Rock Mechanics and Tunneling
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Lecture 50
Methods of Construction (Continued)

Hello everyone, I welcome all of you to the fourth lecture of module 10. So, in module 10, we are discussing related to the basic features of tunneling and we will continue our discussion related to the methods of construction.

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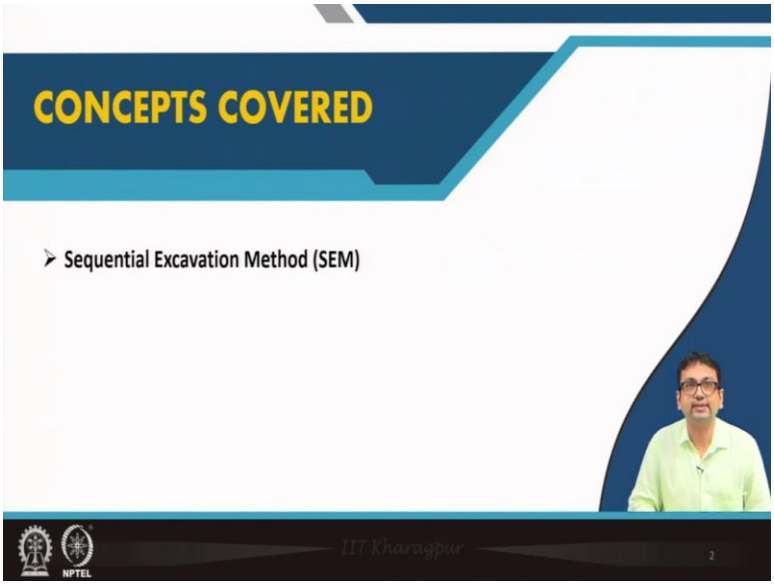

So, we already have discussed about the drilling and blasting then the tunnel construction by using mechanical means, like the road headers and tunnel boring machine, TBM. Now, the third one is the Sequential Excavation Method which is in short also stated as SEM.

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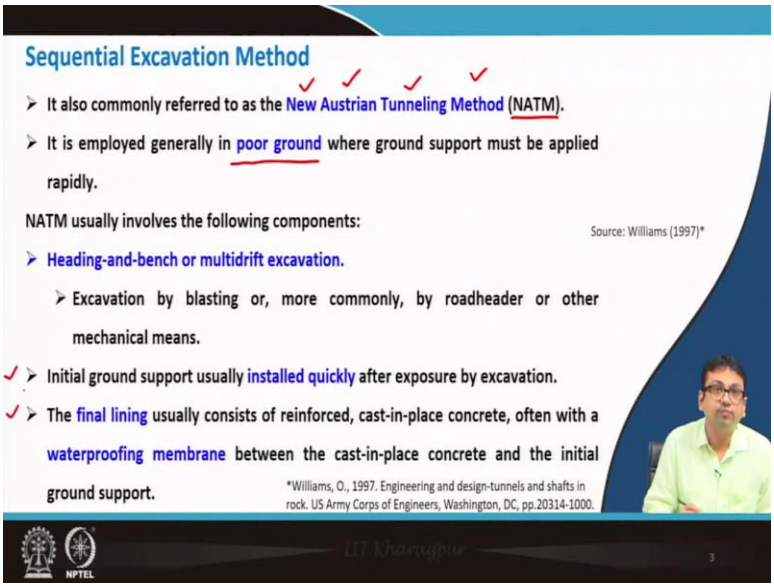

It also commonly referred to as the New Austrian Tunneling Method. So, New Austrian tunneling method in short is written as NATM. It is employed generally in poor ground where ground support must be applied rapidly. So, that is why I highlighted poor ground. This NATM usually involves the following components like heading and bench or multidrift excavation.

The initial ground support usually is installed quickly after exposure by excavation and the final lining usually consists of reinforced cast in place concrete often with a waterproofing membrane between the cast in place concrete and the initial ground support. So, I will show you obviously the schematic diagram that will clear your doubt.

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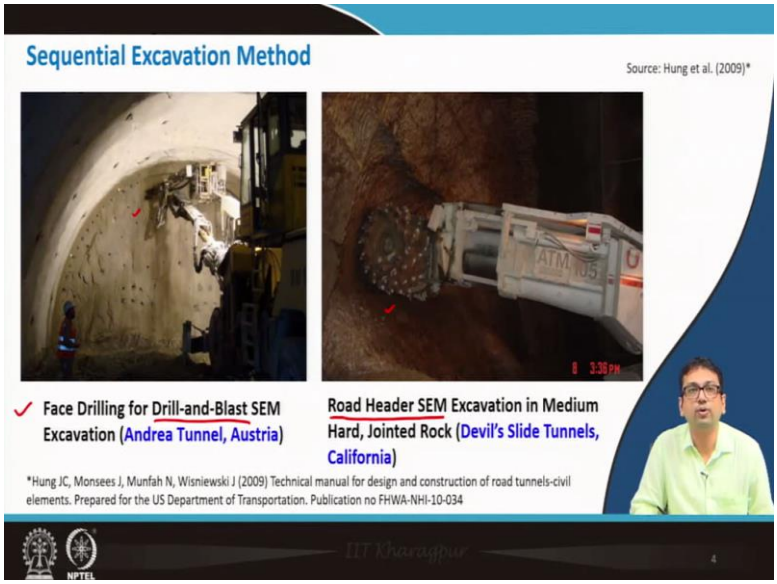

So, now you can see that the sequential excavation is going on. What is written first one is the Face Drilling for Drill and Blast SEM. So, you can see that drilling is going on. On the other hand, roadheader SEM excavation is performed in medium hard jointed rock.

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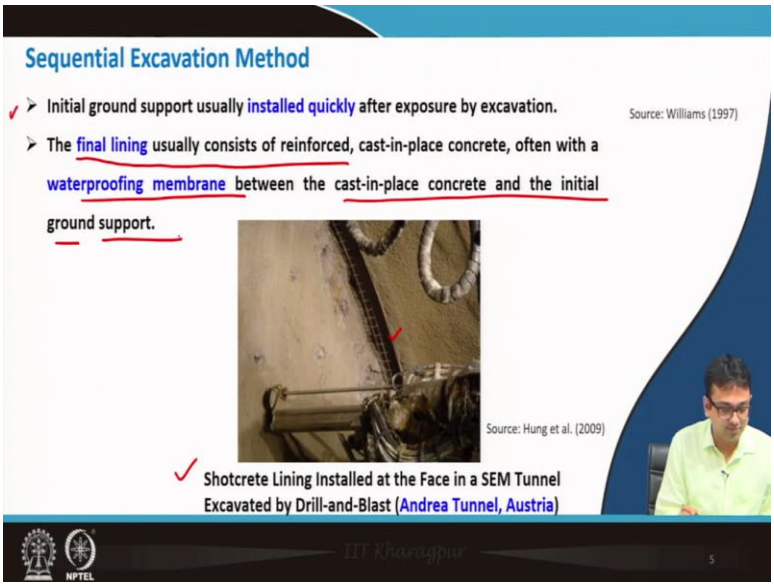

Now, I have mentioned in previous slide only that is only once again written. So, this slide is for this like the drilling and blasting or road header SEM that these two pictures are showing these two things.

Here, it is showing that it is indicating initial ground support usually installed quickly after exposure by excavation and then the final lining usually consists of reinforced cast in place concrete often with a waterproofing membrane between the cast in place concrete and the initial ground support and what is written here shotcrete lining installed at the face in a SEM that is sequential excavation method (SEM) tunnel. Here tunnel is excavated by drill and blast.

So, you see shotcrete lining you see here it is applied over here and, and actually as it is mentioned that final lining usually consists of reinforced cast in place concrete. So, I will show you another picture also.

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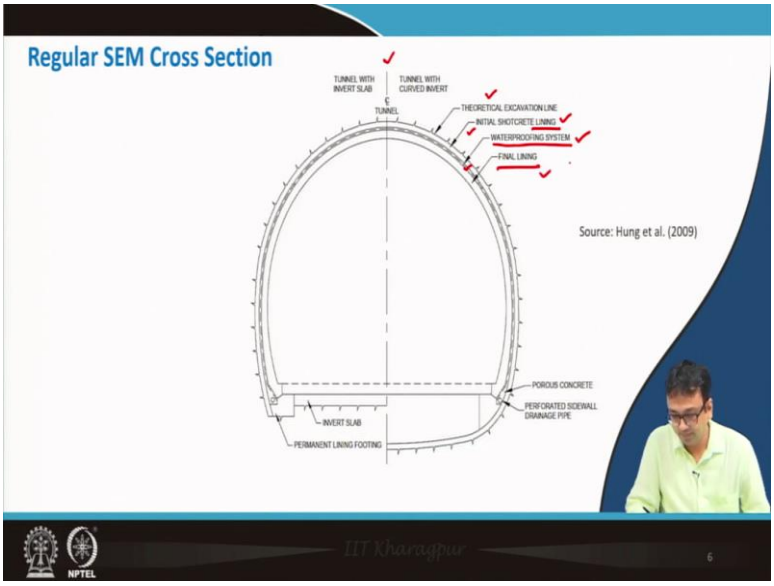

This is what regular SEM cross section. So, please look at this one very carefully, what are the components who can see it see it is the center line of the tunnel now, the layers you try to understand observe. So, this is as you can theoretical excavation line at initial shotcrete lining.

So, basically three layers initial shotcrete lining as I have mentioned here initial ground support usually installed quickly after exposure by excavation and then the final lining in place and, also it is restated that the waterproofing roofing membrane between cast in place concrete and the initial ground support is also placed.

That is what it is shown over. So, it is an initial shotcrete lining, shotcrete lining then water proofing system and then the final lining that what I was telling that the cast in place concrete. So, these are the important things we should know the regular SEM cross section.

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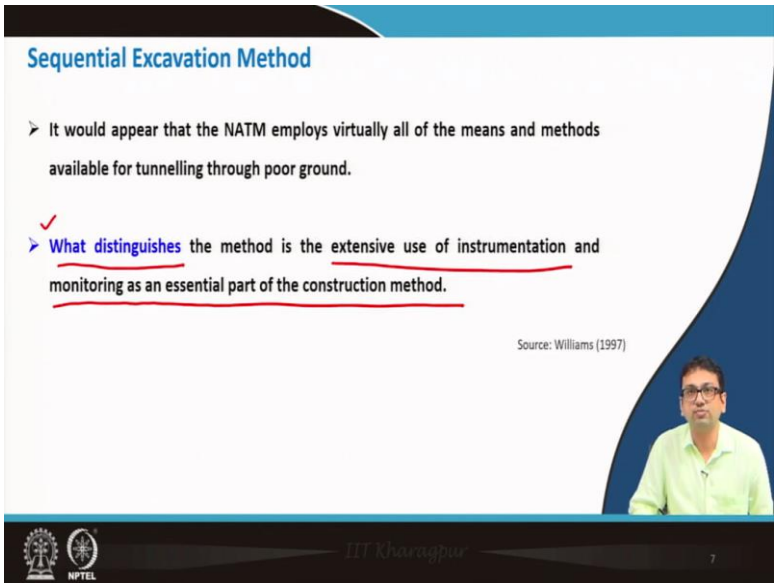

It would appear that in NATM employs virtually all the means and methods available for tunneling through poor ground. So, you can go for drilling and blasting or you can go for like road header. So, all these methods can be means are used in this in NATM actually. So, NATM means New Austrian Tunneling Method. So, which is also nothing but the sequential excavation method.

Importantly, what distinguishes this method from other method is the extensive use of instrumentation. So, extensive use of instrumentation and monitoring as an essential part of construction method.

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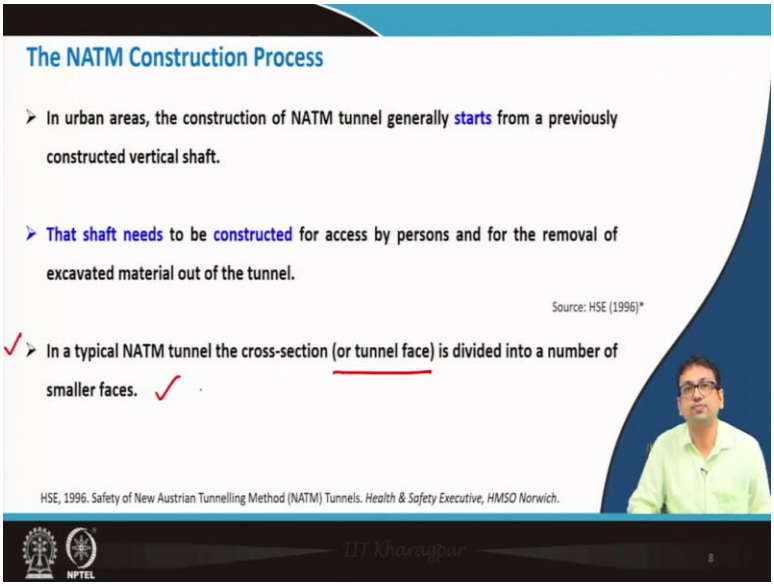

NATM Construction Process

In urban areas, the construction of NATM tunnel generally starts from a previously constructed vertical shaft. That shaft needs to be constructed for access by persons and for the removal of the excavated material out of the tunnel. Therefore, one vertical shaft is required and in a typical NATM tunnel, the cross section or tunnel face is divided into a number of smaller faces. So, this is very important.

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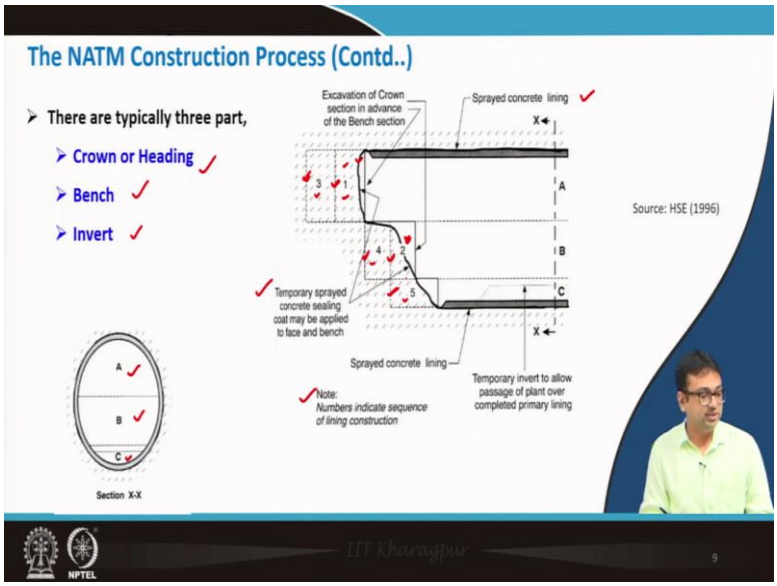

So, we can see that there are typically three parts as shown figure. One is crown or heading this part. Now, next is bench and third one is invert which is this part. So, these are the typical three parts. Now, you see the, this diagram is interesting you see here note that the like numbers 1, 2, 3, 4, 5 are given. Now, what is stated or written over here note numbers indicate sequence of lining construction.

So, first this A zone is excavated and the lining is provided what is done this part is second part is excavated, you imagine this the dotted lines you see initially this is the shape as you can see now, after excavating this A zone it has forwarded up to these now, what it is stating then you excavate this zone and go for the lining after that you again go come here excavate these zone third zone and provide the lining and then the fourth zone and at last fifth zone.

In this way you have to proceed actually, the sequence is like this. So, it is only written numbers indicate sequence of lining construction. It is written over here that you see temporary sprayed concrete. Sealing coat may be applied to face and bench and this is the sprayed concrete lining and all these things up here main thing what I wanted to tell you is like the three parts that is what we have understood and also that you see the sequence like 1 then, 2 then 3, then 4, and then 5. So, these are the things we have learned.

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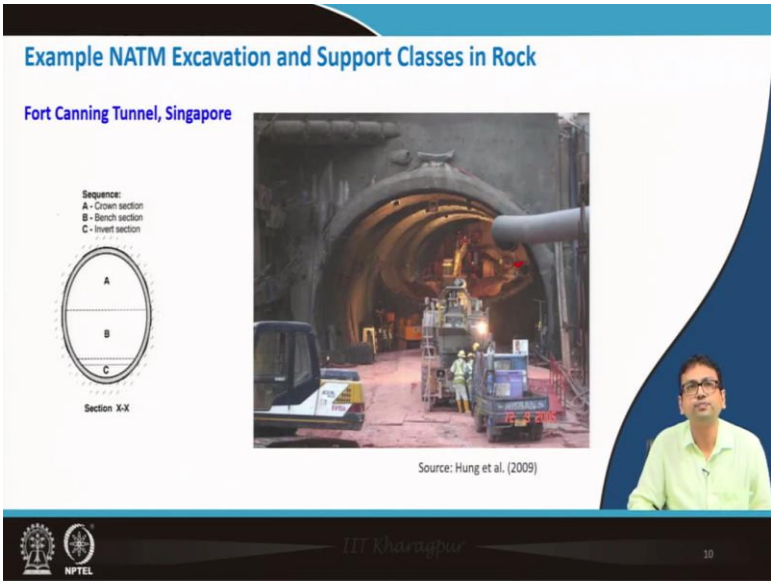

Now, you can see the Fort Canning Tunnel, Singapore. You can see that the tunnel was constructed is applying this SEM. So, you see that the excavation is going on. It will go proceed as I have mentioned in my previous slide, so, you can clearly visualize this part has been like excavated liners are putting

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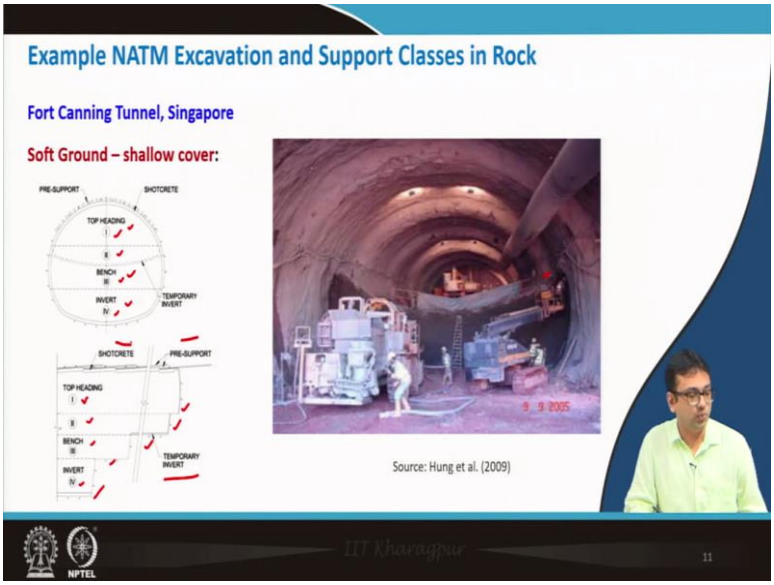

Similar type of figure is shown for Soft ground shallow cover and the process is only going on over here. You can see in the figure that the different zones is divided into that and like the top heading, bench, invert and here also 1, 2, 3, 4 here you see this is on the sectional view if you see

from side you see, you see the 1, 2, 3, 4 these things are shown and you see the sequence temporarily inverts are also shown over, pre-support this the shotcrete all these things are shown.

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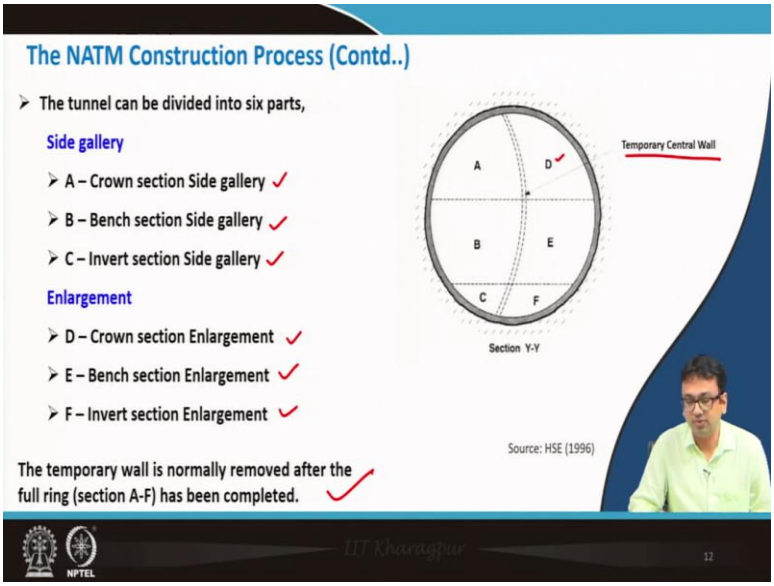

Now, here we have seen three parts right mainly the three parts and A, B, C. Now here you see tunnel can be divided into six parts also. So, one is side gallery, they are three parts A Crown section side gallery, B bench section side gallery, C Invert section side gallery. Whereas, another part is enlargement there again D as you can see the Crown section enlargement, Bench section Enlargement and the Invert section Enlargement and one thing you see temporally this you see here it is shown temporary central wall.

So, the temporary wall is normally removed after full ring that is section 1 8 wave has been completed. So initially, this temporary central wall is kept and then after entire excavation and construction is over, then it is removed.

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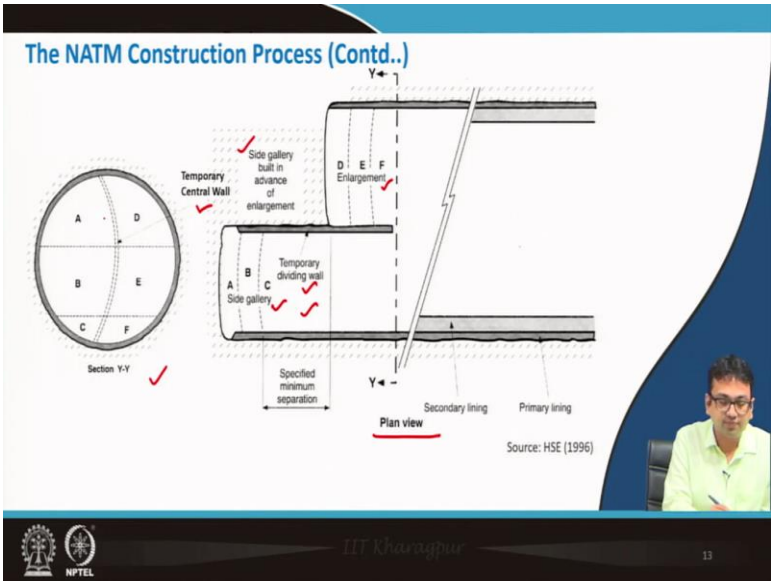

Now you will get a better idea from this diagram. So here, you see same one what I have shown you in my previous slide. Now you can see that it is the plan view. Now in plan-view what you can see that we have learned two terms over here. That is Side gallery and Enlargement. What are they? You see, this is the side gallery part and this is the enlargement part. So, and this temporarily temporary central wall is nothing but here this temporary dividing wall.

One important thing is information is what you are getting side gallery built in advance of enlargement. So, side gallery this part actually you see built in advance of enlargement. So, this is side gallery, this is enlargement. And here you see the three regions as we know A, B, C that is A is here our crown section in side gallery and then the B is Bench section side gallery and C is invert section side gallery.

Similarly, here D is the crown section enlargement, E is that bench section enlargement, F is the invert section enlargement, and the construction process will proceed in this way. So, side gallery this is built in advance of enlargement and in sequence it is moving and that is it. I think these are the information's we are getting from this diagram where 6 divisions are made.

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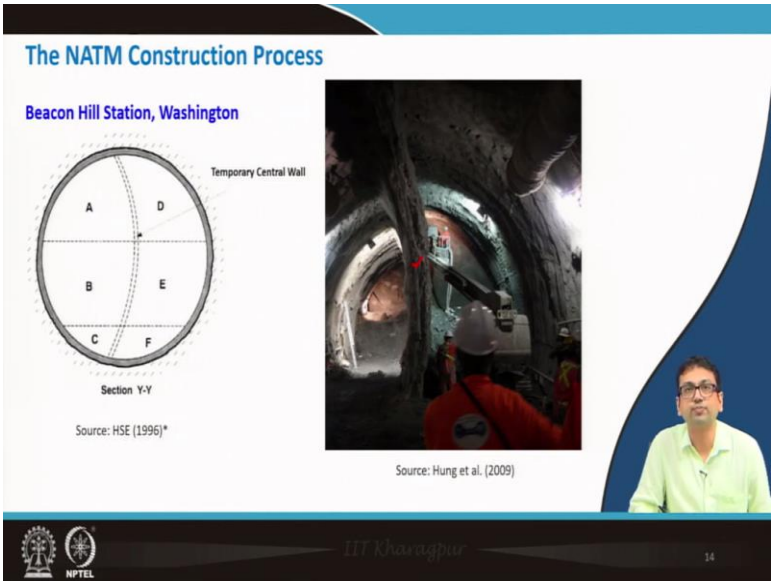

So, now actually Beacon Hill station in Washington there this procedure of this, this method was adopted 6 divisions are made over here and you can see that there is a temporary central wall.

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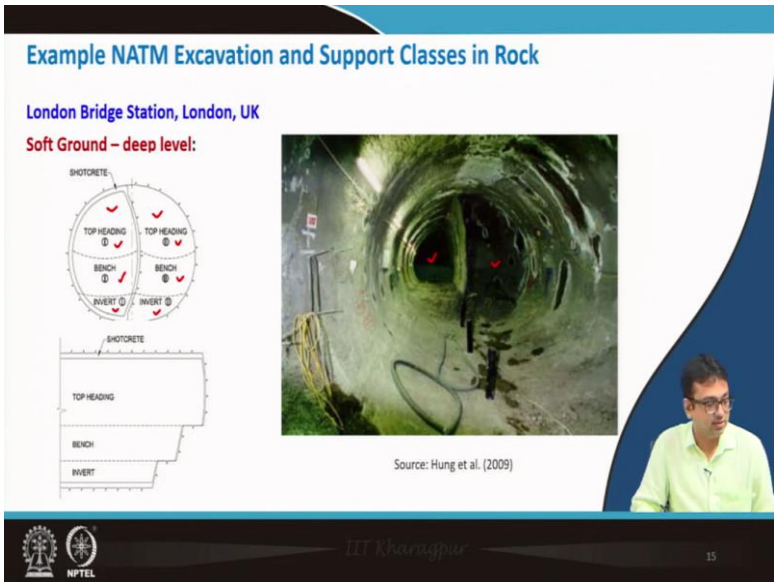

For London Bridge station London UK, this is sub ground deep level and you see this look at here look at here. We have mentioned over here that the side gallery and enlargement. You see this you can clearly notice. So, it is shown that the 6 parts are present. So, there is top heading, bench and invert, top heading, bench and invert and this one is the side gallery and another one is enlargement. So, we can clearly observe from here.

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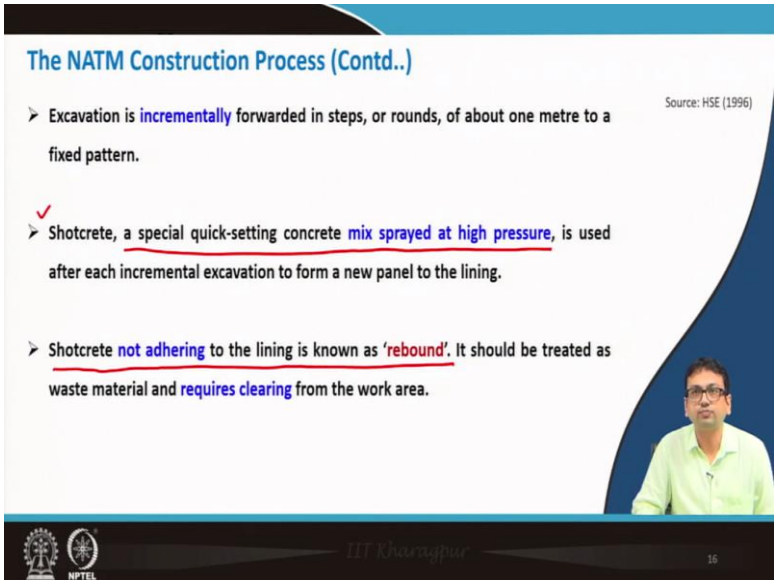

So, the excavation is incrementally forwarded in steps or rounds of about one meter to a fixed pattern. So, depending on obviously the site condition we have to decide that incrementally forwarded obviously. Now we will discuss about the shotcrete.

So, we will discuss in twelfth module in detail about shotcrete. So, here it is written little bit. Shotcrete is a special quick setting concrete. So, it is mix sprayed at high pressure. It is used after each incremental excavation to form a new panel to the lining.

As we have understood from the diagrams also and the shotcrete adhering to the lining is known as Rebound. It should be treated as waste material and requires cleaning from the work area. At high pressure, the concrete mix is sprayed on the wall of the excavated tunnel to give some support initial support.

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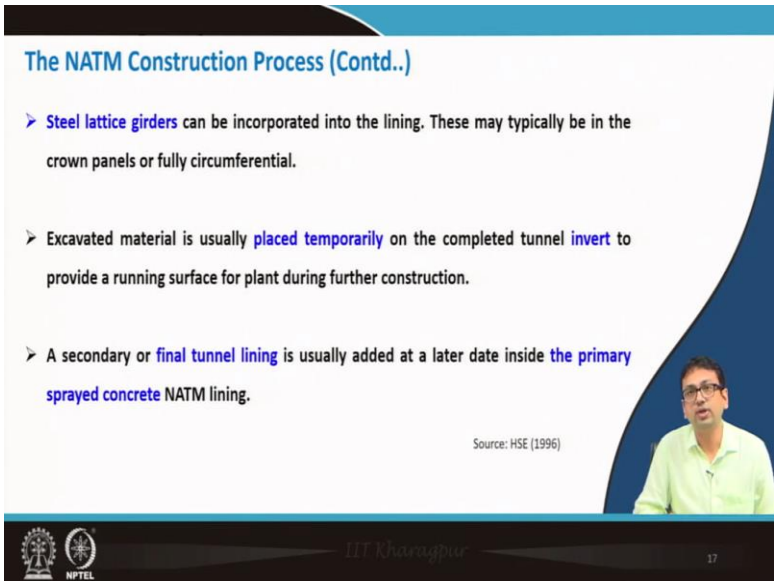

Now, this Steel lattice girders can be incorporated into the lining to give the ultimate or permanent lining. These may typically be in the crown panels or fully circumferential. The excavated material is usually placed temporarily on the completed tunnel invert to provide a running surface for plant during further construction.

Also, it stated that is secondary or final tunnel lining is usually added at a later date inside the primary this sprayed concrete NATM lining.

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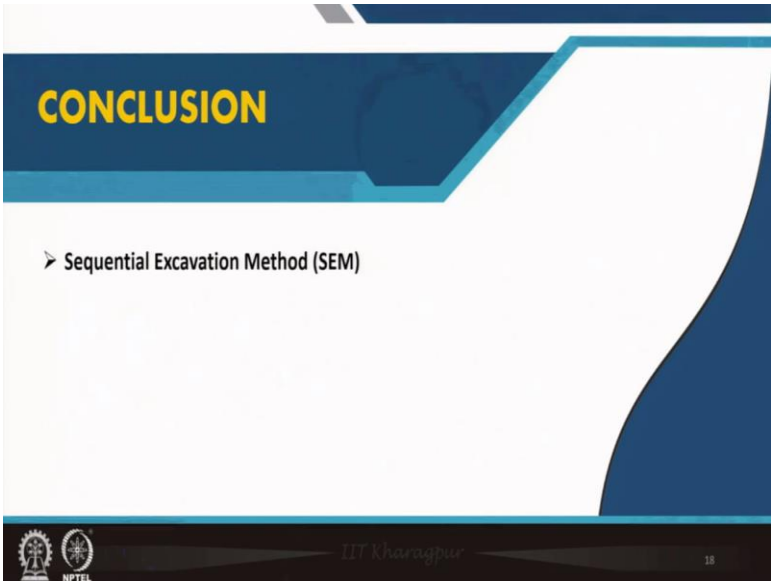

Hence, Sequential Excavation Method is applied to construct the tunnel also. Today, we have learned about this SEM technique of tunnel construction. With this, let us conclude our today's lecture. Thank You.