Underground Space Technology
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Module No # 08
Lecture No # 36
Application of Rock Mass Classification System: Rock Mass Quality (Q) system-01

Hello everyone, in the previous class we learnt about the aspects, related to tunnel hazards with a special reference to squeezing ground conditions. We also saw that, how these ground conditions can be predicted based upon the rock mass number and, we saw that when J_r/J_a is less than 0.5, then you encounter the squeezing ground condition, and for rock burst condition, we saw that J_r/J_a has to be more than 0.5.

So, today we will extend our discussion on the application of rock mass classification system, and here we are going to consider the classification system which is the Q system or rock mass quality system. So, today we will learn that how this system can be used for the determination of the support pressure in case of the underground excavations.

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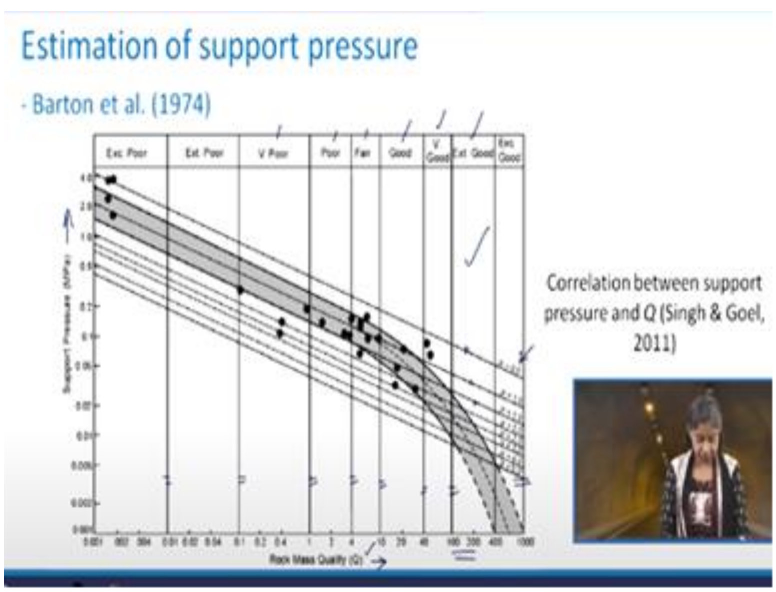

So, Barton et al in 1974 they proposed this correlation and, presented it in the form of a figure or the chart, where on the x-axis they plotted rock mass quality q it is in log scale. And, on y-axis they had the support pressure megapascal, which is also on the log scale. And then, here you can see that they had few vertical lines which are on the basis of the various ranges of q corresponding to the different quality of the rock mass.

Such as, here this is extremely good quality, very good, good, fair, poor, very poor, and like that. So, how to make use of this plot, so you can see that some of these inclined lines these correspond to the various values of J_r, which is varying from maybe 0.5 here to 5.

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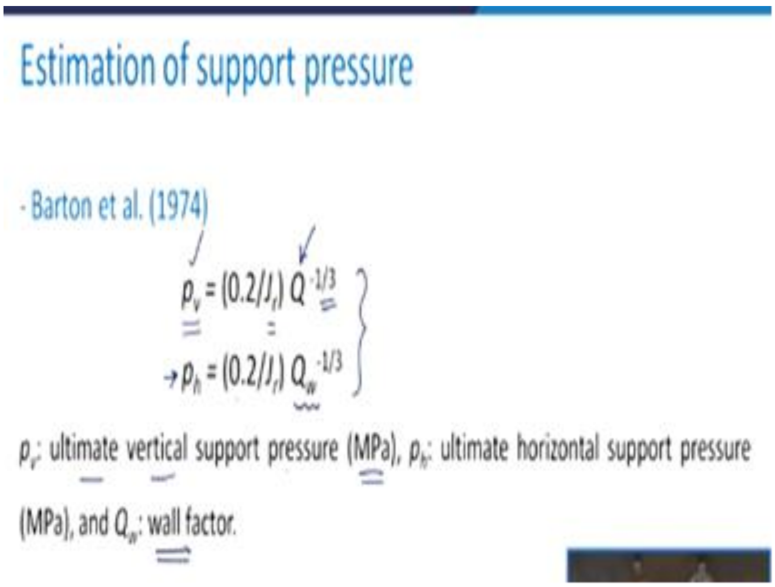

So, Barton et al in 1974, they proposed these expressions for the determination of vertical and the horizontal support pressure, and these were all empirical so we need to be careful about the units. So,

$p_v = (0.2/J_r)Q^{-1/3}$ and

$p_h = (0.2/J_r){Q_w}^{-1/3}$

Where this is the vertical support pressure, p_h be the horizontal support pressure, q is the rock mass quality index, and Q_w is the wall factor. Now the question is how to get the wall factor we will see that.

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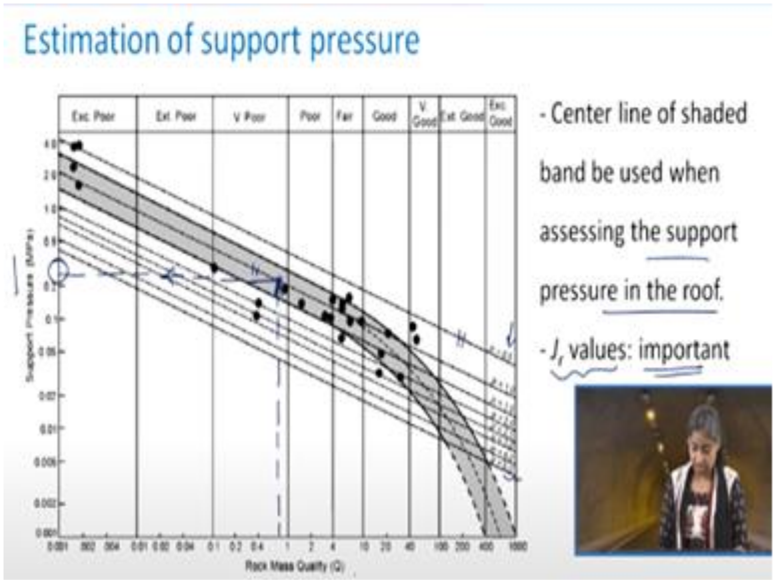

Now, in case if we need to assess the support pressure in the roof, what we need to do is, we need to follow the center line of this shaded portion. So, based upon the value of the rock mass quality I take a vertical line from that wherever it intersects this center line I drop a horizontal line from there, and whatever is this value this is going to be directly the support pressure in megapascal.

So, therefore, here J_r values are quite important as I mentioned to you that you can take a note of these various J_r values which are varying from 0.5 to 5. So, based upon this we can determine the support pressure corresponding to the value of Q as well as J_r.

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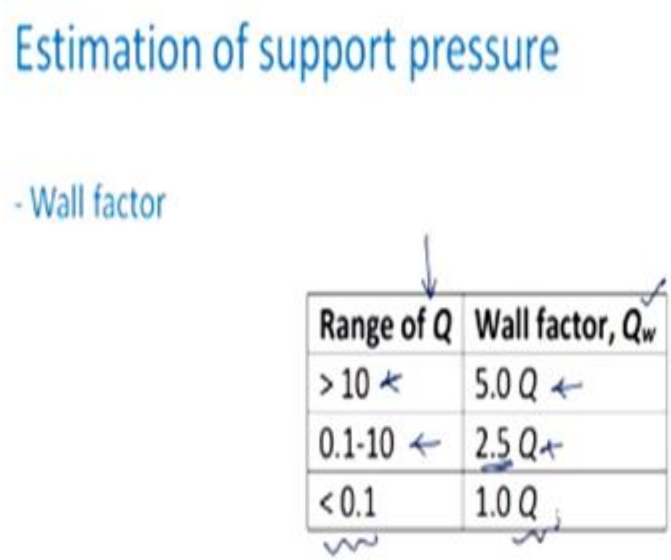

Coming to the value of the wall factor, so it depends upon the range of Q, so if this q is more than 10 the wall factor can be 5 times q. But in case if the range of Q is between, 0.1 to 10 then to obtain the wall factor you need to multiply Q by a factor of 2.5. And in case, if the value of Q is less than 0.1 then this wall factor Q_w becomes equal to Q.

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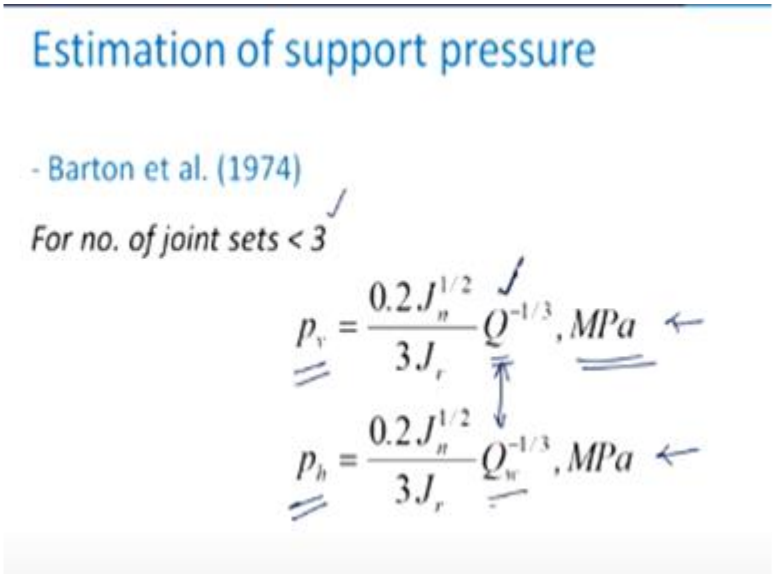

In case, if the rock mass has the number of joint sets which are less than 3, then the support pressures can be determined from these 2 expressions, where

$$p_v = \frac{0.2\, J_n^{\frac{1}{2}}}{3J_r} Q^{-\frac{1}{3}}, \text{MPa}$$

And the horizontal support pressure will be given as

$$p_h = \frac{0.2\, J_n^{\frac{1}{2}}}{3J_r} Q_w^{-\frac{1}{3}}, \text{MPa}$$

So, it is not very difficult to remember these 2 expressions you see the difference between these 2 is only that here q is replaced by Q_w in the expression for p_h.

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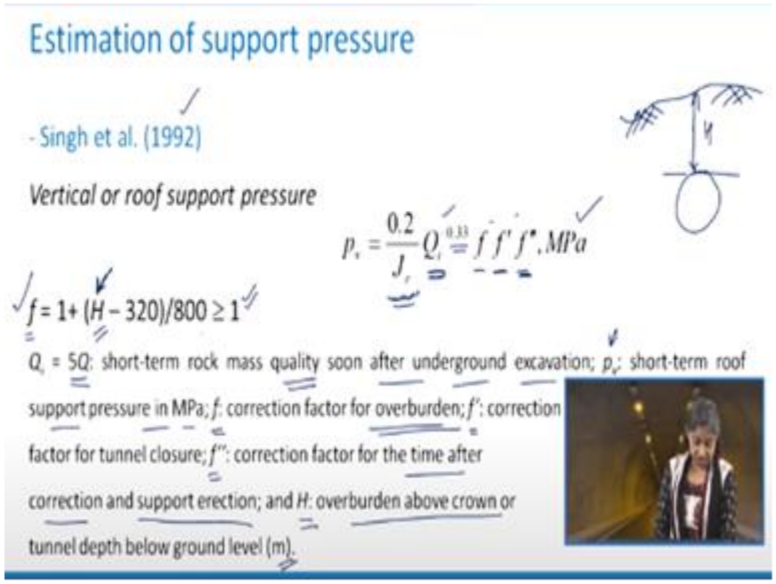

The vertical or the roof support was also proposed by the another set of authors, those are Singh et al and these they came up with this expression in 1992 and the expression is

$$p_v = \frac{0.2}{J_r} Q_i^{-0.33} f f' f''$$

in mega pascal. Now, what all are these terms j_r you know it is the joint roughness factor but what about this qi, f, f′, and f double prime take a look this

$$f = 1 + (H - 320)/800 \geq 1$$

What is h is the depth of the overburden then this $Q_i = 5Q$, it represents the short-term rock mass quality soon after the underground excavation. P_v is the short-term roof support pressure in mega Pascal, this f be the correction factor for the overburden because you see that here only the overburden depth is coming into picture, so this was called as the correction factor for overburden.

Then, f′ be the correction factor for the tunnel closure, f″is the correction factor for the time after the correction and support erection. H as I mentioned it is the overburden above the crown or the tunnel depth below the ground surface, so you see that we have discussed this much many times earlier. Let us see, if this is the excavation so this is the top of the tunnel, or crown of the tunnel and from the ground surface this depth is the h and its unit is going to be in meters.

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Estimation of support pressure

- Singh et al. (1992)

Correction factor f′:

S. No.	Rock condition	Support system	Tunnel closure (u_a/a), %	Correction factor, f'
1	Non-squeezing ($H < 350\ Q^{1/3}$)	-	< 1	1.0
2	Squeezing ($H > 350\ Q^{1/3}$, $J_r/J_a < 0.5$)	Very stiff	< 2	> 1.8
3	-do-	Stiff	2-4	0.85
4	-do-	Flexible	4-6	0.70
5	-do-	Very flexible	6-8	1.15
6	-do-	Extremely flexible	> 8	1.8

Now, what about the other correction factors so, focus on this, that is the correction factor f′, based upon the rock condition, support system, and the tunnel closure one needs to assign the appropriate value of the correction factor. For example, if you have the non-squeezing ground condition represented by this expression that is

$$H < 350\ Q^{1/3}$$

You, basically know as such no support system was recommended as far as this work is concerned.

In this case, the tunnel closure is < 1% and the correction factor will be 1, this correction factor is f′. In case, if you have the squeezing ground condition then the support system if it is needed to be a very stiff support system, that is based upon the tunnel closure which is < 2%, in this case, the correction factor is given to be greater than 1.8. Now 3 to 6 serial numbers, they all correspond to the squeezing ground condition but the difference you see here in the support system, whether it is stiff, flexible, very flexible or extremely flexible.

The thing is that when you have the very stiff or stiff support system the tunnel closure will be low. In case, if you have a very flexible support system then, in that case, you will have larger tunnel closure as indicated here and accordingly, the correction factor f′ value can be assigned based upon what is the magnitude of the tunnel closure. So, using this table if you want to follow this method which was proposed by Singh et al in 1992, then based upon this you can determine the correction factor f′ which is needed for the estimation of support pressure.

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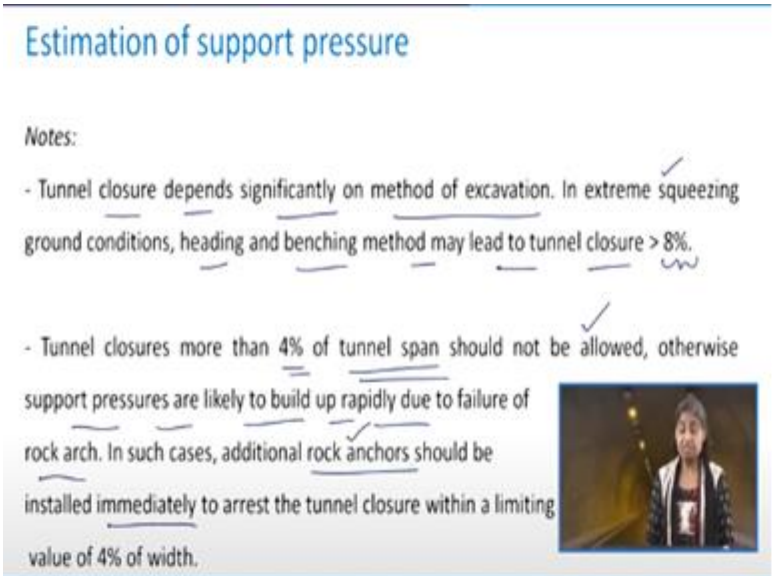

Now, there are few things which you need to take a note of in this case the tunnel closure it depends significantly on the method of excavation. In case of the squeezing ground condition which is extreme heading and benching method may lead to the tunnel closure which, are even larger than 8%. So, the tunnel closures which are more than 4 % of the tunnel span it should not be allowed. Otherwise, what will happen is that, the support pressures are likely to build up rapidly due to the failure of rock arches.

And, in such cases what we need to do is we need to provide the rock anchors immediately to arrest the tunnel closure so that the limiting value of 4% of the width of the opening is met with. So, we need to be careful that in case if we have the extreme squeezing ground condition, and if you are going for heading and benching method of the excavation then, the tunnel closure can be as high as 8% or even more than that.

But, this should not exceed 4% of the tunnel span, so in order to restrict that we need to provide the additional rock anchors, immediately after the excavation of the tunnel

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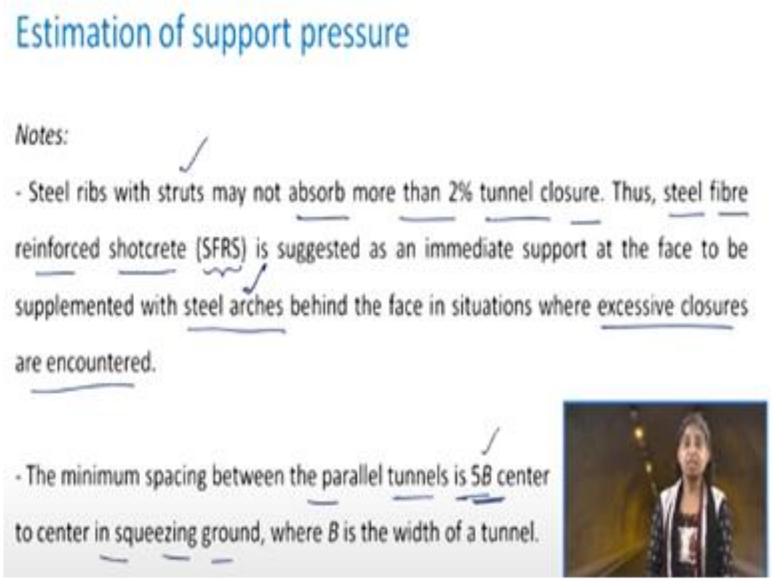
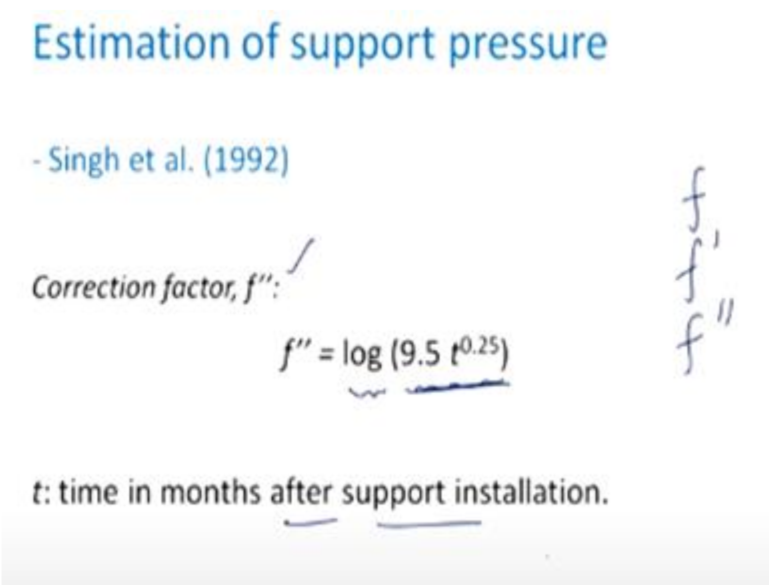


The steel ribs with struts may not absorb more than 2% of the tunnel closure and in this case therefore steel fiber reinforced shotcrete, which is called in short as SFRS, is suggested as the immediate support at the face to be supplemented with the steel arches behind the face wherever these excessive closures are encountered. So, in case if you have gone for the steel ribs with struts then you should go with SFRS first as the immediate support which should be supplemented with steel arches.

The minimum spacing between the parallel tunnels is 5 times B center to center, in the squeezing ground condition, where B be the width of the tunnel. So, let us say that, there are to be more than one tunnel in any horizontal plane then the minimum spacing which is the center-to-center space spacing between the parallel tunnels that should be 5 times B, B is the width of a tunnel. **(Refer Slide Time: 13:51)**



Coming further the third correction factor which is

$f'' = \log\,(9.5\ t^{0.25})$

where t is the time in months after the installation of support systems. So, now we know all the three correction factors f, f′, and f′′the question is how should, we apply that can we apply any of these randomly or should we apply them one after the other? And if we need to apply them one after the other what should be the sequence?

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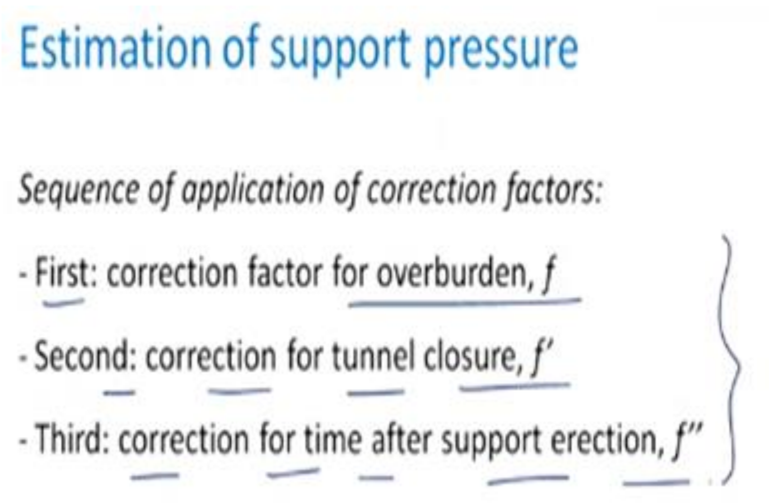

So, the sequence of the application of the correction factors should be first, you should apply the correction factor for the overburden, then correction factor for the tunnel closure, and then the third one which is the correction for time after the support erection. So, one need to be careful about the sequence of the application of correction factors.

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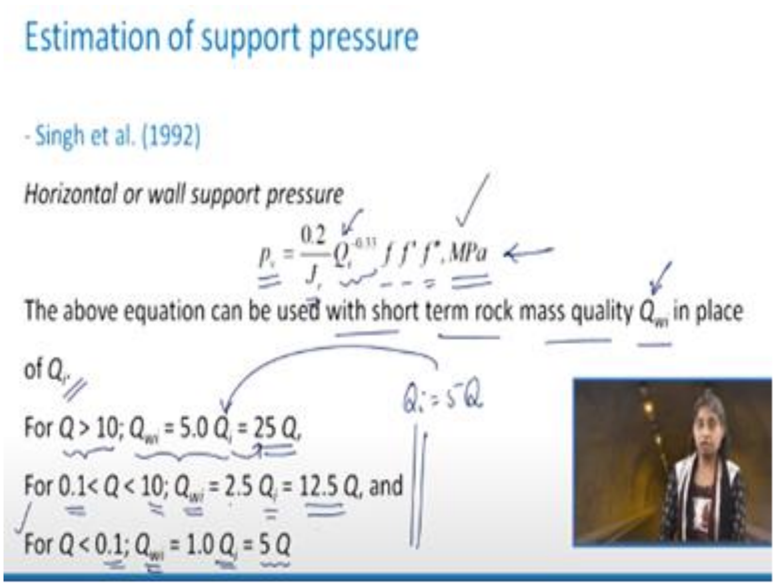

So, till now we learnt about the vertical or the roof support pressure, but when it comes to the horizontal or the wall support pressure there also, Singh et al. gave us the solution. We saw that as far as the vertical support pressure is concerned you can use this expression as

$$p_v = \frac{0.2}{J_r} Q^{-0.33} f\, f' f'', \mathrm{MPa}$$

Now, we can also find out the horizontal support pressure, so this equation can be used with the short-term rock mass quality Q_{wi} in place of Q_i. Now, the question is how to get the value of this Q_{wi} if we want to use it in place of this Q_i. So, in case, if you have

$$Q > 10;\ Q_{wi} = 5.0\ Q_i = 25Q$$

You remember that Q_i was 5 times Q so just substitute it here and you will get this expression. Similarly, in case if you have q varying between

$$0.1 < Q < 10; Q_{wi} = 2.5\ Q_i = 25Q$$

and for

$$Q < 0.1;\ Q_{wi} = 1.0\ Q_i = 5Q$$

So, this is how you can determine the value of Q_{wi} corresponding to any value of q and then substitute it in this expression to get horizontal or the wall support pressure.

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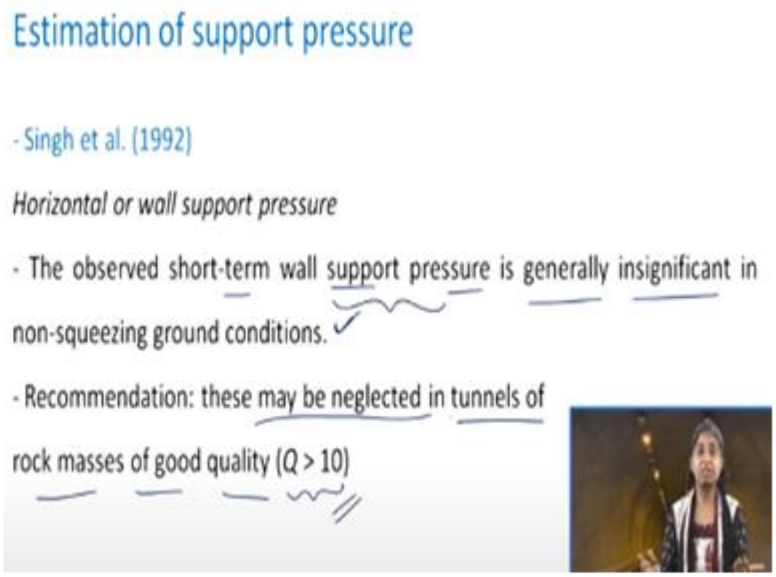

The observed short-term wall support pressure is in general insignificant in non-squeezing ground condition. The recommendation is that, these may be neglected in tunnels of rock masses of good quality where Q >10. So, if this Q value works out to be > 10, in that case, we can say that we do not need to provide the support system or maybe we need to just provide the nominal support system.

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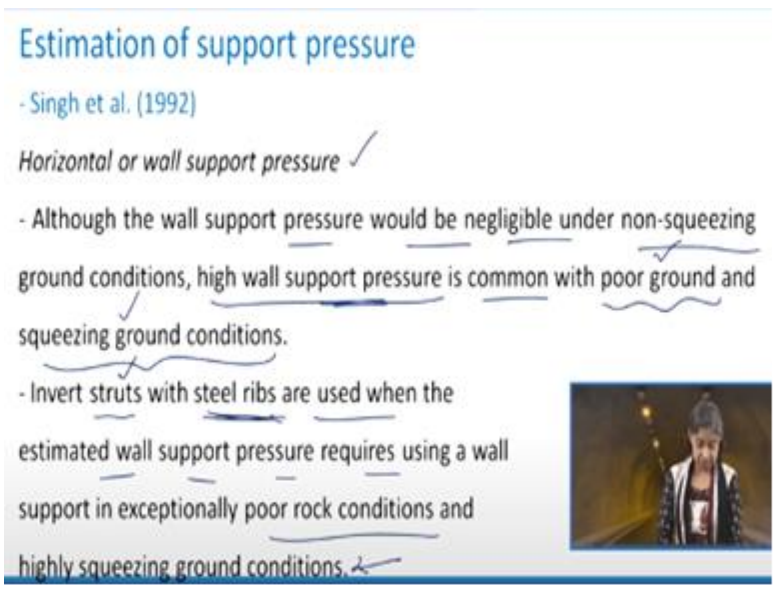

Although the wall support pressure would be negligible under such ground conditions which are non-squeezing, the high wall support pressure is common with poor ground and the squeezing ground condition. So, in case if we have the non-squeezing ground conditions, we can neglect the wall support pressure and then just provide the nominal support system. But in case, if you have the poor ground condition, or the squeezing ground condition, you will observe very high wall support pressure.

So, there we need to properly design the support system to take care of such support pressures. So, in such cases the invert struts with the steel ribs they are used. When these estimated wall support pressure these require using a wall support in exceptionally poor rock conditions or highly squeezing ground condition. So, for such situations, you are going to have large wall support pressure and therefore one should go for inward struts with steel ribs.

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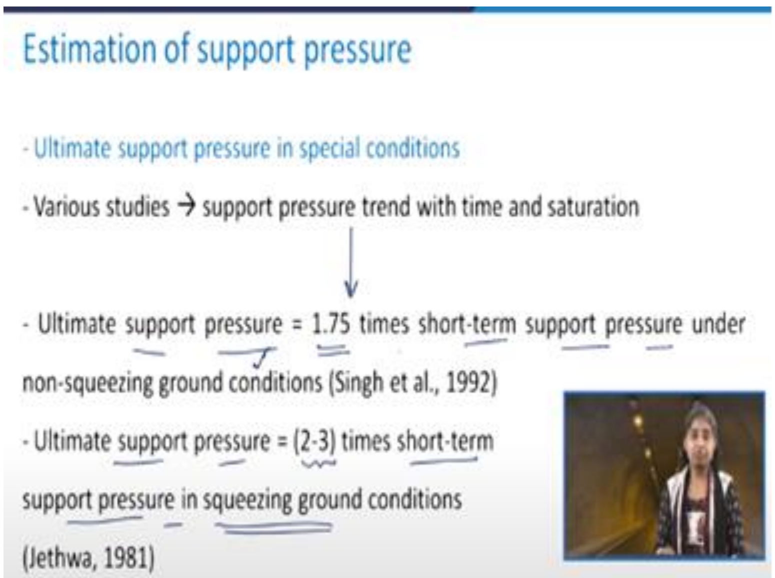

Now, we have some of these special conditions for which one needs to see that, how should we get the ultimate support pressure for such special conditions. So, various studies were conducted where the support pressure trend with time and also with the saturation was studied. So, from here this was obtained that the ultimate support pressure can be 1.75 times the short-term support pressure under non-squeezing ground conditions.

But in case, of the squeezing ground condition, this ultimate support pressure is to the tune of two to three times the short-term support pressure. So, depending upon what kind of ground condition that you are encountering in the field, based upon that you have to adopt that what will be the short-term support pressure. Once, you obtain that then accordingly you can find out what would be the value of ultimate support pressure.

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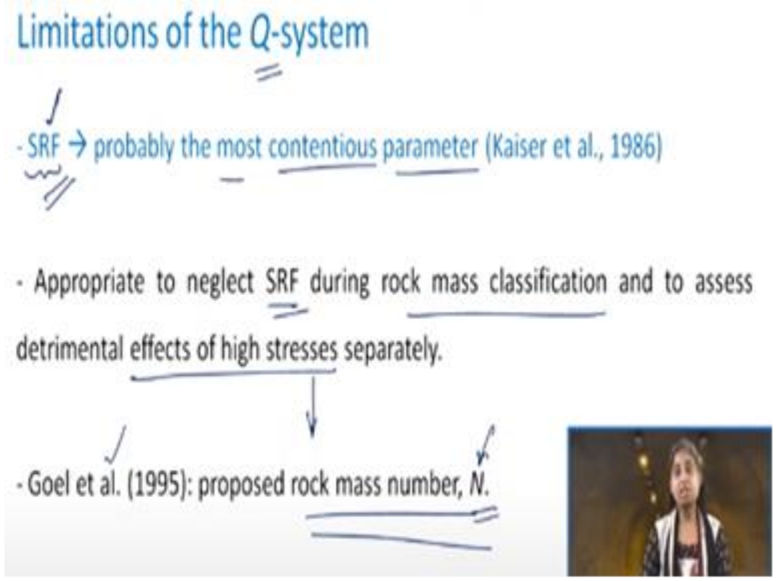

What are the various limitations of Q system, so when we learnt about these classification systems they are also we discussed about some of these. But, just for the continuity here again I have mentioned these limitations, you remember that Q involved six parameters and one was this stress reduction factor SRF. This was probably the most contagious parameter and we need to be careful while taking this account when we determine the value of rock mass quality index.

So, it is to avoid any kind of confusion, it is always appropriate to neglect this SRF during the classification and we should assess the detrimental effects of the high stresses separately. See, when the in-situ stresses are pretty high and when we go for the excavation underground in that case, there are going to be very detrimental effects on the underground excavation. So, what we should do is when we find out the rock mass quality index then we should neglect SRF.

But then when we are analyzing the underground excavation then we should consider these severe effects of high stresses separately. Keep that in mind, do not count it twice that is you took care of this while calculating the q in the form of SRF. And then later on also you are doing the adjustment in the analysis with reference to high stresses, no that should not be done. So, the best way is first you neglect SRF while you find out the Q value for that rock mass, but then later on you consider the effect of high stresses separately.

So, for such an approach that how you can do away with this SRF, we have seen that this rock mass number which was proposed by Goel et al. in 1995. It comes to our rescue we have seen this that how this rock mass number can be determined by neglecting the factor SRF from the 6 factors which were defining the value of Q

. So, this was all about the determination of the support pressure from the Q values or I should say rock mass quality index, there are other application of this Q system that we will take up in the next class, thank you very much.