Drilling and Blasting Technology
Prof. Kaushik Dey
Department of Mining Engineering
Indian Institute Of Technology, Kharagpur

Lecture - 30
Surface Blast Design

Let me welcome you to the 30th lecture of Drilling and Blasting Technology course. In this lecture we will continue to the techniques of surface blasting which you are continue from the last two classes also.

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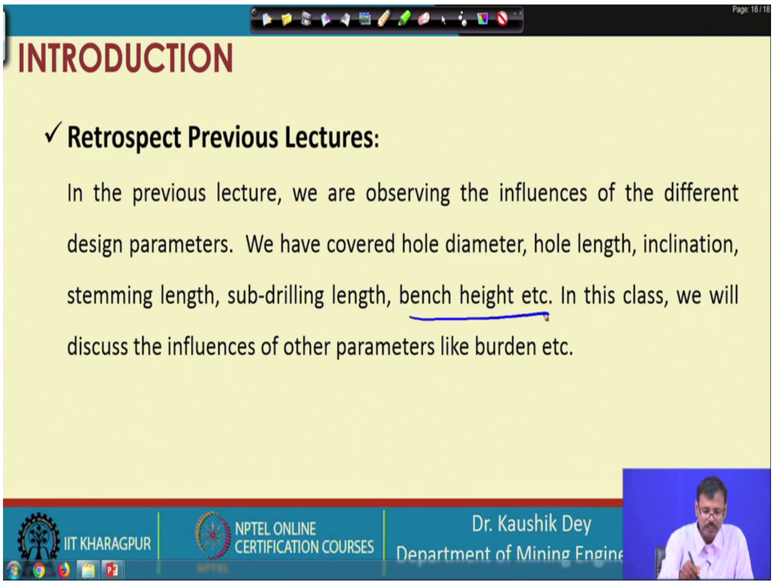

And as you know that in this a class let us first retrospect what we did in the previous lectures. In the previous lectures we are observing the influence of the different designing parameters, we have covered hole diameter, hole length, inclination of the hole, stemming length, sub drilling length, bench height etcetera. In this class we will discuss the influences of other parameters like burden etcetera also. And we will mostly cope our how the designing can be done, so let us see our learning objective.

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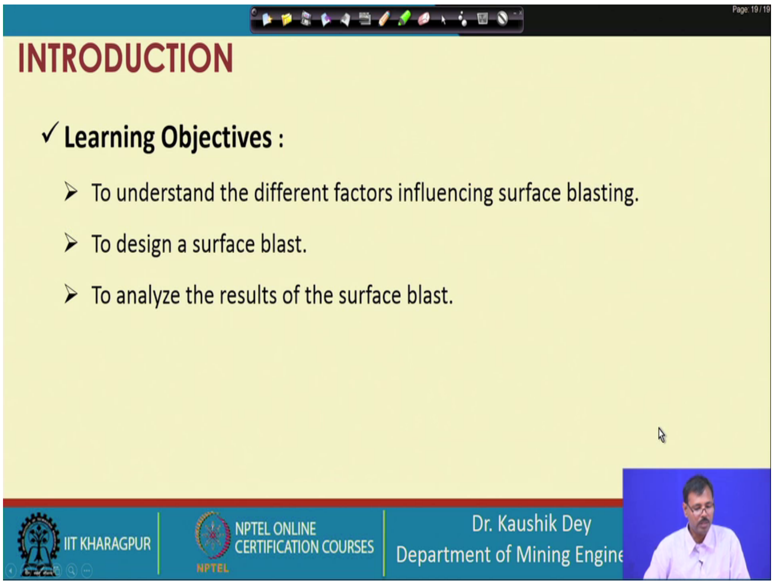

Our learning objective remain same as from the last two classes also, to understand the different factors influencing surface blasting, to design a surface blast, to analyze the results of the surface blast.

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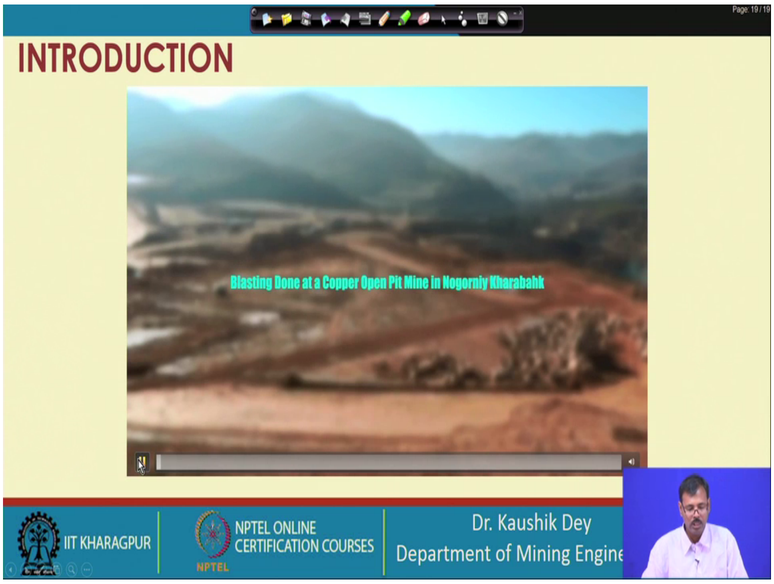

So, like every class let us look into a video which is available in the YouTube also, this is the blasting done at a copper mine pit. So, you can see the blasting is being carried out here you are you are able to observe and you can see the brownish fume has come out.

In the next blast also you can see say you can see little bit brown flame, flame has come out, but other places the fighties flame has come out. So, while we are discussing our explosive properties that time we have we are unable to cover all the properties because of the time constant, but most of the properties we have covered. And probably this property is not covered they are that is the fume characteristics, though this property has been extensively discussed in the text books like a written by doctor Pradhan etcetera. SME hand book also in the different internet literature also it is discussed that fume characteristics is basically gives us the idea about the how the explosive is manufactured and whether it is operating properly or not.

So, here also you can see some of the brown flame has brown fume has come out. So, basically this is a phenomenon where an important property that is called oxygen balance has come out. If you see the major ingredient of the explosive is the ammonium nitrate, we mix ammonium nitrate with the fuel oil mostly it is diesel. And ammonium nitrate act acts as the oxidizer and that is the main source of the nitrogen and fuel oil which is basically C H carbon and hydrogen that is basically the energy source.

So, on reaction it converts into the flame of different types and sorry it is converted into the fumes of different types and these gases are C O 2, H 2 O and different nitrogen oxygen gases. So, it may be N 2 O it may be N O it may be N O 2 like that, so different nitrogenous gases are come out apart from CO 2 and H 2 O. So, what will happen if the nitrogen source is becoming more than the oxygen source then the N 2 O will come out more.

If the carbon source is becoming more than the most of the oxygen will be taken by the by the carbon and hydrogen and that is why the oxygen for the nitrogen become limited. So, that is why what will happen N 2 O will come out in that case and N 2 O is basically representing this brownies flame.

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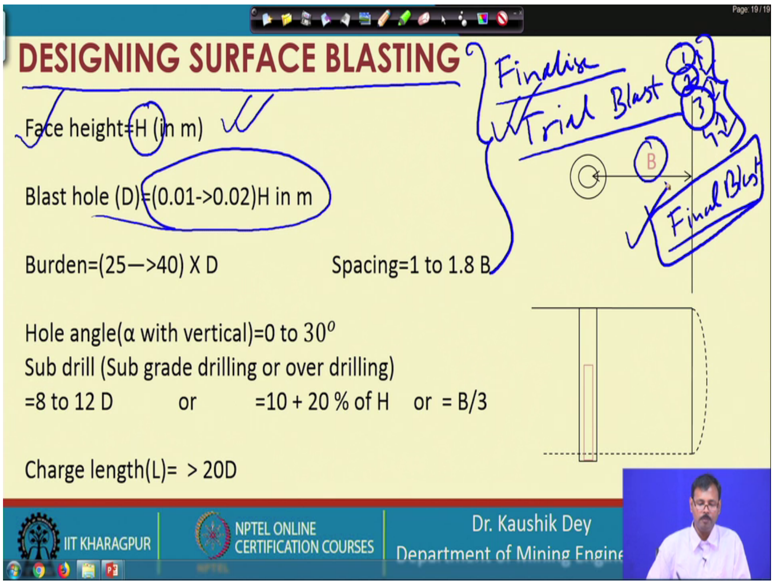

So, fume characteristics is very, very important and that must be considered when you are observing the blast fumes you have to reach analyze your property of the explosive you have to reconsider about the manufacturing of the explosive properly. So, oxygen balance is very, very important and with best oxygen balance only the proper energy can be utilized. Now, let us look into the designing of the of a surface blast; surface blast design our first property is the burden which is very, very important.

So, basically we have already discussed while we have we are discussing how to select the burden that optimum burden it may be less inadequate burden it may be more accessible burden those are already discussed and the how the burden can be selected how the burden can be what should be the importance of the burden that is already discussed in the explosive rock interaction.

So, in general what will happen we are having some rule of thumb which in general try to follow while we are practicing our blasting? Generally one criteria we will discuss here say it maybe one criteria where we can start with the bench height, and a as a rule of thumb where we are trying to design a blast, we will select our blast hole dia as a function of the height.

So, in this first concept we start with the bench height or the face height. So, let me before going into the detail let me clear first thing always, a blast design has to be finalized has to be finalized from the trial blast experiment. That means, trial blasting 1, 2, 3, 4 has to be carried out and every time we will modify different parameters in this trail blasting to finally, arrive at the final blast design.

But we have to start trail blast with some designs and all these guidelines which are given this is say based on face height another time we will discuss about the blast hole best on blast hole dia. So, all these guidelines which are given or n number of guidelines are available in different text books are valid or to be utilized for starting in the trail blastings, that trail blast 1 has to be carried out the trial blast 1 must be closely monitored.

And observing the result of the trail blast 1 the trial blast 2 will be designed, then the it is observing the result of trail blast 2, trail blast 3 has to be designed. And like that way the first the trial blast will be designed to arrive at the final blast design which basically satisfying hours about the performance of the blast or we will see whether the desired blast result in terms of fragmentation is terms of throw, in terms of mark profile, in terms of blast vibration etcetera, etcetera, etcetera we are achieving or not. So final blast design must satisfy those results then only we will adopt that final blast design, otherwise we will go for the trial blast more number of trial blast.

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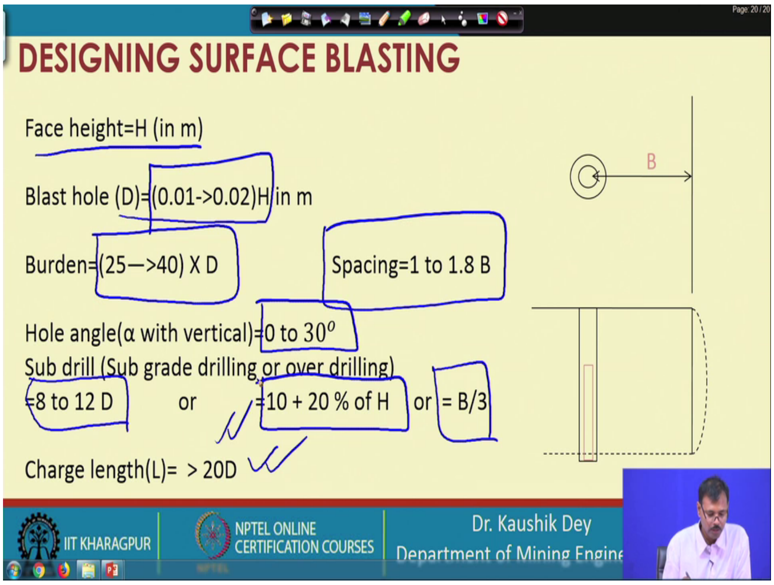

So, in this first guideline we are considering the basis the bench height we have to design our blast from the bench height and the diameter is a function of bench height 0.1 percent to 2 percent.

The burden is a function of diameter which may vary 25 to 40 times of the diameter of the blast hole. And obviously, this depends on the type of rock spacing is a function of burden which may vary from 1 to 1.8 times of the burden, inclination of the hole angle may vary up to 30 degree normal, we do not go for incline hole angle unless and until it is essentially required.

Sub drilling is required in few cases where it should be 8 to 12 times of the diameter of the blast hole or it may be 10 plus 20 percent of the bench heights or it may be B by 3 in different conditions. And charge length must be greater than the 20 times of the diameter, you know if the charge length is less than 6 then it becomes spherical charge to. So, to avoid a to avoid the spherical charge and to achieve a column charge it must be more than the 20 times of the diameter.

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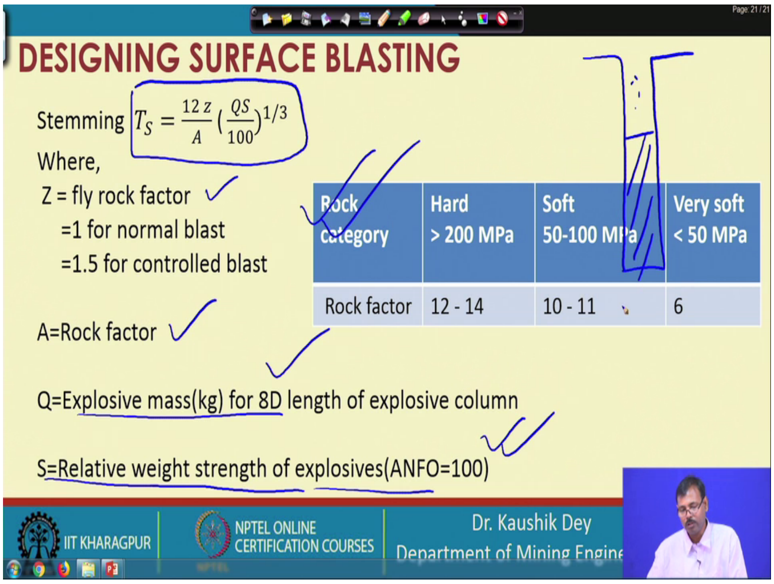

The stemming can be calculated using this formula, where Z is the fly rock factor 1 for normal blast 1.5 for controlled blast, a is a rock factor this is the rock factor given. So, this is basically a developed by (Refer Time: 11:21) et al this is the explosive mass for 8 D length of explosive column and this is the relative weight strength of the explosive considering ammonium nitrate fuel strength of ammonium nitrate fuel oil as the base that is 100.

So, using this formula the stemming length can be determined and obviously, it is considered the stemming length is this one and the total other length of the hole is filled with the explosive. So, this is a prime consideration of this one you can see the rock factor is becoming very high for the hard rock and less for the soft rock. So, the it is expected the that the stemming must be more for the soft rock and must be less for the hard rock. So, the quantity of the charge must be more in case of hard rock.

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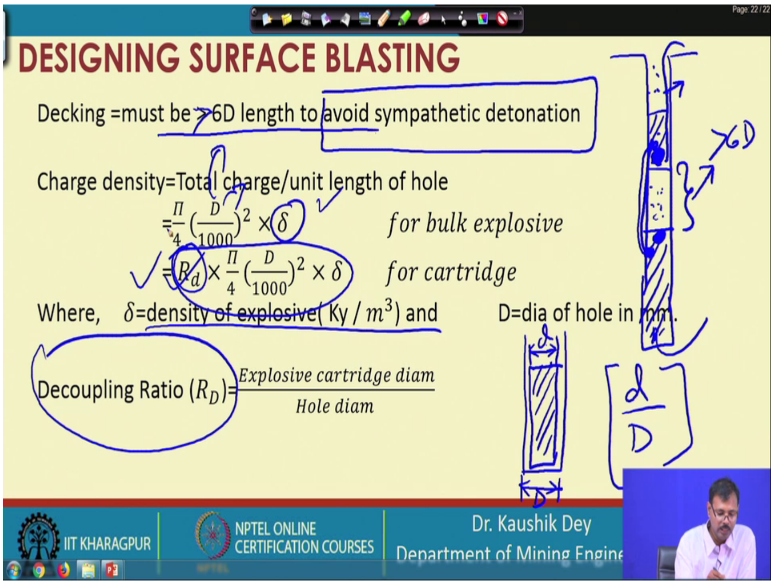

Deck charging may be, deck charging may be carried out and this must be greater than the 6 times of the diameter. So, that sympathetic detonation can be avoided that means, if this is the hole, section of the hole this is the first charge which is being blasted then some deck material is provided then the second charge is provided and finally, the stemming is provided. So, this decking length must be greater than 6 D this inert material which is creating this deck this decking length must be 60.

So, that the shock generated by the explosive at this position should not sympathetically initiate this explosive. So, to avoid this sympathetic detonation the deck charging length must be greater than the 6 D of the diameter, 6 times of the diameter of the hole. It is expected that the initiation from this for this one must be tapped from this to this place either by a detonating fuse or it may initiated from the top if we are very, very sure about the non scattering of the D length. Otherwise it is respected the initiation must tapped from this position to this position using a detonating fuse or something like that.

The charge density is calculated, so this is the linear charge density obviously, pi by 4 into D when it is expressed in millimeter D by 1000 square. So, this is basically pi by pi by 4 r square and delta is basically nothing, but the density of the explosive ok. So, this is the formula if we are using a cartridge charge as the D is the hole dia if we are using the cartridge charge then Rd basically the factor that is the decoupling ratio Rd is basically the decoupling ratio which is nothing, but the ratio of the cartridge dia and the hole dia.

So, suppose if we are using a cartridge, if we are using a cartridge explosive like this, so this is the diameter of the cartridge, so this is the diameter of the cartridge this is the hole dia. So, basically D by D is the decoupling ratio which is considered here as the charge density. So, for cartridge explosive this is the linear charge density this is for the bulk explosive this is the linear charge density.

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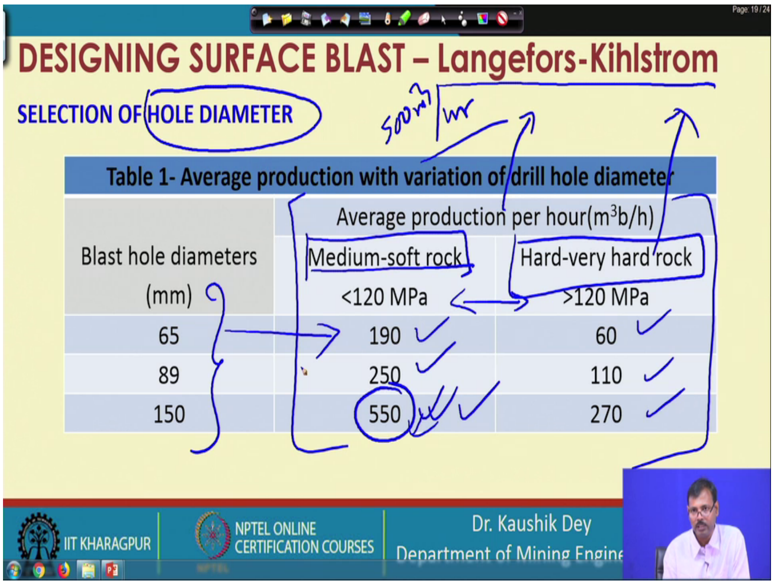

So, this is more or less coyners theory which we have discussed basically carried out based on the bench height, now let us look into another one which is basically the theory of Langefors Kihlstrom. So, Langefors Kihlstrom has given this criteria where we start our designing of the blast from the diameter of the hole. So, the person or the designer first has to choose the diameter of the hole then the rest of the parameter can be easily calculated from the blast hole diameter. But Langefors Kihlstrom has given a guideline for the selection of the blast hole diameter; their guideline is basically depending on the production rate and depending on the strength of the rock.

Suppose the excavation procedure is aiming a production rate which is expressed in meter cube this is bank meter cube that means, in situ rock material per hour, if that production is expected say the mine is expecting that per hour 500 meter cube of material has to be blasted. So, that 500 material meter cube material will be blasted if it is medium to soft rock then it is coming here it may be hard rock then it is actually this is for small dia it will go to the large dia 1. So, that is why the diameter basically will depend on this production factor and it will depend on the rock also.

So, he has classified strength in basically two part one is hard and another is soft a medium soft that is greater than or less than 120 megapascal. And based on that he has given the guideline of the different production rates and the diameter of the drill correspond to that production rate and that strength. So, basically this guidelines will give the idea of the user about that first should be the possible diameter of the blast hole.

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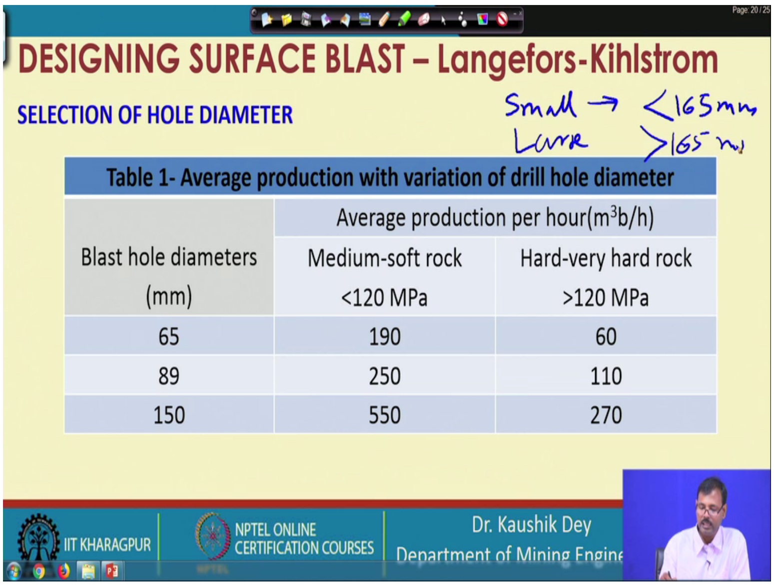

Blast hole diameters (mm)	Average production per hour(m^3b/h)	
	Medium-soft rock <120 MPa	Hard-very hard rock >120 MPa
65	190	60
89	250	110
150	550	270

Here also categorize the blast holing two broad categories one is the small diameter hole, small diameter hole which is less than 165 millimeter dia, he has considered that is as a small diameter hole. So, this 150 comes under small diameter if you go through his original literature his books text book you can easily find out for the large diameter also what he has discussed. In this class I am not discussing the large diameter because it is basically the guideline actual guideline you can have there.

So, this small diameter is for 165, less than 165 mm dia and large diameter is considered if the diameter is more than 165 mm dia. So, in that case he has classified is like this and obviously, this table will become different for the large dia this table is for small dia which is presented here.

So, the basis of Langefors Kihlstrom is the selection of the hole dia first then the other parameters blast design parameters will be calculated based on the hole diameter. The guideline for selection of the hole diameter is given in terms of the production requirement or production target of that excavation area or the mining area. And the strength of the rock on which the blasting has to be carried out, so basically based on that he has given the idea about the hole dia.

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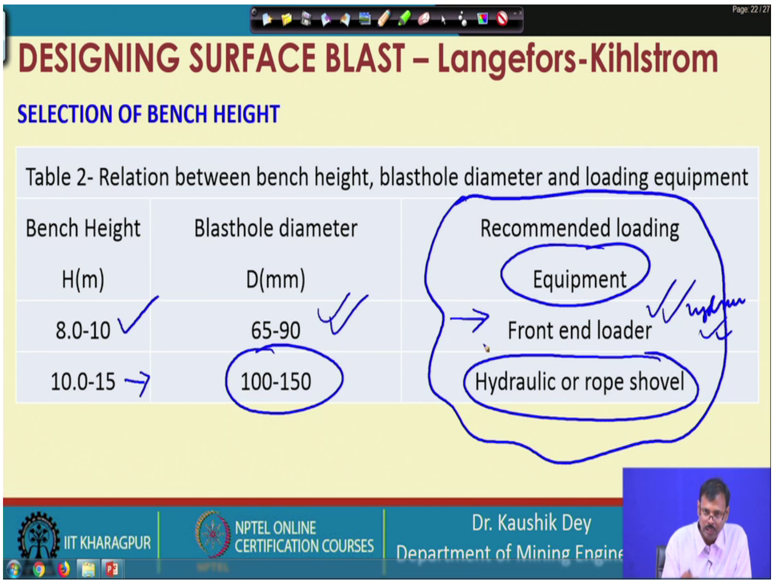

The next purpose is the bench height basically bench height is a function of loading machine also so the loading machine requirement is very, very important. So, he has given a guideline that if a person is using a bench height of 8 to 10 meter then he may opt for blast hole diameter of 65 to 90 millimeter and it is expected a front end loader can give you better loading equipment.

However in case of a little bit larger bench height we have to select a little bit larger blast hole dia then the shovels maybe a good equipment for the loading machine. However, this is the practical easiness of the handling of the material, if the material is very strong very abrasives. And in those cases high specific gravity front end loader may not give the sufficient digging force, because the digging force of the front end loader is very, very limited, in those cases this front end loader may be replaced by a hydraulic ropes hydraulic shovel or maybe a rope shovel also in this place.

So, basically the loading equipment depends on the how much digging force is required at this position, however this part is not a basically blast design part, this is for required for our own understanding only.

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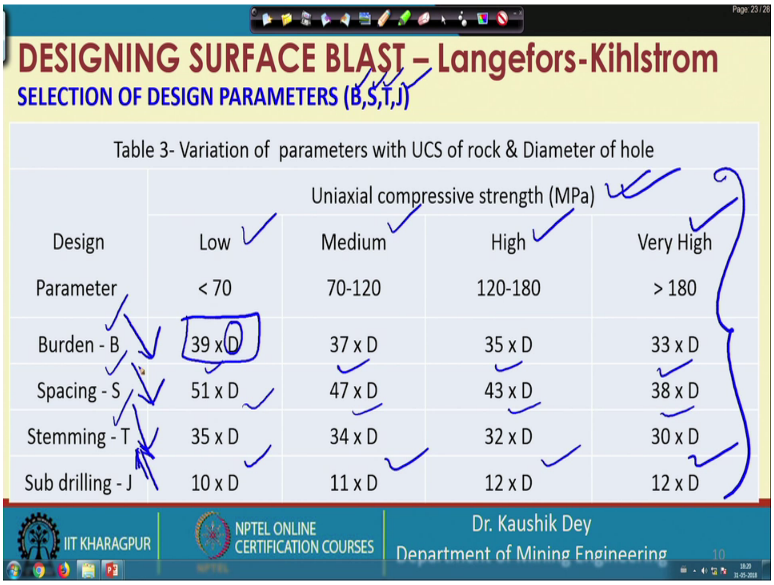

So, for a small diameter hole what should be the different blast design parameters that will be as he has already told that it is must be based on the diameter of the blast hole. So, we can see the burden spacing, stemming and sub drilling as a function of diameter of hole, diameter of blast hole for different compressive strength of the rock expressed in megapascal and that is categorized as the low strength rock, medium strength rock, high strength rock, very high strength rock.

And you can see for low strength rock burden comes around 39 D and in medium the burden value is decreasing high further decreasing, very high again decreasing. So, basically burden value is decreasing with the strength of the rock, stemming value is decreasing with the strength of the rock 51 47 43 38 D stemming value is also decreasing, but not that much significantly 35 34 32 30.

Sub drilling length is basically increasing with the increase, in the strength of the rock 10 11 12 12. So, we need more sub drilling if the rock strength is high, we have to design for a lesser burden, lesser spacing, lesser stemming, if the rock strength is increasing. So, that is why this is as per our requirement, because the explosive charge quantity required more for the stronger rock. And that is why this lesser in the burden spacing and stemming basically ensure us the charge per unit volume of rock will be more if the rock strength is high.

So, basically this is the general consideration, but the guideline is given by the Langefors Kihlstrom for this again let me remind you that this guideline must be followed for designing the trial blast, based on your result achieved from the trial blast you have to modify your design.

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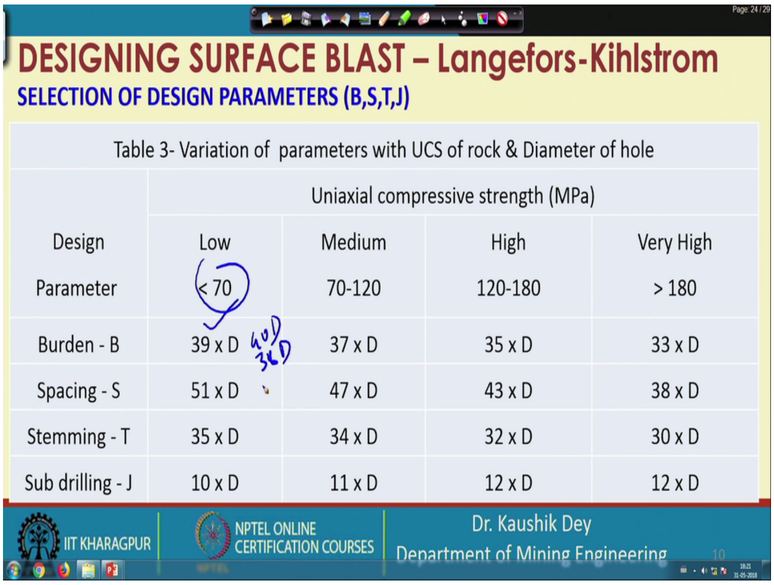

Say you may start with a 39 D burden for a this type of condition then you may increase up to 40 D you can see the result you may decrease it to 38 D you can observe the result. And based on that modification you have to see the other parameters you have to change the other parameters also like that way n number of iteration may be carried out to finally, achieve to a final blast design for that particular mine.

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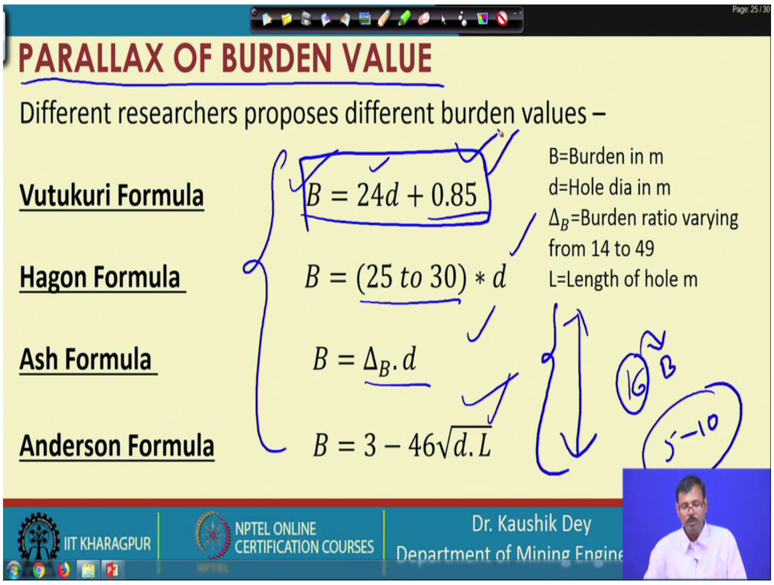

In fact, I am not discussing the guideline which is given by the Langefors Kihlstrom for the large dia holes because obviously, 165 mm is not the end of the drilling diameter presently we are using 350 mm diameter drill hole also. So, that is why large diameter holes are also there that is also used for different blasting's that guideline is also given by Langefors Kihlstrom in its book, but because of the times constant we are not using the, we are not showing it in this lecture, but I strongly suggest you must go through all those guidelines in your further study.

But one thing I must discuss that the burden value, say the heart of the blast design is to establish the burden value and if you go through the literature you will find out not only the conyer and Langefors Kihlstrom n number of burden value formula are there. Say this is the Vutukuri Formula where burden is 24 d, d is the hole diameter plus 0.85. Hagons Formula 25 to 30 d, Ash Formula delta B D where delta B is the burden ratio varying from 14 to 49, Anderson Formula is this one. And in fact, once I have searched literature for that and I have found that there are 16 burden formula are there 16 formula only available, only for burden with different, different influencing input parameters.

And if you try to use all those 16 formula for calculating burden in your own case you will find out the range of result you are achieving using this formula, this formula, this formula, this formula like that 16 formula is significantly very, very high maybe 5 to 10 times of the burden value normally which you are expecting.

So, that is why this basically creating a parallax about the burden value and that creates the problem to the user. So, it is always suggested one must go through the original literature where these values are given, and as these are mostly the empirical relationship empirical formula established based on some case studies. So, that is why their applicability range is lying within the limit of those case study. So, that applicability range of those formula is very, very important prior to utilize those formula as your design criteria.

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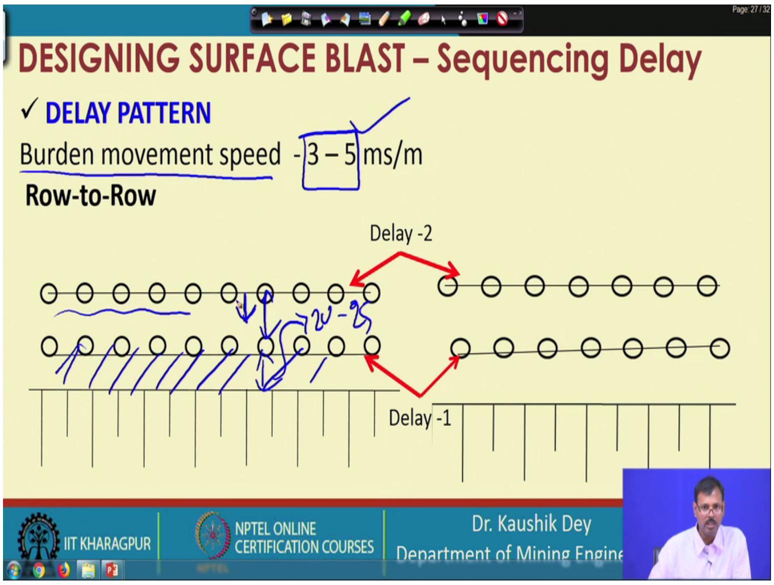

So, that is why the user must be very, very careful about the burden formula which he would like to use for his own case. Now, we have already establish the burden spacing etcetera. So, this is the burden spacing hole, hole depth then the stemming sub drilling all are established and now these are charged and we have to blast this one.

So, while we are going for blasting the multi row or multiple holes it is essentially required that we have to provide some delay in those holes. So, based on that we have already discussed that our holes can, our design can be considered in different categories. The first one is row to row where the a row of hole will be blasted simultaneously and we have to provide delay between two consecutive rows. So, that prior to blasting of the second row the first row will be blasted and a new free face area will be created at this position.

So, this is the essential requirement and we have to a delay between these two rows, how we will design the assign the delay in this two rows of holes, we have to understand the burden movement speed for this. And normally, normally through our high speed photography system it is more or less established the burden movement speed varies between 4 3 to 5 millisecond per mater and that is why if you are using a 4 meter of burden you can consider the 20 to 25 millisecond delay may be sufficient for assigning first row to the second row.

This is essentially required for another purpose this delay should not be very high. So, that the first row will be dispersed and the second row is not moved at all it is essentially which the first row the rock pertaining to the blasted pertaining to the first row must be at air not in the ground prior to at the time of blasting of the second row. So, that that will act as a curtain to the second row of curtain to the rock which are being being fractured by the second row of hole.

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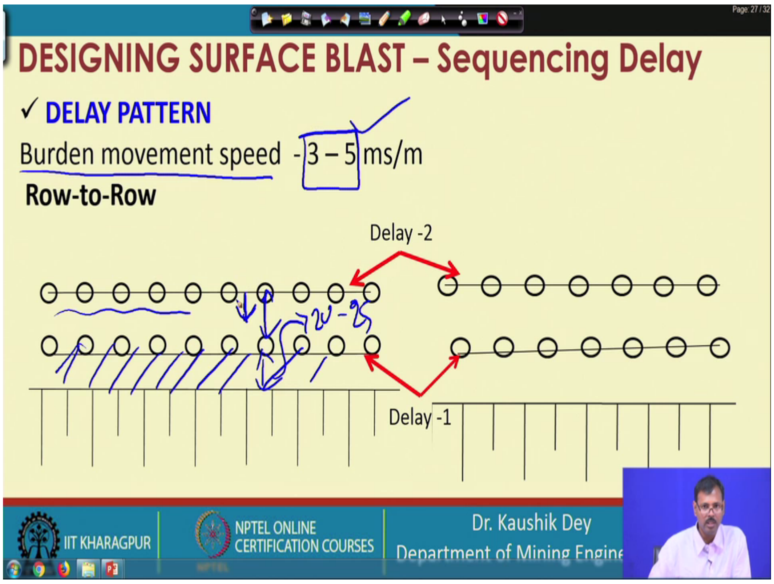

So, basically this is the guideline more or less has to be followed for two row blasting, if we are willing to do it for the V cut the procedure will remains same that we have to blast this hole, we have to blast this hole ahead of blasting this one. So, that a new free face area new free face area will be created like this way and then the effective burden of this hole will become this one.

And when it will be blasted this portion of rock will throwing in this direction and they will collide to each other and the better fragmentation will be observed. So, this is for the V cut blasting, again we will try to provide the delay between two consecutive rows of blasting in the V cut also considering the burden movement speed, the same thing is there for the extended V cut also.

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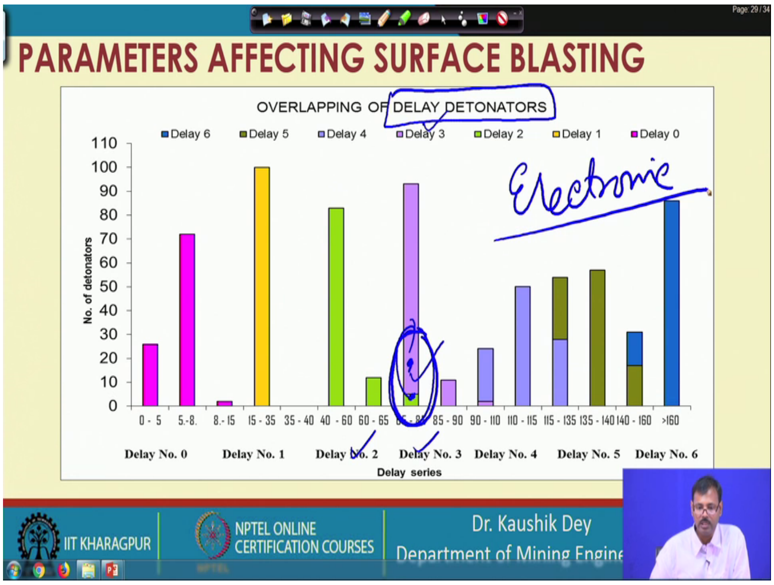

So, that is more or less used for the assigning the delay to the surface blasting here one very, very important parameter is the scattering of the blast, a scattering of the delay in the blasting. And you can see because of the scattering that means the fluctuation of the achieving the actual delay value in the practical field there may be possible that the simultaneous blasting may occur in this delay, so green is delay number 2 and violet is delay number 3. So, this overlapping of delays occurs there and it may be possible that this delay blasted after the blasting of this delay.

So, that must be avoided. So, we have to select a delay time and we have to select a delay detonator which has a very very less scattering and that is why now a day's electronic detonator is becoming very, very popular in the surface blasting. So, that is why this is very, very important in the surface blasting and one must follow the proper sequence and must forehead the overlapping of delays in its consecutive holes blasting.

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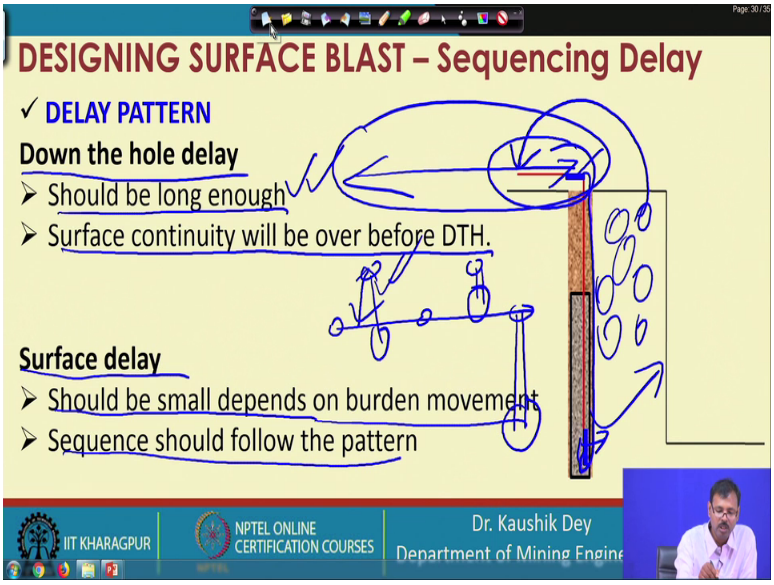

The another important is the sequence of delay, in the down the hole situation and in the surface delay. Generally what is happened, if we are using a non elastic that type of material we provide the detonator inside the explosive. And the nonil is being initiated by another detonator or may be another nonil also and in a multi row blasting multi hole blasting if the total delay time is very high say maybe 500 millisecond or 1000 millisecond, 2000 millisecond generally more than 1000 millisecond we try to avoid. But if it exceeds for a very, very large blast then the fly rocks coming out from this portion of the rock blasted by the first hole may come drop on the surface connection and cut the surface connection.

So, it is always wish that before blasting of the hole the surface connection must be blasted properly for a significant delay should be provided to the down the hole delay. So, that the surface connection will be over prior to the blasting of the rock, so that is why down the hole delay is very, very important and it should be long enough. So, that surface continuity will be over before the down the hole delay blasting of the down the whole delay and that for sequence of blasting will basically be dictated by the delay provided in the surface. So, while you are having this two rows of holes, the delay provided in the surface between this row will remain same as we are down using the down the hole delay of same amount in all the holes.

So, basically the surface still remain the delay of the actual time of blasting and surface delay should be used small depending on the burden movement, sequence should be follow the pattern in surface, down the hole delay must be same and it must be long enough, so that the complete blasting will be over before the first hole has to be blasted.

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One must be aware, I am again dictating this one because it is already discussed once in the explosive rock interaction, burden must be optimum and optimum burden give will give us the best result.

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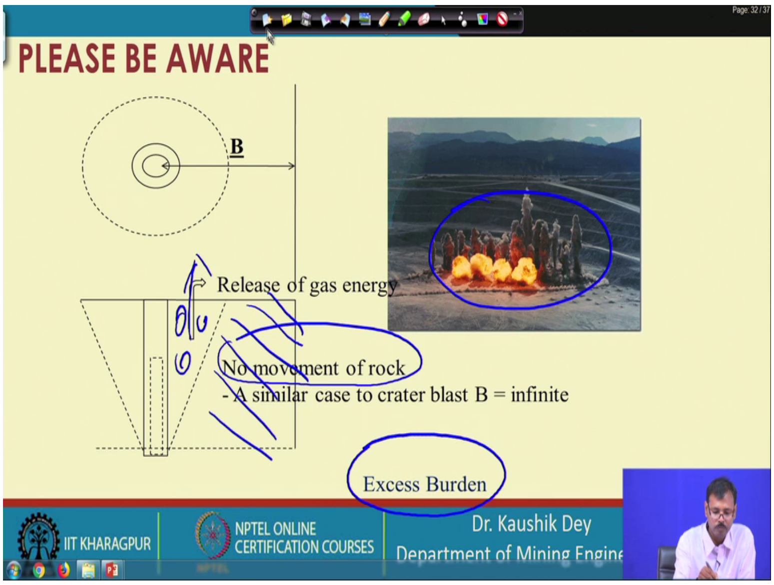

If the burden is excessive then the rock will not move and gas energy will be released in the upward direction. So, you can see a similar type of situations where the blast fragmented rock will be thrown in the upward direction only in this spot, unbroken rock will remain at this spot this spot.

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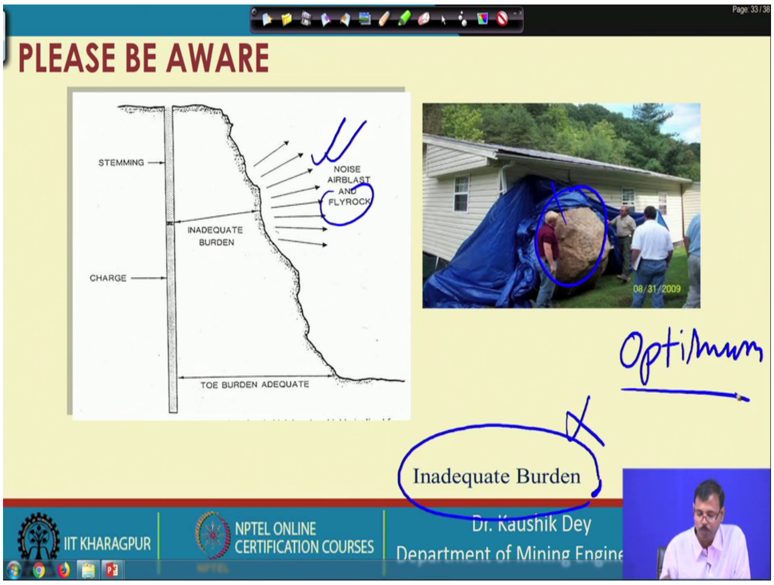

And if we are having a inadequate burdens, small burden if we are having a inadequate burden or small burden. Then the fly rock may be generated at this position noise will be generated at this position and this type of big bolder may stuck onto the houses at a larger distance.

So, basically inadequate burden no, excessive burden no we need only optimum burden. So, optimum burden is very, very important in the blasting and the design basically lies on the selection of the optimum burden.

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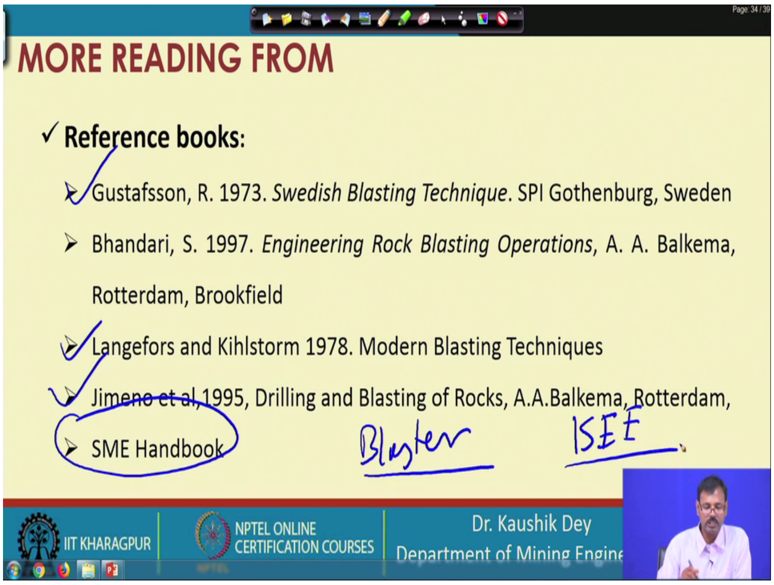

So, let us stop you can have more reading from these books, let us stop at this position. I strongly recommend you the reading of this book and these two basic book for having a more details about the last designs specially surface blast designs. Also SME handbook and blasters manuals of ISEE is also available and also of different manufacturers blaster manuals are also available that that maybe also very, very useful for the further study. So, let me stop at this position here, next class we will continue with the blast designing for the underground mine.

Thank you.