Rock Mechanics and Tunneling
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Lecture 61
Improvement of Rock Mass Response (Continued)

Hello everyone, I welcome all of you to the fifth lecture of the module 12.

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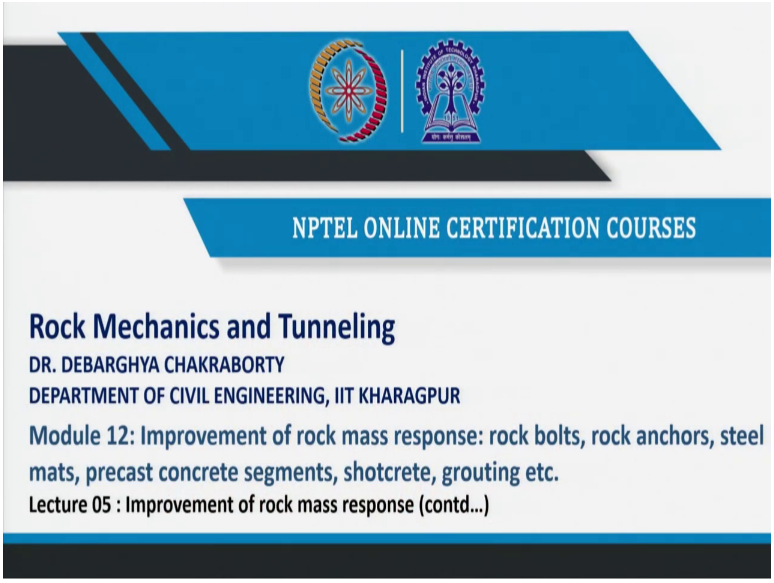

So, in module 12, we are discussing about the improvement of rock mass response. So, this is our actually last lecture of this module as well as last lecture of this course.

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So, today in today's lecture we will mainly discuss about the rock slope stabilization and protection techniques.

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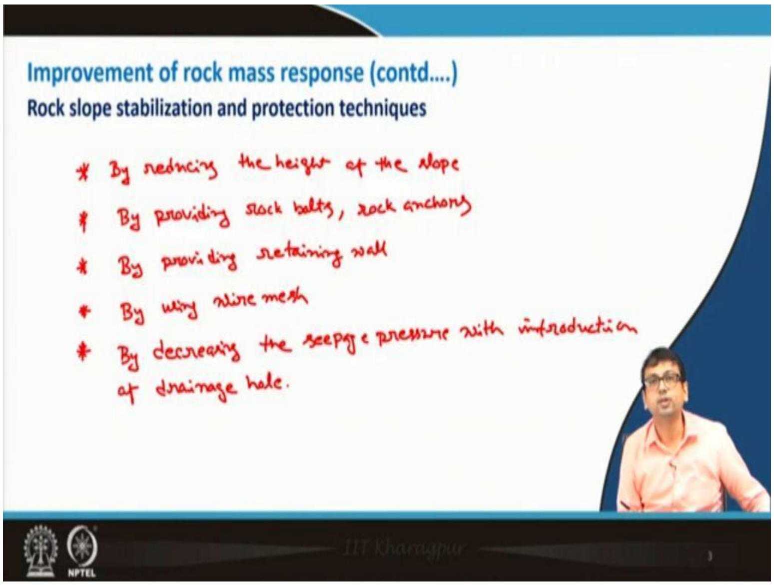

So, rock slopes stabilization and protection techniques. So, some what are mean how it can be done, let us write down some of the common techniques, like by reducing the height of the slope that can be one thing. And then maybe by providing rock bolts, rock anchors, rock bolts, rock anchors; then, also by providing retaining wall. Then, by providing steel like wire meshes, steel mats actually; so, by using wire mesh.

Also, we should also keep in our mind that that poor water pressure should not generate; because if poor water pressure develops then effective stress reduces. So, we should provide enough drainage facilities; so that also you should write down, by decreasing the seepage pressure with the introduction of drainage hole. Now, let us try to see one by one, these things.

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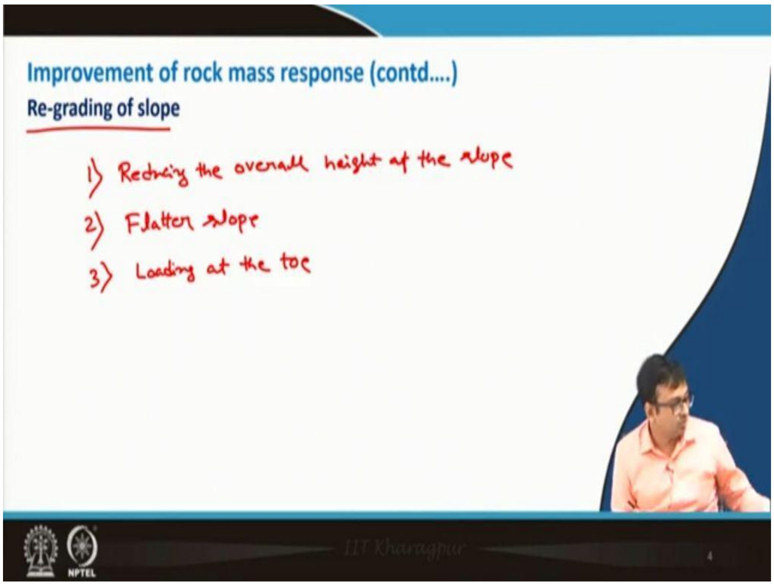

So first is re-grading of slope, means by reducing the height or some other techniques like what we can do. So, re-grading of heights under that that one thing maybe, as we have discussed that reducing the overall height that is fine. So, reducing the overall height of the slope, this maybe one thing; another thing maybe by cutting or filling the slope angle maybe reduced.

So, that means we can go for the flatter slope, so flatter slope; that will also come under the re-grading of the slope. As well as maybe we can, what we can do? We can provide loading at the toe; so, loading at the toe. What is toe, what is face, what is base we know, during slope (()) (04:56) we have learnt about these things.

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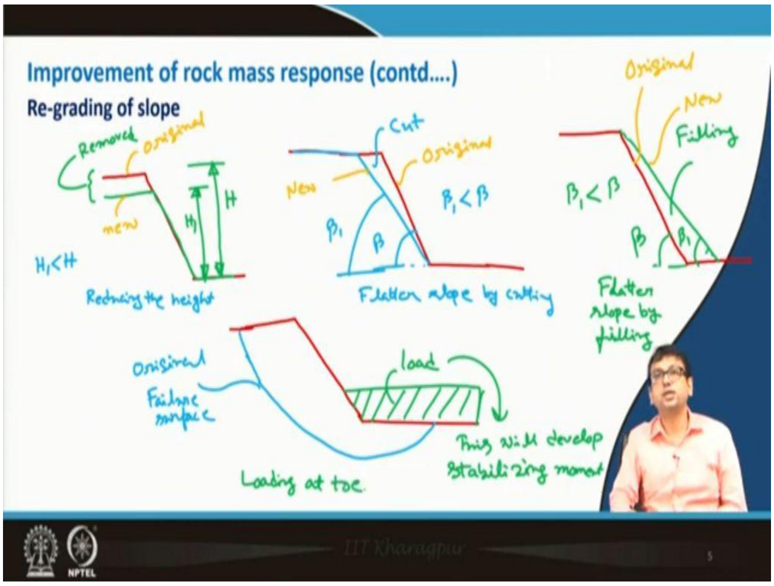

Let me just draw some of the things, what are the methods like one is reducing the height of the slope, one is flattening like flatter slope going for the fatter slope by filling or cutting or providing load. What I mean to say actually, let me try to draw two three diagrams for that. Suppose, initially this was the slope; so now what may happen?

You may now go for, maybe this, this much height. So, initially this was the height, suppose capital H; now it is maybe H1. So, this much this portion is removed; so, this may be one case. And under that situation, obviously if you reduce your height of the slope, the stability is going to increase. So, this is the case, where the as the first case which is stating that the reducing the overall height of the slope; so this is reducing the height.

Now, another thing maybe suppose initially, the slope is like this. Now, what we can do? We can either go for. So, this type of cutting, so this portion maybe you will remove. So cutting or cut this part; so because of that, what will happen? Basically, if initial angle is beta, then the new angle will be suppose beta1. So, what is happening? Your beta1 is less than beta; and whereas here it is H1 is less than H.

So indeed, in this case, your slope will become flatter; so, flatter slope by cutting. And similarly, what we can do? Again maybe the same slope. Now, what may be done is, so maybe we can go for this filling. So, now what will happen, so in that case also you see, if it is now beta, the initial original; now, this one will be the beta1. So anyway, this beta1 will be a less than beta.

So, here also flat flatter slope by filling; so, this is the original and this is the new. Here also this is the original, and this is the new one; here also this is the original and this is the new. And then, another thing is by providing load at the toe; so that means what I mean to say is we will have, suppose this is the one, now let me quick little at higher height maybe; so, suppose this is the one.

Now, what may happen that it may fail like suppose this; this is suppose the failure surface, so original. Now, if we provide load at this toe, so this is the, this is some weight or load. Now, if we provide this load what will happen? This will provide the stabilizing moment. So, we can write here, this load this will develop stabilizing moment. So, if this developed stabilizing moment, so then also the failure probability will reduce. So, this is by adding as I have mentioned loading at the toe. So, these are different ways of stabilizing by re-grading the slope.

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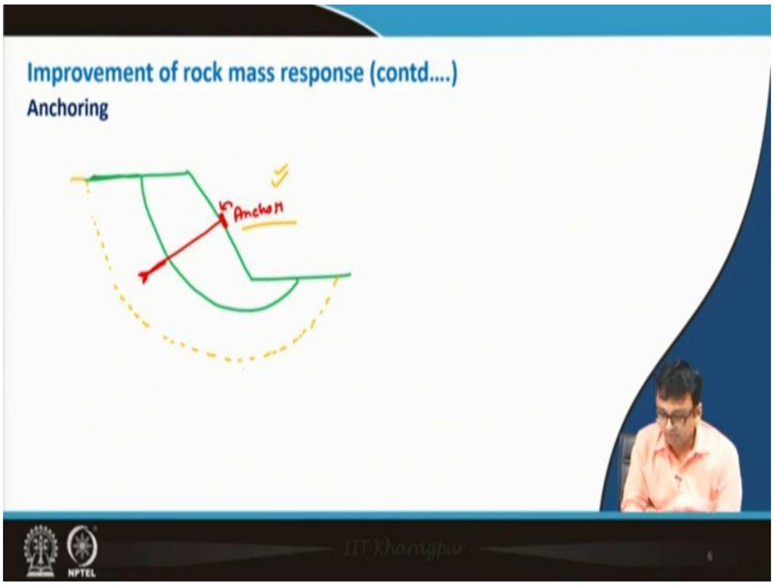

Now, other than that, what can be done by providing anchor; so, as we have learnt already. So, if your failure surface is like this; then, what may be done? We can, we can go for anchor; so can go for anchor; so, this is the anchor. Now, if happens like, if the failure surface goes like this; then this anchor will be of no use.

So, depending on what may be the potential failure surface, we have to design the anchor. How, what should be the length of the anchor that we have to decide. So, this can be another anyways, but anchoring can be one way of stabilizing or protecting the slope; so that can be stated regarding this.

Now, maybe I can write, this will be or, as I have mentioned for this one, this yellow dotted failure surface, this much length of anchor is not good enough that we have to understand. Whereas, for this it is perfectly alright, but here it is not good enough. So, we have to extend the anchor length further maybe, or we have to go for some other technique.

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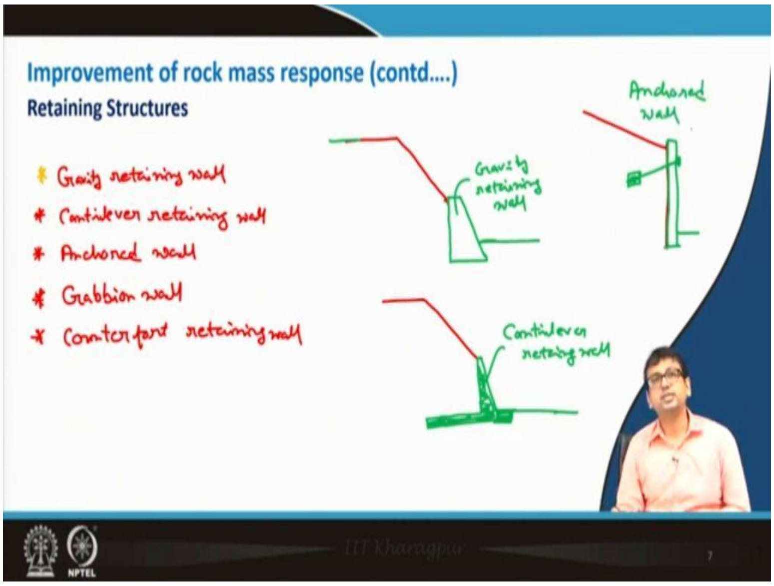

Then, retaining structure. So, we I am sure you know about different types of retaining structures, like retaining structures are like, you must be knowing about gravity retaining wall. Then, you must be knowing about this cantilever retaining wall, then you also know about anchored wall. Then, there maybe another type of wall, the Gabbian wall; or maybe counter fort retaining wall, means whatever.

Now, the how these retaining walls can provide support? That is very simple, like if you have suppose this is the slope. Now, what can be done? Maybe here a retaining wall maybe constructed like this, through which this slope will be supported at this location with the help of this retaining wall.

So, this is nothing but a what type of retaining wall? This is a gravity retaining wall. Likewise, same way we can have something like the cantilever retaining wall will be some just similar to this only, just we will have suppose here ground level only. So, this is my cantilever retaining wall.

So, we can have also the counter fort retaining wall, or a different other thing, like as you know. So, this is the wall; sheet piles wall another thing or the anchored retaining wall whatever I was telling is nothing but, if you have this here and here; the wall is maybe like this. And here the anchor may be provided like this; so, it is anchored wall. So, these are the different ways of providing retaining structures.

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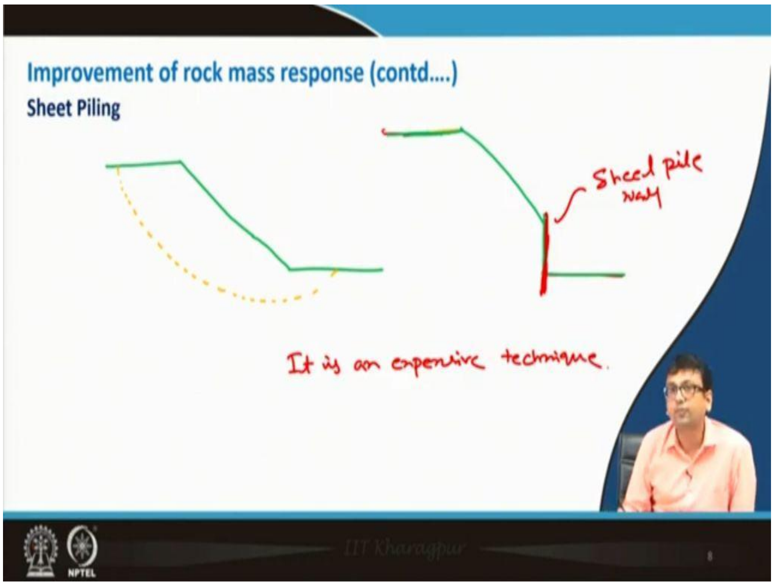

Like sheet piling is also I think one another type of retaining structure, but it is costly; so, anyway, let me draw the diagram. Suppose, what is happening, suppose this is the case. Now, it may happen that initially the failure surface is passing through this. Now, what maybe the way, then what maybe done is you can provide the sheet pile like this.

Now, what will happen? It will no longer be able to, the failure surface will not be able to propagate further. Because if you use, if you properly design the sheet pile wall, this sheet pile wall; it is a sheet pile wall. With the help of this, obviously the failure maybe prevented, but it is costly; so, it is an expensive technique.

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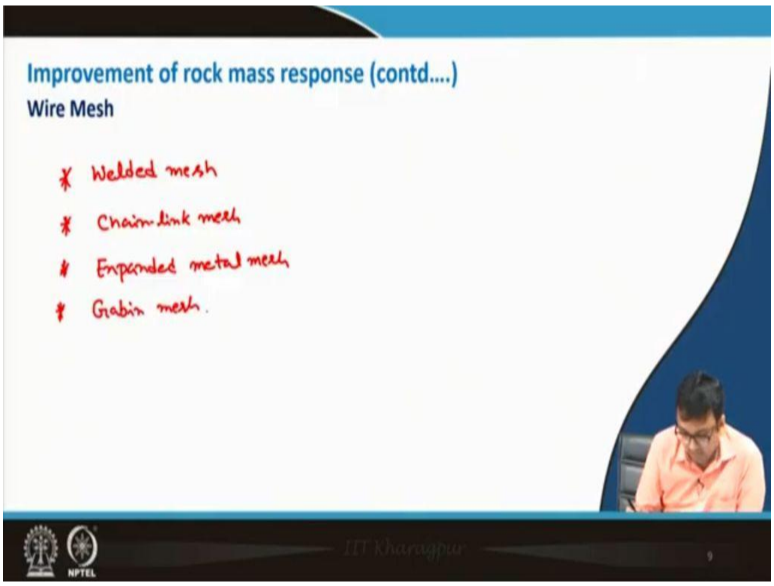

Now, wire mesh. Under wire mesh different type of wire mesh or steel mats can be provided. Let first is suppose welded, welded mesh; then, another type is chain-link mesh. Then, there is expanded metal mesh and here several types; so just I have written some of them like Gabin mesh. Let me just try to draw some of the diagrams like.

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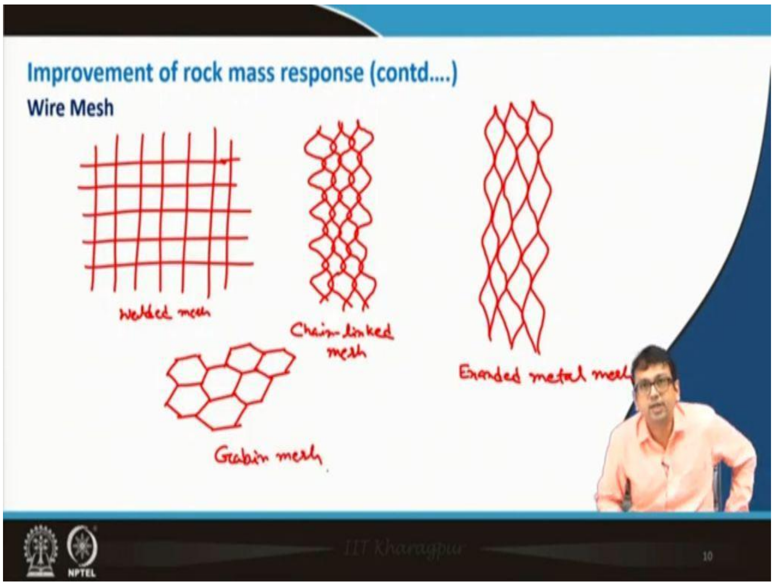

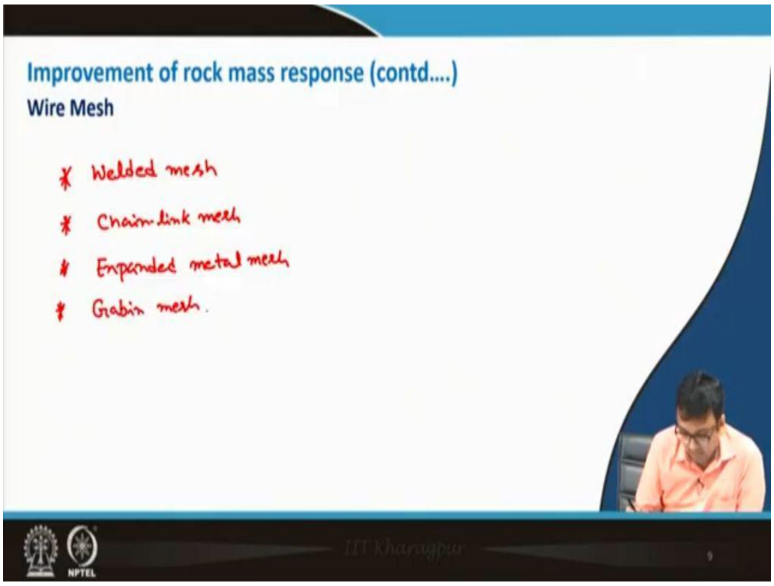

Welded mesh is simple like; it will be welded like this simple; these are the welded mesh, this is welded mesh. Now, in case of the second one that is the chain-link mesh; how it will look? It will be something like, likewise here also it will be like this; I hope you are understanding what must have seen this type of mesh. This is nothing but the chain linked.

Then, another is, as I have mentioned that is the expanded metal mesh. Expanded metal mesh, it will be something like, likewise, I hope you have understood what I am trying to draw; so this is expanded metal mesh. And another one is Gabin mesh. Gabin mesh is something like this. So, this type of mesh is there for Gabin mesh. So, these are different types of wire meshes used for the slope protection purpose.

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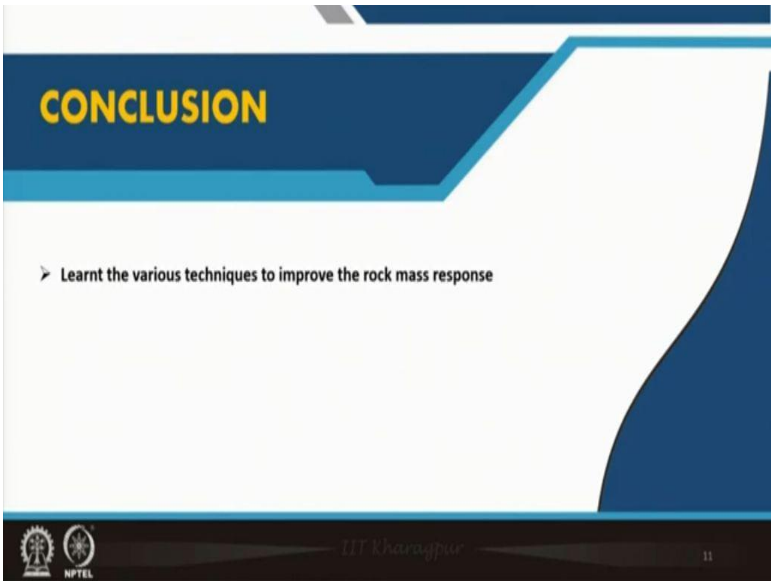

So, so finally, at the end of this module what I can say we have learnt about the various techniques to improve the rock mass response. There are actually many more, but within the short period I have tried to introduce you with the different techniques. And with this I am concluding our this module.

And so finally, what I can say, as the concluding remarks what I can say that. We have actually started our discussion with the topics, we started with the introduction. There we have defined the objective and scope of this course like in this 30 hours course, which we have covered in 12 weeks.

So, we mainly focused our initial discussion on the discontinuities in rock. Then, we have discussed about different classification of rock, based on the formation that we have learnt. Under discontinuities, I hope you remember we have discussed about different types of discontinuities like fall, bedding plane, then fracture, joins; all these things we have discussed.

At that time also we have along with that, we have discussed about the deep strike, deep direction. And we have learnt one excellent technique that is called the stereographic projection. So, using stereonet, how we can identify the intersection of plane on the stereonet with the help of stereographic projection; we have understood at that in our first module only.

Then, in our second module or in our second week, we have discussed about the methods for rock exploration. And under that we have discussed about the rock, basically coring and different rock coring and logging, and the geophysical methods we have learnt in that module.

And in our third week, we have discussed about the physical, mechanical properties of rocks. So, different physical properties as well as mechanical properties, which are very much essential to know actually; that we have discussed in as much as possible in detail within that week. Then, we have discussed about the laboratory testing on rock samples, as well as the in-situ testing of rock mass.

So that, in that, that was mainly related to the experiment related discussion we did; not only the laboratory based experiments, also the field based experiment. Because, as I have told you that, as rock mass is highly heterogeneous and isotropic material; so the only conducting laboratories may not be good enough.

So, we should at least perform some of the field tests to get a better idea about the behavior of rock mass at that particular site. Then, we have discussed about the rock mass classification systems. We have spent one week on that and we have learnt about different classification system like RMR, Hue system; all these systems we have learnt in details. And few other methods also, along with the solved problem also we have solved; I hope you remember.

And we have solved I think quite a good number of problems in that, when we have discussed this rock mass classification system. Then, in our sixth and seventh week, we have mainly discussed about the rock mass failure criteria. So, that was means we spent two weeks time for that; because that is very much important.

So, we started initially with the concept of basic stress, and then stress strength all these things. And then finally, we have discussed to some extent, as much as possible in detail, about the failure criteria like Mohr-Coulomb, Drucker-Prager and Hoek-Brown failure criteria.

This, Hoek-Brown failure criteria, we for that we spent a good amount of time; and along with that, few other empirical failure criteria also we have discussed. And we found that at this moment, this generalized Hoek-Brown failure criteria is quite suitable for rock mass modeling, as far as the numerical modeling is concerned.

Then, in our eighth week, we have started discussing about the applications of these of the rock mechanics. So, in our eighth week we have discussed about the mainly, we have discussed about the slopes; and briefly about the underground excavation. Because we just briefly they are discussed; because the latter, we have discussed about the tunneling and excavation in detail, and I hope you remember.

So, in our eighth week also we have discussed about the applications of rock mechanics, in case of foundation and rock support systems also we have discussed there. So, mainly at that time rock support system means is mainly the natural supports we have discussed pillars and all we have discussed. But, if you remember, as I told at the time also, the artificial supports mainly we have discussed in our 12th week actually.

So, anyway, in our after 9th week after discussing about the foundation and rock support system; in 10th week, we have discussed we have started discussing about the tunneling. So, first we have discussed about the basic features of tunneling, under that like shapes, (()) (30:59), methods of construction; then problems associated with tunnels, and also tunneling in various subsoil conditions in rocks.

And under that we have discussed just discussed about; I think, three case studies. And then in our 11th week, again we have discussed about the mechanics, mainly the stress analysis of stresses actually, in case of opening or tunnels. Means not only tunnels, we also have solved problem on vertical shaft also; circular shaft if you remember we have solved the problem on that.

In 11th week, we have discussed analysis of stresses; under that methods to determine stresses around opening, under that like Kits-equation, we have discussed in detail; several conditions we have taken into in our discussion. Briefly we have discussed about if you remember that Greenspan's method and the (()) (32:02) methods also, we have just briefly discussed; but, Kits-equation we have discussed in detail.

And then also discussed about this pressure tunnel, and lined tunnel, unlined tunnel all these things. Not only that, we also I have also shown you that, how just to give you an idea; we spent one lecture on that how these problems can be modeled numerically, means some of the recent research articles about that I have discussed with you; to give you an idea that how the numerical modeling techniques like, finite element method or finite difference method can be applied, for analyzing these problems, obviously, much more accurately without having that much assumptions.

Because as we know, when we go for the analytical solution; then we have to go for the general assumption. We need to take some several assumptions, we need to consider them. But, in case of numerical modeling, how we are like, we get much more freedom to simulate the actual boundary condition.

So that is why, now, since we have good computational facilities available with us at this in 20, 21; or as we can see that now we have very good computational facilities available. So, that is why this computational, this numerical modeling has become popular; and they are much more accurate. But, definitely we have learned the analytical method, which will in absence of any tools; you can at least, now, you are in a position to analyze the stress distribution around the tunnel.

Means not only a single tunnel, if like the influence zone of the tunnel we have discussed; then the tunnel periphery, the zone which may be vulnerable to failure due to compression or tension, related to that, we also have solved problems also; so you have spent a good amount of time on that part.

And in our last module that is in week 12, we have discussed about the improvement of the rock mass response. So, we have discussed about rock bolts; also we have solved problem on rock bolt. We also have learnt about discussed about this rock anchor, then like this precast concrete lining. Then, cast in-situ lining, then shotcrete, grouting; and different methods for slop stabilization or protection.

All these things we have discussed within this 12th, in our 12th week we have discussed about all those things. As I have mentioned that that discussion could have been extended for again few weeks; but, we do not have that much time obviously. So, I just wanted to introduce with, introduce the terms with the related to these rock mass improvement techniques.

And yes with that we have completed our 30 weeks time, 30 hours time; that is 12 weeks time. So, I hope this course will be beneficial for the students and the practicing engineers. And with that hope I am concluding my lecture here; so thank you, thank you very much for being with me for this last 30 hours. And wish you all the best for your future. Thank you.