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

Lecture – 21
Explosives properties- 1

Let me introduce all of you to the Drilling and lecture number 21 of Drilling and Blasting Technology NPTEL online certification course. In this lecture we will study about the Explosive Properties.

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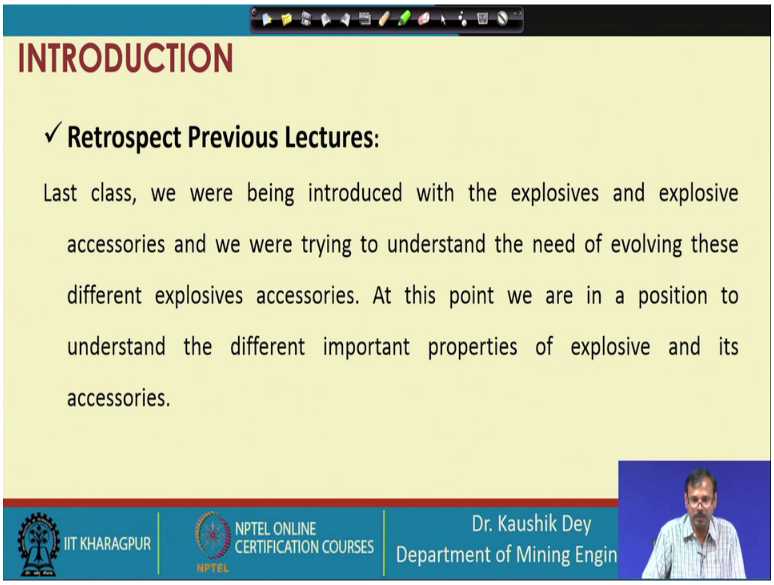

And, but prior to that like every class what we do? We retrospect the previous lecture and in last few classes we are being introduced to the explosives and explosive accessories and we were trying to understand the need of evolving these different explosive accessories. And, at this point we are in a position to understand the different important properties of explosive and it is accessories. And, we should know how these properties are influencing the performance of those explosives and their accessories.

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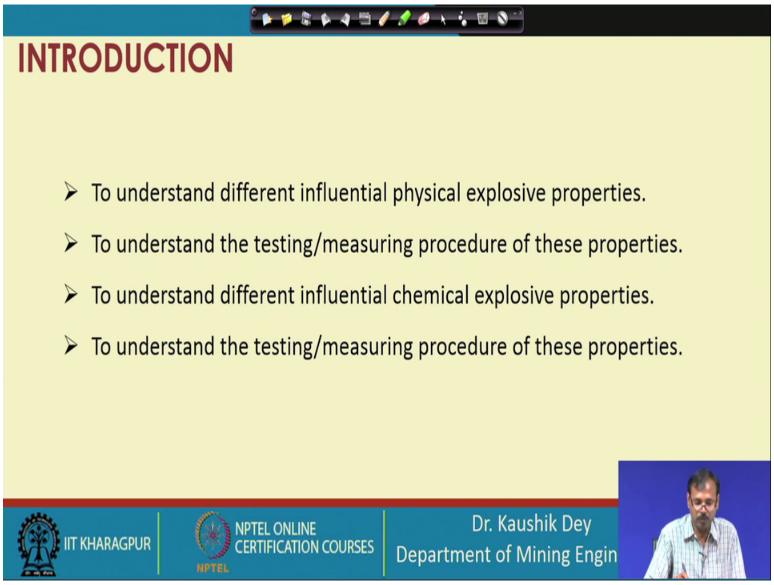

So, this is very very important. So, our learning objective for today's class is to understand different influential physical explosive properties, to understand the testing and measurement procedure of these properties, to understand different influential chemical explosive properties, and to understand the testing and measuring procedure of these properties.

Basically, we have classified these properties into 2: groups physical properties and chemical properties. Most of the time we will I mostly on the physical properties and we measure those things, chemical properties are not within the purview of the mining engineers generally, chemical chemist and chemical engineers are take care of those properties. Basically, we are more a custom with the physical explosive properties and we will discuss more on the physical explosive properties only.

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But, like every class let us observe this video. This video is basically giving you the idea about the use of explosive for the demolition of the building, this video is available in the YouTube; there are n number of other similar videos are available in the YouTube, but by observing this videos it is easier for a for you to understand how this explosive can be used for demolish the buildings.

So, buildings may be placed in the close proximity of the other nearby buildings. And, the challenges are that you should not damage those existing buildings. Neither you will allow the fly of the building broken pieces to a longer distance so, that it can hit someone and some accident may occur.

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So, that is why the demolition of the building is very very important and it is a very very artistic job.

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In the last video you have seen the demolition was not in a proper manner, that is why the toppling of the building block occur, but the last video this video was showing you a very good example of the blasting of the demolition building.

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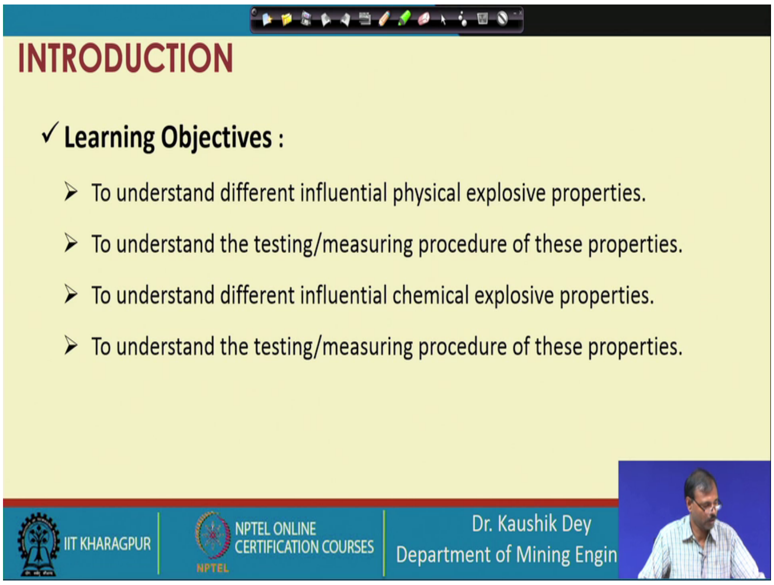

So, let us understand what are the important properties are there which we should know for the explosive and it is accessories?

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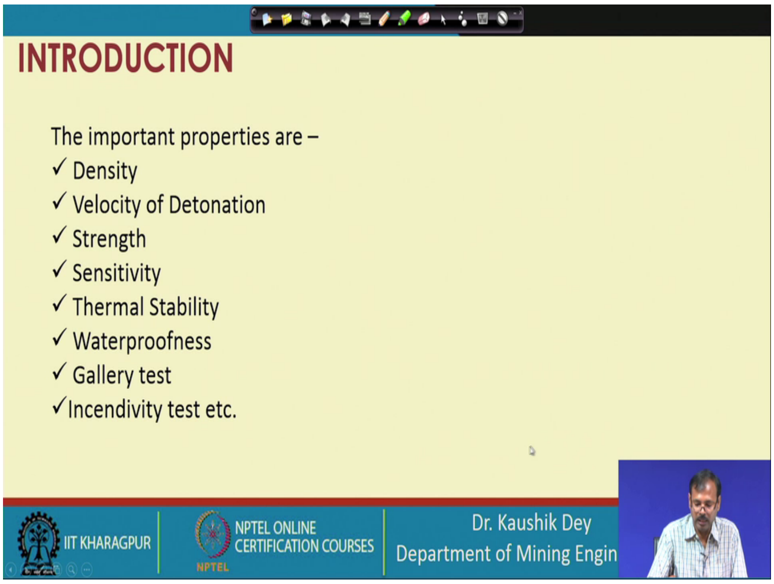

The first important property is density, next the velocity of detonation, next the strength of the explosive, then the sensitivity of the explosive, thermal stability of the explosive, waterproofness, gallery test and incendivity test etcetera n number of other tests are possible with the explosive and it is accessories.

So, in this class we will mainly concentrate on the density and velocity of detonation. We will understand how they are influencing the performance of an explosive.

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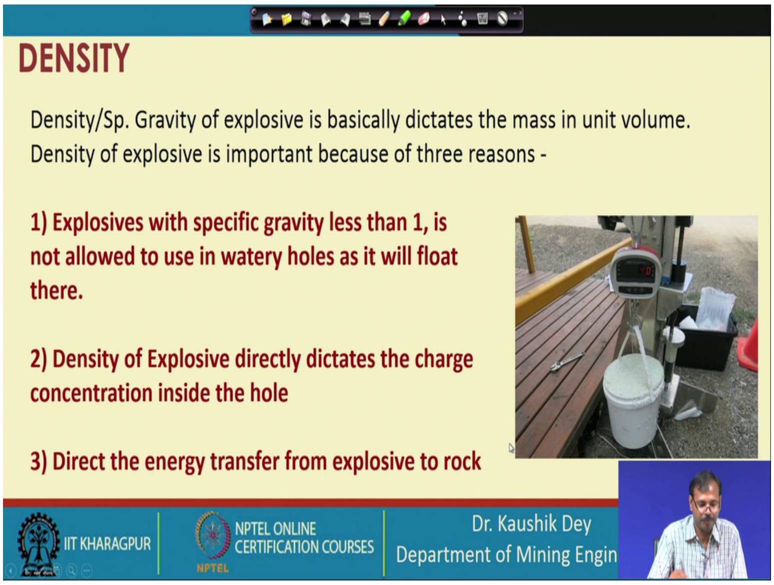

You know density of specific gravity is basically dictates the mass in unit volume. So, density of explosive is important, because mainly of 3 reasons. First the explosive with specific gravity less than one is not allowed to use in watery holes, because it will float on the water. So, if we try to place the explosive below the hole; that means, in the bottom of the hole, that is not possible if the hole is filled with water may it may be rain water it may be ground water. So, in those cases we should use some explosive whose specific gravity is more than one.

Second is density of explosive basically directly dictates the charge concentration inside the hole; that means, if the density of explosive is more than per meter of drill length, if we are placing the explosive with the increase in the density the charge quantity is becoming more. Second is the third is that the direct energy transfer from the explosive to the rock depends on the density of the explosive. We will come all this points gradually, but let us see this picture, you can see in this picture this is a common method of measuring the explosive specific gravity or density.

So, this is the container. In this container, we fill the container with the full of explosive then we find out the weight of the container in a weigh machine. In from the very beginning we know the empty weight of the container, now with the measuring the weight, we can understand what is the net weight of the explosive? Placed inside the container and we know the container volume so, from that we can easily find out we can easily find out what is the density or specific gravity of the explosive?.

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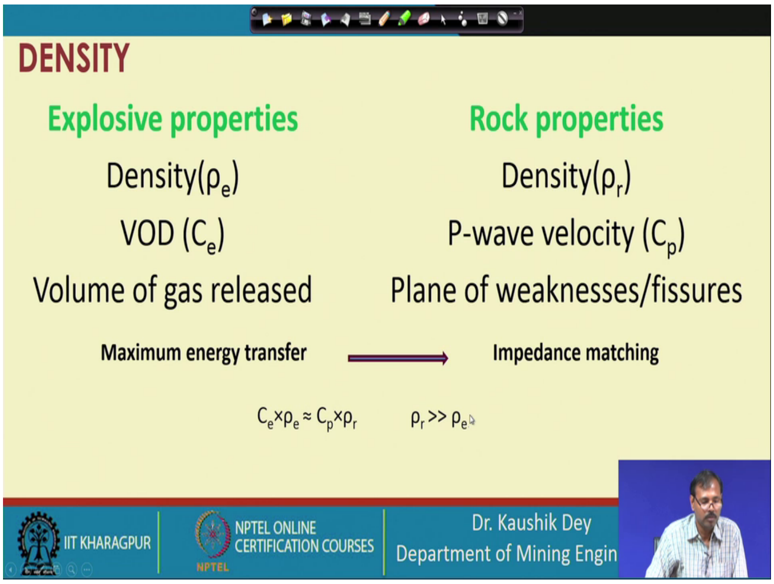

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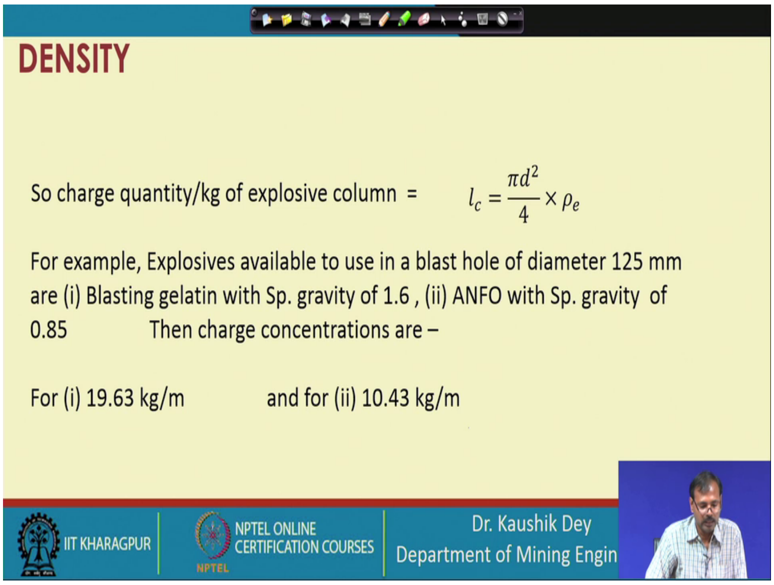

Now, density that is the basically dictates the quantity of the charge per kg of explosive column can be expressed in this equation, which basically l c gives us the linear charge concentration; linear charge concentration, which is basically a measure of our blast design.

So, the moment we are increasing the diameter this is the diameter of the hole and this is the density of explosive. So, the moment we increase the diameter of the hole or we increase the density of the explosive the linear charge concentration will increase. So, suppose we are having we are having some explosive placed at this position to blast this portion of rock mass, then if we are increasing the density of the explosive the charge quantity placed at this will be increased, then the charge per unit volume of rock mass unit volume of rock mass will be increased.

So, if we are using more dens explosive material, then our charge concentration is more and our unit volume per charge requirement is also becoming more. So, basically the charge concentration requirement depends on the strength of this rock mass; strength of this rock mass, if the strength is more in those case we should use high density explosive. So, that our charge concentration will be more for the for that stronger rock mass.

So, let us have one example calculation here, if the explosive available to use in a blast hole of 125 mm diameter and we are having the option to use blasting gelatin with specific gravity of 1.6, and ammonium nitrate fuel oil mixture with a specific gravity of 0.85. In those case if we calculate using this formula, we will find out the charge concentration per meter in case of blasting gelatin will become 19.6 3 kg per meter, for in case of ANFO it is 10.4 3 kg per meter. So, you can find out it like this pi into 125 divided by 4000 sorry let me clear this pi into 0.12 5 by 2 whole square into 1.6 into 1000, to convert it into the kg per meter cube. So, we can find out this is the 19.6 3 kg per meter. Similarly, in that case it is coming 10.4 3 kg per meter.

. So, this shows the blasting gelatin is showing almost double charge concentration over and so on. So, in case of a very strong rock mass, if the rock mass strength is high and it demands it demands more charge concentration increased concentration. In that case we should go for blasting gelatin not for the ANFO, but for the weak rock mass we should go for ANFO instead of choosing the blasting gelatin.

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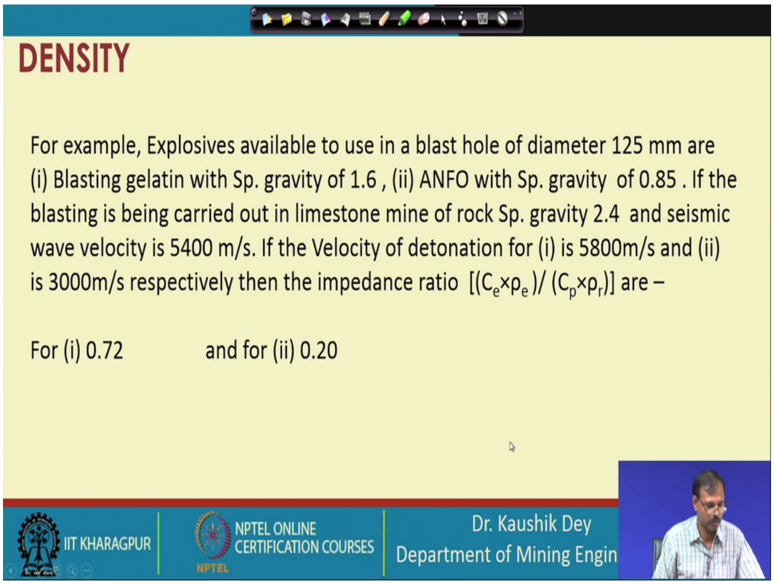

The third point which we are discussing that is the transfer of energy from the explosive to the rock, you know in a blast hole if we are considering this is a blast hole and we are placing our explosive column on this. The moment we provides some initiation in this explosive column, the first the shock is extracted from the explosive.

So, this shock basically propagates in a form of wave up propagates in a form of wave in a similar manner, if you drop a stone on the in the water of a pond the waves are propagating in all direction. Similarly the moment you detonate the explosive the shock waves are generated and the shock waves propagate in all direction similar manner. And, this propagation is similar to the propagation of sound wave and that propagation you know it is in compression dilation manner. So, this is in compression then, again in dilation, again in compression, again in dilation. So, it is moving in compression and dilation manner and by that way the shock waves travel from the explosive to the all direction.

So, what will happen in the interface? In this interface the shock waves are generated from the explosive, the next adjacent medium is rock. And, how the shock will propagate from the explosive to the rock? That depends on the simple wave propagation law; that means, any interface any interface if some wave is coming. And in interface what will happen? The some portion of the wave will be reflected and some will be reflect reflected back. So, the wave propagation follows the Snell's rule of wave propagation and similar way here the wave generated from the explosive, some portion of that will be transferred to the rock, some portion will be reflected back.

Now, how much portion of the shock energy in terms of the wave will transfer to the rock that will depend on the impedance of the shock and impedance of the energy; impedance of the energy and impedance of the rock? What is impedance? Impedance is basically the multi value, which can be obtained by multiplying the density and the wave velocity of that medium.

So, wave velocity of that medium in case of explosive is called VOD Velocity Of Detonation. In case of rock it is called seismic wave velocity or P-wave velocity which can be considered as the C p. So, explosive impedance is the density is the value obtained from the multiplying the density of explosive and multiplying the VOD of explosive. And, the rock impedance will be the value, you can obtain multiplying the density of the rock mass and the wave velocity of the rock mass.

Now, the maximum energy will be transferred from the explosive to the rock, the maximum energy will be transferred from the explosive to the rock. If this impedance of the explosive and the impedance of the rock is coming closer to each other; that means, if these are equal then the 100 percent energy will be transfer from the explosive to the rock, but rarely you can have the equal impedance you may have a have an impedance closer to one. Basically our requirement is that as the rock part, we do not have any control on that. It is in the in situ of the earth, rock is in the in situ of the earth and as it is obtained there we have to take care of that, but we are having the option we can change our explosive or we can change the property of the explosive.

So, that we can match the explosive with the rock and that can be obtained only by changing these 2. So, our objective is that we can choose the explosive in such a manner. So, that the explosive impedance should come closer to the rock impedance, but practically there are some problems. The first problem is that in general the rock density is very very high. You have seen in the first lecture where we have described our mother earth. How it is constitute and you have found the density of the earth is increasing towards the core of the earth? And it is less in the surface, then also though we are excavating our rock close to the surface, then also on an average the earth surface is having a density more than 2 or specific gravity more than 2 density more than 2 ton per meter cube or 2 gram per C c.

So, that is why the density of the rock is in general higher, than the density of explosive the density of explosive which we are using now a days having a range between the 0.85 to 1.6 or 1.7 something like that. So, that is why the density of the explosive is more or less than the density of the rock. Sometimes in sunstone or limestone in those cases we are having rock density in and around 2.5. In case of a chromite etcetera which are very strong rock, very heavy rock, in those cases the density may go up to 7 also 7 ton per meter cube. So, these are very very high density material in those cases we have found our impedance matching is becoming difficult.

Let us see the next slide, then we will understand then we will understand how the density is basically influencing the influencing the impedance? So, for example, explosive available to use in a blast hole of diameter 125 mm as we have got in the last problem are and we are using the same blasting gelatin of specific gravity 1.6, and ammonium nitrate fuel oil of specific gravity 0.85. Now, if the blasting is being carried out in a limestone mine some rock specific gravity of 2.4 and which is having a seismic wave velocity of 54 000 meter per second. Then, we can understand the impedance ratio; that means, the explosive impedance and rock impedance ratio will become 0.7 2 for the blasting gelatin and 0.2, if you express it in percentage 72 percent for blasting gelatin 20 percent for the ANFO.

Because, the blasting gelatin is having the higher density and also the higher velocity of detonation whereas, ANFO is having low specific gravity as well as the low velocity of detonation. So, that is why the energy transferred from the ANFO to the rock mass will be around 20 percent much much lesser than the energy generated on detonation which in, but on the other hand in case of blasting gelatin it is becoming 72 percent so, which is much much better utilization of the energy.

So, basically this specific gravity dictates a lot on the energy transfer condition from the explosive to the rock mass. So, that is why the specific gravity or density of the explosive material is very very important, if you are considering about the energy utilization of the explosive or the transfer of the energy from the explosive to the rock.

So, that is why this density often becoming a has a predominant role on the property performance of the explosive while you are carrying out the blasting.

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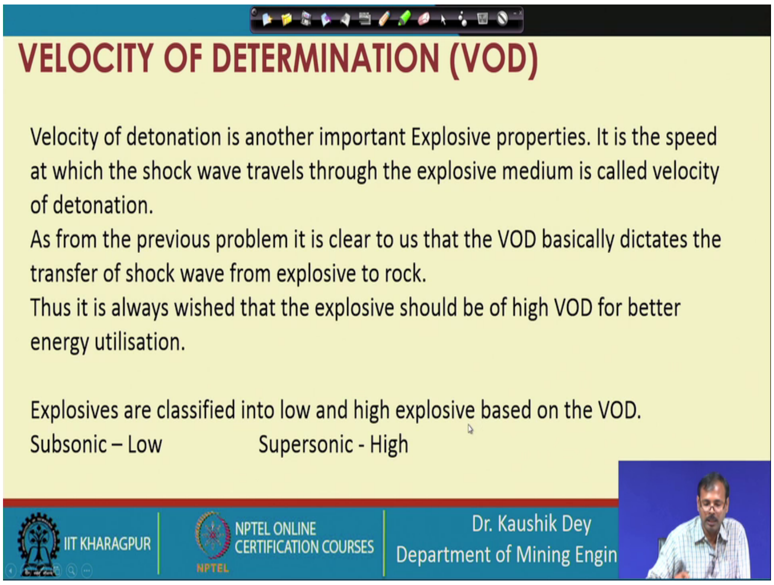

Similarly, the second parameter which is very very important is the velocity of detonation; that means the propagation wave propagation velocity seismic wave propagation velocity inside the explosive material. So, velocity of detonation is another important explosive properties, it is the speed at which the shock wave travels through the explosive medium is called velocity of detonation. So, the shock wave velocity in the rock and shock wave velocity in the explosive both are more or less similar both appear are passing through those medium, but when the it is passing through the medium, that time it is speed is considered as the velocity of detonation.

So, from the previous problem it is clear to us that the VOD is basically dictates the transfer of the shock wave from the explosive to the rock. And, thus we always want the explosive should have a higher VOD. So, that we can have a better energy utilization in case of blasting, but VOD may not be always available very high because specially in Indian mining condition it has been found that most of the nitrate with best explosive, which are generating more VOD or band here.

So, the commercial explosive available are ammonium nitrate based and that is why their VOD are relatively less ok. So, that is our present problem that is why the energy utilizations are also very limited. However, explosives are classified in 2 groups depending on the VOD where this is already told you while we have discuss the explosive that time. The low explosive is called those explosives which are having subsonic VOD and high explosives are those explosives which are having supersonic VOD. So, that is why the VOD is one very very important parameters for the explosive as the, explosive property.

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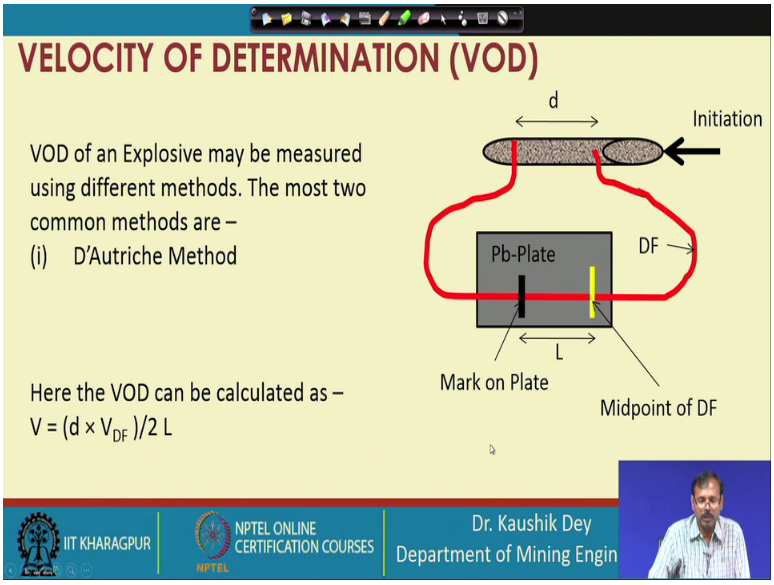

How we can measure the velocity of I think there is some problem in the slide please correct it, this is the velocity of detonation. So, this is the velocity of detonation. So, velocity of detonation of an explosive may be measured using different method. So, in this class we will discuss more most common two method; one is the D'Autriche Method, which can be applicable in the laboratory condition.

And, let us see, what is D'Autriche Method? D'Autriche Method is applicable for a column of short column of explosive or for the detonating fuses. And, you can see the experimental setup, where a column of explosives is kept. Initiation to the column is given from this side and the explosive column is tied with to with a detonating fuse at this point and that this point. So, this explosive and this detonating fuse are tied at this point and a middle portion of the detonating fuse is kept or tied on a led plate. And, the middle point of the detonating fuse is mark at this position.

Now, the moment initiation is given to the explosive. The initiation first reaches at this point the moment initiation reaches at this point that time that detonating fuse of this point got the initiation. Now, the initiation is carrying through the explosive column towards this site and also the initiation carries from the detonating fuse whose VOD is known to us from this site. The moment the initiation reaches at this point that time the this detonating fuse you receive the initiation and the initiation starts detonation of the detonating fuse started from this side towards this direction. So, in both the cases that detonating fuses are having the initiation and the initiation propagation directions are mouth to mouth to each other. And, this is the point, where both the initiations are meeting each other and as both the initiations are meeting each other it gives an impression on the led plate.

Now, from this we are having a known point this one which is the middle point of the detonating fuse, we are having a known point mark point at this one on the led plate which is the meeting point of the both the initiation on the detonating fuse. Now, from here we are having one known length that is L distance between the middle point and the mark on the plate, and one known distance from that is the distance apart of the tying of the detonating fuse on the explosive column. By, knowing this two we can determine the VOD of this explosive or detonating fuse whose VOD is not known to us.

If we are having the no knowledge about the day VOD of the detonating fuse. In those case this formula can be used to find out the VOD of the unknown explosive as the distance of the time part of the detonating fuse in the explosive, the VOD of the detonating fuse and dividing the twice of the length of the distance between the mark on the plate and the midpoint of the detonating fuse. So, from there we can identify we can calculate the VOD of the explosive column, but there are some problems, but there are some problems of the about the D'Autriche Method.

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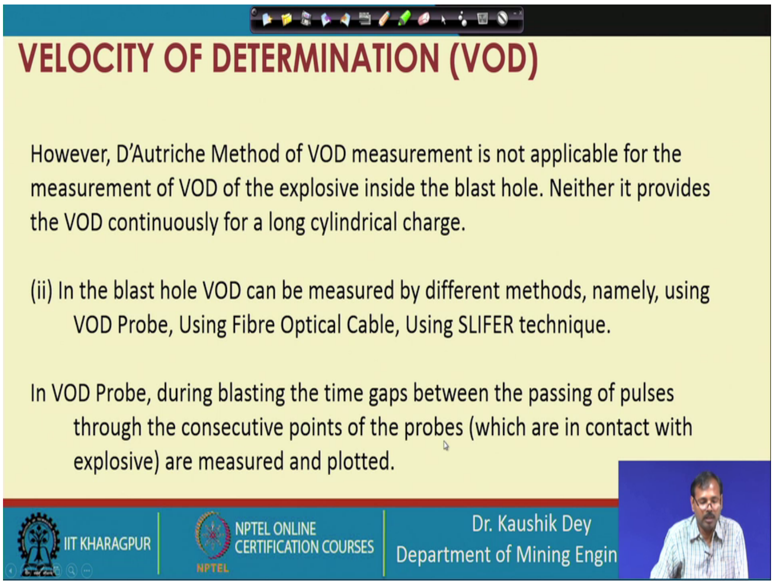

The, first problem is that it is not applicable for the measurement of the VOD of the explosive inside the blast hole. Neither, it provides us the VOD continuously for a long cylindrical charge. So, this VOD which is obtained from the D'Autriche Method is basically the average VOD of the explosive placed between the 2 tying of the detonating fuse. The second problem is that, in the blast hole VOD can be measured by different other methods, which is not described in the which is not possible in case of the D'Autriche Method.

So, the blast hole VOD can be measured using the different methods VOD Probe, Using Fiber Optical Cables, Using SLIFER technique. And this 3 technique can give us continuous VOD, in case we are having a VOD placed in the blast hole. So, that the possibilities is that this is a full pressure blasting maybe carried out then also the VOD can be measured we need not to depend on the samples to be taken in the laboratory to carry out the test.

. So, let us see the first one. First one is the VOD probe. VOD probe is basically during the blasting it measures the time gaps, while the pulses are passing through the consecutive points of the probes, which are in contact with the explosive. That means, the probe is placed along the explosive column having the different consecutive points and the whenever the points are receiving the pulse, that pulse are time of those pulse are memorized or calculated in the oscilloscope, then the time gap between 2 consecutive points in the probe whose distances, how much distance such apart there are previously know to us can be easily obtained. And from there the distance divided by the time gap is giving us the VOD.

And, in those case if you are having n number of probes placed at n n number of distance on those cases we can have different timed gaps in between those consecutive probes. And, we can have the different distances of those consecutive probes from there we can have a continuous VOD measurement along the column explosive column. But, as probe is having little bit problem the main problem is the probe that we need to place the oscilloscope close to the probe and that is why, we cannot have a very full pressure blasting system, if we are measuring the VOD using the probe.

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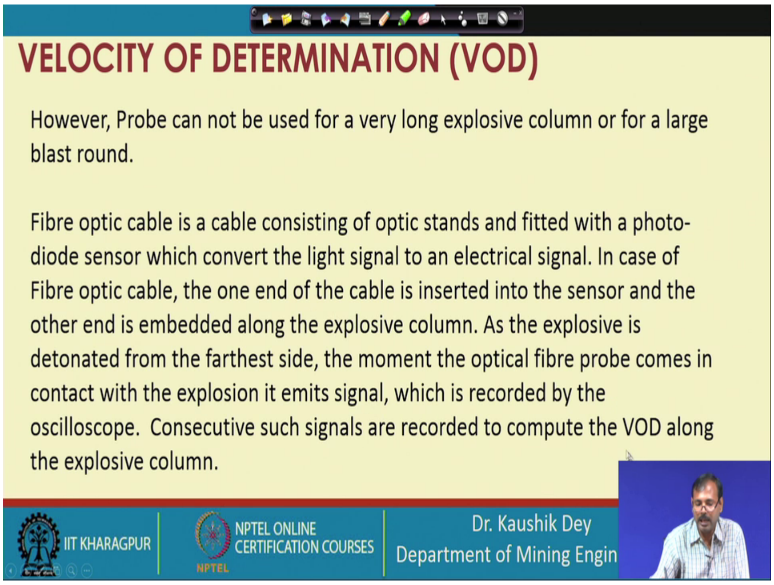

So, probe cannot be used for a very long explosive column not for a very large blast now, but in hole VOD can be measured using the probe. However, the problem of the probe can be overcome by using the fiber optic cable. Fiber optic cable is basically consisting of optic stands and fitted with a photodiode sensor, which convert the light signal to an electrical to an electrical signal. In case of fiber optic cable one end of the cable is inserted into the sensor and the other end is embedded along the explosive column. And, as the explosive is detonated from the further side the moment the optical fiber probes comes in contact with the explosion it emits signal. And, those signals are recorded in the oscilloscope.

So, consecutive such signals are recorded and computed the VOD using the same technique as the probes are carrying out. So, we are having continuous input signals and from those input signals we can calculate the VOD continuously. So, basically this is a continuous monitoring, almost continuous monitoring of the VOD along the blast hole. And, this is very easy. And, some problem in the probe that we cannot have a long explosive column, cannot have a large blast round that can be overcome in the fiber optic cable, because we can have a longer cable length and we can remotely monitor the VOD away from the blast hole.

So, is it may be huge long explosive column, it may be a full pressure blast probe, then also the blast VOD of the explosive in that blast probe can be monitored using the fiber optic cable, but there is a little bit problem in the fiber optic cable. The problem in the fiber optic cable is that it is little bit costly.

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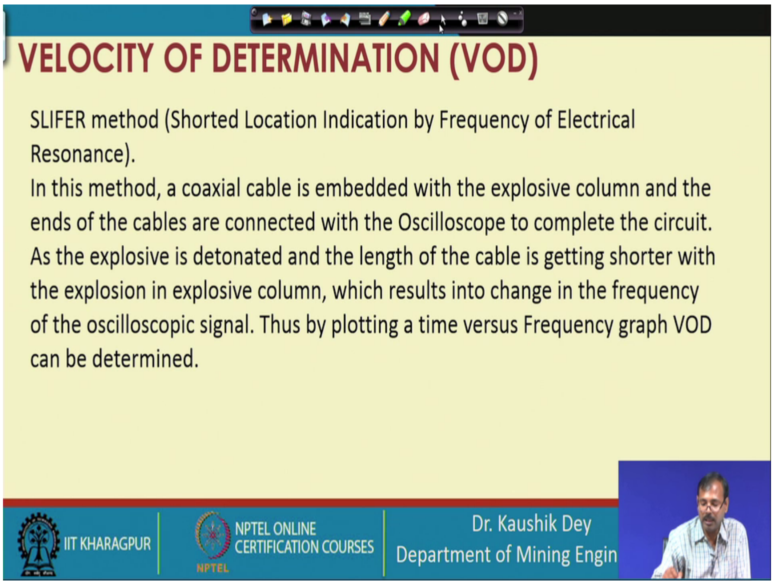

As the fiber optic cable is costly. So, the VOD monitoring cost becoming high and that is why the people are not encourage enough to measure the VOD frequently in the mine. So, to overcome that problem SLIFER method that is the Shorted Location Indication by Frequency; Shorted Location Indication by Frequency of Electrical Resonance. So, this SLIFER method is used. This is similar to the fiber optic cable method, but instead of fiber optic cable which is very costly that is replaced by a coaxial cable which is very

very cheaper. The coaxial cable is embedded with the explosive column and the ends of the cables are connected with the oscilloscope to complete the circuit.

Now, as the ends of the cables are connected with the Oscilloscope to complete the circuit. The explosive when it is detonated and the length of the cable is getting shorter with the explosion in explosive column, this results into the changes in the frequency of the oscilloscopic signal. So, what is happened? As the electrical resistance with the shorting of the cable length coaxial cable length, electrical resistances are changing and the oscilloscope is getting the different frequency signal because of that from the coaxial cable. And that is why a plotting is carried out between the frequency and the time or frequency and with the distance.

Basically, time is giving us the shorting of the length. So, it is a frequency with the length shortage, length shortage with which gives us the distance of initiation travel or detonation travel in the explosive. And on the other hand this length is also given in a time frame. So; that means, we can gave we can obtain the time versus length considering the frequency and from there we can easily compute the VOD. This coaxial cable is not very costly it is very very cheaper and that is why this allows us for the continuous VOD monitoring and remotely monitoring for a full pressure blast round. So, this basically eliminates all the problems of infield VOD measurements and now a days popularly VOD is being monitored.

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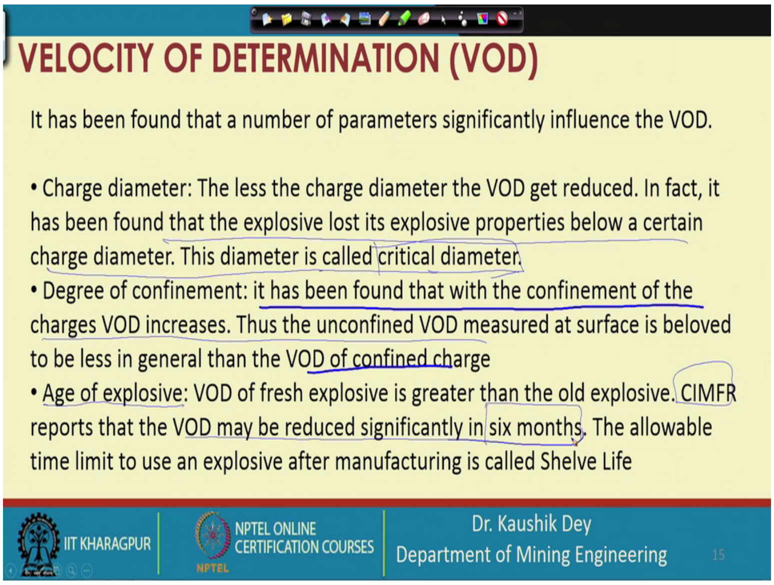

So, it has been found that a number of parameters significantly influence the VOD charge diameter. In fact, increasing the diameter of the charge the VOD get increased decreasing the charge VOD get reduced. And on doing so, it has been found there is the diameter, there is a diameter below which below which the explosive rules lost his explosive properties and that diameter is called critical diameter. So, every explosive has a critical diameter and below that diameter explosive the lost his explosive parameters that is why this diameter of the charge is very very important.

Second is that, it has been found that the with the confinement of the explosive VOD get increased; that means, when the VOD is measured using the D'Autriche Method in the surface, that time the VOD obtained is very very less than the VOD obtained in case of in the hole VOD measurement. So, if the VOD is measured if the VOD is measured in case of in the hole in that case we can have a increase VOD for the confined condition.

Similarly, the age of explosives is another important factor and CIMFR has found that the significantly the VOD get reduced in the, if it is age is more and it has it has been proposed that it is no explosive can be allowed to be used, if it exceeds 6 months. So, that is why the age of explosive is very very important the allowable age of explosive is called the shelve life; that means, that is the limit up to which the explosive can be kept in the store.

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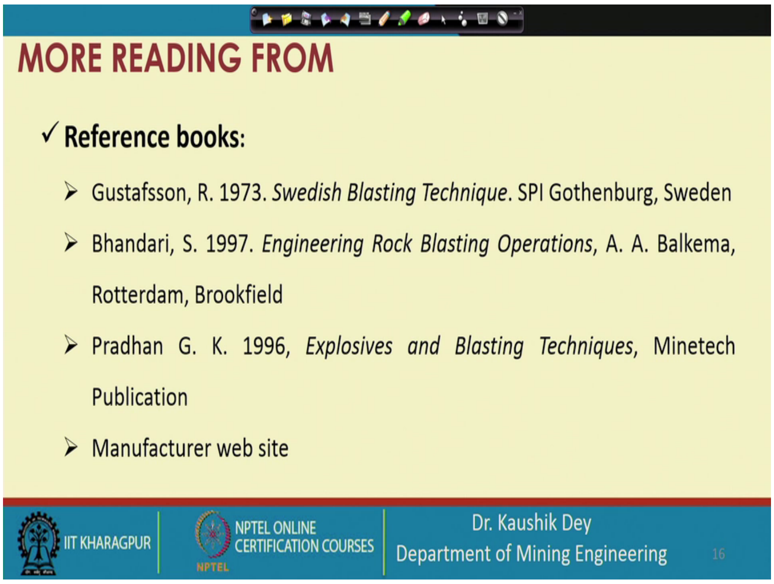

So, these are the these are the few reference you can read those reference for knowing more on those explosive and explosive properties, specially the books written by G. K. Pradhan explosive and blasting techniques will be very very useful for this chapter.

Thank you.