Rock Mechanics and Tunneling
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Lecture 23
Rock mass classification (continued)

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Hello everyone. I welcome all of you to the second lecture of module 5. So, in module 5 we are discussing rock mass classification. In our previous class, we have discussed a few things about the rock mass classifications and we have mainly focused on the factors affecting the discontinuities, those factors will be playing an important role further in this study.

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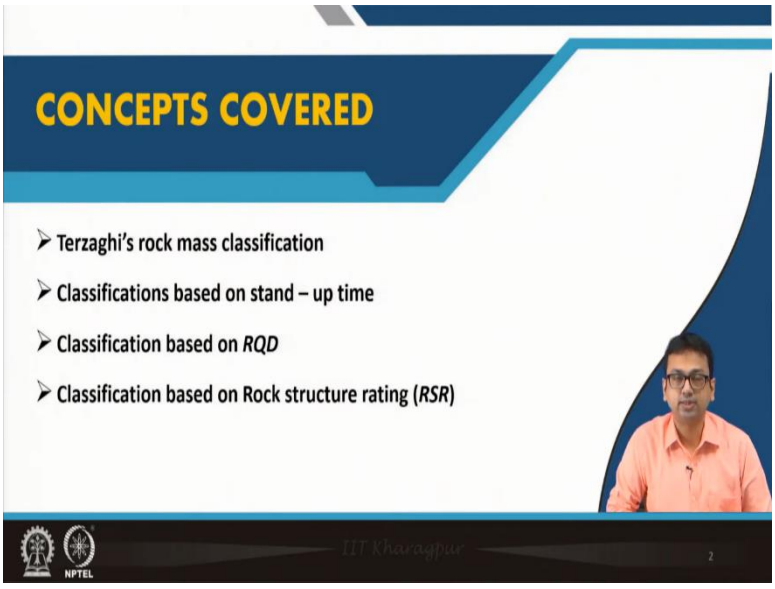

Let us now begin with actual rock mass classification. Today we will discuss Terzaghi's rock mass classification and classification based on stand-up time. Then we will discuss the classification based on RQD which we have already discussed and classification based on rock structure rating RSR. Also, we will solve a simple problem based on RSR.

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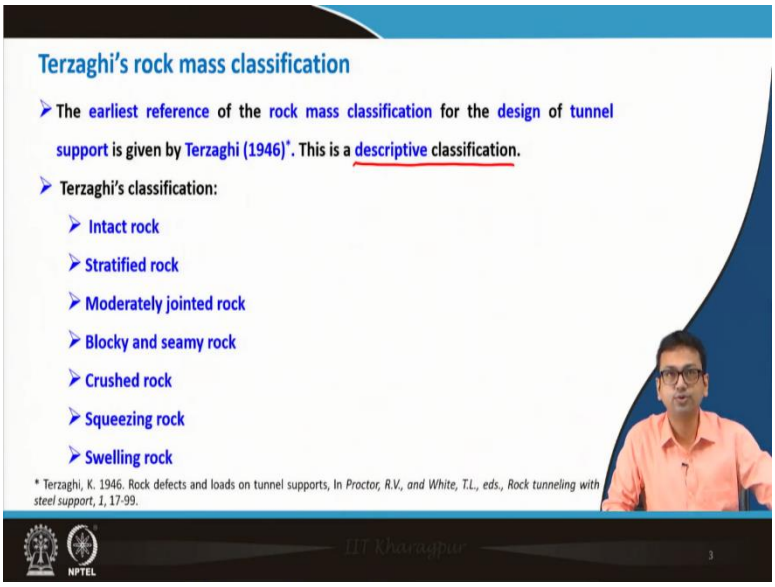

Terzaghi's rock mass classification. The earliest reference of the rock mass classification for the design of tunnel support is given by Terzaghi in 1946. It is a descriptive classification.

In Terzaghi's classification, the rock mass is divided into different categories- intact rock, stratified rock, moderately jointed rock, blocky and seamy rock, crushed rock, squeezing rock and swelling rock. This classification, as I have stated already, is descriptive classification not quantitative we should at least know about this classification system.

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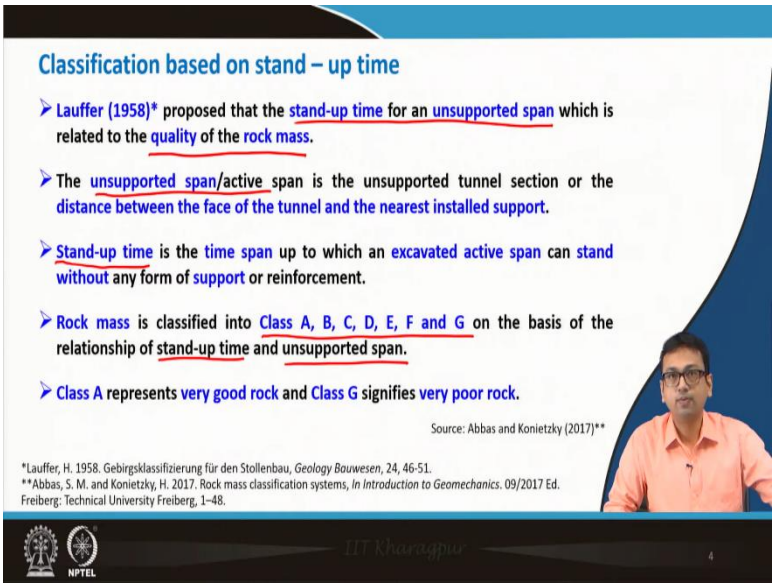

Let us discuss another classification system that is based on stand-up time. Lauffer 1958 proposed the stand-up time for an unsupported span which is related to the quality of the rock mass. What is an unsupported span or active span? The unsupported span or active span is the unsupported tunnel section or the distance between the face of the tunnel and the nearest installed support.

Stand-up time is the time span up to which an excavated active span can stand without any form of support or reinforcement.

We know an increase in the span of the tunnel leads to a significant reduction in the time available for the installation of the reinforcement. Rock mass as per stand-up time is classified into class A, class B, class C, class D, E, F and G. it is based on the relationship between stand-up time and unsupported span.

Stand-up time and unsupported span are two quite important terms. So, based on the relationship of stand-up time and the unsupported span, classes A to G divisions are there, where class A represents very good rock and class G signifies very poor rock.

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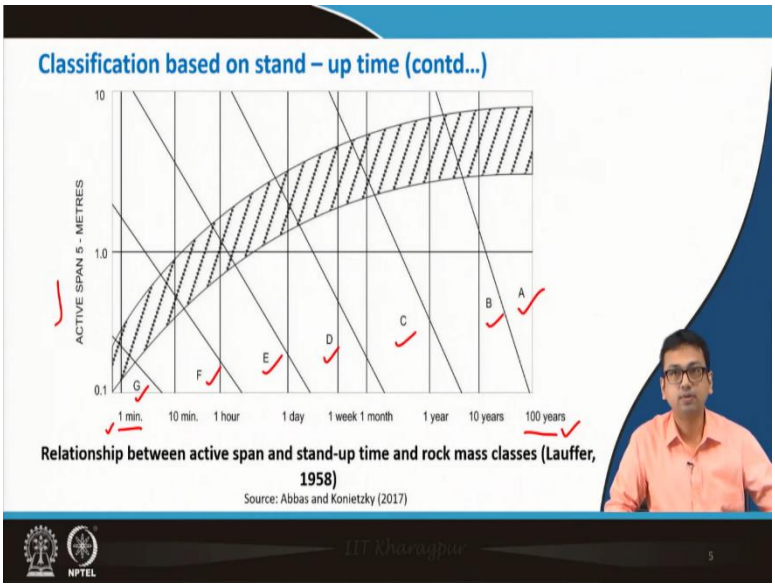

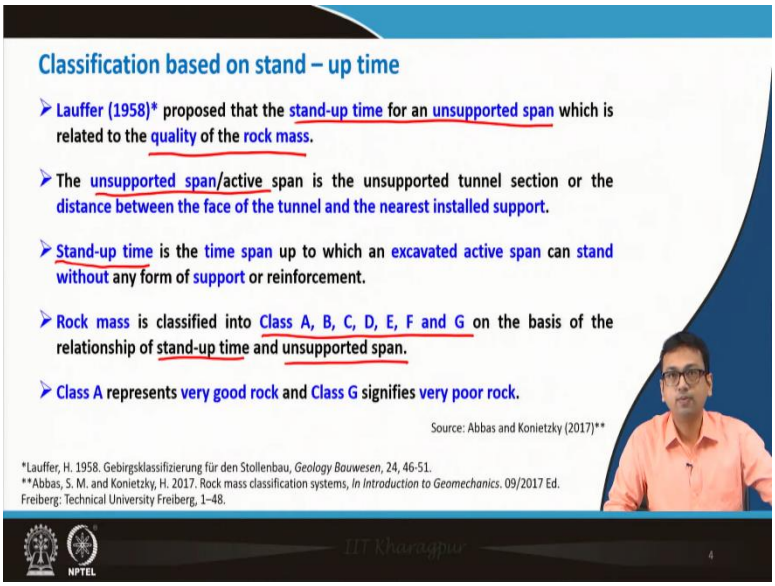

To understand the classification system better, refer to the figure in the slides- the y-axis is the active span and the x-axis represents stand-up time. A represents very good rock means, it will have more stand-up time and class G signifies very poor rock.

Now, we can see that the stand-up time is 1 minute for G whereas for A it is 100 years. So, this is quite a useful classification system to design the support system in case of a tunnel in the rock.

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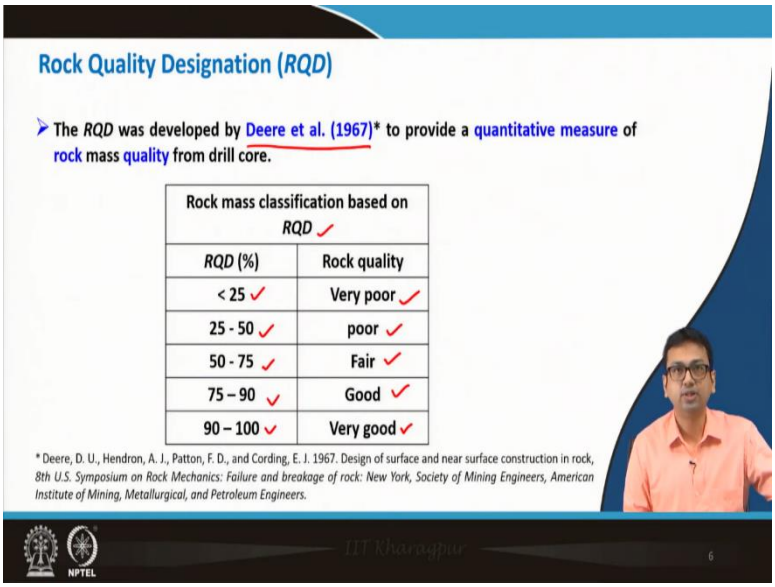

Now we will see the RQD, rock quality designations and the classification based on this. This is a very simple way of classifying the rock mass and RQD was developed by Deere et al. in 1967 to provide a quantitative measure of rock mass quality from drill core. We have already seen how to find out RQD.

Now, from the table shown before we know that when RQD is less than 25 per cent it indicates very poor quality rock likewise 25 to 50 is poor, 50 to 75 is fair, 75 to 90 is good and 90 to 100 is very good.

I would like to mention here that later we will see RQD become one of the important parameters for another type of classification system that is called the RMR system, the rock mass rating system.

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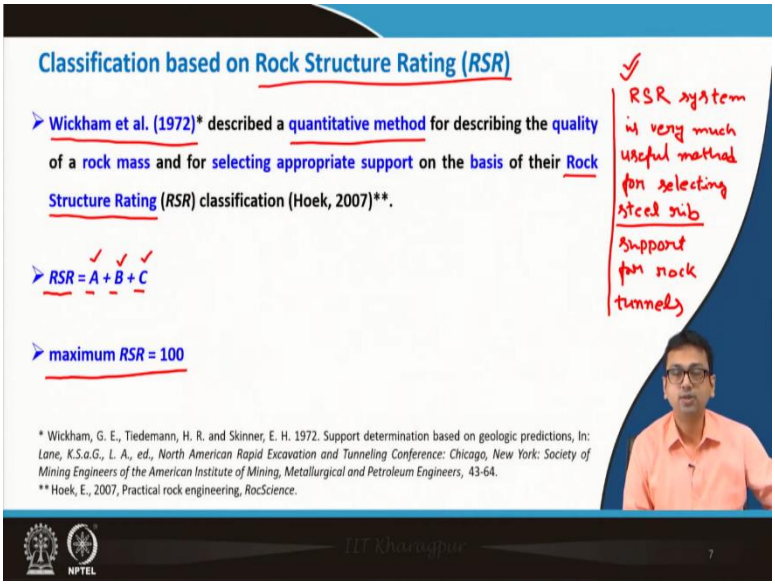

Now we will discuss the classification based on rock structure rating RSR. This rock structure rating concept is very useful. This classification system is very useful for selecting steel ribs. Steel ribs support when we are designing a tunnel in the rock.

Now, with a little background, Wickham et al. 1972 described a quantitative method. This is a quantitative method unlike Terzaghi's method which is descriptive.

Quantitative methods are always preferred because they give quantitative measure, numbers based on which we can classify the rock mass quite conveniently and that serves better2.

So, Wickham described a quantitative method for describing the quality of rock mass and for selecting appropriate support based on Rock Structure Rating classification. As already mentioned above RSR system is very much useful method for selecting steel rib support for rock tunnels.

Rock Structure Rating is the summation of three parameters that is A, B and C. Now, how to get A, B and C that we will see. Wickham et al. have provided three tables to extract values of parameter A, parameter B and parameter C.

From table 1, we will get this A parameter from table 2 we will get B parameter, from table C we will get C parameter and we will just add them. Now, one important thing is maximum RSR can be 100.

$$RSR = A + B + C$$

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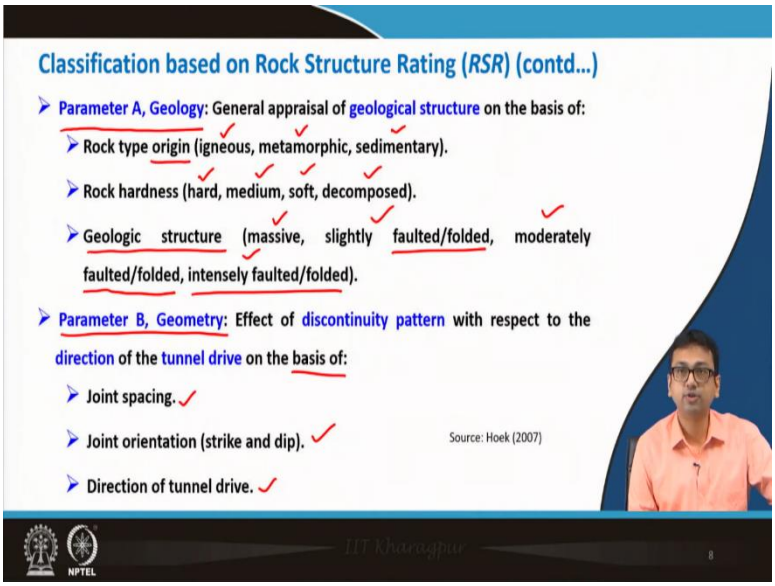

Now, this parameter A is corresponding to the geology. General appraisal of geological structure on the basis of few things, first very important thing is rock type origin.

In our first module we have discussed about rock mass classification based on origin, it can be divided in three categories-igneous rock, metamorphic rock, sedimentary rock. Second is rock hardness; whether the rock is hard or medium or soft or decomposed that will also become one of the important component of this classification system for finding parameter A.

And third one is geologic structure which means it may be massive, it may be slightly faulted or folded, then moderately faulted or folded and intensively faulted or folded. So, these four types of geological structures are also considered in this classification system to get parameter A.

Now, parameter B is related to the geometry. Effect of discontinuity pattern with respect to the direction of the tunnel drive based on joint spacing, joint orientation (strike and dip) the direction of the tunnel drive, direction of the tunnel drive. These three things we have to consider to get the parameter B which is related to the geometry.

I have stated it earlier also that for rock mass classification, along with the engineering properties of rock the condition of the discontinuities has a very important role as far as the rock mass classification is concerned.

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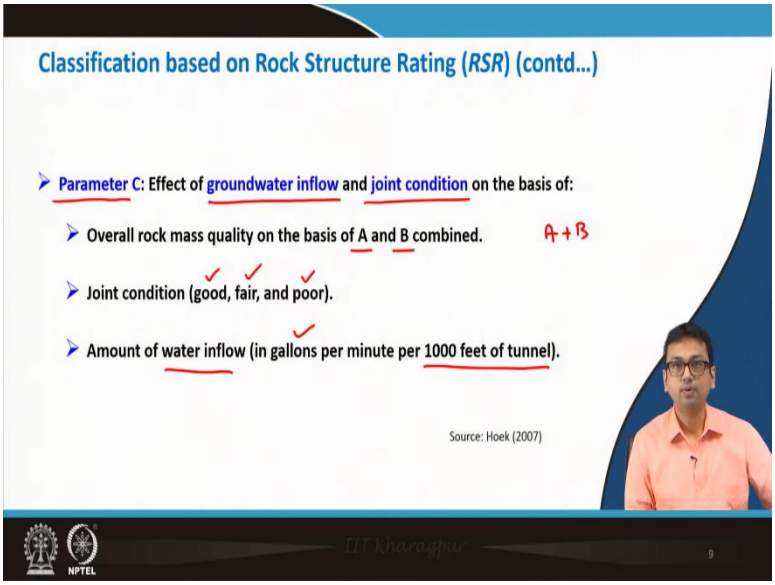

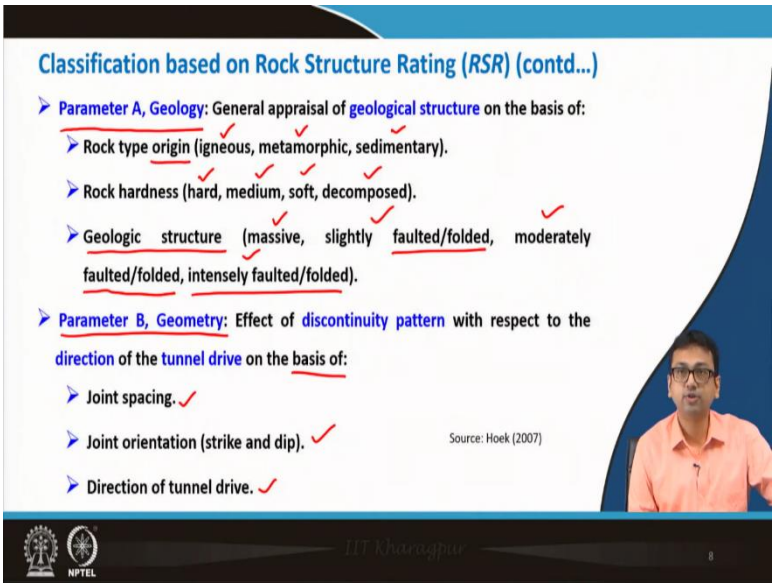

Now, parameters C, it gives us some idea about the effect of groundwater flow and joint condition on the basis of overall rock mass quality on the basis of A and B combined. In order to get parameter C, we have to already obtain rock mass quality on the basis of A and B.

We have to find out $A + B$. Then we have to consider a joint condition whether it is good, fair or poor and the amount of water inflow in gallons per minute per 1000 feet of tunnel. Now we have some idea about parameter A, parameter B and parameter C.

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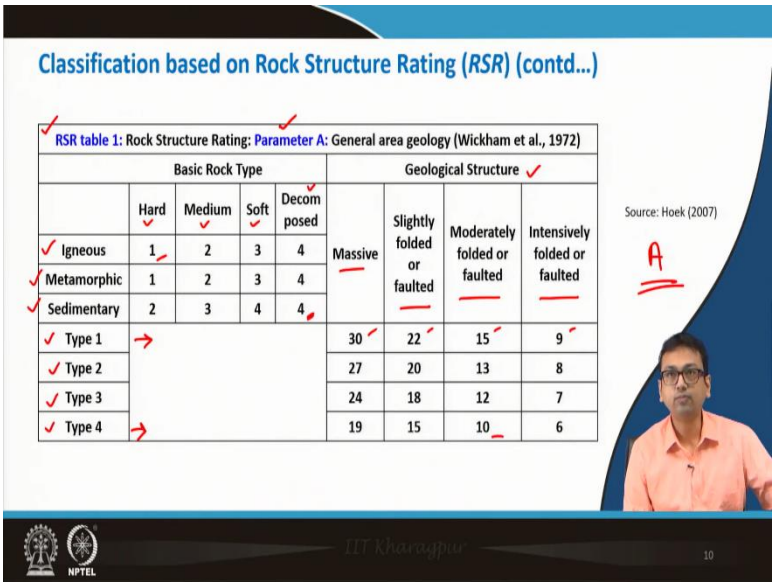

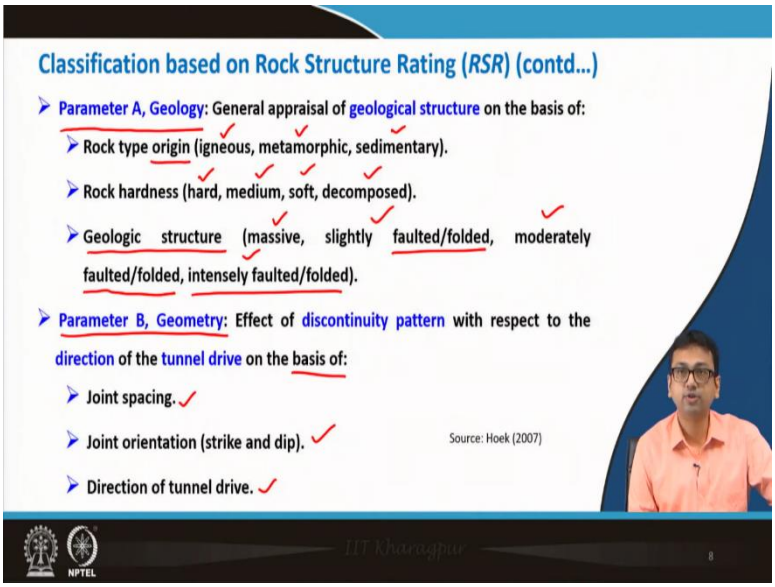

Now, let us see what the table will look like. So, RSR table 1 will give us parameter A. This is related to general area geology. So, this is something that we have to understand. The basic rock type is given as igneous, metamorphic, sedimentary as well as the hard, medium, soft, and decomposed parameters are there.

So based on rock type and rock hardness we will conclude its type i.e. type 1, type 2, type 3 or type 4 for instance if it is stated as hard igneous rock, then it is 1 and if it is stated as a decomposed sedimentary rock then it is 4. Now, once I conclude the type 1 then we have to notice the geological structure.

For geological structure means we have to see whether it is a massive structure or slightly faulted or folded or moderately faulted or folded or intensely faulted or folded.

So, suppose just for example, if the rock mass is hard igneous rock and the geological structure is massive, then hard igneous rock means type 1. Now, for type 1, if the geological structure is massive, then the A value will be 30. Now, for type 1, if the geological structure is intensively folded or faulted, then it reduces to 9.

Similarly, for type 4, just let us consider igneous rock decomposed. So, it is type 4. So, for type 4, if the geological structure is massive, then it is 19. Whereas, if the geological structure is moderately folded or faulted, then it is 10.

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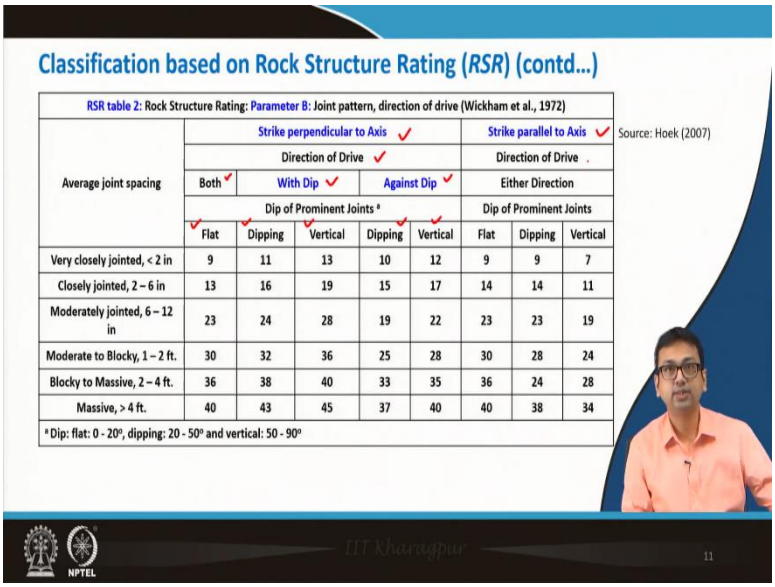

Now, problem, RSR table 2, which is related to the parameter B, where we focus on the joint pattern direction of this drive. Now, two things are important. One is we have to see whether the strike is perpendicular to the axis or the strike is parallel to the axis and other is the direction of drive.

The direction of drive that is either with dip or against dip or both and then dip of prominent joints given as like flat, dipping, vertical, dipping vertical.

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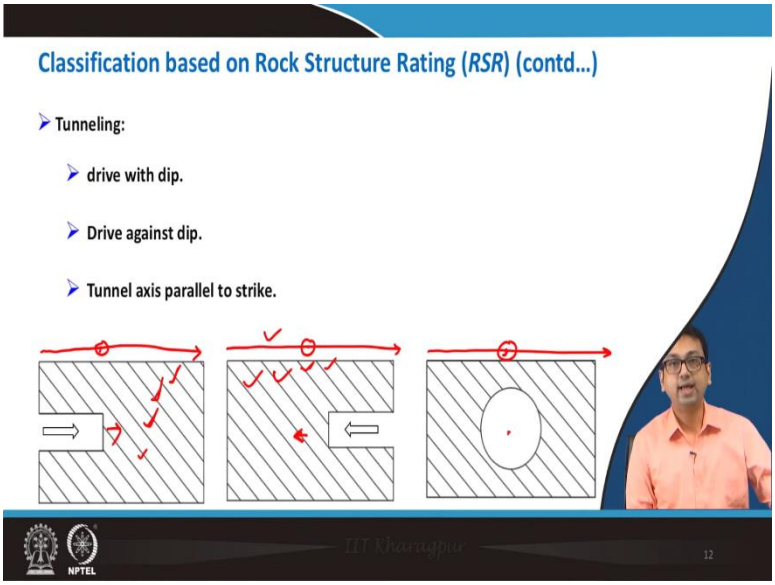

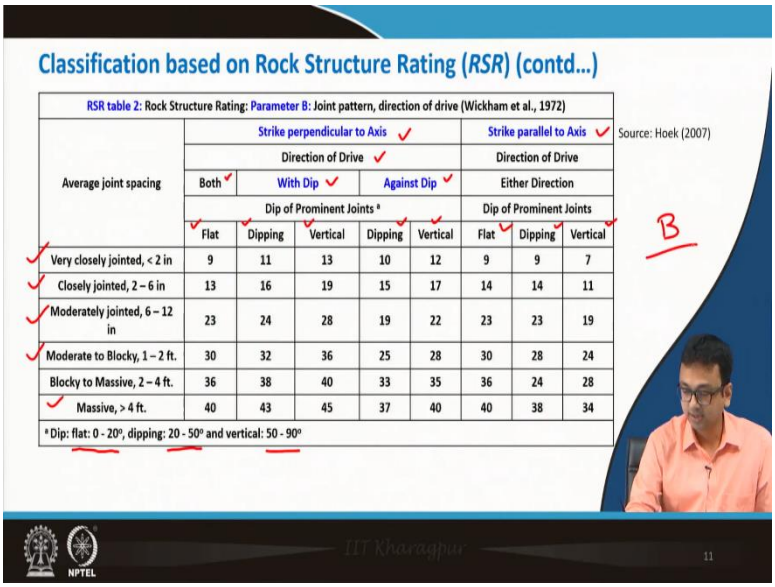

For a better understanding of drive with dip, drive against dip and strike parallel to the tunnel axis, refer to diagrams in the slide.

In the table, flat indicates dip is 0 to 20 degrees, dipping is 20 to 50 degrees and vertical is 50 to 90 degrees. Also, you see for strike parallel to the axis their direction of drive does not matter.

Then we can see average joint spacing as very closely jointed, closely jointed then moderately jointed and moderately jointed indicates 6 to 12 inches. Likewise moderate to blocky. So, this is 1 to 2 feet, likewise massive is greater than 4 feet. So, these parameters have to be considered to get parameter B.

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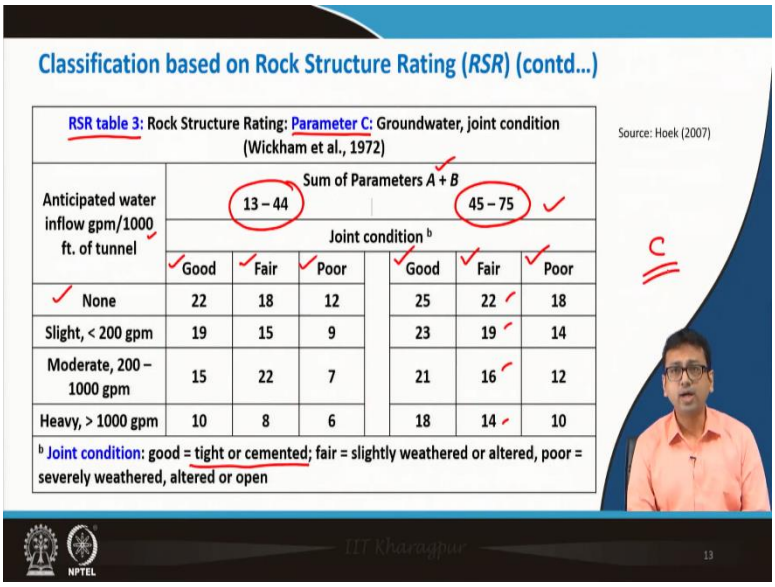

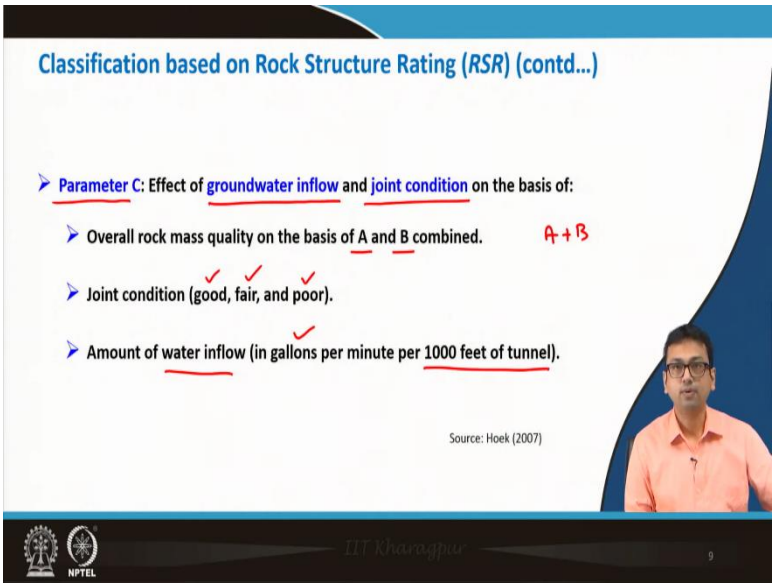

And now, the third parameter that is parameter C. For that the RSR table 3 we have to use and this is related to groundwater, joint condition and parameter A and B. So, now here first we have to find out $A + B$. We will get A and B from RSR table 1 and RSR table 2.

So, now you have to find out whether $A + B$ is falling in the range 13 to 44 or 45 to 75 and after that, we have to see what is the joint condition provided. It may be good, it may be fair, it may be poor for this 13 to 44 range as well as for 45 to 75 range also good, fair and poor.

Now, good joint condition tight or cemented likewise fair means slightly weathered or altered and poor indicates severely weathered, altered or opened. So, these three are the different conditions. Now, let us focus on the anticipated water inflow gallon per minute per 1000 feet of the tunnel. There are values for no water inflow. Suppose, we are getting $A + B$ as 50 then we have to focus on 45-75 part only.

Now, we have to see whether the joint condition is fair or good or poor, if it is fair then we have to look out for inflow conditions. If there is no water inflow then the C parameter will be 22. On the other hand, if it is slight means less than 200 gallons per minute, then it is 19 likewise, if it is heavy greater than 1000 gallons per minute then it is 14. So, in this way, we have to utilise this table 3 which will give us parameters C.

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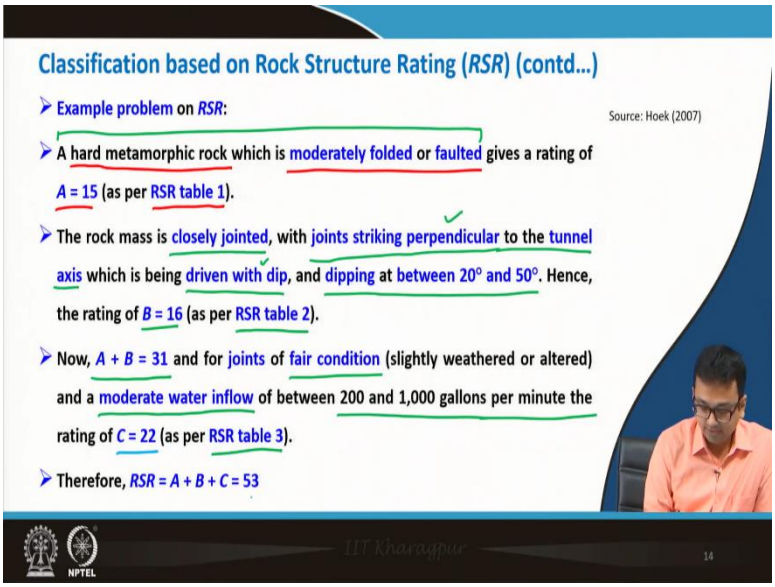

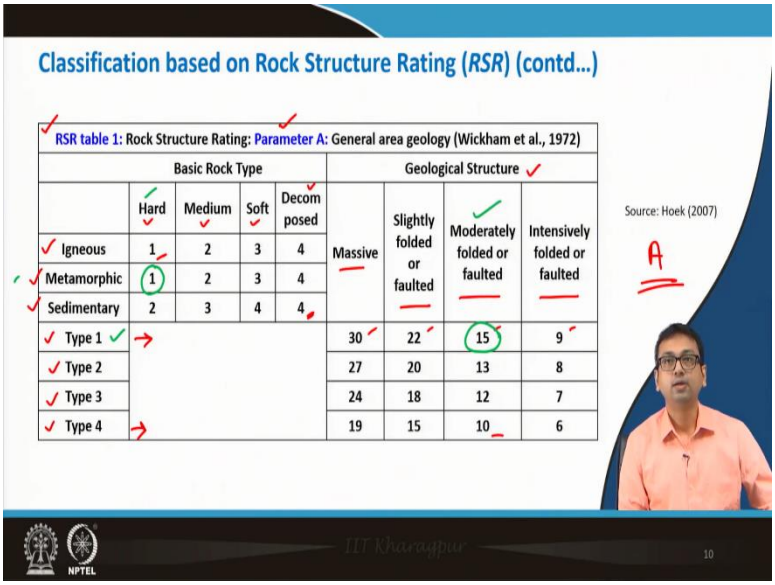

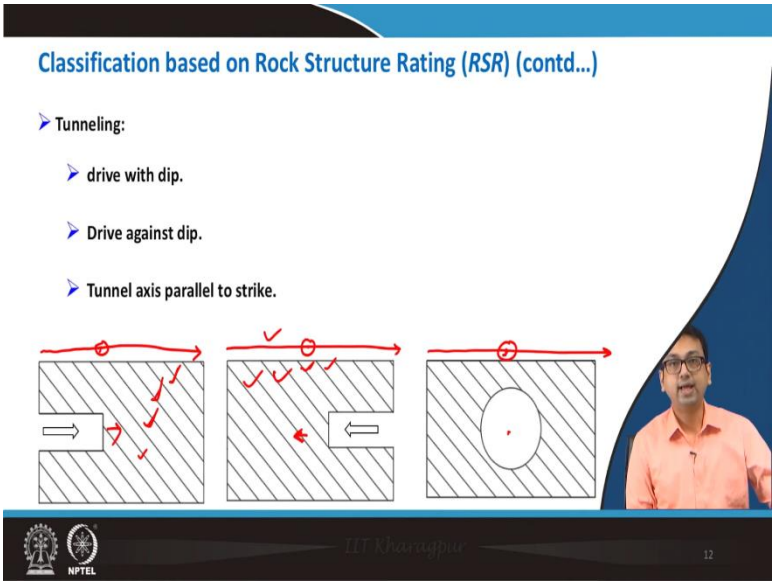

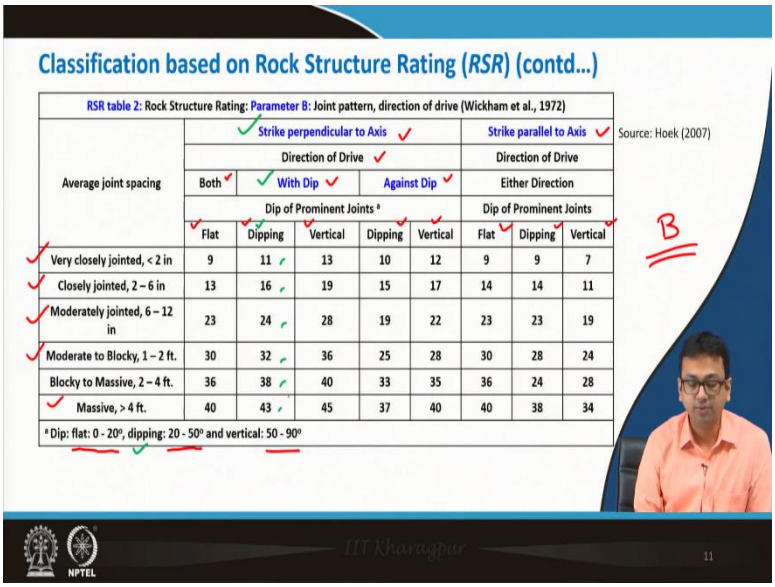

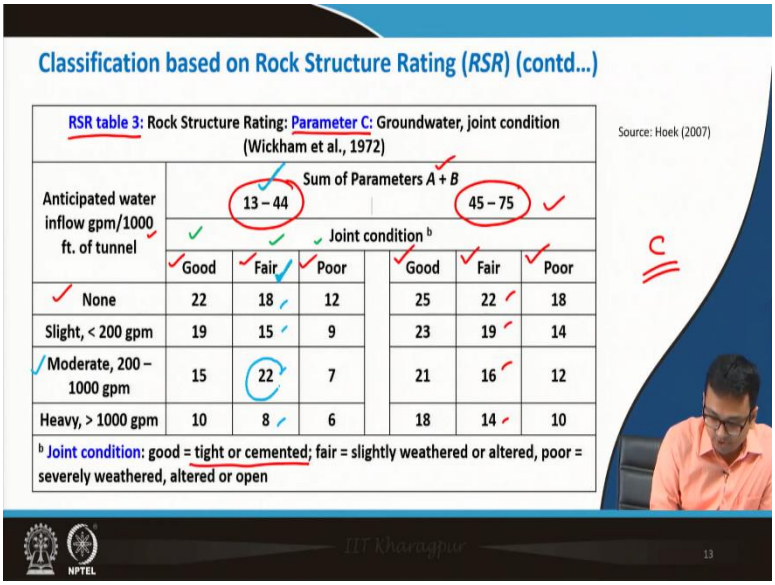

Now, I will take a small problem, and we will clear our doubt completely. So, example problem on RSR.

Suppose, it is given that a hard metamorphic rock is moderately folded or faulted, according to this what will be my A value? We have to see RSR table 1 and from there we have to find out what is A value. A value is 15.

In table 1, it can be seen that hard metamorphic rock is type 1.

So, now from this type 1, we have to choose the geological structure which is moderately folded or faulted. So, that indicates my A value is 15.

Now, let us see what about B, and what information we have regarding B. The rock mass is closely jointed, joints striking perpendicular to the tunnel axis which is being driven with dip. dipping at 20 to 50 degrees.

So, that also you have to consider so, if we have these four information like closely jointed, this joints striking perpendicular to the tunnel axis, then another information is driven with dip and dipping at between 20 degrees to 50 degrees. So, from there using RSR table 2 we can get our B value.

So, first we will see that so, strike perpendicular to the tunnel axis. So, fine and driven with dip. So, strike perpendicular this one we will choose, now driven with dip this one we will choose and then it is stated that dipping is 20 to 50 degrees. So, we will choose dipping.

So, basically out of all these columns, we are now focusing on dipping column of , strike perpendicular to the tunnel axis drive with dip. Now, we have to look at what type of joint it was stated. So, it is stating that the rock mass is closely jointed.

So, that means out of all these values, we have to choose 16. So, my B value is 16. Now, $A+B$ becomes 31 and it is stated that for joints of fair condition, fair condition means slightly weathered or altered and a moderate water flow and a moderate water flow of between 200 to 1000 gallons per minute.

We can obtain the rating from RSR table 3. So, let us see A plus B is 31, joints of fair condition and moderate water inflow. So, value 31 falls in 13-44 range. Now, joint of fair condition was stated . Now, under fair it may be 18, 15, 22 or 8 based on what is the water inflow condition. So, what is stated is moderate water flow. So, that means my C value is 22. So, now what we can say is my RSR is A plus B was 31 plus 22 is 53. So, if it is asked to find out the RSR value, it will be your answer. So, RSR is 53.

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So, with this, I am concluding my today's lecture. So, in our next lecture, we will start discussing the RMR classification system which is quite important and useful classification system. Thank you.