Drilling and Blasting Technology
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Lecture - 35
Blasting results – 3

Let me welcome you to the 35th lecture of Drilling and Blasting Technology course. We are discussing the blasting result. This is the 3rd lecture on Blasting result in which we will discuss some of the blasting result, which we are discussing in the last class also.

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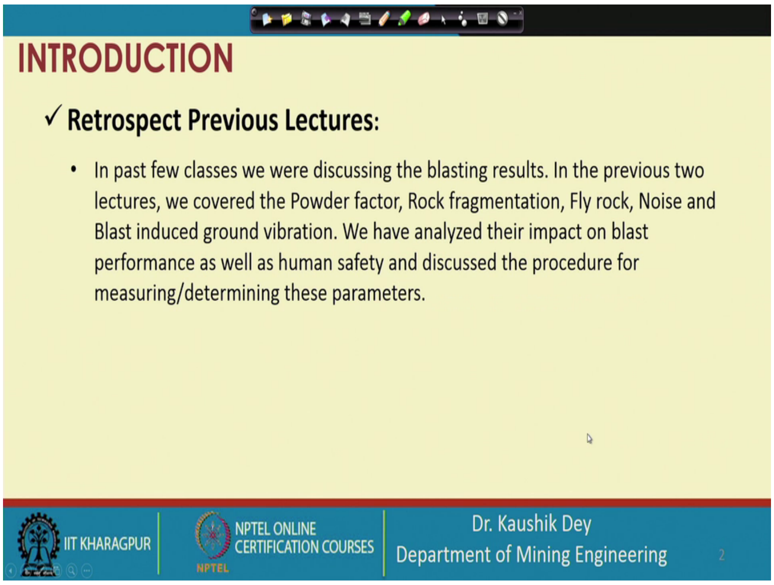

Like every class, let us retrospect what we have covered in last few classes. In past few classes, we are discussing the blasting results. In the previous two lecture, we have covered the powder factor, which is basically the economic parameter through which we judge whether our blast is economically acceptable or not. We have covered rock fragmentation, basically which is the basic objective of the blasting fragmenting the rock, how we can assess that one we have covered that part also. We have covered fly rock, which is basically the safety parameter of the blasting. Noise and blasting induced ground vibration, we have partially covered. Noise we have covered, partially we have covered blast induce ground vibration, where we have discussed the different types of waves, which are generated during the blasting, how those obstacles like that.

We have analyzed the impact of these different blast performances, which we have discussed, and as well as the human safety, and discuss the procedure for measuring or determining these parameters. So, we have already discussed, how we can measure powder factor, we have already discussed how we can measure the rock fragmentation characteristics, how we can find out the fly rock distances, how we can determine the noise, and we will discuss how we can measure the ground vibration.

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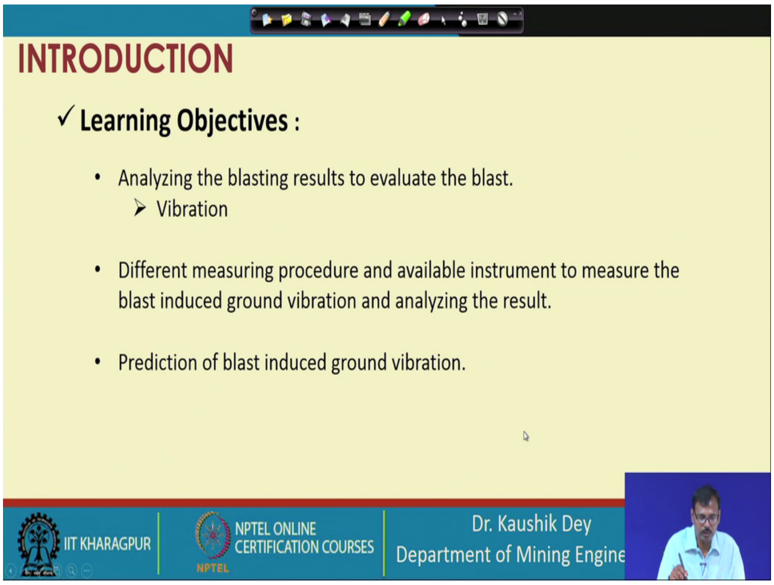

So, objective of this present class is that, to analyze the blasting result to evaluate the blast in which we will discuss the ground vibration monitoring and the measurement techniques. Different measuring procedures and available instruments to measure the blast induced ground vibration and analyzing their results. Prediction of blast induced ground vibration through different estimator. So, this is the basic objective of today's class.

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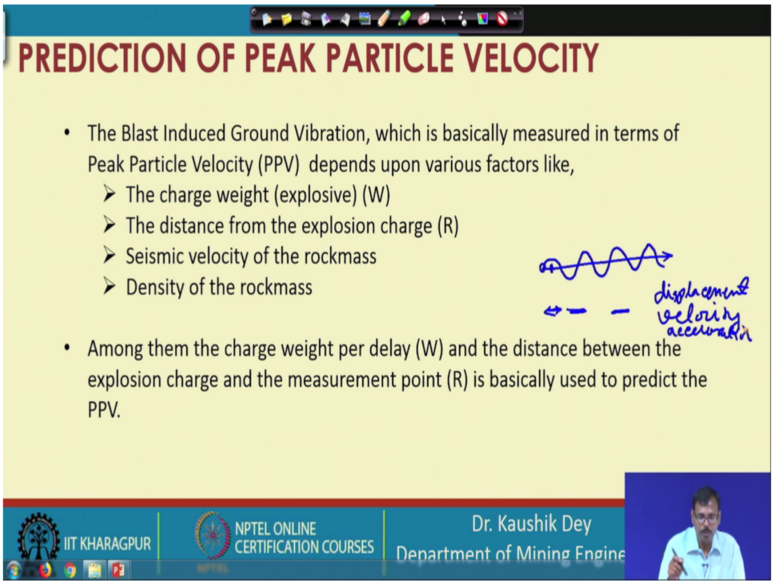

And we have already discussed that during blasting explosives are detonated. And on detonation of explosive, first the shocks are released from the explosive. So, the first shock energy is travelled through the rock medium in a form of mechanical wave. And we have already known that this mechanical wave can be classified in two groups; one is pressure wave P wave, which transmit in compression dilation, second one is the shear wave, which transmit in shearing action.

So, these are the two basic body wave generated from the explosive detonation. And when the body waves are reaches in the reached in the contract surfaces that time it converts into the surface waves, there are n number of surfaces major one is the Rayleigh wave. So, these are already discussed.

And the blast induced ground vibration, which is basically measured in terms of particle velocity that means the velocity of the oscillation of the particle. So, if you see the wave is propagating, this is the source of the wave, and the wave is propagating in all the direction from the source in similar to a sign wave, in last class we have already discussed. If you drop a stone on the pond water, you will find the waves are generated and the waves are moving from the moving away from the source towards the side of the pond. So, this is the similar way, the waves are propagating in all the direction from the source.

And there is if you look at the leaf which is floating on the water, you will find the find out the leaf is going upward and downward direction, but actually there is no displacement of the leaf. So, what is happened, the particle which is at this position which is at this position is basically oscillating is basically oscillating like this with time oscillating like this with time, and thus there is no actual displacement of the particle from that position, only the relative displacement occur for a time bound manner, but no displacement occur in eventually on to that particular particle.

So, basically the particle is oscillating on the on the same place towards each direction. And this wave which is propagating here may be decided as the displacement with time, which basically gives the position of the material with time, second one we can measure the velocity also with time, and we can measure the acceleration also with time. So, basically when a particle is oscillating, we can measure the movement of the particle either in terms of displacement or in terms of velocity or in terms of acceleration of that oscillation.

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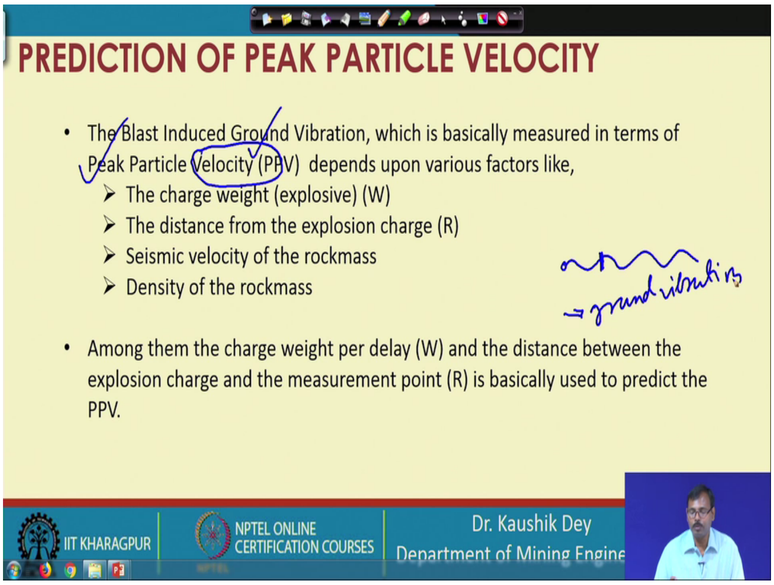

In mining purpose, while we are basically define our ground vibration, we express the vibration in terms of velocity in terms of velocity. So, basically we are interested in the measuring of the velocity of the oscillation of the particle with respect to the time. So, this is the major measuring technique and we found we have found that this velocity, the peak of the, that is called peak particle velocity that means, from the blast vibration, the vibration which is moving away from the source.

Now, we are looking at the oscillation of the particle, so this is becoming the ground vibration, this is becoming the ground vibration that means, we are now talking about the oscillation of the particle because of the blasting, so that is why this term this term which we are using here is blast induced ground vibration that means, the oscillation of the ground because of the blasting waves, we are discussing here. And this ground vibration we are measuring in terms of velocity.

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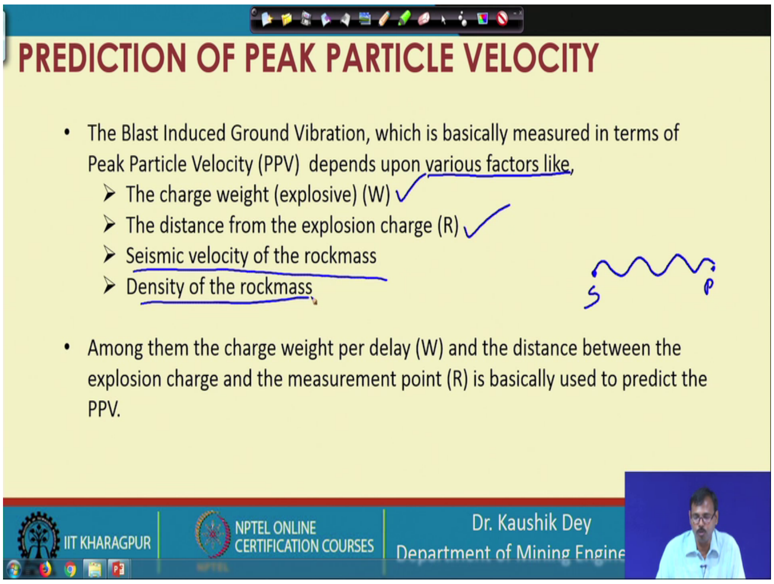

And we are interested the peak value of that velocity considering the stability of the ground or the compactness of the ground, so that we can find out how much magnitude of vibrating ground vibration is being generated because of blasting up to a sensitive structure or up to a point of interest. And it has been found a various factors are affecting that one.

The first factor which is very very important is the charge weight that means, the explosive charge, which is being detonated for that blasting, especially it is the at a particular instant, at a particular instant what is the charge that is being generated. Second one is the distance of the place, where our point of interest is lying.

Then the seismic velocity of the rock mass, because the source the point of interest. So, this is source, this is the point of interest, the wave is blast wave is propagating through this, and compactness of the rock mass basically gives us the damping coefficient that means, the how much wave blast wave will be damped prior to reaching to the point of interest is also very very important, and that is why the density is also very important, because the energy transferred from one medium to another medium depends on the density as per Snell's law is known to all of us, so that is why these are these are very very important factors.

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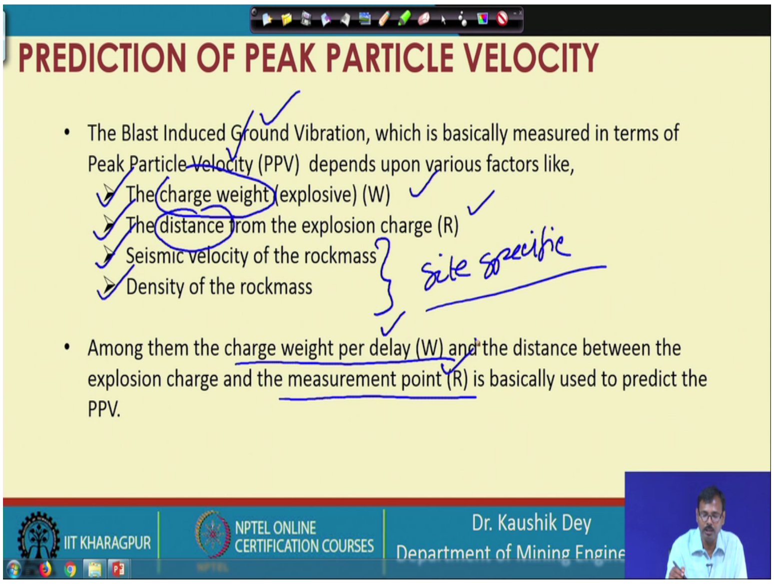

Charge weight or explosive charge at that particular instance, then the distance from the charge explosive explosion charge to point of interest, the medium characteristics, and the again the medium characteristics, so these are very very important. And it has been found by the researchers that if we are considering the charge weight and the distance as two variable, then the rest two part may be taken care of well by some site specific constant.

So, this can be categorized as a site specific condition, and may be included in a constant for these two variables. And considering these, it has been found that the major variables dependent variables which are basically guiding the ground blast induce ground vibration for a particular point or you can say the peak of that peak particle velocity of that particular point, basically a dependent of this one and this one.

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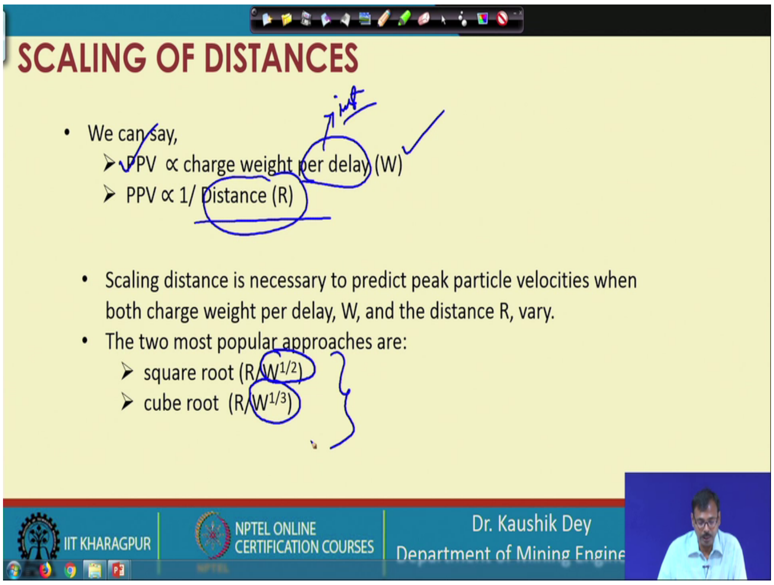

So, with this consideration, researchers have found that peak particle velocity that means, peak magnitude of the ground vibration in term measured in terms of velocity is directly proportional to the charge weight per delay means at that particular instant at that particular instant, and it is inversely proportional to the distance. So, this is very very important point that it has been found, it is proportional to the charge weight, it is inversely proportional to the distance.

And after that with the further research, it has been found at as basically it is the proportionate distribution of the energy, it may be approximated. The PPV is dependent on some power of the proportional to some power of the charge weight, it may be square root or it may be cube root. In consideration that, it may be spreaded in sphere or it may be spreaded in area.

However, the developments of these two are based on some dimension less constants based on some dimension less analysis, so that is why their development are based on that, but that is not the subject of this lecture. So, our dependency has been fixed in consideration with this square root scaling distance and cube root scaling distance, where the distance, where the distance is considered as a variable and some power component of the charge is considered as another dependent variable for this statistical approximation of the peak particle velocity.

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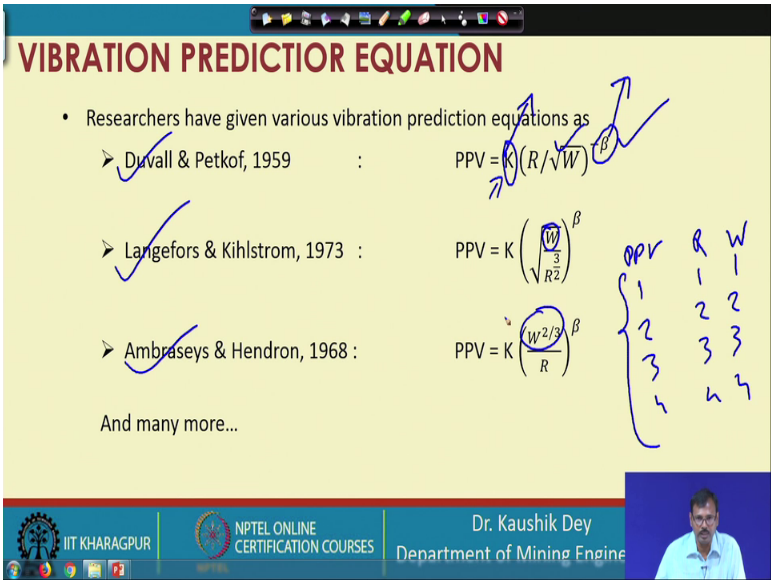

And different researchers, researchers have proposed different predictor equations for blast induced ground vibration. And you can see the Duvall, Petkof as are good for square root scaling distance, this square root scaling distance for the peak practical velocity analysis. And they have are good two constant, these two are site specific constant, this is propagational constant, and this is a site specific constant or you can say rock constant.

These two are taking care of basically the rock parameters or the parameter, which are dependent on the medium through which the blast waves are propagating. So, if n number of values are measured for a particular site, this PPV values are measured, R values are measured, and W values are measured, then all after getting all this reading, a particular plot may be created statistically analysis the regression through this regression analysis, the constant K and constant beta can be established very easily.

Langefors, Kihlstrom has proposed for R to the power 3 by 2 that means, the weightage are given this weightage are given less to this W. Ambraseys, Hendron has proposed a the more weightage on the W. So, like that way different scaling distances are possible for possible as approximated by different researchers from time to time. So, this is site specifically this is designed, however dependency are proposed by different researches at time to time.

And the proposed predictor a scaling predictors are equally acceptable for all the cases. Basically, this all these equations this all these equations are basically giving some additional weightage or some lesser weightage on some dependent variables, so that is why this most of the cases if you are having a one particular set of data, and if you try to fit all this predicted equation, you will find out in most of the cases, this dependent variables this constants will be found statistically acceptable for all the cases, so that is why it is the individual choice that what type of predictor equation or predictor will be followed by that particular user.

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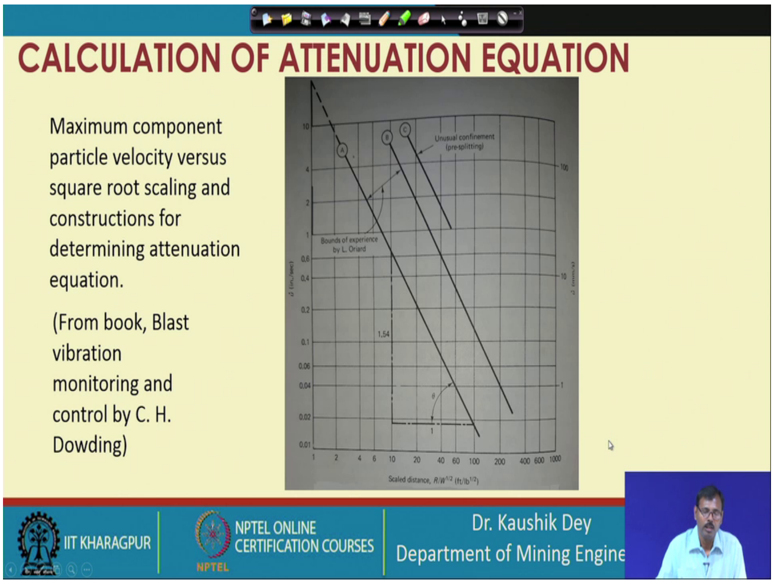

So, what has to be done in this case? This is the plotting given by Dowding. First time he has plotted this predictor like this. Let us analyze this one the next slide.

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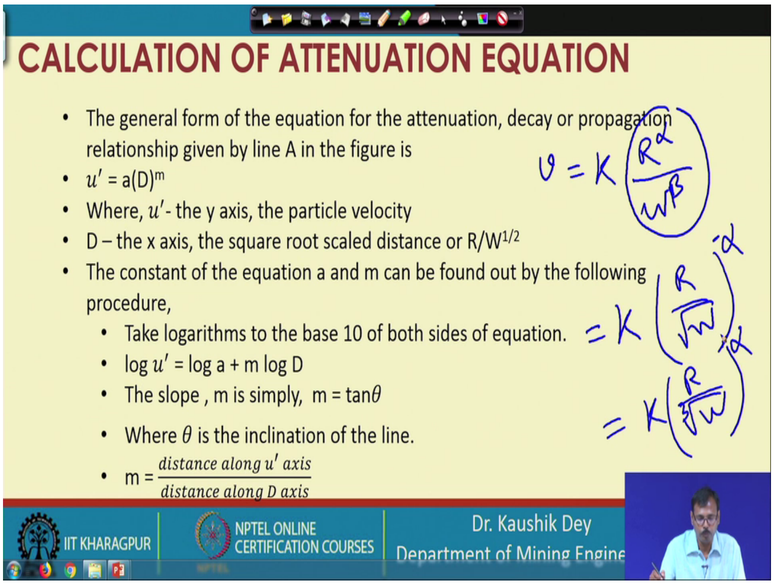

What approximation carried out in this, see as this is in last class we have seen, this is a sinusoidal wave, we are measuring the velocity. And as per our dependency, we have found that velocity is proportional to K may be R to the power alpha or W to the power beta that may be the some understanding, which is carried out. In the previous slide, we have seen different dependency of this alpha beta is proposed.

And in square root, it is basically proposed like this; and in cube root, it is proposed cube root of W by alpha, obviously this alpha is having a negative value, because we have seen the peak particular velocity is inversely proportional to R, so that is why this alpha is supposed to have a negative value. So, this is the simple arrangement, which is agreed by all the researches in different times.

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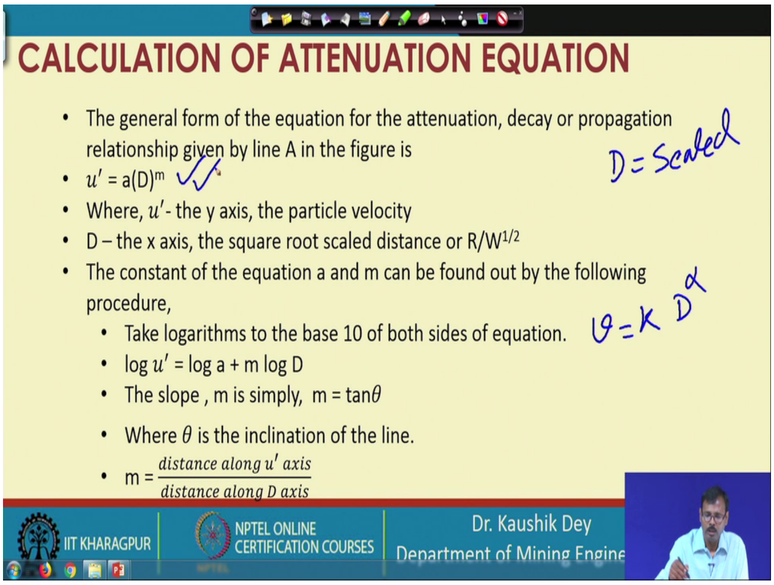

And this R by K R by root over W or whether it is R by cube root of W, it is considered as a D, which is called scaled distance; and this scale distance may be square root cube root or may be n number of variations are there as we have observed. So, it has been found the velocity is proportional to D to the power alpha, which is expressed as this in this case.

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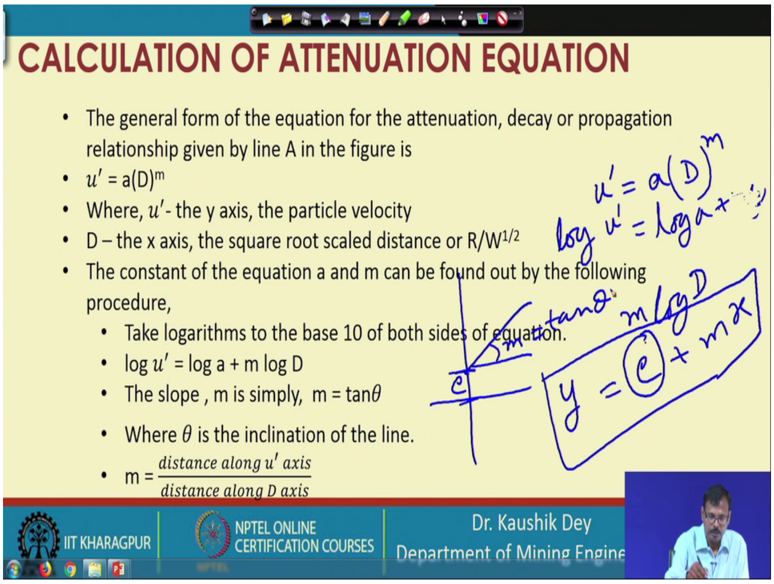

So, if you carry out this the same writing D to the power m and take the log in the both side, you will find log u dot is equal to log a plus m into log let me rewrite it plus m into log D. So, by taking this log, we are making this equation in a straight line equation, which is a straight line equation, so that that can be plotted very easily, so where c is the c is the value, which we observed when x is equal to 0 that means, if it is plotted like this, whatever value observed here that is c, and m is basically the slope of this equation.

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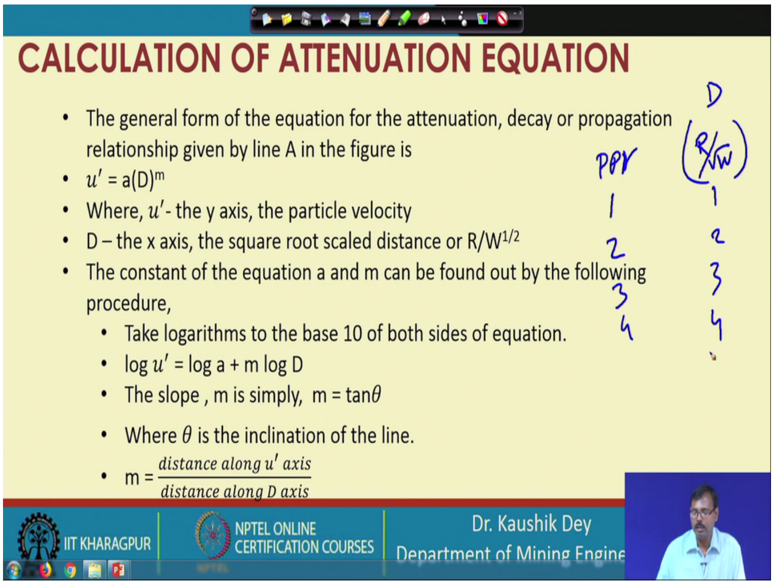

So, basically this dependency we have converted by taking this log in both the side in a linear form, so that if we are having a data PPV, then say R by root W let us consider this is the D. So, if we are having this value, then after that we go for taking the log value of this one. So, let me erase this one.

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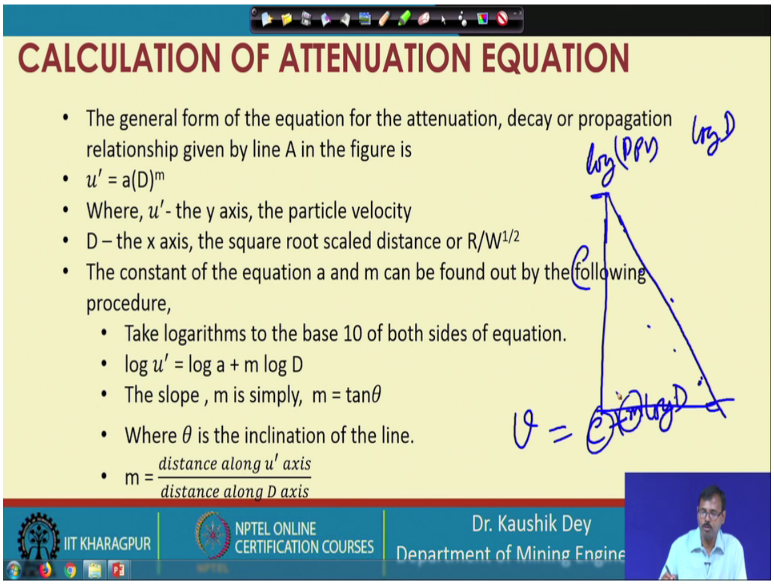

Then we have to compute the log PPV and log D value, then whatever value will be observed. After getting this value if we plot a line in between this, we will get a C value, we will get a C value here, and we will get the slope of this one and we can plot considering this, we can get the equation v is equal to c plus into m. So, this c and m value can be computed very easily.

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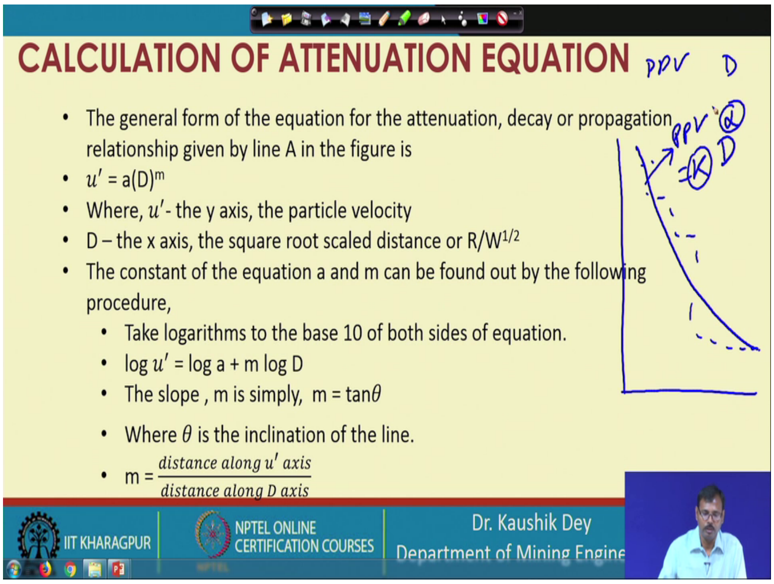

However, nowadays we need not to go for doing all these things because of the computer application. We can directly plot a non-linear curve, where PPV and D values may be plotted like this, and a non-linear power curve may be plotted regression line may be plotted for those points, and the equation will be given by the computer like PPVs directly equal to K, which is the constant given by the computer D to the power alpha. So, this K and alpha value will be directly given by the computer, so that is possible nowadays with this present computational system. In fact, this also ensure us to having the flexibility with that square root scaling system.

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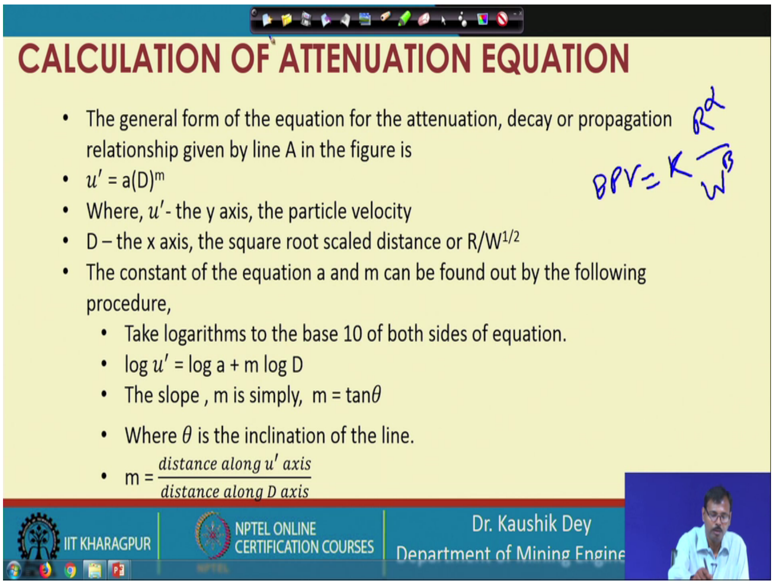

And we can now go for PPV is equal to K into R to the power alpha W to the power beta, which is basically the generalized equation for the blast vibration prediction.

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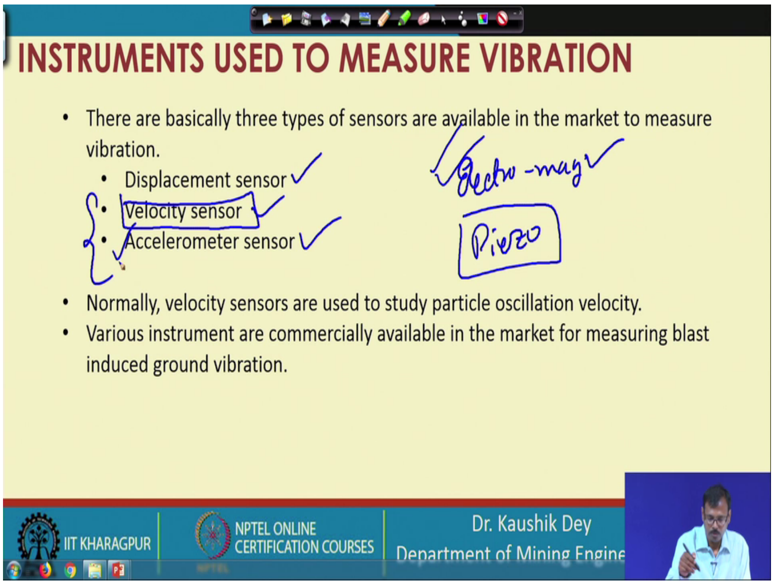

So, this is more or less we plot it like this after the ground vibration predictor is developed. We go for following the we go for carrying out the blasting or we re-design our charge quantity considering the proximity of the sensitive structure or proximity of the point of interest, we re-design our blast by after viewing this vibration magnitude at different places.

Vibration can be measured using the instrument, which is called seismograph. So, basically seismograph is the instrument, which measure the vibration. And this seismograph is basically having is basically having three types of sensor; one is displacement sensor, another is velocity sensor, another is accelerometer sensor. Basically, a seismograph should have one type of sensor, and the other are others are convertible.

Generally most of the seismographs are possessing either a electromagnetic sensor electromagnetic sensor or a piezoelectric sensor. If an electromagnetic sensor is reduced, in general we go for velocity measurement, because that is the natural output of the electromagnetic sensor. If we are using a piezoelectric sensor, we generally go for acceleration measurement or that is called accelerometer sensor, because that is the natural output of the piezoelectric sensor.

However all the measurements carried out by the electromagnetic sensor may be differentiated to achieve the acceleration; accelerometer sensor result may be integrated to achieve the velocity values. So, basically these two types of sensors are very very popular and very commonly used in most of the blast vibration monitoring cases.

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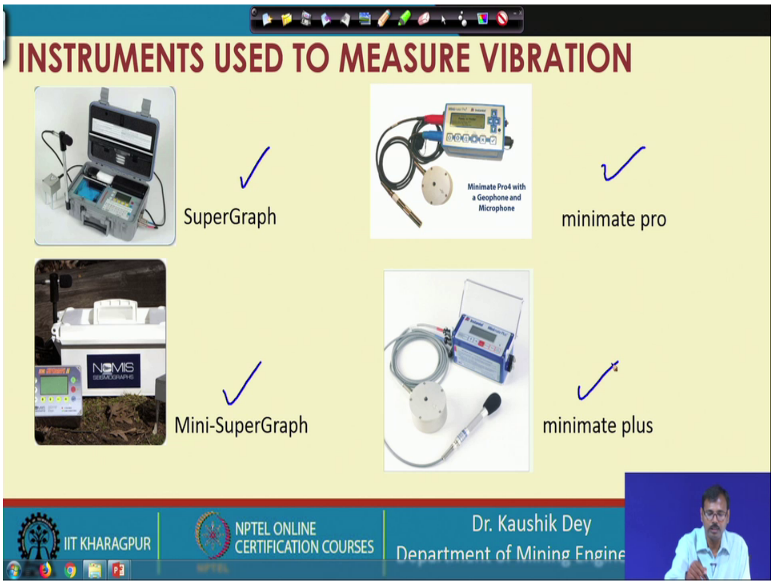

These are some of the commercially available seismograph. Most of the cases used in the Indian mice, these two are manufactured by the (Refer Time: 25:46) these are the manufactured by the (Refer Time: 25:48). And the basic principle for all the seismographs are more or less similar, and may be they are having some differences in the data accusation system or may be the data presentation system, otherwise all the seismographs are more or less similar in nature.

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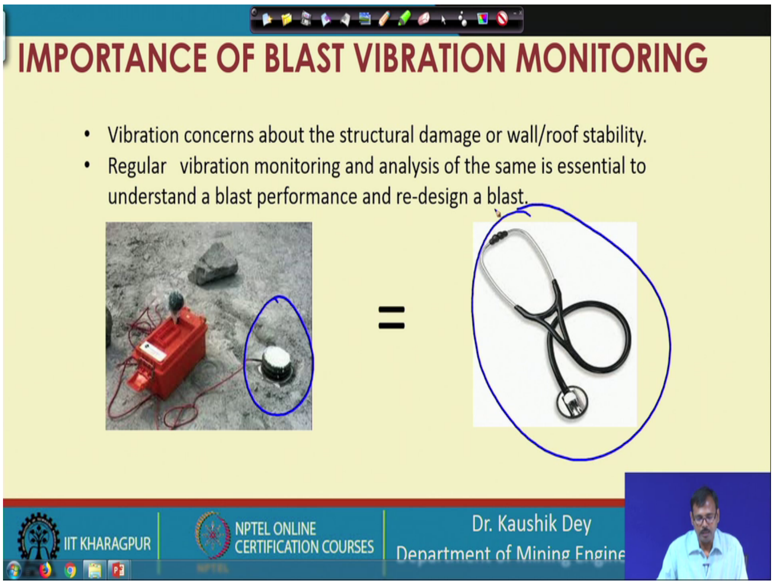

However, blast vibration monitoring is very very important, because personally I believe the blast vibration monitoring which is carried out by a seismograph is more or less similar to a stethoscope for the blasting engineers. So, a seismograph observing the result of the seismograph that is the blast vibration in a time scale or the oscillation of that particular point in a time scale, a blasting engineer may draw a number of conclusion, and the blast may be re-designed based on that.

So, vibration concerned about the structural damage. So, it is not that only for controlling the structural damage blast vibration will be monitored. However, vibration monitoring gives us the idea about how the blast is being progressed during its execution. So, basically for that, blast vibration monitoring is essential for all the blast, and that will give a very very good input to the user.

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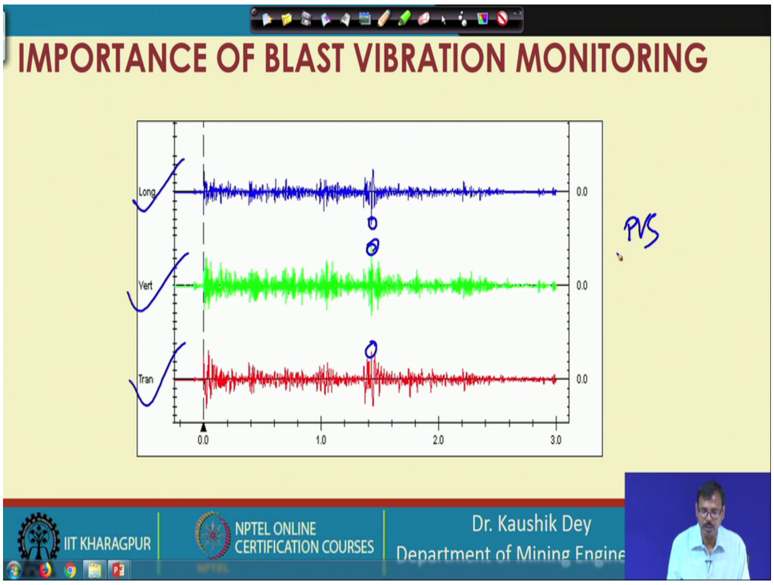

This is more or less an output, which is observed from a vibration monitoring. And you can see in last class as we have discussed, the monitoring is carried out in three channel; longitudinal channel, vertical, and transverse channel. In longitudinal channel, the sensors are facing the blasting site. Transverse is the perpendicular to that and vertical is the vertically perpendicular to that direction.

So, this is in general, and peak particle velocity may be achieved in each channel separately, so that in this case, you can see this is the peak occurred in longitudinal channel, this is in peak in the vertical, and this may be in the transverse one ok. So, this is please remember, this is the acceleration measurement. So, this is the three peaks, which are observed in three different channel.

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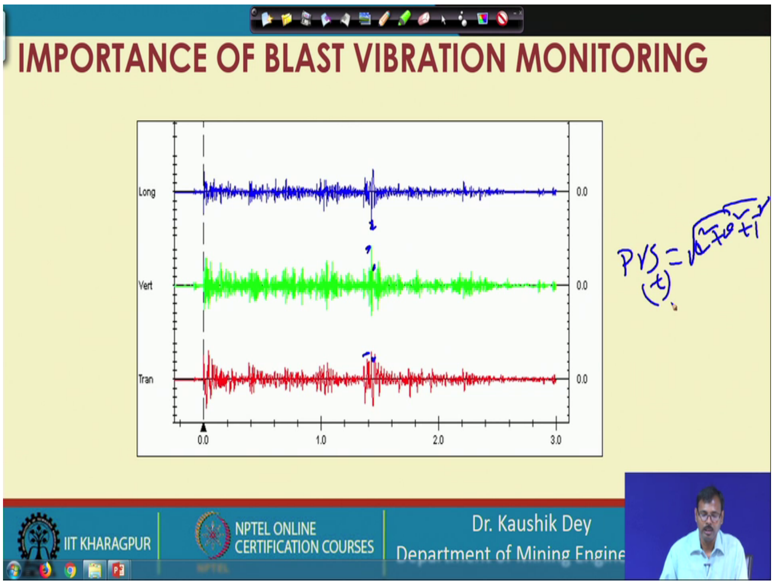

However, if you wish to have a peak vector sum that may be different, because the time of occurrence if you want to have peak vector sum, the time of occurrence of this one and this one may not be at a particular time, and this one may be of different time. So, the peak vector sum of this one and may be at this point at this place may be this point at this place has to be summed like L square plus v square plus T square, so peak of this will gives us the peak vector sum, not the individual peak of one channel. So, peak vector sum of time t has to be calculated, not the peaks are to be concerned in this case, so that is another point. One must be very very judicious, while they are using this one.

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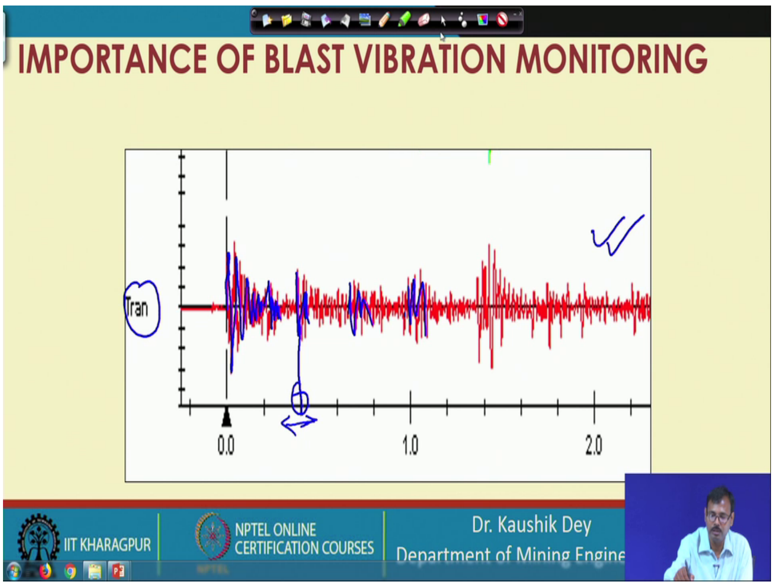

So, let us look into the wave form obtained from the one channel. So, in last slide what we have seen, I just enlarge that one what we have observed in the transverse channel. And you can see this is acceleration measuring. So, the first one which is observed is the peak, then you will find out that is gradually damping. Then probably the second delay is blasted, so the second one has come, so that is damped. Again the third one has come that is damped, then that one. So, like that way in every delay, it is excited and it is then gradually damped.

So, this is the phenomena by which one can detect, which delay is performed at what position. So, you can find out the time of occurrence of this one, and may be you can find out how much how much scattering of delay is occurred because of that one. So, this is very very important, if someone is willing to access the progress of his blast, this vibration monitoring is a good tool to him for access that one in his analysis, so that is why this is very very important.

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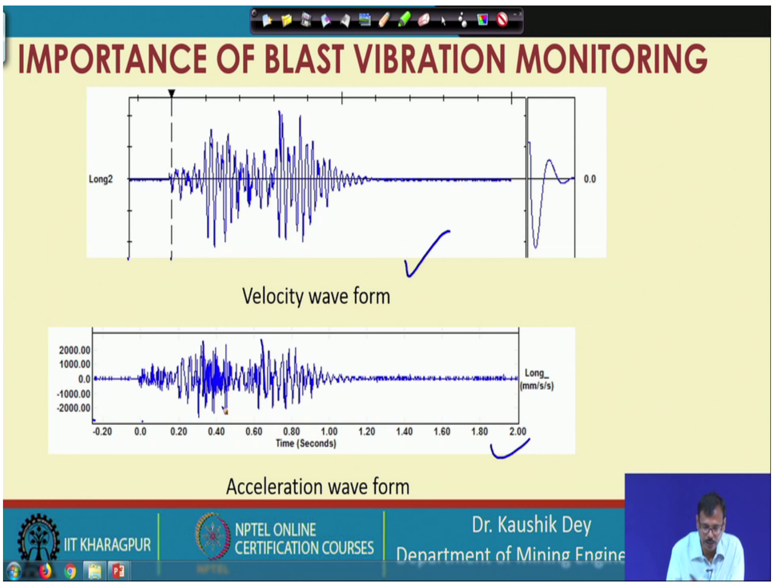

This is this slide is basically showing you the difference between this is the velocity wave form. For the same blast, if you go for the acceleration wave form, you will find out this one. I have tried to place it in a same scale, but I think it is scattered a little bit. So, this point is at this position this point is at this position, so it is little bit scattered, but if you can see the it is more or less this one is more or less similar, so this part is belongs to this part and this part is belongs to this part.

And this is as this is acceleration channel, you can find out the damping are more easily observed in the acceleration channel better than the velocity channel that is why the acceleration measurement may be sometimes very very useful for our own purpose, and that is why it is judicious. All the wave form which is measured either may be vertical scale velocity scale or may be acceleration scale has to be looped in both the scale once at least once.

So, this is in the same time scale you can see, which is properly tried to be match properly, you can see these 0s are coinciding. So, you can see this top velocity which is achieved that may not be at a at an acceleration, which is very high, so that is why it is not guaranteed that the acceleration is high, means the velocity is also high, so that is very very important thing that has to be considered, while we are discussing this wave.

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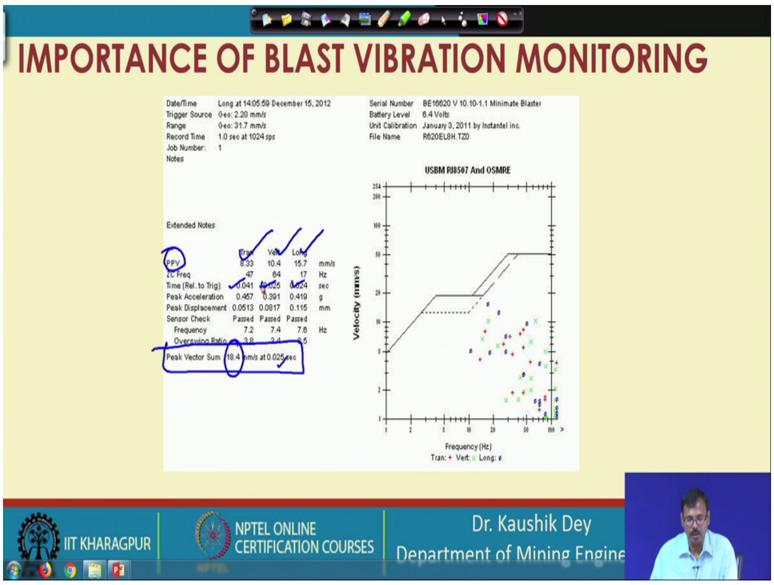

However, the structural damage etcetera are dependent on the velocity, not on the acceleration. So, in general, you can have a peak particle velocity value from the report of the seismograph in each channel it is given, its time of occurrence is also given in each channel. You can see the peaks are occurring at different times, it is 0.24 millisecond for longitudinal, vertically it is 25 millisecond, and 41 millisecond for the transverse.

However, peak vector sum, which is achieved at 25 millisecond, which value is this one, that is different from the peaks all peaks value. Though it is now coinciding with this

0.25 millisecond for vertical and peak vector sum, but there is no guarantee that the peak vector sum will be at the same point, where some peaks of the some of the channels are arriving, so that is why if here considering peak vector sum that is basically for drawing this vibration predictor that is basically a little bit pessimistic analysis, but if someone is considering the peak of any of the channel or may be the highest peak of the channels, then it is an optimistic prediction one, so that is why these are none is wrong. Please remember, none is wrong, but it is the consideration of the analysis, some analysis is optimistic analysis, and peak vector sum analysis is basically a pessimistic analysis.

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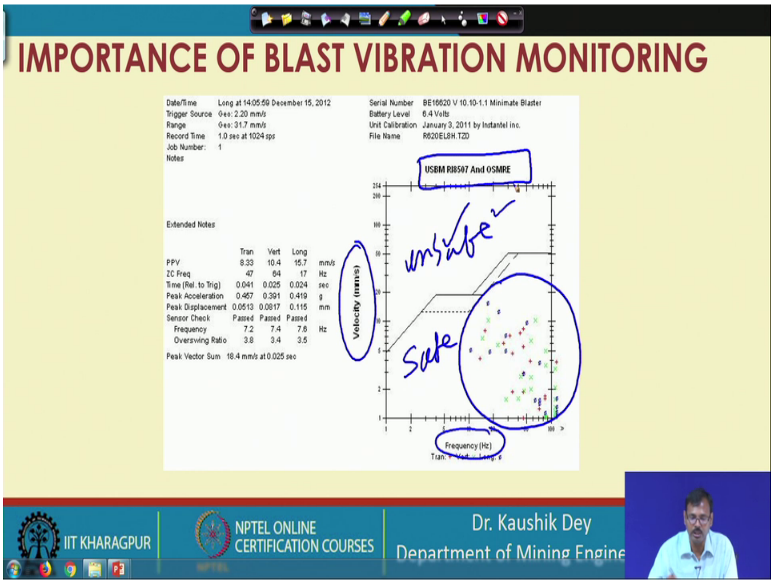

This is the plotting with respect to the frequency of the different peaks, which are observed. These are L, V, T is also given, which one is absorbed at which place. And if any peak is going above this one, this is if it is below this one, it is considered safe, above this one is considered unsafe. Though this is the very very crude thinking, but anyway this is considered a not safe answer by can say it is over or lower. So, this is if it is these are the peaks observed here, is considered acceptable; if it is there, is considered unacceptable blast design modification is required.

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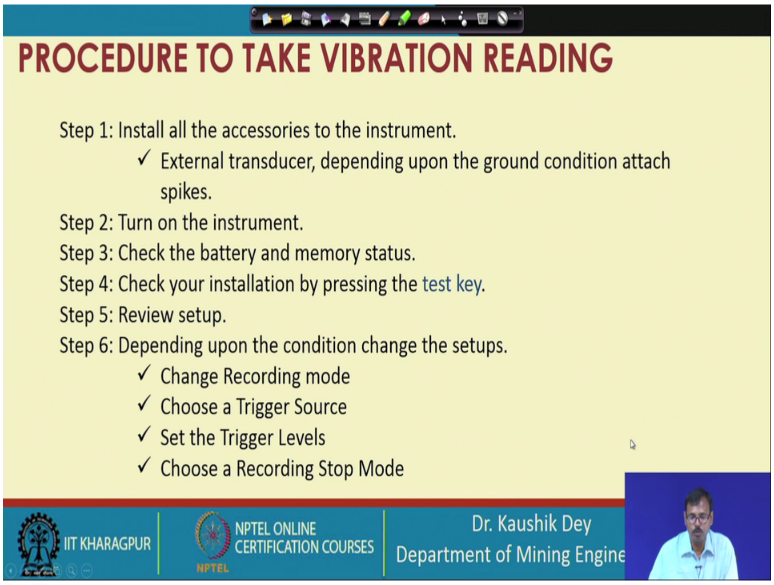

So, the procedure to take the vibration is that install the accessories and instrument. Then turn on the instrument. Check the battery memory status. Check the installation by test key. Then review the setup. Then give the instruction to give the instruction to the instrument.

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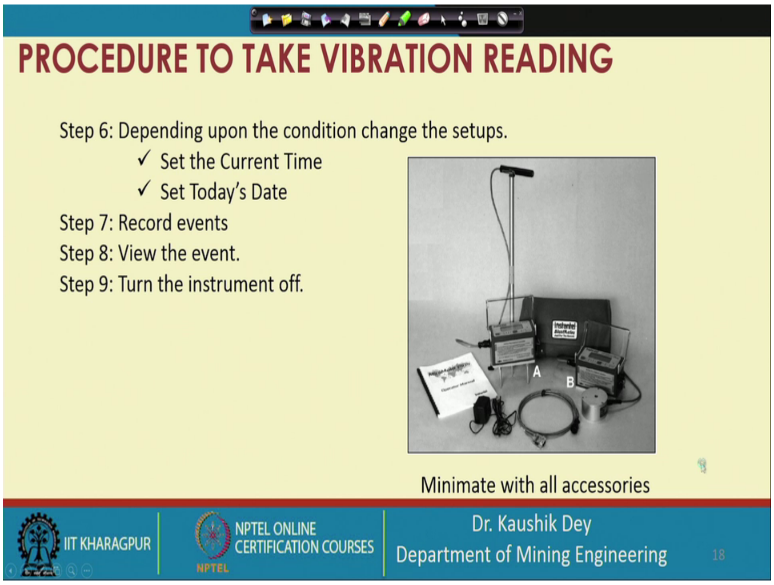

Then the time setup will be there, date has to be there, then the events will be recorded. And finally, the recorded event will be transferred to the computer, and the event will be viewed or further analysis may be carried out in the computer software.

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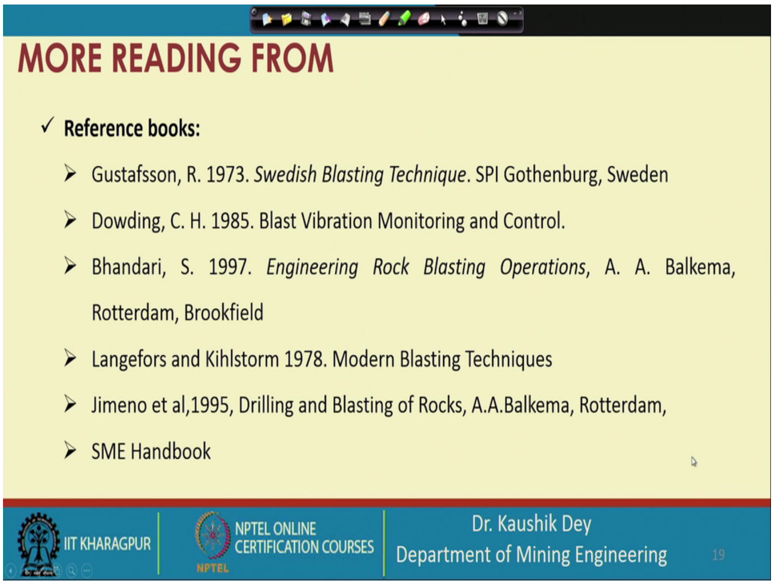

I expect that more reading made from all these reference books, especially the Gustafsson book, Dowding book, will give you a very better understanding of the blast vibration. So, let us stop today's class, next class we will start the blast induced rock damage or blast induced structural damage.

Thank you.