Rock Mechanics and Tunneling
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Lecture 24
Rock mass classification (continued)

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Hello everyone. I welcome all of you to the third lecture of module 5. In this module, we will continue our discussion on the rock mass classification.

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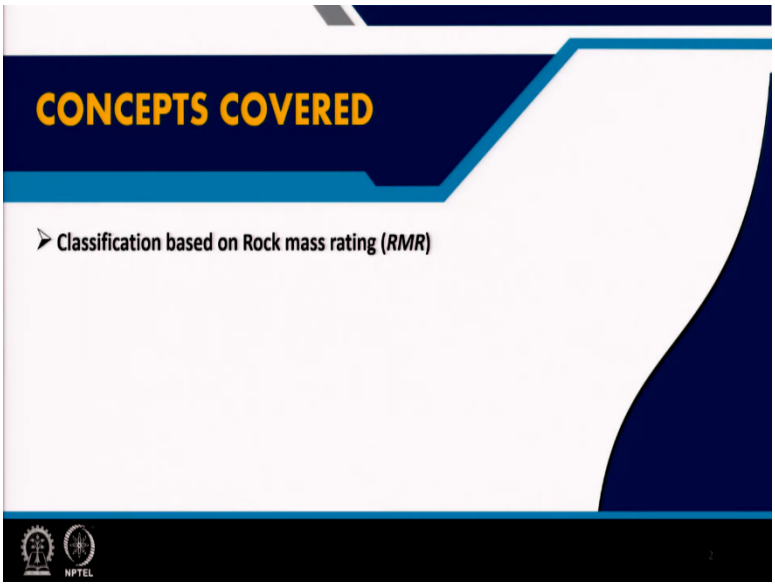

So, today we will discuss about one of the very important classification system, that is called the Rock mass rating, or RMR. We will solve couple of problems also.

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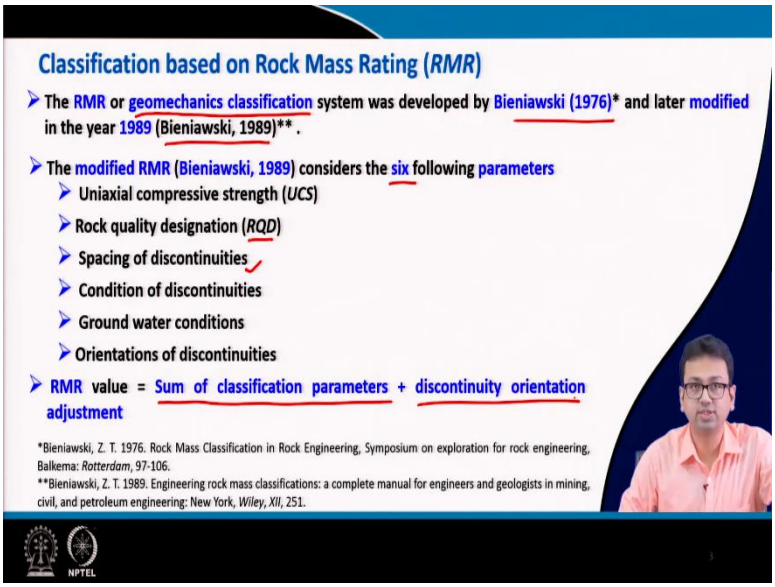

So, the RMR, also known as the geomechanics classification system was developed by Bieniawski in the year 1976 and later modified in the year 1989, by Bieniawski only. So, the RMR classification system which we will discuss today is the modified RMR which came in the year 1989. So, this modified RMR considers six parameters.

First is uniaxial compressive strength (UCS), point load strength index was also considered as one of them. We will see this in detail in a tabular form and we will understand in a better way.

Second is rock quality designation RQD. As we know that it is one of the important parameters in other classification systems like RMR.

Third is spacing of discontinuities. It is also one of the important parameter for this rock mass classification as per RMR system. Fourth is discontinuities. Fifth is groundwater conditions, it is one of the important parameter and sixth is the orientation of discontinuities, which again, is very important.

So, in this classification system, all these six parameters are considered the RMR value is obtained in the following way,

$$\text{RMR value} = \text{Sum of classification parameters} + \text{discontinuity orientation adjustment}$$

Let us now understand exactly this classification works.

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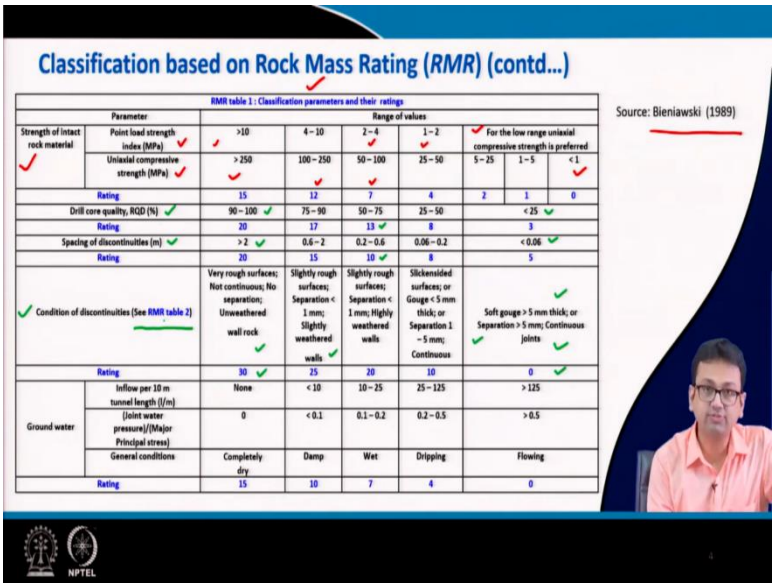

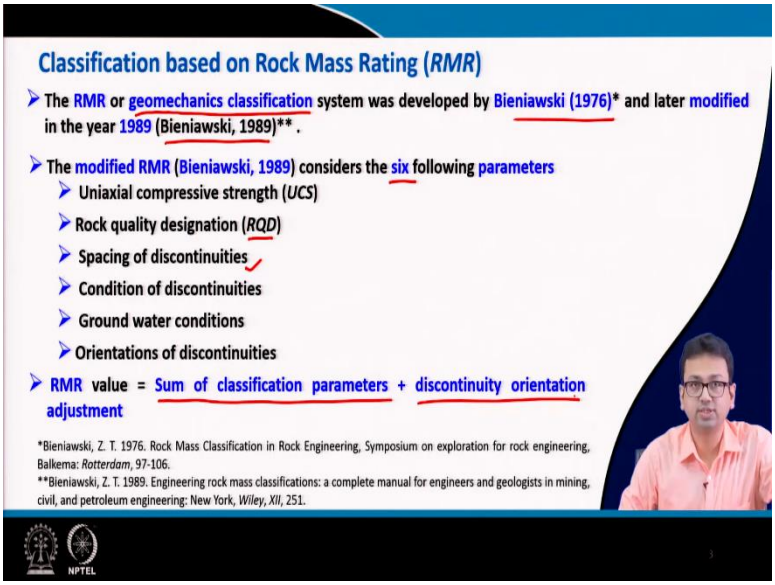

So, first we will see few tables given by Bieniawski. Let us focus over this table and try to understand it. So, you can see that in heading classification parameters and their ratings is given. And here first thing what we can see, the strength of intact rock material.

So, under parameter column you can see strength of intact rock material. It may be UCS value or point load strength index value. As already told UCS is preferable, but if UCS is not available, then we can go for the point load strength index.

Now it can be seen that the UCS range is given from less than 1 MPa to greater than 250 MPa whereas, point load strength index is from 1 MPa to greater than 10 MPa but remember that for the low range uniaxial compressive strength is preferred.

For instance if after conducting the UCS test we are getting the uniaxial compressive strength as 200 MPa then my rating for strength of intact rock material will be 12 or similarly, if I

have the point load strength index available and that is 3 MPa then corresponding rating for strength of intact rock will be 7.

Now, similarly, if I consider the second parameter i.e. RQD. So, RQD ranges from less than 25% to 90% - 100% is given and if we know the RQD value suppose 60 %, then for RQD component will be 13.

Similarly, third parameter was spacing of discontinuities. It ranges from than 0.06 meter to greater than 2 metres and corresponding ratings are provided. Suppose, the spacing is 0.4 metre then corresponding rating will be 10.

Next one was condition of discontinuities. So, now, for condition of discontinuities different conditions are given. First one is, very rough surfaces, not continuous, no separation and unweathered wall rock. Second one is, slightly rough surfaces, separation less than 1 millimetre and slightly weathered rock likewise, the last one is soft gouge greater than 5 mm thick or separation greater than 5 mm continuous joints. Corresponding ratings are given below the ranges, like for last case it is 0 and for very rough surfaces it is 30. Now, this is will if the, if we get some little extra information regarding the condition of discontinuities, then you see it is written that see RMR table 2.

If you have less information available on discontinuity condition use this table 1 only, but if you have a little more information available then refer to RMR table 2 provided here.

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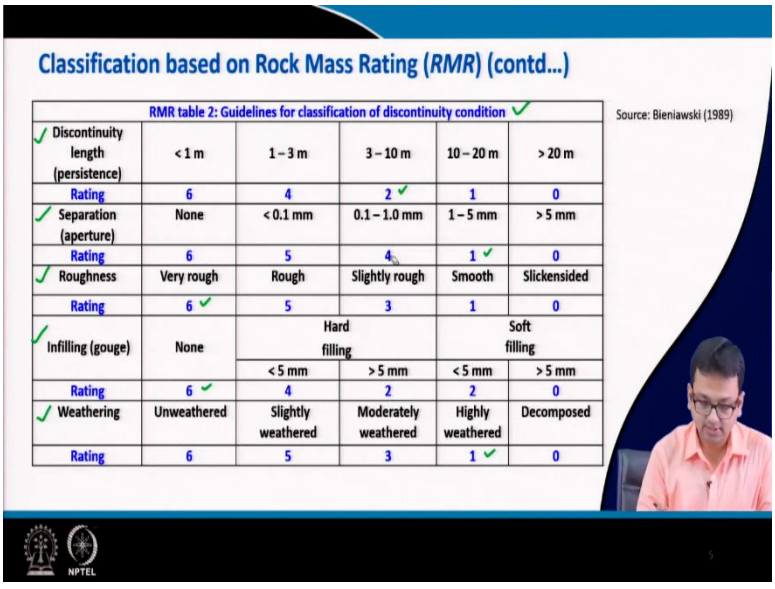

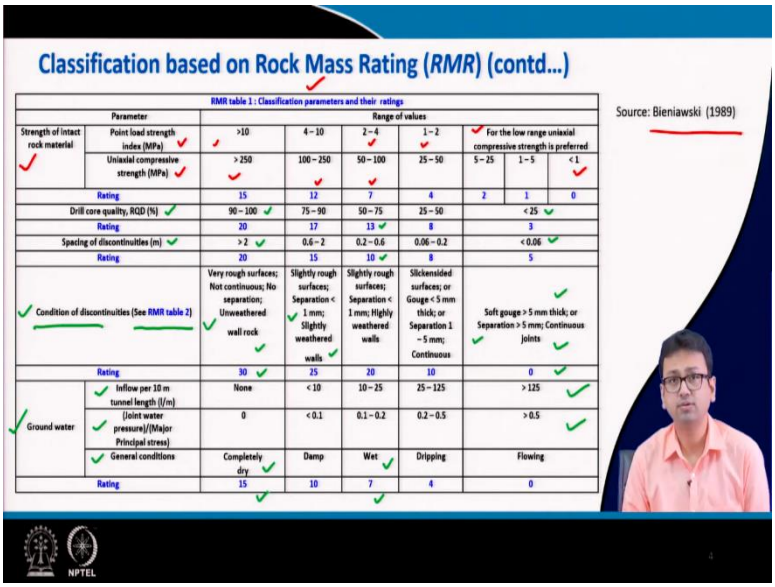

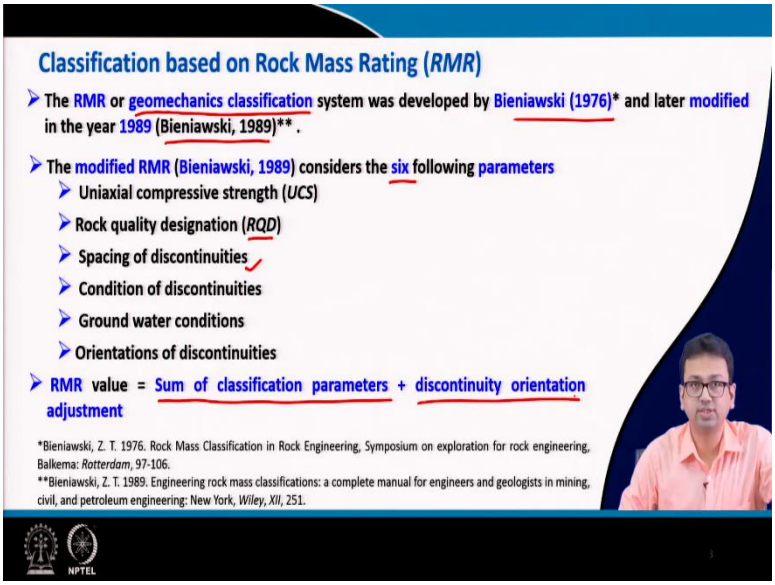

RMR table 2 is the guideline for classification of discontinuity condition. So, if the persistence or discontinuity length, the separation or aperture, roughness, infilling, and weathering are known to us then instead of using table 1, we will use more detailed table 2 which is given by Bieniawski.

So, suppose if the discontinuity length is 4 metres, then the rating will be 2, likewise, if it is stated that the aperture is 2 millimetre then it will have a rating of 1 likewise, if it is stated as very rough then it will be 6, then if no infilling is there the rating will be 6 and again for weathering if it is stated that the condition is highly weathered then it is 1. Table 2 is to be used when all the above stated information is given otherwise table 1 is preferred.

Next parameter in table 2 is groundwater condition. Different conditions like inflow per 10 metre tunnel length, joint water pressure by major principle stress and general conditions.

Most of the time we will see these general conditions will be provided but if more information is provided regarding the inflow and joint water pressure by major principle stress, then we should look into respective quantitative values.

If it is stated that the general condition is wet, then the rating will be 7. If it is stated as completely dry condition, then the rating will be 15 for groundwater condition.

Now, last one is orientation of discontinuities. For thia we have table 3 given by Bieniawski

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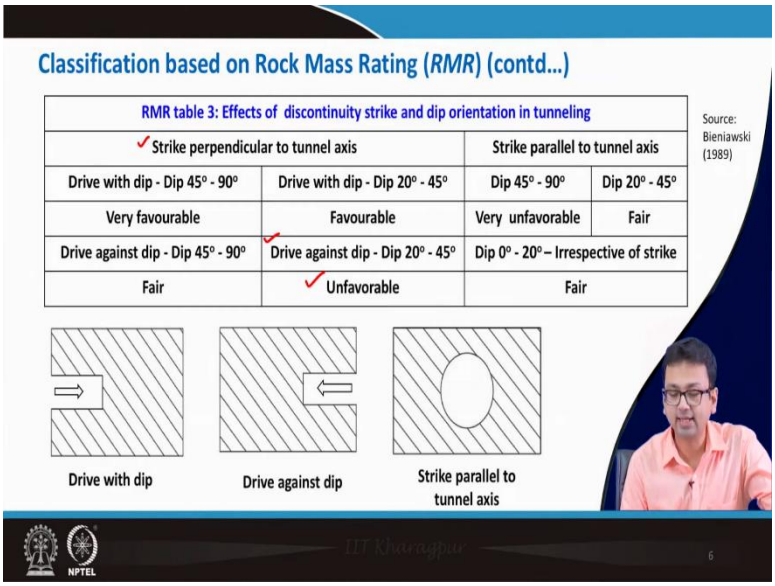

Two conditions in this table are strike perpendicular to the tunnel axis and strike parallel to the tunnel axis. Now, for strike perpendicular to the tunnel axis, it may be drive with dip or drive against dip (explained in the figures below the table).

Now, again for the drive with the dip condition, if the dip is 45 degrees to 90 degrees then it is declared as a very favourable whereas, if it is 20 to 40 degree it is favourable. For drive against dip if dip is 45 to 90 degrees then it is fair and if dip is 20 to 45 degrees, it is unfavourable.

Now, for the case where strike is parallel to tunnel axis, if the dip is 40 to 90 degree it is very unfavourable and if the dip is 20 to 45 degree it is fair. Now, irrespective of the strike, dip of 0 to 20 degrees, it is considered as fair. Now, terms like very favourable, favourable, fair, unfavourable got from table will be used in our next table which is table 4.

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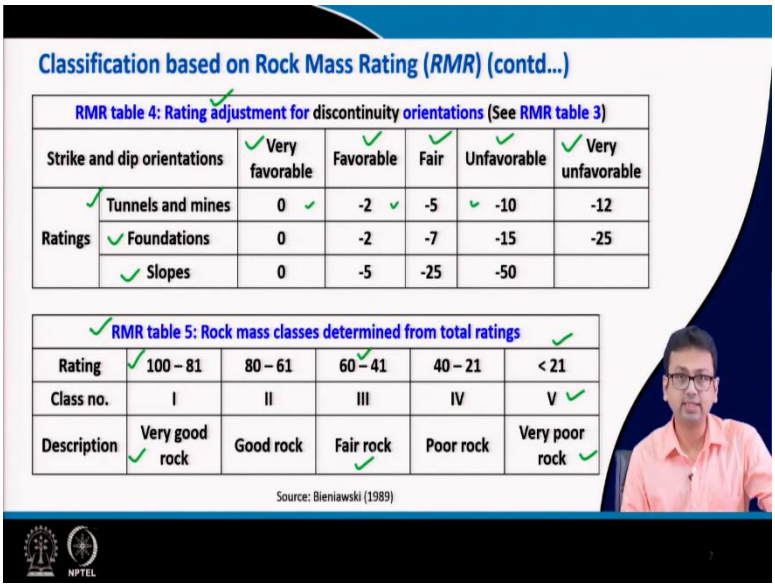

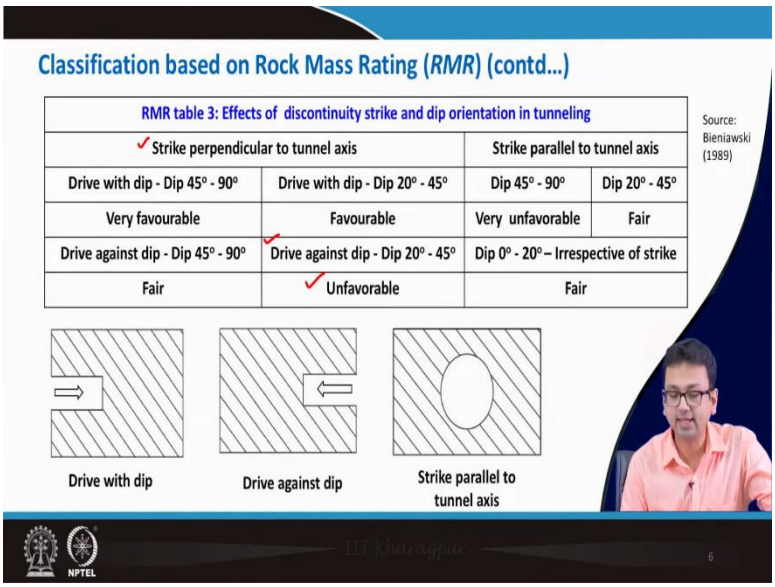

Table 4 is regarding the rating adjustment for discontinuity orientation. Using the terminologies from table 3 we get the adjusted rating in table 4 for tunnels and mines or foundations or slopes.

Now, algebraic sum of all the ratings will give the rock mass rating, the RMR value and based on that using table 5 we can get rock mass classes. For example if the RMR value is falling under 81 to 100, then it is class number 1 and it can be described as a very good rock whereas, if your total RMR becomes less than 21, then it is class 5 which means very poor rock, if you get an RMR of 50, it falls in class 3 which describes as fair rock.

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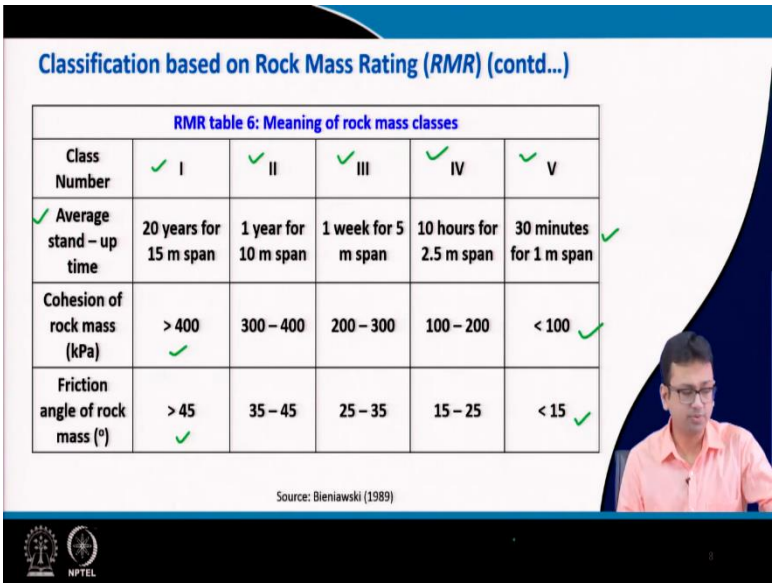

Based on these five tables type of rock can be concluded. Table 6 provided by Bienaiwski defines the meaning of different classes

Class 1 indicates average stand-up time of 20 years for 15 metres span. Cohesion of rock mass greater than 400 kPa and friction angle of rock mass is greater than 45 degree whereas, if rock mass falls under class number 5, then the average stand-up time is 30 minutes for 1 metre span which is not a good sign. Then cohesion is less than 100 kPa and friction angle is less than 15 degrees.

So, using these six tables, we can get a lot of information about the rock which may be useful for our design purpose.

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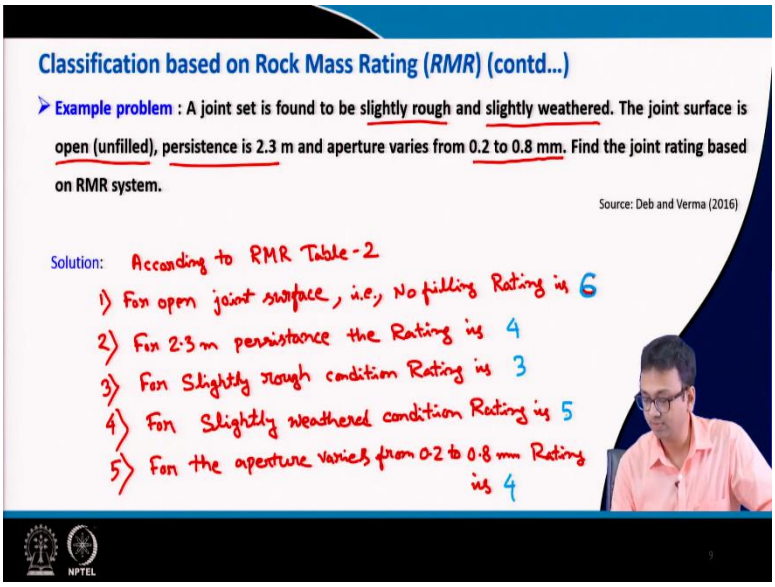

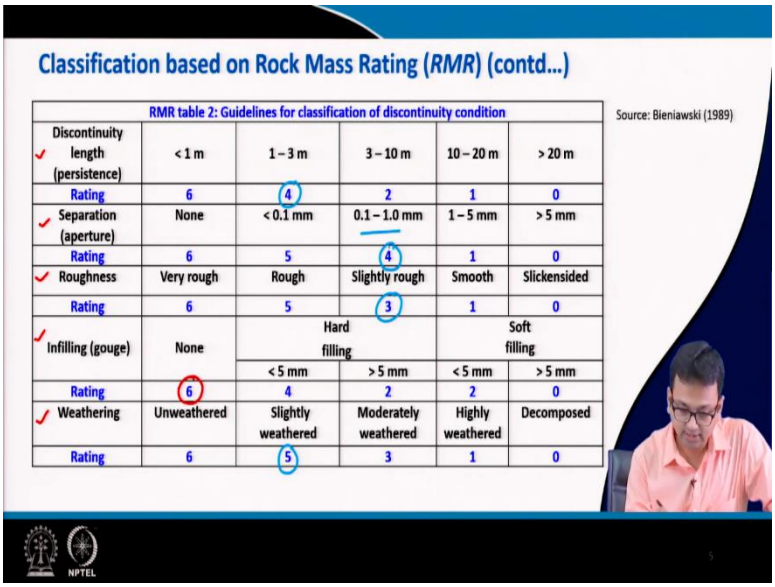

Now, let us take the problem and let us try to understand how to utilize this table and find out the RMR value.

Example problem: A joint set is found to be slightly rough and slightly weathered. That joint surface is open (unfilled). Persistence is 2.3 metres and aperture varies from 0.2 to 0.8 millimetre. Find the joint rating based on RMR system.

Solution:

According to RMR table 2

1) for open joint surface, i.e., no filling rating is 6
2) for 2.3 metre persistence the rating is 4
3) for slightly rough condition rating is 3
4) for slightly weathered condition rating is 5
5) for the aperture varies from, varies from 0.2 to 0.8 millimetre rating is 4

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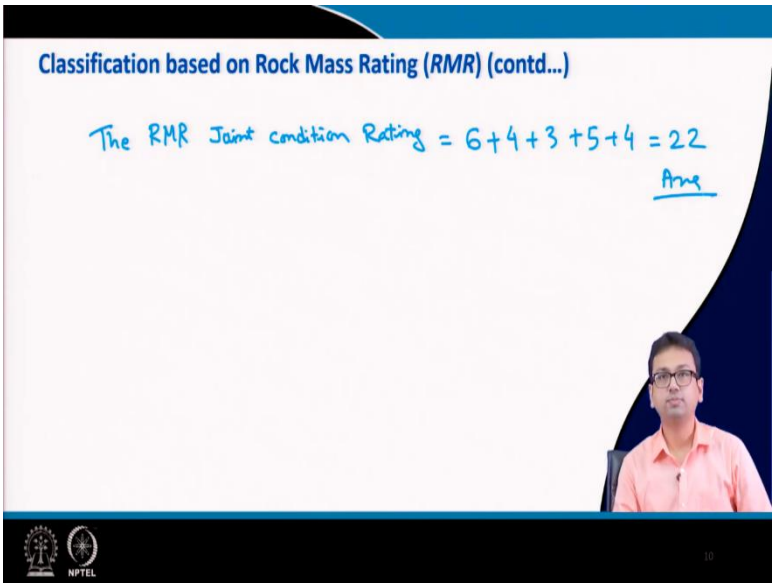

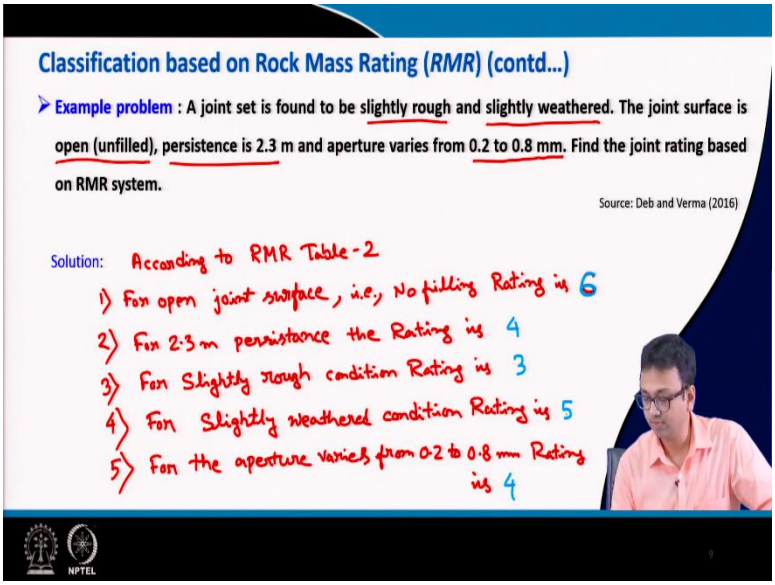

The RMR joint condition rating $= 6 + 4 + 3 + 5 + 4 = 22$ (Ans)

Quite simple!

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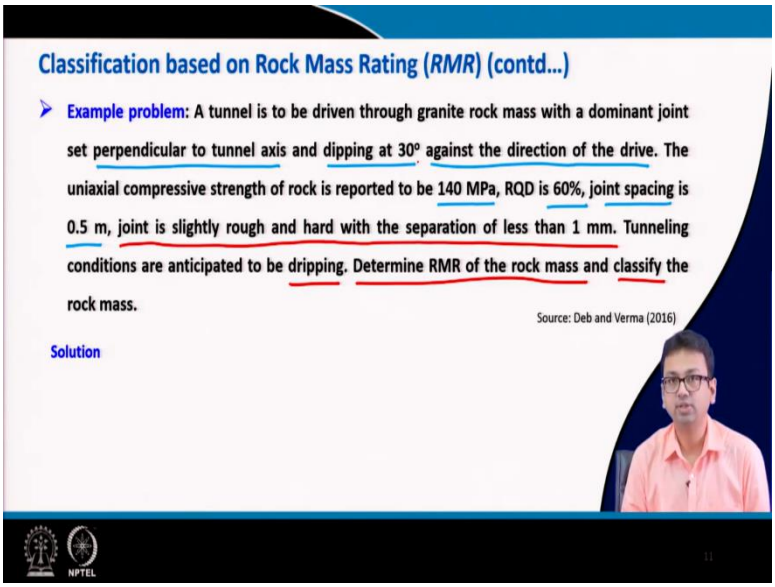

Now, let us take another problem where we will consider total RMR.

Example problem: A tunnel is to be driven through granite rock mass with a dominant joint set perpendicular to the tunnel axis and dipping at 30 degrees against the direction of the drive. The uniaxial compressive strength of rock is reported to be 140 MPa, RQD is 60%, joint spacing is 0.5 m, joint is slightly rough and hard with the separation of less than 1 mm. Tunnelling conditions are anticipated to be dripping. Determine the RMR of the rock mass and classify the rock mass.

Solution: Prepare a table for the ease of solving the problem

Classification parameters	**Description**	**According to RMR table**	**Rating**
Strength of intact rock materials(UCS)	140 MPa	1	12
RQD	60%	1	13
Spacing of discontinuities	0.5 m	1	10
Condition of discontinuities	Slightly rough surfaces, separation<1mm, hard joint rock	1	20
Ground water	Dripping	1	4
Adjustment for discontinuity orientation	Unfavorable	3 and 4	-10
		Total RMR value	49

The rock can be considered as fair rock (as per RMR table 5) (Ans)

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Classification based on Rock Mass Rating (*RMR*) (contd...)

Classification parameters	Description	According to RMR table	Rating
Strength of intact rock material (UCS)	140 MPa	1	12
RQD	60%	1	13
Spacing of discontinuities	0.5 m	1	10
Condition of discontinuities	Slightly rough surfaces, separation < 1 mm, hard joint Rock	1	20
Ground water	Dripping	1	4
Adjustment for discontinuity orientation	Unfavorable, Tunnel	3 and 4	−10
		Total RMR value	49

- The rock can be considered as fair rock (as per RMR table 5).

Classification based on Rock Mass Rating (*RMR*) (contd...)

- **Example problem:** A tunnel is to be driven through granite rock mass with a dominant joint set perpendicular to tunnel axis and dipping at 30° against the direction of the drive. The uniaxial compressive strength of rock is reported to be 140 MPa, RQD is 60%, joint spacing is 0.5 m, joint is slightly rough and hard with the separation of less than 1 mm. Tunneling conditions are anticipated to be dripping. Determine RMR of the rock mass and classify the rock mass.

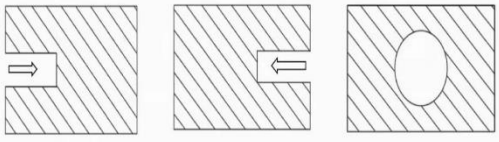
Source: Deb and Verma (2016)

Solution

Classification based on Rock Mass Rating (*RMR*) (contd...)

RMR table 3: Effects of discontinuity strike and dip orientation in tunneling			
Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45° - 90°	Drive with dip - Dip 20° - 45°	Dip 45° - 90°	Dip 20° - 45°
Very favourable	Favourable	Very unfavorable	Fair
Drive against dip - Dip 45° - 90°	Drive against dip - Dip 20° - 45°	Dip 0° - 20° – Irrespective of strike	
Fair	Unfavorable	Fair	

Source: Bieniawski (1989)



Drive with dip | Drive against dip | Strike parallel to tunnel axis

Classification based on Rock Mass Rating (*RMR*) (contd...)

RMR table 4: Rating adjustment for discontinuity orientations (See RMR table 3)

Strike and dip orientations		Very favorable	Favorable	Fair	Unfavorable	Very unfavorable
Ratings	Tunnels and mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

RMR table 5: Rock mass classes determined from total ratings

Rating	100 – 81	80 – 61	60 – 41	40 – 21	< 21
Class no.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

Source: Bieniawski (1989)

Classification based on Rock Mass Rating (*RMR*) (contd...)

RMR table 1: Classification parameters and their ratings

Parameter		Range of values						
Strength of intact rock material	Point load strength index (MPa)	>10	4 – 10	2 – 4	1 – 2	For the low range uniaxial compressive strength is preferred		
	Uniaxial compressive strength (MPa)	> 250	100 – 250	50 – 100	25 – 50	5 – 25	1 – 5	< 1
Rating		15	12	7	4	2	1	0
Drill core quality, RQD (%)		90 – 100	75 – 90	50 – 75	25 – 50	< 25		
Rating		20	17	13	8	3		
Spacing of discontinuities (m)		> 2	0.6 – 2	0.2 – 0.6	0.06 – 0.2	< 0.06		
Rating		20	15	10	8	5		
Condition of discontinuities (See RMR table 2)		Very rough surfaces; Not continuous; No separation; Unweathered wall rock	Slightly rough surfaces; Separation < 1 mm; Slightly weathered walls	Slightly rough surfaces; Separation < 1 mm; Highly weathered walls	Slickensided surfaces; or Gouge < 5 mm thick; or Separation 1 – 5 mm; Continuous	Soft gouge > 5 mm thick; or Separation > 5 mm; Continuous joints		
Rating		30	25	20	10	0		
Ground water	Inflow per 10 m tunnel length (l/m)	None	< 10	10 – 25	25 – 125	> 125		
	(Joint water pressure)/(Major Principal stress)	0	< 0.1	0.1 – 0.2	0.2 – 0.5	> 0.5		
	General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
Rating		15	10	7	4	0		

Source: Bieniawski (1989)

Classification based on Rock Mass Rating (*RMR*) (contd...)

RMR table 2: Guidelines for classification of discontinuity condition

Discontinuity length (persistence)	< 1 m	1 – 3 m	3 – 10 m	10 – 20 m	> 20 m
Rating	6	4	2	1	0
Separation (aperture)	None	< 0.1 mm	0.1 – 1.0 mm	1 – 5 mm	> 5 mm
Rating	6	5	4	1	0
Roughness	Very rough	Rough	Slightly rough	Smooth	Slickensided
Rating	6	5	3	1	0
Infilling (gouge)	None	Hard filling		Soft filling	
		< 5 mm	> 5 mm	< 5 mm	> 5 mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Rating	6	5	3	1	0

Source: Bieniawski (1989)

Today we will conclude here. In our next class, we will take another problem on RMR which will clear the doubts if any. So, thank you.