Surface Mining Technology
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Lecture 20
Technology for Surface Blasting –VI

Let me welcome you to the 20th lecture of Surface Mining Technology. This is the sixth and last lecture related to Technology for Surface Blasting. We will continue with our discussion with the blasting results.

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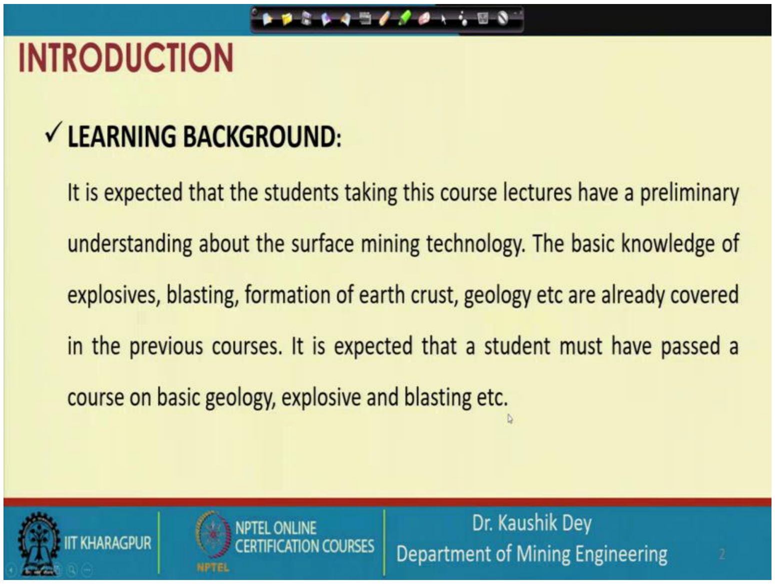

As we give you a glimpse of the learning background, required for the surface mining technology course.

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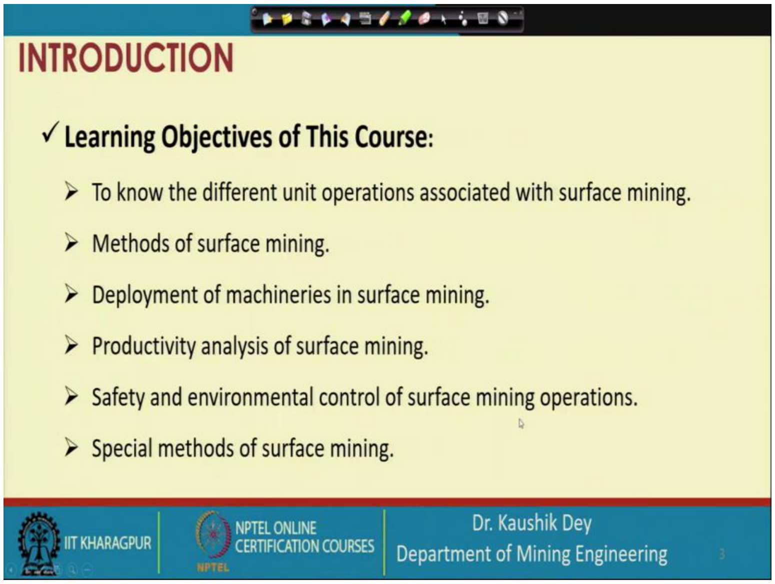

Learning objective of the surface mining technology course.

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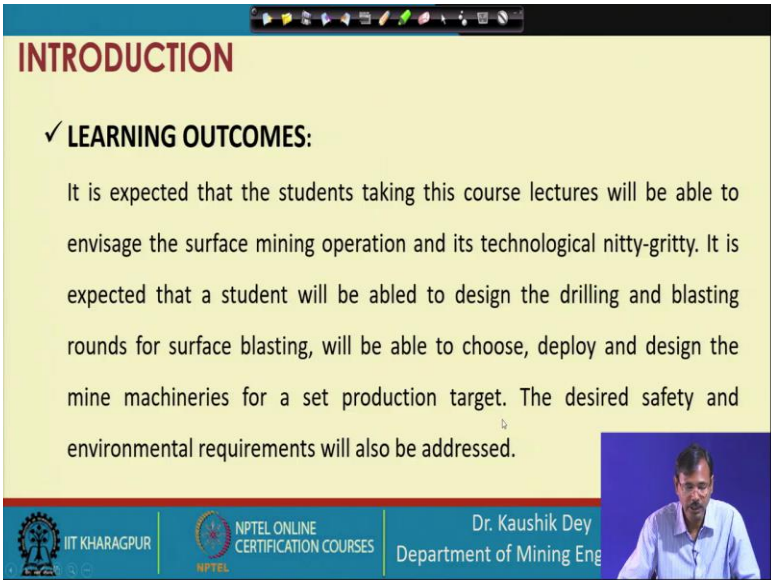

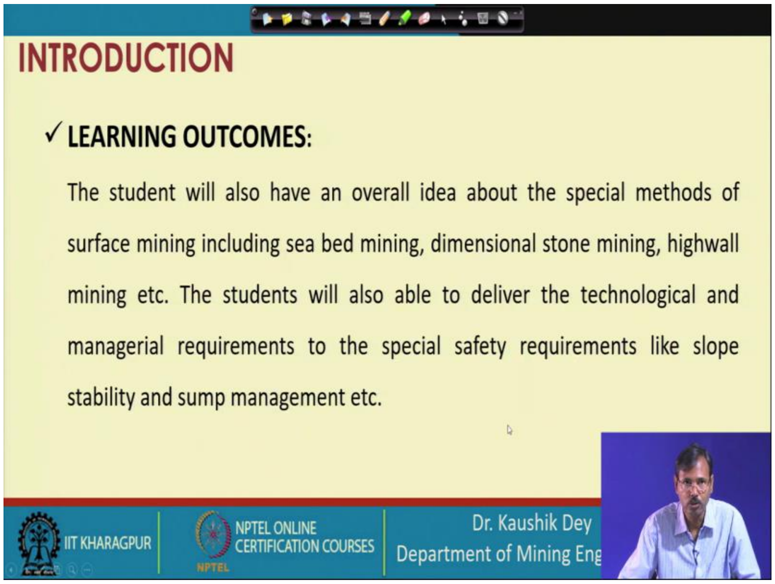

And these are the expected learning outcomes of the surface mining technology course.

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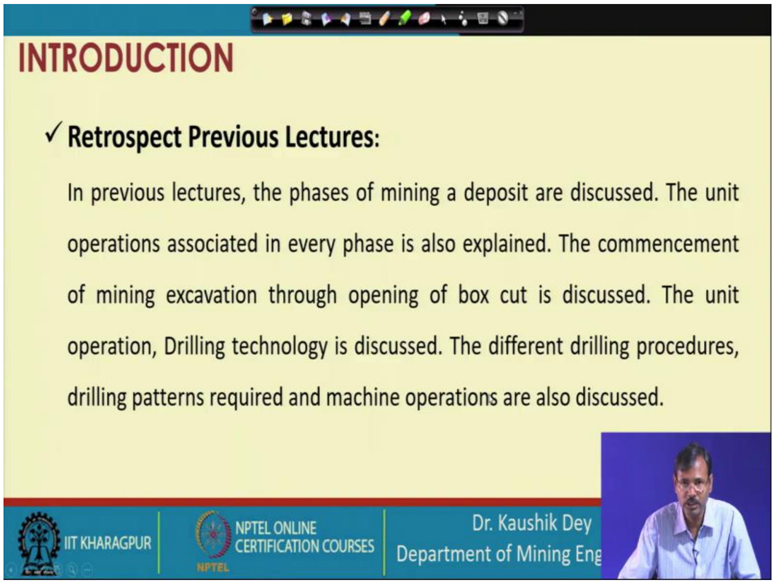

And this is the retrospect of the previous lecture. Before blasting, we have covered phases of mining we have covered the opening of mining, surface mining through box cut, we have covered drilling technology, and mostly blasting technology is also covered. Before this lecture, we are discussing the blasting results, fragmentation, and fly rock is already discussed.

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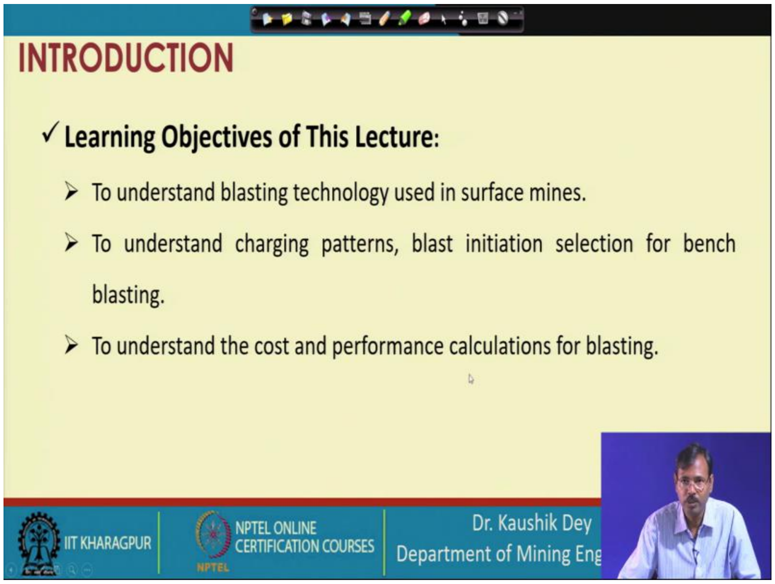

In this lecture, we will discuss the ground vibration generated by the surface blasting and the back break created by the surface blasting and their effects in this lecture.

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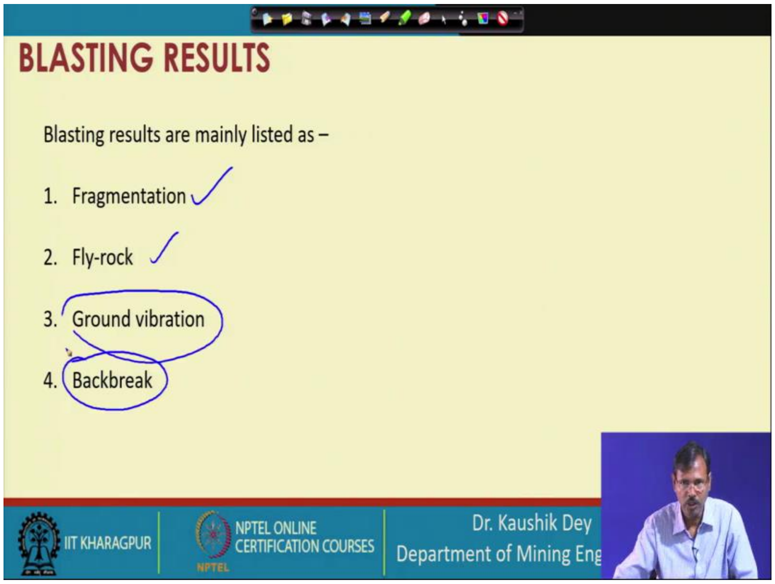

So, as I have discussed already, we have covered fragmentation, we have covered fly rock, and in this lecture, we are basically giving our interest in this two topic.

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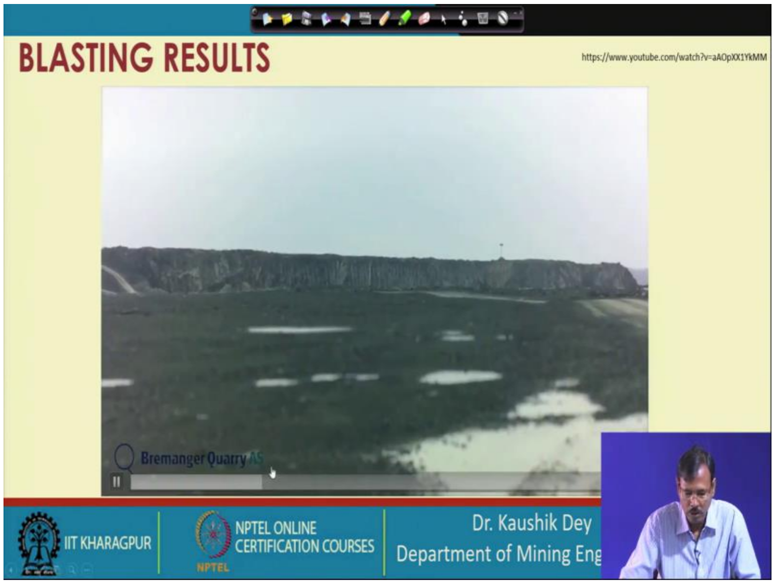

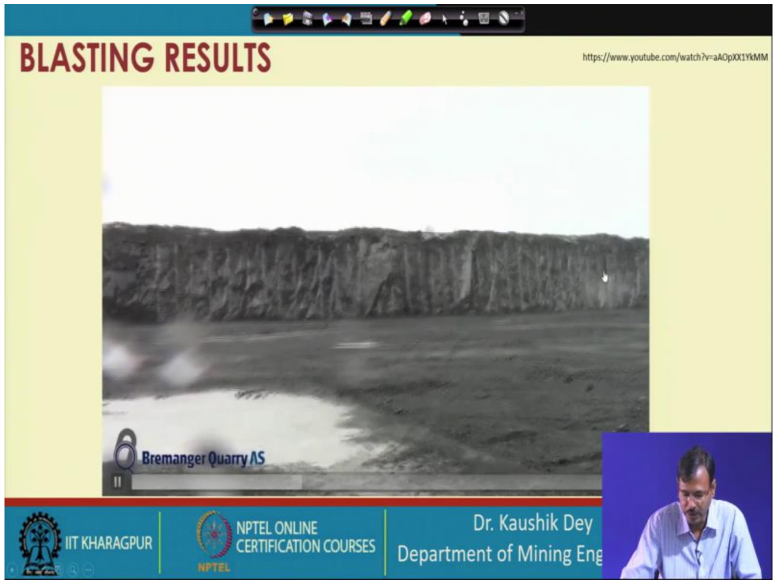
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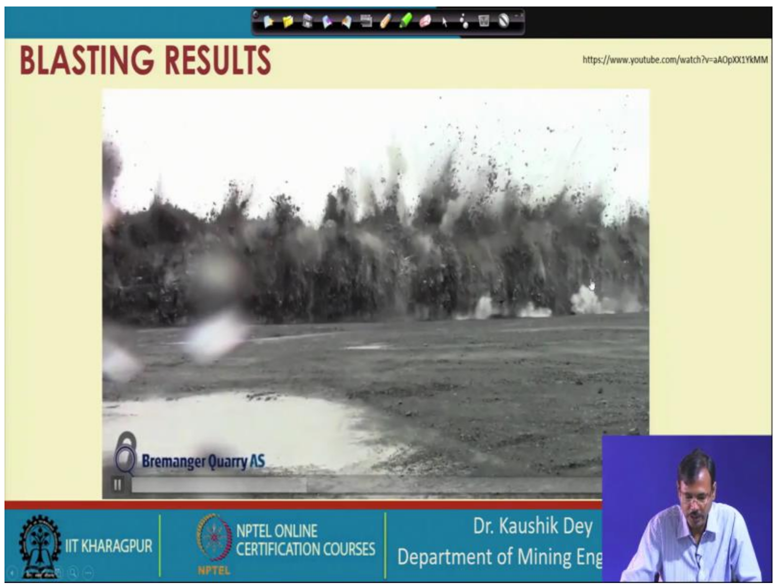
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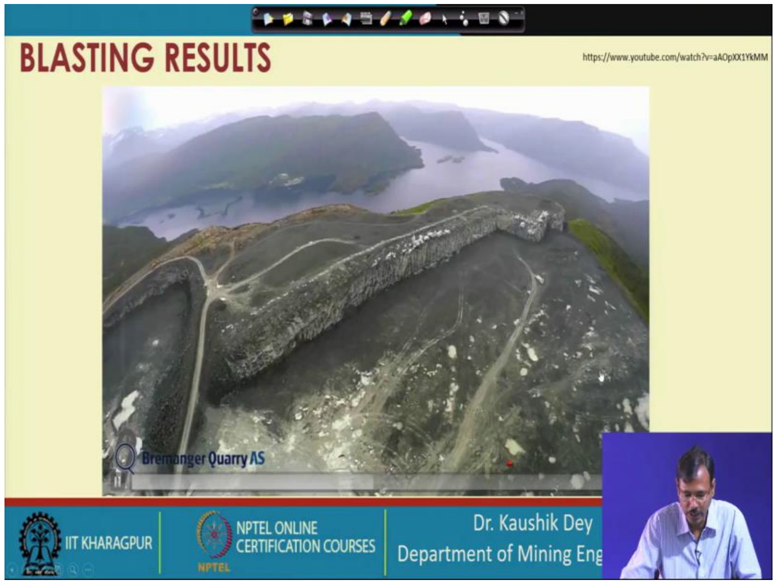
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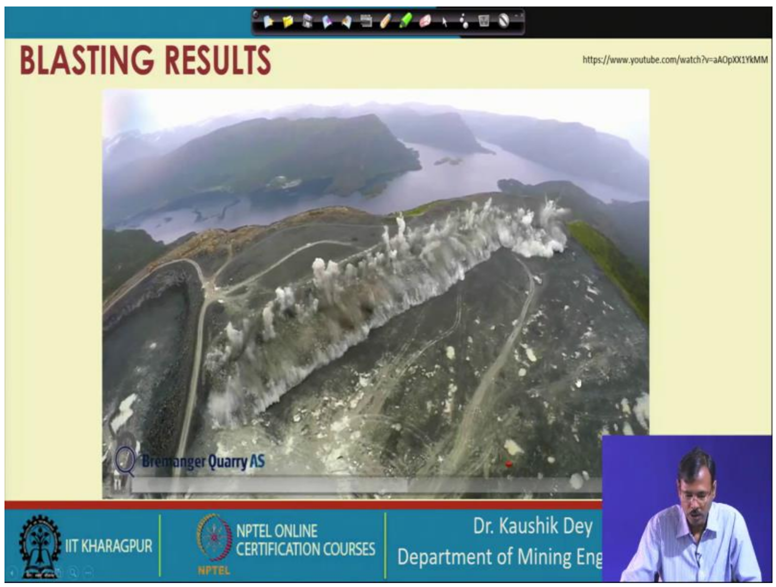
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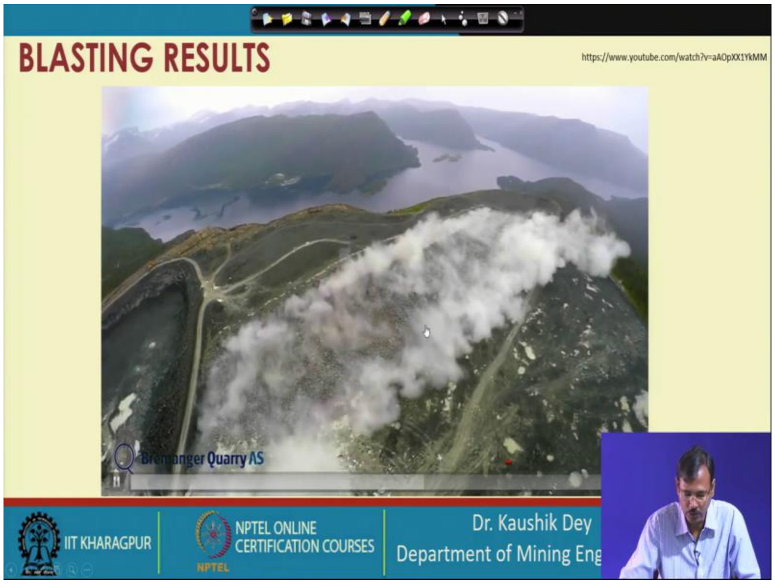

So, before that, let us look once again into the this is the largest production blast in the Norway, and you can see how this blasting is carried out. This is very well maintained 380 meter long bench is blasted here and very precisely blasted. You can see here this is a photograph taken by the drone. So, this link is available on the YouTube, and you can see the fragmented size.

This is another picture from the drone. 360,000 tonnes of explosives are used for blasting this one, and you can see how good, and excellent the post-blast bench wall is. You can see how the almost uniform fragmentation is met, and obviously this will increase the efficiency of the excavator message.

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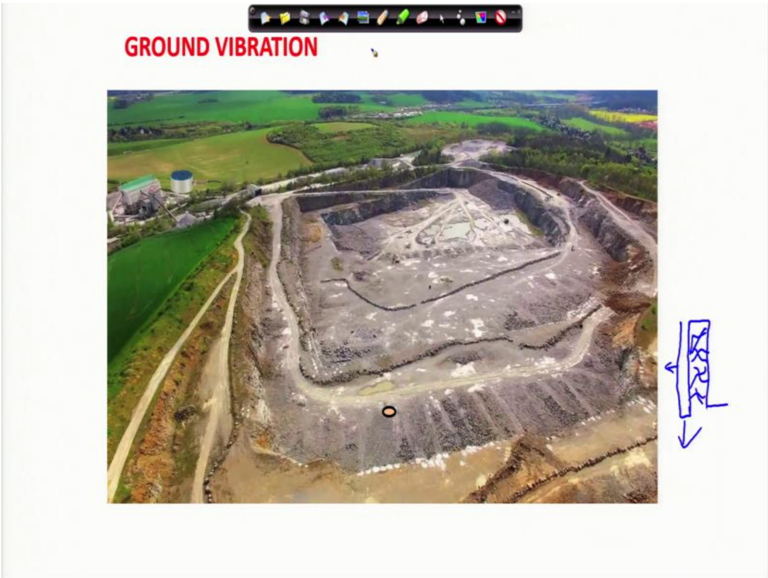

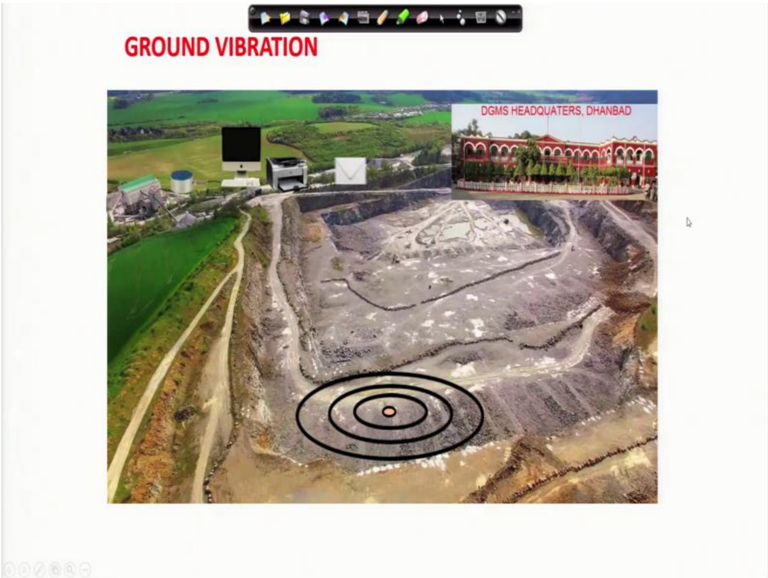

Now, let us see what ground vibration is? Whenever we have carried out blasting, then on blasting of this hole at this position, it is in the front side of the hole the shockwaves propagate to generate cracks in the rock mass. But in all other direction , the shockwave ropagates infinitely without creating damage and this propagation of the shockwave is called ground vibration. So, when this blasting is carried out, the shockwave propagates. The result of that propagation of the shockwave is called ground vibration.

So, animated way, if you think, suppose this blasting is carried out then the wave is propagating in all direction, and that is generating vibrating at this position and our current Indian system is that after vibration measured in the surface mine, every blast of the surface mines ground vibration must be measured. After measuring this, the report has to be sent to the APEX body of the country.

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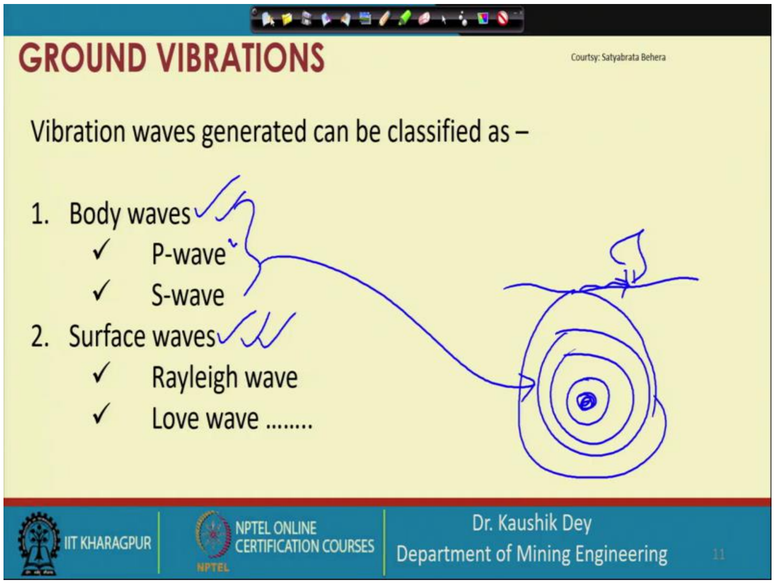

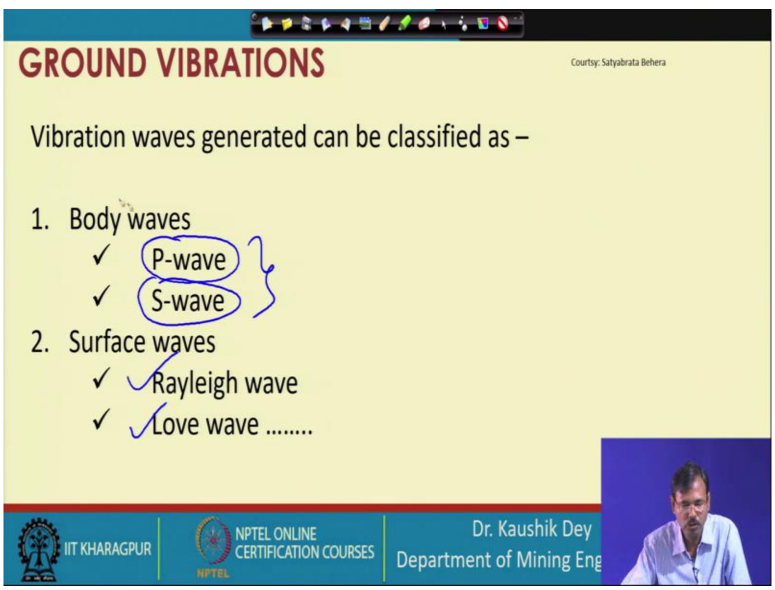

So, that is the general provision of the ground vibration measurement for every surface mines. It is now mandatory to measure the ground vibration for all the blasts. This shockwave, which propagates through the ground, has two ways and can be classified in two ways: one is called a body wave, and another is called a surface wave.

So, when you are detonating some explosive below the Earth's crust, it is generating shocks, and these shocks basically have body waves. When these body waves are reaching at this surface, they travel on the surface, becoming a surface wave. So this is why it is classified into a body wave and surface wave.

Furthermore, the body wave is classified into two wave; one is P-wave or pressure wave, S-wave, or a shear wave. So, these are the two types of body waves possible and surface waves are of different types. Two major surface waves are the Rayleigh wave and the love wave. So, before going into the ground vibration, let us have a little knowledge related to these waves.

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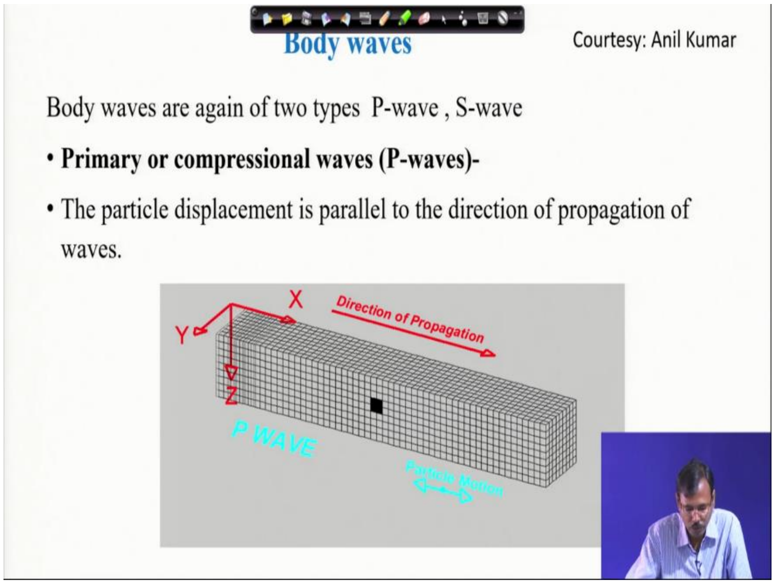

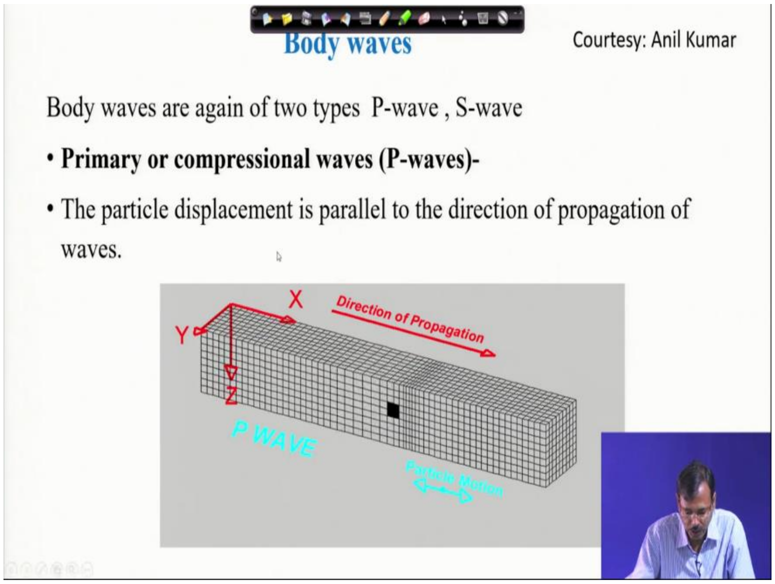

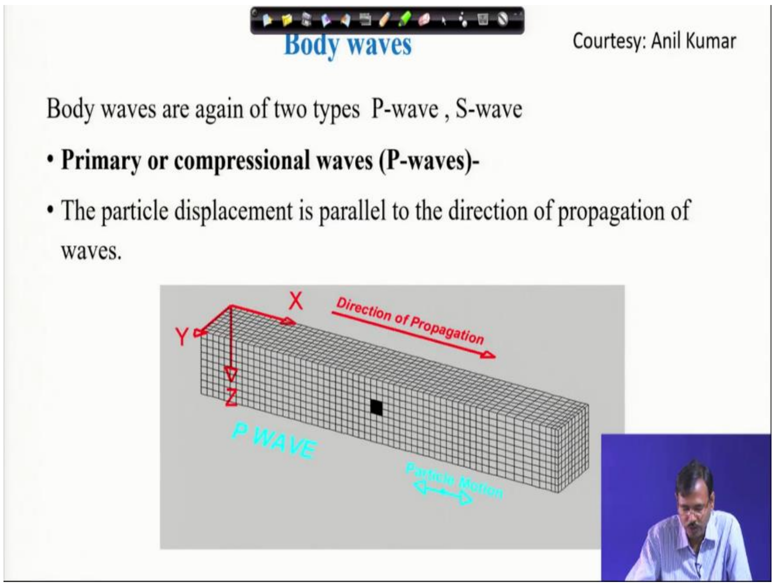

So, this is the primary wave, pressure wave, or compressional wave. You can see these waves are moving in a longitudinal direction, and just like a sound wave it is moving in comparison and dilation, it is moving in comparison and dilation. So, you can see this in this animated video which is available. I think on Google also it is available Wikipedia. So, from there, it is taken by Mr. Anil Kumar, and he gave it to me. So, this is the animated propositional, animated video of P-wave propagation.

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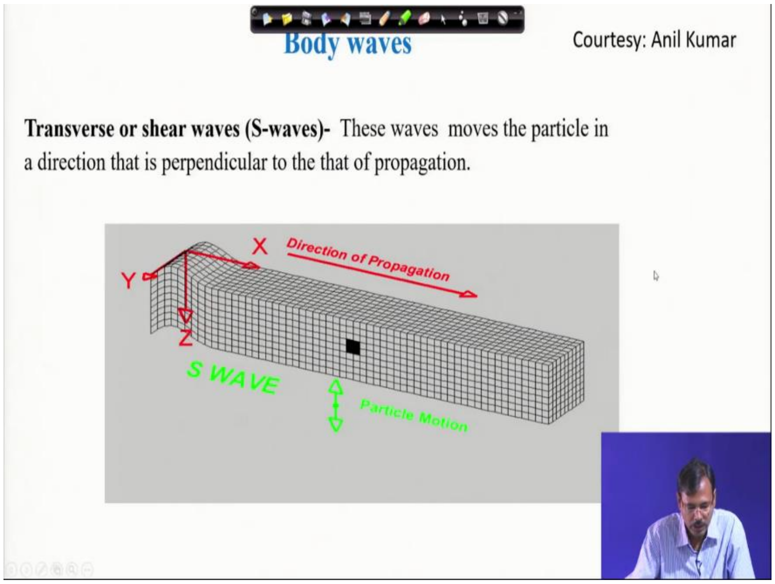

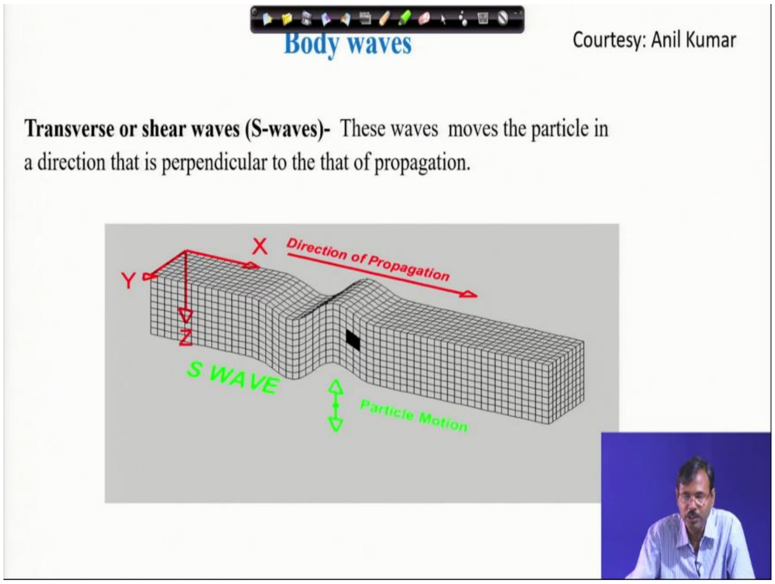

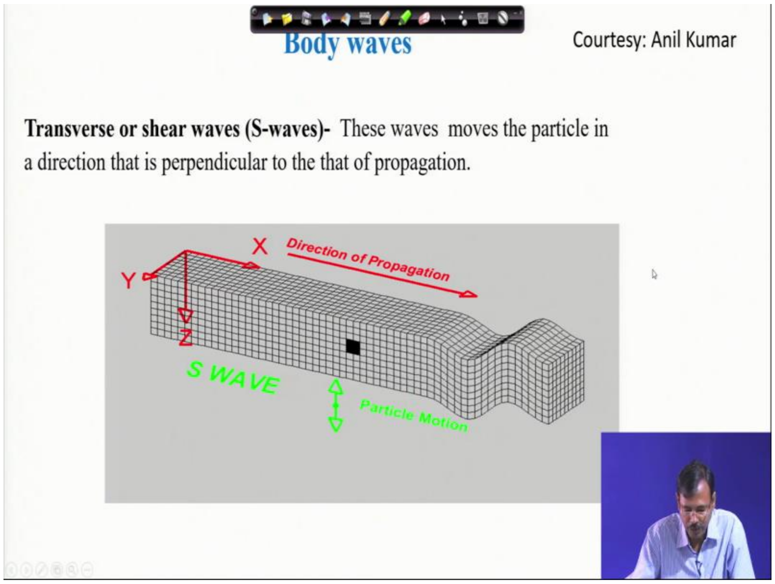

Similarly, you can see this is the propagation of the S-wave where the wave is propagating by shearing the medium, and this is the S-wave propagation. So, in the P-wave shape, when the P-wave is passing in the medium, the shape of the medium does not change, but the size of the medium changes. But in this S-wave propagation, the size of the medium is not changing, but the shape of the medium changes. So, that is the main difference between this propagation of two waves, body waves, and S-waves, and it is easily understood as this is happening.

So, as the shape is specifically changing, that is why the S-wave cannot travel in the liquid medium or the air medium, but P is a compressional wave, where the size is changing, but shape is not changing. That is why it can propagate through the liquid medium and air medium. Th sound is a pressure wave that moves through the air.

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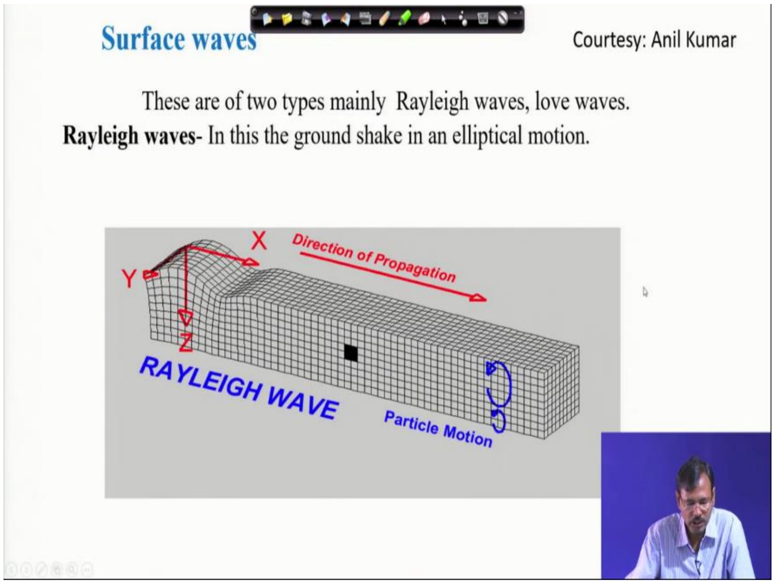

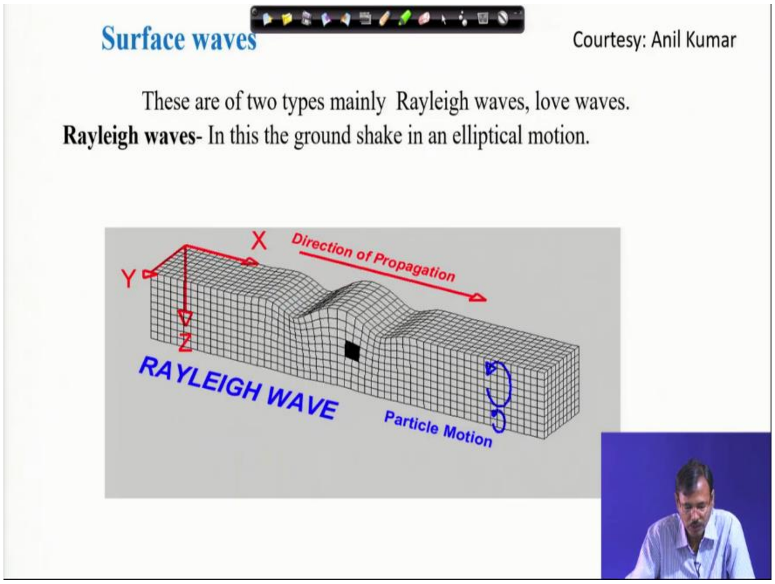

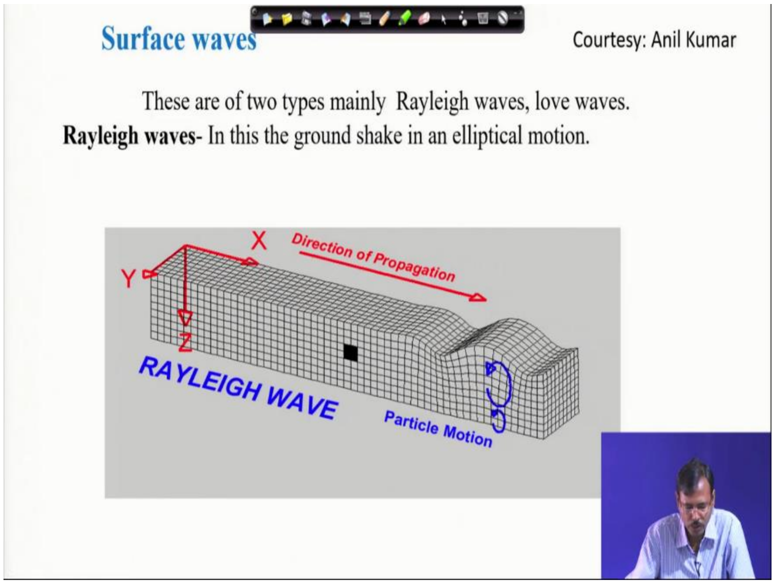

So, this is the Rayleigh wave. Propagation is almost similar to the shear wave, but it has horizontal and vertical shearing. So, this is the Rayleigh wave.

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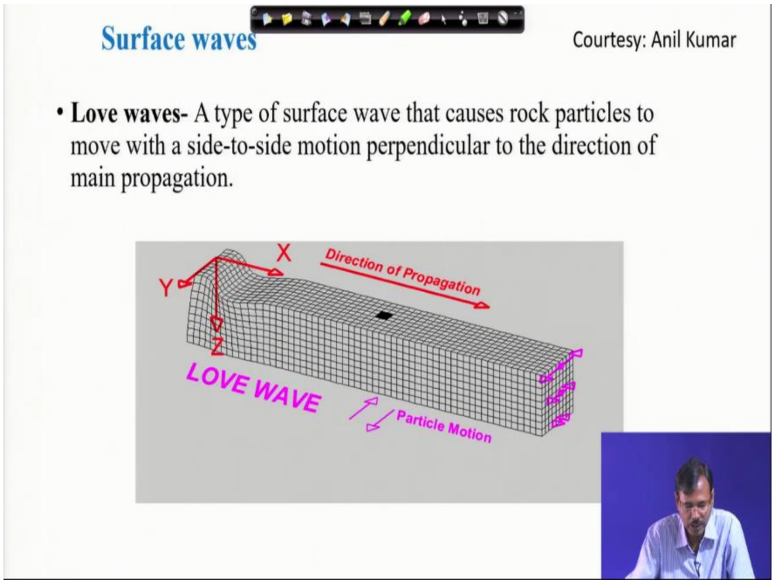

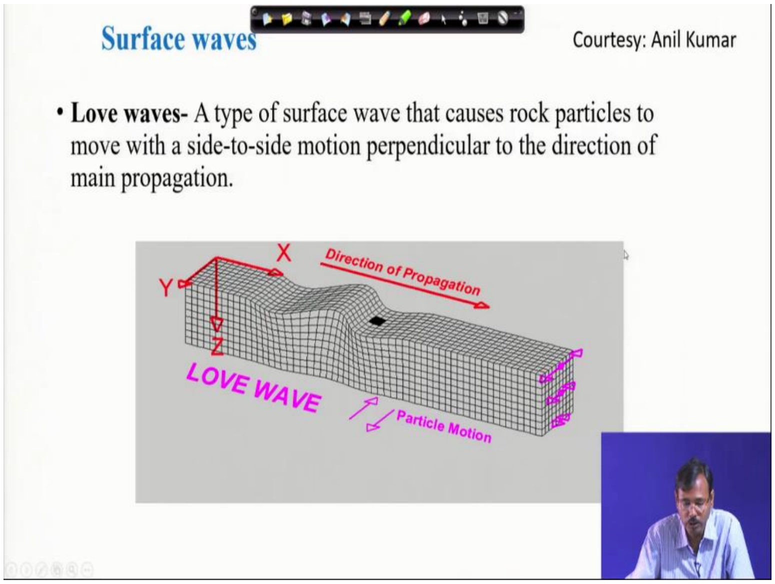

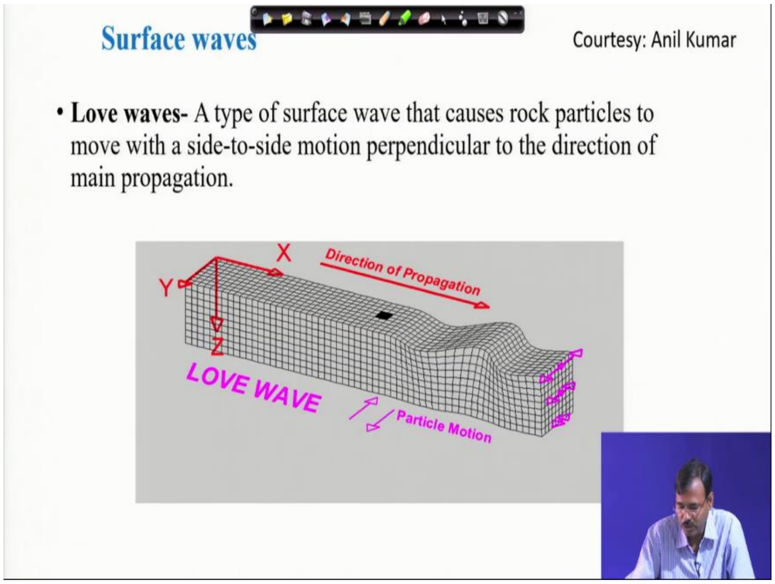

And this is the love wave. So, this is the propagation of the love wave in the horizontal direction you can see. This is the particle motions in that direction. So, these are the surfaces, and when the body waves reach the surface, only the surface waves are generated.

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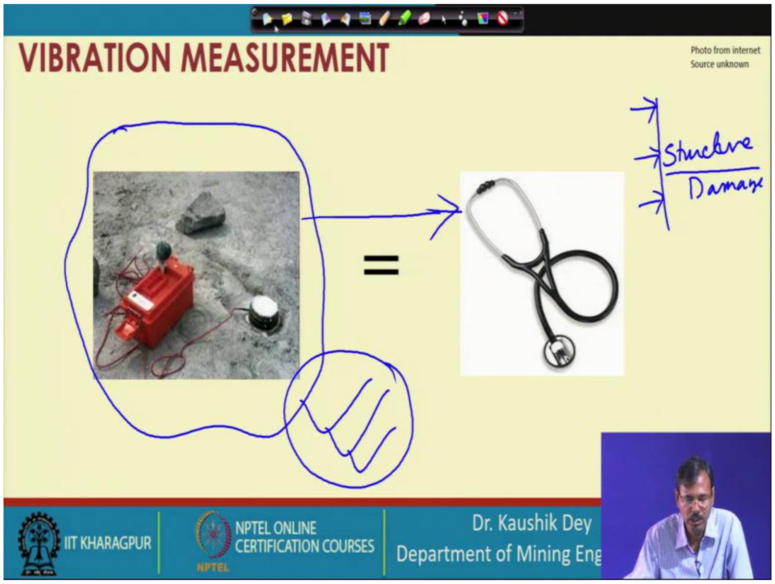

Ground vibration is required to be measured for different reasons. However, it is a very common belief in our mining sector that we measure ground vibration only to know whether the vibration generated is damaging the structure nearby or not. So, structural damage is considered the main objective of ground vibration monitoring.

However, that is not true. Structural damage by the ground vibration may become a possible reason it is required. Still, ground vibration dictates a lot of details about the blasting, which is impossible for the blasting engineers to understand. That is why it is better to say that the seismograph, the instrument used for measuring the ground vibration, can be considered a stethoscope of a doctor to identify why the blasting process went wrong. So, that is very, very important. Let us understand that.

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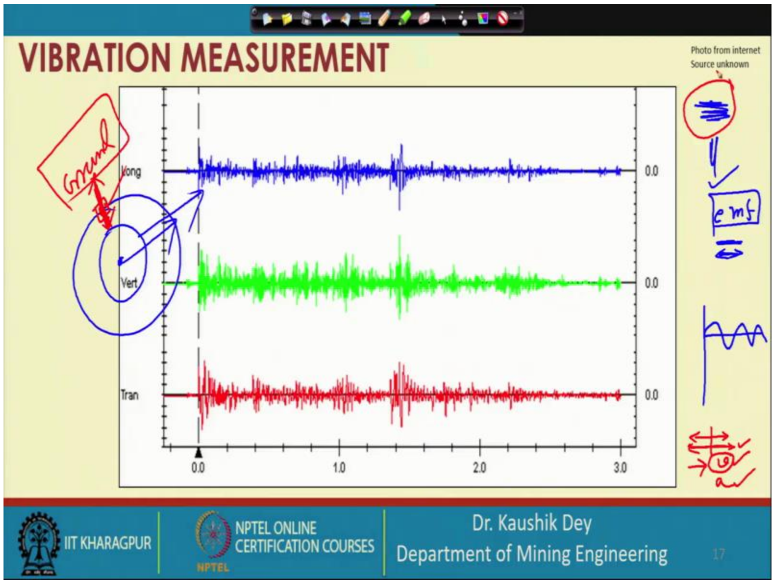

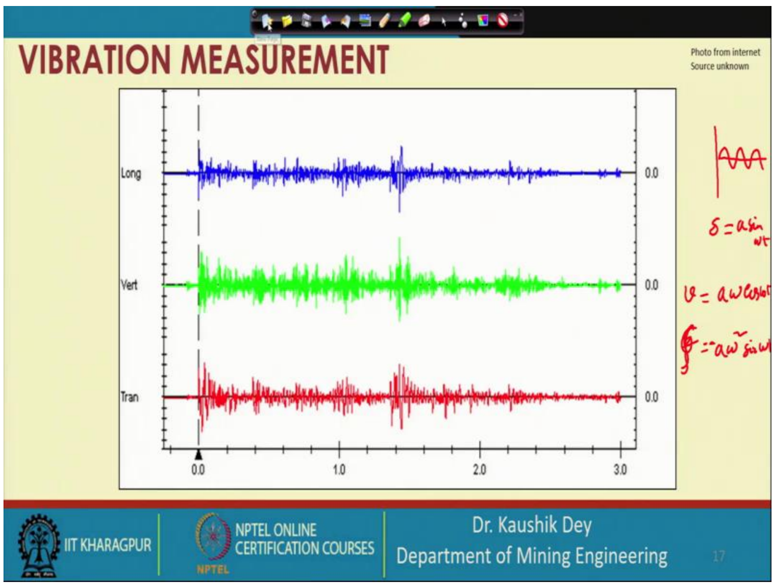

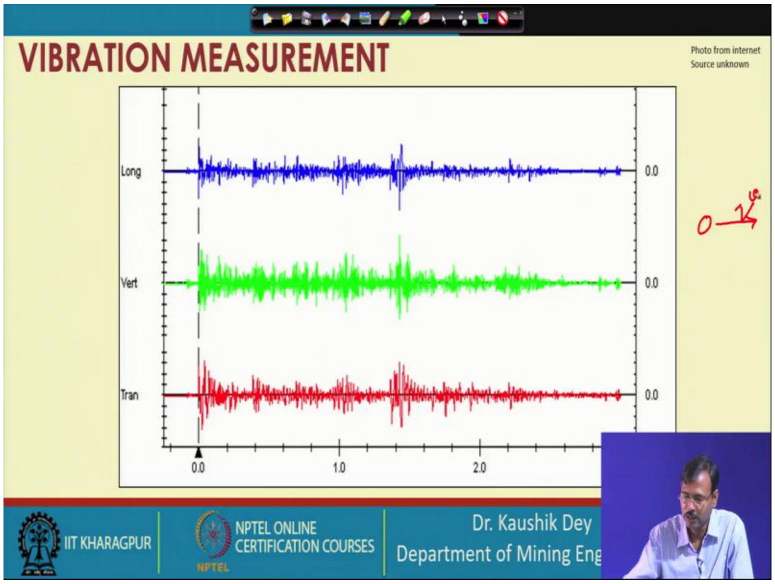
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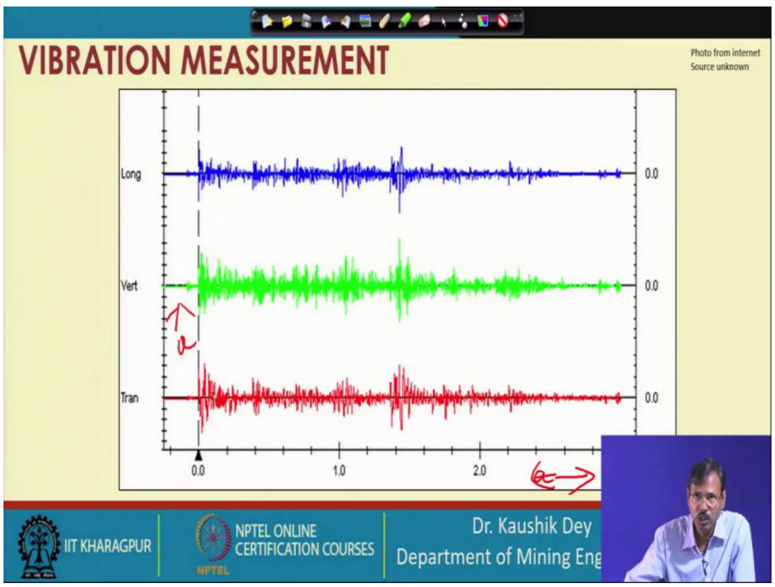
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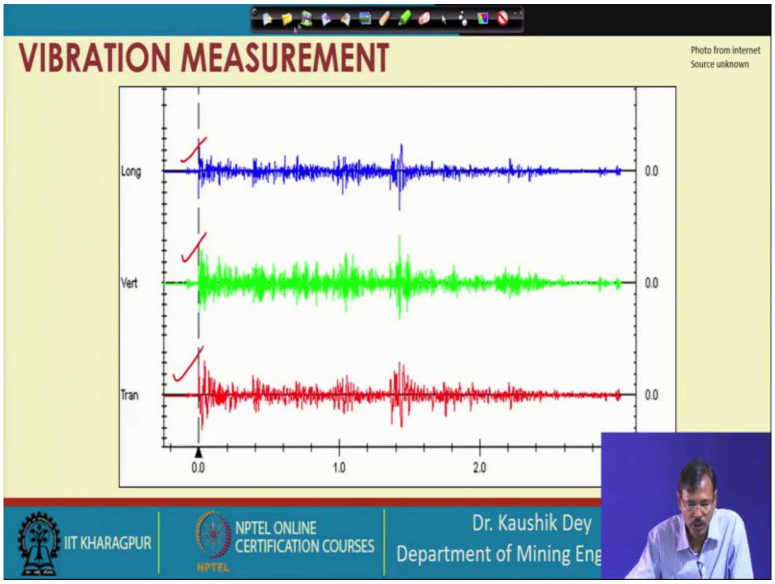

What is there in the seismograph? In the seismograph which we have seen, we have shown in the previous slide that a seismograph comprising either a magnet and coil system, if the oscillations occur to that, then the emf or voltage generated as the magnet is oscillating around a coil then emf is generating. So, when the ground is vibrating, the interest is basically oscillating, and that is generating emf. We are measuring that one.

Similarly, we can have piezoelectric where the because of the ground vibration, the emf is generated. So, basically, we measure the ground vibration from different generations of emf. What is ground vibration? Ground vibration is nothing but a sinusoidal curve, or you can say the particular particle is oscillating like this. Say if it is under the POF if it is oscillating like this, if it is SOF, it is oscillating like this. So, this is the oscillation of a particle called ground vibration.

Again let me give you an explanation. Blast vibration and ground vibrations are not the same. In blasting, we are allowing the propagation of the waves. So, from the blasting, this wave propagates in all directions. In a similar fashion, if you drop a stone on the pond water, the waves are generated, and the waves propagate in all directions. So, similar waves are generated here, and the waves are propagating in all directions from the blasting point. So, that is the blast vibration that is moving towards this.

But what is ground vibration? Ground vibration means we have placed a seismograph at this position, and we fixed this seismograph at this position. We are observing the oscillation of the seismograph like this. So, oscillation of the seismograph in this direction, we are measuring this one, so that is the ground vibration. So, this is blast vibration; this is ground vibration.

So, we are measuring this ground vibration, which means the particular particle oscillation at this position. So, that is why the ground vibration measure the ground vibration is considered the particle velocity. So, why this velocity term has come? Let us get the idea of this, say as the particle oscillates. We are considering it as a sinusoidal approximation.

So, the particle is oscillating like this. So, as it is oscillating like this, similar to a pendulum manner, if you consider, the displacement is with the time changing. So, this is the displacement of the particle, and as the, with the time, the displacement changes, so obviously, it has a velocity. Similarly, you can assume that it has an acceleration also.

So, as the displacement is there, velocity is there, and acceleration is there. Still, in mining, we are more interested in this velocity because the damage criteria are made based on the velocity. But in other cases, in most of the other civil engineering, etc., acceleration is considered as the measurable parameter, not the velocity, but in mining, we generally opt for the velocity.

$$\delta = a \sin \omega t$$

$$\delta = a\, \omega \cos \omega t$$

$$f = a\omega^2 \sin \omega t$$

So, if you are considering the sinusoidal curve, if the displacement is a sine omega t, then if you change it to velocity that is dv by dt, it will be an omega cos omega t. The acceleration, let us write f for acceleration, then it is minus an omega square sine omega t. So, as the acceleration is in the opposite direction of the displacement, you can consider it is, says oscillation is occurring at this position.

So, this is the general theory behind ground vibration. This is the output of the seismograph. We place the three sensors, one in the longitudinal direction; if you consider this, this is the longitudinal direction, this is the transverse direction, and if you are considering the vertical one, then the vertical is regarded as the third direction.

So, we measure the ground vibration in these three directions, and these are the three readings. This is basically an accelerometer reading. So, you can understand that acceleration is given on the x-axis, and this is the time on the x-axis and acceleration on the y-axis. So, time on the x-axis and acceleration on the y-axis. You can say this is 1 second; these are in the millisecond. Now, if you look in detail at these curves, you will find out, see let us consider, this is for longitudinal vertical and transverse for to look a better figure, let us go to the next slide.

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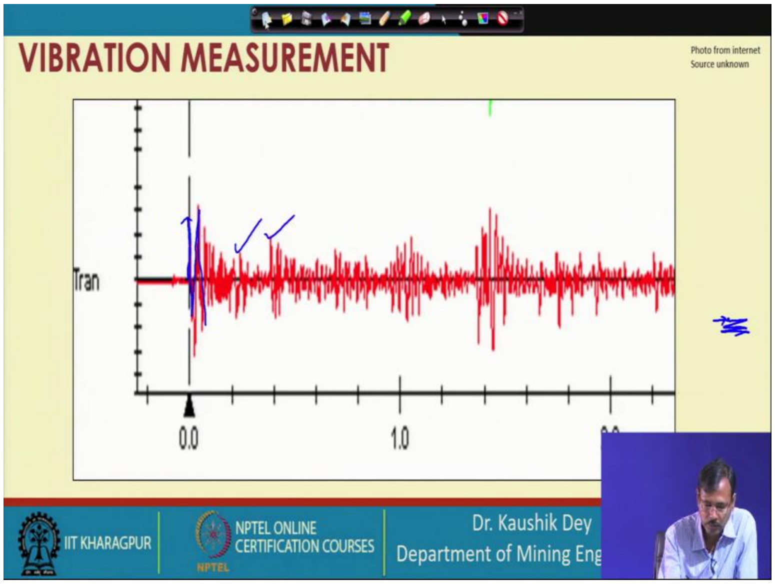

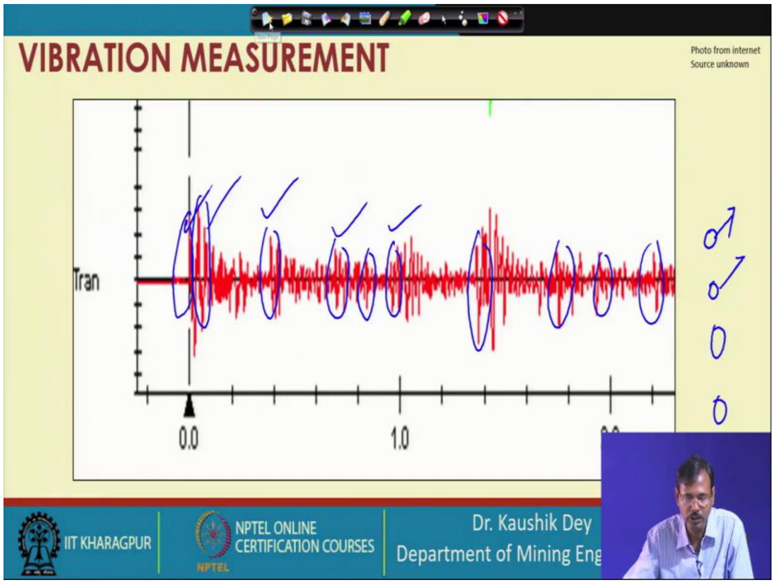

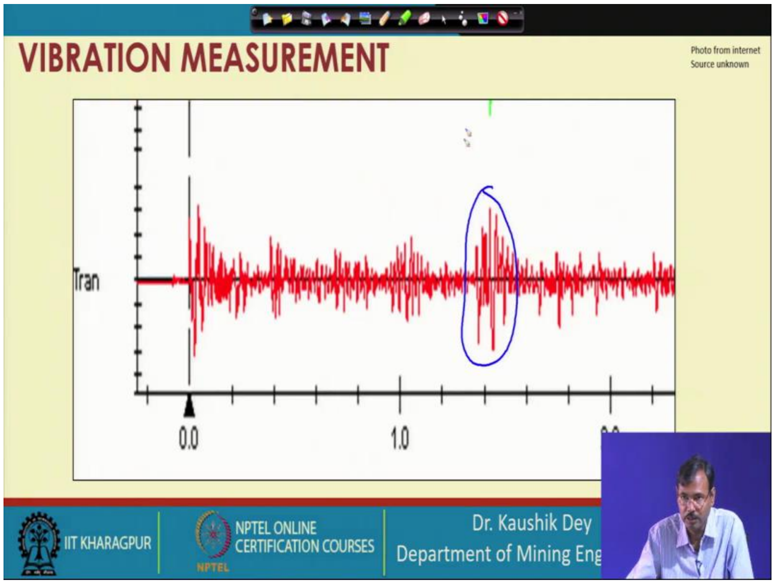

See now I have enlarged this transverse one, and this is, as this is off, let us take the blue color now. You can see when the first blast wave has arrived at this position; there is a sudden jump. So, the moment the first blast wave struck this, it started moving like this. So, this happens. Now, the particle starts moving, oscillating. You can see this is the oscillation. But as the damping is there, it is gradually trying to damp, but you can see from time to time it is again increasing.

So, whenever you have to blast for multiple holes, whenever the first wave has arrived from this, this is the jumping; the second wave is the jumping. So, you can easily identify at what delay is acting at which time in this output of the seismographs. You can then analyze whether your blasting process has been thoroughly executed or if there is some problem that occurred here.

So, you can see there is a certain price at the peak at this position. So, it may occur because in that particular position, probably the burden value was not executed properly. In that case, the excavation, the confinement of that specific hole to excavate was probably high. That could be the reason for generating the high value of ground vibration in this particular area.

Alternatively, there may be possible that there may be phase addition occurs of the wave at that position, and that may generate a higher vibration value at that particular position. So, these are the important parameters that must be considered during the analysis of the seismograph results.

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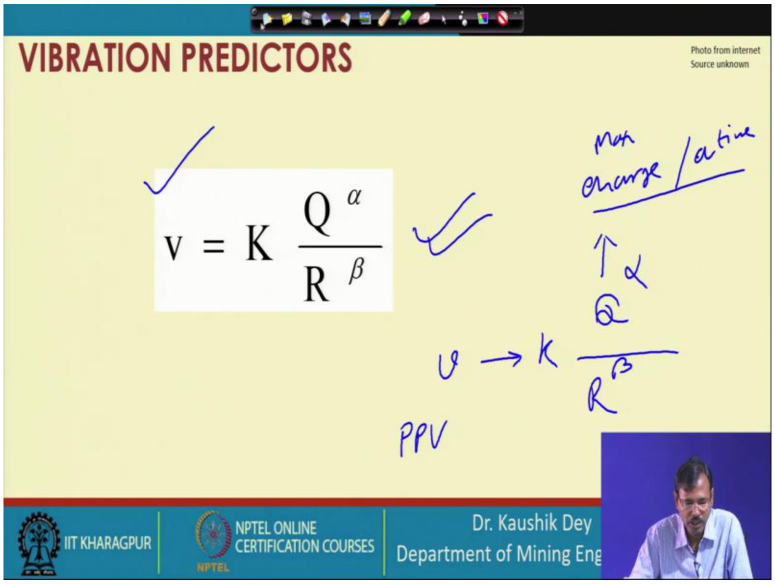

And a predictor equation is basically advised by different mining researchers where v is considered as the peak particle velocity and K is a size constant, Q is the charge quantity detonated, maximum charge quantity detonated at one instance, at one instance that is Q and R is the distance of monitoring from the blast hole. So, if you consider this one, the alpha and beta are the two power constants considered for the propagation of the wave.

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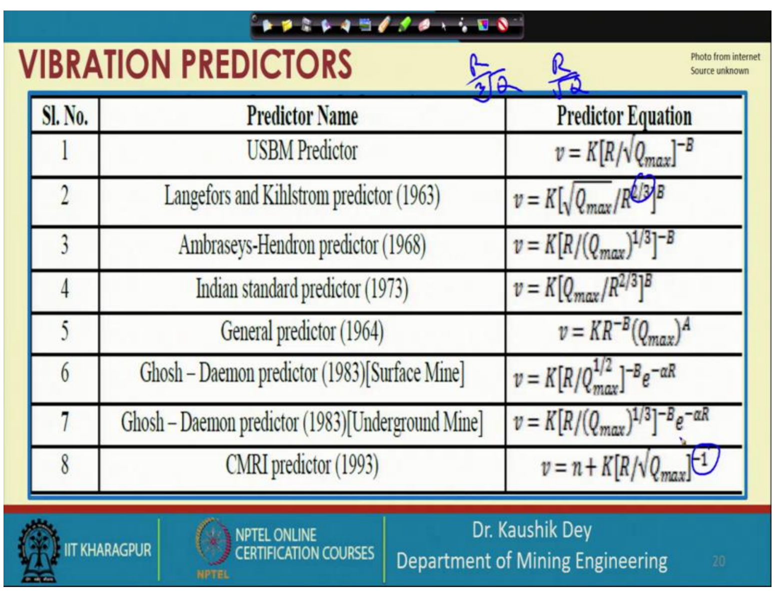
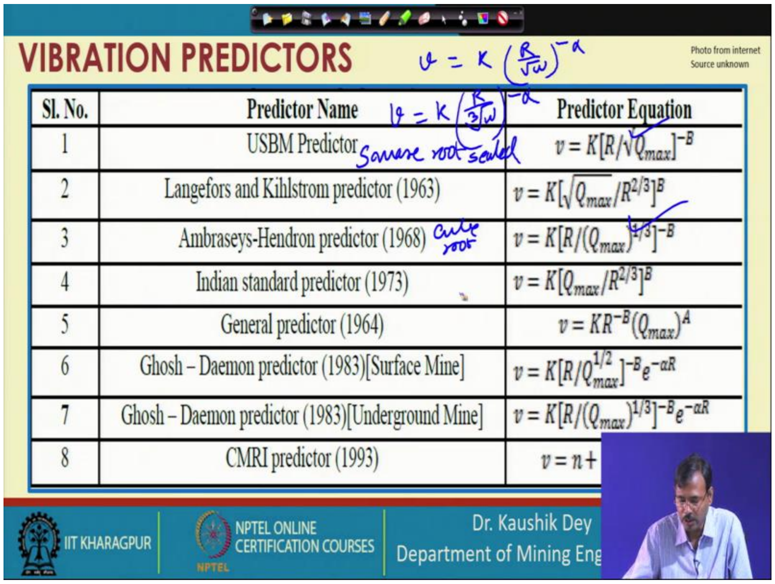
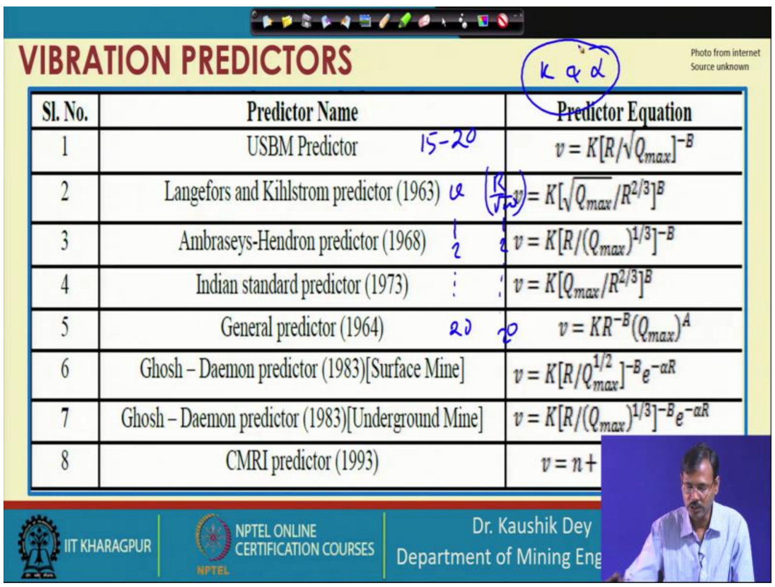


Sl. No.	Predictor Name	Predictor Equation
1	USBM Predictor	$v = K[R/\sqrt{Q_{max}}]^{-B}$
2	Langefors and Kihlstrom predictor (1963)	$v = K[\sqrt{Q_{max}}/R^{3/4}]^{B}$
3	Ambraseys-Hendron predictor (1968)	$v = K[R/(Q_{max})^{1/3}]^{-B}$
4	Indian standard predictor (1973)	$v = K[Q_{max}/R^{2/3}]^{B}$
5	General predictor (1964)	$v = KR^{-B}(Q_{max})^{A}$
6	Ghosh – Daemon predictor (1983)[Surface Mine]	$v = K[R/Q_{max}^{1/2}]^{-B}e^{-\alpha R}$
7	Ghosh – Daemon predictor (1983)[Underground Mine]	$v = K[R/(Q_{max})^{1/3}]^{-B}e^{-\alpha R}$
8	CMRI predictor (1993)	$v = n + K[R/\sqrt{Q_{max}}]^{-1}$





So, there are the generalized equations of the vibration predictor, and different researchers have come out with the different dependencies between R and Q. Sometimes, it is proposed that the dependency is R by Q; sometimes it is R by the cube root of Q, sometimes it is 2 by 3, sometimes it is 1. So, different dependencies are considered.

But in a nutshell, the generalized equation is broadly classified in two ways: either V is considered equal to K into R by root w to the power minus alpha, or it is considered us V is equal to K into R by the cube root of w to the power minus alpha. So, this is two dependencies, one for square root, another for cube root is considered, and in these two cases, this is called square root scaled distance, and this is called cube root scaled distance. So, these are the two most common criteria and two most common predictor equations, in general, followed in mining.

So, that is basically considered. Once this is made statistically, some 10, 15, to 20 datasets are generated for V and R by root w. For this, 10 to 20 datasets are generated, and then a regression analysis is carried out to find out the K and alpha values for this equation. So, once it is established, it is very easy to then, henceforth the predict the ground vibration can be predicted using this R and Q value. So, the Q value is basically depending on the number of holes that are detonated at one instance by providing the delays in the holes.

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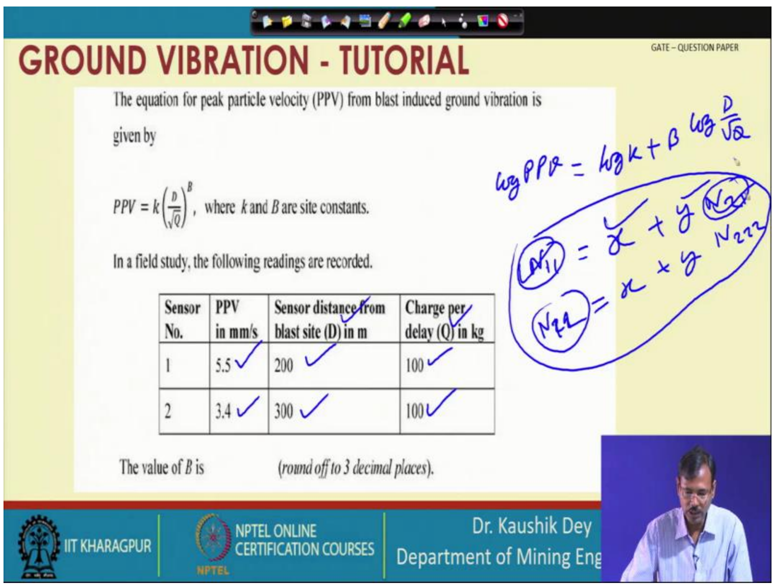

So, one tutorial can be considered that if the PPV values are given that 5.5ld be and 3.4 which are measured at distances D and 200 and 300 for the same maximum charge per delay of 100 kg, then the value of K and beta cou. So, you have to take a log on both sides for this. So, log PPV will become log K plus B into log D by root Q. So; you can find out these values from this and this. So, you will get this is your known value, some numerical value you will get here. This is your first unknown x. This is your second unknown y, and this is also the known value of 2.

So, similarly, you will get into N21 x plus y into N22. So, using this, you can solve how to get the value of N11 and N22. Actually, both are the same, this x and y; you will get the value of x and y using the values of N11, N21, N12, and N22. So, you can easily solve this. So, you can see the solution on the next page.

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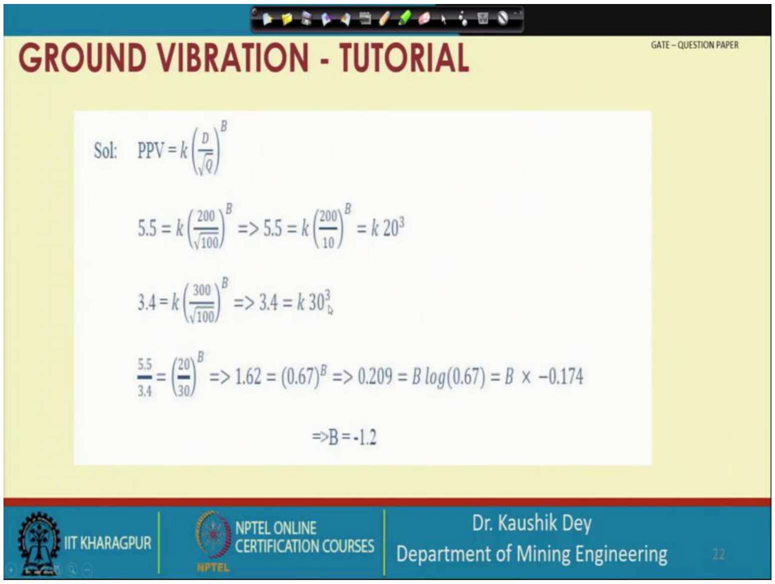

So, you can do this, and from there, you can find this is the value of alpha, and I think the K value is also given somewhere. So, if you get this value, you can also get the K value.

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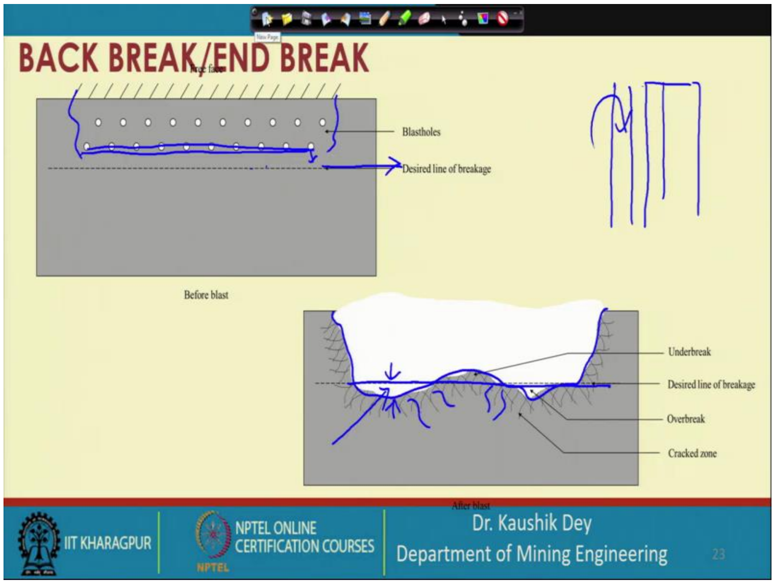

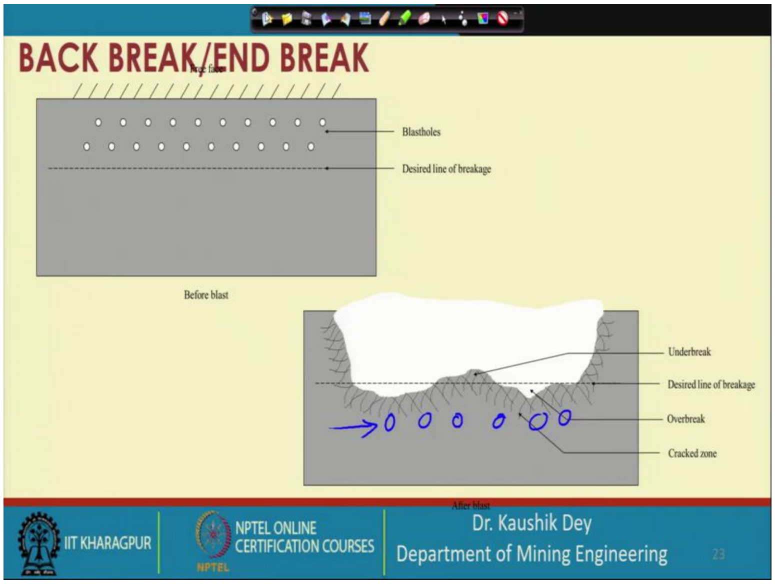

Our last result is basically the back break or end break for which we are interested. Now, let us understand what is called back break. If this is our last line of holes and we are interested in blast this portion of rock mass, we expect some additional breakages, and our final desired line of breakage may be at this position. So, we expect up to this position; for a very bad blast, we can expect up to these.

But if after blasting, we find out this is our desired line of excavation, but we have got the final periphery line like this. This portion of the excavation zone is called over braked, and you can also observe a huge cracked area, which occurs because we know the crushed zone. The blasting creates a crack in this side zone and at the opposite side of the excavation.

So, that is why these are generating cracks beyond this, and these cracks are basically creating problems of the drilling. So, these cracks are, while you will go for carrying out drilling at this position, this will create the problem, so that is unwanted, basically increasing the drilling cycle time.

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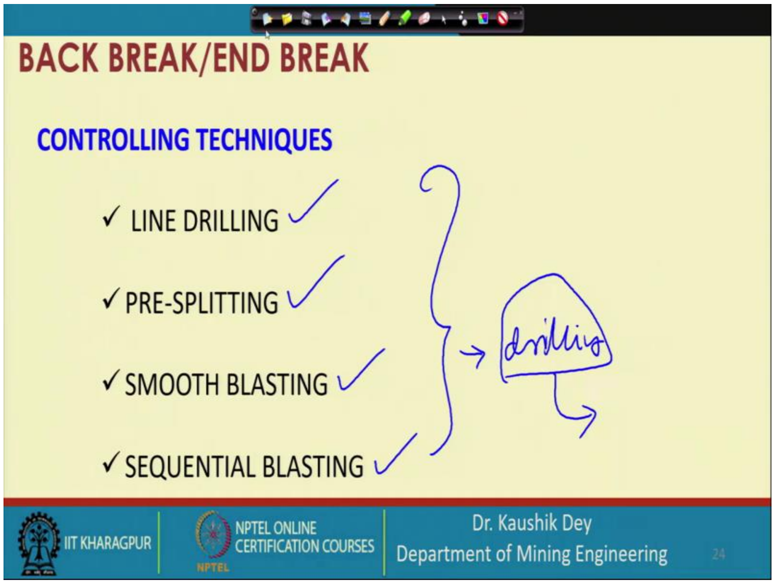

So, to avoid that one, there are a few techniques available. These are the techniques that are available or commonly used line drilling, pre-splitting, smooth blasting, and sand equential blasting, but all these drillings depend on the heavy drilling; these methods depend on heavy drilling requirements, and that is why these are costly and practiced only when it is felt essential. So, this is more or less about the back break and end break. We stop our blast, blasting technology for surface mines at this position. Thank you.