Drilling and Blasting Technology
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Lecture – 25
Basics of blasting-2

Let me welcome all of you to the 25th lecture of Drilling and Blasting Technology course. And in this course, we are basically continue our previous lecture in 24th lecture, where we have started the Basic of blasting and we will continue this.

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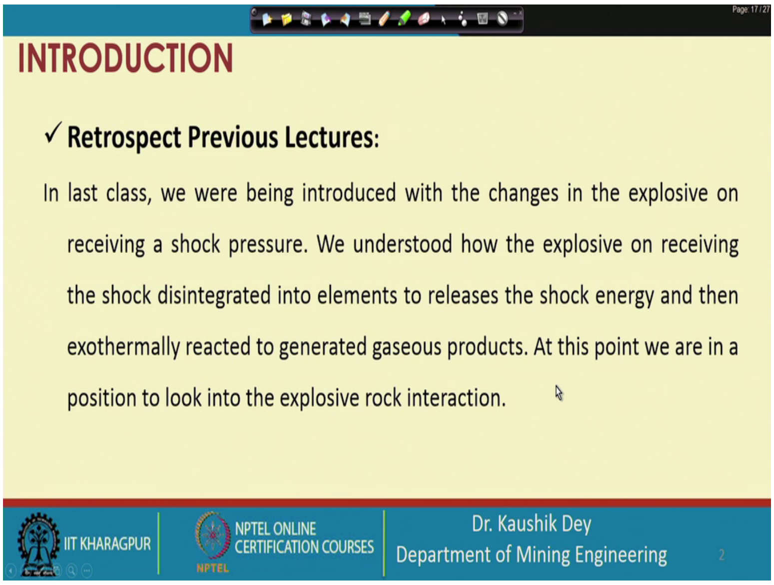

So, let us retrospect what we have covered in the last class. In last class, we were introduced with the changes in the explosive on receiving the shock pressure. We understood the moment we give a shock pressure for detonating an explosive. The explosive will first immediately disintegrate into the elements and on this disintegration the shock, further shock will be released from the explosive and this shock starts traveling all the direction in a form of wave.

And the elements take some little more time to rejoin them self to produce the gaseous product. So, that is why there is basically a time gap between the release of shock from the explosive and release of gas to complete the reaction explosive reaction. So, there is a time gap between these two and we utilize these phenomena for fragmenting our rock.

So, basically we will understand in this class, how that is being used for fragmenting the rock. So, let us continue with today's lecture.

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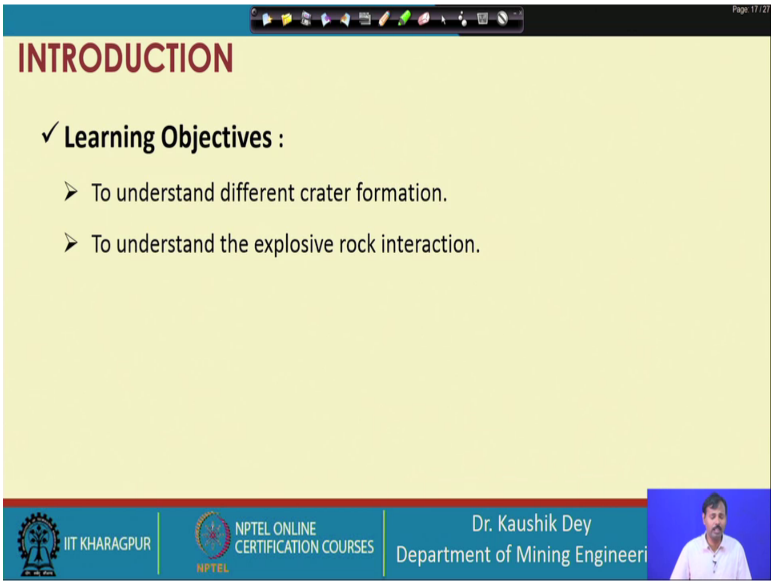

So, our today's learning objective is to understand different crater formation. So, we will understand what is called a crater and how it is formed?

And then, we will understand how, what will be the explosive and rock interaction why we go for blasting the rock on benching method?

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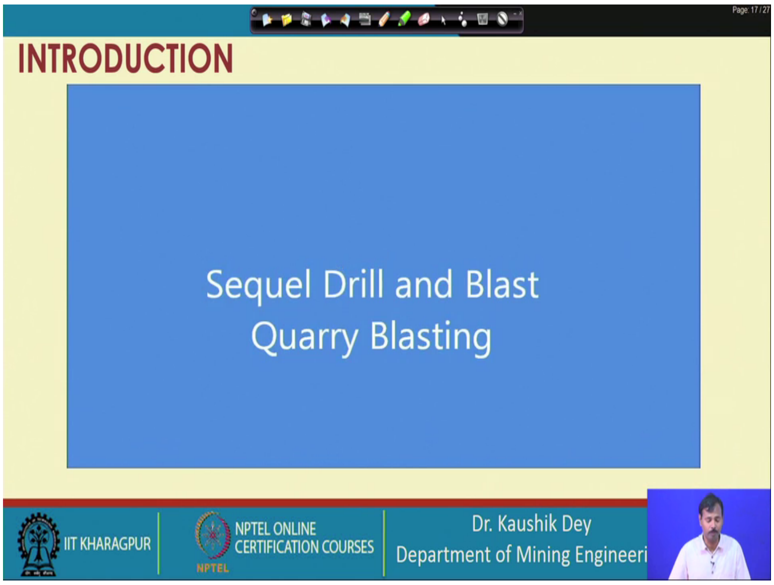

But as usual let us go for observing a video first in which we can see different blasting. So, as this videos are available in the YouTube, you can see this video n number of times.

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You can see the initiation on the bench mouth of the holes first; you can see those initiation first and then, the gaseous product will produce. So, first you can see if you see the blasting you see the blasting, the initiation with the see the initiation is first; then, the gas is produced and then, the fragmentation occurs.

So, basically you can see the gases are produced at a later stage. You can see the is propagated ahead of the gas, then the gases are coming out fragmenting is carried out later on and throw of the rock is being carried out because of the gaseous products. So, this is basically if you are observing n number of videos.

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You will find out in all those videos the shocks are generated ahead; as the shocks are you can see the shocks first. Then the gases are produced, then the rock are rock is thrown in the front direction. So, this all are benches; in all these benches explosive explosion is carried out through the explosives, where the explosives are placed in a inside the rock mass through a hole and then, the explosives are detonated and shock pressure is released and by this way we are fragmenting the rock.

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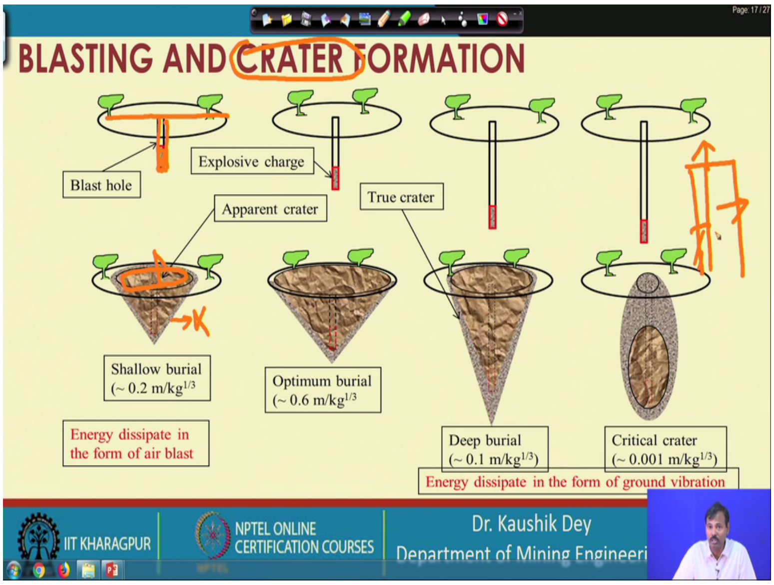

So, first let us understand what is called a Crater. So, this experimentation carried out at very very early stage. The objective was that what will happen, if we initiate some explosive inside the earth crust or inside the rock mass. So, say this is the surface and what we did? We did a we have drilled a hole and we insert some quantity of explosive, then we blast it and it will fragment the rock surrounding it. So, this is the fragmented rock. So, initially it is largely fragmented, there are little bit damages in the periphery and after that there is no damage zero damage and this portion of rocks will be thrown in the upward direction.

So, this is the common phenomena occur when on a simple ground on a plane ground, we drilled a hole, place some explosive inside the hole. But what will happen if we are increasing the depth of the whole keeping the charge same? So, this experimentation is carried out at the very early stages to understand, how the explosive is damaging the rock and how its effects are there? So, what is a Crater? The term Crater is basically the moment; we insert an explosive inside the ground without a free face except the surface 1, without any other preface not like a bench not like a bench; where, there is a free face in the upward direction that is the surface and another additional free face in the front direction.

So, in that bench condition we are adding 2 free faces; but in this case, we are having a single free face. This is the single free face, we are having and in those cases the damages occur is called Crater. So, basically this is single free face blasting, where the explosive is inserted into the hole and it is allowed to damage its surrounding; it is allowed to damage its surrounding rock mass and the experimentation was carried out like this way; Shallow burial, Optimum burial, Deep burial. So, what we did? We insert the explosive in a hole carried out blast; then, we increase the drilling length. Increase the drilling length, carried out the blast; further increase the drilling length, carried out the blast.

So, basically the same quantity of explosive is allowed to be blasted placing it at a deeper and deeper position. So, what will happen? We place the explosive at a shallow depth and observe, what is the volume?

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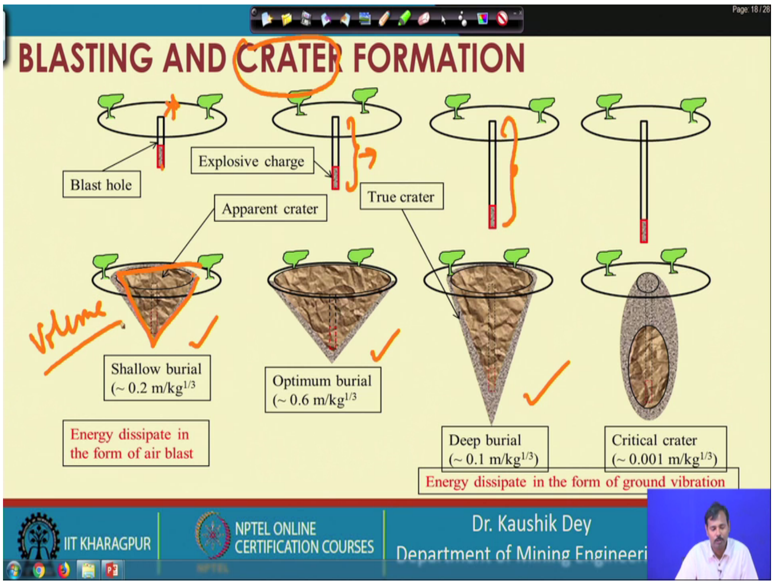

What is the volume of Crater? So, basically we are trying to optimize the use of explosive so that the quantity of explosive remains same and we are increasing the depth and by that way you are observing, if we place that much quantity of explosive; then, where we are able to get the maximum volume of crater that means, maximum fragmented rock mass.

So, the maximum fragmented rock mass representing represented by the maximum crater. So, the maximum crater is formed at what depth? So, you can see in the Shallow depth. In the shallow depth we have observed some crater. Then we have observed a maximum crater; maximum crater at a certain depth and if we are increasing if we are increasing further the depth, then the crater volume is reduced crater volume is reduced; so that means, we are going to the over optimum position. And finally, there will a will be a position where we will find out the surface impression of the crater is negligible or almost zero.

So, this crater where we are getting the maximum crater in this condition the depth of burial is called as the Optimum burial. So, the depth of burial at which we are getting the maximum crater is called the Optimum burial and depth of burial where we are not getting any crater that is called Critical crater. So, basically Critical crater is the depth at which the image impression of the explosion inside the ground is not observable from the surface. So, there is no surface impression of the explosion. So, that is why this is called Critical crater. But our objective is that always we should understand what is the Optimum crater because that is giving us the maximum energy utilization.

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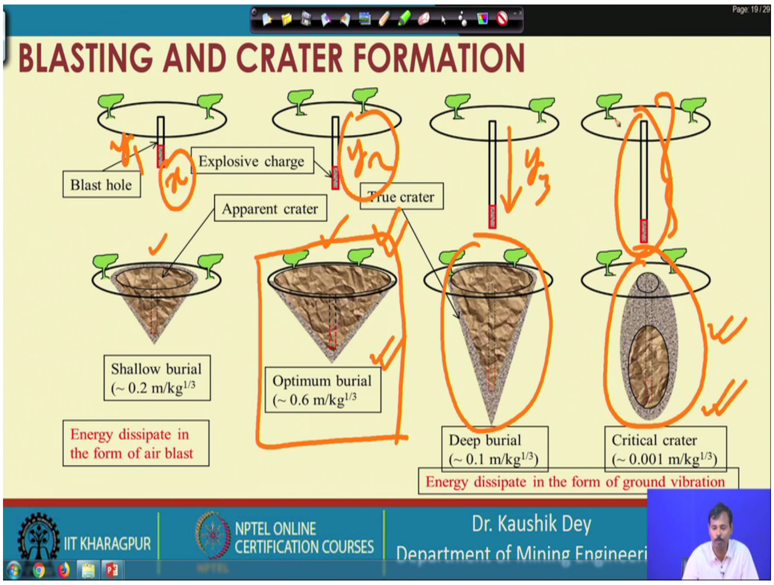

So, suppose this is x amount of x kg's of explosive placed at a depth of y 1. This is giving us the Shallow burial condition, where we are getting some crater volume which is not which is less than the Optimal burial. Then, we are getting y 2, this is y 3 and comparing y 1, y 2, y 3 burial, we are found that the maximum we are observing at y 2. So, this is the Optimum burial. So, this is the optimum depth of crater and depth of burial and in which we are getting the optimum crater. This is again reducing. Further this is the Critical depth of burial where there is zero impression.

So, this is very very important because we understand the explosive energy utilization on the rock. Basically this explosive utilization on the rock depends on a number of factors. The important factors are that we have already discussed the explosive properties. The important factor is that we utilize the shock energy, we utilize the gas energy; but whenever we are considering the about the crater because the throwing is not important in this case. So, crater is basically the energy utilization of the shock energy.

So, how much shock energy generated by the explosive is may be something; but the how much of that from the generated energy is transferred to the rock for its meaningful fragmentation is very very important and that idea can be obtained from the crater blasting.

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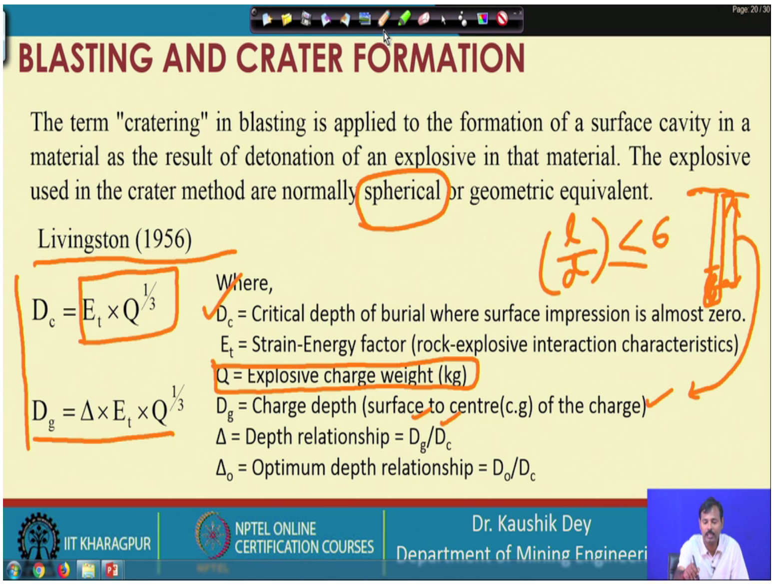

And a number of researches has been carried out experimentation on this Livingston 1956 as I have told also you earlier that this is very very important. Livingston 1956 has generated some equations related to this. So, "cratering" is the term in blasting is applied to the formation of the surface cavity in an material as the result of detonation of an explosive in that material.

The explosive used in the crater method are normally spherical and or geometrical equivalent. So, the first condition of the crater experimentation is that it must be a spherical charge. In this context, let me explain you what is spherical charge? A spherical charge is consider, where the l by d ratio is less than equal to 6; that means, the charge length, which are being utilized for the crater experiment if that length is less than the 6 times of the diameter, then the charge is considered as the spherical charge.

So, crater blasting, it is always wanted the charge must be a spherical charge otherwise the Livingston theory may not be applicable. So, this spherical charge are utilized and Livingston has formed that the critical crater depth; the critical depth of burial D c can be considered as this equation can be estimated as this equation, where it is the strain energy factor that is the rock explosive interaction characteristics and Q is the explosive charge quantity expressed in kg.

And the depth of charge can be relate with the crater volume and that can be obtained using this equation; where D g is the charge depth surface to the centre of the charge ok;

that means, if this is the surface and up to this is charge is placed. Then, this is the centre and this is the surface. So, surface to the centre this depth is called D g. Depth relationship D g by D c is the ratio of D g with the critical depth and delta 0 is basically showing is the optimum depth. By this experimentation, we can achieve if we know the D 0; then, we can know the optimum depth relationship delta 0 by D 0 by D c.

So, these equations can be utilized for understanding the importance understanding of the importance of the explosive rock explosive interaction.

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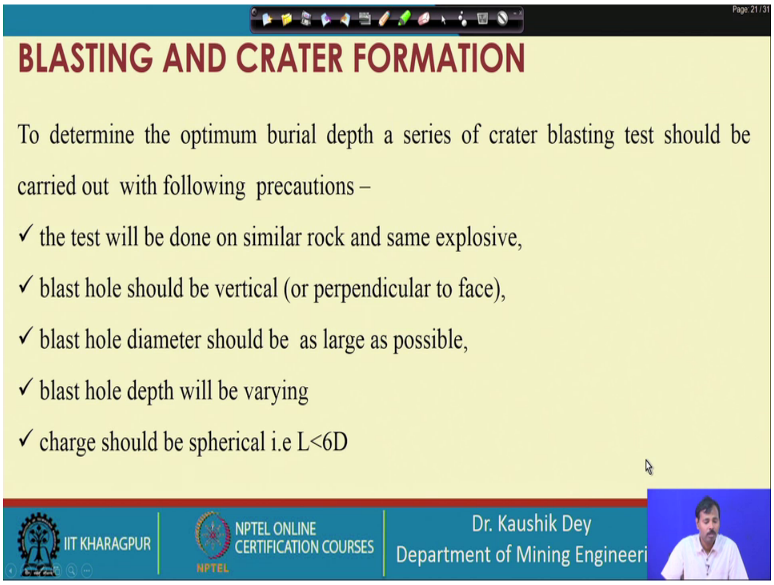

So, to determine the optimum burial depth, a series of crater blasting test should be carried out with the following precautions. The test will be done on similar rock or and same explosive must be used because we want to know the explossive rock explosive interaction between 2 thing; one explosive and one rock. So, that that is why the experimentation must be carried out on the similar rock. May, it is better to use on the same bench and we should not change the explosive during our experimentation.

Blast holes must be vertical so that it should be perpendicular to the surface. Blast hole diameter should be as large as possible which is utilizable for our purpose because there is a constant of the critical diameter also. So, we should overcome that one not only that our l by d ratio will give us the optimization of the charge length also and hole depth should we should vary and charge must be a spherical one.

So, in the other way, we can carry out this experimentation like this way we can keep the charge length same, we can vary the explosive we can keep the depth of burial same; but we can change the charge quantity that will also give us similar effect to that.

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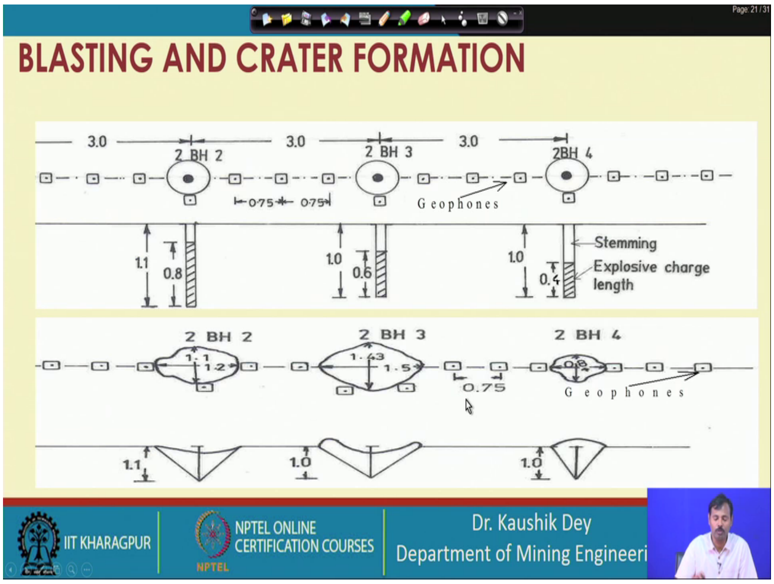

In fact, I am now presenting you one such that type of experimentation, when 1 meter hole depths or depth of holes are kept 1 meter and varying charges 0.6 kg, 0.8 kg and 0.4 kg charges are used.

And to have found the different crater volumes are observed obtained.

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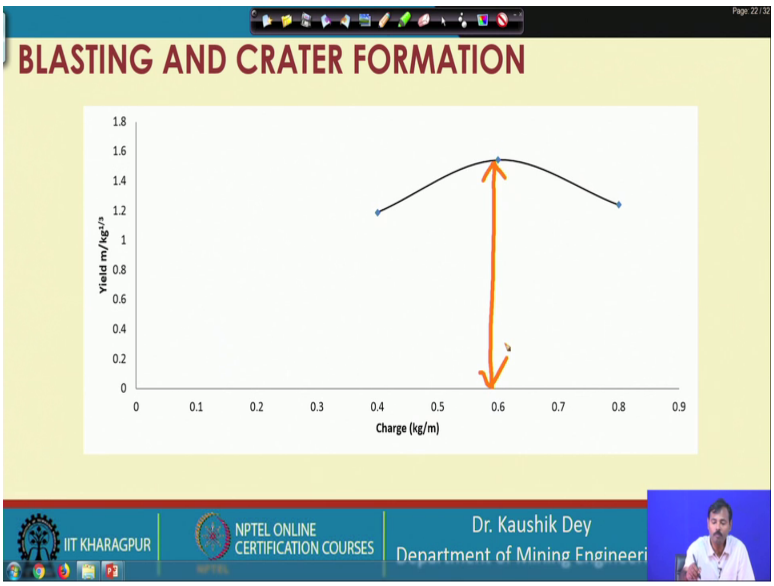

And from there we are able to identify the, we are able to identify the optimum one. So, that can give us that middle one that is the 0.6 kg was building the better crater than the 0.8 kg and 0.4 kg. So, probably the 0.6 kg is a better option for this type of Explosive-Rock Interaction.

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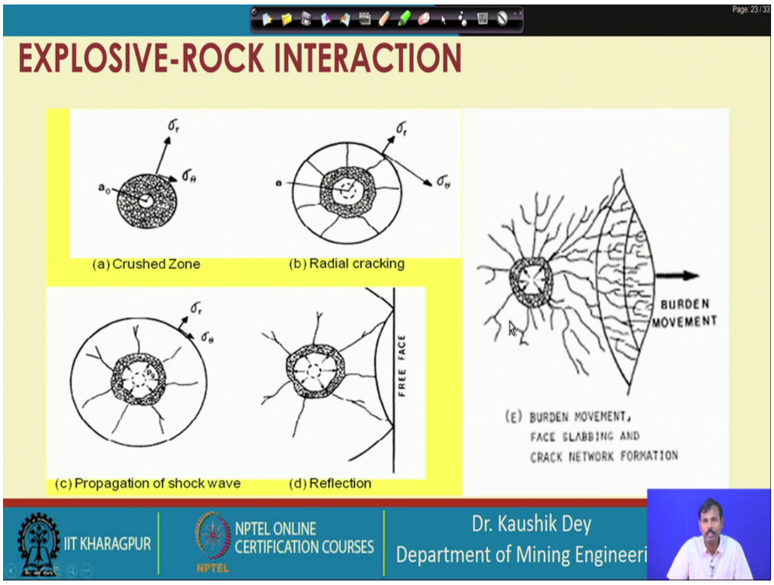

So, this is basically experimentation. This is basically the experimentation for understanding the explosive rock interaction so that based on the quantity of the rock we can set the our charge requirement in a blast hole. But this is not giving us the understanding about the bench blasting, where we are having 2 three-phases. One is in the surface side, one is in the front side and we are also not able to understand how we can utilize the time gap between the shock energy and the gaseous products generated; between this time gap how we can utilize this as our better result obtaining better result in the blasting.

So, let us see what will happen if we are placing some explosive in a hole which is drilled in the bench.

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So, let us consider this is a bench and this is a hole ok. So, let me actually this hole became a little bit more larger dia. So, let me reduce the dia. So, this is the hole ok; diameter of the hole. So, you are now using reduced dia hole for blasting and let us draw a sectional view of the same. So, this is the bench and let me draw this hole say this is the explosive charge inside the hole.

Now, what will happen as it is you understand that the moment we explored the explosive, first the shock energy is released and what will happen as the shock energy is released in a form of wave? So, shock energy is released in a form of wave. So, the moment shock energy is released from the explosive, first it moves as a wave and encounter the first rock wall. So, basically the explosive medium is different, the rock medium is different. So, as there is a change in the medium, the following the Snell's law the shock wave will enter into the rock wave from the explosive.

So that means, in the hole explosive then this side is rock this side is rock. So, this is the partition, the wave will come like this and some portion will reflect back and some portion will move in the front direction like this and this transfer will depend on the properties of explosive and the properties of the rock. So, the first is that the explosive we must choose of that type, where the maximum energy should be transferred from the explosive to the rock. So, this is the first case we will discuss this part later on; but for our case consider this is some explosive is there, we understood the explosive is being detonated allow the wave to travel entered into the rock.

So, now the explosive shock energy is entered into the rock. Shock energy is entered into the rock and it is being travelled into the rock in this direction. So, what will happen the moment that is huge quantity of shock energy enter into the rock and it is trying to move in the similar way the sound wave this being moved that means, on compression and dilation, due to that moment it will subject its medium inside the rock that the rock medium it will be subjected to the compression and dilation. And as initially from explosive, it is entering into the rock. This compressive pressure that the as the wave is propagating; this compressive pressure given by the wave is very very high.

So, the compression is very high and the rock compressive strength is less than that compression pressure and that is why rock fails under compression as at that side. So, whenever you will observe this blasting videos, you will find out the post blast drill mark there is a zone, where the rock fails under compression; rock fails under compression and this is called Crushed zone this is called crushed zone or compressive failure zone ok.

So, this crushed zone here rock fails under compression and that is why it became a powdery form. So, this side also you will find out there is a zone, where rock fails under compression and it happened in the both side, where free face is there, where free face is not there; in both side it will happen. Now at this point shock has already lost its energy. So, that is why the wave does not have that much strength to fail the rock under compression; but still it is propagating. So, up to this is compressive failure, but still the wave is propagating. But it is unable to the wave is unable to fail the rock under compression.

But we know rock is having different heterogeneity, there may be different cracks are there; there maybe the changes in the particle there that means, the properties of that fragment segment of rock is different than this segment of rock. So, these are the possibilities. So, that is why what is happened the wave gives the differential motion among the rock.

So that means, if we are considering this is a rock which is having a different rock part at this position and different rock part at this position; then, as the wave is propagating as the wave is propagating it will allow a differential motion of this one; differential motion of this one and this will generate a shear along this; shear along this plane and this will initiate a crack this will initiate a crack at this position.

Similarly, if the rock if the rock is having some existing cracks, then because this cracks are already existing this is the medium change is there; you will observe a different motion of this portion of the rock there will be a different motion of the this portion of the rock. So, the cracks existing cracks will be avoidant. So, the cracks will be having differential motions, create shear among that crack and crack will be widened. If the heterogeneity of rock is there, shear will occur on that contract position and new cracks will be generated.

So, by that way rock fails under shear in this position because of the wave propagation. So, what will happen? There will be a zone, where rock fails or cracks are initiated because of the shearing motions among the rock grains. So, this is called Cracked zone. So, you can observe this here also the cracks will be initiated in this case. So, this cracked zone will we there, but wave is still propagating and what will happen? We will find out that wave is no longer that much strong, it can fail the rock under compression also; that means, though differential motions are there, but it is not strong enough to fail the rock under shear because the shear strength is very very little bit higher than that.

But still wave is propagating. So, wave is propagating further to this also. And finally, the wave is reaching at this position. So, finally, the wave is reaching at this position. What is there in front of this? As it is there which is very very lighter medium most of the energy from this medium will reflect back. So, what will happen if you drop a stone on the pond water of the pond, you will find out the wave is propagating in the all the direction around the dropping point and the wave will reach up to the side of the pond then it will again reflect back in the opposite direction.

So, the moment in a pond we are dropping a stone, the waves will move like this and the moment it is reaching at this position, you will reflect in the opposite direction. So, the wave will start moving like this and it reflect back; it reflect back like this. Now again I refer the dropping stone on the pond if you drop that and try to observe that one, you will find both the waves are moving; it is called Wave number. The first wave is moving, then the second wave is moving. So, these 2 peaks; this is wave number 1; this is wave number 2. So, these are the 2 peaks.

So, as wave is moving; finally, it is reaching up to the end reflected back most of the part is reflected back. So, it is reflecting back in the opposite direction and while it is travelling in this direction, it will meet the front waves. So, there is a meeting point of this wave and this wave; if you drop a stone on the pond you will find this type of meeting is carried out. Then, what will happen? In this position, you will find there is a sudden drop. The reason is as it is a wave propagation on reality there is no particle movement.

So, suppose if you are considering this particle say this is the particle. Let me enlarge the particle; this is the particle. So, this particle and this particle is in the top stage. Similarly, when it is reflecting back this particle is also in the top stage. But the problem is while this compression and dilation, you know this is the compression and dilation. So, compression and dilation means it is compressing and dilating. So, whenever this is going towards this direction on compression and dilation, similarly when it is reflecting back. So, this is the compressive way this is the reflecting back you can consider it is a tensile way.

So, in compression and dilation, this is in the in this direction while it is returning back this is in this direction; so that means, this particular element is under a stress because of the front wave towards this direction, because of the reflected wave towards in this direction. So, basically the particle is under a tensile stress at this position. So, what will happen? The tensile stress of the rock is the minimum one; it is almost one-seventh, one-eightieth, one-tenth, one-twelfth of the compressive strength. So, as this portion of rock is being subjected to the tensile stress. So, the long cracks generates here because of the tensile failure.

So, this long cracks occurs, this portion will be cracked in a plane. So, what will happen? In this portion of the rock, rock fails under tensile and as it is failed under the tensile. So, we will find out the long cracks like this. Basically, we utilize this phenomenon of shock energy released ahead of the gases. So, what will happen? As the gas shock energy is released from here first, the shock energy immediately crack the crack portion crushed zone, then shear the shearing zone; then, go up to this, then return back from here creating the tensile creating this tensile, tensile cracks prior to release of the gas energy from release of the gas energy from this.

So, our objective what? Because there is a time gap between the shock energy released and the gas energy release, what we want that before the release of the gas energy or because of the formation of the gas and that gas is reaching up to the cracked position, before that our tensile failure which is called tensile slabbing; this is called tensile slabbing, this tensile slabbing must be completed ahead of the gas is reaching at this position.

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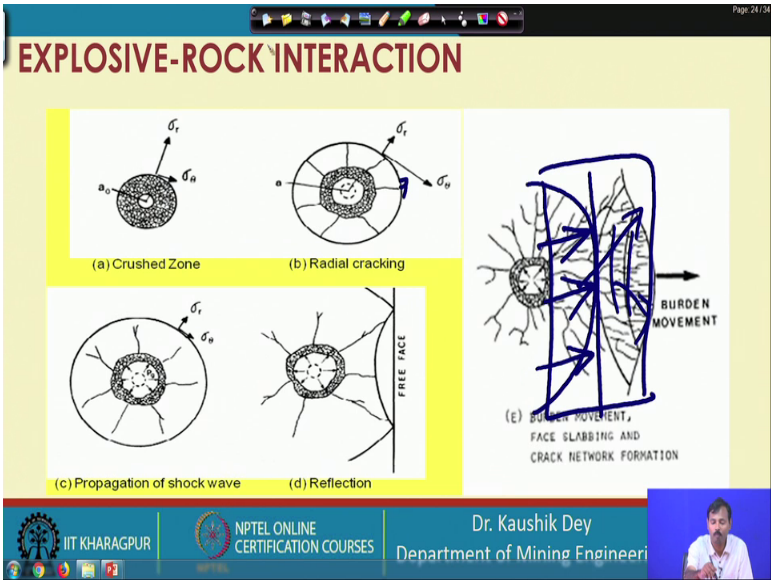

So, basically, so basically we carry out the same thing. Here, you can see this is the crushed zone. This is the radial cracking zone and this is the reflection which is basically giving us the tensile slabbing, this is the tensile slabbing.

So, this tensile slabbing and prior to completion of this tensile slabbing up to the boundary of the radial cracking zone up to this boundary of the radial cracking zone, it must be tensile slabbing must be completed and we allow our gas energy only after that the gas energy should come and it can throw this portion of rock. The reason is our gas which is produced that is of limited quantity of limited pressure can be generated and if there is the huge solid rock mass like this is there in front of the gas energy gas produced from the explosive detonation it cannot that rock ok.

So, we have to give some weak joint weak fragmented rock mass at this position; we should there should be some fragmented rock gathering at this position so that our gas can throw generated gas can throw the fragmented rock in the front direction. So, our purpose is that shock must be released and so that our shock must be released and we should allow the fragmented rock fragmentation prior to the throwing of the prior to the throwing of the rock by the gas.

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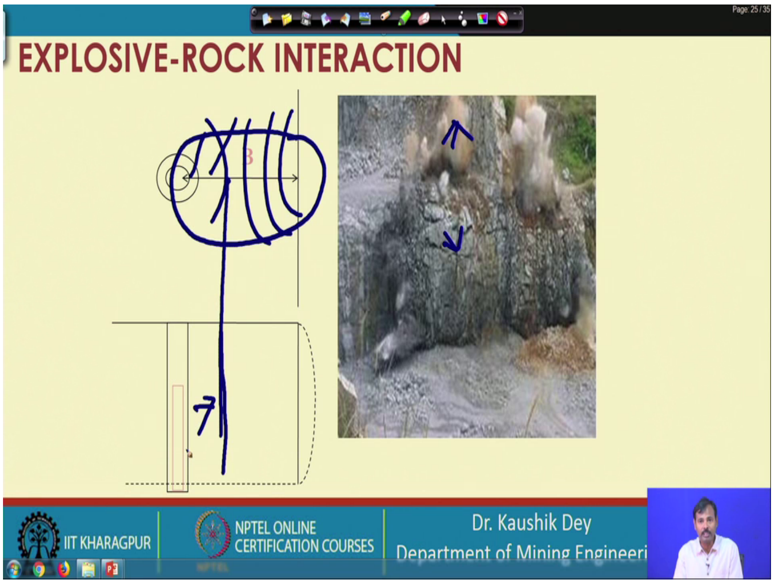

So, our objective is to choose a burden, choose a burden such that this crushing zone, radial cracking zone and tensile slabbing zone must be completed ahead of the gas is reaching at this position. So, basically this is the utilization of the time gap from the shock energy released and the gas energy released and to understand the to, by understanding the energy transferred from the rock to the from the explosive to the rock from the crater blasting experimentation, we are able to utilize that to design a proper burden power rock fragmentation.

So, basically this shows us the explosive rock interaction. We can utilize this explosive rock interaction for design our blast for fragmenting our rock for our rock excavation purpose.

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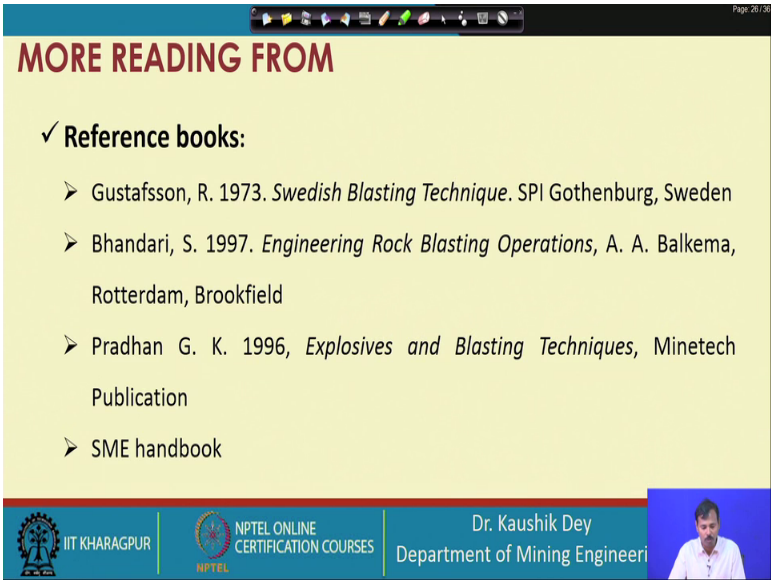

So, basically this is basically this is all from the explosive rock interaction. If you are not able to understand yet, you can go through some reference book written by Gustafson, Bhandari, Pradhan, SME handbook is also having a very good text on this Explosive-Rock Interaction. So, Explosive-Rock Interaction is the basic of rock fragmentation by blasting.

All the designing parameters etcetera has to be fixed from the understanding of the explosive rock interaction. Basically, this gives us the idea about the burden and rest of the parameters can be determined, if we are able to understand what should be the burden for a particular condition. So, that is all from the explosive Basics of the Blasting. We will start our next topic in the next class.

Thank you.