Underground Space Technology
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Module No # 10
Lecture No # 48
Calculation Sequence for Rock – Support Interaction Analysis -01

Hello everyone, in the previous class we learned about some of the support system and, the determination of their stiffness and the maximum support pressure. We also saw, that, how can we take care of the situation when 2 types of support systems are provided in the single application. So, today what we will do is, whatever that we have done till now, as for Ladanyi's analysis of rock mass tunnel support interaction is concerned.

Let us try to write all the calculation sequence and then, what we will do is, We will take an example and, we will try to solve and understand this particular phenomena that, how the analysis and the design of the support system can be carried out for any typical underground exchange aviation using Ladanyi's analysis. So, what we are going to do is, in the next 2 classes we will learn that what are going to be the calculation sequences for each and every task.

What all things, which are needed as the input parameter? And then, in the third class from now, we will learn with the help of an excel example that, how we can approach to solve such type of analysis problem? So, we have the typical sequence for the interaction analysis.

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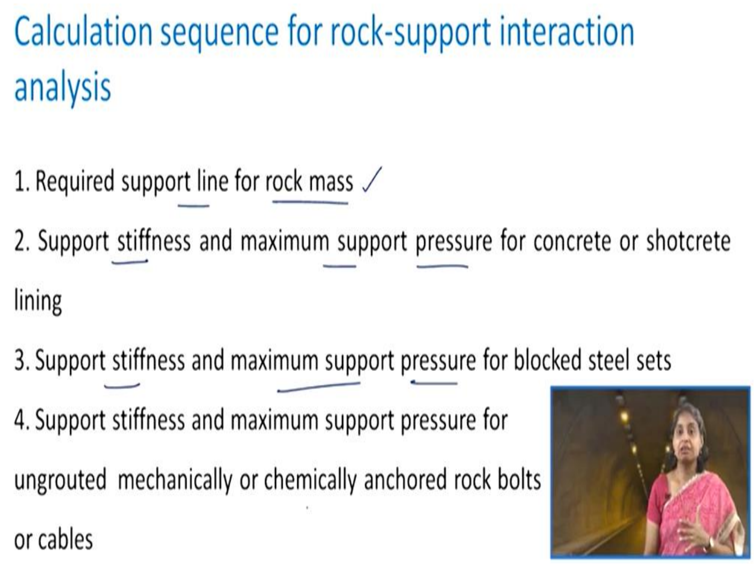

So, the first step in that, is that we need the required support line for the rock mass. So first, we will do the calculations for this, then we will find out what is the support stiffness and the maximum support pressure for concrete or the shotcrete lining. Then, we will see, what are the support stiffness and the maximum support pressure for blocked steel sets followed by the support stiffness and the maximum support pressure for ungrouted, mechanically, or chemically anchored rock bolts or cables. **(Refer Slide Time: 02:45)**

Calculation sequence for rock-support interaction analysis

5. Available support curve for a single support system
6. Available support curve for a combined support system

And then, we will need the available support curve for the single support system and then, finally for the combined support system. So, each and every step of these 6 steps that I mentioned here, we already have learned. All we are going to do is compile everything and put them in a proper sequence. So, when we try to solve any analysis, it is just that we will follow this sequence one after the other.

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1. Required support line for rock mass

Input data required –

σ_c : Uniaxial compressive strength of intact rock mass
m & s : material constants for original rock mass
E : modulus of elasticity of original rock mass
ν : Poisson's ratio of original rock mass
m_r & s_r : material constants for broken rock mass
γ_r : unit weight of broken rock mass
p_o : in-situ stress magnitude
r_i : radius of tunnel

So, in this connection, let us take the first step where we want or where we need the required support line for the rock mass. So, for such thing, what all are the input data required let us try to note them down. So, the first one is the σ_c which uniaxial compressive strength of intact rock mass. Then, we have or we can say that it is of the intact rock. Then, we have m and s material constants for original rock mass. E is the modulus of elasticity of original rock mass.

Then we have m_r and s_r which will be material constants for broken rock mass. Then we have γ_r, which is the Unit weight of the broken rock mass. Then p_0 is in-situ stress magnitude and r_i radius of the tunnel. So, for the required support line for the rock mass, these are the data that would be needed as starting point**.**

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1. Required support line for rock mass

Calculation sequence –

a) $$M = \frac{1}{2}\left[\left(\frac{m}{4}\right)^2 + m\frac{p_o}{\sigma_c} + s\right]^{1/2} - \frac{m}{8}$$

b) $$D = \frac{-m}{m + 4\left[\frac{m}{\sigma_c}(p_o - M\sigma_c) + s\right]^{1/2}}$$

c) $$N = 2\left[\frac{p_o - M\sigma_c}{m_r\sigma_c} + \frac{s_r}{m_r^2}\right]^{1/2}$$

So, what is going to be the calculation sequence, So, the first one is Step a, we will calculate M all these things we have already discussed. All I am doing is putting them at once place in a proper sequence

$$M = \frac{1}{2}[(\frac{m}{4})^2 + m\frac{p_0}{\sigma_c} + S]^{1/2} - \frac{m}{8}$$

Then, we will find out this term

$$D = \frac{-m}{m + 4[\frac{m}{\sigma_c}(p_0 - M\sigma_c) + s]^{1/2}}$$

Then, the next step is calculate,

$$N = 2\left[\frac{p_0 - M\sigma_c}{m_r \sigma_c} + \frac{S_r}{m_r^2}\right]^{1/2}$$

So, these are the first 3 steps that you need to do.

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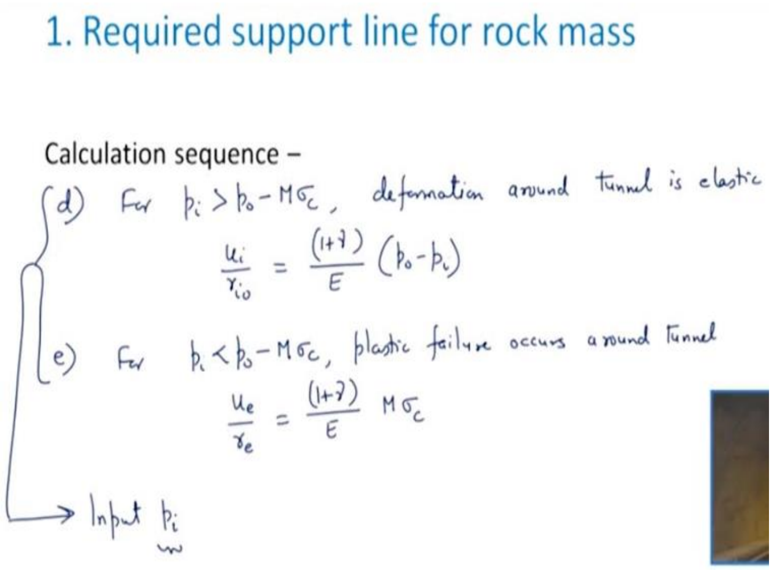

Then, followed by the next one which is D that is for

$p_i > p_0 - M\sigma_c$, the deformation around the tunnel is elastic.

So, what we have is

$$\frac{u_i}{r_{io}} = \frac{(1+\gamma)}{E}(p_0 - p_i)$$

And the next step is for

$p_i < p_0 - M\sigma_c$, we will have the plastic failure around tunnel. And in this, we will have

$$\frac{u_e}{r_e} = \frac{(1+\gamma)}{E} M\sigma_c$$

So, basically for these 2 we will also need to give input P_i. So, when we solve the problem in excel. Then you will note that, how do we vary this P_i starting from P_o that is the in-situ state of stress.

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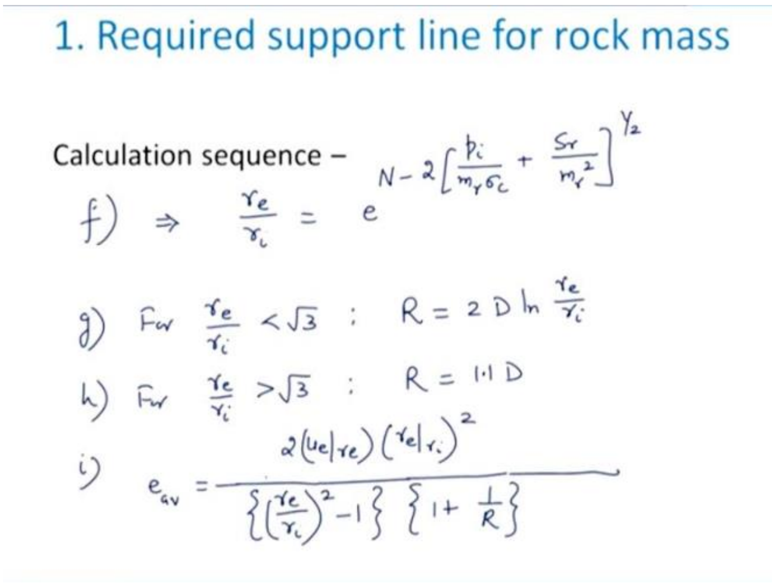

Now, the next step is going to be that we need to find out the radius of the elastoplastic boundary, so that, will be

$$\frac{r_e}{r_i} = e^{N-2\left[\frac{p_i}{m_r \sigma_c} + \frac{s_r}{m_r^2}\right]^{1/2}}$$

Then, we have the next step that is, when, we find out this

r_e / r_i, we will compare it with the square root of 3 so,

$$\frac{r_e}{r_i} < \sqrt{3},$$

We will find out the

$$R = 2D \ln \frac{r_e}{r_i}$$

and if we have

$\frac{r_e}{r_i} > \sqrt{3}$ we have

$$R = 1.1\,D$$

And then, we find out what is

$$e_{av} = \frac{2(u_e/r_e)(r_e/r_i)^2}{\{(\frac{r_e}{r_i})^2 - 1\}\{1 + \frac{1}{R}\}}$$

So, this is how, we can find out this e average.

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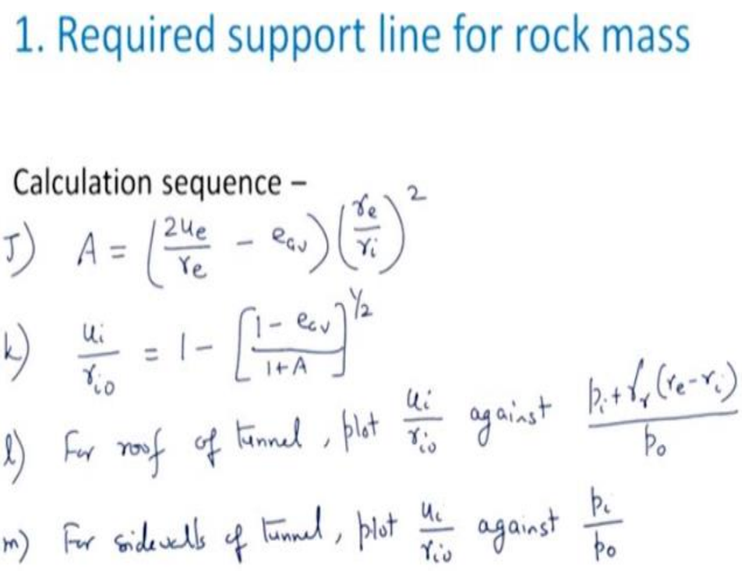

The next step to find out the support line for rock mass that is J

$$A = \left(\frac{2u_e}{r_e} - e_{av}\right)\left(\frac{r_e}{r_i}\right)^2$$

Then we ask

$$\frac{u_i}{r_{io}} = 1 - \left[\frac{1-e_{av}}{1+A}\right]^{1/2}$$

Then, we need to plot the u_i upon r_i against the support pressure. So, in this case, if you recall we discussed that the weight of the broken since of the rock mass should be added or subtracted depending upon the whether it is for roof or for floor.

So, for roof of tunnel, we need to plot

$$\frac{u_i}{r_{io}} \text{ against } \frac{p_i + \gamma_r(r_e - r_i)}{p_0}$$

and for the side walls of the tunnel. We know that, the weight of the broken rock mass in the roof portion will not influence the side walls of the tunnel. So here, we will just plot

$$\frac{u_i}{r_{io}} \text{ against } \frac{p_i}{p_0}$$

but what will happen to the floor?

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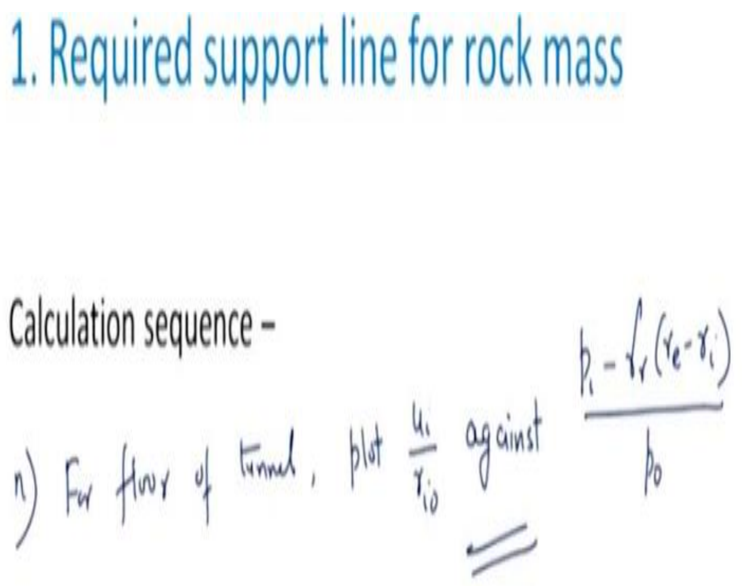

In that case, we have to again take care of the weight of the broken zone. So, for the floor of tunnel, we need to plot

$$\frac{u_i}{r_{io}} \text{ against } \frac{p_i - \gamma_r(r_e - r_i)}{p_o}$$

So, this is how, that we can determine the required support line for the rock mass or kind of ground response curve for the rock mass.

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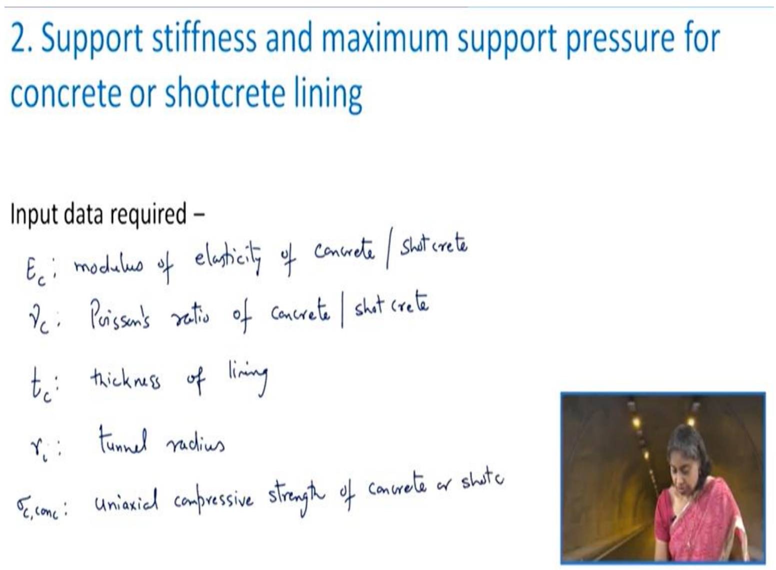

But, what about these support system, so, let us take a look what all going to be the input data needed for the determination of support stiffness and the maximum support pressure for the concrete or the shotcrete lining. So, the list of the data is needed will include E_c as the modulus of elasticity of concrete or shotcrete. Then we have γ_c which is the Poisson's ratio of the concrete or shocrete. Then, we have t_c which is the thickness of lining.

Then we have r_i tunnel radius and finally, we will need the UCS of concrete or the shotcrete that is represented as σ_c of concrete. So, this is uniaxial compressive trend of concrete or shotcrete.

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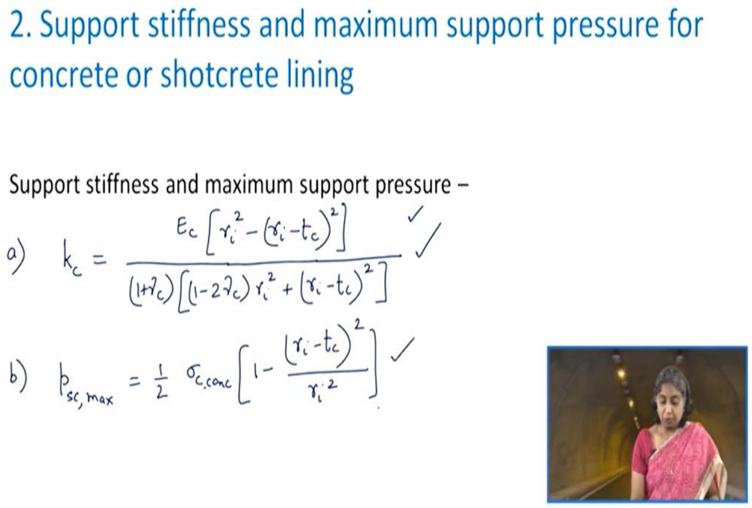

Now, once we have this then how can we determine the support stiffness and the maximum support pressure for concrete or the shotcrete lining? So, for that we need to follow this that is for the support stiffness which is represented as:

$$k_c = \frac{E_c[r_i^2 - (r_i - t_c)^2]}{(1 + \gamma_c)[(1 - 2\gamma_c)r_i^2 + (r_i - t_c)^2]}$$

So, this is how we can determine the support stiffness.Coming to the maximum support pressure which we will be representing as

$$p_{sc,max} = \frac{1}{2}\sigma_{c\ conc}[1 - \frac{(r_i - t_c)^2}{r_i^2}]$$

So, this is how the support stiffness and the maximum support pressure for a concrete or the shotcrete lining can be obtained. So, as I mentioned to you that, all we are doing is we are trying to put all these calculation sequences at one place to facilitate, that what all are going to be systematic way of taking up this rock mass tunnel support analysis using Ladanyi's method.

So, in all, we had 6 steps so 2 steps, we saw along with their calculation sequences. So, remaining 4 we will take up in the next class followed by an example, that we will solve using excel. And there. we will generate the ground response curve and support reaction curve for a particular problem. Thank you very much.