Underground Space Technology
Prof. Priti Maheshwari
Department of Civil Engineering
Indian Institute of Technology – Roorkee

Lecture – 53
Various Support Systems Rock Bolts

Hello everyone, In the previous class we discussed about the shotcrete in connection with different support systems. So, we discussed in detail that how the mix design will be done and what all are the precaution, that one needs to have while using the shotcrete support system. The other type of support system, which is commonly used is rock bolts. So, today we will have the discussion on the various aspects related to rock bolts.

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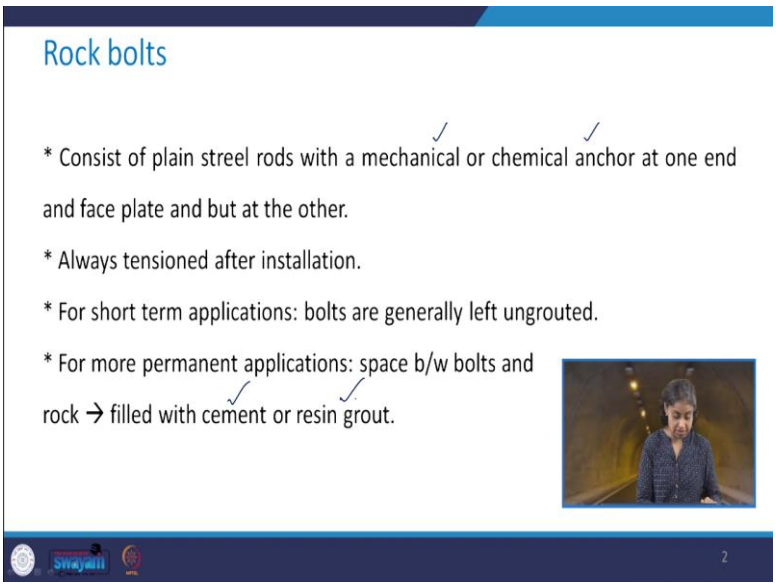

Basically, these consists of plain steel rods with the mechanical or chemical anchor at one end and face plate and, but at the other end. These are always tensioned after the installation. This means that, once you install it and then, from the other end you just tension these bolts. Now, for short-term applications these bolts are generally left ungrouted, but in case, if the requirement is such that they should serve, more permanent application.

Then, in that case, the space between the bolts and the rock should be filled with the cement, or resin grout. When should we use cement grout or resin grout there again, we have to take a call based upon the requirement plus the quality or the type of the rock mass.

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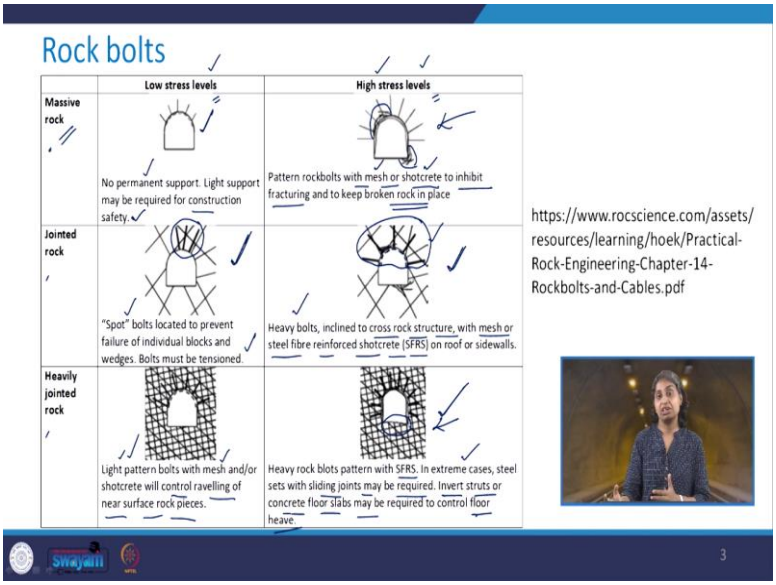

This figure gives us the idea that, what type of the rock bolt we should install. When I say what type of the rock bolt means, what should be the pattern of the rock bolt to be provided in a particular type of rock, or the rock mass, or maybe it can in the combination with shotcrete or with a mesh. So, all that has been shown in this figure. So, as far as the massive rock is concerned there are low stress levels and high-stress levels.

So, we have the dedicated two columns corresponding to each one of these low-stress levels and high-stress levels corresponding to each type of rock or rock mass. So, we have here the first row comprising of the massive rock and, in case, if there are low-stress levels in case of massive rocks in that situation no permanent support is needed, and maybe some light support is required for the safety during the construction.

And, therefore, after the installation of that light rock bolts the cross-section of the excavation along with the support system will look like this, but in case if the massive rocks are subjected to high-stress levels, in that case, the pattern rock bolts with mesh or shotcrete is installed. This helps in inhibiting the fracturing and, to keep the broken pieces of rock in place.

So, you see that here because of the high-stress level, you can see here in this zone and in this zone broken rock mass is there. So, what they do is we provide the rock bolts along with the mesh or the shotcrete. So, this is how in the cross-section the combination of the support system along with the rock bolt will look like. In case of the jointed rock with low-stress

levels, there is to be installation of the spot bolts which are located to prevent the failure of the individual blocks and the wedges.

So, you see that here the rock bolts are provided only in this area or zone therefore we are calling it as spot bolting. Of course, after the installation, the bolts must be tensioned. In case if a jointed rocks are subjected to high-stress level which is this particular case. In this one, one needs to go for heavy bolts and these should be installed inclined to cross rock structure with mesh or steel fibre reinforced shotcrete which we call in short as SFRS on the roof as well as on the sidewalls.

So, based upon the situation one needs to go for this. So, you can see that the dotted lines are there. So, these represent the mesh or lining of SFRS on the roof in this case, but then if needed, one needs to go for the sidewalls as well, and you can see that the heavy rock bolting has been done in the area, which is much more than this one, where the jointed rock were subjected to low-stress levels.

Coming to the next category of heavily jointed rock with low-stress levels in this case light pattern bolts with mesh and or shotcrete will control the raveling near the surface of the rock pieces. So, here you see that since it is heavily jointed so, there will be wedges which will be found and the lose piece of rocks they may fall into the excavation. So, to prevent that one needs to provide the mesh and shotcrete or mesh or shotcrete along with the light pattern bolts.

In case, if you have the other condition, which is the heavily jointed rock with high-stress levels that means this particular figure. So, in this case heavy rock bolt pattern with SFRS which is steel fibre-reinforced shotcrete is to be provided. Now, in extreme cases steel sets with sliding joints may also be needed then inverts struts or concrete floor slabs, they may be required to control the floor heaving because you see in this situation, you can see that some heave is there.

So, to have the control about this floor heave one needs to go for invert struts or concrete floor slabs. So, this is how based upon, what type of rock mass that you have along with the stress levels, you can decide, or you can get the overall idea that what type of rock bolts should be provided plus whether they should be provided all alone, whether they will be

sufficient all alone or they should be provided with the mesh or in combination with shotcrete.

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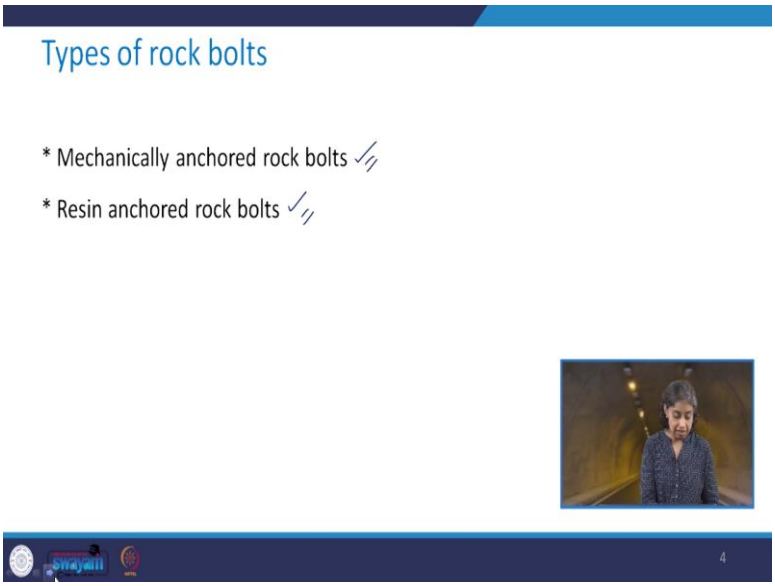

Then, the type of the rock bolts that are available, they are too which are mechanically anchored rock bolts and resin anchored rock bolts, there is a different mechanism as far as anchoring of the rock bolts to the rock mass is concerned for both of these.

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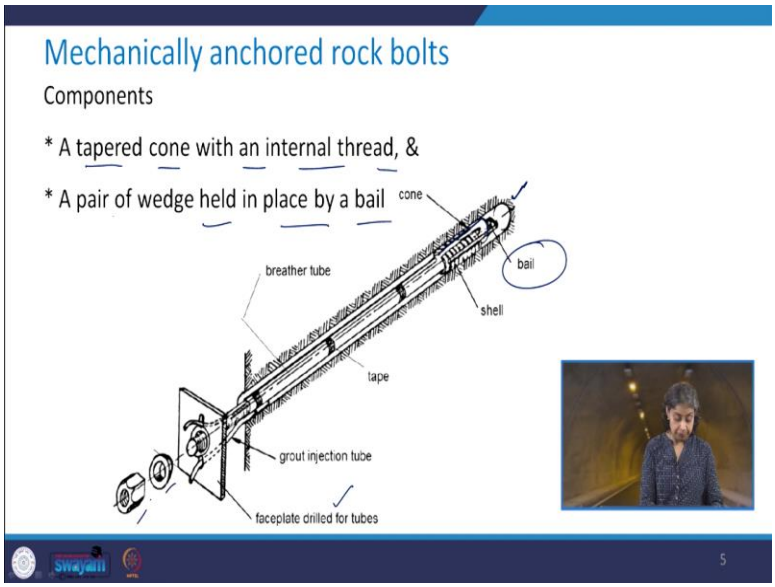

Let us take a look in detail that, what do we mean by these bolts which are mechanically anchored and resin anchored. So, first, we take the case of mechanically anchored rock bolts. There are two components as far as such rock bolts are concerned the first one is that there is a tapered cone with an internal thread. So, you can see here that this is what it is this is the cone.

And then, there is a pair of wedge, which is held in place with the help of bail which is here. So, what we do is we have a drill hole in the rock mass and then this bolt is inserted and, then it is anchored here at this end and, on the other end you have this face plate which is fixed with the washer and the nut.

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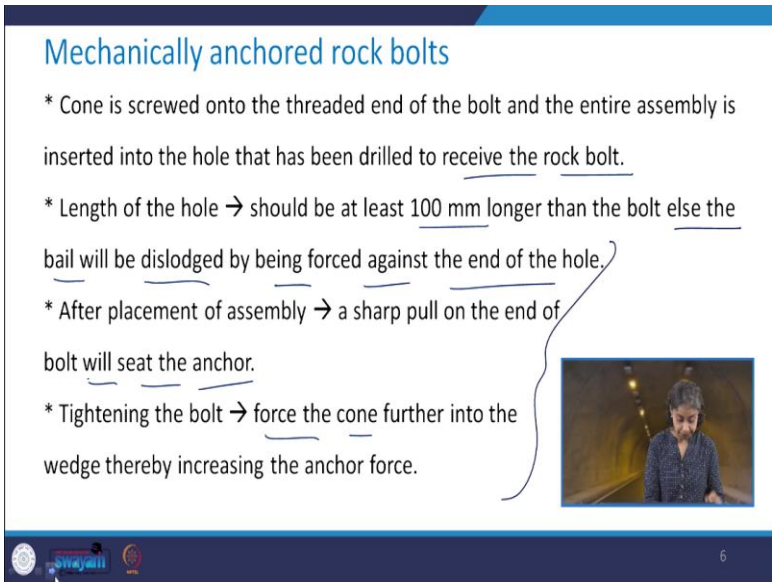

So, what happens in this case how this works is that the cone is screwed onto the threaded end of the bolt and, the entire assembly is inserted into the drill hole which has been made in the rock mass to receive the rock bolt. The length of the hole should be little bit longer than the length of the bolt and, this should be at least 100 millimeters longer.

Otherwise, what will happen is that the bail will be dislodged by being forced against the end of the hole. Now, what we do is after the placement of the assembly in the drill hole we apply a sharp pull on the end of the bolt this helps in seating the anchor, then, we tighten this bolt. So, this results into the forcing of the cone further into the wedge, thereby increasing the anchor force.

So, what happens is at one end, which is at the end of the drill hole in the rock mass there the anchoring takes place by doing these actions.

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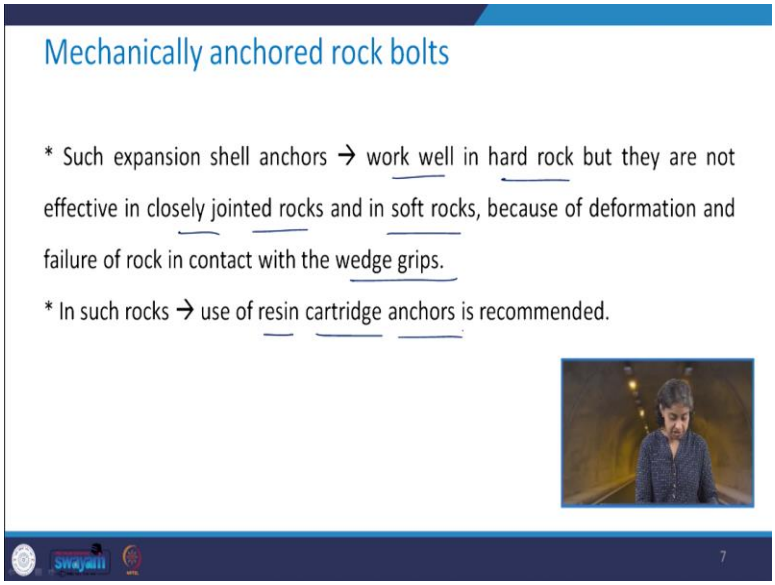

Such expansion shell anchors, these work very well in hard rock, but they are not very effective in closely jointed rocks and, in soft rocks also because of the deformation and failure of the rock in contact with the wedge grips. So, in such rocks, it is recommended to use the resin anchored rock bolts rather than mechanically anchored rock bolts.

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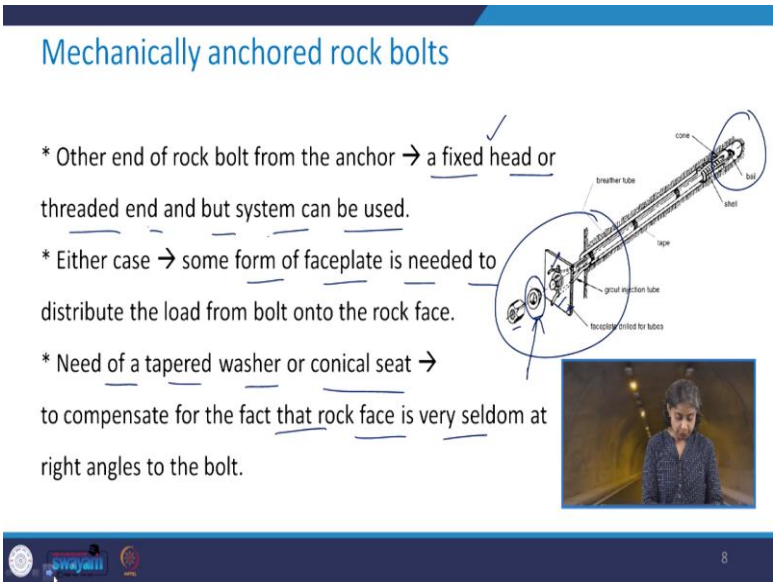

Now, the other end of the rock bolts from the anchor so this one is the one end which is being anchored the other end is this one. There is a fixed head or threaded end and, but system which is used. So, you can see here there is a face plate which is drilled for the tube, I will come to that that what these two tubes are, and then there is not washer assembly through which the bolt is tightened with the help of this face plate.

So, whether it is a fixed head or it is a threaded end and, but system in either of the cases some form of face plate is needed, this helps in distribution of the load from bolt to the rock face. There is a need of a tapered washer or the conical seat, which is here to compensate for the fact that rock face is very seldom at an angle 90 degree to the bolt. So, there this type of conical seat or the tapered washer comes to our rescue.

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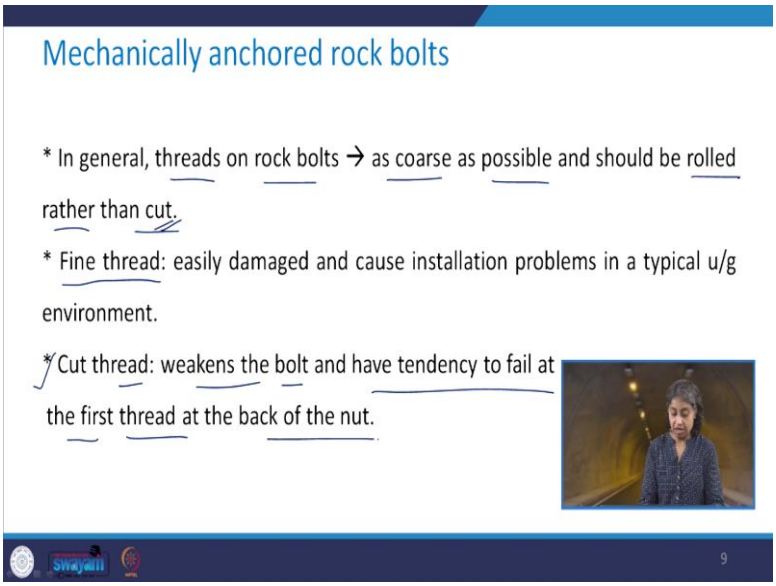

In general, threads on the rock bolts should be as coarse as possible and these should be rolled rather than cut maybe in the next slide or so, I will show you what is the difference between the rolled and the cut threads. Fine threads what happen they are easily damaged and they cause installation problems in a typical underground environment. So, therefore the threads on the rock bolt should be as coarse as possible.

In case, if you use the cut thread rather than the rolled thread what happens is the cut threads, they weaken the bolt and these have the tendency to fail at the first thread at the back of the nut.

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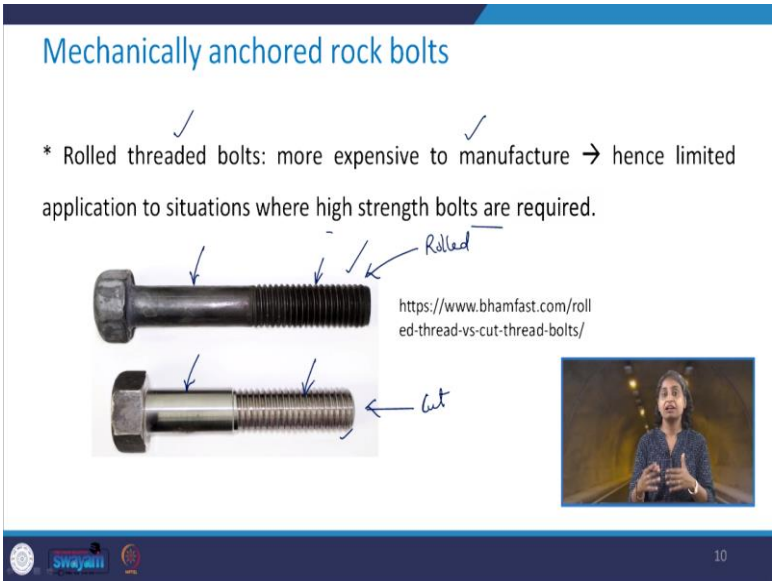

So, here is a picture the first one is the rolled one and the second one is the cut thread. What happens in case of the rolled threaded bolts. Although, these are more expensive to manufacture and therefore, their limitation to situation where high-strength bolts are required. So, here is a picture, as I mentioned that the top one is the rolled one and the bottom one is the cut one, so you can see what is the difference.

See, the diameter of the bolt shank here and in this zone, where the threads are there, and see it is here and here. There is a difference in the diameter. So, apart from this diameter, there are other differences also. We are not going into the details I kept this figure just to give you the idea that what exactly do we mean by rolled threaded bolts and cut threaded bolts.

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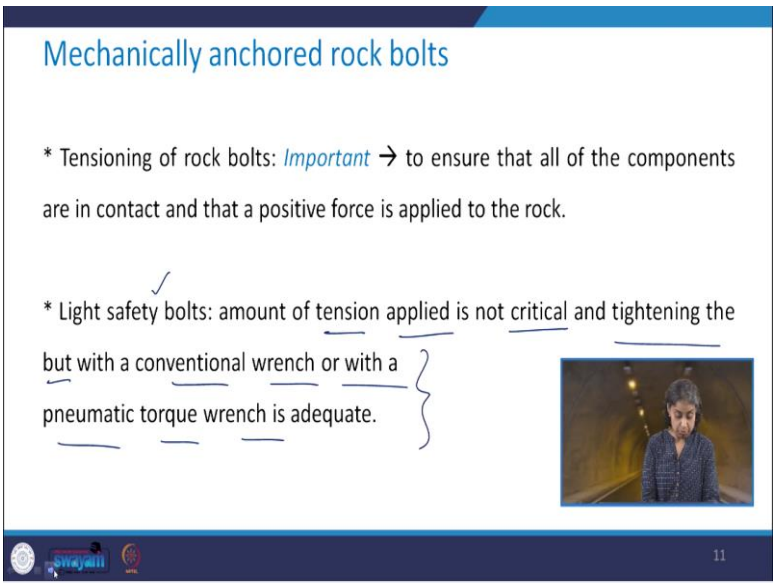

Then, the tensioning of the rock bolt is a very, very important action while installing the mechanically anchored rock bolts. The tensioning ensures that all of the components are in contact and that a positive force is applied to the rock. Coming to the light safety bolts the amount of the tension applied to such bolt is not very critical and tightening the but with a conventional wrench or with a pneumatic torque wrench is adequate, in the case of light safety bolts.

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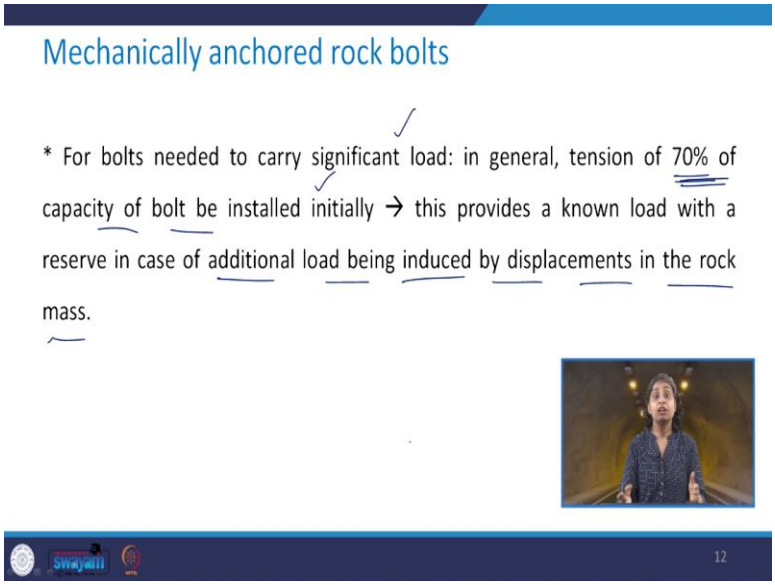

But for the bolt, which are needed to carry significant amount of load in general tension of the order of 70% of the capacity of the bolt should be installed initially, what happens when we do so? This provides us a known load with a reserve, in case, if we have the additional load which is being induced by displacement in the rock mass. You know that, when the excavation is made although we have done the exploration beforehand, but sometimes surprises happen during the excavation.

So, there in case, if the additional load is being induced by excessive deformations in the rock mass, then this type of the tensioning will take care of such type of situation.

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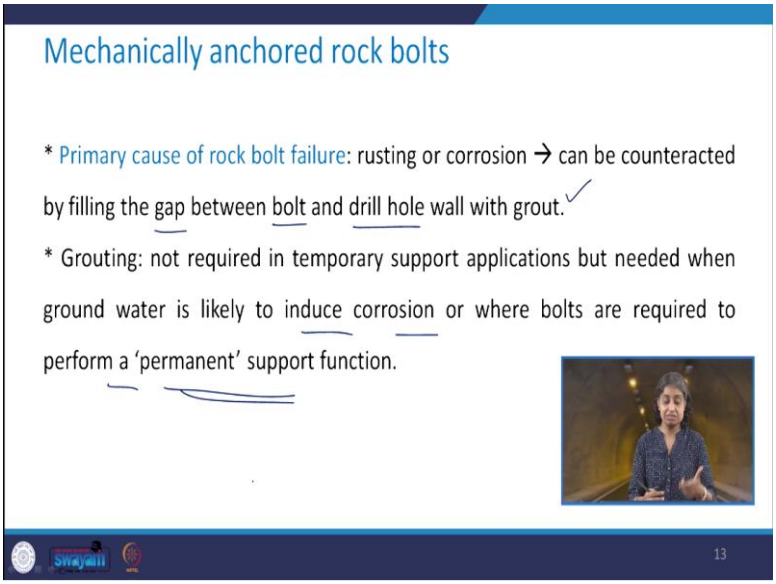

Now, what are the primary cause of the rock bolt failure? It is mainly rusting or the corrosion of the rock bolt, which can be counteracted by filling the gap between the bolt and the drill hole wall with the grout. The grouting is not required whenever there is a temporary support application, but it is needed wherever you have the ground water presence. So, what happens in the presence of the ground water.

It induces the corrosion and therefore, the grouting is needed then the second point where the grouting is needed is where the bolts are required to perform as a permanent support system. So, there grouting is must, but even though it is a temporary support application, but if the ground water is present, then also the grouting is needed.

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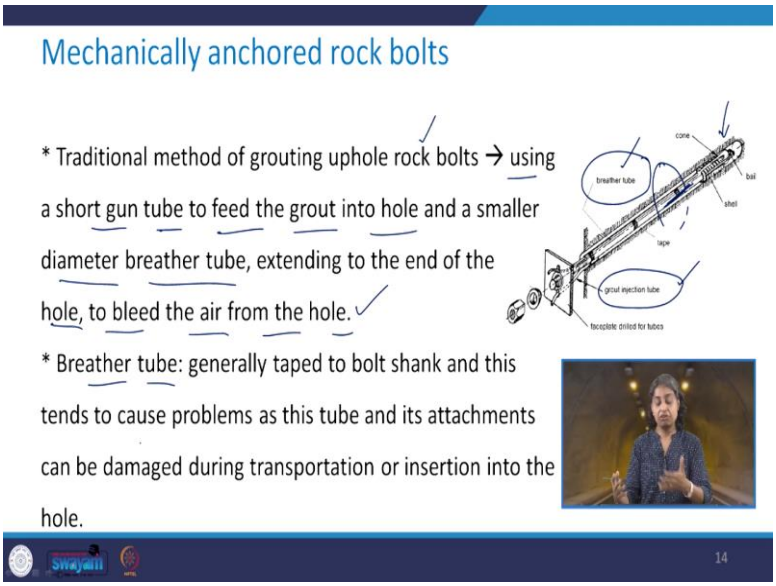

The traditional method of grouting and uphole rock bolt, what we do is we use a short gun tube to feed the grout into the hole and a smaller diameter breather tube which is extending to the end of the hole is also installed. This helps to bleed the air from the hole. So, take a look at this picture. So, here you see that two tubes are there which is not very clear in this portion of the figure.

But, if you see here, we have the grout injection tube and at the top this one, here we have the breather tube. So, the grout injection tube has the application that the grouting is done or the grout is sent to the location under pressure through this tube and the breather tube is used such that, the air can be taken out from the hole. So, basically, this breather tube is generally taped to the bolt shank which is here this one.

And, this tends to cause the problem, because this tube and its attachment these can be damaged maybe during the transportation or while inserting the rock bolt assembly into the drill hole.

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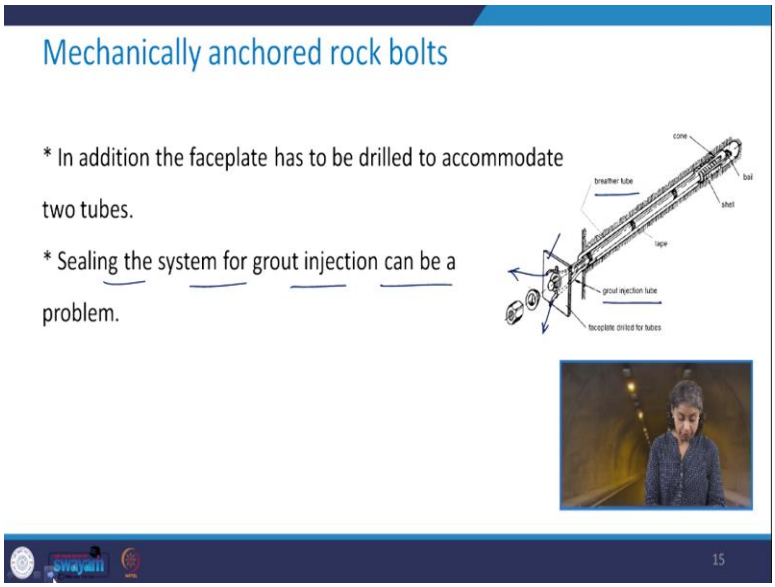

And then, further difficulty which is there is that the face plate should be drilled or, it should have two holes to accommodate both these tubes which is, grout injection tube and breather tube and, here, you can see that, how through the face plate these tubes are coming out. So, you see this is the one and this is the other one. Sealing the system for the grout injection, it can be a problem.

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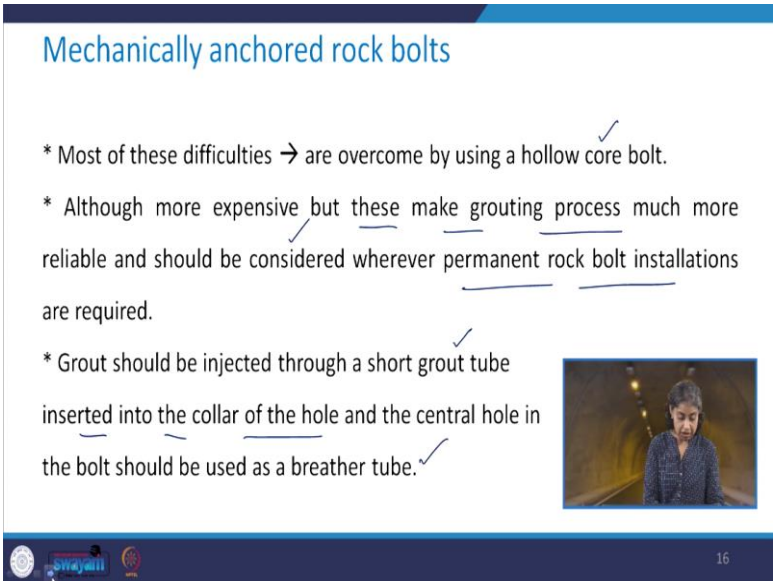

Some of these difficulties, these can be overcome by using hollow core bolt. Although, these are more expensive, but, these make, grouting process much more reliable and hence should be considered wherever we need the permanent rock bolt installations. These grout should be injected through short grout tube which is inserted into the collar of the hole and, the centre of the hole because, now it is the hollow core bolt. So, the center hole of the bolt should be used as the breather tube.

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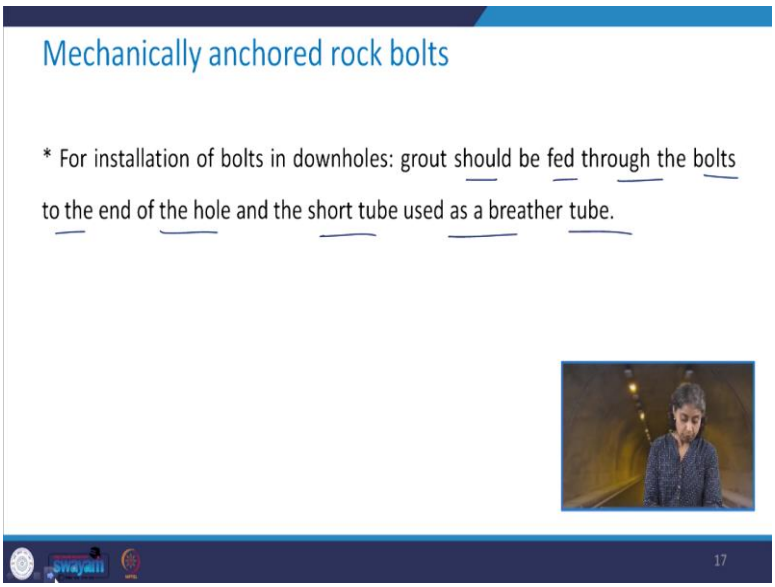

Now for the installation of the bolts in down holes. So, till we were talking about the up holes now if it is down holes, then the grout should be fed through the bolts to the end of the hole and, the short tube should be used as a breather tube.

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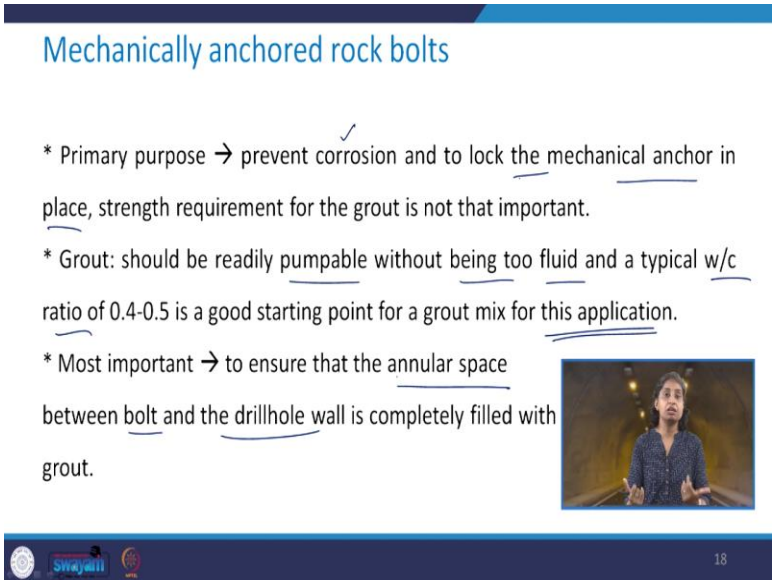

So, the primary purpose of this grouting is to prevent the corrosion and, to lock the mechanical anchor in place. So, basically, the strength requirement for the grout is not really that important because the primary purpose is not to attain these strengths using the grout, but to prevent the corrosion and to lock the mechanical anchor in place. Grout should be readily pumpable without being too fluid and a typical water-cement ratio of about 0.04 to 0.05 is a good starting point for a grout mix of such application.

Most important thing here to note that, one needs to ensure that the annular space between the bolt and the drill hole wall should be completely filled with the grout because, if it is not done, then, we will not be able to derive the maximum benefit of the installation of the rock bolts.

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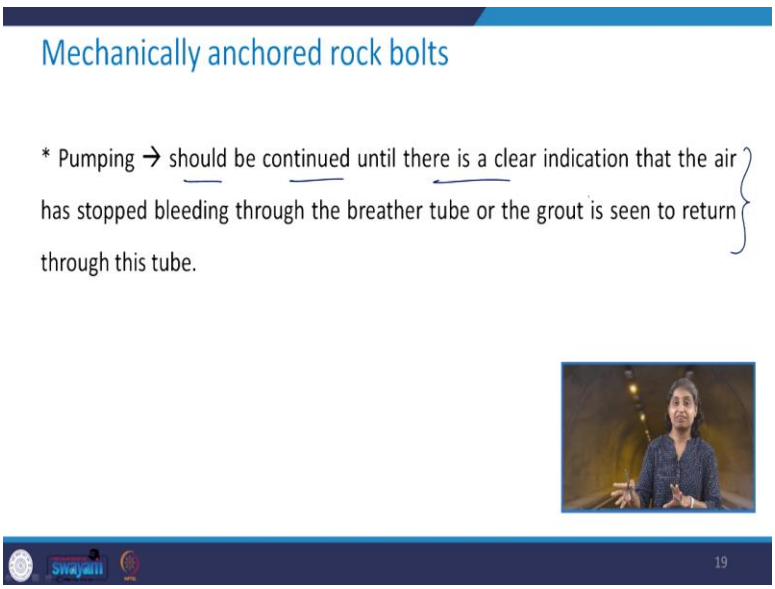

So, the pumping how long it should be continued. So, here is a point regarding that pumping should be continued until there is a clear indication that, air has stopped bleeding through the breather tube or if the grout is seen to return through this tube. So, this will ensure that no more air there and one can stop pumping the grout.

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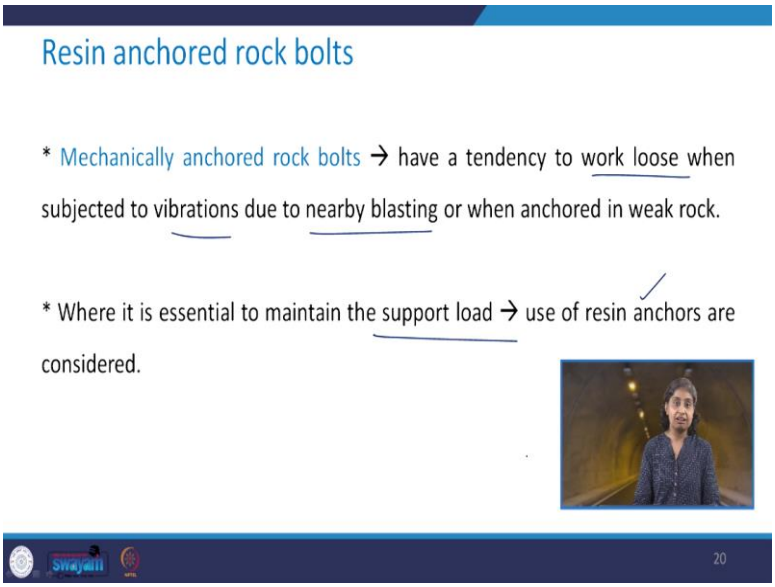

Coming to now, the resin-anchored rock bolts. So, some of the difficulties that we had is that the mechanically anchored rock bolts these have a tendency to work loose, when these are subjected to vibrations due to maybe nearby blasting or when these are anchored in the weak rock. So, wherever it is essential to maintain the support load, it is always recommended to use the resin anchors as compared to mechanically anchored rock bolts.

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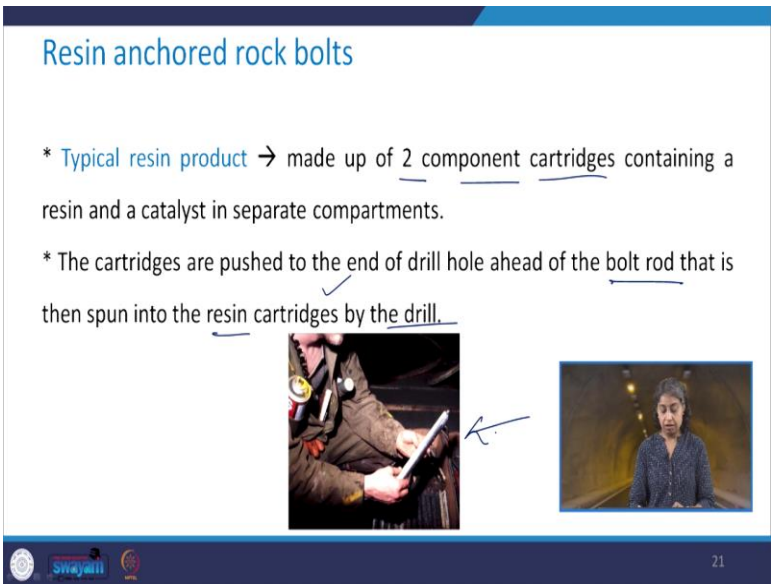

So, in the resin-anchored, rock bolts is a typically resin product is important which is made up of two component cartridges containing resin and a catalyst in separate compartments. So, when happens is these cartridges, they are pushed at the end of the drill hole which is ahead of the bolt rod and then this bolt rod is spun into the resin cartridges by the drill. So, here is a picture which is showing you the resin-anchored rock bolts.

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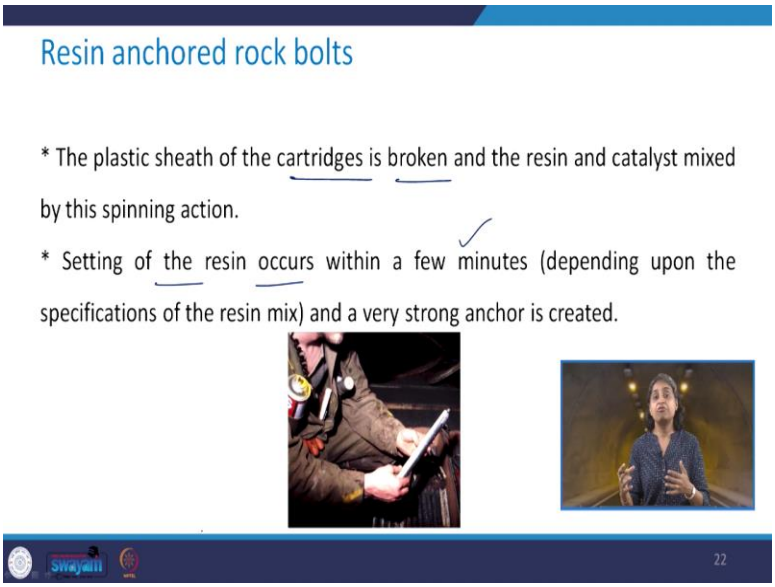

So, what happens is with this spinning action, the plastic sheath of the cartridges is broken and the resin, and the catalyst, they get mixed with this spinning action, then the setting of the resin occurs within a few minutes and this time depends upon the specifications of the resin mix and this results into a very strong anchor.

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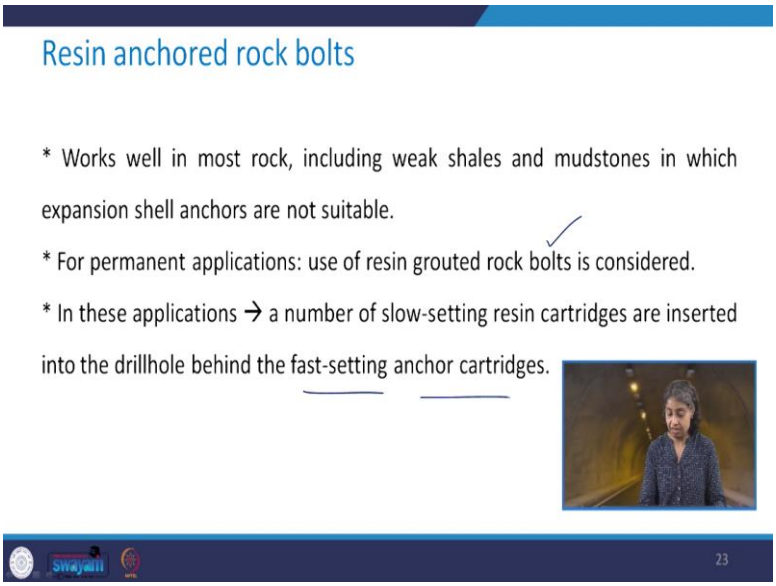

It works well in most of the rocks including weak shales and mudstones in which the expansion shale anchors are not suitable, as we discussed earlier for the permanent applications, the use of resin-grouted rock bolts is recommended or consider. In these applications what happens is that a number of slow-setting resin cartridges, they are inserted into the borehole or the drill hole that you have made for the purpose of the installation of the rock bolt.

And, these slow-setting resin cartridges, they are put behind the fast-setting anchor cartridges see how this looks like.

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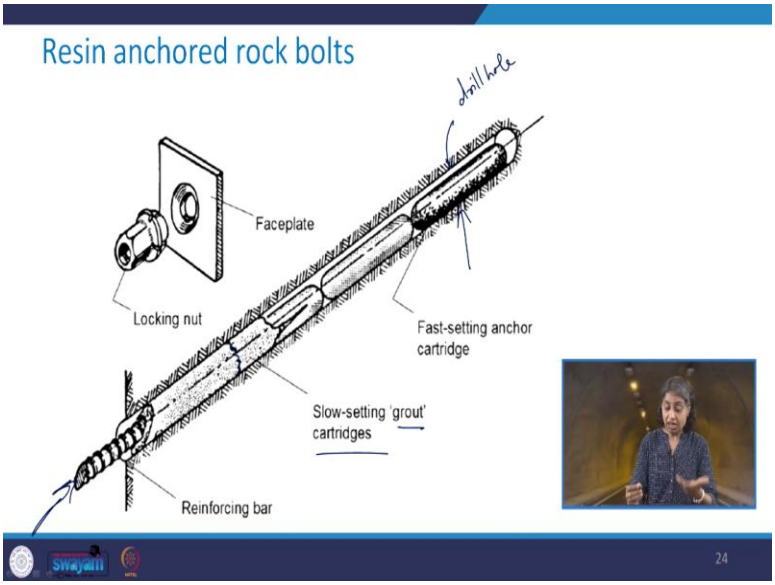

This is what is a drill hole and, then first we insert the fast-setting anchor cartridge and, this is followed by slow-setting grout cartridges, and see this is the reinforcing bar. So, when this is inserted what happens is that the plastic sheath is broken and when this goes up to here and then the spinning is done. So, what happens is they get mix. So, there is a sequence that when should we start mixing the catalyst because, here, we have two types of anchor cartridges one is fast setting another one is slow setting.

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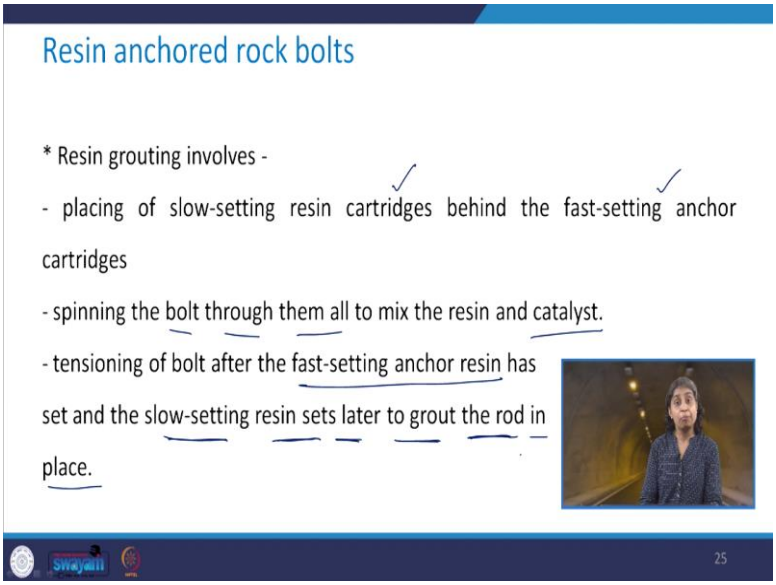

Take a look here. So, this resin grouting involves the placing of slow-setting resin cartridges behind the fast-setting anchor cartridges, spinning the bolt through them all is to mix the resin and the catalyst then the tensioning of the bolt is to be done. If you recall, we discussed this, when we were discussing about the mechanically anchored rock bolts, that the tensioning of the rock bolt is extremely important.

So, even for this case tensioning of the bolt is important, but when should we do that? So, this is done after the fast-setting anchor resin has set and the slow setting resin sets later to grout in the rod which is in place and the slow-setting resin sets later to grout the rod which is in place in the drill hole.

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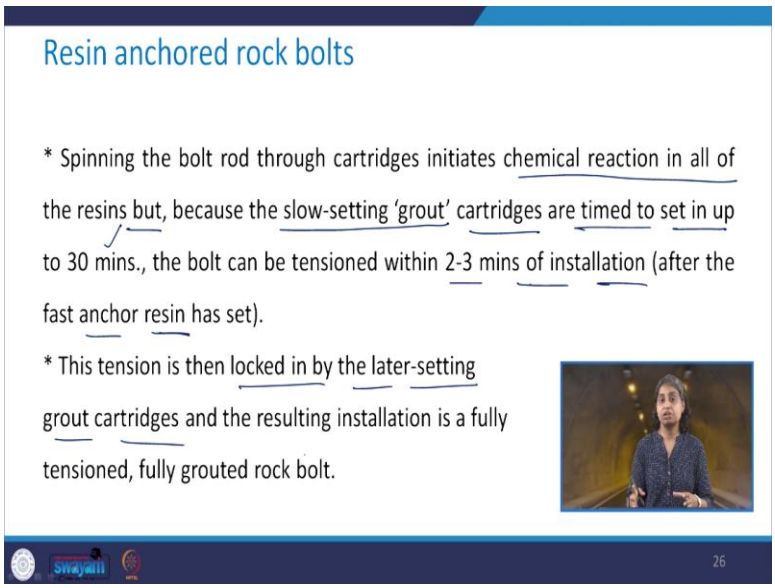

Now, spinning the bolt rod through these cartridges which are the combination of the fast setting at the end of the drill hole followed by the slow setting one. What happens is that it initiates the chemical reaction in all of the resins but because, the slow-setting grout cartridges are timed to set in up to 30 minutes the bolt can be tensioned within 2 to 3 minutes of installation.

This is the duration in which more or less the fast anchor resin has already set. This tension is then locked in by the later setting grout cartridges and the resulting installation is a fully tensioned, fully grouted rock bolt.

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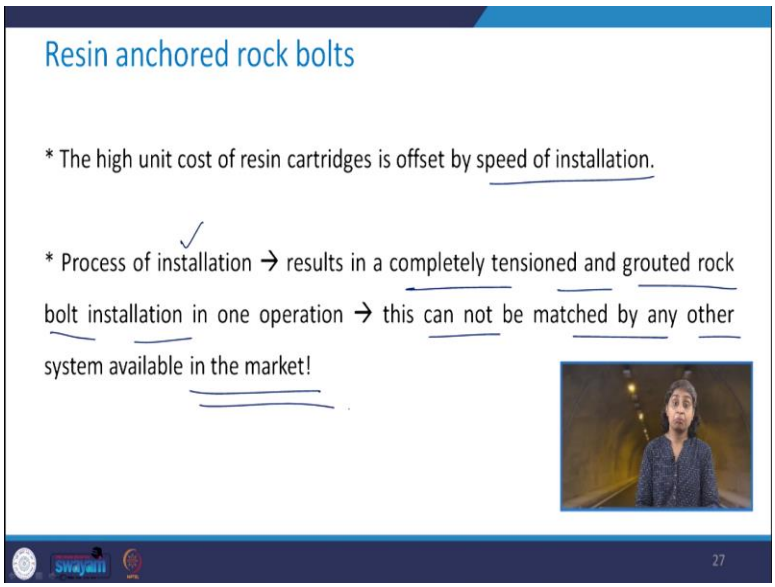

The resin cartridges have very high unit cost, but they are installed at very great speed. So, therefore the high unit cost of these cartridges they are compensated by the speed of the installation of such rock bolts. The process of the installation it results in a completely tensioned and grouted rock bolt installation in just one operation, which cannot be matched by any other system which is available in the market.

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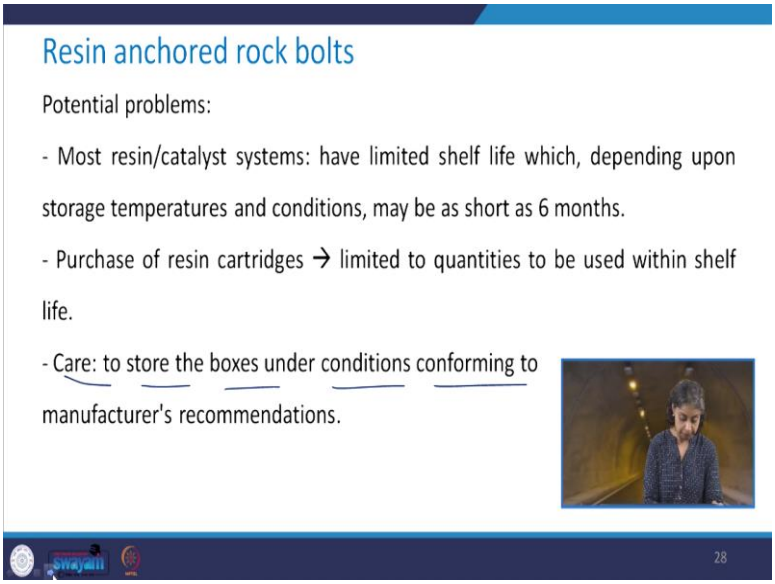

The potential problems, which are associated with resin-anchored rock bolts, they involve that most of the resin and the catalyst system, these have limited shelf life. These depends upon the storage temperature and conditions which may be as short as 6 months. So, wherever one has to purchase it for any project, there one needs to be careful that whatever are the quantities, which are required to be used within the shelf life, only that much should be purchased.

One needs to be careful to store the boxes under the conditions confirming to the recommendations from manufacturer because, if you do not follow then it may happen that you have installed the rock bolts, but then it is not providing you that kind of support system for which it was installed.

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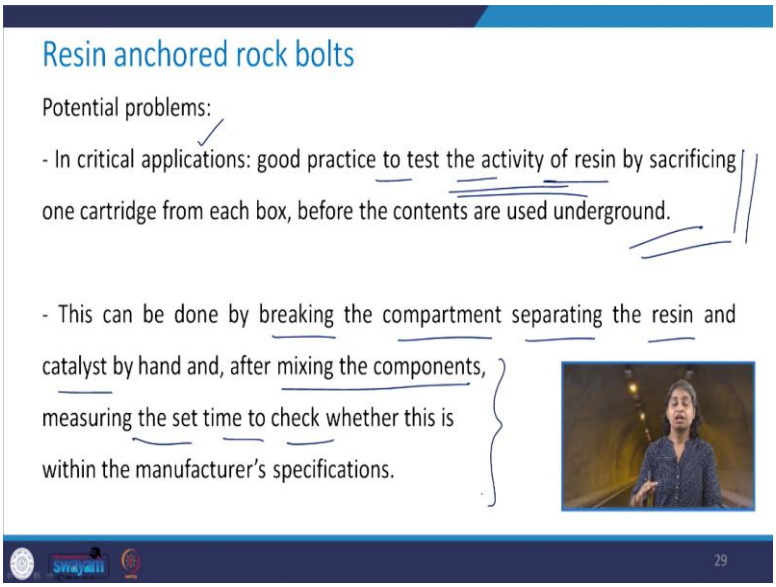

Another potential problem is that, when you have the critical application, it is always a good practice to test the activity of the resin by maybe sacrificing one cartridge from each box before the contents are used underground. So, as I was mentioning that, let us say if you have not done this activity and you have already installed and, the ultimate product is not what we designed.

And therefore, especially in case of the critical applications, we cannot afford to have such type of situation because it would hamper the safety of that underground excavation. Now, how to do this test? So, this can be done by breaking the compartment which is separating the resin and the catalyst by hand and then by mixing the components, followed by measuring the set time to check whether this is within the specifications which was provided by the manufacturer.

So, maybe you will waste one or two cartridges from each box, but then, it will save lot of time and effort towards the end after the installation.

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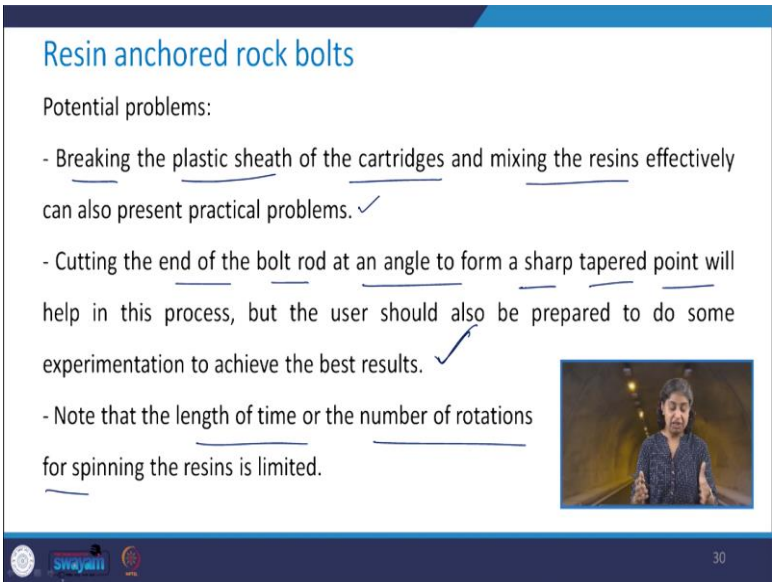

Now, the next problem may be the breaking of the plastic sheath of the cartridges and mixing the resins effectively can also present the practical problems then cutting the end of the bolt rod at an angle to form a sharp tapered point will help in this process, but then user should also be prepared to do some experimentation to achieve the best results. You need to keep a note that the length of the time or the number of rotations for spinning the resins, they are limited, because the setting time is small for the fast-setting anchor resin.

So, you need to be careful about these two factors that is the setting time and the number of rotations which are needed for spinning the resins.

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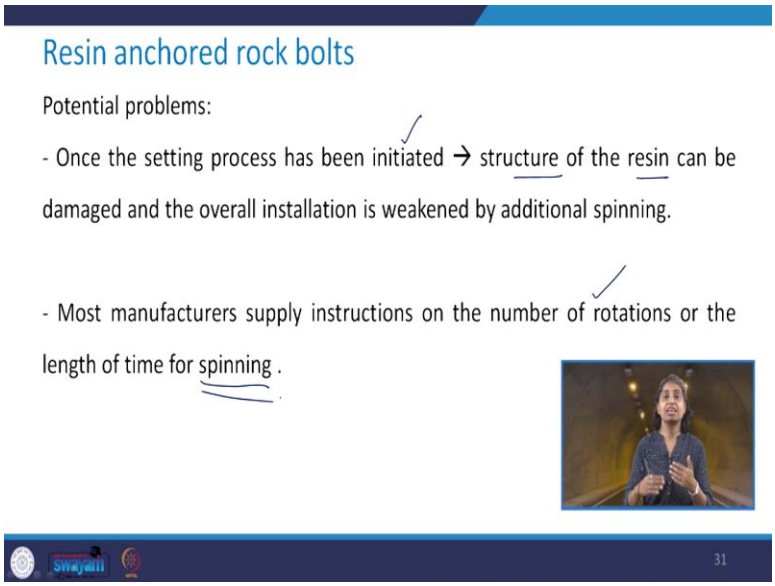

Once the setting process has been initiated the structure of the resin can be damaged and the overall installation is weakened by the additional spinning. So, most of the manufacturers, they supply the instructions on the number of rotations, or the length of the time for spinning. So, you need to be extremely careful, let us say, that if it is given that maybe you provide n number of rotations.

So, after you provide the n number of rotations the structure of the resin has been set. If you provide, let us say, more number of rotations so what happens is that particular structure, it gets disturbed, it gets damage and, therefore the overall installation will get weakened.

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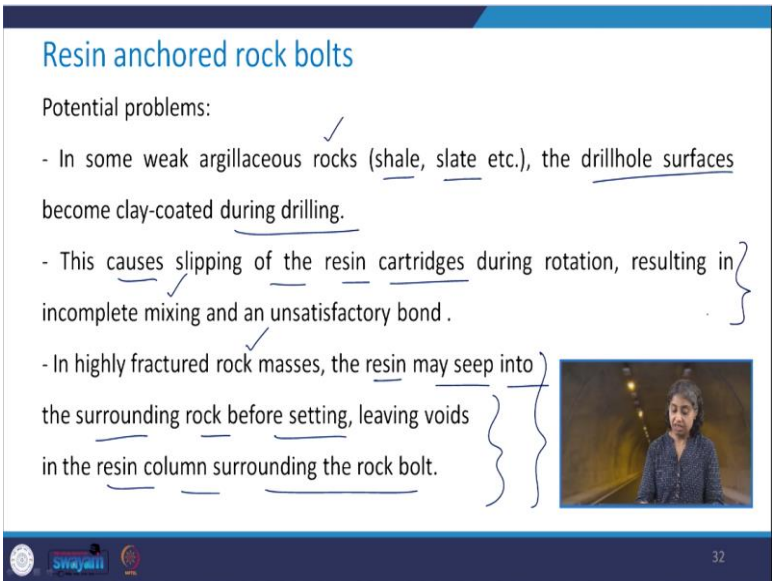

In some weak argillaceous rocks such as shale and slates the drillhole surfaces they may become clay coated during drilling itself. So, this causes slipping of the resin cartridges during the rotation which results in the incomplete mixing and unsatisfactory bond between the bolt and the rock mass. Another problem which is associated in highly fractured rock masses the resin may seep into the surrounding rock even before setting.

And, this results in the voids or the creation of the voids in the resin column which is surrounding the rock bolt. This is also one of the practical problems. So, whether it is this problem in highly fractured rock mass or it is the slipping of the resin cartridges in some weak argillaceous rocks.

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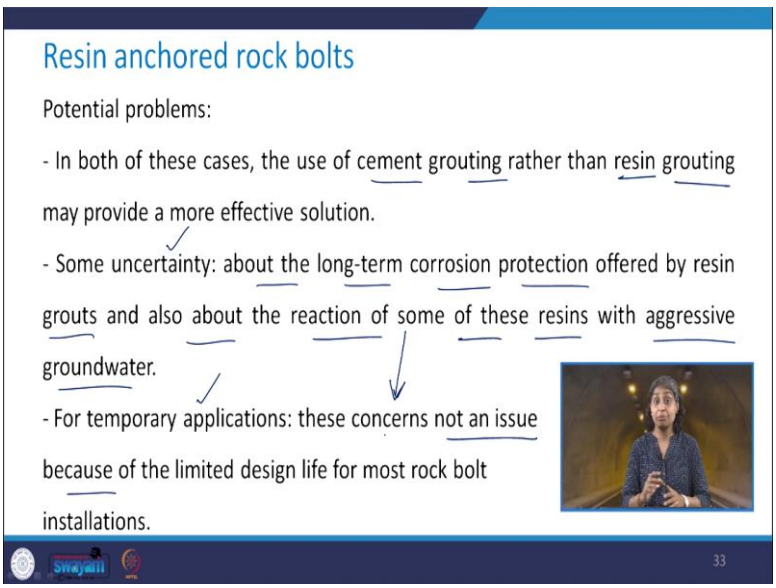

In both of these cases, the use of cement grouting rather than the resin grouting may provide more effective solution. Although, there are some uncertainties which are associated that is about the long-term corrosion protection, which is offered by resin grouts and also about the reaction of some of these resins with aggressive groundwater. As far as temporary applications are concerned, these concerns are not an issue because of the limited design life for most of the rock bolts installation because, these are for temporary applications.

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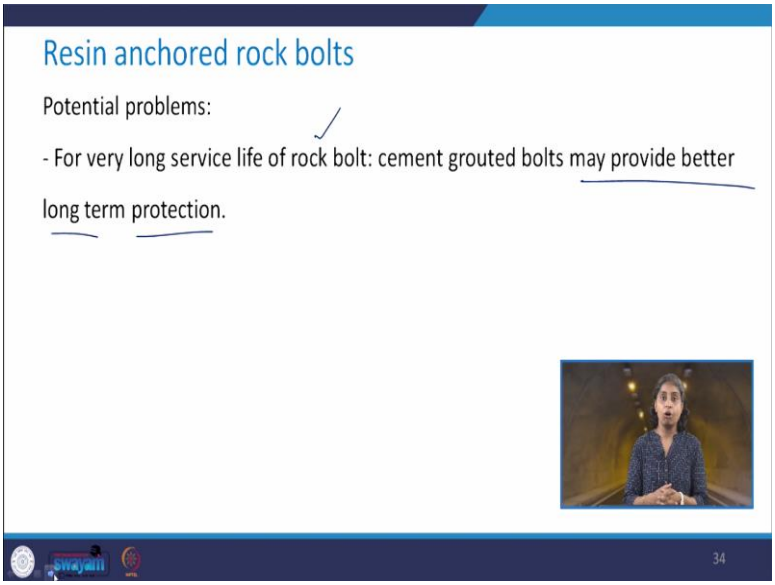

However, for very long service life of the rock bolt cement grouted bolts they may provide better long-term protection as compared to resin-anchored rock bolts. So, this was all about the rock bolts. So, we learned about the mechanically anchored rock bolts and resin-anchored rock bolts. Philosophy remains the same, but then the way it is anchored to the rock mass is different for these two types of the rock bolts.

And then, I also mentioned that for a particular type of rock mass and depending upon the stress levels, what should be the pattern whether rock bolts itself alone with serve the purpose or it should be provided in combination with the mesh or the shotcrete. So, this finishes our discussion on the second type of rock system which was rock bolts. So, in the next class we will learn few aspects related to permeability and grouting in rocks. Thank you very much.