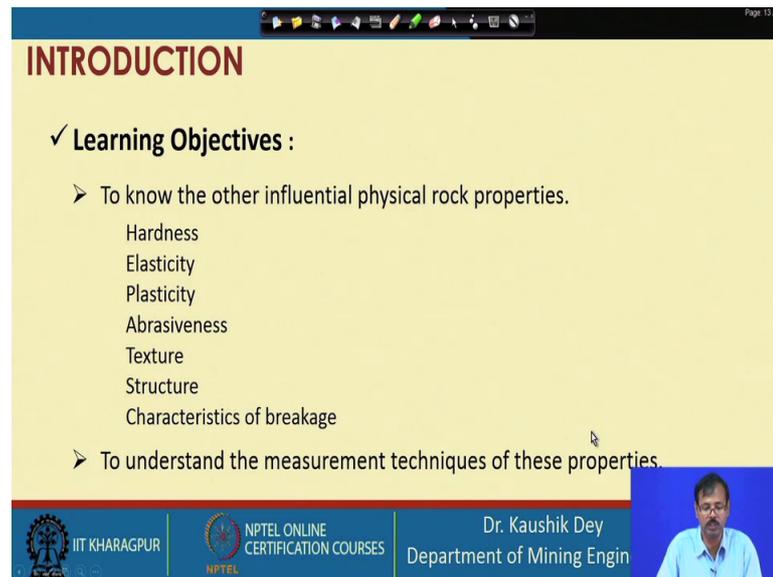
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The slide is titled "INTRODUCTION" in a bold, dark red font. Below the title, there is a checkmark icon followed by the text "Retrospect Previous Lectures:". The main body of the slide contains a paragraph of text: "In previous lectures, we understand the Strength of the rockmass under the influence of compression, tension and shear. We have also understood the different experimental techniques to measure the strength of the rock. So at this point we are in a position to categories different rocks according to their rock strength." The slide has a yellow background and a blue footer. The footer contains the IIT Kharagpur logo, the NPTEL logo, and the text "NPTEL ONLINE CERTIFICATION COURSES". On the right side of the footer, it says "Dr. Kaushik Dey" and "Department of Mining Engineering". There is a small number "2" in the bottom right corner of the footer.

We have also understood the different experimental techniques to measure the strength of the rock. So, at this point we are in a position to categorize different rocks according to the rock strength, and from there we can say it may be soft rock it may be hard rock it may be medium hard rock. So, from there we now let us see the other influencing parameters of the rock properties.

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INTRODUCTION

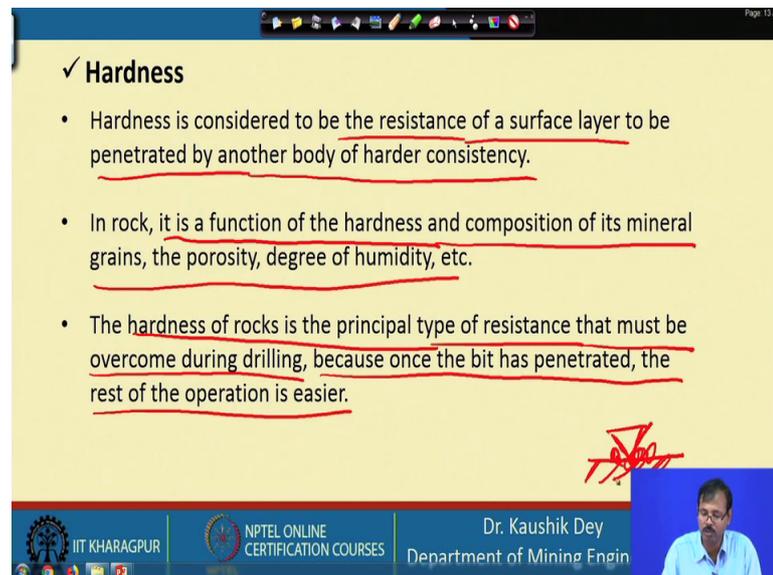
✓ **Learning Objectives :**

- To know the other influential physical rock properties.
 - Hardness
 - Elasticity
 - Plasticity
 - Abrasiveness
 - Texture
 - Structure
 - Characteristics of breakage
- To understand the measurement techniques of these properties.

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And this class our objective is to know the other influential physical rock properties like hardness, elasticity, plasticity, abrasiveness, texture structure characteristics of breakage, and to understand the measurement techniques of this rock properties. So, let us start with the first rock property that is hardness.

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✓ **Hardness**

- Hardness is considered to be the resistance of a surface layer to be penetrated by another body of harder consistency.
- In rock, it is a function of the hardness and composition of its mineral grains, the porosity, degree of humidity, etc.
- The hardness of rocks is the principal type of resistance that must be overcome during drilling, because once the bit has penetrated, the rest of the operation is easier.

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So, hardness is considered to be the resistance of a surface layer to be penetrated by another body of harder consistency. So, that means, say suppose we are having a knife,

the material is hard how much hard against that knife is considered how easily the knife is basically scratching that material.

So, basically that is the hardness of that material against the knife. So, in rock also we consider it is a function of the hardness, and composition of it is mineral grain the porosity degree of humidity. So, basically a rock material is considered hard if it is not able to be scratched by most of the other rock material. So, that is considered hard. So, hard is the one rock property, and it has been found most of the times if the rock material containing very hard grains.

So, that material shows the larger hardness and often the material formed under high temperature shows the high hardness with respect to the other rock material. So, the hardness of rock is the principally the type of resistance that must be overcome during the drilling, because once the bit has penetrated the rest of the operation is easier. So, the first the rock layer if the bit is able to penetrate this one, then the rest portion rest grains can be easily sheared off or may be easily crushed off. So, the penetration of the first point first angular point is essential and that is depending on the hardness of this rock material. So, that is why hardness is basically a very, very important parameter while we are considering the drilling operation.

(Refer Slide Time: 04:26)

✓ **Hardness Test Procedure**

- Mohs' Scale of Hardness (1882): Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

Handwritten list of materials for Mohs' Scale of Hardness:

- 1 - Talc
- 2 - Gypsum
- 3 - Calcite
- 4 - Fluorite
- 5 - Apatite
- 6 - Orthoclase
- 7 - Quartz
- 8 - Topaz
- 9 - Corundum
- 10 - Diamond

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The most popular test procedure of hardness is called Mohs' scale hardness. Basically, 100 years back Moh has develop of this scale which is basically a number scale from 1 to

10, 1 is the talc and 10 is the diamond, . So, there are 2, 3, 4, 5 up to 10 is there. The easier to remember this is called you can have something said the German cat feared an oriental cue into complete death. So, t the Germans t is talc, g is gypsum cat is calcite, f is feldspar, a is apatite, o is orthoclase, q is quartz, t is topaz and c is corundum and D final one D is diamonds. So, this is a 1 to 10 scale of hardness which is basically a qualitative test which is basically a qualitative test of hardness of the material.

(Refer Slide Time: 06:10)



✓ **Hardness Test Procedure**

- **Mohs' Scale of Hardness (1882):** Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

Talc

The slide features a central photograph of a talc mineral specimen, which is a soft, white, fibrous mineral. The word 'Talc' is printed in white text at the bottom right of the image. The slide is part of a presentation, as indicated by the navigation icons at the top and the footer containing logos for IIT Kharagpur, NPTEL, and the Department of Mining Engineering, along with a small video inset of Dr. Kaushik Dey.

So, let us observe these video which basically give you the details of this. This video is available in the, you tube you can download that video from there also. One of the factors used to identify minerals is their hardness, which means how well they resist being scratched by a harder mineral. So, what we are going to do is consider and show you the steps that we would take to show hardness for the minerals, this is talc; this is listed as number one on your list. With talc it is one of the softest minerals and if you notice that even my fingernail will leave a scratch on it.

(Refer Slide Time: 06:54)

✓ **Hardness Test Procedure**

- Mohs' Scale of Hardness (1882): Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

Selenite (Gypsum)

The slide features a central image of a translucent, white, fibrous mineral sample labeled with a small white circle containing the number '2'. The background is dark. The slide is part of a presentation with a blue header and footer. The footer contains the IIT Kharagpur logo, NPTEL Online Certification Courses logo, and the name 'Dr. Kaushik Dey, Department of Mining Engin'. A small video inset of the speaker is visible in the bottom right corner.

This is number 2 it is called selenite.

(Refer Time: 06:56) Than talc (Refer Time: 06:56).

It is also a very soft mineral.

(Refer Time: 06:58) Cut the talc.

And. So, we can also.

(Refer Time: 07:00) hardness of the nearly around 2.5 (Refer Time: 07:03).

(Refer Slide Time: 07:06)

✓ **Hardness Test Procedure**

- **Mohs' Scale of Hardness (1882):** Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

Calcite

The slide features a central image of a translucent, white, rhombohedral calcite crystal resting on a dark, textured surface. The word 'Calcite' is printed in white text at the bottom right of the image. The slide is part of an NPTEL presentation, with logos for IIT Kharagpur and NPTEL Online Certification Courses visible at the bottom. A small video inset of Dr. Kaushik Dey is located in the bottom right corner of the slide area.

Show that it was scratch. This is called calcite it is number 3 on your list. This one we can try with your fingernail, but it really is too hard for my fingernail to leave a scratch.

So, you can see calcite (Refer Time: 07:17).

So, from the next step we would try a penny which is made of copper, and we will find that if we press hard enough you see it leaves the scratch mark.

Can be scratch by (Refer Time: 07:28).

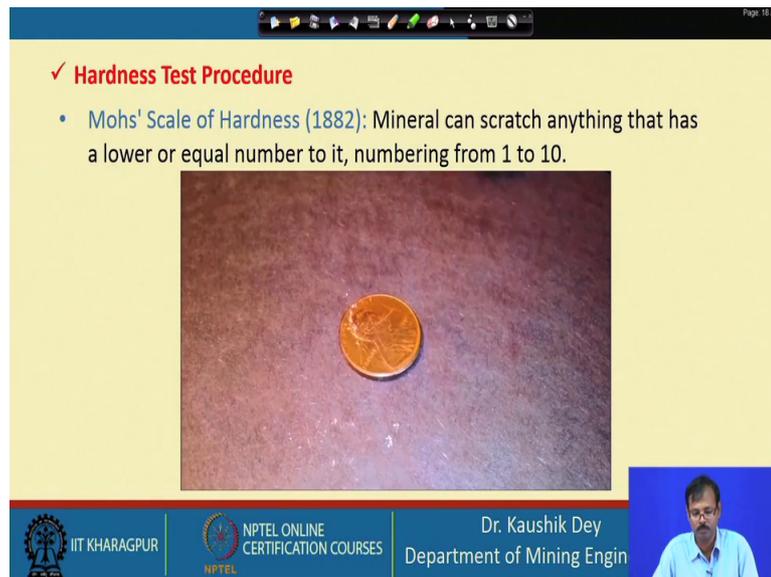
Fluoride is going to be a little harder than the calcite. This time the penny is not going to scratch it, but if we take the fluoride we can scratch the penny. So, you see it is here you see the scratch.

Yes.

I think.

We see.

(Refer Slide Time: 07:50)



✓ **Hardness Test Procedure**

- **Mohs' Scale of Hardness (1882):** Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

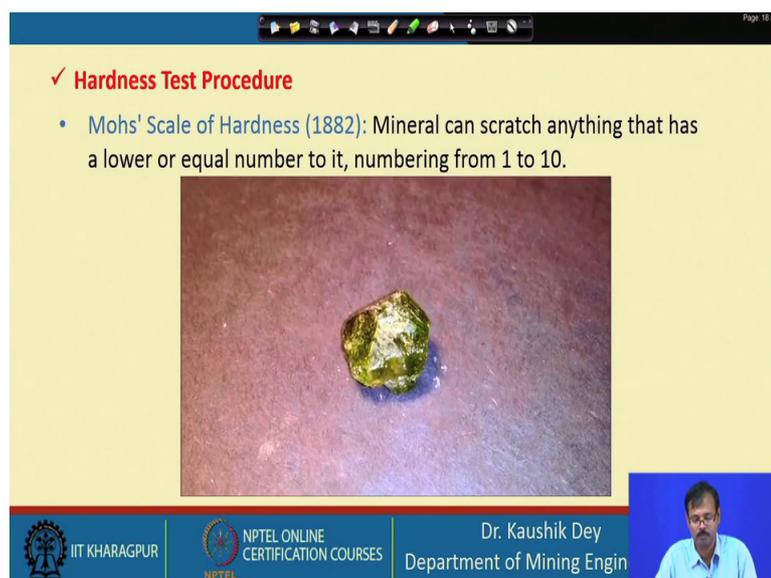
The slide features a central image of a copper coin (likely a 10-paise Indian coin) resting on a dark, textured surface. The slide is part of an NPTEL presentation by Dr. Kaushik Dey from the Department of Mining Engineering at IIT Kharagpur. The footer includes the IIT Kharagpur logo, NPTEL Online Certification Courses logo, and the presenter's name and department.

And so, that means, a fluoride is harder than the copper. Then we can also, but we can find something that is harder than the fluoride, if we use a blade and then.

(Refer Time: 08:08).

A metal blade we can actually then scratch the fluoride. So, it takes them this is going to be harder than the fluoride, yes of course, this is the blade scratches.

(Refer Slide Time: 08:20)



✓ **Hardness Test Procedure**

- **Mohs' Scale of Hardness (1882):** Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

The slide features a central image of a green, crystalline mineral specimen resting on a dark, textured surface. The slide is part of an NPTEL presentation by Dr. Kaushik Dey from the Department of Mining Engineering at IIT Kharagpur. The footer includes the IIT Kharagpur logo, NPTEL Online Certification Courses logo, and the presenter's name and department.

We are getting a little bit harder, this is called apatite, this is number 5 on the list. We were going to find that the blade will also scratch it, and this ones a little bit harder to see the great blade will scratch it (Refer Time: 08:35), but it is harder it is harder for me to scratch it with the blade. So, that is because this is harder than the fluorite that we scratched before there was a little bit easier to scratch. So, we were getting harder each time.

This is number 6, it is called feldspar.

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✓ **Hardness Test Procedure**

- **Mohs' Scale of Hardness (1882):** Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

Feldspar

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So, this is feldspar.

This time where we cut we were not able to scratch the others with the blade.

(Refer Time: 08:56).

This one is not going to scratch with the blade.

(Refer Time: 08:59) around 6 (Refer Time: 09:01).

If I pressed it even press it down I cannot get it to scratch. So, that means, this is harder than the blade, but if I take a piece of glass, the feldspar can scratch the glass. If that blade is coming it there

Hum.

(Refer Time: 09:22).

(Refer Time: 09:24).

So, the feldspar.

(Refer Time: 09:29:30) scratch (Refer Time: 09:31).

Is harder number 7, it is quartz.

(Refer Slide Time: 09:34)

✓ **Hardness Test Procedure**

- Mohs' Scale of Hardness (1882): Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

Quartz

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And this one is also going to be harder than the glass, but it should scratch the glass a little bit easier because it is harder.

Let us see if it does. Very definitely cuts through the glass

Hum.

Much easier than the feldspar there; where we had quartz before, this is number 8, this is topaz.

(Refer Slide Time: 09:55)

✓ **Hardness Test Procedure**

- **Mohs' Scale of Hardness (1882):** Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

Topaz

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So, as the numbers get higher we were getting harder. So now, we are going to take the topaz and see that it to prove that it is harder, it will scratch this quartz. But it is a little bit harder to get them to scratch as we get hard harder and harder. This one does not move

Are we seeing anything?

No (Refer Time: 10:25).

Yeah (Refer Time: 10:31) it is.

(Refer Time: 10:32).

The topaz can (Refer Time: 10:33).

And so, we get harder than they are harder. And so, we are not going to get as easily as scratch as we did before.

(Refer Slide Time: 10:41)

✓ **Hardness Test Procedure**

- **Mohs' Scale of Hardness (1882):** Mineral can scratch anything that has a lower or equal number to it, numbering from 1 to 10.

The slide features a central photograph of a person's finger wearing a diamond ring, which is being used to scratch a small, dark mineral specimen labeled with the number '9'. The background is a light yellow color. At the bottom of the slide, there is a blue banner with the IIT Kharagpur logo, NPTEL Online Certification Courses logo, and the text 'Dr. Kaushik Dey, Department of Mining Engin'. A small video inset of the speaker is visible in the bottom right corner.

Number 8 again was the topaz. Number 9 is called corundum; corundum is one of the hardest minerals that we have. And we were going to see that if it does a pretty good job I am scratching the topaz.

(Refer Time: 10:55).

(Refer Time: 11:00).

Coradum gun scratch on topaz (Refer Time: 11:03).

(Refer Time: 11:04) Gun scratches right there, all right. Once again 9 corundum, then number 10 you will notice that I if you see anything in your, if we look at the kit it is going to say not in the kit.

Yeah.

For a number 10.

Most hardest material is the diamond.

Number 10 is a diamond.

(Refer Time: 11:24).

This happens to be my in my ring the diamond is there, we talked about in class that diamonds are the hardest, diamond if I could get to the diamond to the edge of it, it would scratch the corundum; Because diamond again is the hardest mineral that we have talc.

(Refer Slide Time: 11:44)

✓ **Hardness Test Procedure**

- **Rebound devices:** a group of devices that use a spring-loaded mechanism to measure rebound of a metal object against a rock face.
 - Schmidt Hammer
 - Equotip
 - Piccolo

Schmidt Hammer

Equotip

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Apart from this most scale of hardness, the surface hardness can be tested quantitatively by a few other tests though those are, these are not always the direct test. Some of the indicative tests also. So, one of such test is called schmidt rebound hammer. This is the schmidt rebound hammer, other two types of hammer is also there, but the most common one used is schmidt rebound hammer. Where a ball is dropped and it is rebound length is measured using the hammer.

So, this is very, very commonly used. There are two types of Schmidt hammer available l type, n type. And most commonly for rock in general we use n type of Schmidt hammer. And Schmidt hammer facilities that it can be used for measuring the hardness of the surface hardness basically of the rock in any direction.

(Refer Slide Time: 12:58)



So, let us see use of Schmidt hammer in this video.

This is simple and Schmidt used for and create a Schmidt rebound hammer gives the (Refer Time: 13:17).

(Refer Time: 13:18).

(Refer Time: 13:19) this is (Refer Time: 13:21) from 10 to 100. These are very found the Schmidt standard resistance in terms of spring system. So, (Refer Time: 13:26).

Very, very important.

Schmidt hammer (Refer Time: 14:22), it shows the rebound number; that is, 13 (Refer Time: 14:28).

(Refer Slide Time: 14:28)



✓ **Hardness Test Procedure:** Schmidt Hammer

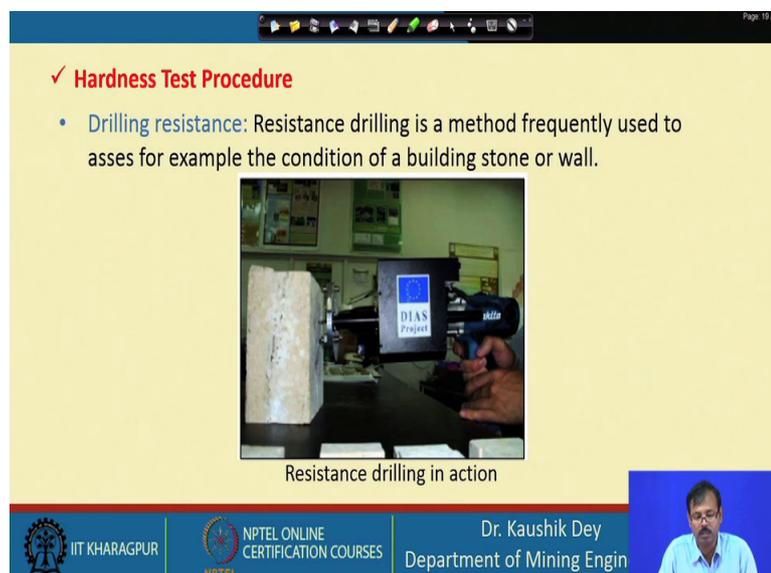
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Once again I can press point, this is (Refer Time: 14:34) and 10, 10 number of this is 13 (Refer Time: 14:43). So, we takes 10 number of samples, discards the value of higher and maximum higher and (Refer Time: 14:53).

We can observe (Refer Time: 15:00).

On rebound, the indicator has moved up to the number, and that is why it is called rebound number. So, rebound number can be directly correlated with the other mechanical properties also.

(Refer Slide Time: 15:19)



✓ **Hardness Test Procedure**

- **Drilling resistance:** Resistance drilling is a method frequently used to asses for example the condition of a building stone or wall.

Resistance drilling in action

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So, basically Schmidt hammer gives the surface hardness of the rock structure, even when it is in the in situ, and this remand rebound number basically dictating the hardness of the rock surface. Apart from that some other hardness measuring procedures are there like brinell hardness etcetera, though you can read those things from the textbook standard textbooks available for the rock properties.

So, this is the drilling resistance, where drilling resistance is a method frequently used to assess the example for example; the condition of a building stone or wall something like that. And here the drilling resistance is carried out by measuring the by carried out the miniature drilling on to the specimen.

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✓ **Hardness Test Procedure**

- **Rockwell scale:** It is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload.

Rockwell Scale (X=)	Indenter	P major (kg)
A	Brale (diamond)	60
B	1/16" ball	100
C	Brale (diamond)	150
D	Brale (diamond)	100
E	1/8" ball	100
F	1/8" ball	60
M	1/4" ball	100
R	1/2" ball	60

$$HRX = R_x = M \cdot \frac{(P_2 - h_2)}{0.002}$$

M = 100 for A, C, and D scales
M = 130 for B, E, M, R, etc. scales

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Hardness is also measured using the Rockwell scale, it is a hardness scale, it is a hardness scale based on the indentation of the indenter indentation hardness of a material. So, basically this is the indentation test; where in this indentation test hardness is determined by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. So, basically here the indenter is allowed to penetrate in the sample, with a small load and with a large load.

So, say first the initially a small load is given on to the ball indenter, or cone indented diamond cone indenter. So, and on the same indenter subsequently a large load in a separate experiment cycle a large load is given to find out the penetration depth. So, using this penetration depth, this hardness is determined; where this AB and CD, these

are constants are given depending on the for the rock rocks well scale, depending on the weight, and types of balls also. So, these details are given using these details the in the Rockwell scale the hardness of the surface hardness of the material can be determined. So, let us observe once such video available in the into YouTube for measuring the Rockwell hardness.

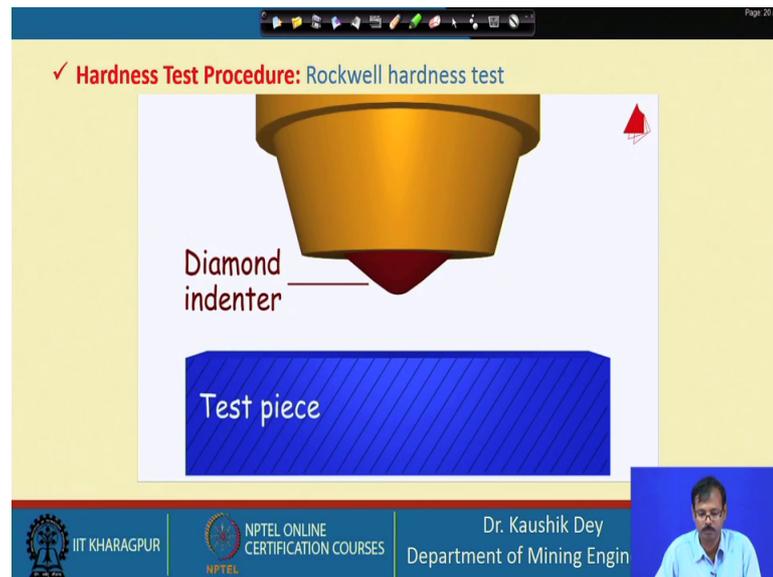
(Refer Time: 18:27) Scale C.

(Refer Slide Time: 18:37)



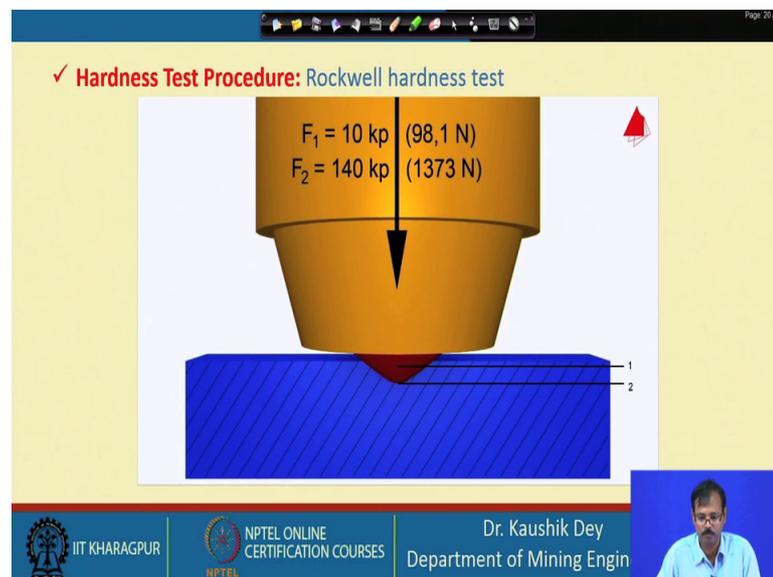
The Rockwell hardness test is scale C. In this video we will show how the Rockwell hardness test works using a gear wheel.

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The basic idea of this test method is to measure the permanent depth of indentation of a hardened indenter under a test force. In the process variant scale C, around it cone made of diamond is used as an indenter. In step one the diamond cone is pressed onto the test piece surface with a minor force of 10 kilo ponds.

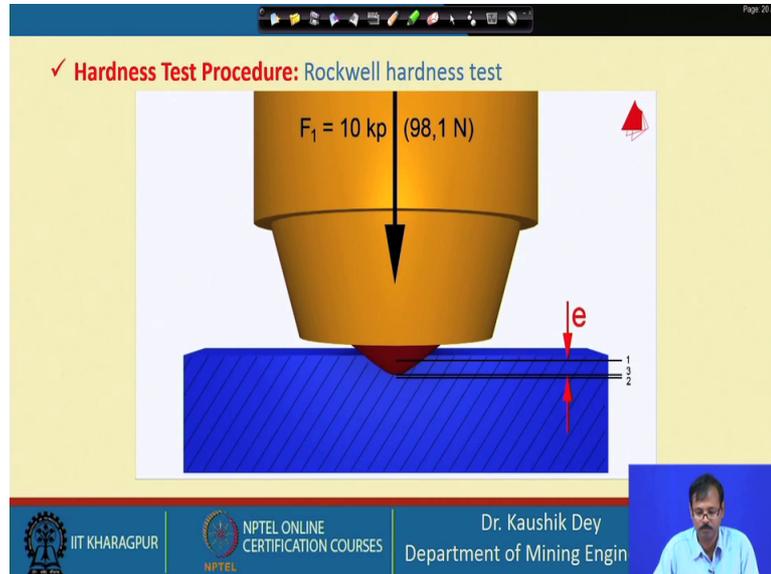
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The depth of indentation under this preliminary load is the reference point. In step 2 the test force is increased by a, 140 kilo ponds which is acting as the major force. This

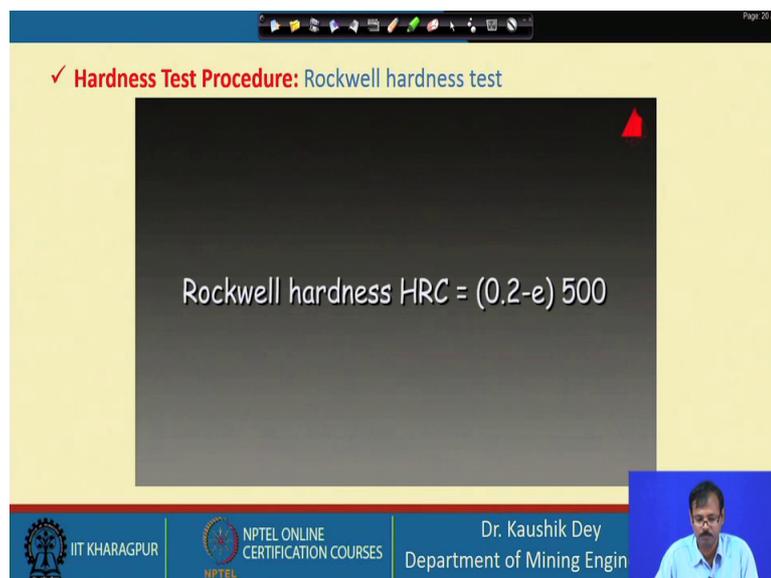
means that an overall force of 100 and 50 kilo ponds is now acting on the indenter and this force is held for a certain time.

(Refer Slide Time: 19:27)



In step 3 the major force is removed again. While the minor force is still acting the permanent increase in depth of indentation e is measured.

(Refer Slide Time: 19:29)



This is how the Rockwell hardness is calculated. Rockwell hardness HRC is equal to 0.2 minus permanent depth of indentation e in millimetres times 500. Let us take a look at how the test is carried out in practice. The tester selects the co little.

(Refer Time: 19:47) Indenter.

Diamond indenter and installs it in the testing machine.

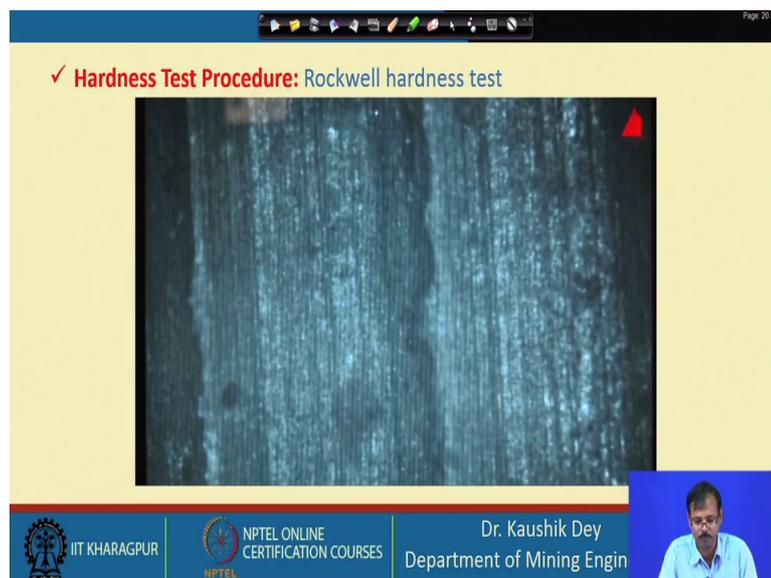
Diamond cone indenter.

(Refer Slide Time: 19:54)



Then he picks up the gear wheel and puts it on the support table. After rotating the microscope lens to it is vertical position he can adjust his test piece.

(Refer Slide Time: 20:18)



As soon as the focused image can be seen on the screen, the surface of the test piece is in the correct height.

(Refer Slide Time: 20:22)



The test can start in modern testing machines the Rockwell hardness test is fully automated. That is why the Rockwell hardness test is used so often in automated production lines.

(Refer Time: 20:33) provided.

That is, it, the Rockwell hardness of our gear wheel.

(Refer Slide Time: 20:53)

✓ **Elasticity**

- The majority of rock minerals have an elastic-fragile behavior, which obeys the Law of Hooke, and are destroyed when the strains exceed the limit of elasticity.
- The elastic properties of rocks are characterized by the elasticity module 'E' and the Poisson coefficient 'ν'.

0.1 - 0.25

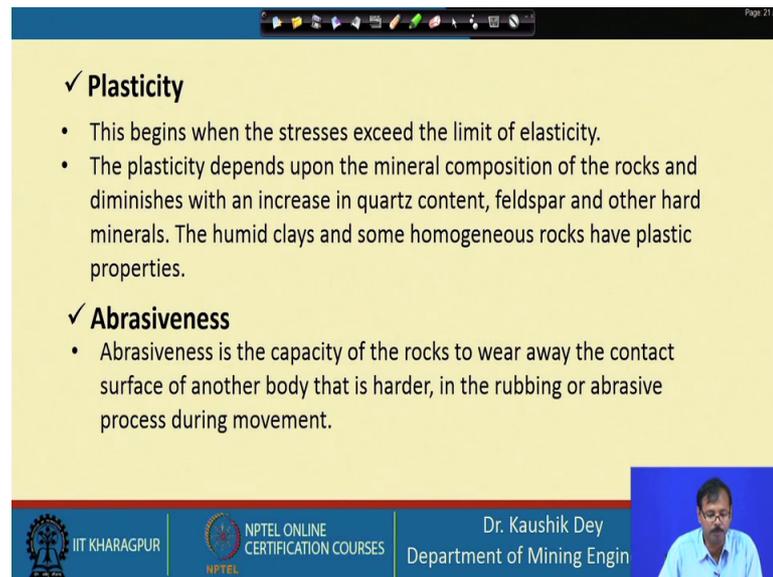
The graph shows three curves representing different rock types. The y-axis is Uniaxial Compressive Strength (MPa) from 0 to 300. The x-axis is Deformation (mm x 10³) from 0 to 60. Curve B (Fragile-Elastic Rocks) rises to a peak at approximately 270 MPa and 25 x 10³ mm deformation. Curve C (Fragile-Plastic Rocks) rises to a peak at approximately 180 MPa and 45 x 10³ mm deformation. Curve C' (Plastic and Very Porous Rocks) rises to a peak at approximately 80 MPa and 55 x 10³ mm deformation. Points B', C, and C' are marked on the curves.

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So, the next property is elasticity. Elasticity is for most of the rocks this is basically giving an elastic fragile behaviour which obeys the Hooke's law and are destroyed when the strain exceeds the limit of the elasticity. So, basically elasticity is basically we measure using the Poisson's ratio. And as in the last class also we have discussed, the Poisson's ratio of most of the rocks is varying between 0.1 to 0.25. You know, the limit of Poisson's ratio is 0.5. Most of the cases we found the Poisson's ratio.

Varying between these two we can measure the Poisson's ratio while we are we are carrying out our universal compressive test by providing a strain gauge at the site portion of the sample, we can determine the Poisson's ratio. Otherwise if we are carrying out the wave velocity elastic wave seismic wave velocity we are carrying out the measuring of seismic wave velocity P and S wave velocity on the rock sample. In those cases, also we can we can indirectly calculate the Poisson's coefficient using mechanical using some physical relationship amongst them.

(Refer Slide Time: 22:51)

A screenshot of a presentation slide with a yellow background. At the top right, it says 'Page 21/21'. The slide contains two sections: '✓ Plasticity' and '✓ Abrasiveness', each with a bulleted list of points. At the bottom, there is a blue footer bar with logos for IIT Kharagpur and NPTEL, and text identifying the speaker as Dr. Kaushik Dey, Department of Mining Engineering. A small video inset of the speaker is visible in the bottom right corner of the slide.

✓ **Plasticity**

- This begins when the stresses exceed the limit of elasticity.
- The plasticity depends upon the mineral composition of the rocks and diminishes with an increase in quartz content, feldspar and other hard minerals. The humid clays and some homogeneous rocks have plastic properties.

✓ **Abrasiveness**

- Abrasiveness is the capacity of the rocks to wear away the contact surface of another body that is harder, in the rubbing or abrasive process during movement.

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A plasticity begins when the rock stress exceeds the limit of elasticity, then plasticity a plasticity comes and residual stresses are becoming important when the plastic stage is there. So, plasticity depends upon the mineral composition of the rock and diminishes with an increase in the quartz content feldspar and other hard minerals. However, most of the rock behaves more brittle nature than the ductile nature; that is why the plasticity limits are very limited after the moment elastic it cross the elastic limit cracks are developed, and residual strengths are becoming not that much significant.

Abrasivity is one of the very, very important parameters when we are considering the drilling part because; abrasivity basically dictates the consumption of the drill steel by blunting the drill bits. Abrasiveness is the capacity of the rock to wear away the contact surface of another body, which is harder. So, in rubbing of 2 bodies, the abrasive material basically erode the another body so, abrasivity basically very, very important. It has been found that abrasiveness increases with the hardness. So, that directly hardness is basically dictating the abrasivity.

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✓ **Abrasive Test Procedure**

Cerchar Abrasivity Test:

- The Cerchar Abrasivity Test has been introduced in the 70s by the *Centre d'Etudes et Recherches des Charbonages (CERCHAR) de France* for abrasivity testing in coal bearing rocks.
- The testing principle is based on a steel pin with defined geometry and hardness that is scratches the surface of a rough rock sample over a distance of 10 mm under 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.

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The moment the rock material containing angular and tough mineral grains, it exhibits more abrasivity than the other material. There are two common tests available for the abrasivity measurement. One of that is very, very famous cerchar abrasivity test. Another one is (Refer Time: 24:54) abrasivity test. The reason is that basically abrasivity is related with the content of the quartz or the silica content. So, cerchar abresivity basically determines the percentage of the silica. Whereas, cerchar abrasivity is a direct pin test where the pin is scratched to find the how much the pin tip material has lost it is angularity.

So, that is why, this is cerchar abrasivity test is very, very popular for testing the abrasivity. So, the testing procedure is that it is a steel pin with a defined geometry; that means, it is having it is having a 45 degree, it is having a particular tip angle. And the steel is have a specified hardness. It is allowed to scratch over a rock sample up to a distance of one centimeter under a static load of 7 kg, almost 7 kg 70 Newton. So, the sharpness lost in the tip is defined as the cerchar abresivity. So, basically this is a direct measurement of the abrasivity carried out. Let us observe this one.

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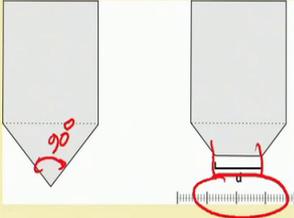
✓ Abrasivity Test Procedure

Cerchar Abrasivity Test:

$$CAI = 10 \cdot \frac{d}{c}$$

Where,

CAI = Cerchar-Abrasivity-Index (-);
 d = diameter of wear flat (mm);
 c = unit correction factor ($c=1\text{mm}$)



Sketch of the steel pin with rectangular shape before the test (left) and after the test (right) with the wear flat d .

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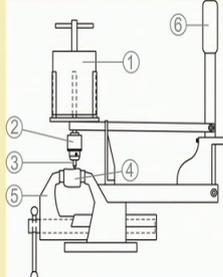
So, basically this is the steel pin, if I do not forget this is probably exhibit the angle of 90 degree. I will communicate it after observing the literature. So, we observe the bluntness of the tip after scratching it, after scratching it on a sample of one centimeter length under a 7 kg load, we will observe this bluntness of the tip in a ocular microscope of 200 magnification.

So, the cerchar abrasivity is calculated using this formula where d is the distance not the diameter actually this is the distance of the flatness, and c is the correction factors applied. So, this is basically giving us magnification of the that with the 10 is giving us the cerchar abrasivity of the material.

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✓ **Abrasivity Test Procedure**

Cerchar Abrasivity Test:



1 – weight
2 – pin chuck
3 – steel pin
4 – sample
5 – vice
6 – hand lever

Setup of a modified Cerchar testing device according to Cerchar (1986)

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So, this is a direct use of the abrasivity of the material where the pin is subjected to under a abrasion. And this movement of the pin of 10 mm or one centimeter length has to be carried out within a time span of one second. So, basically this is the set up, this is the set up commonly used for the cerchar abrasivity testing. However, cerchar abrasivity it is also closely related with the drilled rate index.

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✓ **Texture**

- The texture of a rock refers to the structure of the grains of minerals that constitute it. The size of the grains are an indication, as well as their shape, porosity etc. All these aspects have significate influence on drilling performance.

✓ **Structure**

- The structural properties of the rock masses, such as schistosity, bedding planes, joints, diabases and faults, as well as their dip and strike affect the alignment of the blastholes, the drilling performance and the stability of the blasthole walls.

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So, that also can be carried out in different cases for the indirect measurement of the cerchar abrasivity. So, let us see about the texture, texture of a rock refers to the structure

of the grains of the minerals that constitute it the size of the grain are an indication as well as they are safe porosity etcetera.

So, the angular grains are more hard and sub grains are more hard. So, those are to be considered while we are carrying out the drilling operation on a rock. The structural properties of the rock mass is also important. Schistosity, bedding planes, joints these are faults and their orientations are also very important while the drilling is being carried out.

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✓ Ultrasonic testing

- Determine compression (P-wave) and shear (S shear (S -wave) velocities of rock core wave) velocities of rock core.
- Nondestructive measurements.
- Fast and inexpensive.
- Evaluation of small-strain elastic stiffness (strains $< 10^{-6}$ mm/mm).

Dynamic
Compact Strength

The diagram illustrates the ultrasonic testing setup. It includes a Pulse Generator Unit (Trigger & output), a main output connected to a Transmitter, a Rock Specimen, a Receiver, a Pre-amplifier, a Time Delay Circuit, an Electronic Counter (start/stop), and an Oscilloscope. The receiver outputs a direct pulse and a transmitted pulse, which are displayed on the oscilloscope. An arrow points from the oscilloscope to the labels V_p and V_s , representing P-wave and S-wave velocities respectively.

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And ultrasonic testing is carried out to know the P and S wave velocity of the rock. This basically gives us the idea about the compactness, compactness of the rock inside the rock mass. And this also indicates the strength of the rock mass. Basically in other words you can say the ultrasonic testing for the determining the P and S wave velocity of the rock is the only test for which gives us the dynamic or gives us the indication over the dynamic property of the rock.

So, basically these are also dictates how the energy will be transferred from the explosive to the rock, all these are depending on these ultrasonic rock properties. So, this is also very, very important while the dynamic failure is carried out. There are other properties also which are influencing the drilling and blasting operations; however, let us stop at this position. The other rock properties it is desired that you should read from the textbooks available for this. I strongly recommend the books of Gemino, I strongly

recommend the books of cube for drilling. This has to be referred for your further study in your own place.

Thank you.