Rock Mechanics and Tunneling
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Lecture 57
Improvement of Rock Mass Response

Hello everyone, I welcome all of you to the first lecture of module 12; so, this is our last module.

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In this module we will discuss about the improvement of rock mass response. So, under that several things we will learn. Among them like rock bolts, anchors, steel mats, precast concrete segments; then shotcrete and grouting etcetera, we will learn. So, basically we will begin with the improvement of rock mass response.

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So, what are the things we will learn today? As I have mentioned, the overall objective of this module is to learn about the improvement of rock mass response techniques. So, today first we will discuss about the different types of rock improvement techniques, and then we will start discussing about the rock bolts.

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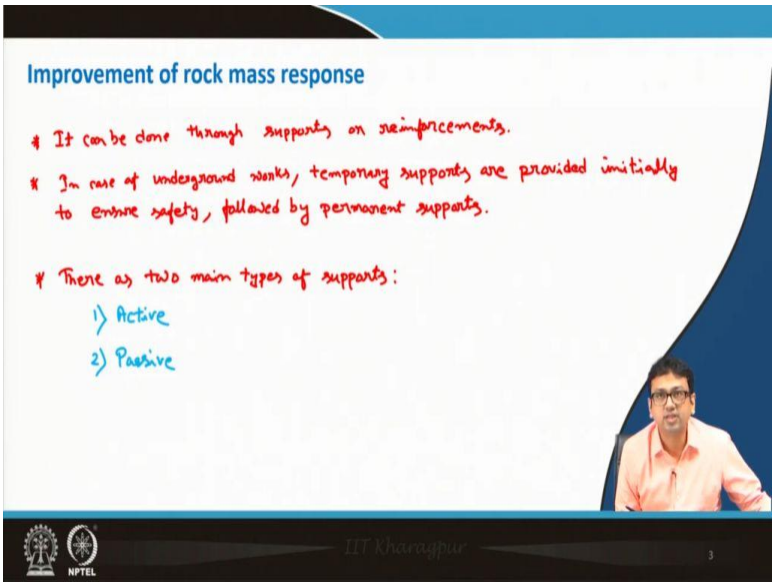

It can be done through may be by providing support, or by including reinforcement. So, first point may be written as, it can be done through supports or reinforcement; quite self-explanatory, means either suppose some slope is failing.

So, either you can provide some support, you can create a retaining wall; or otherwise you can provide reinforcement, you can include there. So that like rock bolting, rock anchoring, or the steel mats you can provide there to stabilize the rock mass.

Other than that, we can also write that in case of underground works, we generally provide a temporary support; and then we go for the permanent support or lining.

So, we can write that also in case underground works, temporary supports are provided; Temporary supports are provided initially to ensure safety. Then we provide the permanent support. Now, actually there are two types of support; one is called active support, one is called passive support. I hope you are familiar with these two terms active and passive; because when in soil mechanics, you have learned about the retaining wall, there you must have learnt about the active earth pressure and passive earth pressure. So, active, passive these terms I am guessing it is known to you. Now, anyway, nevertheless, we will discuss about this further. So, what is active support or what is passive support, let us understand.

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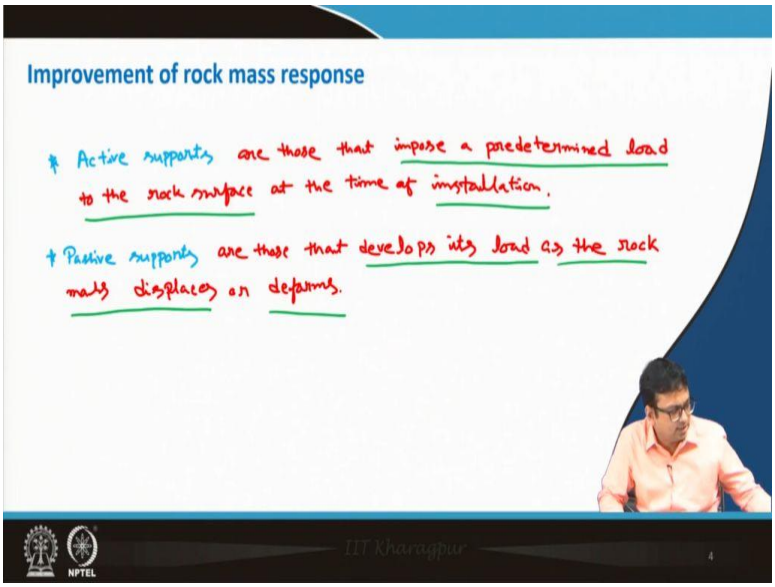

So, first is the active support. So, active supports are those that impose a predetermined load to the rock surface at the time of installation. On the other hand, passive supports are those that develop its load as the rock mass displaces or deforms. So, with deformation or displacement, it starts developing the load; so these are the basic differences, we should at least know what are they.

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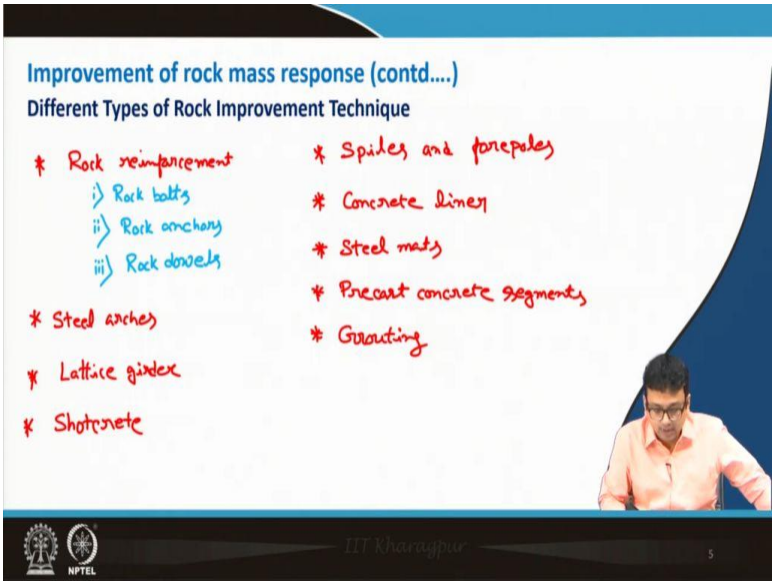

Now, different types of rock improvement techniques that is very important, which we will learn actually one by one in this module. So, some of the names we can write now, like first is of course the rock reinforcement. Now, under rock reinforcement, there maybe rock bolts like rock anchors, then rock dowels all these things are there; we will discuss about these

things. So, rock bolts are used widely, in fact very widely used. Rock anchors, they are also very popular; and rock dowels.

Then next is steel arches; then, we have the lattice girder. These terms are probably now known to you; because during the discussion of that tunnel excavation, I have discussed about these terms probably lattice girder. Then next is shotcrete, so that also I think now, you have heard from me shotcrete. Then we have the spiles and forepoles; we will discuss about this also briefly.

And then concrete liner; concrete liner also you have heard, this is used in tunnel stabilization. Then steel mats, precast concrete segments and another important thing is grouting. So, these are some of the techniques name of the techniques I have mentioned over here.

There are obviously several others present; these are the main techniques. We will try to at least discuss about these techniques to some extent. Some parts we will focus like rock bolts; then maybe shotcreting, then grouting; these things we will obviously discuss in more detail.

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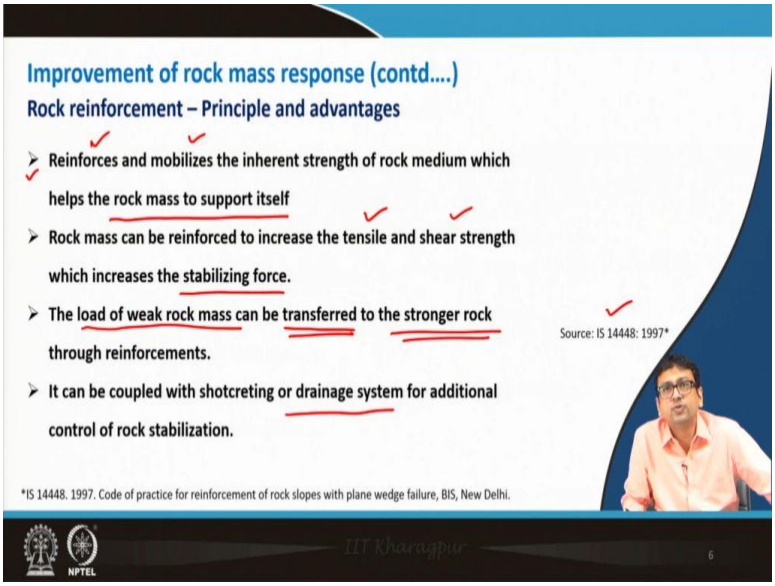

So, let us begin our discussion. Now, the first is rock reinforcement principle and advantages. So, these are some of the points as per IS code Indian Standard code; these things I am mentioning to you. Like the reinforcements and this rock reinforcement principle and advantages reinforces and the rock reinforcement what it does?

It reinforces and mobilizes the inherent strength of rock medium which helps the rock mass to support itself. So, this is very important rock mass to support itself. Then rock mass can be reinforced to increase the tensile and shear strength, which increases the stabilizing force; so, mass can be reinforced. So, if we can do that, it is quite obvious as we know the rock is good in taking compression.

Then also it can be stated that the load of weak rock mass can be transferred to the stronger rock through reinforcement. Like that is the purpose of we will learn obviously, that through rock bolt that is only done mainly; that the load of the weak rock mass can be transferred to the stronger rock through reinforcement. So, load of the weak rock mass can be transferred, this is important transferred to the stronger rock through reinforcement; that is another important thing.

And also, it can be coupled with shotcreting or drainage system to augments for additional control of rock stability. So, as we know that shotcreting roughly we have seen earlier, what we do in case of shotcreting. So, we will learn it obviously in detail also in our subsequent lectures. So, through shotcreting number one, the stability can be further increased; or another is drainage. See drainage, if the proper drainage is not there, then pore water pressure will develop; and that will ultimately decrease the effective stress. So, that is why this is important that drainage system is important; so it what it can be stated that the coupled with shotcreting or drainage system for additional control of rock stabilization. So, these are as per the IS 14448-1997; so, one can refer this also for further details. These are the main points what I have written; what are the recommendations actually of this IS code.

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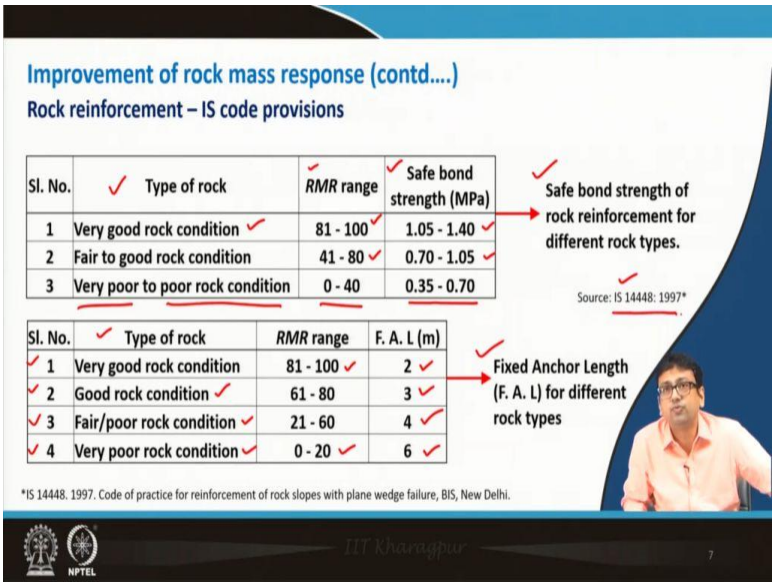

And now, this is useful again, that IS code again recommends some for the purpose designing, the IS code has recommended some of the useful values of like safe bond strength, corresponding to the RMR. So RMR, we know rock mass rating system, and we have learnt it in detail. Now, you see what it says for very good rock condition.

Then, as we know for very good rock, generally this RMR is 81 to 100. So then, the safe bond strength in MPa should be 1.05 to 1.4. Now, this is just additional; it is also mentioned a safe bond strength of rock reinforcement for different rock types.

So, these are different rock types and safe bond strengths are provided over here. Then fair to good rock condition; it is 41 to 80; it means a wide range of rock type is covered actually here. So, for that safe bond strength is 0.7 to 1.05; and very poor to poor condition means 0 to 40, the safe bond strength is 0.35 to 0.7. Now, this is also actually from IS code 14448: 1997.

Now, another thing is fixed anchor length F.A.L for different rock types; that is also provided there in this IS code. So, for different rock types, here the rock types we can see four categories are there. So first is very good rock condition, as it was for the previous table; and their RMR is 81 to 100, and fixed anchor length is here is 2 meter.

And for good rock condition, it is 61 to 80; so, here it is fixed anchor length is 3 meter recommendation. Then fair to poor rock condition, it is 21 to 60; once again quite a big range 21 to 60 that is why fair to all poor rock condition. So, If F.A.L that is fixed anchor length is 4 meter; and for very poor rock condition where it is 0 to 20, F.A.L is 6 meter. So, these are some of the recommendations of IS code, we can find. And as I have mentioned, one can refer this, read this IS code for further knowledge.

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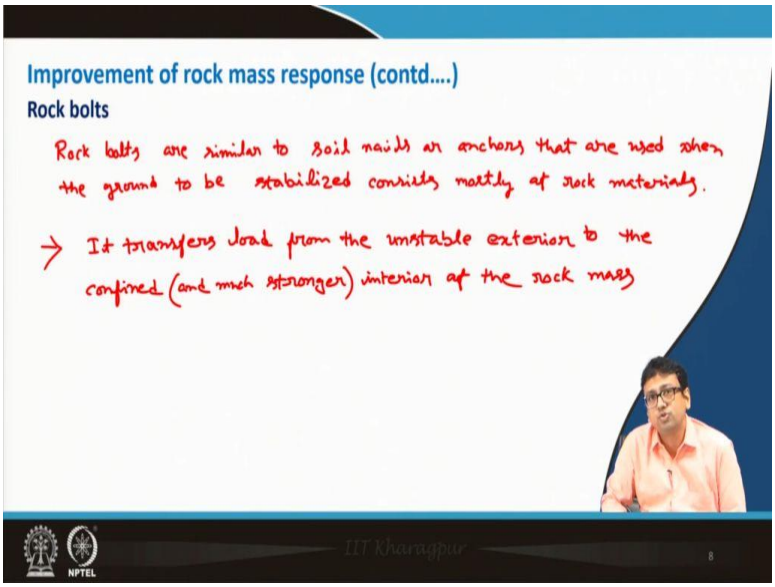

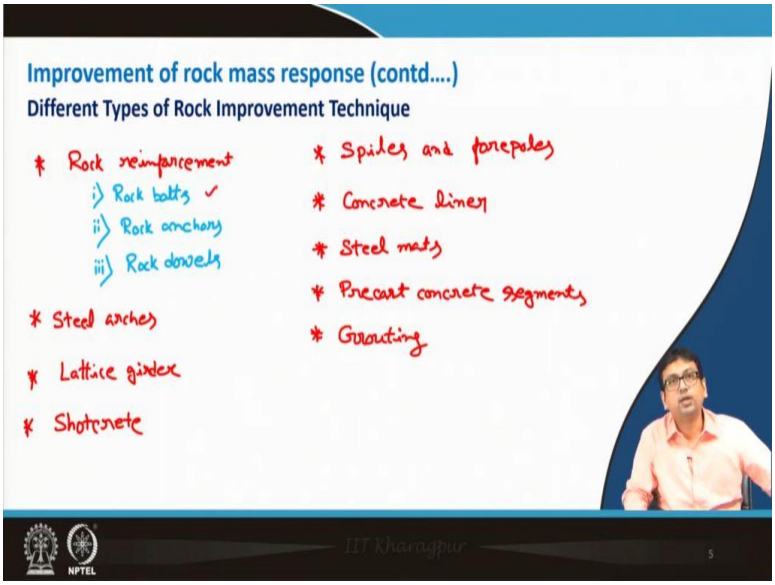

Now, rock bolts. So, rock bolts as I mentioned and written also over here; the first type of reinforcement is this rock bolt. What we will discuss first, so we will begin with the rock bolts today only. So, basically this rock bolting actually in soil, probably have heard about like soil nails and anchors.

So, it is also similar to something like that, which is used in case of rock for stabilizing the rock mass which is weak and supposed to fail. There we use rock bolt, so it can be stated that rock bolts are similar to soil nails or anchors that are used when the ground to be stabilized, consists mostly of rock materials.

So, this is what we can say, as I mentioned. Then what we can also say is, it actually transfer the load; it transfer load from the unstable exterior to the confined, or we can say means confined or and much stronger interior.

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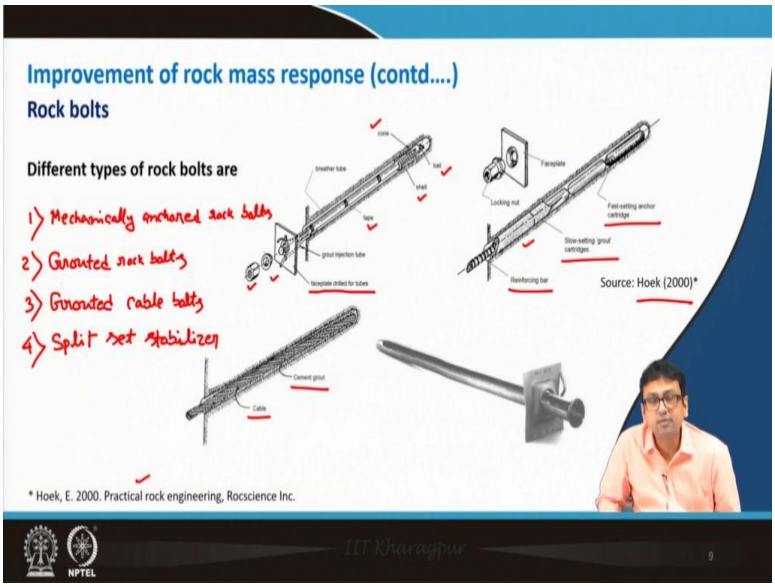

Now, there are different types of these rock bolts available. So, first is here you can see four diagrams; First one is mechanically anchored rock bolts. And another type of rock bolt is like the grouted rock bolts. Then another type commonly used rock bolts are like grouted cable bolts; and another type is split set stabilizer. We will also see another type of rock bolt that is called swellex in our next lecture. So, we can look into these diagrams, you see what are the components here it is called the bail, there it is shell, then cone, then like here tape. You see the bolts are there, you see washers are there. Here you see the faceplate drilled for tubes, we can see that also; so, these are the different components for this.

Now, you see, if you look at here what we can see? This is the reinforcing bar. And here you see the fast-setting anchor cartridge some is written over there. Then slow-setting grout cartridge; so, these are the grout, so grouted rock bolts you can clearly see over there.

Now, another one was the grouted cable bolts. So, surrounding is cement grout provided there. So, these are some pictorial representation of these things; so these are taken from Hoek 2000. This book actually is practical rock engineering.

There you can see maybe, a few other different types of picture of other types of rock bolts; So, as I have mentioned, the mechanically anchored rock bolt and grouted rock bolts are extremely common and it is used widely and grouted cable bolts are also quite useful.

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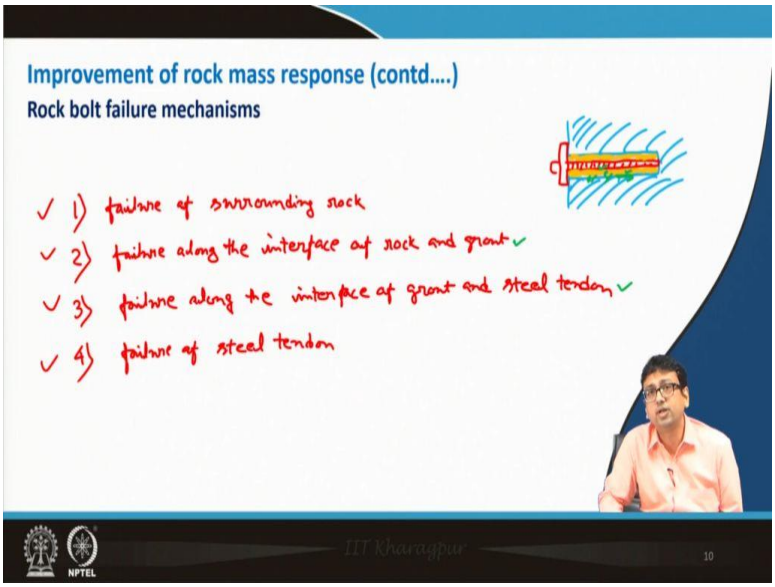

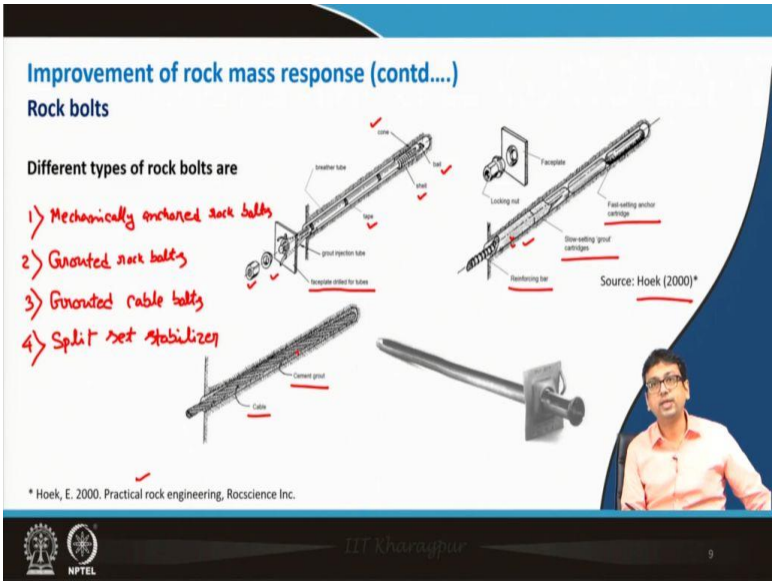

Now, rock bolt failure mechanism. So, how it may fail? So, basically rock bolt can fail due to the failure of the surrounding rock. If the surrounding rock itself fails, then what can this rock bolt do. So, obviously it will along with the surrounding rock mass fail. But other reason which is related to you can think about the rock bolt designing; that may be the failure along the interface of rock and grout. So, what I mean to say here if we just look at; you see there may be some slippage or failure, between the grout and the rock mass itself; so, then it will fail.

Then, another thing can be failure along the interface of grout and the steel rod or tendon; this is also called grout and steel tendon. So, what I mean to say is, so there may be number one, one failure is happening; suppose, let me maybe draw. You can see from over here that the between the steel rod or the cable here, what you can see here; and between rod and the surrounding grout. There can be slippage, so that can also fail.

So, let me draw a diagram that will probably clear your confusion; So suppose this is the one. Here now, suppose this is the bolt. Now, here suppose this is the grout. So, one is this one, what it is stating failure between this and this. So, this is the rock mass; Basically this is your rock. So, first one what is stating that the failure along the interface of rock and grout; Now, next one, what it is stating the failure along the interface of grout and the steel tendon; so that is also quite possible like, this is the steel rod or steel tendon and here the grout.

So, interface between grout and the steel tendon, there may be some slippage or failure; so, this can be another reason. And also another quite possible reason is the failure of the steel rod and the steel tendon. So, if the material of that steel rod is not having good yield strength means reasonably high steel strength, then what may happen, that the rod may fail; so, that can be another possible reason.

So, these are some of the points, what I have written over here. There may be few, maybe several other reasons of this rock bolt failure; but these are some of the common reasons. So, with this let us conclude our today's lecture. I will continue our discussion related to rock bolts in our next lecture also. Thank you.