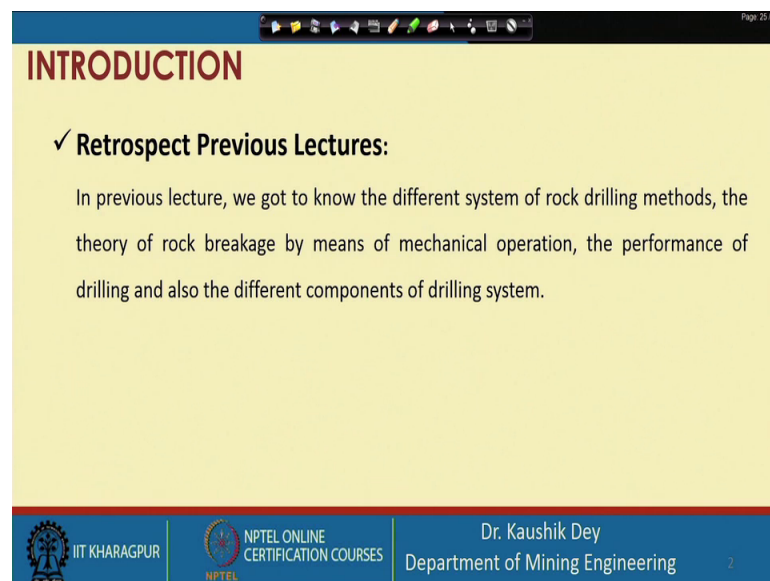


Drilling and Blasting Technology
Prof. Kaushik Dey
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Lecture – 09
Drillability of Rock

Let me welcome you into the 9th lecture of Drilling and Blasting Technology. In this lecture we will discussed Drillability of Rock.

(Refer Slide Time: 00:29)



The slide is titled "INTRODUCTION" in red text. Below the title, there is a checkmark icon followed by the text "Retrospect Previous Lectures:". The main body of the slide contains the following text: "In previous lecture, we got to know the different system of rock drilling methods, the theory of rock breakage by means of mechanical operation, the performance of drilling and also the different components of drilling system." At the bottom of the slide, there is a blue footer bar containing the IIT Kharagpur logo, the NPTEL Online Certification Courses logo, and the name and department of the lecturer, Dr. Kaushik Dey, Department of Mining Engineering. The page number "2" is visible in the bottom right corner of the footer.

But like every class let us retrospect our previous lecture. In last class we have we have covered the different system of rock drilling methods, the theory of rock breakage by means of mechanical operation. We have seen there are different theories of rock breaking.

But in mining or you can say the drilling and blasting cases, we carry out drilling only by means of mechanical operation. We are not using other thermal seismic etcetera; we use only mechanical operation. And in that mechanical operation, we use only rotary percussive or rotary percussive hybrid operation. And the performance of drilling and also the different components of drilling systems we have discussed. That means, how the energy is transferred from it is source; that is the drill machine to the drill bit through the drill steel. And how drill bits are having different crossing action, then the chipping action is carried out for increasing the depth of the penetration in its action of drilling.

(Refer Slide Time: 01:43)

INTRODUCTION

✓ **Learning Objectives :**

- To understand the rock drillability and its purpose.
- The classification of rock drillability.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineer

This slide is the first of two in a presentation. It features a yellow background with a blue header and footer. The title 'INTRODUCTION' is in red. Below it, the learning objectives are listed. A small video inset of the speaker is in the bottom right corner.

Now, our learning objective for this class is to understand the rock drillability. And why it is required we will also discussed that, we have also find out the classification of the rock drillability that is the different methods of the rock drill drillability we use in our practical field. Basically, we have introduce ourselves with the rock drillability in that last class. But we will discuss this matter in details in this class. So now, let us discuss what is drillability.

(Refer Slide Time: 02:12)

DRILLABILITY

- Drillability is the resistance of rock to penetration by a drilling technique, and it is a term used to describe the influence of numbers of parameters on the drilling rate (drilling velocity) and the tools wear of the drilling machine. Penetration of rocks is influenced by rock properties as well as machine parameters.
- In 1927, B.F. Tillson introduced the concept of "rock drillability," researchers in many countries carried out lots of work on the rock drillability and its classification.

→ Excavation | → Cost of Drilling
→ Performance of Drilling

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineer

This slide is the second of two in a presentation. It features a yellow background with a blue header and footer. The title 'DRILLABILITY' is in red. Below it, two bullet points define drillability and mention B.F. Tillson's work in 1927. Handwritten red notes include a small diagram of a drill bit, a bracket grouping the first bullet point, and arrows pointing from the second bullet point to 'Excavation', 'Cost of Drilling', and 'Performance of Drilling'. A small video inset of the speaker is in the bottom right corner.

Basically, drillability is the resistance of a rock. It is the resistance of a rock to be penetrated by a drill machine. So, that means, a rock is there which has to be penetrated by a drill machine. And this term is used to describe the influence of number of parameters on the drilling rates. So, basically while some drilling has to be carried out on the rock, how the rock is resisting to be penetrated that can be considered as the drillability. The first tilson has used in 1927 first this term rock drillability. And after that a long research is carried out on the drillability, because drillability is a prime factor on two thing.

One is the cost of drilling, second one is the performance of drilling; that means, how fast we can achieve the completion of a drill hole. Not only this, not only drillability is defining the drilling only, but also drillability gives us some idea about the mechanized excavation: mechanized excavation; that means, how easy to cut a rock, that is also possible to be assess if we know the drillability of a rock.

So, that is why drillability is a very very important parameter required in the rock blasting or rock drilling part.

(Refer Slide Time: 04:18)

✓ **The purpose of studying the drillability of rock is for:**

- Choosing a suitable drilling method, equipment, and technology to achieve best results on project progress and economy;
- Estimation of the drilling rate and working life of the drilling tools to offer the basic data of project planning;
- Offering reliable data of rock performance for design and improvement of drilling machines.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey | Department of Mining Engineering

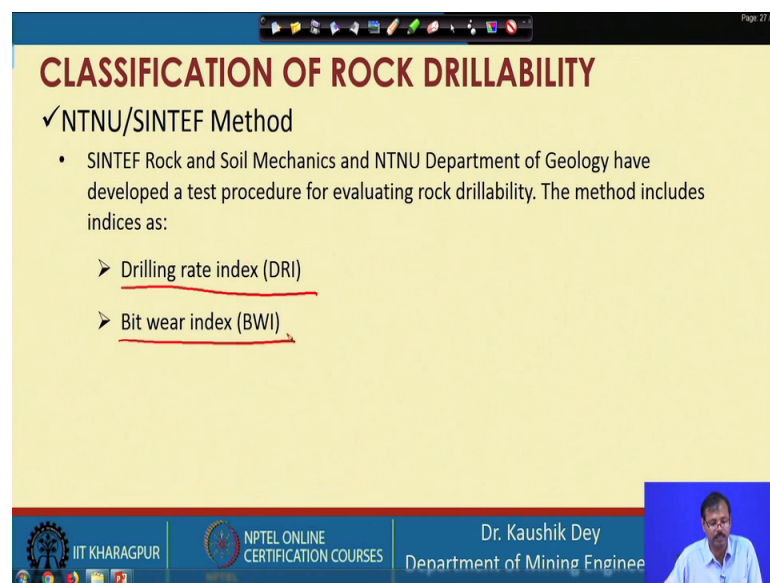
So, basically what is the purpose of this? The purpose is we have to choose a suitable drill machine for drilling that particular rock. We have to choose a suitable method of drilling. We have to find out the suitable technology to achieve the best result while we are carrying out the drilling. That means, our options are that whether we will use a

percussive drilling, or whether we will use a rotary drilling, or we will use a rotary percussive drilling, should we use the circulation fluid, which type of circulation fluid can be used. All these decisions are dependent on the drillability of that particular rock.

This drillability also discussed the drilling rate. Working lives of the drill tools; that means the drill bit drill steels etcetera. And these are very very important as these are directly dictating the economics of the drilling. Apart from that drillability also gives us the performance and improvement of the drilling machines. That means, what should be the drill feeding rate to be provided by the drilling machine to achieve the optimum drilling.

How much should be the thrust? How much should be the rotary force to be given by the drilling machine to achieve the best performance, this all decisions depends on the drillability of the rock.

(Refer Slide Time: 06:12)



The slide is titled "CLASSIFICATION OF ROCK DRILLABILITY" in bold red text. Below the title, it says "✓ NTNU/SINTEF Method". A bullet point states: "SINTEF Rock and Soil Mechanics and NTNU Department of Geology have developed a test procedure for evaluating rock drillability. The method includes indices as:". Two sub-points are listed: "➤ Drilling rate index (DRI)" and "➤ Bit wear index (BWI)". The slide has a yellow background. At the bottom, there is a blue footer with logos for IIT KHARAGPUR, NPTEL ONLINE CERTIFICATION COURSES, and Dr. Kaushik Dey, Department of Mining Engineer. A small video inset of Dr. Kaushik Dey is visible in the bottom right corner.

So, basically drillability is a term which dictating or which is basically guided by the rock properties and also the machine properties. So, mostly we are using NTNU or SINTEF method, where drillability is basically governed by 2 thing: one is the drilling rate index, another is the bit wear index.

Now, to have a detailed look on this, let us see what is drilling rate index.

(Refer Slide Time: 06:49)

✓ **Drilling rate index (DRI)**

- The DRI is assessed on the basis of two laboratory tests:
 - The brittleness value (S_{20}) test ✓
 - The Sievers' J value (S_j) miniature drill test. ✓
- The brittleness value (S_{20}) test:
 - The brittleness value S_{20} is an indirect measure of rock resistance to crack growth and crush. S_{20} is determined by the Swedish Stamp Test.
 - The crushed and sieved aggregate, sizes ranging 16.0–11.2 mm, is placed in a mortar and then struck 20 times with a 14-kg hammer. The mortar aggregate volume corresponds to that of a 0.5-kg aggregate with a density of 2.65 tons/m³.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineering

Drill rate index is basically assessed by a nomograph. In that nomograph we have to plot 2 things. One is the brittleness value S_{20} value, and second one is the Sievers' j value, which is come which comes out from the from the miniature drill test. So, we have to carry out brittleness test, we have to carry out miniature drill test to come with the value of drill rate index.

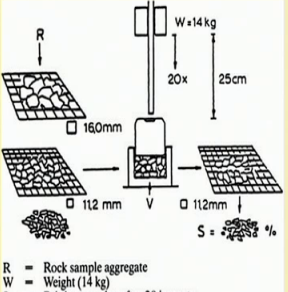
Now, let us see what is the brittleness value test or say S_{20} test. The brittleness value S_{20} is an indirect measure of rock resistance to the crack growth and crush. And S_{20} is determined the Swedish stamp test. What is carried out here? The crushed and sieved aggregates sizes ranging from this to this size. So, this size range of material is placed in a mortar, and that struck 20 times with a 14 kg hammer, ok.

So, this 14 kg hammer is striking 20 times of a fixed quantity of this size aggregate. So, this is half kg of aggregate, and this is compared with the standard material of this much kg of density of this one, specific gravity of 2.65. Now as this is compared with this, we find out the S_{20} , we find out the S_{20} value as the equal percentage of undersize material that passes through 11.2 mm mesh size that passes through 11.2 mm mesh size after this drop test.

(Refer Slide Time: 08:42)

✓ **Drilling rate index (DRI)**

- The brittleness value (S_{20}) test:
 - S_{20} equals the percentage of undersized material that passes through 11.2-mm mesh after droptest. S_{20} is presented as a mean value of three or four parallel tests.



R = Rock sample aggregate
W = Weight (14 kg)
 S_{20} = Brittleness value after 20 impacts

Fig. 2.5 Outline of the brittleness value by stamp test

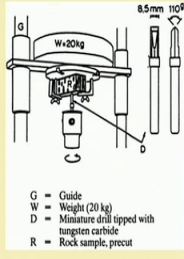
IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineer

So, the percentage of material which is coming below this is considered as the brittleness value of the test.

(Refer Slide Time: 09:17)

✓ **Drilling rate index (DRI)**

- The Sievers' J value (S_j) miniature drill test :
 - The S_j miniature drill test is also an indirect measure of rock resistance to tool indentation (surface hardness).



G = Guide
W = Weight (20 kg)
D = Miniature drill tipped with tungsten carbide
R = Rock sample, precut

Fig. Sievers' miniature drill test

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineer

Now, in Sievers' j value, miniature drilling is carried out in the in the rock sample.

(Refer Slide Time: 09:42)

✓ **Drilling rate index (DRI)**

- The Sievers' J value (S_j) miniature drill test : *Stand. Load*
 - The hole depth in the rock sample is measured after 200 revolutions in 1/10 mm.
 - A mean value of four to eight test holes is used.
 - The orientation of the rock specimen can affect test results.
 - Therefore, the S_j value is always measured for holes parallel to rock foliation. In coarse-grained rocks, care must be taken to ensure that a representative number of holes are drilled in the different mineral grain types.

IIT KHARAGPUR NPTEL ONLINE CERTIFICATION COURSES Dr. Kaushik Dey Department of Mining Engineering

(Refer Slide Time: 09:48)

✓ **Drilling rate index (DRI)**

- The DRI is determined by the diagram.
- The DRI can also be seen as the brittleness value corrected for its S_j value.

Diagram used to determine DRI

IIT KHARAGPUR NPTEL ONLINE CERTIFICATION COURSES Dr. Kaushik Dey Department of Mining Engineering

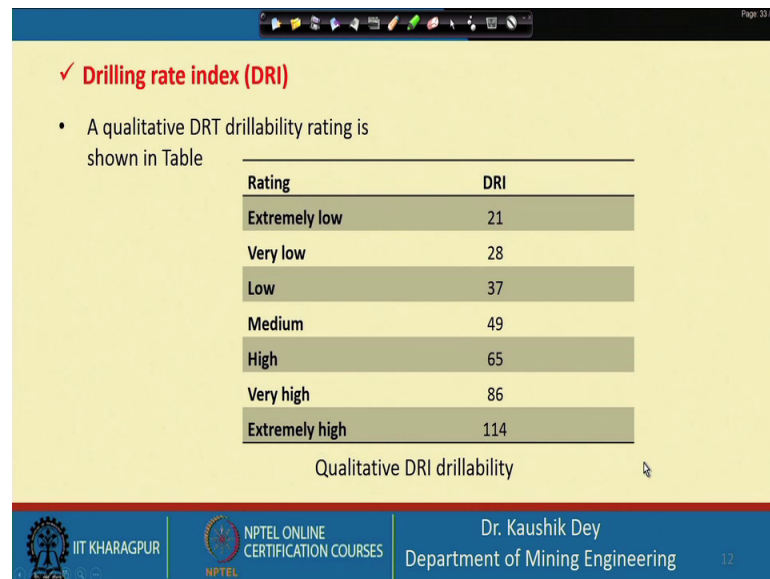
And in this test, the standardized drill bit is allowed to penetrate the rock sample and the penetration depth is measured after 200 revolution.

So, this rotary drill this is miniature rotary drill, which is carried out under a standard load and after 200 revolution the penetration depth is measured in a one 10th mm scale. And that value is considered as the drill rate index value. So, 4 to 8 tests are carried out on that, and that value is considered as the Sievers' j value. And then this Sievers' j value

is plotted against thus this brittleness value. This Sievers' j value are plotted against this brittleness value to arrived at the particular drill rate index.

So, in this nomograph the brittleness value and Sievers' j value are plotted to have a drilled rate index.

(Refer Slide Time: 11:22)



✓ **Drilling rate index (DRI)**

- A qualitative DRT drillability rating is shown in Table

Rating	DRI
Extremely low	21
Very low	28
Low	37
Medium	49
High	65
Very high	86
Extremely high	114

Qualitative DRI drillability

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineering | 12

Now, these are some of the a drill rate index the qualitative assessments are given, the DRI 21 is considered as the extremely low, 28 is considered very low, 37 is low, 49 is high, medium 65 is high 114 is extremely high. That is drilled rate index may be considered as per the table value.

(Refer Slide Time: 12:01)

✓ **Bit wear index (BWI)**

- The BWI is assessed on the basis of two laboratory tests.
 - The abrasion value (AV) test.
 - Abrasion value cutter steel (AVS) test
- The abrasion value (AV) test
 - The AV test constitutes a measure of the rock abrasion or ability to induce wear on tungsten carbide. The development of the AVS test was based on the AV test method. The same test equipment as for the AV measures the AVS, but the latter uses a test piece of steel taking from a TBM cutter ring.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey | Department of Mining Engineering

Bit wear index is basically giving us the loss of the bit and this can be assessed again by 2 tests. One is the abrasion value test, second is the abrasion value cutter steel test. So, if you see the abrasion value test. Abrasion value test continues a measure of rock abrasion, or ability to induce wear on the tungsten carbide. The development of abrasivity steel test was based on the abrasivity AV test abrasivity value test method. And the same test equipment are used for as for the AV is measured the AVS.

But the in abrasivity steel test, a test piece of steel is taking from the TBM cutter ring to assess the cutter abrasion values of those steels.

(Refer Slide Time: 13:12)

✓ **Bit wear index (BWI)**

- The abrasion value (AV) test
 - The AVS constitutes a measure of rock abrasion or ability to induce wear on cutter ring steel. The abrasion powder used for both the AV and AVS is normally prepared by the use of test material from the extractions used to determine S_{20} and should hence be regarded as representative and homogenized sample material.

Outline of the AV and AVS test

Dr. Kaushik Dey
Department of Mining Engineer

So, this is the abrasion value test, here abrasion value steel continues a measure of rock abrasion or the ability to induced wear on the cutter ring steel. The abrasion powder used for both the abrasion value and a abrasive abrasion value steel is normally prepared by the use of test material from the extraction used to determine S 20, and should hence be regarded as a representative of homogenized sample material.

So, basically in both the cases we use the same abrasive powder for carrying out this test.

(Refer Slide Time: 14:03)

✓ **Bit wear index (BWI)**

- The abrasion value (AV) test
 - AV is defined as the weight loss of the test piece in milligrams after 5-min testing. AVS is defined as the weight loss of the test piece in milligrams after 1 min of testing. The AV and AVS tests are normally performed on 2–4 test pieces.

Dr. Kaushik Dey
Department of Mining Engineer

And the abrasivity value is defined as the weight lost of the test piece in milligram after 5-minute testing. So, 5-minute abrasion is allowed on the test piece, and how much weight is lost that is measured here. In the abrasivity steel also the weight lost of the test piece in milligram after 1 minute of testing is used. So, basically these are the test loss of the material of the test samples are basically considered in this case.

(Refer Slide Time: 14:46)

Classification of rock drillability by NTNU/SINTEF

Class	S ₂₀ value (%)	S _j value (mm/10)	AV (mg)	AVS (mg)
Extremely high	≥66.0	≤2.0	≥58.0	≥44.0
Very high	60.0–65.9	2.1–3.9	42.0–57.9	36.0–44.0
High	51.0–59.9	4.0–6.9	28.0–41.9	26.0–35.9
Medium	41.0–50.9	7.0–18.9	11.0–27.9	13.0–25.9
Low	35.0–40.9	19.0–55.9	4.0–10.9	4.0–12.9
Very low	29.1–34.9	56.0–85.9	1.1–3.9	1.1–3.9
Extremely low	≤29.0	≥86.0	≤1.0	≤1.0

The table is annotated with red checkmarks in the first column and red circles around the 'Extremely low' row. A red bracket on the right side of the table groups the last three rows (Very low, Extremely low, and the row above it).

Dr. Kaushik Dey
Department of Mining Engineering

And if it is compared you can see the extremely high considered reversing the table this is the Sievers' j value, sorry this is the Sievers' j value, this is the abrasive value this is the abrasivity steel value, if it is consider. So, this is for a 5 minutes this is for 1-minute test. And these are the different values you can observe for high, very high medium low very, low and extremely low conditions.

So, these are very very good situation for carrying out the drilling operation.


(Refer Slide Time: 15:38)

CLASSIFICATION OF ROCK DRILLABILITY

✓ Method of Impact Penetrate

- In 1980, Northeastern University, China (NEU), published their research result of rock drillability classification using the method of impact penetrate with two indexes of “specific impact penetrate work” and “abrasion width of bit” and developed two sets of measurement apparatus.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineering



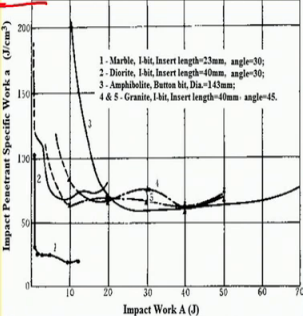
There are, another method of achieving the rock drillability is also possible.

(Refer Slide Time: 15:48)

CLASSIFICATION OF ROCK DRILLABILITY


✓ Concept of impact penetrate-specific work (IPSW)

- The work consumed for impact penetrate on a unit volume of rock is called “impact penetrate-specific work (IPSW).” It is the basic physical quantity for the percussion (rotary-percussion) drilling of rock.



Relationship between impact work and IPSW

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineering



So, here in this case in 19 80 china has developed this one, for specific impact penetration work and abrasive width of the bit is considered and to, these 2 measurements are carried out, these are developed in the china, and that is why this is not that much popularly is. So, first one is the impact penetration specific work.

Here the work consumed for impact penetration on a unit volume of rock is called this. And this is the basic physical quantity where rotary percussion action of the drill drilling is utilized.

(Refer Slide Time: 16:45)

CLASSIFICATION OF ROCK DRILLABILITY

✓ **Concept of impact penetrate-specific work (IPSW)**

- There is a critical value of impact work (A_c) for the tested rock. When the applied impact work (A) is less than a certain value (A_c), the value of IPSW is not stable and varies greatly as the small impact force only produces a scar and small powder cannot produce any chipping.
- When impact work (A) is greater than (A_c), IPSW reach a plateau. The phenomenon tells us that the impact work as a main parameter of the test apparatus must be greater than the critical value, A_c , of any rock to be tested.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey
Department of Mining Engineer

And here there is a critical value of impact work for the tested rock when the applied impact work is less than the certain value; that is the critical value, the value of impact penetration specific work is not stable, and varies greatly as the small impact force only produces a scar on the small powder cannot produce any chipping.

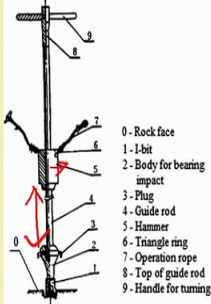
So, the impact work must be higher than the critical impact work. And when the impact work is greater than this, then the test can be carried out in the actual condition.

(Refer Slide Time: 17:39)

CLASSIFICATION OF ROCK DRILLABILITY

✓ **Test apparatus- impact penetrate apparatus (IPA)**

- The weight of hammer (5) is 4.0 kg. The hammer free fall height along the guide rod (4) is 1.0 m. The hammer impacts the body (2) with an I-type bit connected in the bottom and the bit chisels the rock.



Impact penetrate apparatus

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineering

So, here what is carried out? A weight of hammer of 4 kg; so this is the hammer of 4 kg is allowed to free fall from a height. So, this height is fixed, this height is fixed, the hammer impacts the body with a I-type bit. So, I section bit is used, which is connected in the bottom and this is acting on the rock.

(Refer Slide Time: 18:25)

CLASSIFICATION OF ROCK DRILLABILITY

✓ **Test apparatus- impact penetrate apparatus (IPA)**

- After every impact, the bit is turned 15° by the top handle of the rod. The diameter of the bit is 40 ± 0 and made with Type YG-11G tungsten carbide insert. Insert angle is 110° .
- For measuring the abrasion of the bit, a new bit (or newly grinded bit) must be used for every test. The rock face to be tested is placed horizontally, and a shallow nest is previously prepared manually for locating the tested bit.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineering

Now, next after every impact after every impact bit is turned 15 degree by the top handle of the rod, the diameter of the bit is this, and insert angle is this one. So, for measuring the abrasion after this every impact the bit is tilted. After the completion of that the

measuring for a abrasion of the measuring a new bit is every time used fresh bit. And the rock face is to be tested which is placed horizontal, and shallow next to the previously prepared manually locating tested bit.

(Refer Slide Time: 19:15)

CLASSIFICATION OF ROCK DRILLABILITY

✓ **Test apparatus- impact penetrate apparatus (IPA)**

- The net depth of the drilled hole, H, is measured and recorded after total 480 impacts for each rock specimen. The IPSW, a, can be calculated using the following formula:

$$a = \frac{A}{V} = \frac{nA_0}{\frac{\pi}{4}d^2H} = \frac{480 \times 39.2}{\frac{\pi}{4} \times 4.1^2 \times \frac{H}{10}} = \frac{14252}{H} \text{ J/cm}^3$$

a impact penetrate-specific work (IPSW), J/cm³;
 A total impact work of 480 freely falling of the hammer
 J; V rock volume to be broken after 480 impacts, cm³;
 N total impact times, n = 480;
 A₀ work of single impact, A₀ = 39.2 J;
 D actual hole diameter after drilling, d = 41 mm (bit diameter = 40 mm);
 H net depth, mm.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineer

So, the finally, we measure the net depth of the hole which is h is measured. And the number of impacts generally that is kept 480 impacts is carried out, and then this can be calculated using this formula, where this is the value IPSW value have a joule per centimeter cube. This is the 480 total impacts of free falling. V is basically the volume of rock broken. N is the total impact times. A 0 is the work done by a single impact. D is the actual hole diameter and H is the net depth.

So, using this formula we can calculate. And finally, this can be achieved by this formula where the hammer. So, hammer weight number of penetration, number of impacts and, height of impacts are kept fixed. And from that calculating the energy we can directly if we press the value of H. Then we can directly get the IPSW value.

(Refer Slide Time: 20:43)

CLASSIFICATION OF ROCK DRILLABILITY

✓ Test apparatus- impact penetrate apparatus (IPA)

- After the test of IPSW, the abrasion of the bit is measured as well. The measurement is carried out using a reading microscope, expressed as "b" in mm.
- In the system of rock drillability using the method of impact penetrant, rock drillability is divided into seven classes and three categories according to both the index of impact penetrant-specific work (IPSW) "a" and the index of bit abrasion "b".

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Kaushik Dey, Department of Mining Engineering

So, after the test of IPSW, the abrasion of the bit is measured as well the measurement is carried out by using a reading microscope and the bluntness of the bit is measured, that is in mm.

So, as we have discussed in the searcher also, the bluntness of the bit is measured and that reading is taken in the microscope. Using this method of impact penetrant, rock drillability is divided into 7 classes and 3 categories, according to both the index of impact penetration specific work and the index of bit abrasion. So, considering these 2 the entire rock drillability is divided into 7 class and 3 categories. You can see this in the next slide.

(Refer Slide Time: 21:54)

CLASSIFICATION OF ROCK DRILLABILITY

✓ **Test apparatus- impact penetrate apparatus (IPA)**

Rock drillability classification by impact penetrant-specific work index "a"

Class	I	II	III	IV	V	VI	VII
Drillability	Very easy	Easy	Fair easy	Fair difficult	Difficult	Very Difficult	Extremely difficult
IPSW "a" (kg m/cm ³)	≤19	20-29	30-39	40-49	50-59	60-69	≥70

Rock drillability classification by bit abrasion index "b"

Category	1	2	3
Abrasive	Weak	Medium	Strong
Bit abrasion "b"	≤0.2	0.3-0.6	≥0.7

*Energy
Drill bit
steel
1m*

. So, these are the 7 classes. This is the class one is considered to be very easy, if the impact penetration is less than value is less than 90. It is easy if this value is 20 to 29 this is fairly easy. If these values are value varied between 30 to 40. If this is 40 to 50 considered difficult. It is fair difficult, it is difficult if it is 50 to 60, very difficult 60 to 70, and greater than 70 is considered extremely difficult.

So, basically IPSW which is basically considering the energy requirement, this is considering the energy requirement of drilling per meter of per meter of drilling. Considering this energy requirement as the energy requirement is more than 70 kg meter per centimeter cube. Then it is considered as the extremely difficult drilling condition. Now as extremely difficult condition does not means that it is very very abrasive. Abrasivity depends on the abrasivity of the rock. So, that is why this economic part we need to know how much drill bit and drill steel will be consumed. So, this is basically dictating the consumption of the drill bit or consumption of the drill steel.

So, for that it is categorized in 3 part. One is weekly abrasive. Second is medium abrasive. Third one is very strong abrasive. So, the bit abrasion that is a bluntness is coming less than point 2 millimeter. So, if the bluntness on the bit is coming less than point 2 millimeter, then the rock is considered of net weakly abrasive. If it is between point 3 to 0.6, then it is considered as the medium abrasive. And if it is considered as the greater than 7, 0.7 then it is considered as the very very abrasive.

So, basically this abrasivity gives us the loss of the drill bit which is basically an economic term. So, this Chinese method is also very robust system, and that can be popularly used for identifying the drillability of the rock rock. And accordingly the machine can be deployed on that, and we can assess the economics of that drilling also.

This is more or less covering the drillability part. We can stop the drillability part at this point. I request you to have more reading on the drillability from a number of books are available, on the drillability even if all the drilling books rock properties books dealing with this specially, where the TBM are is essentially considered drillability is, must to be drillability test is must to be carried out there.

So, I request you more reading on this drillability. Let us stop at here in this class.

Thank you.