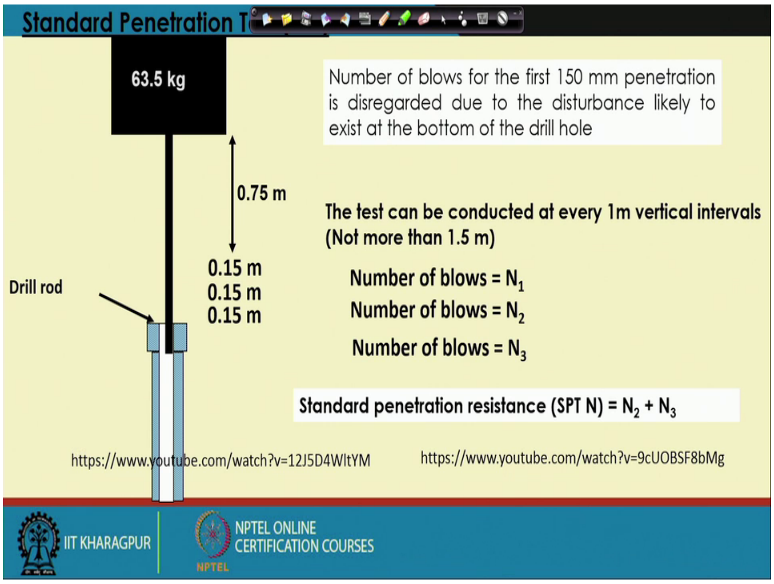
Foundation Engineering
Prof. Kousik Deb
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture - 09
Geophysical Exploration - I

So, in the next previous lecture I have discussed about different indirect methods. And today I will discuss about another exploration method that is Geophysical Soil Expression; now before I start the geo physical soil expression. So, these are the indirect methods if I summarize all the indirect method that I have discussed.

(Refer Slide Time: 00:44)

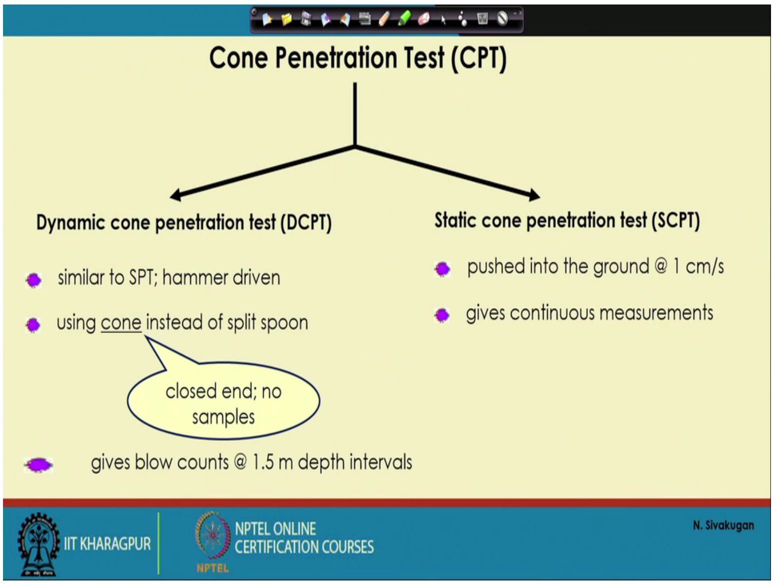


So, first one I have discussed about the; standard penetration test. So, that where a borehole is required in the borehole we are placing a speed spoon sampler tube and with the drill rod we are applying hammer blows on the speed spoon sampler tubes and we penetrate that sampler tube into the soil and then we count the number of blows required for 150 millimeter penetration.

So, there are three 150 millimeter penetration, we neglect the first one and you consider the second and third one the summation of these third and second number of penetration required for each 150 millimeter penetration is called as N value or SPT value. And then we apply number of corrections so that we have discussed for as per the IS code and as per the American code.

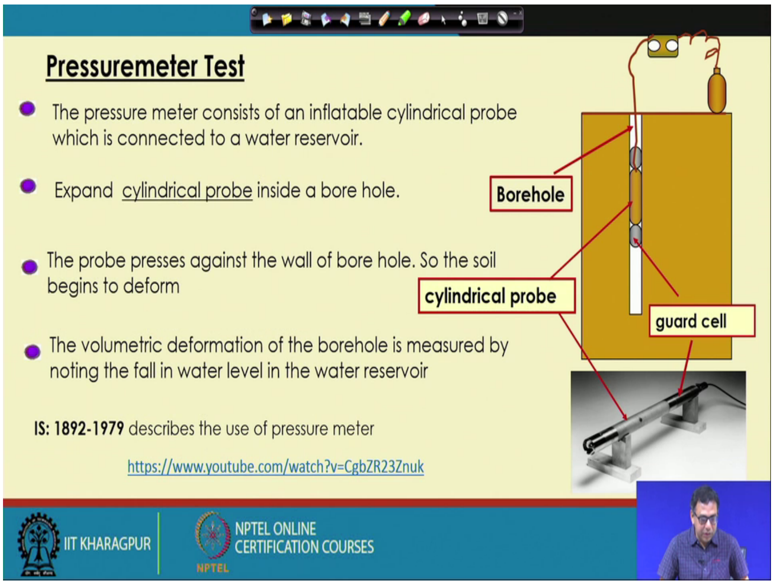
So, and then this is the standard weight and with standard height we are applying the hammer blow; so this is SPT.

(Refer Slide Time: 01:47)



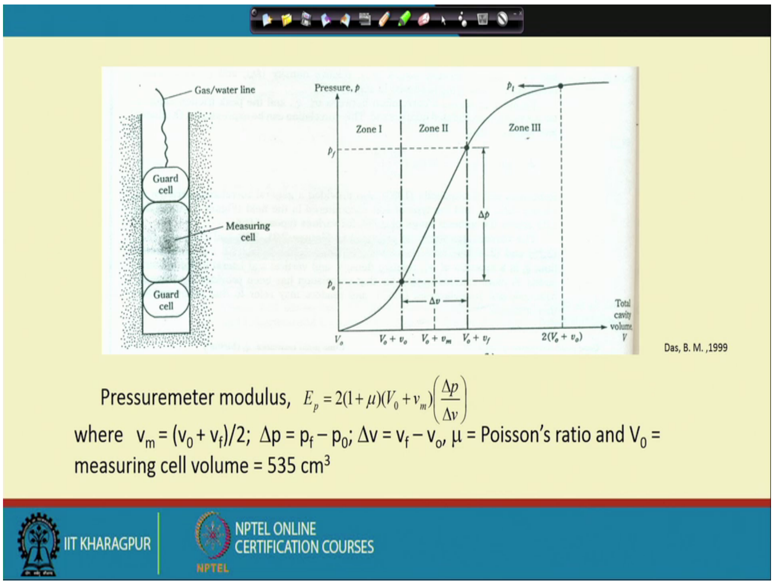
And then we discussed about the cone penetration test where there are 2 types of cone penetration test; one is dynamic cone penetration test another is static cone penetration test. In the static cone penetration test, we are pushing the cone into the soil and we are measuring the cone resistance or tip resistance and the friction resistance. And in dynamic penetric cone penetration test, we are applying the hammer blow into the cone and we are driving the cone into the soil and number of blows required for the 100 millimeter penetration is recorded.

(Refer Slide Time: 02:22)



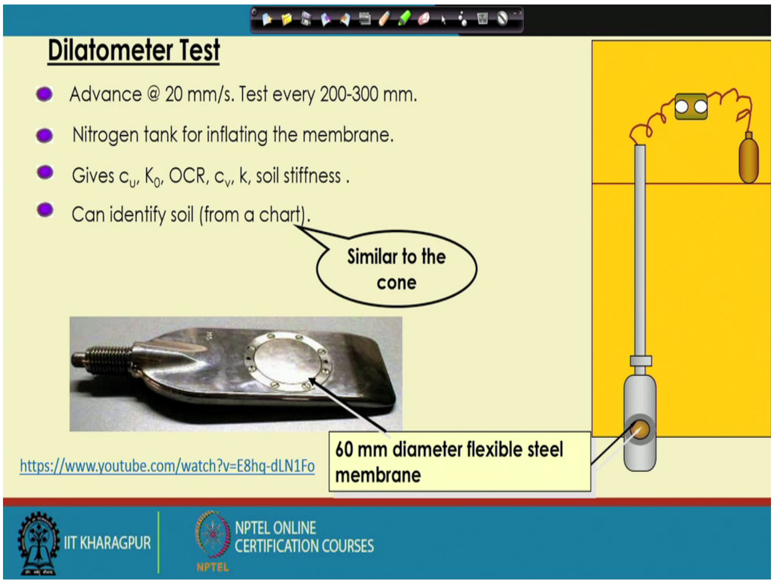
So, and then the next one we discussed about the pressure meter test where, cylindrical probe is inserted into the borehole and the pressure is applied with the application of the pressure, the volume of the probe, or the cavity or the borehole increases. So, that volume increases measured;

(Refer Slide Time: 02:40)



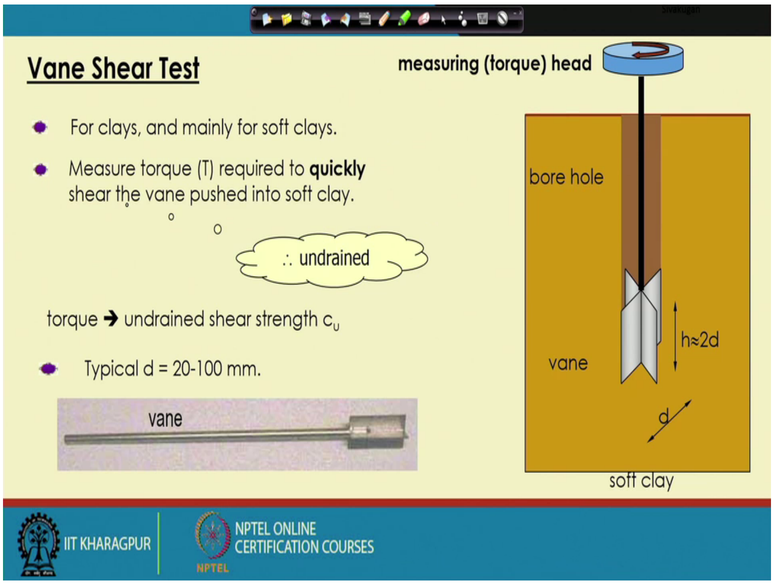
So ultimately we will get pressure versus a volume curve and from it this curve we identify 2, 3 different zones and from 3 different zones, we got p 0, p f value and p l value. So, with the help of this p 0, p a value and v 0 and v a value ah; we got the pressure meter modulus. So, this modulus is also a calculated and based on that we determine the various soil properties. Similarly, the SPT in and the CPT resistance also you we used to determine the various a soil properties.

(Refer Slide Time: 03:18)



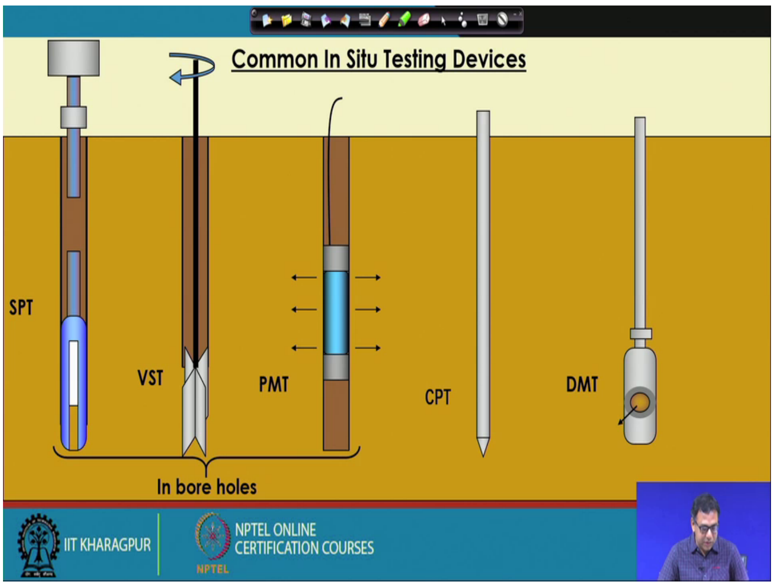
Similarly, we next we discussed about the dilatometer test where the nitrogen tank is used; so to inflating the membranes. So, here where which is similar like a pressure meter test, where this is the flexible membrane which where the inflating which is this membrane is inflating with the help of the nitrogen so, that resistance the pressure initial pressure and the pressure after the expansion is recorded.

(Refer Slide Time: 03:52)



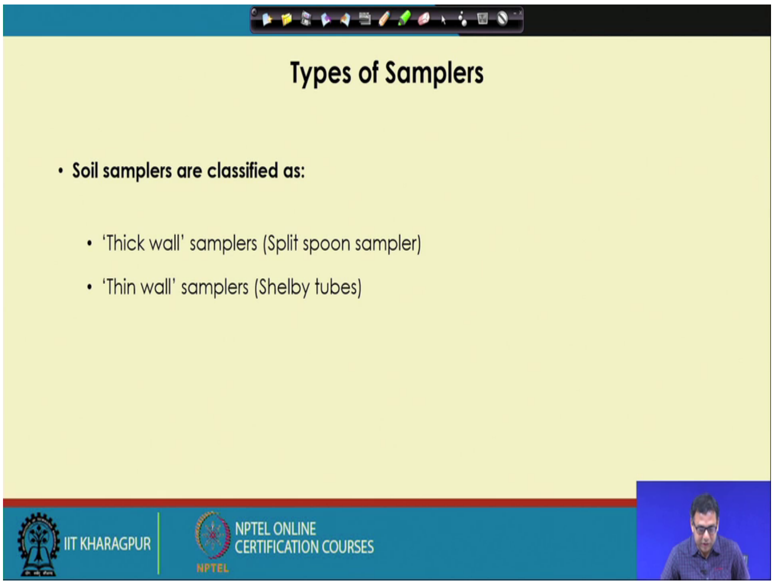
And based on that you determine various soil properties like the k 0 value over considered at the ratio, then elastic modulus of the soil, undrained cohesion of the soil. Then next one we have so, discussed about the a vane shear test, dilatometer test then the next one we have discussed about the vane shear test where the vane is inserted into the borehole and then a torque is applied. This torque is measured and this when height and diameter is measured and with the help of this measurement we determine the undrained cohesion of the soil it is suitable for the soft clay.

(Refer Slide Time: 04:34)



Now, and these are the all test where the SPT, or Standard Penetration Test, then Vane Shear Test, Pressure Meter Test; here the boreholes are required, instrument is inserted into the borehole and where the CPT; Cone Penetration Test and DMT; Dilato Meter Test; where it is pushed into the soil or in CPT also it is these cone is driven into the soil, but borehole is not required.

(Refer Slide Time: 05:08)



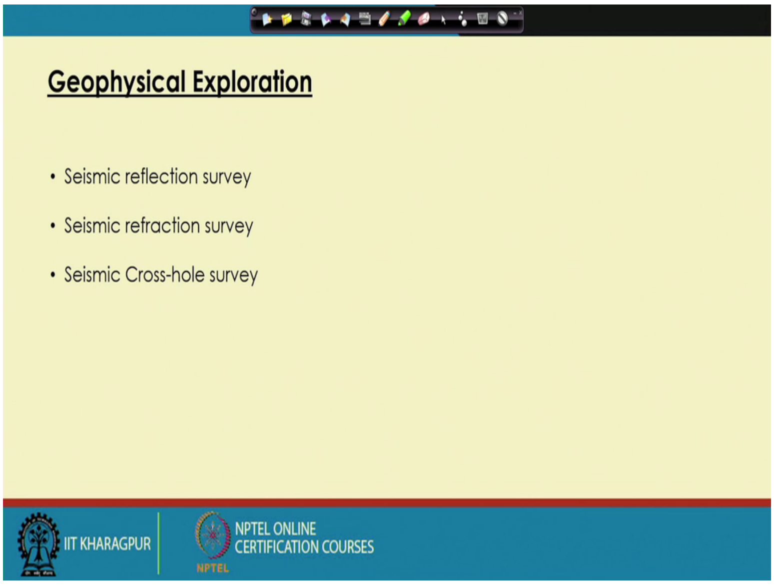
So, these are the all test that I have discussed common In Situ test that we are conducting to determine the soil properties. Then we have discussed the difference samplers tubes because these are 2 types of sampler tubes; one is thick wall sampler, it is split spoon sampler and then the thin wall sampler; it is Shelby tubes.

And we have discussed that this is the sampler tube which is attached in the SPT, which is the split spoon sampler tube. So, and we have already discussed; thus this if I collect the soil sample with the help of this split spoon sampler tube, then the soil is highly discharge.

So, the soil sample that you are collecting with the help of SPT which is which is the disturbed soil sample. So, and then we talked about the criteria's to collect the undisturbed soil sample we can use the thin wall sampler tube to collect the undisturbed soil sample. And then the boring also we have discussed that we can collect the soil sample by boring and whenever we can if I want; we can collect the soil sample by using the sampler tube also.

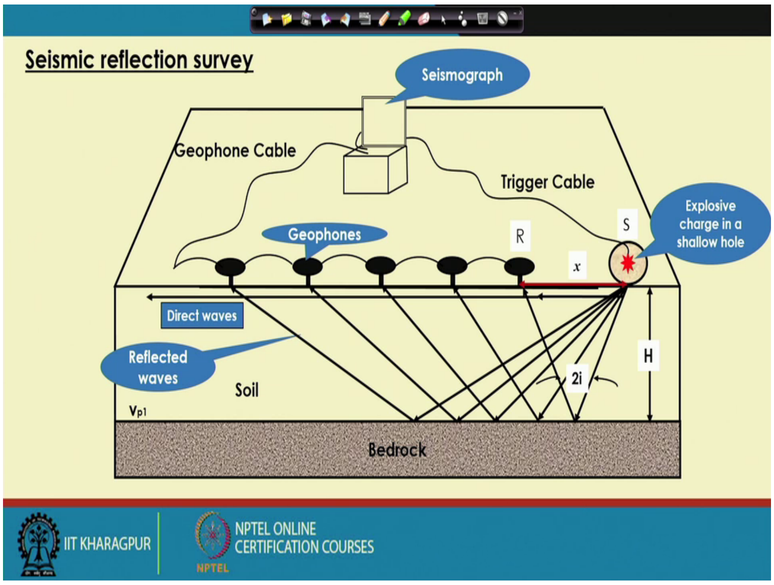
So, these are the 2 sampler tube generally we use in value you use to collect the soil samples; so one will give you the disturb soil sample, another will give you the undisturbed soil sample. So, now today I will discuss the next exploration; next type of exploration which is geophysical exploration.

(Refer Slide Time: 06:29)



So, there are 3 mainly 3 types of geophysical exploration; one is seismic reflection survey, another is seismic refraction survey, and seismic cross-hole survey. So, there are I mean depending upon the position of the receiver and the source, it can be seismic down hole survey, seismic up hole survey also. So, I will discuss about this 3 a seismic geophysical exploration. Now, the question is why it is called the seismic?

(Refer Slide Time: 07:06)



Because the procedure of this seismic first I am talking about the seismic reflection survey. So, the procedure is that we there is a source where we are generating some wave and we are placing some receivers which are called geophones at different intervals. And from this source the wave which is generated will be received by this receiver. So, these receivers we are also placing on the surface and the source is also on the surface.

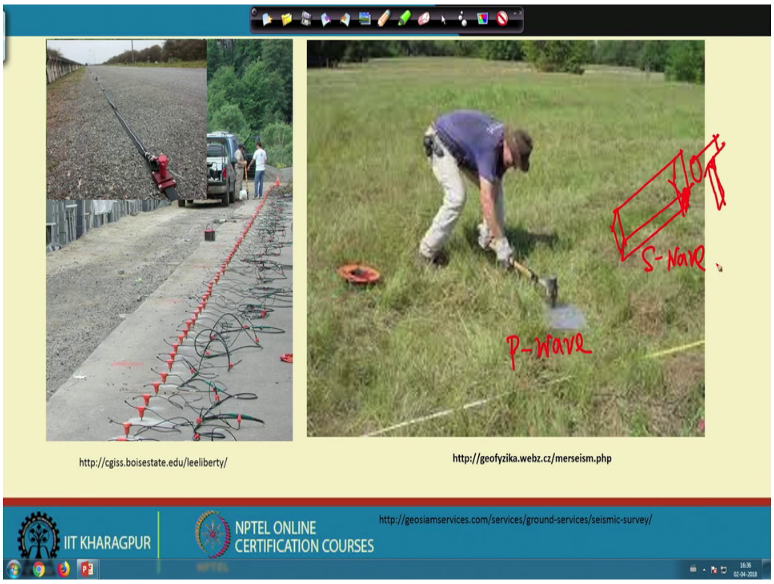
So, how these waves are received by the receivers? It is received by the reflection of the ray from the soil to different soil layer interface. So, because as we had 2 different soil layer; so, this ray will reflect it from these interface and we measure these reflected rays time period. At what time these rays are received by the geophone after it is generated from the source?

Now, this; so now, why it is called seismic? Because when there is the earthquake there are different types of waves are generated. So, there are mainly 2 types of waves are generated one is the body wave, another is the surface wave. Now these body waves are 2 types one is the P wave or primary wave, and S wave or the shear wave, or the secondary waves.

So, here basically we are generating these body waves in the source. So, either wave generating P wave already generating the S wave. So, that is why these waves which has generating the seismic during the seismic activity or the earthquake; so, it is called the seismic reflection survey.

So, here you can see that this is a so; that means, how these waves are generated? So, waves are generated there is a possibility that the we can do a small a explosion. So, that is we can do, but it is a small explosion or we can make some hammer blowing.

(Refer Slide Time: 09:34)



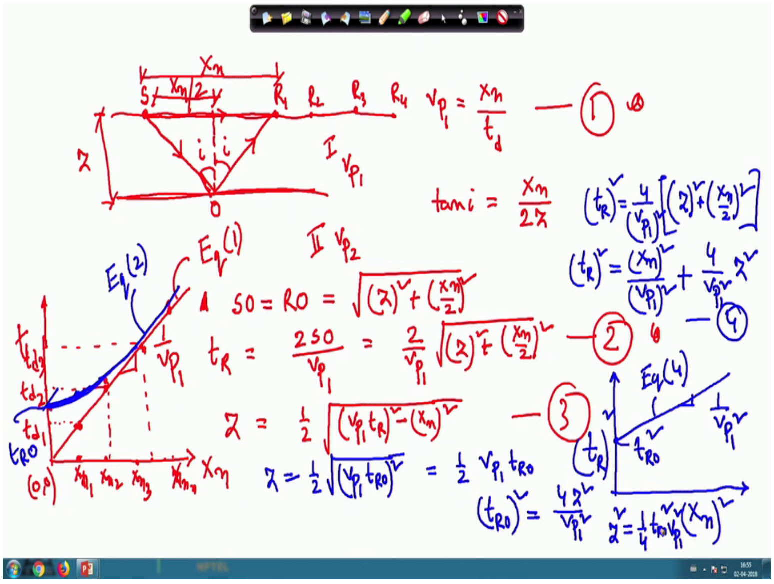
We you can see that generally this is the common technique we use that this is a plate where we are placing a hammer in these way. And these are the geophones which are placed certain intervals these geophones are receiving the time required to this to the travel this wave from the source to the receiver or the geophone.

So, these are there basically measuring this time; so now, if I apply the hammer blow in this way, then the wave which is generated each is rich with P wave or the primary wave. Now if I apply hammer blow and different way like this suppose we have a. So, we have a iron block and we are applying this hammer in this way. So, we are this is the iron block, we are placing this iron block on the soil and we are applying the hammer blow in this side of the iron block. Then the way that will be generated will be reach with S wave. So, this will give you the P-wave, and this will give you the S-wave; so, this is the rich with P wave.

So, either depending upon how we are generating the wave; we can measure the P wave or the S wave; what we are measuring actually? We are basically measuring the velocity of this wave either P wave or S wave and the thickness of the soil layer.

So, first if I discuss about; so, about the how these things we can measure, how we can measure these wave velocities and the thickness; so, we have to derive expression. So, let us derive those expression then we will understand how I will you will this determine these velocity of the waves and the thickness of the soil layer. And from this velocity of the wave we can determine the other soil properties like the shear modulus of the soil or the bulk modulus of the soil. So, let us discuss about how we can we can measure this property. So, first suppose this is the ground surface.

(Refer Slide Time: 12:23)



So, this is the wave that is the source and here we have one geophone or that is the receiver and we have another soil layer. So, this is the layer I this is the layer II and as I mentioned we can generate the P wave or S wave depending upon how we are applying the hammer blows.

So, suppose in the all the derivation I am doing with that we are generating the P wave ah. So, we will take velocity of the P wave and if I generate in other way by putting the iron block and apply the hammer blow inside of the block then that will generate with the S wave and so. But here I will derive all the equations with the considering that we are generating the P wave, but if we generate the S wave then all the velocity of the P wave will be replace to the velocity of the S wave.

So, now this is the layer II and we assume that the velocity of the layer one is V P 1 and this is velocity of the layer 2 is the V P 2. And the thickness of this layer is z; now this is the 2 layer interface. Now when there is a source and so, the when there is a source that the infinite number of waves will be generated in the infinite direction because there is the wave will not generate in one particular direction it will generate say, it will generate in this direction, it will generate in this direction, it will generate this direction, this direction any direction. So, but we will consider one particular wave; so, that will go directly from here to here. So, this is one possibility that the wave will the will travel form the source to the receiver directly and if this distance is say X or X n.

So, then we can measure; so, here what we are measuring? We are measuring the time required this direct rays to travel from S to R. So, if we measure that time; so, geophone will measure this time. So; that means, if I measure this time; so then the velocity of the first layer V P 2. So, that will be equal to X n divided by td; td is the direct time required to this wave travel from S to R.

So, this wave we can determine what is the velocity of this wave in layer I. So, that is we can measure so; that means, here X n is known; td will measure through the geophone; so we will get the velocity of the first layer. And this X n is the known because we can place geophone as a known distance from the source.

Now, there is another wave what will happen? This will come here and the; it will reflect and it will go and receive by the geophone. So, why I have considered this wave? Only because of the position of the geophone; if I change the position of the receiver or the geophone then a different wave we have to consider, but the things remain same. So, that is why that is why; so, suppose this angle is i; so, this angle will be i. So, this is the reflected rays so; that means we are measuring this reflected rays.

Now, if I call this is will be the X n divided by 2 and this is the z. So, I can write that tan i is equal to X n divided by 2 into z because this is i, this is X n this is z. So, tan I will be X n by 2 divided by z; so this I will get i. Now, similarly we can write that or if I write this is O. So, you can write; SO equal to RO is equal to z square plus X n by 2 whole square; because this is z, this is X n by 2. So, this one will be z square plus X n by whole squared.

Now, the time required of this reflected rays t means d means the direct, R means the reflected. Now times required for this reflected rays will be equal to 2 SO divided by V P 1 because; SO is equal to RO. So, 2 SO divided by V P 1. So, I can write 2 V P 1 root over z square plus X n by 2 whole squares. So, this is that; so now, how can I determine the V P as z. So, the z will be equal to half root over V P 1 t R square minus X n square. So, this will be half V P 1 t R square minus X n square.

So, V P 1; I will get from equation number 1 and this is the equation number 2. So, and z I will get; so, this is equation number 3. So, z I will V P 1 I will get from equation number 1 t R I will measure we will measure to the geophone X n is known. So, we can get what is the value of z?

So, this way we can determine the velocity of the first layer and the velocity and the thickness of this soil layer. Now the problem is that here we have considered only one geophone, but if I use only one geophone data then there is a possibility that we may get more error because; that means, that there is possibility of measurement there.

So, rather than here using one particular geophone; if we use say N number of all the more than one geophones. And then the possibility error possibility of the error will reduce so that is why using one geophone we will use N number of geophone. Now, if we use the N number of geophone then if in that case if I draw a particular graph and that graph will represent that X n and the t maybe direct t may be reflected.

So, and this is the 0 0 and X n will indicate the position of each geophone. So, this is the R R 1 in that case, this may be the R 2; so, this may be the R 3, so, this may be the R 4. So, in this figure R shown that there is a number of geophones we are placing with certain interval. So, now in that case and every geophone in case of every geophone we are we will get this type of expression. So, what will happen? That for every geophone there is a direct ray and is there is a reflected ray. So, now we have basically 3 expressions basically we have 2 expressions and this is the different form of expression 2.

So, if we have 2 expression of time now if I draw the first expression of the time. So, is a this is the X 1; so X n 1 or this is X n 2, this is X n 3 on up to X n. So; that means, here; so now for this first expression we will get this type of curve; so, if we will get this type of curve. So, point may be in this form; so; that means, we will get best fit curve. So, these are the points because these are the points so; that means time required to travel directly from the source to this geophone which is placed as X n 1; we will take this time. And for the X X n 2; this is the time requires to travel the wave directly from source to the geophone.

So, similarly this is our td 1, this is td 2, this is td 3. So, we will get a straight line where we are getting the best fit curve; so possibility of the error will reduce. Now what will once you get this curve; so, the slope of this curve will give me 1 by V P 1; the slope of this curve will give me 1 by V P 1.

So, instead of using a particular geophone data; so if we have N number of geophone data then we draw this points in a graph x versus t then we will get a straight line. So, this will represent the equation number 1; and if I get the slope of this curve at this straight line it will give me the 1 by V P 1.

Now, next one if I draw the similar curve for equation number 2 then I will get if I use a different color. So, I will get a curve which is in this form. So, this will represent equation number 2; because this forms this expression.

So, this will give you t R versus X n so, but this will give this is of equation one is a high parabolic equation 1 is a straight line and equation 2 will give you a high parabolic curve. Now, from here; so, if I extend; so, how I form here? I get the z value. So, if I extend; so suppose I will get this curve up to u this point. So, if I extend this curve here; so these will give us value which is t R 0; t R 0 is a value where the X n is equal to 0.

Now if I put this value here; so, there I will get z equal to half root over V P 1 t R 0 square because X n is 0. So, it will be half V P 1 t R 0 or you can get from this here; here also this will be your X n equal to 0. So, you will get your z will be t R V P 1 divided by 2.

So, this t R 0 is this value this is t R 0 ok. So, from here I will get the z value from the curve also. Now there is the problem of this test is that. So, we have to measure 2 different rays travel time one is the direct ray another is the reflected ray. So, this is the problem because here this is a difficult task know. So, which one is the direct ray, which one is the reflected ray; it is very difficult to you know which difficult to judge. So, that is why to remove this limitation we will go for the seismic refraction test.

Another one in this test what we are doing? We are measuring the thickness of the first layer and the velocity of the first layer. So, but yeah if there is N number of layers; then our seismic refraction rays is more suitable. So, I will discuss that about the seismic refraction ray surveys in the next class. So, in that this class also; so, this is the one limitation that you have to measure 2 rays and identification of these 2 rays is sometimes difficult, so to avoid that we have to go for the seismic refraction rays.

In another way even if we use this test; so, drawing a hyperbola graph is very difficult rather than drawing a straight line. So, instead of drawing a hyperbolic curve; if I draw a straight line then in this in this curve then it will be better. So, how we can do that? So, instead of this curve what we are doing that we have expression 2.

Now, if I square this expression then this expression 2 square both side then expression 2 will become t R square is equal to 4 V P 1 square then z square plus X n by 2 whole square. So, this is the expression if I square both side now if I further simplify this will be t R square equal to; if I take X n ah. So, this will be the your X n square, then this 4 this 4 cancel out, this will be V P 1 whole square this is V P 1 and then plus we can write 4 by V P 1 square into z squared.

So, now this is our expression number 4; now I if I draw this curve. So, instead of drawing x curve x n curve we are drawing X n square divided by t R square curve. So, now, it will be a straight line; so now this will be straight line; the slope of this curve will give you 1 minus V P 1 square; so, this is equation number 4. So, because so; that means, that is 2 ways either you use this curve. So, where dp 1 we can easily determine because it is the straight line, but getting the z value it is a hyperbolic curve.

So, rather sometimes is very difficult to draw from the points a hyperbolic curve. So, its why what we are doing? We are making a square graph X is X n square and t R square and now we are drawing this curve. So, the slope of this curve will give us 1 minus V P 1 square.

So, now from here I will get the V P 1 value and then how I will get the z value? So, again this will give t t this value will give t R 0 square. Now if I put t R 0 square with X n equal to 0. So, it will give t R 0 square equal to X n is 0 4 z square by V P 1 square. So, z square I will get from here z square is equal to 1 by 4 t R 0 square and V P 1 square.

So, we will get which is similar to this value also; so, this is half into V P 1 into t R 0. But as it is in square form; so, directly we can put these values here, then we can take what is that because if z V P 1 square; we are getting from here and t R 0, we are getting from here and then we will get the z value.

So, instead of in the second method instead of using 2 different curve by one curve, we are getting V P 1, as well as the z value, but still the those limitations that I have discussed will remain. So, we have to remove those limitations; so, to remove those limitations we have to do the next test that is seismic refraction test and in the next class, I will discuss about the seismic refraction test.

Thank you.