Rock Mechanics and Tunneling
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Lecture 59
Improvement of Rock Mass Response (Continued)

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

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So, in module 12, we are discussing about the improvement of rock mass response and rock bolts, rock anchors, steel mats, then precast concrete segments, shotcrete, grouting all these things we are discussing. So, we will continue our discussion on this topic only.

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Today, we will mainly discuss about rock anchors, then rock dowels, then lattice girders, then sprayed concrete and grouting.

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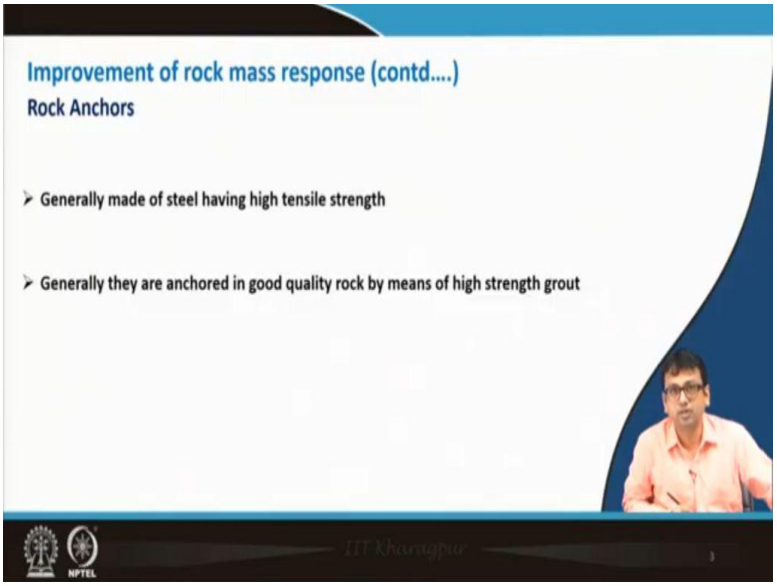

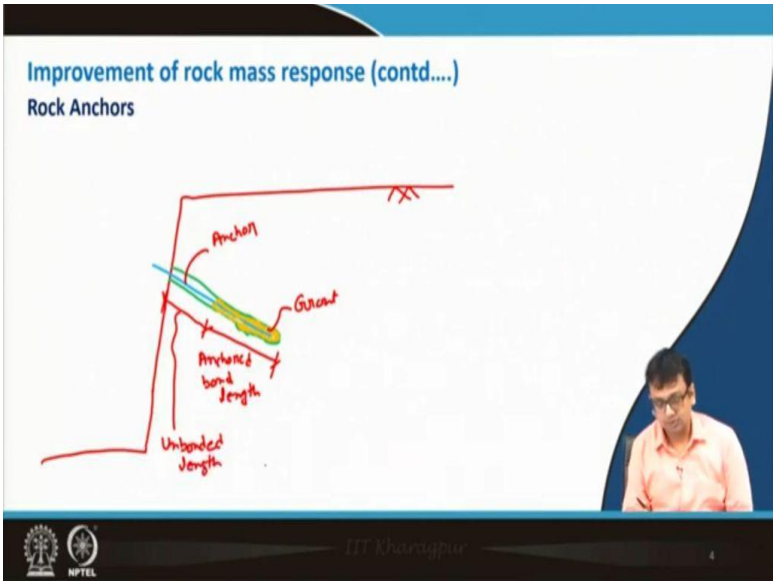

Rock anchors: So basically means, in general, these rock anchors are made up like this; mainly it is made of steel, and the steel should have high tensile strength. And generally they are anchored in good quality rock by means of high strength grout. So, this how it looks actually, just a simple schematic diagram if I want to draw.

Like if it is the, suppose the soil domain. Suppose here is some slope, or maybe let me take an inclined face maybe, maybe like this. So, now here anchors are embedded like this. And before doing that, what is done? A hole is created like this, borehole is created like this; and the grout is injected.

So, if I, grout is now injected here; so, basically this zone, this zone is called as so; so these are, this is the grout actually, and this is that the anchor. So, anchor this is made up as we know that high steel having high tensile strength; now, his zone is anchored bond length. Now, if suppose this portion is no grout is present; then this may be unbonded length maybe.

It depends how much grout you will apply, depending on how much strength is required, several factors are there. So anyway, this portion the nomenclature is unbonded length; so this portion is unbonded length. So, more or less how it looks like I have shown you here.

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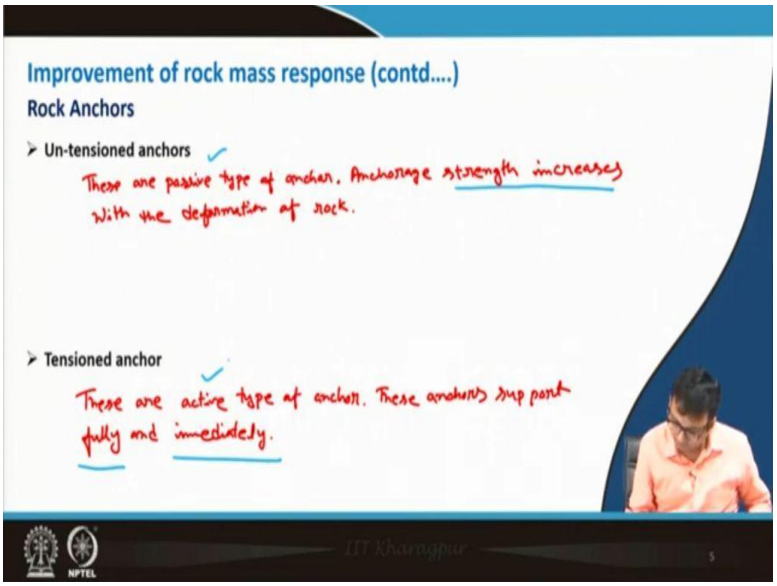

Now, these rock anchors are can be divided into two categories, like un-tensioned anchors and tensioned anchors. So now, what is this un-tensioned anchor? This basically these anchors are like passive type of anchors. These are passive type of anchor, and that is what we can say; and on the other hand, the this tensioned anchors are the active type anchor.

So, these are active type of anchor. Now, because of passive type of anchor what will happen? This, in this scale, the anchored strength increases with the deformation of the rock. So the here anchorage strength increases with the deformation of rock.

On the other hand, in case of since it is active type of anchor here; so these anchors these anchors support fully and immediately. So, these are the important things like just fully and immediately, means just after installation. Whereas, here, anchor strength increases as the deformation of rock increases; so that is why this is passive type and this is active type, fine.

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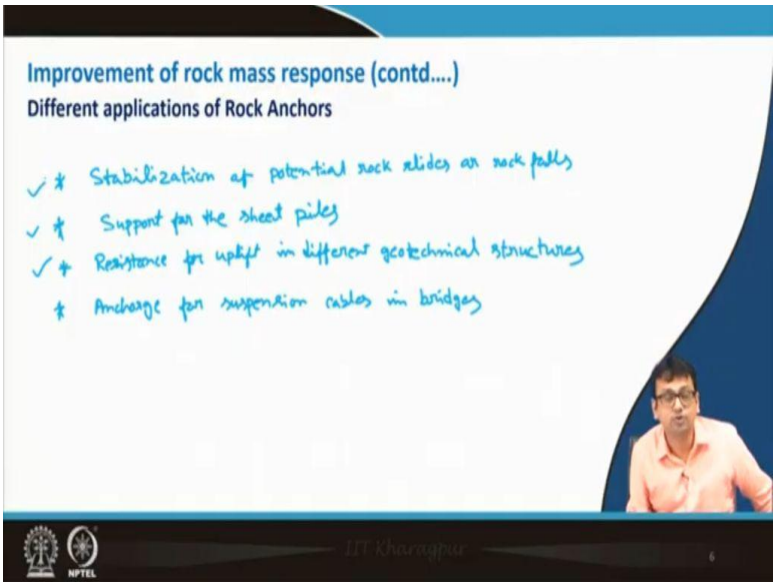

Now, different applications of rock anchors; so what are they? So some of the applications, it is used for stabilization of stabilization of potential rock slides or the rock falls. This can happen when for that purpose it is it can be used. Also support for the sheet piles that for that purposes it is use.

Also, resistance for uplift in different geotechnical structures like dam, foundations etcetera; I will draw some of the diagram in my next slide, so, resistance for uplift in different geotechnical structures. And also for the anchorage of suspension cable for bridges; that also means you have to anchor those cables.

If you have seen this suspension cable bridges; so there the cables are ultimately anchored. So, for that purpose also, they are also it is used this anchor. So, anchorage for suspension cables in bridges; likewise, there may be several applications. I will draw some of the diagram mainly related to this, this case that resistance for uplift in different geotechnical structures as well as the sheet pile, as well as for the stabilization of potential rocks slides.

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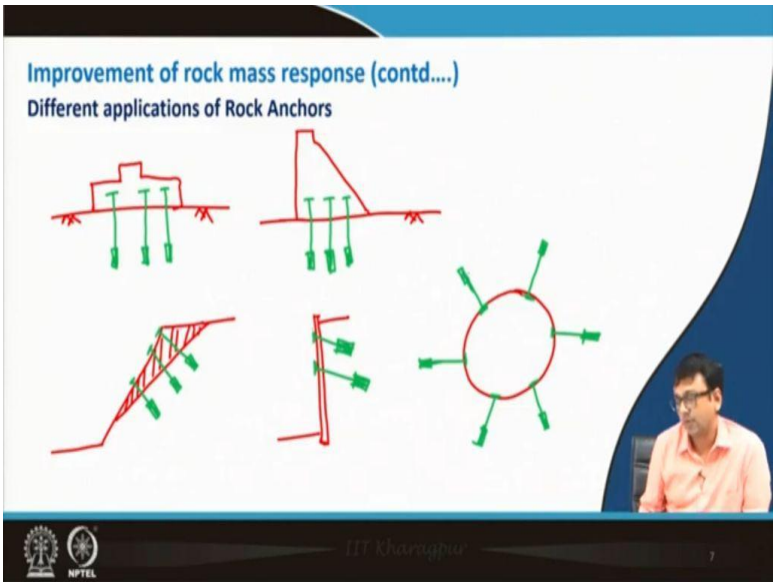

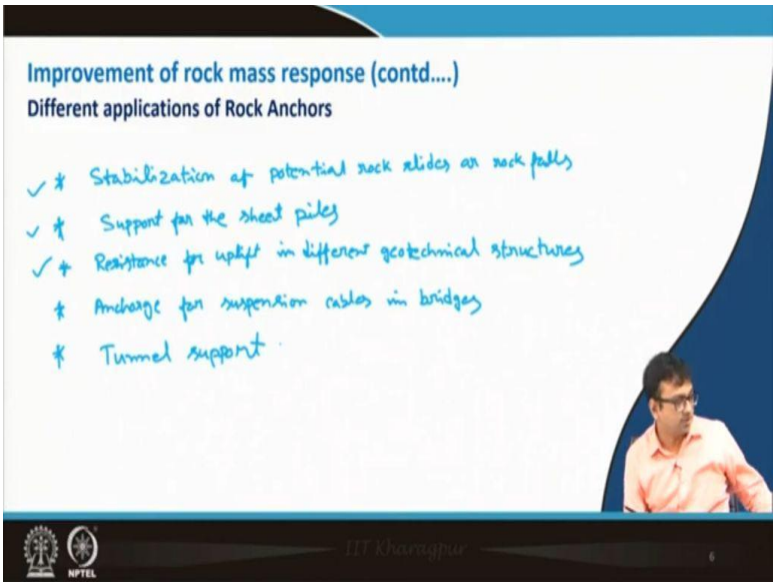

So, some just schematic diagrams; so, for example, first if I draw foundation. So, how it will be? Suppose this is the ground surface. Now, over here the foundation is present; now, maybe that foundation is subjected to, there may come some, may be this may be subjected to huge uplift pressure.

So in that case, what may happen? So, what can be done is the anchors may be provided; depending on the requirement, the anchor design also needs to be done; so, this can be one thing. Likewise, dam, dam is another structure where these anchors are provided; so, what is to avoid any kind of failure due to uplift like this.

Then, also rock fall prevention; for that purpose also, it may be used. Suppose, this portion is, is there is a chance of failure suppose. So, then the these rock anchors may be provide over

here. Likewise, as I have mentioned for sheet pile also, it may be a required; so suppose this is a sheet pile, or any retaining structure. So, here may be this kind of support maybe there; you may have to provide.

Also, another case may be the sometimes for the tunnels also, it may be provided, so likewise, so this way, it may be used. So, maybe you can write over here, for the tunnel also; tunnel support. Likewise, there may be several applications, some of the diagrams; only I have drawn over here. So, this is about may be the this rock anchors.

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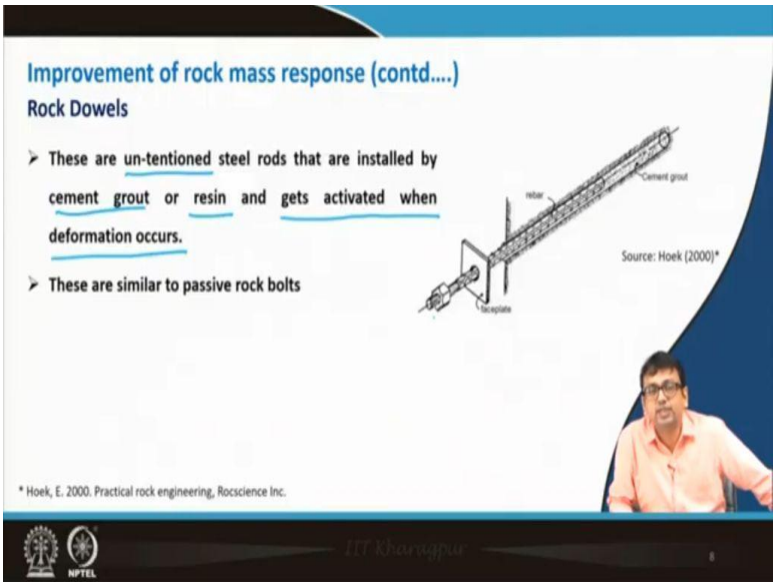

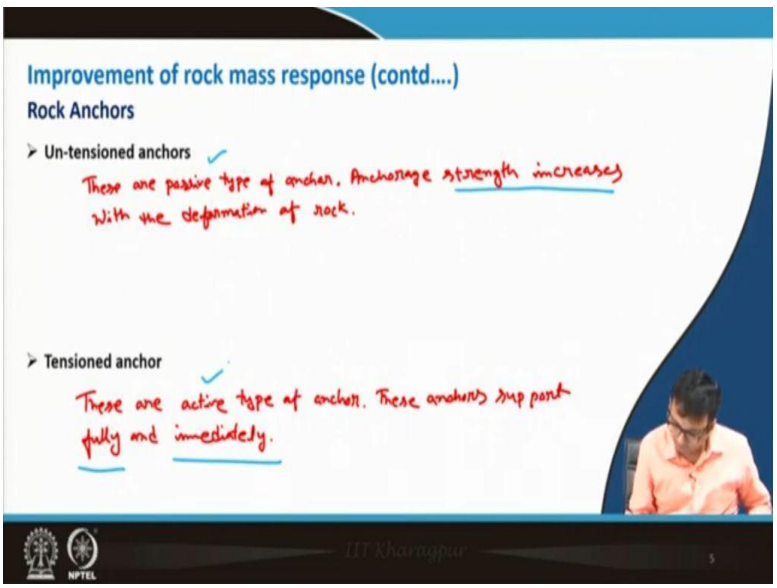

Now, kind means almost similar to that rock dowels are there; so, this is also another type of reinforcement. These are un-tensioned steel rods that are installed by cement grout, or resin cement grout, or resin; and get activated when deformation occurs. So, it is un-tensioned, as I

have mentioned un-tensioned rock anchor we have as we have discussed, which is nothing but a kind of passive type of support as we have discussed over here.

Similarly, these rock dowels are kind of un-tensioned steel rods, and it looks like this. So, so this is how dowel will look like; means almost similar to we can see like very deep. From this diagram, you may feel that it is very much similar to the other reinforcement types, like bolt or these anchors also. So anyway, these are different types of reinforcement; so bolts, anchors and dowels, we have discussed. So, these are similar to passive rock bolts as I have mentioned. Passive rock anchor or passive rock bolt, whatever you say it is similar to that.

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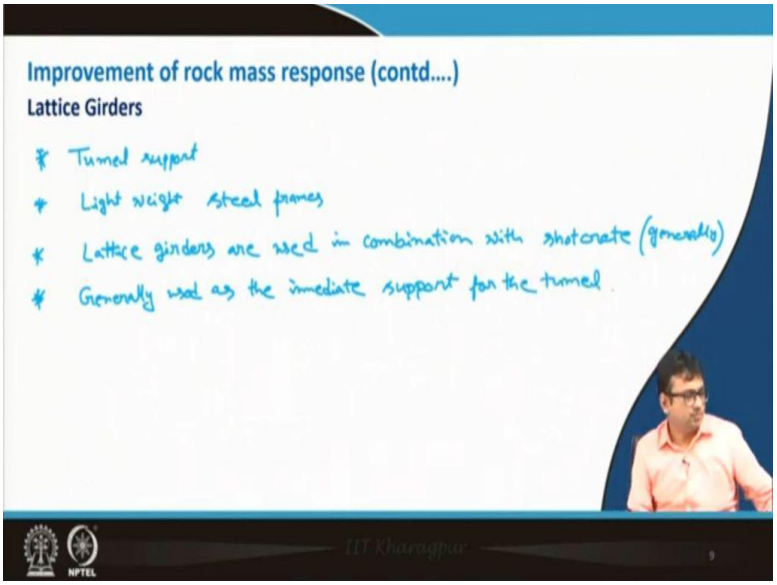

Now, another thing is lattice girders. So, lattice girder what is this? These lattice girders are, these are used for the, for constructing the tunnel supports. So, it is used for mainly for tunnel supports, for there it is used and these are very lightweight steel frames. Generally, these lattice girders are used with the along, this is used in combination with the shotcreting; we will learn about the shotcreting very soon.

But, you already have mentioned what is shotcreting earlier also briefly; so, these lattice girders are used in combination with shotcrete generally. And another thing it can be stated the generally used as the immediate support; so this is basically tunnel support, but mainly as the immediate support for the…

When the excavation is going on, then that time as the immediate support, these are generally used. So, generally used as the immediate support for the tunnel; this much I think fine for this. Now, at least you should be familiar with this term that is my objective. Obviously,

designing all these things for that we need much more time, so that is not here. We do not have that much time available. But, at least you should know what are the measures available, then you can further explore these topics for your better understanding.

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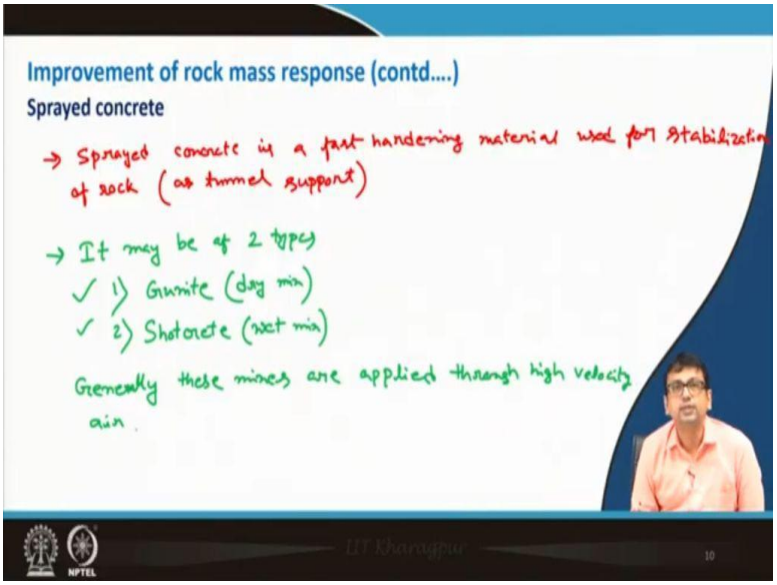

Now, sprayed concrete; so, this is again very important thing. Here only the shotcreting will again come. So, the sprayed concretes, these are the fast hardening material used for that purpose. And it is used mainly as for the for providing the support to the tunnel; when the tunnel excavation is going on. So, sprayed concrete is a fast hardening material, fast hardening material used for stabilization of rock, mainly as the, as or for simply that as tunnel support.

Now, these, this sprayed concrete may be of two types; so, it may be of two types. Number one is the dry mix; dry mix is called as the gunite; g u n i t e. So, it is the dry mix. And second one is shotcrete; shotcrete, it is nothing but the wet mix. Gunite, dry mix, shotcrete, wet mix.

Now, these commonly these mixes are sprayed with the help of high air pressure actually. So, generally, these mixes are applied or sprayed actually through high air pressure or high velocity air maybe we can write; which will obviously generate pressure. So, high velocity air with the help of this; these are actually applied.

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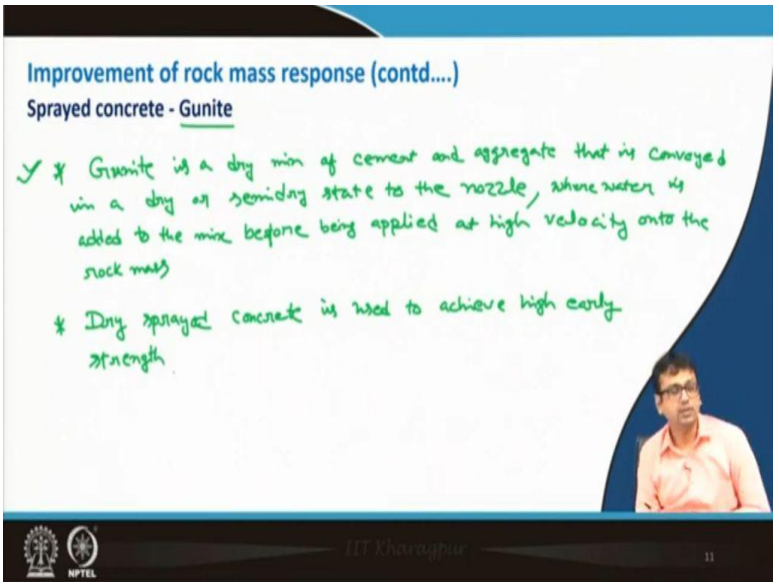

Now, a little more if we discuss about this dry mix, how it is. So, it can be stated that that this gunite. So g u n i t e, so gunite is a dry mix of cement and aggregate. That is actually what is done, means that is conveyed in general in dry form, or almost in dry form, till the nozzle of the pipe through which it will be sprayed. And there is little amount of water is added to moist the thing.

So, gunite is a dry mix of cement and the aggregate; that is conveyed in a dry or semi dry form to the nozzle. And then as I have mentioned, where water is added to the mix, before being applied at high velocity onto the rock mass; this is one thing.

Basically these are used as the like the to gain early strength. So, this is the immediate arrangement what is done for that purpose the dry mix is generally used; so, we can write that point also. So, dry sprayed concrete, this dry sprayed concrete is used to achieve high early strength.

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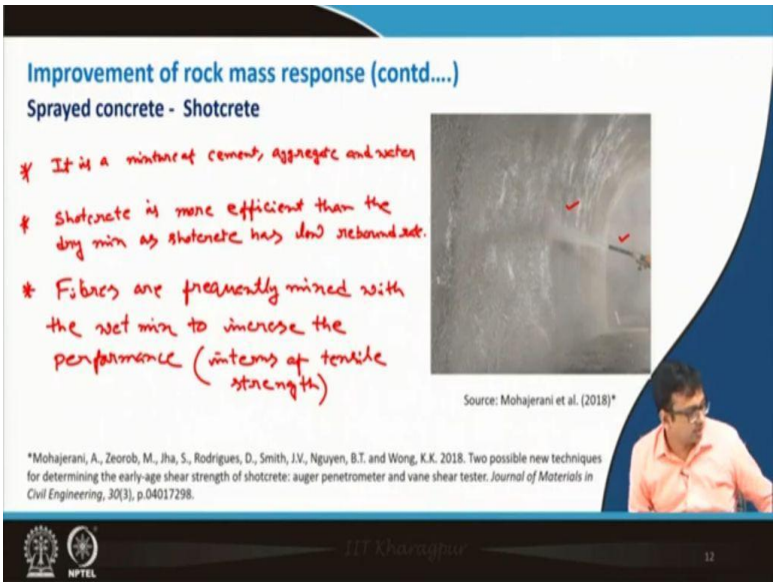

Now, sprayed concrete. So, second type of sprayed concrete is shotcrete, which is nothing but the wet mix. So, this diagram indicates the things very nicely. You see, with the help of the nozzle, the weight mix is being applied over this rock mass. You can understand this is nothing but, means this is; this operation is going on for creating the tunnel support, you can clearly understand.

So, one or two things we can write here like the. These shotcretes are the, it is a mixture of cement, cement, aggregate and water; and it is applied through this arrangement as you can see. From here like this it is applied, and also it can be stated that the shotcreting; this is more efficient than the layer the dry mix actually. This shotcrete is more efficient or effective than the dry mix. The reason is this shotcrete has low rebound rate; dry mix as shotcrete has low rebound rate.

Now what is the rebound rate we have discussed earlier? Means the you see the spraying is going on here as you can see. Now, some amount of concrete or this wet mix or dry mix whatever you say; this sprayed concrete would not actually remain attached with the wall means the rock wall.

So, some part will what will happen? They, they will fall down on the floor of the tunnel. So, that is how much is falling over the floor of the tunnel; based on that the rebound rate is fixed actually. So, quite obviously, in case of dry mix of since the it is dry; so chance of this developing this addition will be relatively less.

So, as compared to the shotcreting this dry mix will have high rebound rate; whereas this wet mix will automatically it will, the chance of mean; it attached with the wall face will be higher. So, that is what another thing we can say.

Also, another thing is the fibers are frequently mixed actually, fibers are frequently mixed with, this wet mix; are frequently mix with the wet mix to increase the performance; means performance in terms of, performance means in terms of the tensile strength. So, roughly I think we have discussed about the shotcreting also in brief.

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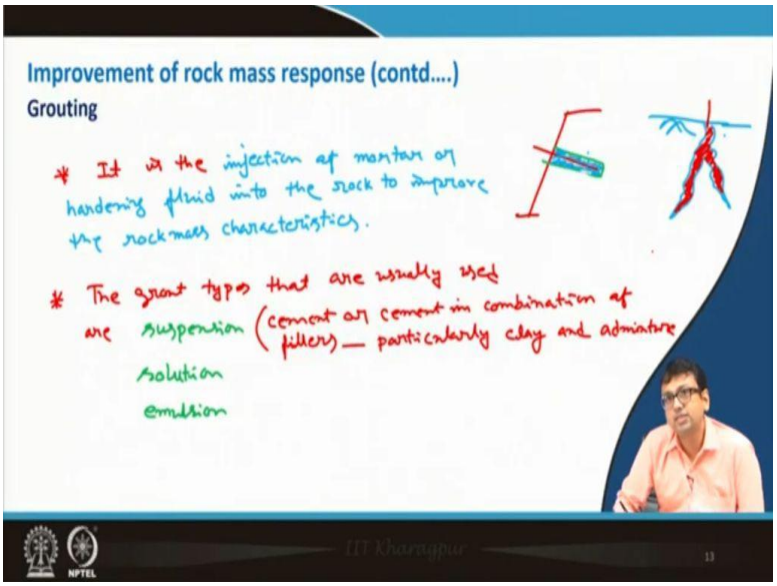

So, so next topic is grouting. So, grouting already we have discussed about the grouting little bit; at least, it is used to in case of anchor we have seen. Also we have when we have discussed about the bolts; so then also we have seen this grouting. So, what are these, this is made of what? What kind of material it is?

Actually these are, it is or the. It is the injection of the mortar or the hardening fluid. So, suppose for example, like cement, cement grout. So, if you inject it, what will happen? After some time, it will like that, it will harden. So, as a result of that, if you as we have seen like the, if you suppose this is your anchor maybe.

If you now fill this one with suppose the cement grout, so what will happen? After sometime that grout will harden. And there will be good bond will develop between the rock and the ground, as well as the grout and the, this steel rod; so, as we can understand. So, that is what actually this; that means, that is what we can say the grout is nothing but, when hard; means it hardens very fast.

And that kind of material it is; so at least let me write down that one. So, it is the injection of mortar or hardening fluid into the rock to improve the rock mass characteristics. Basically, it not only increases the strength of the rock mass, it also provides; means work as the like behave as the like impermeable layer in case of, suppose if you are injecting it in a, suppose there is some crack developed.

So, suppose there is some cracks developed like this; so these are the cracks are there. Now, if we inject this grout over there, so if we inject grout; so what will happen? These things will close, number one. Along with that, the permeability also will reduce. So, these are the other things, what happens if we apply these grouts. So, now these are mainly these the grout types that are usually used are number one, it is suspension form; so number two, it may be in the form of solution or the emulsion.

Now, commonly used as I have mentioned cement grout. So, that is that will fall in the category of suspension generally that will fall. So, we can say the cement or cement in combination of fillers. So fillers, under the means fillers means that maybe like the clay it may be there, or maybe some admixtures.

So, we can write over here particularly clay and admixture with different type of admixture are available in the market; that may be mixed with this cement and may be used as this as a grout. Also, different other chemicals also available in the market, which are used as the effective solution for these type of situations. Number one; for bolts, anchors, dowels, it may be used; otherwise, like these cases like there is some crack developed, you can apply these and you can reduce the permeability and all.

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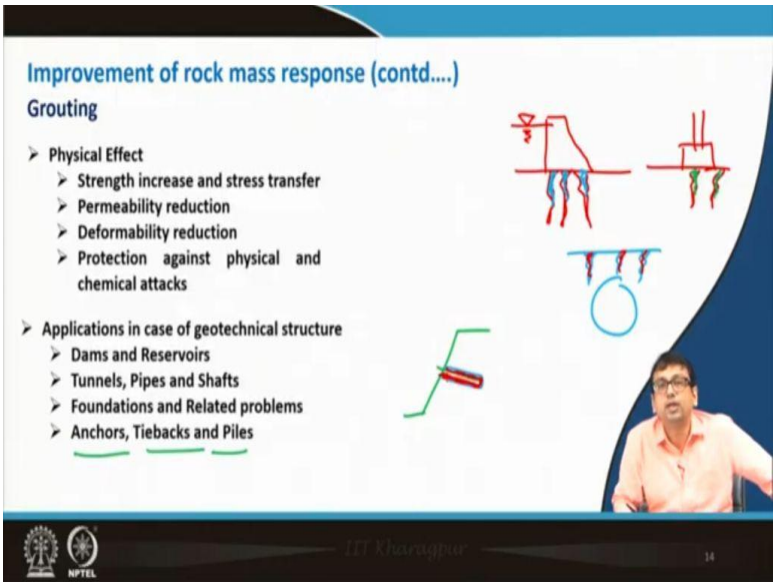

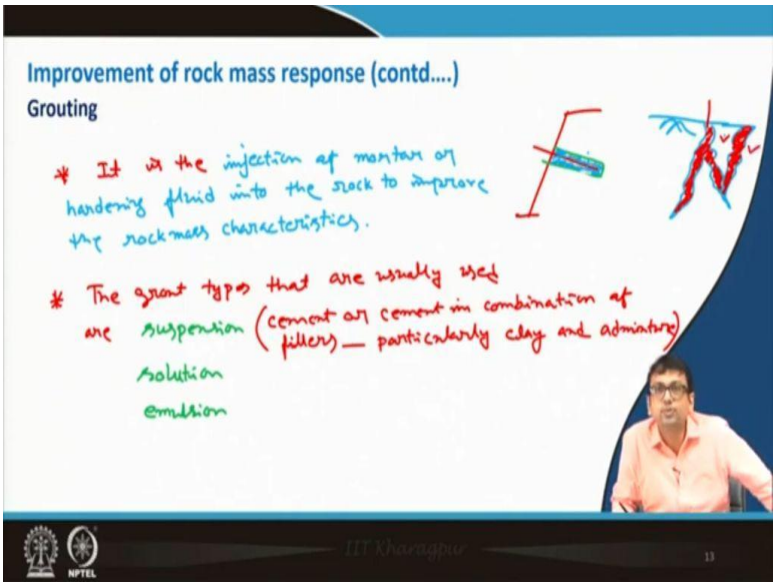

So just to make these things a little bit clear, here are some of the things I have listed down, from one literature like, it grouts physical effects. Some of the physical effects can be the strength increases because of this, as strength increases and stress transfer happens. Basically, what I was telling over here, if you there was initially crack present. Now, if you input this, suppose there is also another crack.

So, now, if you fill that with grout what will happen? Initially there was crack, there was is no connection between these two parts. So, they were actually separated this rock portion and this rock portion. Now, because of the application of the grout, obviously, the overall strength will increase, stress transfer will happen; so that is one thing what I have listed here, strength increase and stress transfer.

Other than that, what will happen? Permeability reduces. So, if you fill those cracks or other voids with grouts, what will happen? Obviously permeability will reduce. Then, deformability reduces, obviously if your strength increases your deformability will definitely reduce.

And protection against physical and chemical attacks; so this is also another obvious reason, that if you fill those places with like grout, then different chemical may not percolate through that because of the reduction in the permeability. And also because of all these reasons, you are priority will give protection against chemical attack; as well as physical forces that will also be well taken care by the rock mass, if you provide the grout.

If you remember when, when I was discussing about the tunneling through case studies; one of the case studies regarding the tunneling through rock mass or rock or soil. There one case, if you remember I was discussing that, there at the time of very beginning at the very beginning only at the time of surveying or when they have tried to find out the rock property, then only they found that the rock mass is not of good quality.

So, what they did? Before starting the actual tunnel boring operation, they actually provide the injected grout in that region over a huge stretch. And they have improved the strength characteristics of the rock mass there, as well as this permeability reduction. All these aspects they handle or increase the strength, reduce the permeability; all this thing they could able to do, by applying the grouts only.

So now, some of the applications in case of geotechnical structures like dams and reservoirs. So, if you have a dam like this present over there. Now, what may happen? Suppose there are some cracks are present; so, and these dams are huge structures. So, what may be done, so there these grout may be injected to increase the strength. Likewise, tunnel as I have mentioned in case of tunnels, pipes and shafts also; it is very much essential.

So, in case of tunnel some if some crack is present there, crack is present there; so that maybe easily filled with the grout, so that the strength may increase. Likewise, foundation and related problems, so similar to these maybe there is a foundation; and here some cracks are present. So, in order to avoid that what can be done? So, that this grout maybe injected. And in case of anchors and tiebacks and piles, means there we have seen, I have drawn that the diagrams again and again; like this you may have to provide the grout over there for providing enough anchorage.

And it will actually develop enough bond strength will develop between the interface of the grout and the rock, and the interface of steel rod and the grout. So, with this let us conclude our today's lecture; so next lecture we will, again we will discuss about some of the other improvement techniques. Thank you.