Soil Dynamics
Professor Paramita Bhattacharya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture 30
Determination of Dynamic Properties (Block Vibration Test)

Hello friends. Hope you are all doing well. So, today we will discuss another field test to determine the dynamic properties of soils.

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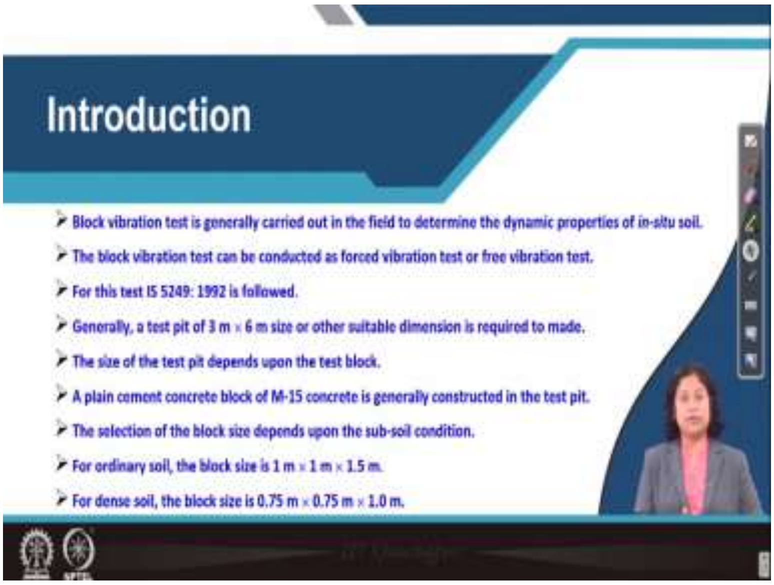

We will first study the block vibration test which is generally carried out in the field to determine the dynamic properties of in situ soil. The block vibration test can be conducted as forced vibration test or free vibration test. Here, we will discuss the forced vibration test. So, for this test we will follow IS 5249 published in 1992. For this test generally a test pit of size 3 meter by 6 meter or other suitable dimensions is required to made at the site.

The size of the pit mainly depends upon the test block. A plain cement concrete block of M 15 great concrete is generally used to construct the test block in the pit. The selection of the block size depends upon the sub soil condition. For ordinary soil generally we take the block size 1 meter by 1 meter by 1.5 meter that means the plain area is 1 meter by 1 meter whereas the depth of the block is 1.5 meter. However, for dense sand or dense soil the block size is changed to 0.75 meter by 0.75 meter by 1 meter in depth.

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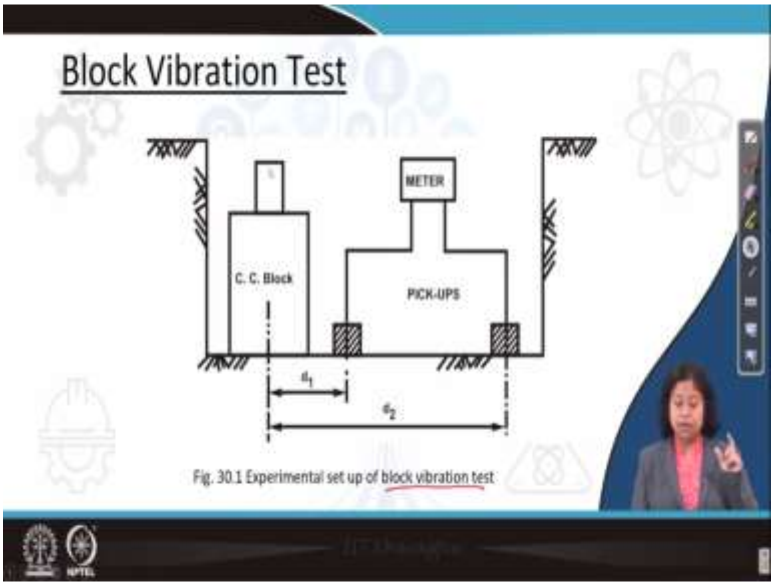

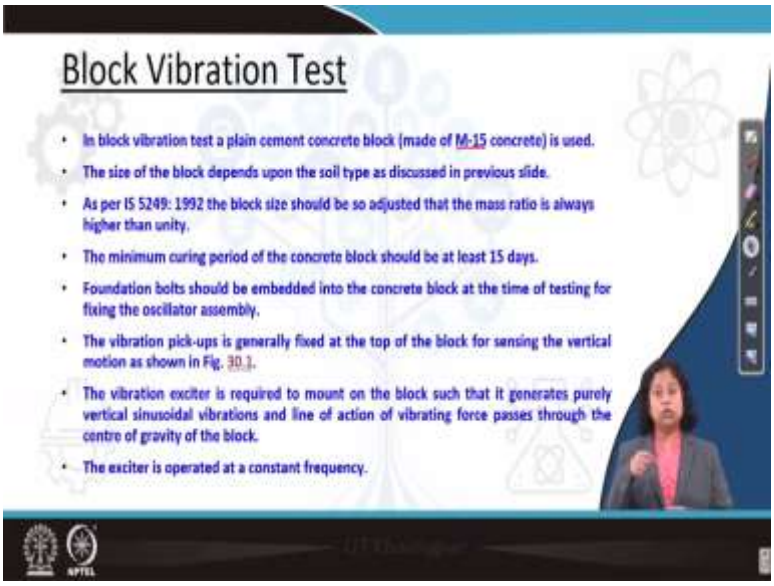

So, in figure 1 you can see typical experimental setup for block vibration test. So, let us see the procedure of block vibration test. In block vibration test a plain cement concrete block made of M 15 grade concrete is used. The size of the block depends upon the soil type as we have already discussed. As per IS 5249 published in 1992 the block size should be adjusted so that the mass ratio is always higher than unity. The minimum curing period of the concrete block which will be tested should be at least 15 days.

That means we need to allow minimum 15 days for the curing of the concrete block. Next is the foundation bolts should be embedded into the concrete block at the time of testing for fixing the oscillator assembly. The vibration pickups is generally fixed at the top of the block for sensing the vertical vibration as shown in figure 1. So, here you can see pick up mounted on the block.

The vibration exciter is required to mount on the block such that it generates the pure sinusoidal wave vibration and line of action of the vibration or vibrating force passing through the CG which is center of gravity of the block. So, if I go back to the figure so the line of action of the sinusoidal load should pass through the CG of the block. The exciter is operated at a constant frequency in block vibration test.

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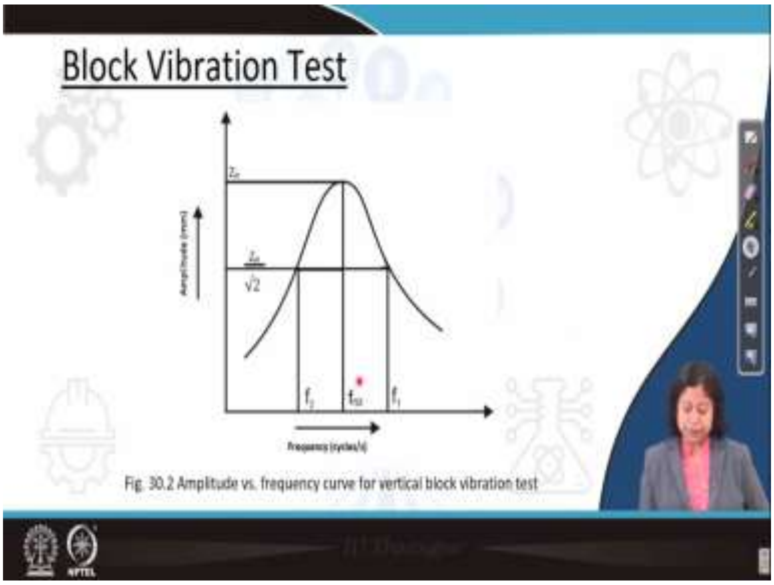

So, in this figure you can see the variation of the amplitude with the frequency. So, with the increase of frequency what is happened amplitude also increases up to the maximum value of z M say in this case and then it starts to decrease you can see the trends with increasing frequency. Now, we need to find out the maximum amplitude and the corresponding frequency which is f n z in this case.

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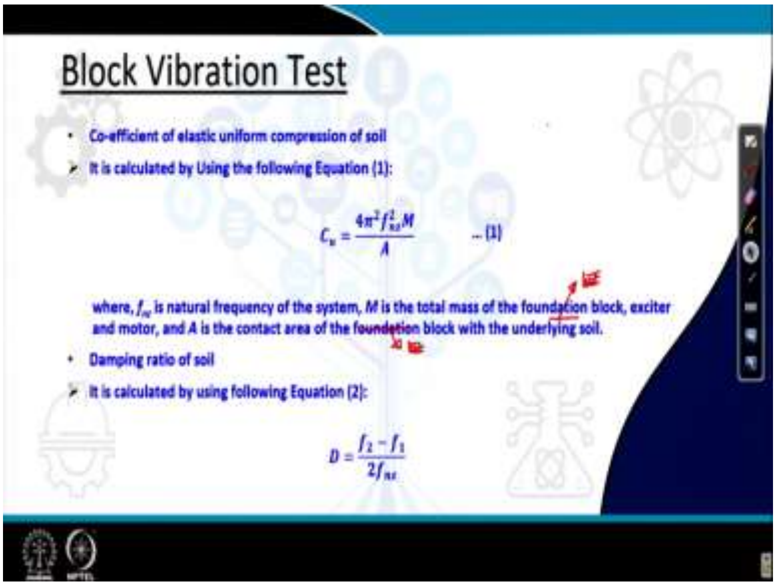

Now, from this curve we can calculate two important parameters for the soil. One is coefficient of elastic uniform compression of soil which is calculated by using this equation C u; C u is the coefficient of elastic uniform compression of soil that is expressed by 4 pi square times f m z square times M divided by A. What are the meanings of these parameters? Here f n z is natural frequency of the system.

Whereas M is the total mass of the foundation block exciter and the motor together. A is the contact area of the foundation block with the underlying soil. Now another important parameter which we can find is damping ratio of soil. Damping ratio you can call it or you can call it as damping factor as well. So, for that we can use this formula directly. Please make a few correction what we have discussed about C u.

This is not for foundation block because the word foundation block may create trouble for all of us. It is better to use the word test block and here also it is test block then the question what will be C u; C u means coefficient of elastic uniform compression of soil when we are designing the foundation block. Foundation means here the actual foundation for the machine. So, that time how we will calculate C u.

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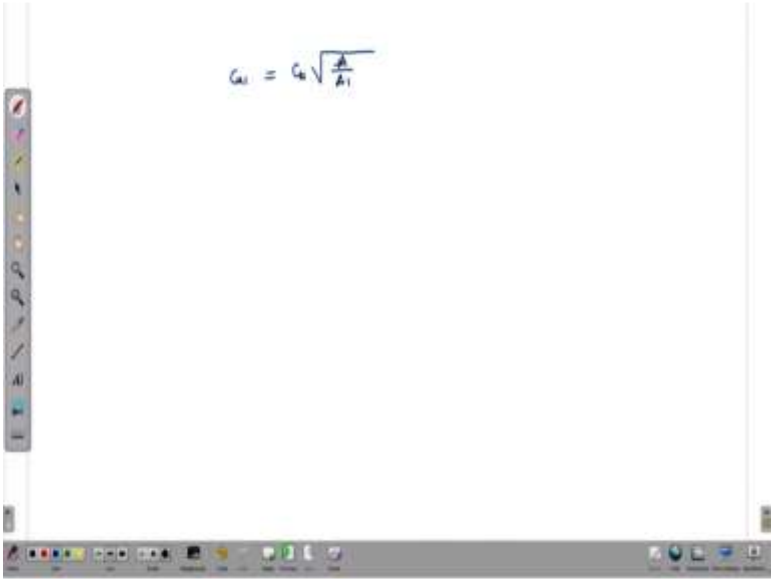

So, let us take that C u is C u 1, C u 1 is equal to alright where already we have seen what is A and A 1 is the contact area of the actual foundation to the soil. Now, generally if the value of the A 1 exceeds 10 square meter that time if we need to calculate C u 1 then we take the value of C u 1 considering A 1 is equal to 10 square meter. Now, what is the f 2 and f 1? If I will show you here.

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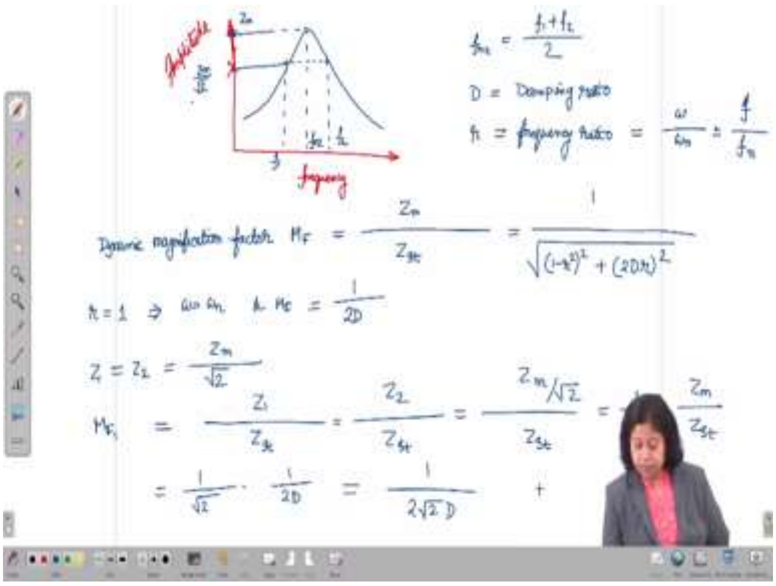

So, I can draw amplitude versus frequency curve horizontal axis is representing frequency here whereas vertical axis represents amplitude. Here you can see now I am just going back to the white board the same curve I am plotting here. Now, here this is the maximum amplitude which we can write as so this maximum amplitude is Z m. Now we will choose f 1 and f 2 in such a way that first let me mark f m z.

Now we will choose f 1 and f 2 in such a way that the amplitude corresponding to both f 1 and f 2 should be equal to Z m divided by root 2. So, first here I will mark the position of Z m divided by root 2. Now, this give two operating frequency smaller one is f 1 and the larger one is f 2. Eventually we can see that f m z we can get the average of approximately we can get this.

Now, if I know f 1 f 2 and the corresponding amplitude that is Z m divided by root 2 where Z m is the maximum amplitude corresponding to f and z that means the natural frequency of the entire system then how we will calculate the damping ratio of soil which is represented by capital D that we will now see. We already know that dynamic magnification factor which we can define by M F capital M with a subscript F is equal to sorry here we are using Z.

So, Z maximum divided by Z static. Now, from this what we can write in we can also express it as 1 divided by square root of 1 minus r square whole square plus two times D times r whole square where D is the damping ratio. I am writing here D is damping ratio and r is frequency ratio. So, if operating frequency of a machine is omega and natural frequency of the system is omega n then r is equal to omega divided by omega n or in terms of frequency in cycles per second we can write f divided by f n.

So, in our case we will define frequency ratio using f 1 and f 2. Now, when the amplitude is Z m divided by root 2 that time what is happened. Before seeing that first let us see what is the magnification factor when r is equal to 1. So, frequency ratio r is equal to 1 means what it means omega is equal to omega n and magnification factor becomes almost equal to 1 divided by 2 D it becomes actually equal to 1 divided by 2 D.

Now this is when r is equal to 1 that means amplitude is Z m. Now we have another amplitude let us take Z is equal to or I can write it as Z 1 and Z 2 actually both are same. Z 1 and Z 2 corresponding to f 1 and f 2 so this equals to Z m divided by root 2. So, what I can write a new magnification factor M F 1 that when the amplitude is Z m divided by root 2 or Z 1 that time what is the magnification factor that I am trying to write here.

So, Z 1 by Z static or I can write it also as Z 2 by Z s t that is equal to what I can write in place of Z 1 or Z 2, I can write Z m divided by root 2. Now in Z s t remains as it is so it is now becoming 1 divided by root 2 times Z m divided by Z s t. Now Z m divided by Z s t means 1 divided by 2 D so I can write here then M F 1 is equal to 1 divided by root 2 times 1 divided by 2 D. So, we are getting 1 divided by 2 times root 2 D.

So, this magnification factor is corresponding to the amplitude Z m divided by root 2 that means for this case. Now, at that point let us take frequency ratio we can write frequency ratio at that point is instead of writing r, I can write as capital R 1 or capital R also I can write.

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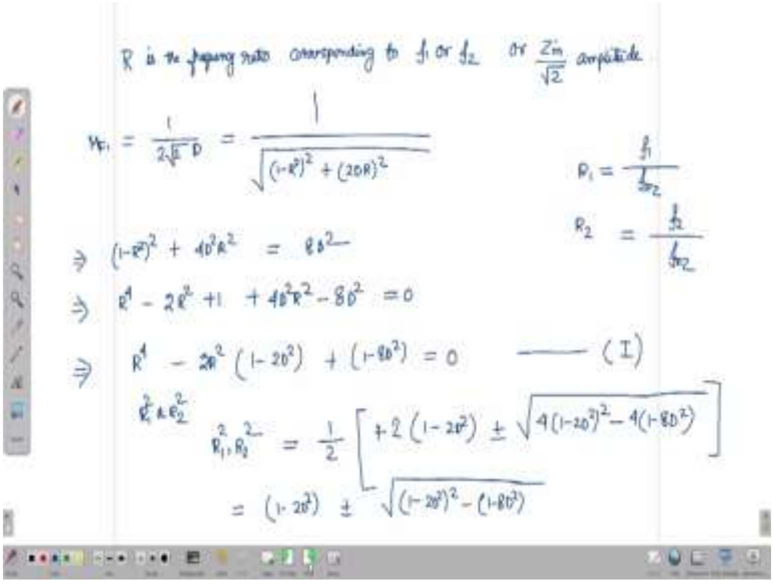

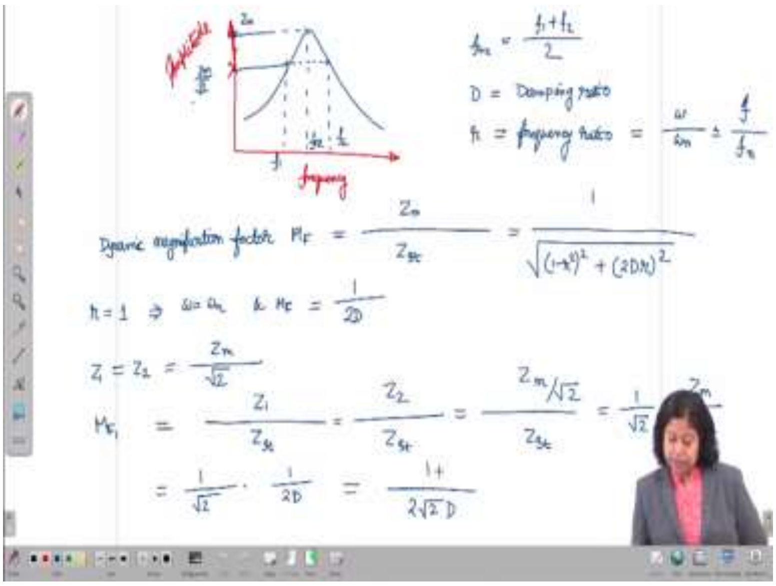

So, capital R, I am going to the next page, so capital R is the frequency ratio corresponding to f 1 or f 2 or we can say corresponding to amplitude Z m divided by root 2. So, what is the mathematical form of R that first we need to find out in this case. So, M F 1 we already get as 1 divided by 2 root 2 times D. So, I can write in place of first M F 1 as 2 times 1 divided by 2 times square root of 2 times D which is equal to the mathematical expression for the magnification factor which is 1 minus capital R square whole square plus 2 D capital R whole square.

Now, from this what we can write? We can write 1 minus R square whole square plus 4 D square R square which is equal to 8 D square then I can expand this term as R to the power 4 minus 2 R square plus 1 plus 4 D square R square minus 8 D square is equal to 0. From this what I can write? I can write R to the power 4 then minus 2 R square times 1 minus 2 D square plus 1 minus 8 D square is equal to 0.

Now, we can see it is a fourth order equation of R. So, we will get two positive value for this R let us take R 1 and R 2 because we know R 1 is equal to f 1 divided by f n Z and R 2 is equal to f 2 divided by f n Z. So, from this now I will try to write this expression in terms of R 1 and R 2. So, the two roots are R 1 square and R 2 square for this equation I can give it a number roman 1.

So, if R 1 square and R 2 square are the two roots of this equation 1 then what we can write? We can write R 1 square and R 2 square should be equal to half of we can write here this is equal to here half so minus, minus plus 2 R square sorry, no 2 R square only 2, 2 1 minus 2 D square then plus minus square root of 4 1 minus 2 D square whole square minus 4 times 1 times 1 minus 8 D square.

So, 1 minus 8 D square. I can simplify this also as 1 minus 2 D square plus minus square root of 1 minus 2 D square whole square minus 1 minus 8 D square. I can simplify it also once again. So, we have seen how to find out the two roots R 1 square and R 2 square.

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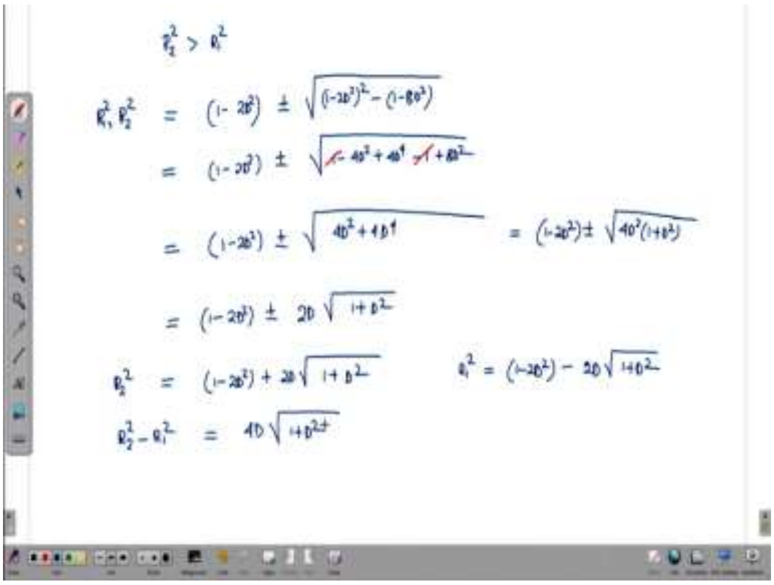

In this case always this R 2 square is greater than R 1 square this is the first thing then now what we can write R 1 square or R 2 square that is equal to 1 minus 2 D square plus minus. So, when R 2 square is greater than R 1 square that means for R 2 square we need to consider here plus and for R 1 square we will consider minus sign. However, now we can write the expression for R 1 square and R 2 square.

So, that is 1 minus 2 D square plus minus square root of 1 minus 2 D square whole square that we have written in the previous page minus 1 minus 8 D square. Now as I said I need to expect this 1 minus 2 D square whole square. So, for the expression within square root will be 1 minus 4 D square plus 4 D to the power 4 minus 1 plus 8 D square. Now here what we can see here there is 1 plus 1 and here there is 1 minus 1.

So, these two will be cancelled out other than that we have 8 D square minus 4 D square. So, that we can write as 4 D square. So, next line will be 1 minus 2 D square plus minus square root of 4 D square plus 4 D to the power 4 which is equal to 1 minus 2 D square plus minus now whatever written within square root there I can write 4 D square common so 4 D square times 1 plus D square that is within square root.

Then in the next line what I can write 1 minus 2 D square plus minus 2 D times square root of 1 plus D square. So, here what is R 2 square then? R 2 square is 1 minus 2 D square plus 2 D times square root of 1 plus D square whereas R 1 square is equal to 1 minus 2 D square minus 2 D times square root of 1 plus D square then from this we can write R 2 square minus R 1 square which is equal to R 2 square minus R 1 square is equal to 4 D times 1 plus D square.

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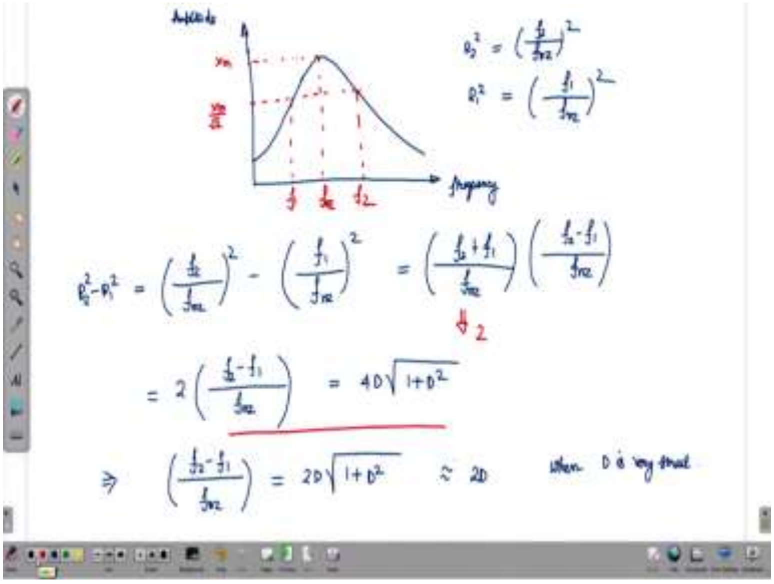

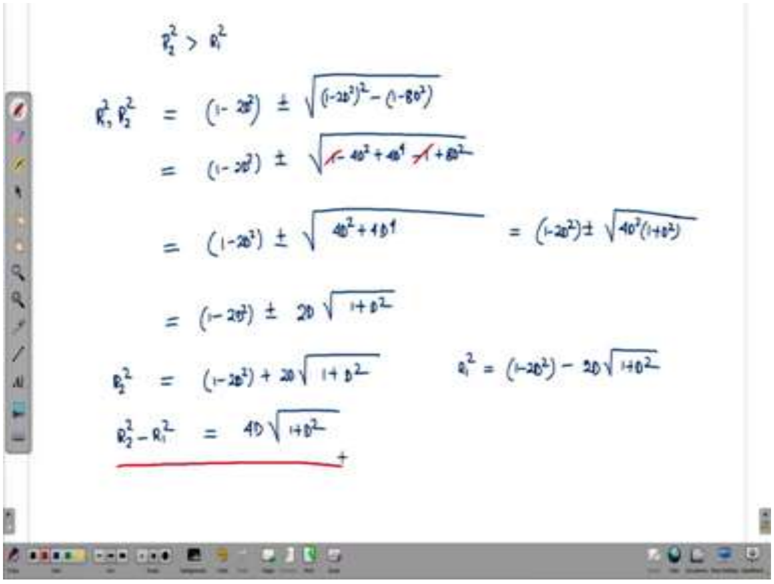

Now, if I will go to the next page. First please recall this curve. So, what we can seen here we have this kind of curve or I can make that tip little bit smooth like this or just this is not looking smooth so I am just erasing, like this. So, what we have taken this peak is if it is x m then we have considered a point x m divided by root 2 and the corresponding frequencies are f 1 and f 2 and the frequency corresponding to x m is denoted as f n z.

Now, here what is then R 2 square minus R 1 square if you see R 2 square means referring to these figure what we can write? We can write f 2 divided by f n z whole square. Here you need to level the axis this is frequency and this axis is amplitude that we have already seen also. So, R 2 square is already written. What is R 1 square? As per this figure R 1 square is equal to f 1 divided by f n z square.

F 1 divided by f n z whole square that is R 1 square. Now then we can also write R 2 square minus R 1 square is equal to f 2 divided by f n z whole square minus f 1 divided by f n z whole square which is equal to f 2 plus f 1 divided by f n z times f 2 minus f 1 divided by f n z. Now, today only just a few minutes before what we have seen about f 2 plus f 1 divided by f n z that is equal to 2, only 2.

So, I am just writing once again, this is equal to 2 then what I can write R 2 square minus R 1 square is equal to 2 times of f 2 minus f 1 whole divided by f n z. Now, this expression is also equal to what we get in the previous slide that is R 2 square minus R 1 square is equal to 4 D times square root of 1 plus D square then I can write it here also 4 D times square root of 1 plus D square.

Now then from this expression what we can write? We can get the value of f 2 minus f 1 divided by f n z and that value f 2 minus f 1 divided by f n z is equal to 2 D times square root of 1 plus D square or what I can write we can write this is approximately equal to 2 D when D is very small; very small means you can give a try when D is equal to 0.25 that means (())(33:51) has 25 percent damping that time.

What will be the value of square root of 1 plus D square that will be equal to 1.03 or something like that, that is the reason we are neglecting the term which is written under square root. Now, from this what we can write finally.

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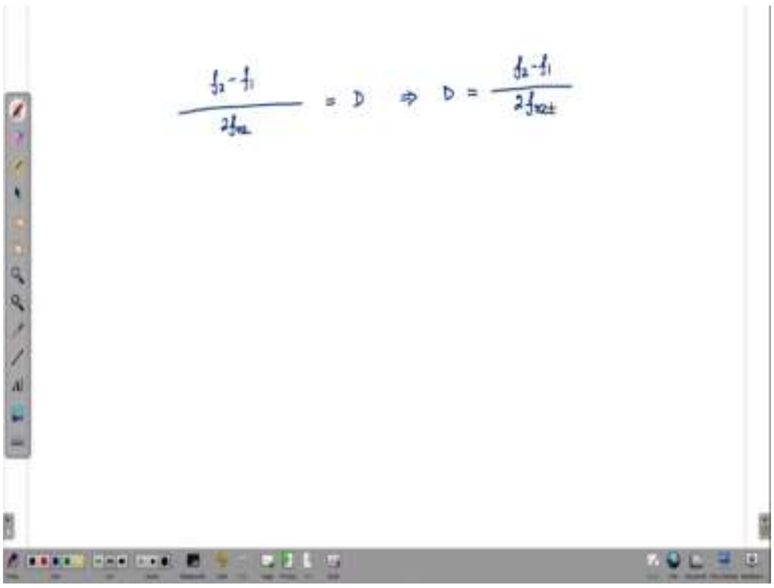

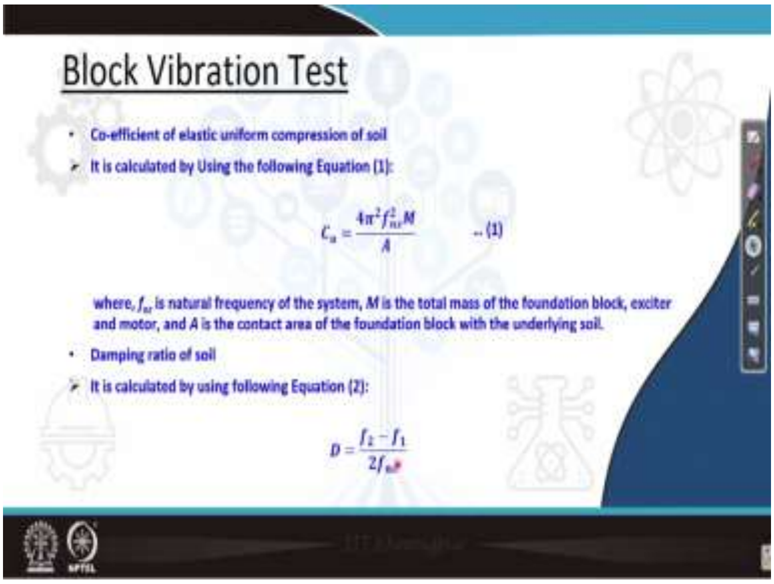

Now what we can write from this f 2 minus f 1 divided by 2 times of f n z is equal to D. Generally, we write it as D is equal to than f 2 minus f 1 divided by 2 times of f n z. In this way we can calculate the damping ratio of the soil by conducting block vibration test. So, here you can see the same expression is mentioned directly that damping ratio D is equal to f 2 minus f 1 divided by 2 times of f n z.

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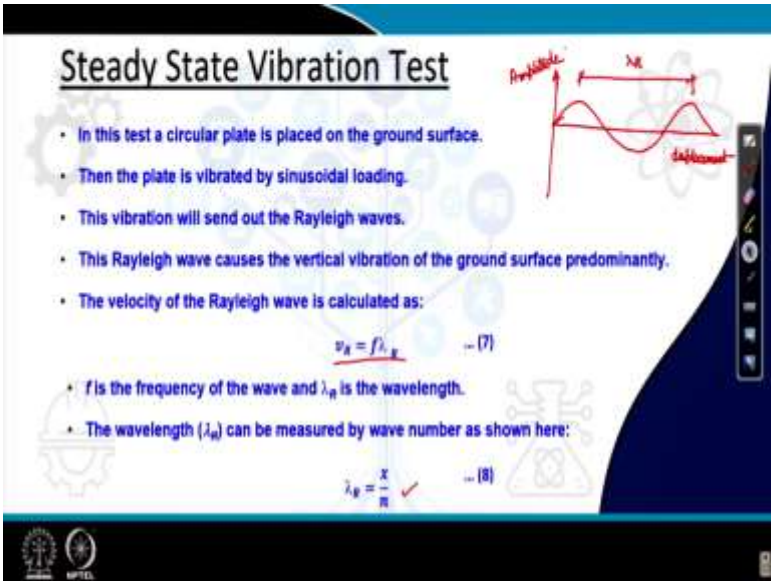

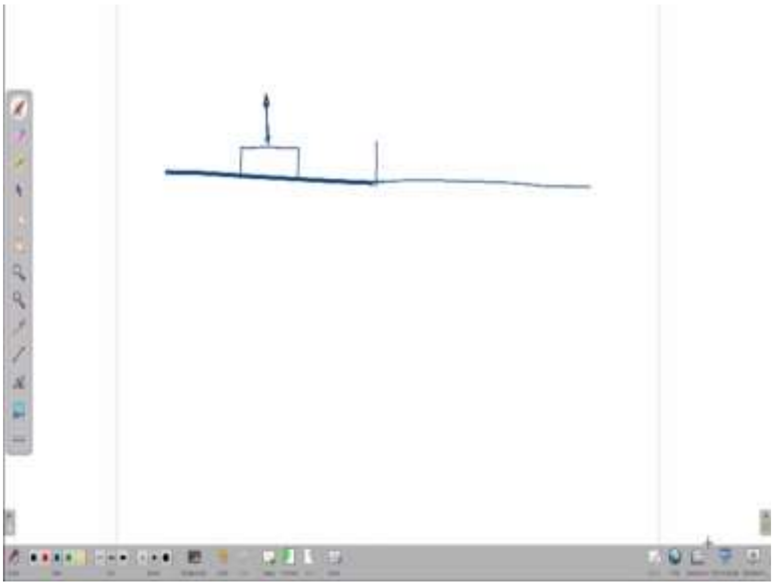

Now, another test is steady state vibration test. So, what is happened in steady state vibration test? In this test generally a circular plate is placed on the ground surface then the plate is subjected to vertical sinusoidal loading, then what is happening? This vibration will send out the Rayleigh waves and this Rayleigh wave causes the vertical vibration of the ground surface predominantly.

So, what I am saying I am just trying to draw here we have taken one circular plate test it on the ground surface. So, this is our ground surface let us take this is the circular plate which is subjected to vertical vibration. So, what will happen from here sinusoidal wave will generate and what else will be happened this ground surface will be vibrated because of this sinusoidal wave.

Now this Rayleigh wave it is already mentioned that the Rayleigh wave causes the vertical vibration of the ground surface predominantly. Now, how we calculate the velocity of the Rayleigh wave? For that we need to know the wavelength of the Rayleigh wave and the frequency. So, if I can draw a figure here so if the Rayleigh wave is like this then what is the wavelength here? Wavelength is this much this is lambda R; R stands for Rayleigh wave.

So, if we know the wavelength and also if we know the frequency then using this relationship that frequency times wavelength is equal to the velocity of the wave we can calculate the velocity of Rayleigh wave. Now the question how we can measure the wavelength lambda R. So, we can measure the number of wave or we can call it wave number for a particular distance x.

Suppose, wave number is n then we can calculate the wavelength which is x divided by n you can see in this equation 8. Here just I have forgotten to write the axis so horizontal axis is representing displacement, please correct it, please write it here and the vertical axis represents the amplitude of the wave.

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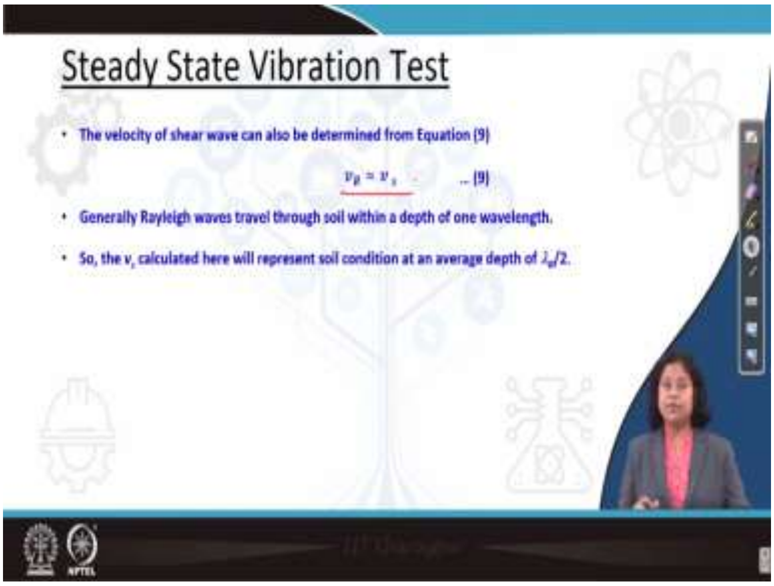

We have already seen that the velocity of the Rayleigh wave is almost equal to the velocity of the shear wave. So, we can calculate, we can report the velocity of the shear wave from the velocity of the Rayleigh wave using this relationship. Now, generally Rayleigh wave travels through soil within a depth of one wavelength that means from the ground surface to the depth lambda R we can expect the Rayleigh wave because it is a surface wave. So, the velocity of the shear wave which is v s here represents the soil property for a soil having average depth lambda R by 2 where lambda R is the wavelength of the Rayleigh wave.

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So, come to the summary of today's lecture. In this lecture field test related to determine the dynamic properties of soils are discussed. What are those field test? Block vibration test and steady state vibration.

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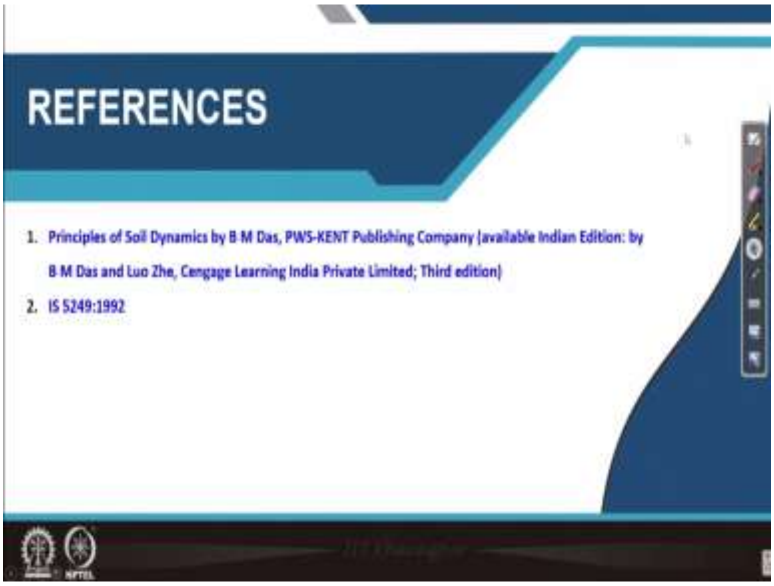

So, these are the references which I have used for today's lecture, one textbook and IS code 5249 1992. Thank you.