Rock Engineering

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Lecture – 24
Classification of Rock Mass: Rock Mass Quality (Q-system) - 2

Hello everyone, in the previous class we had discussed about the classification of the rock mass and in that one we studied about the classification system that is Q-system. And I mentioned to you that there are 6 parameters which are used to evaluate the index Q and we saw the details of all those 6 parameters along with the procedure to obtain their rating. So today we are going to discuss few other issues related to all those parameters and then we will see how on the basis of this Q index one can define the rock mass and finally we will see the application of this Q-system.

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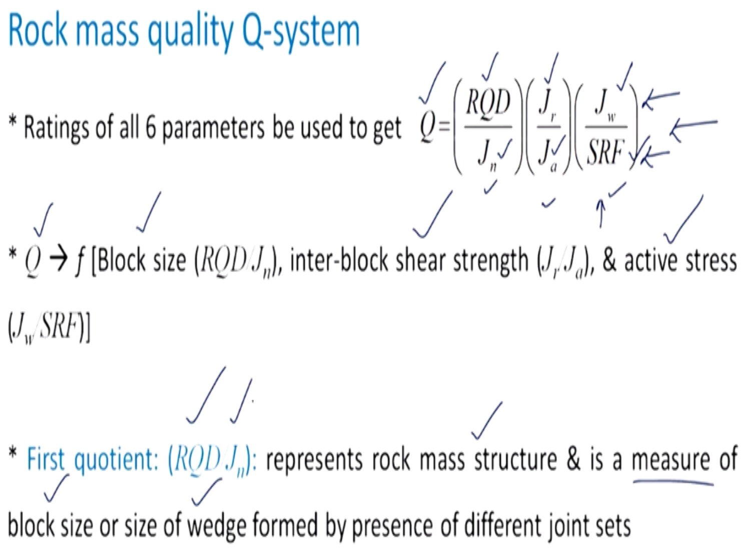

So as I mentioned that we had 6 parameters RQD, J n, J r, J a, J w and SRF and I mentioned to you that higher values of each of these parameters in the numerator it represents the better quality of rock mass and lower values of these parameters which are there in the denominator that also represent the better quality of the rock mass. So, we saw that there are various tables which can be used to assign the rating to each of these parameters.

Just substitute all those values in this expression and one can obtain the index Q. So, basically this Q is a function of these 3 quotients. The first one represents the block size physically. The second one deals with the inter-block shear strength because both these parameters J_r and

J_a they are related to the joint that is the one is related to joint roughness, and another one is related to joint alteration.

So depending upon the condition of the joint the shear strength will be decided. So that is why the second quotient decides about the inter-block shear strength. And the third quotient that is J_w upon SRF, it deals with the active stress. So, coming back to the first quotient once again which is defined as RQD upon J_n it represents the rock mass structure and it is a measure of block size or the size of wedge which is formed by the presence of different joint sets.

Larger is the RQD bigger will be the block size and therefore you will have this first quotient be representative of the block size.

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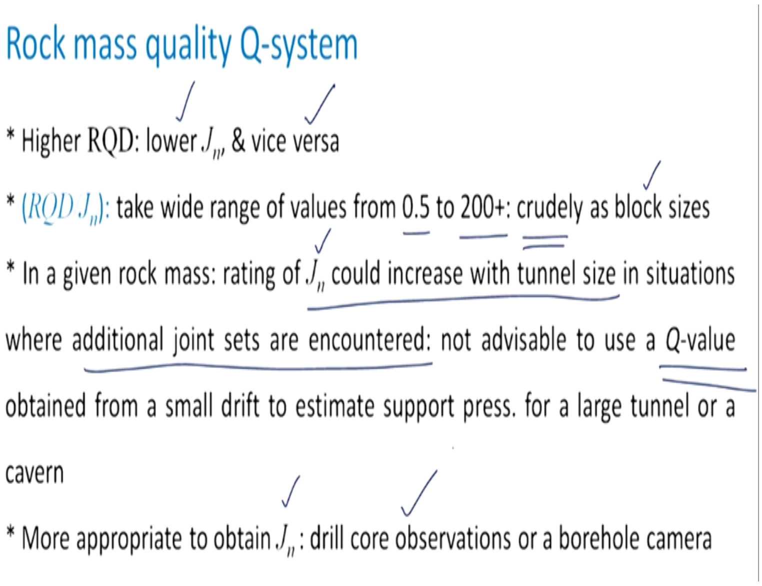

Higher RQD, lower J_n and of course vice versa, so this RQD upon J_n it takes wide range of values from 0.5 to as high as 200 plus. So, it gives us the idea about the block sizes in a crude manner. In a given rock mass, the rating of J_n could increase with the increase in the tunnel size in the situations where additional joint sets are encountered. So, in such cases it is not advisable to use a Q value which is obtained from a small drift to estimate the support pressure for a large tunnel or a cavern.

So, one is to be careful about these issues that when we go to the field sometimes it is required to excavate a small size tunnel in order to have these observations. So, in case you have such type of situation where J_n could increase with the tunnel size and where the additional joint sets are encountered, one should not rely on the Q-value. It is more appropriate to obtain J_n in such cases from the drill core observations or a borehole camera.

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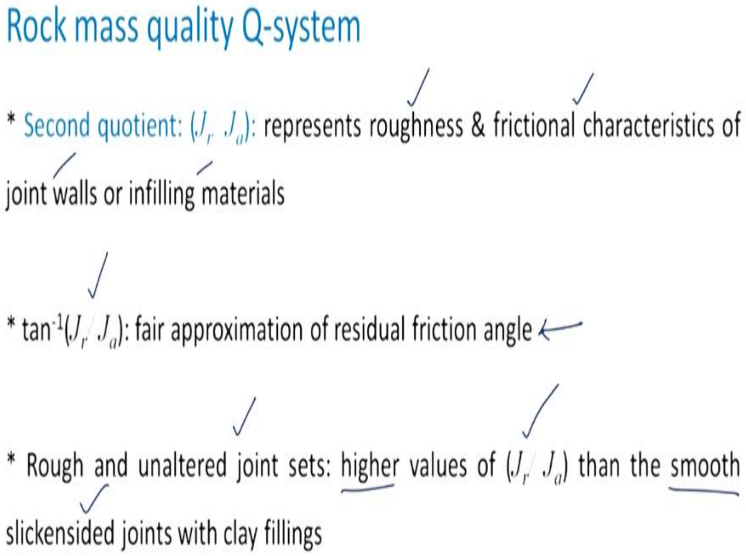

Second quotient is defined by J_r upon J_a, it represents the roughness and the frictional characteristics of joint walls or infilling material. The inverse tangent of this quotient that is $\tan^{-1}$ (J_r/J_a) it gives us the idea about the residual frictional angle. In case if you have rough and unaltered joint sets, these will have higher values of this quotient J_r upon J_a as compared to that of the smooth slicken sided joints with clay filling.

So better is the roughness characteristic of the joint higher will be the value of this second quotient J_r upon J_a.

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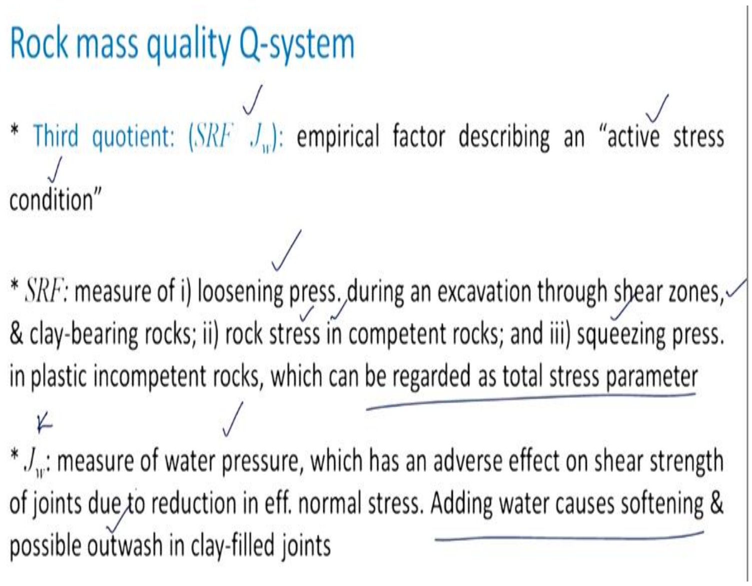

Now the third quotient is SRF upon J_w. It is an empirical factor which describes an active stress condition. I mentioned to you that this SRF is a measure of loosening pressure during an excavation through shear zones and clay bearing rocks. Second was rock stress in the competent rocks and the third was the squeezing pressure in plastic incompetent rocks and this can be regarded as the total stress parameter.

And if you recall our discussion in the previous class when we were assigning the rating to this JRF we considered each of these conditions in that table. Coming to the parameter which is J_w a measure of the water pressure, obviously when the water is there it will have an adverse effect on the shear strength. Because of the simple reason that the presence of the water makes the effective normal stress reduce and therefore the strength characteristic also reduces.

So, adding the water causes softening and there may be possible outwash in the clay filled joints. So, this whole thing gives the reduction in the shear strength of the joints.

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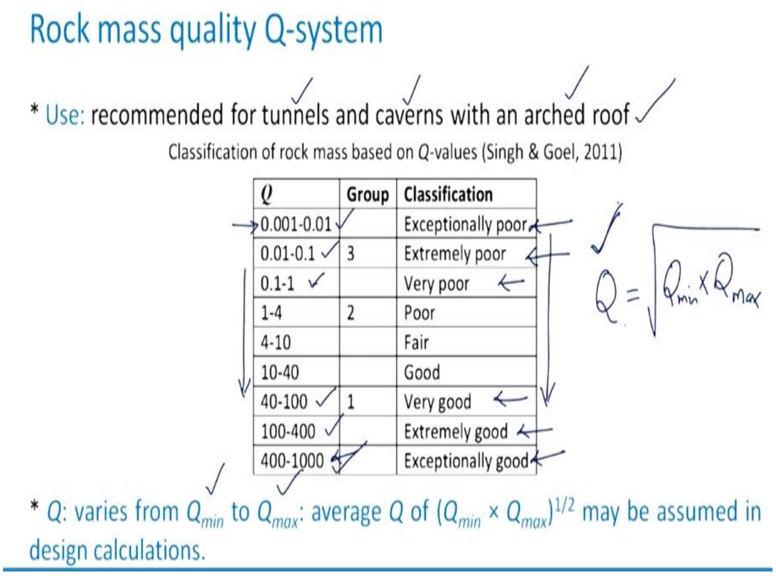

Q	Group	Classification
0.001-0.01		Exceptionally poor
0.01-0.1	3	Extremely poor
0.1-1		Very poor
1-4	2	Poor
4-10		Fair
10-40		Good
40-100	1	Very good
100-400		Extremely good
400-1000		Exceptionally good

Now we have obtained the ratings of each of these and we can calculate the index Q. Its use is recommended for tunnels and caverns with an arched roof. In the beginning I mentioned to you that each of these systems, were developed based upon few researchers experience in few areas. So, like in case of the RMR system where it was the experience on the shallow depth tunnels. Similarly here in case of Q the experience was for the tunnels and caverns with an arched roof.

So, when you have to use this Q-system for other type of structure, you need to be careful and you need to apply lot of engineering judgment when you use these systems which were developed for some other conditions. So, the use is recommended for this situation. Q is varying from 0.001 and it goes to become as high as 1000. As the value of Q increases, the quality of the rock mass also increases or it gets better.

So for the range of the Q varying between 0.001 to 0.1 the classification of the rock mass is exceptionally poor. For 0.01 to 0.1 it is extremely poor, 0.1 to 1 very poor and likewise for 40 to 100 it is very good, 100 to 400 extremely good, and 400 to 1000 it is exceptionally good. Sometimes, the condition in the field they are such that that you may not get one single value as a rating to be assigned to a parameter rather it may be a range.

So in that situation Q-value will not be a single value, but then it may vary from Q minimum to Q maximum. So, in that case the average value of Q which should be taken that should be equal to square root of Q minimum into Q maximum. So, this value of Q should be used in the design calculation.

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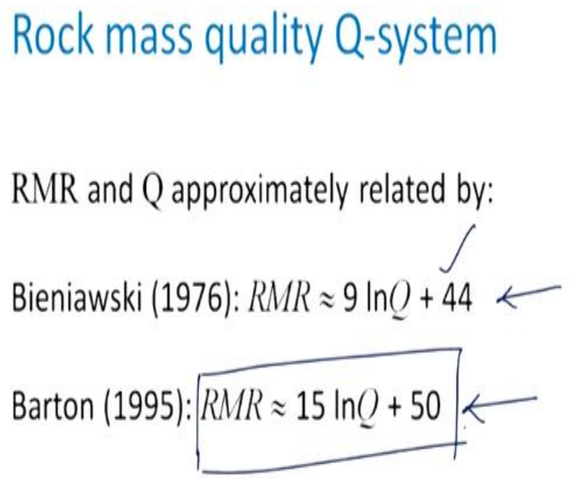

There is the correlation which exists between RMR and Q, these are approximate relation. However, it has been seen that in some of the cases they work quite fine. So, two of these relations I have mentioned here. First one was developed by Bieniawski in 1976 and it is quite widely used to obtain either *Q* from RMR or RMR from the Q-value. So, this is given as RMR = 9 natural log of Q + 44.:And the second expression was given by Barton in where this RMR is approximately equal to 15 natural log of Q + 50.

So, there are few cases where you will be able to get the value of RMR but not Q and then subsequently you may need *Q*, but you have already *R* with you, so you can use these expressions in order to get either of the quantity from one another. Like RMR can be obtained from *Q* and *Q* can be obtained from RMR.

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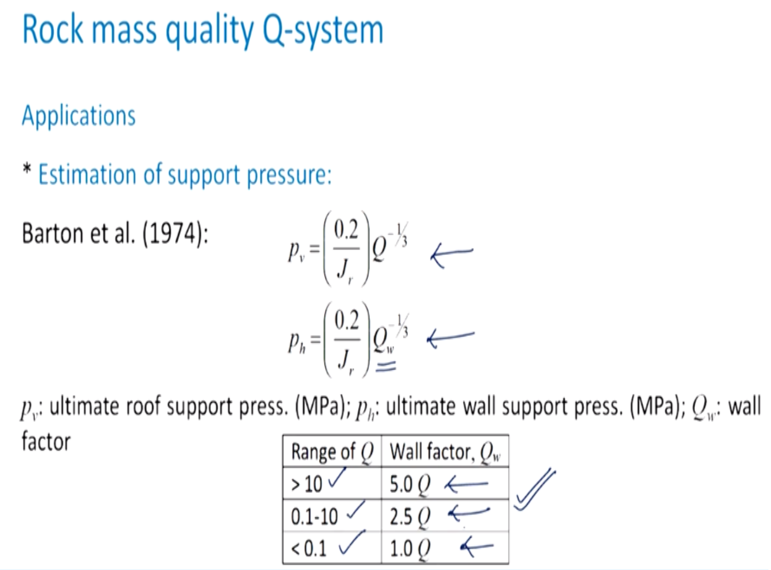

Coming to some of the application areas related to this Q-system. The first application includes the estimation of the support pressure and these expressions were given by Barton et al in 1974. So the vertical roof pressure that is given by this expression and the ultimate wall support pressure is given by this expression and you can see that here a term wall factor comes into picture.

So, depending upon the range of *Q*, you can assign this value of wall factor as per this table. So, if the value of *Q* is more than 10, wall factor Q_w can be taken as 5 times *Q* and if the range of Q is between 0.1 and 10, then this wall factor can be taken as 2.5 *Q* and for the value of *Q* less than 0.1 it is equal to *Q*. So, you can find out the wall factor, just substitute in this expression and you should be able to get the ultimate roof support pressure and the ultimate wall support pressure.

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Rock mass quality Q-system

Limitations of Q-system in obtaining support pressure:

* *SRF* is probably the most contentious parameter

* It may be appropriate to neglect the *SRF* during rock mass classification & to assess the detrimental effects of high stresses separately

Some of the limitation while obtaining the support pressure as far as the Q-system is concerned they include with respect to SRF. That is the SRF is probably the most problematic parameter here in the evaluation of *Q*. So, it may be appropriate to neglect this SRF during the classification system and to assess its detrimental effects of high stresses separately during the analysis.

So, we need to be careful that it should not happen that we are considering the SRF while calculating Q and also taking this effect in the analysis. One needs to be careful here.

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Rock mass quality Q-system

Applications

* Modulus of deformation:

Barton (2008):

MPa

$$E_d = 10\left(\frac{Q q_c}{100}\right)^{1/3} \text{GPa} < E_r \; [\text{for } Q = 0.1 \text{ to } 100 \;\&\; q_c = 10 - 200\,\text{MPa}]$$

0.1 – 100 q_c

q_c: UCS of rock material

The next application is the determination of the modulus of deformation and the related expression was given by Barton in 2008 where the modulus of deformation was defined by this expression and this modulus of deformation which you get is in gigapascal. So, this should be less than the elastic modulus of the intact rock which is obvious. And this expression is valid for the value of Q varying between 0.1 to 100 and the UCS of the intact rock varying between 10 to 200 Mega Pascal.

Once again, I would repeat when we discuss about the empirical correlation then you need to be careful about the units of its parameters like in this case q_c should be in MPa and then only you will get this modulus of deformation in gigapascal, where this q_c is the UCS of the rock material.

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Rock mass quality Q-system

Applications

Average UCS of a variety of rocks, measured on 50 mm diameter samples (Singh & Goel, 2011)

Type of rock	q_c, MPa	Type of rock	q_c, MPa	Type of rock	q_c, MPa	Type of rock	q_c, MPa
Andesite (I)	150	Granite (I)	160	Marble (M)	<100>	Shale (S, M)	95
Amphibolite (M)	<160>	Granitic Gneiss (M)	100	Micagneiss (M)	90	Siltstone (S, M)	<80>
Augen Gneiss (M)	160	Granodiorite (I)	160	Micaquartzite (M)	85	Slate (M)	<190>
Basalt (I)	160	Graulite (M)	<90>	Micaschist (M)	<80>	Syenite (I)	150
Clay Schist (S, M)	55	Gneiss (M)	130	Phyllite (M)	<50>	Tuff (S)	<25>
Diorite (I)	140	Greenschist (M)	<75>	Quartzite (M)	<190>	Ultrabasic (I)	160
Dolerite (I)	200	Greenstone (M)	110	Quartzitic Phy. (M)	100	Clay (hard)	0.7
Dolomite (S)	<100>	Greywacke (M)	80	Rhyolite (I)	85	Clay (stiff)	0.2
Gabbro (I)	240	Limestone (S)	90	Sandstone (S,M)	<100>	Clay (soft)	0.03
				Serpentine (M)	135	Silt, sand (approx..)	0.0005

(I): Igneous; (M): Metamorphic; (S): Sedimentary; < >: large variation

< >

For your ready reference I have presented the typical values of the UCS for different types of rock in this slide. So, you can see that the first column gives you the idea about the type of the rock and the column adjacent to that gives the typical values of the UCS in MPa. The letters which are there in the bracket like I, S, M, etc. these include like I stands for igneous rock, M for metamorphic rock and S for the sedimentary rock.

That means andesite is an igneous rock. Basalt is an igneous rock. Similarly, here if you just see gneiss is metamorphic rock and Shale it can be sedimentary or metamorphic and accordingly their values of the UCS have been given. Now another thing which you must note here is this type of symbol that shows the large variation that means let us say that the type of the rock which is the metamorphic rock marble.

And there is average value of 100 Mega Pascal is given with this sign, so that means that around 100 MPa large variation in the UCS of marble rock can occur ok. So, like that you can take the example here like quartzite its value will be varying quite large around 190. Similarly for hard clay it is the 0.7 megapascal and in case if you have silt sand approximately all these material, then you will have this low value of UCS.

So, this gives us the idea about the UCS. So, when we have this UCS we can substitute in the previous expression along with the value of index Q in order to obtain the modulus of deformation from the q index. So, this is what that I wanted to discuss with you with respect to this rock mass classification system which is called as Q-system. So, what we discussed was that what all those three quotients they define physically.

And then how the rock mass can be classified on the basis of the value of Q index. And then we saw some of the limitations related to this system followed by various application areas. So, in the next class, we will learn about another classification system which is geological strength index. Thank you very much.