Drilling and Blasting Technology
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Lecture – 36
Blasting results – 4

Let me welcome you to the 36th lecture of Drilling and Blasting Technology course, we are continue with the Blasting result and this is the 4th lecture on the blasting result.

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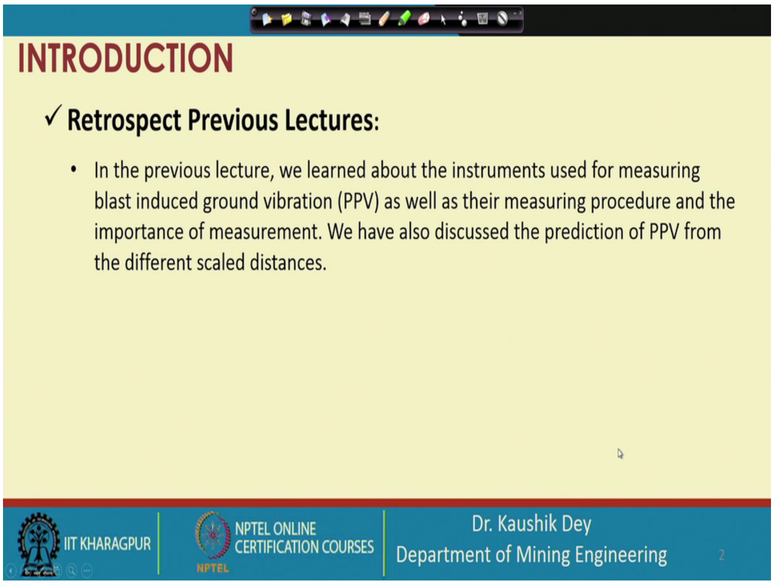

So, like every class let us retrospect what we did in our previous lectures in previous lectures, we have learnt about the different blasting results how that those are those could be evaluated. In particularly last class, we have discussed about the vibration; ground vibration and how the monitoring of the ground vibration maybe carried out. The importance of that ground vibration is also discussed and the how the ground vibration, may be predicted from those measurement earlier measurement of the ground vibrations that is also discussed in the last class.

In this class we will discuss about the side effect of this ground vibration, you can say how this ground vibrations are basically creating damages to the surrounding. It may be the structural damage, it may be the rock damage, but any unwanted damaging effect of the ground vibration. The assessment of that one, the measurement of that one and how to control those damages will be discussed in this class. So, our learning objective is to study on the blast induced damage, measurement techniques of the damage and control blasting techniques to minimize the damage will be discussed in the lecture.

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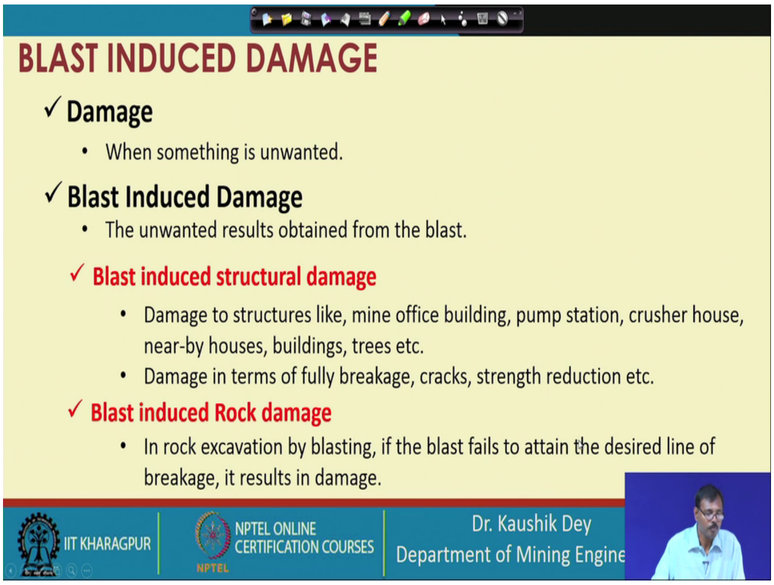

So, what is damage? In fact, the something which is unwanted is called damage, particular referring to the blast induced ground vibration. So, blast induced is damages the unwanted result obtained from the blast is called blast induced damage. It may be the blasting induced structural damage, if because of the ground vibration generated from the blasting are damaging the nearby structures, nearby pumping stations, crusher house, offices, etcetera. That is called blast induced structural damage; it may be complete damages to the structure or maybe some initiation of the cracks in the structure.

Similarly, instead of structure it may be carried out into the surrounding rock mass also. In that case it is called blast induced rock damage, where the rocks are damaged because of the ground vibration and that decrease the stability of the rock.

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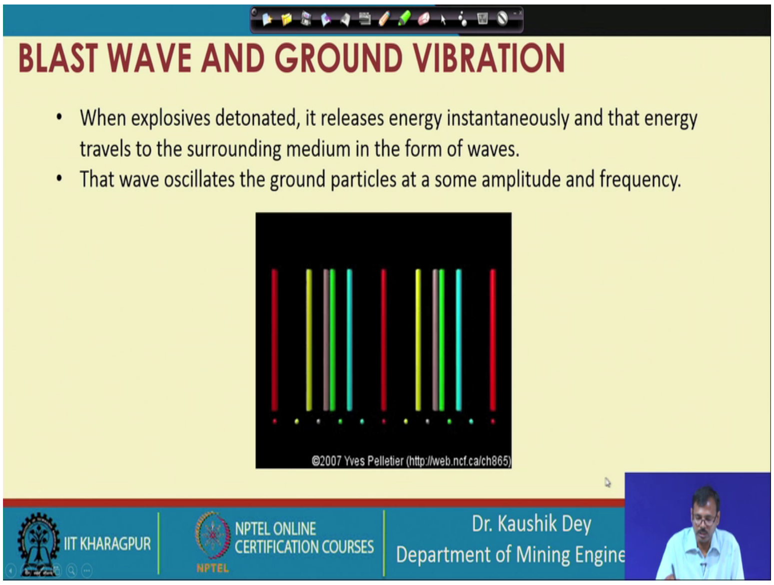

So, basically the blast induced damage is classified in two group; structural damage and rock damage and if you see this video you can understand that, when an explosive is detonated it releases energy instantly in the form of a shock wave and the wave oscillates the ground particle and the because of this ground the particle oscillation strain is generated on the ground. In fact, that strain is basically the major contributor for creating this damage.

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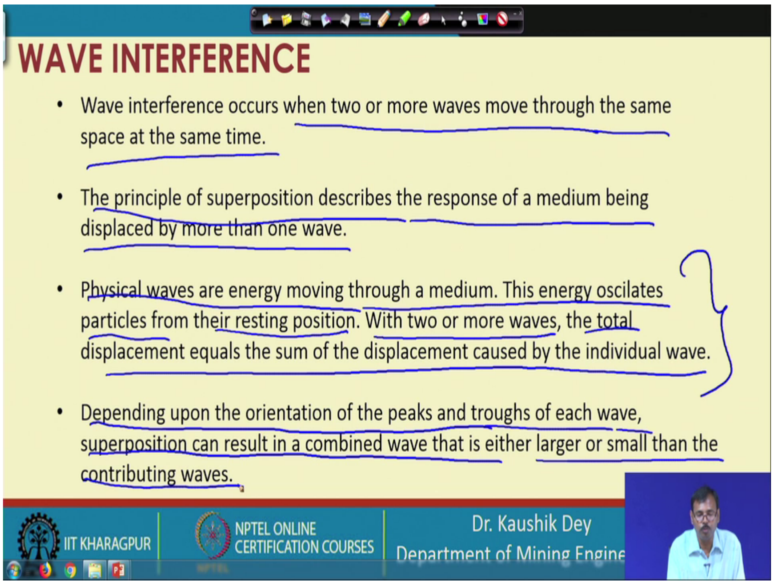

So, let us understand the wave interference because the blasting is not only release of single wave, which is coming out from the explosive. It is an explosive column, which is being blasted through a time apart from that n number of holes are being blasted. So, there are n number of sources of shock wave generation and that is why, there are multiplication of the waves which are coming into the same place. So, when in a particular point the ground vibrations are being monitored that time there are superimposing of waves occurs and this is called interference of the wave.

So wave interference occurs, when two or more waves move through the same space at the same time. The principle of superposition describes the response of a medium, being displaced by more than one wave. Physical wave are energy moving through a medium this energy oscillates particle from their resting position with two or more waves. That total displacement equals the sum of the displacement caused by the individual wave. But there are something that is called phase, the phase is important when two waves are meeting each other.

So, depending upon the orientation of the peaks and troughs, the each wave superposition can result in a combined wave that is either larger or smaller than the contributing wave and that is why this phase addition is an important parameter in the interference.

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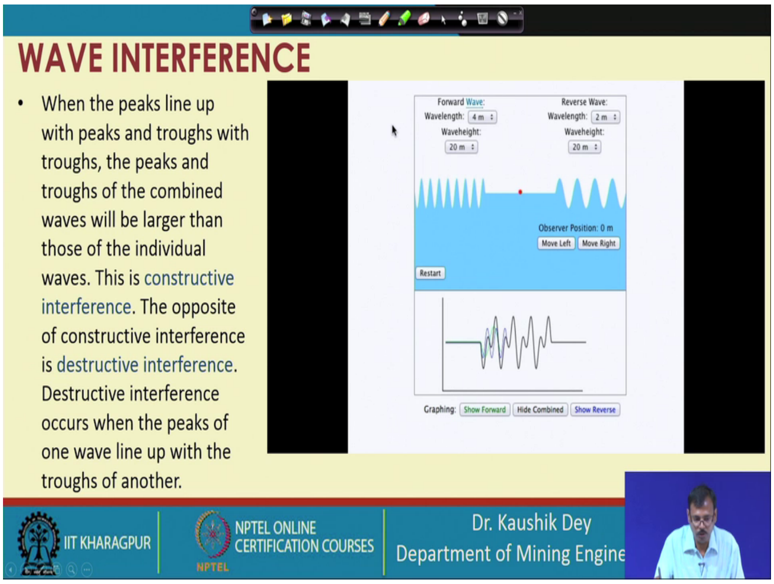

So, you can see the result of addition the result of superimposing of two waves, in this video I want that you must listen this video properly.

A link to the illustration can be found in the various description the illustration expose constructive and destructive interference by observing the movement as two waves pass each other moving in opposite directions, when the page first loads the illustration, shows one stack of waves to the left. The wavelength and waveheight are shown up here, wavelength is 4 meters, waveheight is 20 meters. There is no reverse wave right now, because the waveheight to the right is set to none, all of these settings can be changed with these selecters.

In the middle, is an observer its position is shown a bit lower to the right. The number is related to the centre of the illustration; centre is 0, left is negative and right is positive. The chart at the bottom plots the position of the observer as the wave moves across the screen, three things can be charted. Movement due to the forward wave shown in green, movement due to the reverse wave shown in blue and movement and the actual movement shown in black.

To move the wave click start, when the wave hits the observer the graph begins to show the movement. Since no reverse there is no reverse wave, the movement due to the forward wave and the combined wave are the same. To observe interference we can just create a reverse wave, to begin with we will hide the combined and show pause the reverse and the forward wave.

With these settings these two waves will be in phase, when they meet the observer this will result in constructive interference. By showing just the two waves and then adding the combined, we can see the features of this interaction. Each wave individually is equal to other, because their wavelengths and waveheights are the same and they are in phase. So, the when you show the actual movement, it is constructive interference the actual movement of the observer is greater than the height of the each of the individual waves contributing to the movement. Once the waves moves passes each other, they return to their original size.

By moving the observer 1 meter, which in this case is 1 quarter of the wavelength and not changing anything else. We can demonstrate destructive interference, this destructive interference causes the observer to not move as the two waves pass the spot occupied by the observer, you can see that the waves are completely out of phase, which will results in a net motion of 0 of the observer. This is the two end conditions different patterns can be seen by moving the observer to other positions over by changing the waveheights and wavelengths of each wave.

After take other patterns I would like to call attention to, is the one created when one wave has half the wavelength of the other in this case, the forward wave has a wavelength of 4 meters. The reverse waves wavelength is 2 meters, the observer is positioned in the middle. The combined wave alternates between constructive interference and destructive interference. Those of you familiar with earth science, tidal patterns may recognise this as a semidiurnal tide of trough pattern it is a nice example, if I get complex patterns from wave interactions. Again once the waves pass each other they are no longer interacting and they return to their origin sizes.

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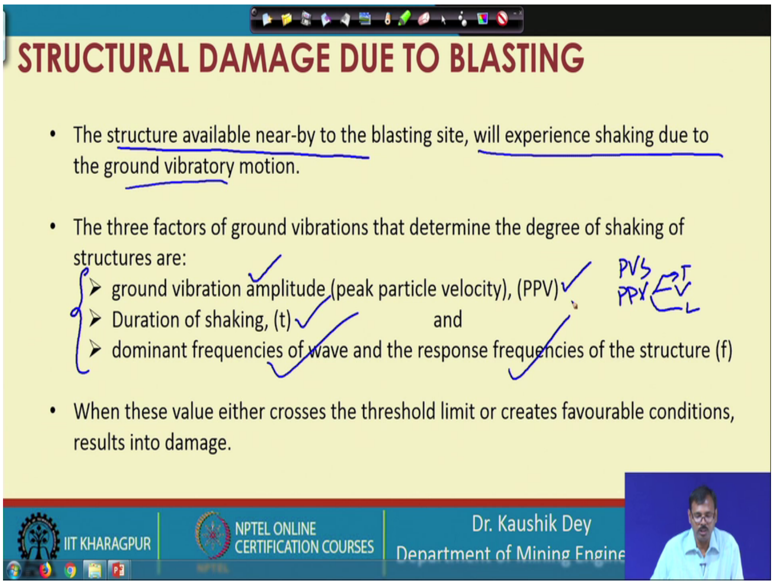

So, I think now it is clear to you about the wave interference. So, let us now discuss about the structural damage, which is carried out due to blast induced ground vibration. The structure available nearby to the blasting site will also experience the ground vibration due to because of blasting and the three factor which are very very important for the damages occurred to the structure because of the ground vibration. The first one is the amplitude, amplitude means as we are measuring the velocity and directly relating the velocity with the damage. So, this is the velocity and it is peak particle velocity again as we have discussed in the previous slides, that it may be a PVS or it may be peak of the peak at any channel of LVT.

So, first is the amplitude is very very important, that is the peak velocity is important then the next one is the duration of vibration for which it is experienced shaking. So, that is very very important, third one is the dominant frequency of the wave and the response frequency of the structure that is also important. In this case, I would like to give you some idea about the earthquake. So, you have I think personally all of you have experienced earthquake maybe sometimes and what is happened earthquake also, the vibration occurs ground vibration occurs which is more or less similar to the blast vibration.

But the difference is that, first is that earthquake which is happened at a very longer distance it carries a high magnitude ground vibration, whose amplitude is high, but not only amplitude is high. The duration of shaking is also very high maybe for 5 second, 6 second, 7 second the shaking occurred in the earthquake.

And as the source of the earthquake is at very very depart part of the earth, when the wave is reaching at the surface that time is frequency is very very low that is why the low frequency waves are coming in the earthquake and unfortunately most of our civil structures having some response frequency, which is also low and that is why resonance occurs that is the basic idea and that is why the damages occurs in the earthquake are so much concerned about.

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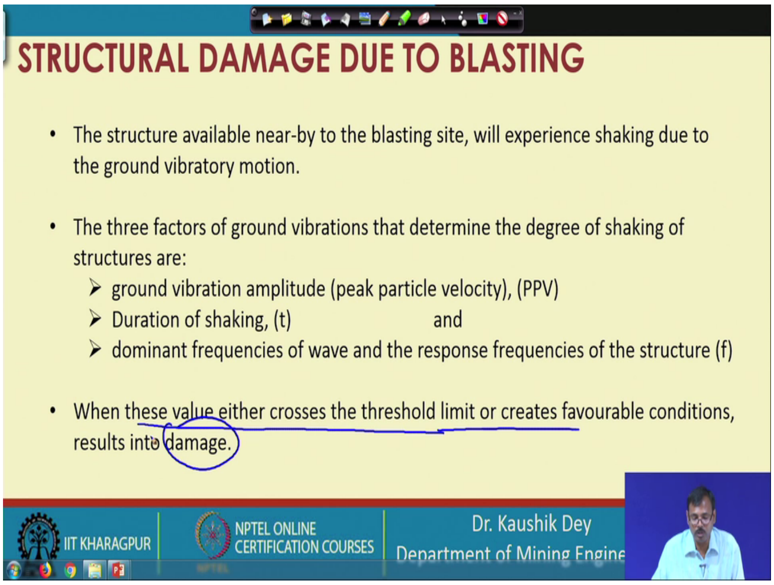

However, in blast vibration most of the cases the amplitude is also high, but not of that much as it is observed in the earthquake and duration of shaking is almost negligible for, if you compare it to earthquake because most of the ground vibration generated from the blasting generally damped within 1 second or 2 second.

And frequency generated by the blasting wave are always high frequency, low frequencies are not that much available in the blast vibration because it is close to the source. So, the threshold values of this one if, it is crosses the step the already given limit then, that may become potential to damage though there is no guarantee that the structure will be damaged because of that one, but it is considered it may be potential to damage if those limits are crossed.

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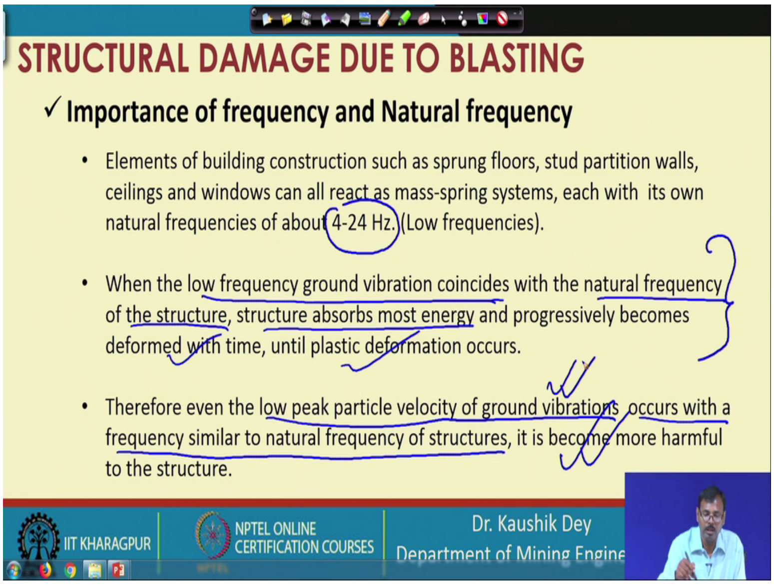

So, natural frequency of the structure is very very important in this case, it has been found that most of the civil structures have this type of natural frequency, which is low most of the cases blast vibration frequencies are more than this and low frequency ground vibrations, if it is coincide with that one with the natural frequency of the structure then the structure will absorb the maximum energy and it may be deformed progressively deformed and plastic deformation may occur.

So, if that is the resonance case and that is why it is better to avoid this type of situation as much as possible therefore, low peak particle velocity of ground vibration occurs with a frequency similar to the natural frequency of the structure. May be very very harmful to the structure if you compare that to high frequency vibration and high amplitude vibration then also, this maybe more dangerous more damaging for that particular case.

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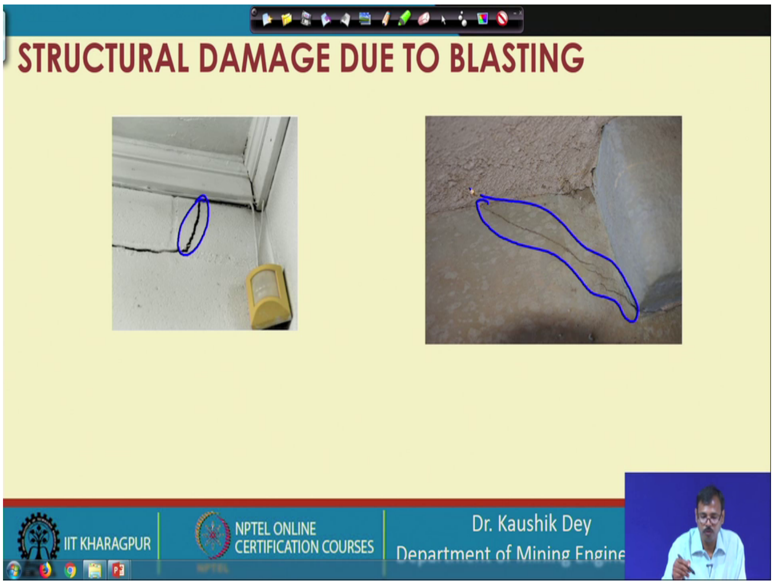

These are some of the pictures, one can see the damages occurred to the nearby structure because of the blasting you can see these are the cracks occur at this position in the roof corner of the roof this is in the floor part.

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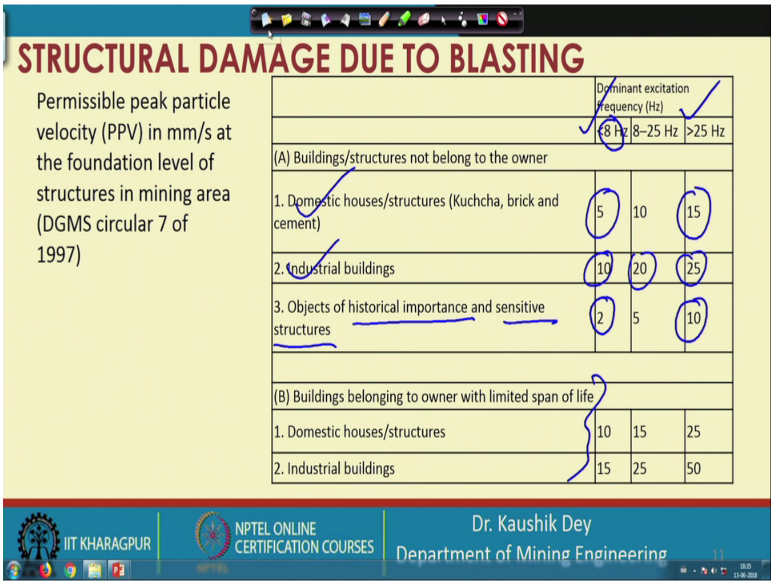

And this is basically DGMS stipulated guideline, which must be followed that the no blast vibration should cross this limit for the domestic houses, where the blast vibration frequencies are less than 8 hertz, the allowable amplitude or the peak particle velocity is 5 millimetre per second for the high frequency, it is 15 millimetre per second for the industrial buildings, which belongs to that owner or etcetera, then it may be little bit relaxed to 10, 20, 25 millimetre per second.

However for the historically important or sensitive structures like petrol pump or hospital or some may be socially important like temple etcetera. This may be further reduced to 2 millimetre per second for a low frequency blast wave and 10 millimetre per second for high frequency blast wave. So, there are some relaxation given to the buildings, which are belongs to owner if that is damaged because of that industrial owner it is belongs to. So, that that is why this relaxation is given for those structures. So, that is why this is DGMS guideline and you can see this guideline specially for this particular historical building is very very tough and that needs to be addressed by redesigning the blasting process.

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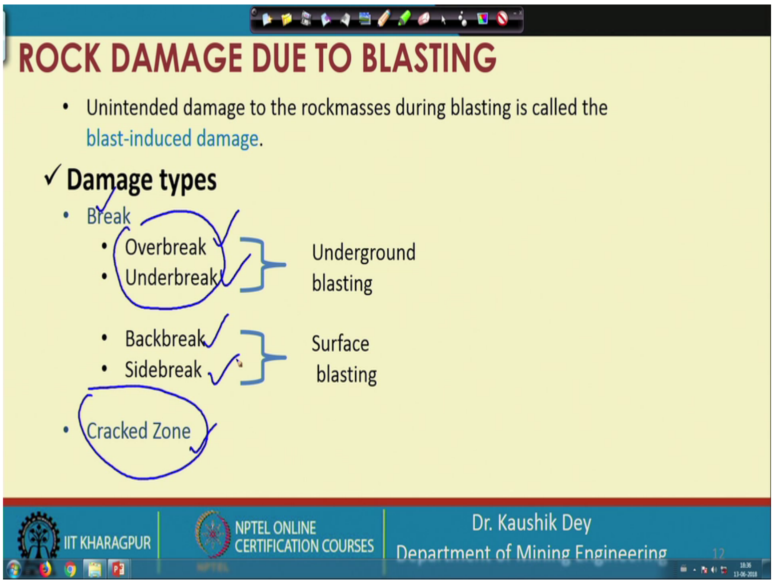

So, this is structural damage for which we are concern, but there is another part of damage which is called rock damage. That is the damage occurs to the rock because of the blasting carried out in the nearby vicinity. So, this damage is also classified in two groups either, it is a breakage or it is a crack. So, if the breakage occurs; that means, it is excavated it is disclosed, it is already the rock are taken out excavated out from the rock mass or it is some cracks are generated in the rock mass, that may also occur. So, the damage may be classified either in break or in crack. If it is break in underground it is called overbreak or underbreak, in surface it is called backbreak or sidebreak.

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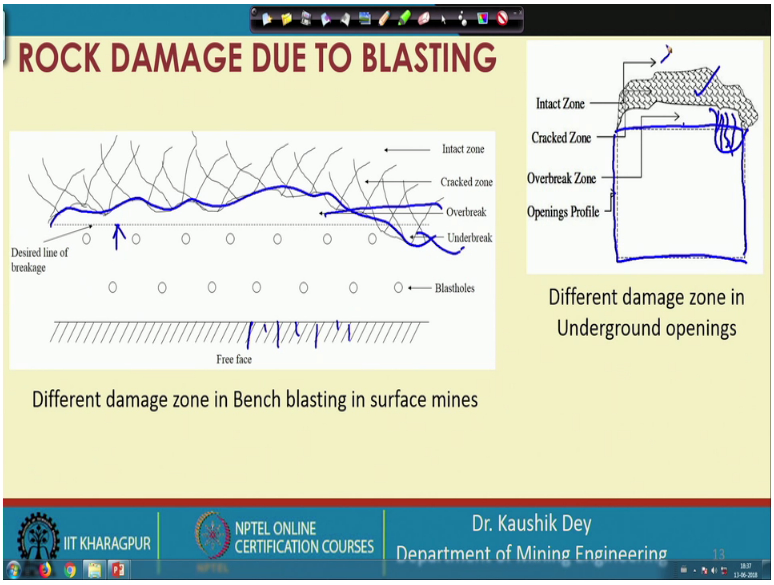

In overbreak and underbreak, it is the over excavation or under excavation condition, backbreak it is the breakage occur in the back sides, sidebreak it is the breakage occur in the sidewise in the surface blasting.

So, this is one good figure for the overbreak underbreak tracked zone can be classified say if this is the free face, if this is considered as the free face and these are the holes and it is desired that that the last line of breakage must be this one, then if our post blast periphery we observe like this, then this part it is called underbreak this blast part it is called overbreak and the crack generated here is called cracked zone then beyond that is the intact zone.

Similarly, if you considering this is the underground opening, where this is supposed to be the designated opening or the designed opening then this is considered overbreak.

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If some part is like this way then it will become the underbreak, this is the cracked part and then the intact zone part. So, this is the more or less pictorial presentation of the classification of the breakages and a cracked portion in surface and underground cases. Here you can see the photographs, where the backbreak and inbreak occurs these are the you can see over excavation part, this is the breakage part which is which can show it is 4 meter and sometimes it is 20 meter also; that means, huge cracked generation occured in the remaining rock mass.

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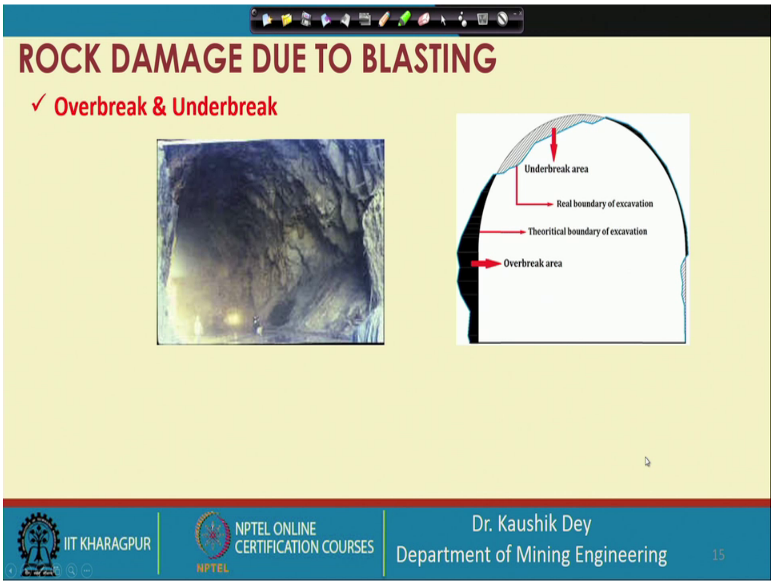

Same thing is there for the underground excavation, you can see the picture of this one. The sidewise over excavation occurs in this particular place and this is the under excavation occur at this particular place, which can be easily observed in this figure.

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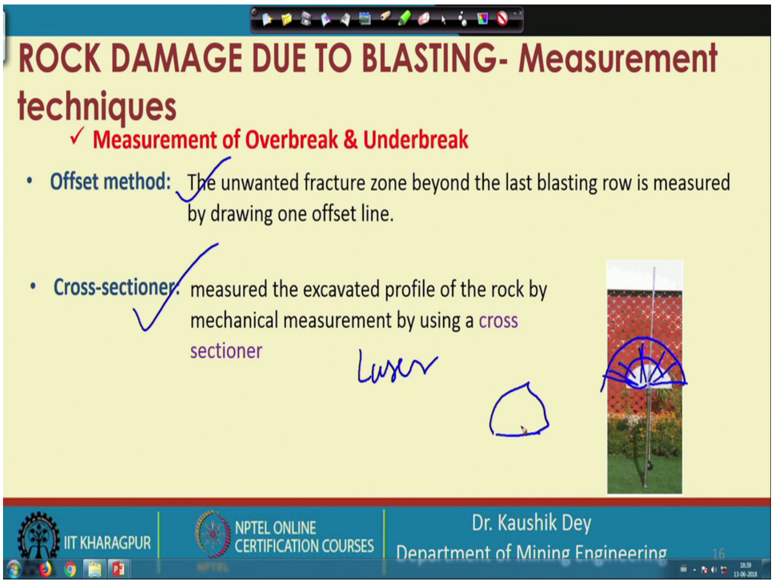

The monitoring system which is in general used for damage monitoring for overbreak and underbreak, which is basically excavation generally surveying methods are used either by using surveying with total station by taking the offsets or using a cross sectioner, where this type of material is used which takes the offset at different angles and by plotting those offset of from different angles finally, the plots can be made like this. Same thing is possible with the laser also, where the laser, laser rotates like this and the distance observed by the laser is directly taken into the memory device and that can be plotted to ultimately find out the periphery and from which the area can be detected very easily.

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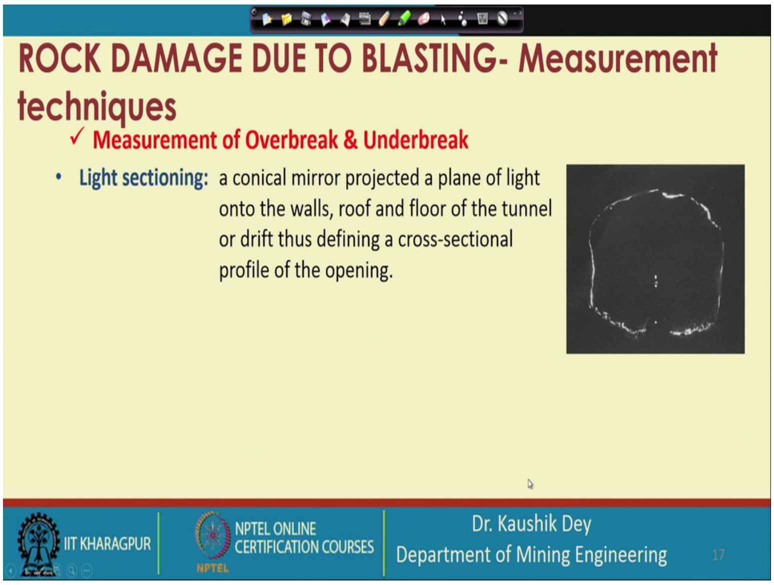

So, cross sectioner maybe a mechanized one may be a laser based one and this is the light sectioning method, where the complete section complete profile of the underground opening can be taken by light sectioning method and directly the area can be computed in this case.

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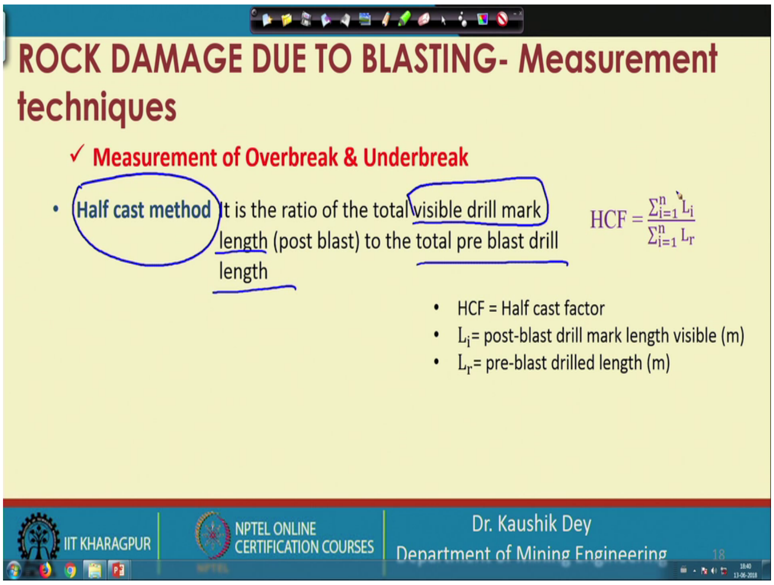

There are some indirect method of measurement of damage specially, which is carried out in the surface and underground. One is half cast factor, where half cast is basically the visible drill mark length divided by the total pre blast drill length.

So, if you were see the post blast wall then, we measure the visible drill mark on that wall, the summation of that visible drill mark if that is divided by the total drilling length will give us the half cast factor which is basically an indirect measure of over excavation measurement.

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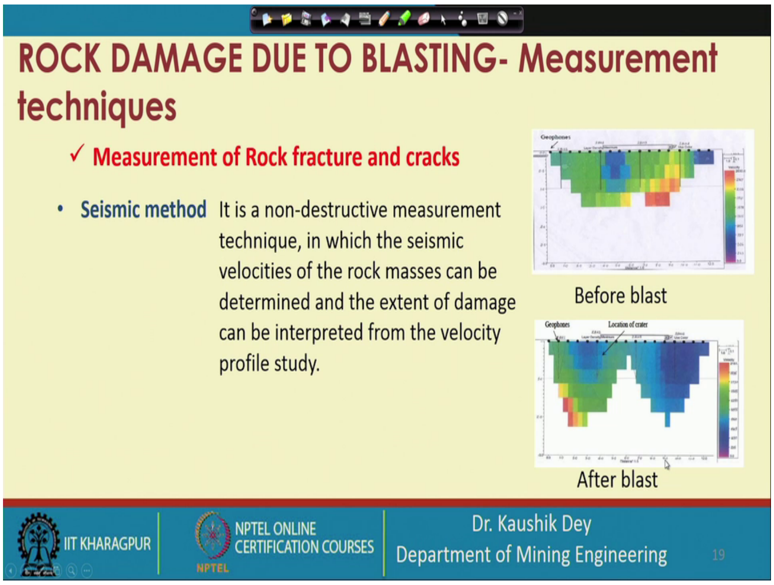

However, this over excavation measurements are applicable for the overbreak and underbreak only, but for the cracked zone there are basically two tools commonly used, one is seismic methods where seismic profiling of the pre blast and post blast is carried out and if it is observed that the seismic velocity of the rock is decreased significantly that is considered there are cracks are generated in to the remaining rock mass. So, it can be considered like that.

So, similarly there are other methods where bore hole gas pressures are carried out measurement of the gas pressures are carried out to understand, whether cracks are generated, but that is not that much popular.

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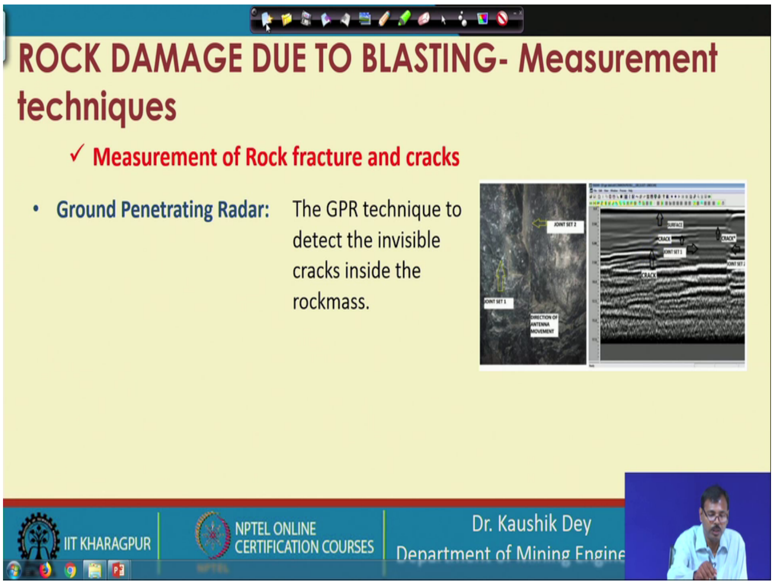

After seismic use of the seismic method, the next method which is popular is ground penetrating radar. The benefit of ground penetrating radar is that the ground penetrating radar not only a search out the occurrence of the cracks or not, it also find out the position of the crack, it also find out the position of the crack, where the crack is existing and how much what is the extent of the crack is also available there.

So, that is why this position where cracks are there may be easily identified by the ground penetrating radar using a suitable type of radar.

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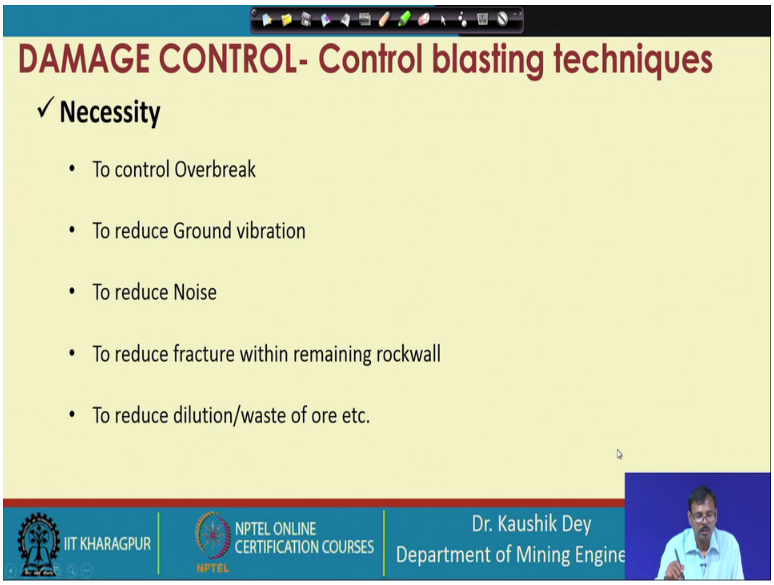

But this overbreak, underbreak and the cracking of the remaining rock mass is totally unwanted. If you are considering the underground excavation case, if over excavation occurs then the during the concreting of that lining a additional quantity of concrete is required. If cracking occurred in the remaining rock masses in the underground then, additional supporting system like roof bolting etcetera is required because the rock strength will be decreased.

Further to that in some cases it may be required the grouting may be carried out for reinstating the strength into the rock, which may be very very costly that is why the damage control is very very essential in the underground also similarly, in surface also it is often required where the side walls slopes needs to be a monitored or needs to be returned for a longer life in those cases all those damaging towards the wall must be controlled significantly and that is why this damage control is an very very important requirement, while the blasting is carried out as the excavation technique.

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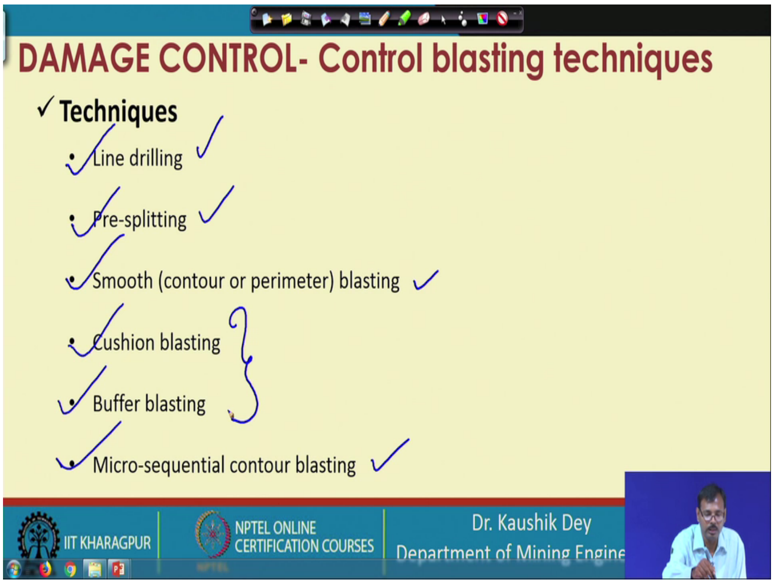

So, there are some modified blast designs possible for controlling the damages in the remaining rock mass and those designing techniques are called control blasting technique. This control blasting techniques are classified in a number way, the line drilling, pre splitting, smooth blasting, cushion blasting, buffer blasting, micro sequential control blasting among these lines drilling, pre splitting, smooth blasting and micro sequential control blastings are very very popular these two are more or less similar to the smooth blasting or you can say it is a modification or modified or special type of smooth blasting technique.

So, in this lecture we will discuss line drilling, pre splitting, smooth blasting and micro sequential blasting in some remaining slides.

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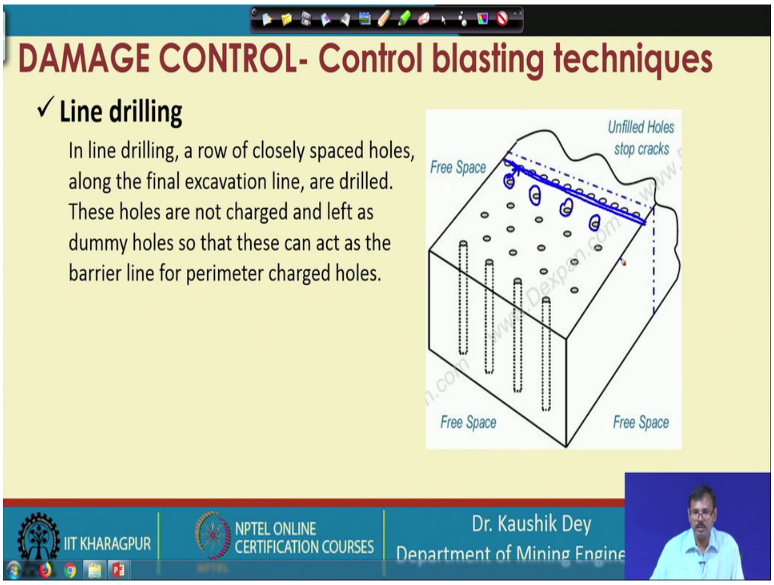

What is line drilling? In line drilling basically we keep a row of closely spaced hole, we keep a row of closely spaced hole in the final excavation line and this hole are not charged. So, the charged holes or explosive laden holes are placed at this position and a closely spaced holes are drilled, a closely spaced holes are drilled in the final excavation line so, that the excavation will be arrested at this position. So, in line drilling a row of drilled hole are placed as a curtain to the excavation or as a curtain to the propagation of the wave generated from the blasting.

So, this method is called line drilling, this line drilling efficiency is very very high; however, because of dealing of a number of holes it may be often costly.

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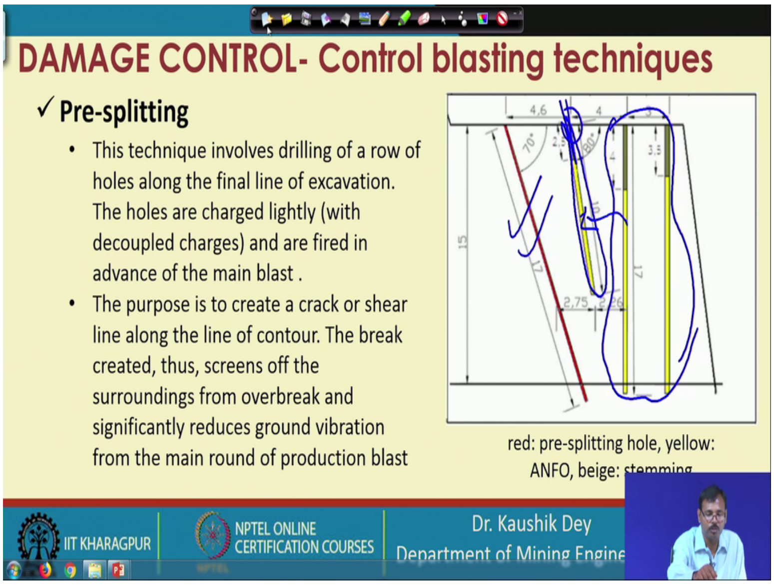

After seismic use of the seismic method, pre splitting is another type of control blasting techniques, where a closely spaced holes are placed a closely spaced holes are placed just like a line drilling in the final boundary area and this closely spaced holes are charged lightly and blasted ahead of the main blasted blasting rock blasting holes. So by blasting, this closely spaced holes there is a breakage line created in the final periphery line. So, that any ground vibration generated from these or blasting waves generated from this, will not pass this already broken area. So, the remaining rock mass will remain not unaffected from this blasting wave.

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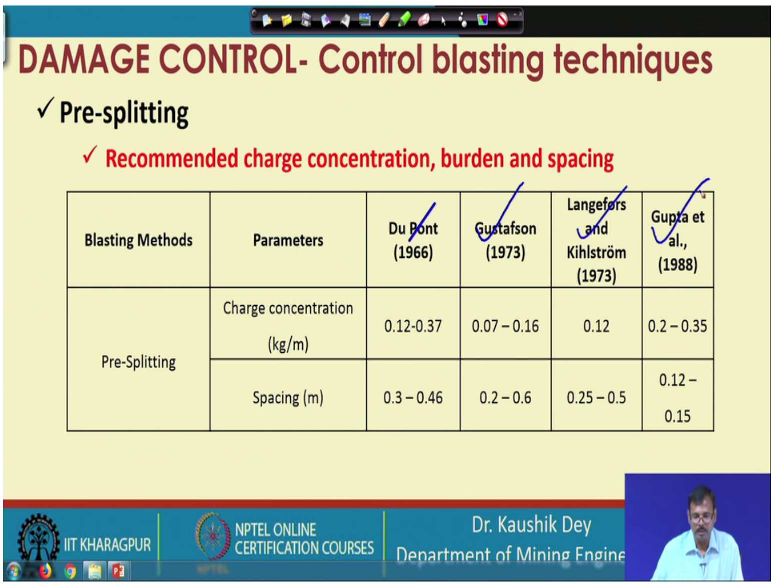

So, that is the basic principle of the pre splitting. The design guidelines of the pre splitting as given by the Du point, Gustafson, Langefors, Kihlstrom, Gupta et al are given in this slide, these are more or less similar by given by the all the researchers. So, you can see the spacings are very very less this if you are comparing and this is the charge concentration, which are also very very less for most of the cases.

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Smooth blasting is just reverse or of the pre splitting, where pre splitting the blast row that is the periphery row where closely spaced holes are made are blasted ahead of the main blasting area, but in smooth blasting main blasting is carried out then the last row is being blasted, where closely spaced holes are charged very very lightly with decoupled charged and that are blasted at the end. So, that that damage maybe controlled beyond the periphery line.

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So, that is why smooth blasting is just reverse of the pre splitting and the smooth blasting. Guideline may be as follows as given by the Du pont, Gustafson, Langefors, Kihlstrom and Gupta et al and you can see the spacings are less, because it is closely spaced and the charges are very very lesser. So, that is why the difference between pre splitting and smooth blasting is mainly that the pre splitting is blasting is carried out of the last row first, but in smooth blasting it is carried out as usual way at the last.

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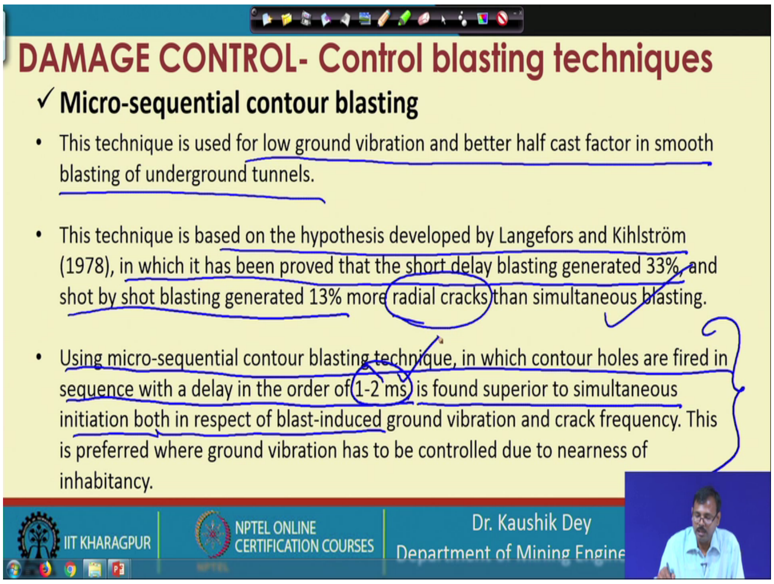

A micro sequential is a special type of blasting, which is basically proposed by Langefors Kihlstrom and later on practiced by professor Rustin, this technique is used for low ground vibration and better half cast factor in smooth blasting of underground tunnels. This technique is based on the hypothesis developed by Langefors Kihlstrom on his experience on the Plexiglass, it has been proved that the short delay blasting generate 33 percent and shot by shot blasting generates 13 percent more radial cracks than the simultaneous blasting.

So, Langefors Kihlstrom experimented in Plexiglass with this type of delay system and in micro sequential blasting. It has been found that if the control holes are fires in a sequence with a delay in order of 1 to 2 millisecond using electronic detonator, which is now possible is found superior to simultaneous blasting, where it is blasted in a same time in respect of blast induced ground vibration and crack frequency.

So, with the invent of electronic detonator which allows to give 1 to 2 millisecond delay, that gives better result over simultaneous blasting of the holes and then the radial cracks generates are much lesser in case of this case and that is why the damages to the remaining rock mass may be controlled using this micro sequential control blasting.

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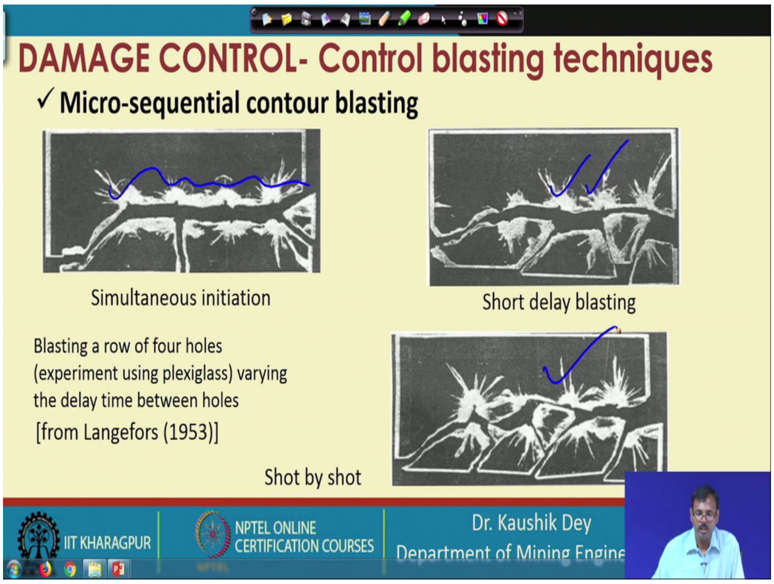

So, you can see this is the plexiglass experiment carried out by Langefors Kihlstrom and you can see this is the simultaneous shot giving very very less damages to the remaining plexiglass. This is short delay which creates damages and shot by shot gives damages, which is very very significant as compared to the simultaneous blasting.

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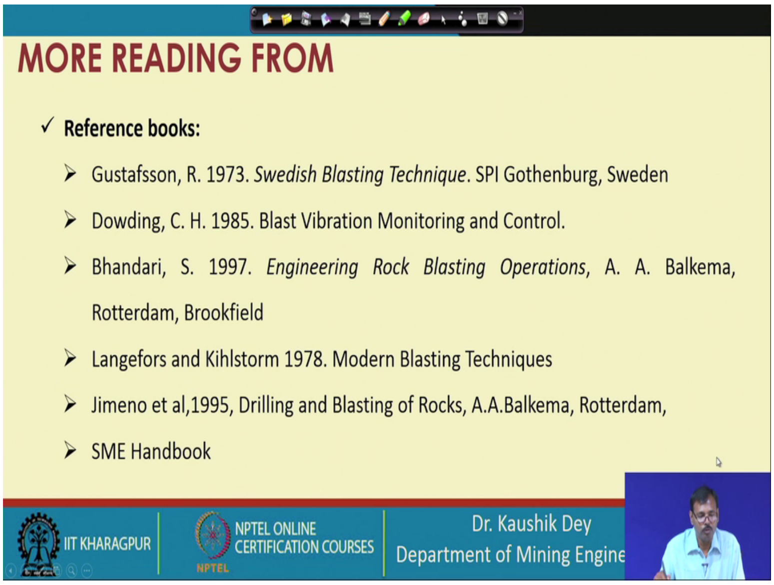

So, this is more or less about the rock damage, you can go for further reading from these are the books from where you can go for the further reading and more or less our discussion on the course is also finish at this point. We will practice some of the problems in the remaining classes so that you can have a good understanding of the subject.

Thank you.