Rock Mechanics and Tunneling
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Lecture 48
Methods of Construction

Hello everyone. I welcome all of you to the second lecture of module 10. So, in module 10 we are discussing about the basic features of tunneling and today we will discuss about the methods of construction.

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So, first we will discuss about the types of excavation and followed by tunnel excavation methods and we learn about different tunnel excavation methods and then we will discuss today about the drilling and blasting.

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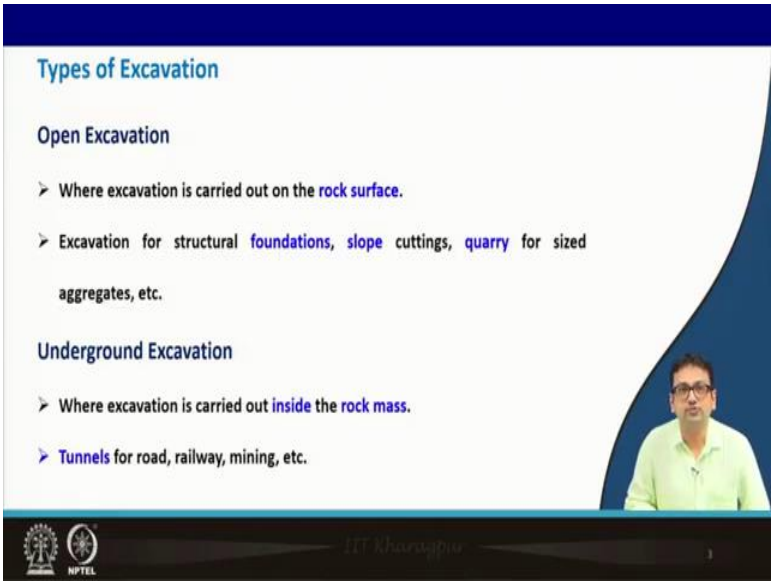

The types of excavation

Excavation can be divided in two categories; mainly one is open excavation; another one is underground excavation. So now, what is open excavation?

- Open excavation
    - When excavation is carried out on the rock surface, so that is called as the simply open excavation, as from the name also you can understand.
    - Excavation of structural foundation, slope cutting, quarry for sized aggregates etc.
- Underground excavation
    - When excavation is carried out inside the rock mass; obviously, the example what comes to our mind is tunnels, Tunnels for road, railway, and mining etc.

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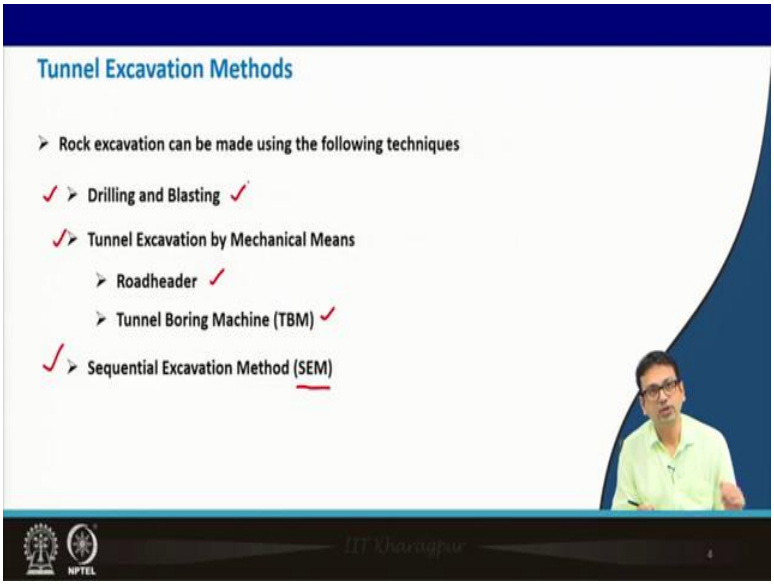

Tunnel excavation method

Rock excavation can be made using the following techniques.

So, first is drilling and blasting, other than that there is tunnel excavation by mechanical means. Under mechanical means, we will learn about the road header and tunnel boring machine which are commonly used and another technique is sequential excavation method or in short SEM. So, today in our today's lecture, we will focus on this drilling and blasting.

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Drilling and blasting

Since the word, blasting is there, therefore, obviously we have to understand that we have to use some explosives. Commonly used explosives are nitroglycerin based explosives; very common. Other than that, ammonium nitrate, and fuel oil, in short it is called as ANFO. Then slurry explosives, emulsion explosive, heavy ANFA, so ANFO is as we know ammonium nitrate and fuel oil so heavy ANFO. Other than that, liquid oxygen explosives and shape charges and cast boosters can be used. So, these are different types of explosives generally used for this blasting operation.

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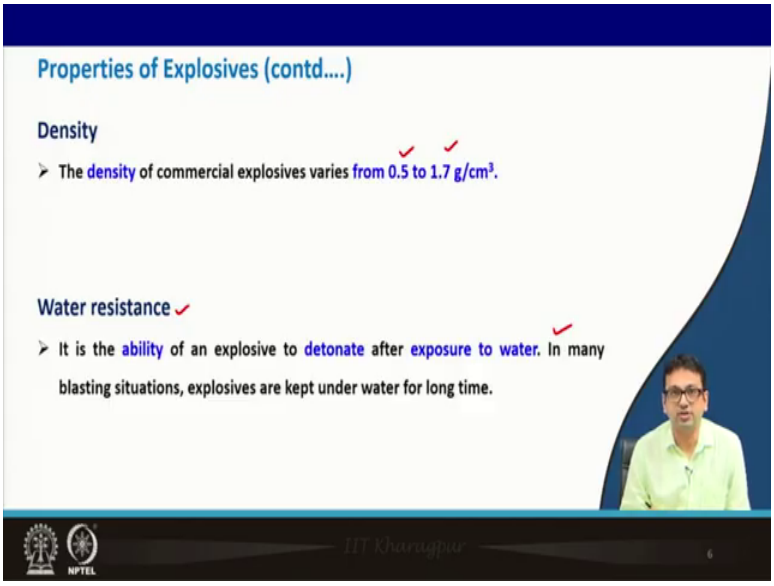

Properties of explosive

We should know little a bit about the properties of these explosives. So, first property is the density. Density of the commercial explosives varies from 0.5 to 1.7 g/cm^3. Then second property is water resistance. It is the ability of an explosive to detonate after exposure to water. So, actually in many blasting situations explosives are kept under water for long time.

So, it may happen means it is quite common or it can happen like you may have to go for a tunneling under water. Water level is may be quite high, there may be different situations where you may have to deal with the water also. So, in that case, it is stated that in many blasting situations, the explosives are kept under water for long time. So, that is why, this property is very important.

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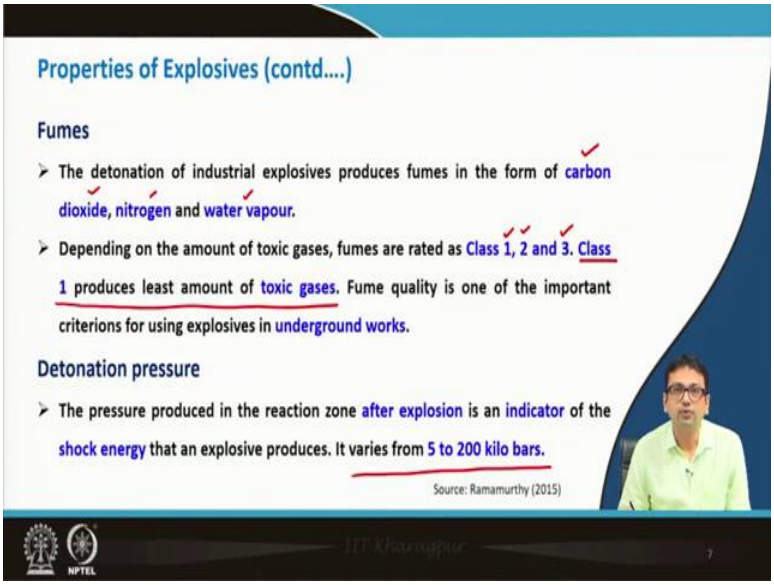

Next property is fumes. This is very important. So, basically, the detonation of industrial explosives produces fumes in the form of carbon dioxide, nitrogen, and water vapor. Now depending on the amount of toxic gases fumes are rated as class 1, 2 and 3. Now what does it mean?

So, class 1 produces least amount of toxic gases. Fume quality is one of the important criterions for using explosives in underground works.

Detonation pressure

The pressure produced in the reaction zone after explosion is an indicator of the shock energy that an explosive produces. Generally, it varies from 5 to 200 kilo bars.

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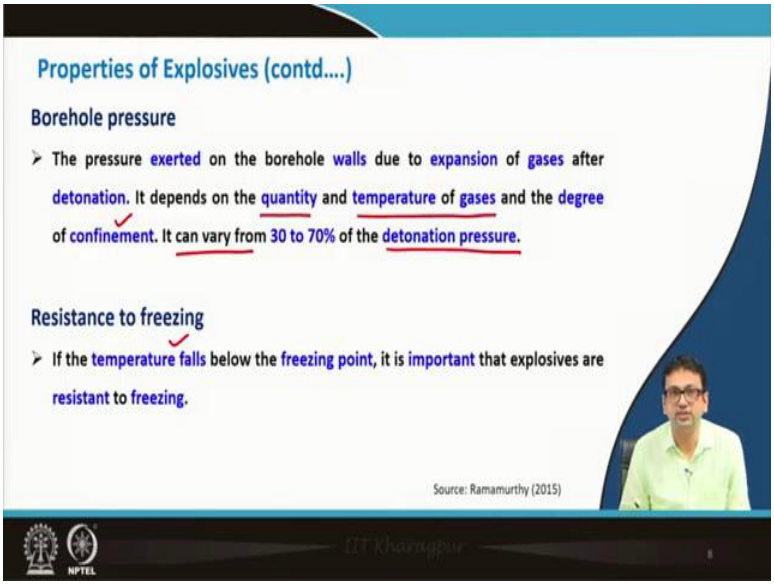

Borehole pressure

The pressure exerted on the borehole walls due to the explosion of gases after detonation. It depends on the quantity and temperature. So, it depends on the quantity and temperature of gases and the degree of confinement. So, that is very important. It can vary from 30 to 70 percent of the detonation pressure.

Resistance to freezing

If the temperature falls below the freezing point, it is important that the explosives are resistant to freezing. So basically means you may have to construct any tunnel in means at high altitude where basically this situation may arise means temperature may fall below the freezing point, so that is why it is important that explosives are resistant to freezing.

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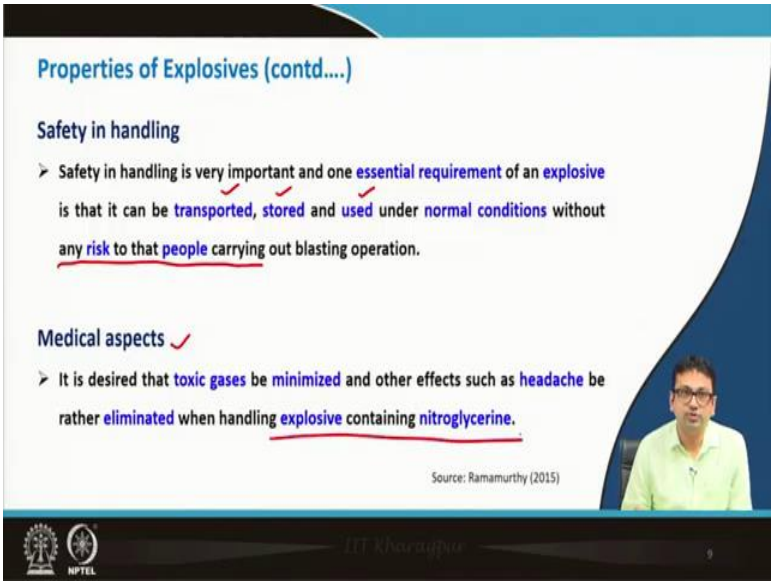

Safety in handling

Safety in handling is very important and one essential requirement of an explosive is that it can be transported, stored, and used under normal conditions without any risk to the people carrying out blasting operation. We should ensure that at the time of selecting the exclusive.

Medical aspects

Medical aspect is extremely important because it is desired that toxic gases be minimized and other effects such as headache be rather eliminated when handling explosive containing nitroglycerin.

So, that is very important, so medical aspects also we should keep in our mind. So, these are some of the important properties.

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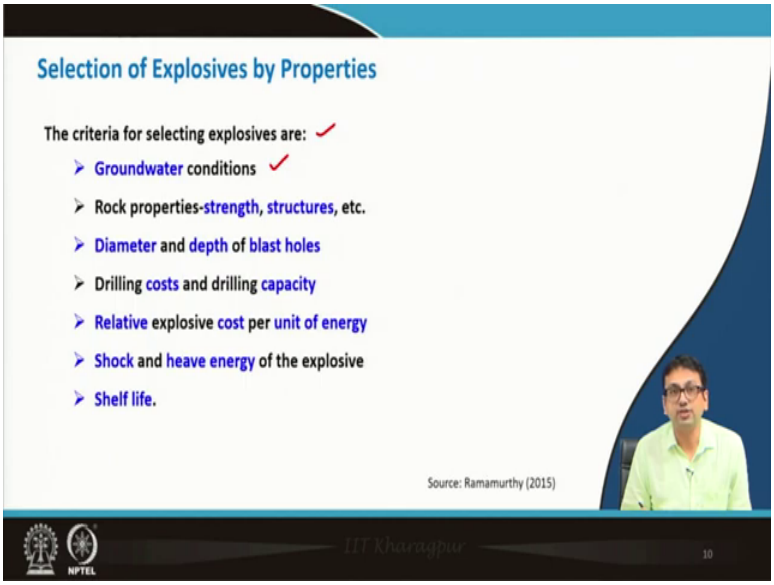

Selection of explosives by properties

We have understood the properties, now actually after knowing the properties of an explosive now what are the criteria for selecting the explosives? Like we have to look into the ground water condition, the reason is if the explosive is like resistant to water then obviously very good. In that case, if we have to go for the blasting below ground water table then also no issue. But if we find that the explosive is not having good water resistance, so we cannot use that actually in that particular situation where the ground water table is above the location where we have to go for the blasting. So, that is why groundwater conditions that also need to consider.

Now, rock properties means strength, structure etc. also very important depending on that you have to choose which explosive we will use. If it is very like good quality rock then obviously in order to go for blasting there means if you need to have an explosive of which should be higher capability. So that is why it is very important, rock property, strength and structure etcetera that is also very much important at the time of selecting the explosive.

Then, diameter and depth of that blast holes that is also obviously important. Drilling cost and drilling capacity so that is definitely is going to govern the selection of these explosives. Now relative explosive cost per unit of energy is also needed to take into account. Likewise, shock and heave energy of the explosive along with that the shelf-life of the explosives also we need to consider.

So, at the time of selecting explosives, we need to look into these aspects also.

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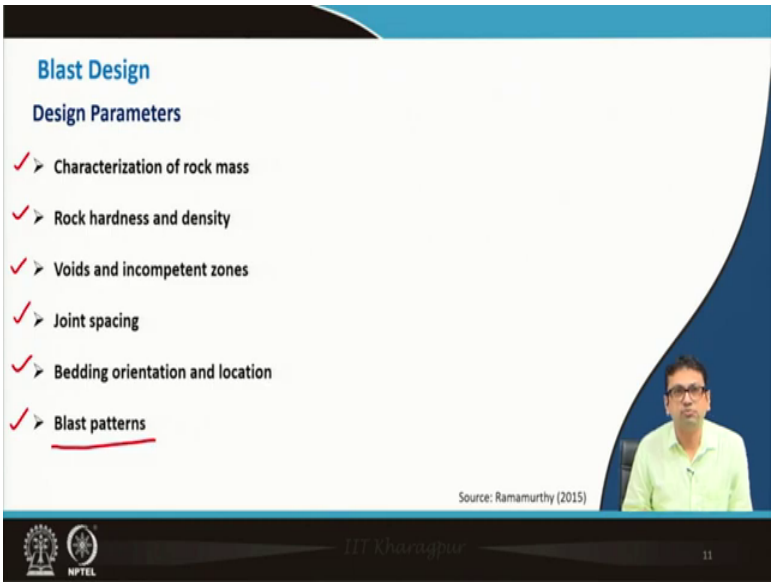

Blast design

Design parameters for blast designs are what like the characteristics of rock mass (i.e., the surface geology: the joint orientation, and the frequency of the joints all those patterns).

So surface characteristics, surface geology you can be very much useful thing, so that is why its stated characterization of rock mass based on observation the surface geology. Then rock hardness and density; so obviously as in our previous slide, also I mentioned rock hardness and density is extremely important for blast design. Then voids and incompetent zones; whether it is present or not that is also important.

Other points are joint spacing, bedding orientation and location as well as the blast pattern. So, now we can little bit more discuss on blast pattern because more or less other terms are known to us.

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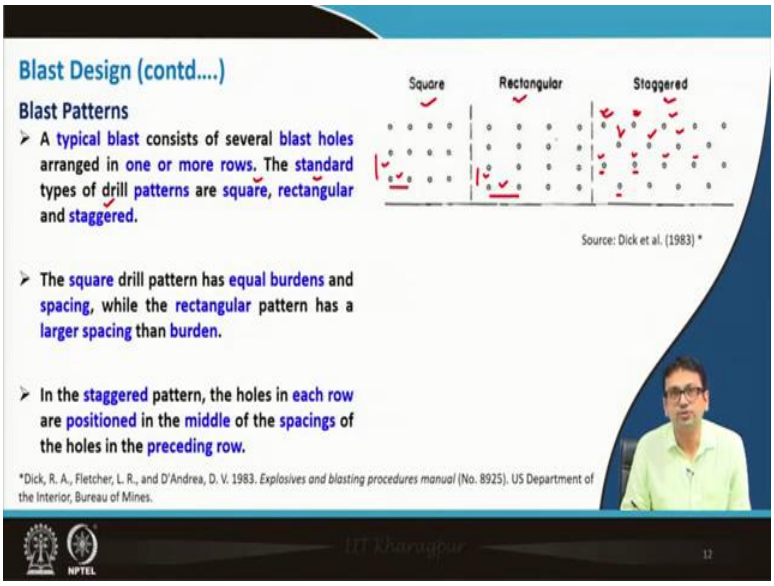

Blast patterns

Now a typical blast consists of several blast holes arranged in one or more rows. The standard types of this drill patterns are square, rectangular, and staggered. From figures, you can identify the difference between square, rectangular and staggered.

You see the like this distance and this distance they are equal whereas here what you can see; this distance is less than this distance. So, it is obviously the rectangular pattern. And now staggered; what is happening here? This row like this and then in next row this is at the midpoint actually, so this one is at the midpoint, this one is midpoint, this is a midpoint of these two, this hole and this hole and this hole.

The square drill pattern has equal burdens and spacing while the rectangular pattern has a larger spacing than burden. So, you can see the spacing in figure.

Now, in the staggered pattern the holes in each row are positions in the middle of the spacing of the holes in the preceding row.

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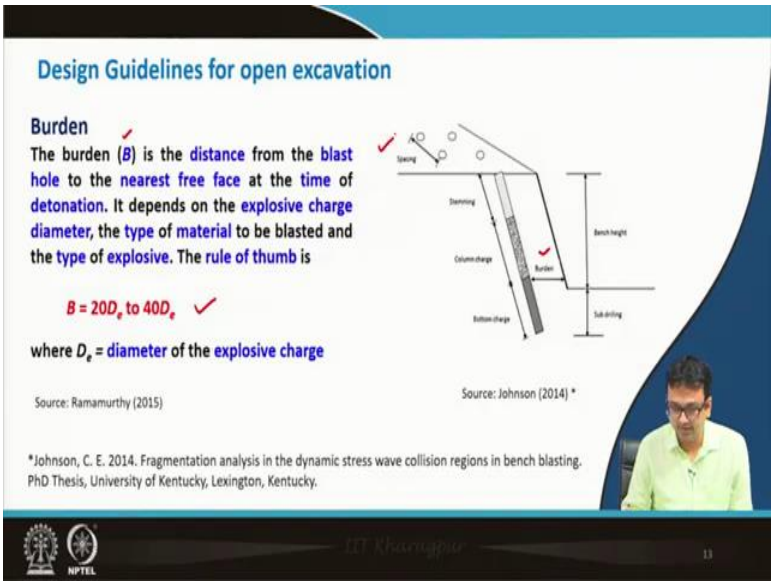

Burden

In diagram, it is nicely explaining all these things. We use this symbol *B* for burden. The burden (*B*) is the distance from the blast hole to the nearest free surface at the time of detonation. It depends on the explosive charge diameter, the type of material to be blasted, and the type of explosive. The rule of thumb is this *B* is equal to 20 to 40 times of D_e, now what is this D_e? D_e is the diameter of the explosive charge. So, this is important to get some idea about this *B*.

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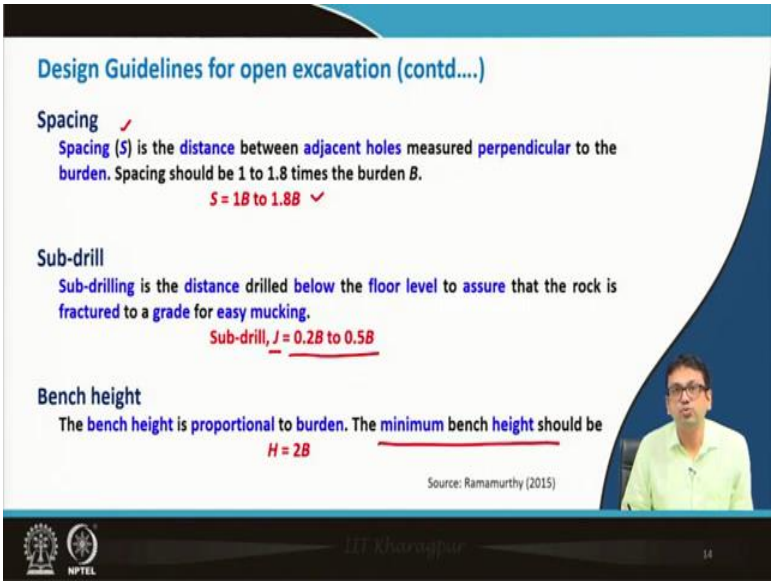

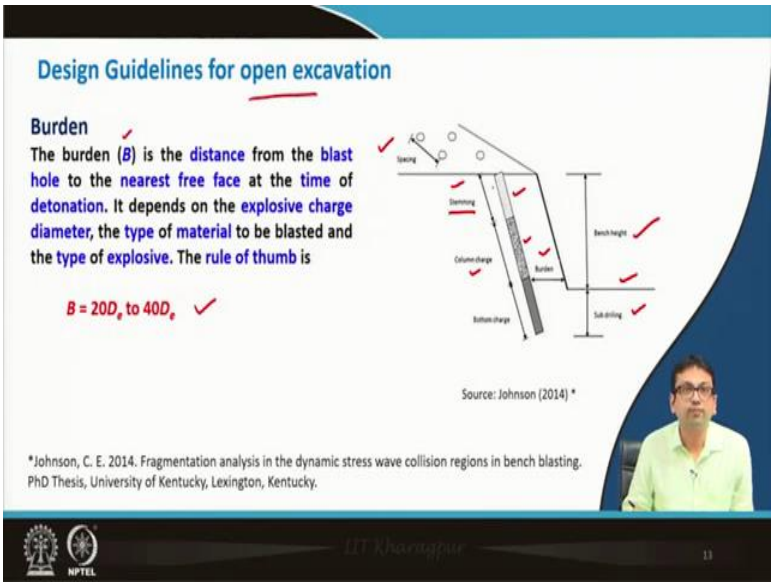

Spacing

So we can refer again this diagram you can see the spacing, so what is spacing? Spacing is the distance between adjacent holes measured perpendicular to the burden, so spacing should be 1 to 1.8 times of the burden, so that is also another thumb rule.

Sub-drill

Let us try to to understand. Sub-drill is the distance drilled below the floor level to assure that the rock is fractured to a grade for easy marking. So, sub-drill generally *J* symbol is used and equal to 0.2*B* to 0.5*B*. So, this is the floor and below that, this is sub drill portion.

Bench height

Bench height is proportional to burden, the minimum bench height should be the minimum that is important minimum bench height should be that *H* bench height and *H* is equal to 2*B*. So, let us see in the again picture so you see the bench height is this one, so some idea we could able to have now based on this, so for the design of blasting these things we need to remember. So, remember these things mean this is related to mainly the open excavation, you see mainly the open excavation, these type of patterns we use.

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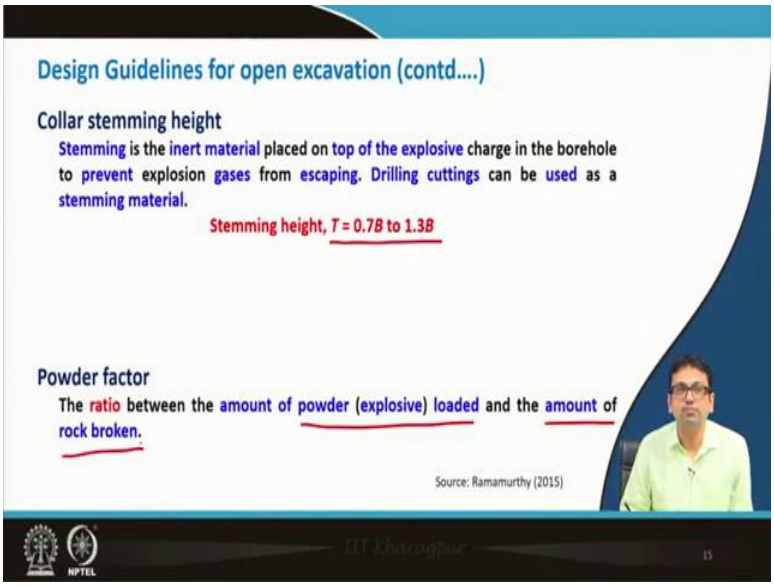

Collar stemming height

What is the steaming height? Let us first visualize you see that this is the stemming you this region. Stemming is the inert material placed on top of the explosive charge in the bore hole to prevent explosion gases from escaping the, drilling cutting can be used as a steaming material. So, there is again some thumb rule that *T* is equal to 0.7*B* to 1.3*B*.

Powder factor

The ratio between the amount of powder explosive, powder means explosive loaded and the amount of rock broken.

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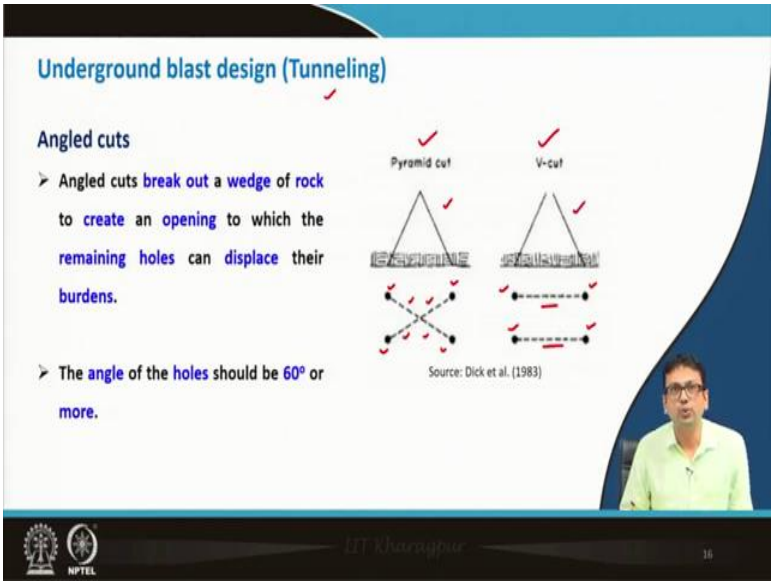

Underground blast design (Tunneling)

Angled cuts

Angle cuts break out a wedge of rock to create an opening to which the remaining holes can displace their burdens and the angle of the holes should be 60 degree or more.

Now you see there like regarding angle cuts there are different types of angle cuts like pyramid cut, V-cut, so as you can see from here that if this is suppose the front view, these are the holes like you see and the pattern is like this, you see which in like top view will give you a shape like pyramid. Try to visualize in 3D and this is called V-cut, so these are the holes and they are extended like this as you can see, front view now top view it will look like this. So, angle cut at least the terms you should know, so angle cut one type of pattern.

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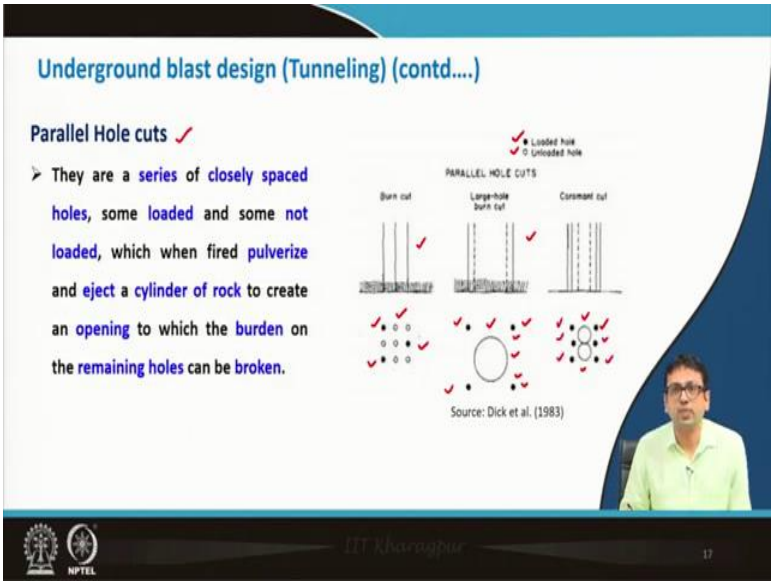

Parallel hole cut

The pictures are very nicely explaining, the things like you see, like again if you see this is the front view. Then from top view, it will look like this, this is the barn cut then large hole burnt cut okay, so here you see one large hole is there surrounding that part you 4 holes where the explosives will be placed. So, let us read what is stated over here.

They are a series of closely spaced holes some loaded and some not loaded which when fired pulverize and eject a cylinder of rock to create an opening to which the burden on the remaining holes can be broken. So, you see here, you can see here, there is a large hole whereas here like 3 dots are for you can see the loaded three holes and remaining 6 holes are unloaded.

So likewise, these patterns are also used here, you can see two relatively like medium size unloaded holes and here 3 this side, 3 this side. So, different types of these patterns are used for as per the requirement actually.

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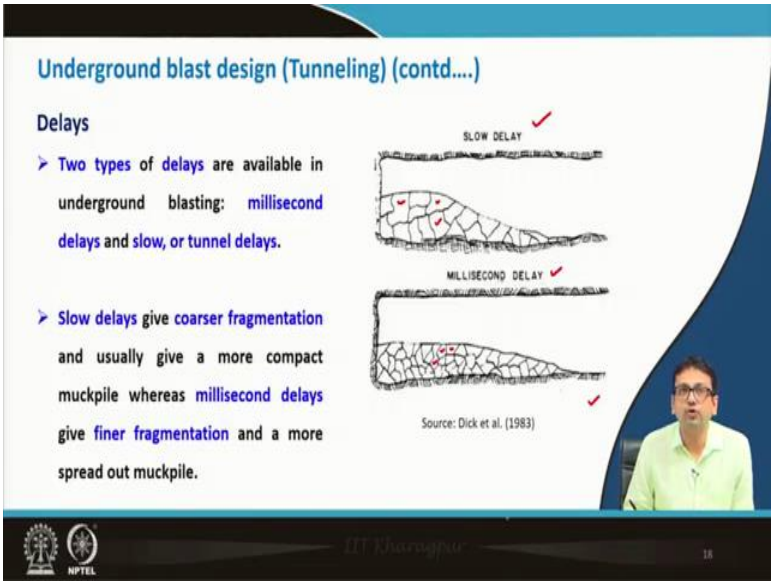

Delays

So now, another small thing we should know that is the delays. Two types of delays are available in underground blasting. One is millisecond delays and another running slow or tunnel delays. So, now millisecond delays and what is slow down tunnel delay, so what is that? So, slow delays give coarser fragments and usually give a more compact muck pile whereas millisecond delays give finer fragmentation and a more spread out muck pile.

So, you have to choose whether you will go for like slow delay or millisecond delay. So, this is one thing that you should remember.

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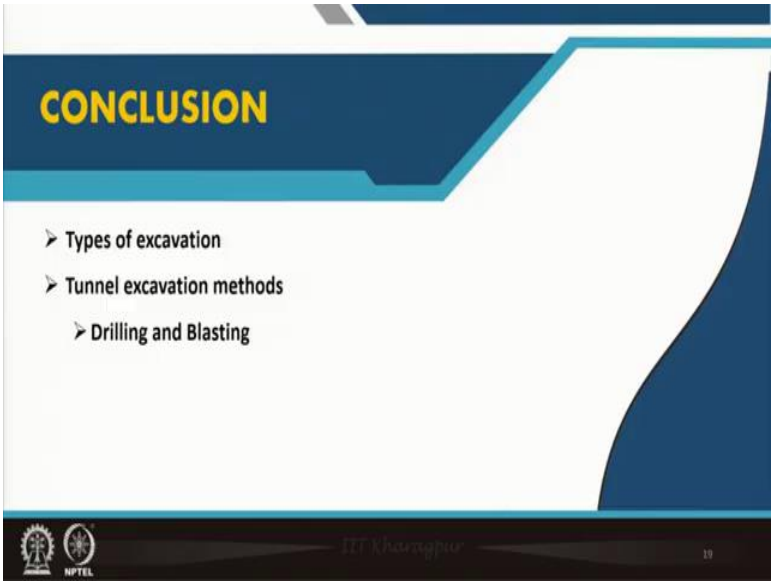

So, in conclusion, what we can say; today we have discussed about the types of excavations and then tunnel excavation methods and different tunnels, name of different tunnel excavation methods. We have learnt and then among them one of the tunnel excavation method is drilling and blasting, so we have discussed about the drilling and blasting today. Thank you. So, with that let me conclude our todays lecture.