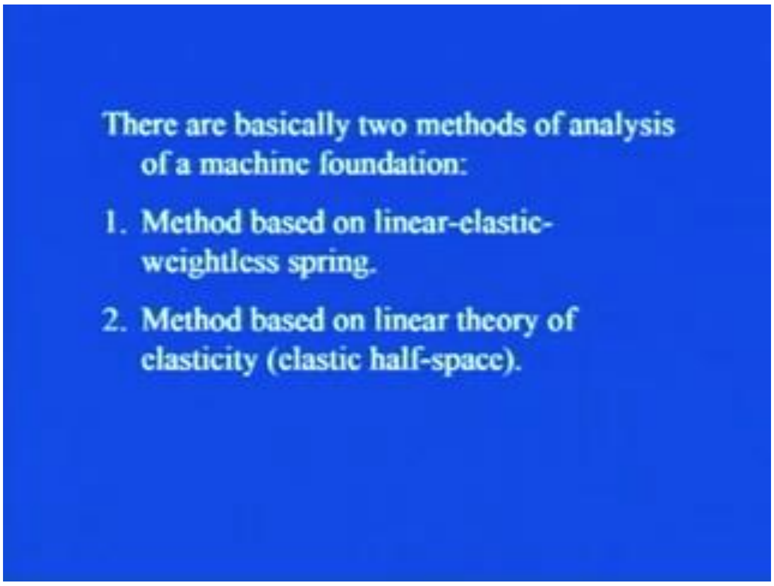
Foundation Engineering
Dr. Priti Maheshwari
Department Of Civil Engineering
Indian Institute Of Technology, Roorkee

Module - 2
Lecture - 14
Machine Foundations - 2

Hello viewers, in the last class we saw, that what are the various terminology related to Machine Foundations and then we saw that how you can analyze, a linear spring soil system. Then, we saw what exactly do we mean by, free vibration, force vibration and how the analysis can be carried out with and without damping. We saw, in the last class also, that there were three types of foundation one was block, then box, and then wall foundation.

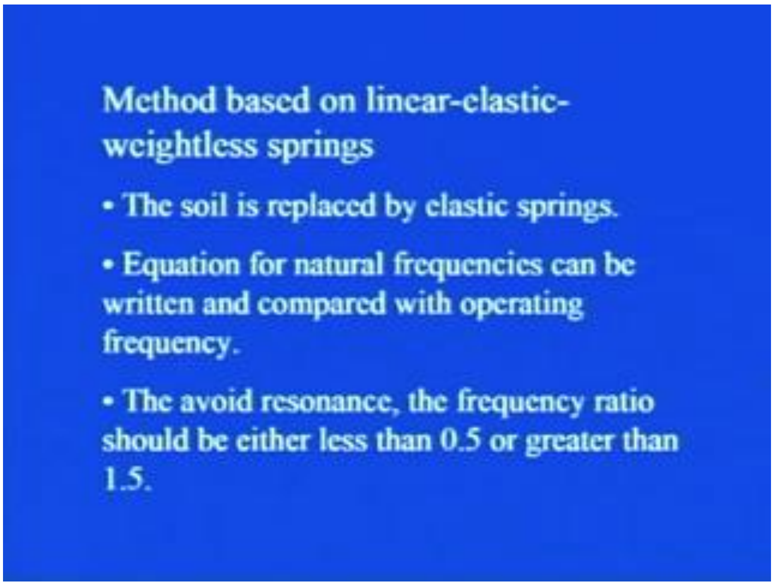
So, within the scope of your course, we have this block foundation, so let us try to see, that how you can analyze, this block foundation, what exactly are the methodologies adopted for this analysis, so the we will discuss now, the method of analysis of a block foundation.

(Refer Slide Time: 01:25)



Basically, there are two methods for the analysis of, this machine foundation, first one is method based on linear elastic weightless spring, that you have already seen that how, you can represent the system by spring and mass system. Then, method based on linear theory of elasticity that is elastic half space, so first let us try to see, that how this method based on, linear elastic weightless spring works.

(Refer Slide Time: 02:02)



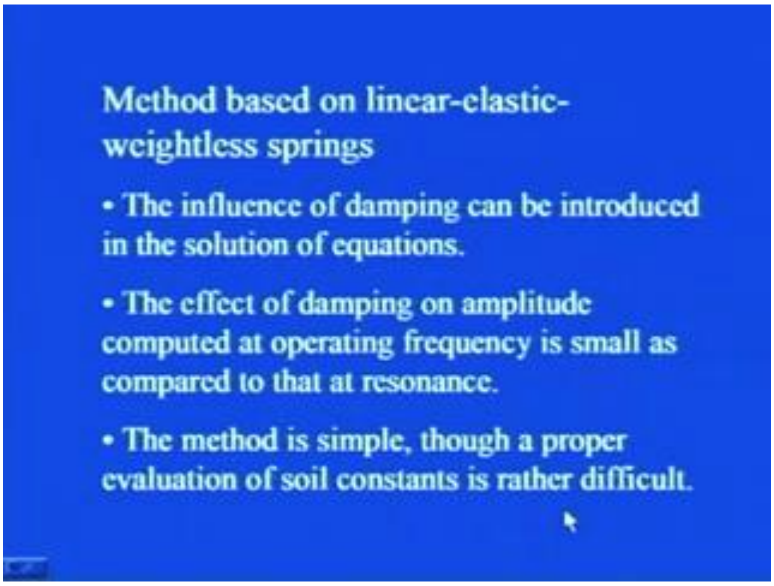
In this method, the soil is replaced by elastic springs, see anything that if you want to have, it is response you have to convert into some mathematical form. So, that you can gets it is response, so in that case, as such soil you cannot it is natural occurring soil, natural occurring material, so we really need to replace it such that, we can convert this natural occurring soil to some kind of model, so for modeling the soil, the elastic springs are used.

Equation for natural frequencies, can be written and compared with operating frequency, you have already seen that, when we were discussing about this soil this spring mass system. In that one you have seen that, how you can get the equation for natural frequency and how you can compare that, with operating frequency using that frequency ratio are, which was the ratio of operating frequency of machine and the natural frequency.

And the standard curve with respect to, that is frequency ratio verses magnification factor have been given for 0 damping as well as, with damping. So, from there we can get this, natural frequencies to avoid resonance, the frequency ratio should be, either less than 0.5 or greater than 1.5. We have seen that, exactly the resonance condition occurs at exactly, frequency ratio to be equal to 1 however, in the vicinity of r is equal to 1 also the amplitude values are quiet high.

So, that is why to avoid any kind of resonance, the frequency ratio is kept in the range of 0.5 and 1.5.

(Refer Slide Time: 03:53)



The influence of damping can be introduced in the solution of equations that we have already seen, that how it has been introduced, that effect of damping on amplitude computed at operating frequency is small, as compared to that as resonance. As, I showed you the earlier figure, in that one we have seen that at resonance the amplitude is quiet high, while at operating speed that is, when the frequency ratio are quiet high then the amplitude or the magnification factor was not that much, it was very small, so the amplitude is not that much at operating speed.

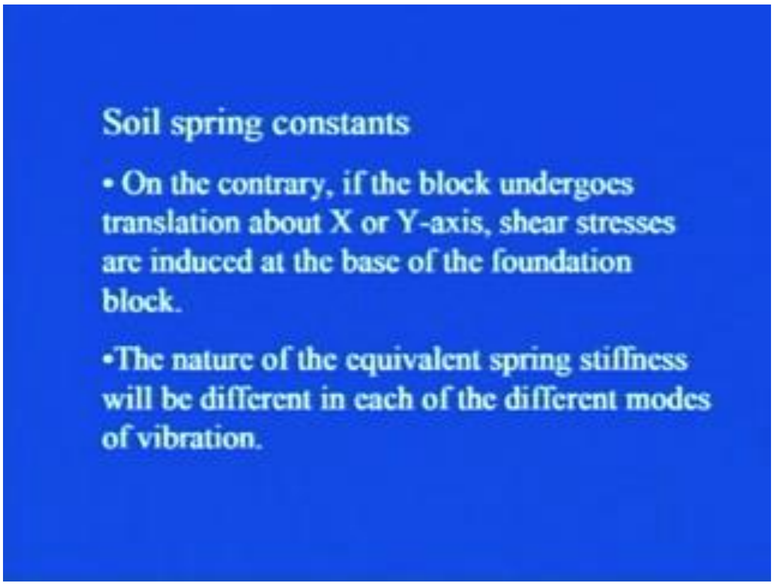
The method is simple, though a proper evaluation of soil constants is rather difficult since, you are replacing the soil by equivalent spring. So, you need to know that, what exactly, is the characteristic of that particular soil, so that the modeling can be done properly, and to evaluate these soil constant it is quiet difficult, we have different measures, so let us try to see, that what are the different soil constants, and how we can obtain them.

(Refer Slide Time: 05:11)

So, first soil spring constants, spring constant is defined as a force causing a unit deformation, so wherever, I am using that spring constant, you this picture should come into your mind that is the force, which will cause unit deformation. For the analyses of a block foundation, one of the approaches is to consider the soil as weightless elastic springs, so if this, since we are talking of the analysis of block foundation, so the soil is being modeled as, weightless elastic springs that a series of springs will be there.

When the block foundation, undergoes vertical oscillation the compression is induced at the base of the spring, sorry footing. You have seen, that the block foundation, it rests on the soil, and in case, you are representing the soil by a set of springs, whenever this block foundation, will be subjected to the load it will, I mean, that machine foundation is there. So, it will be, subjected to static as well as dynamic load, with result of that, it will undergo some oscillation, and so, with the consequence of this oscillation, this compression, will be induced at the, base of the footing.

(Refer Slide Time: 06:34)



On the contrary, if the block undergoes, translation about X or Y axis, shear stresses are induced, at the base of the foundation block. So, you see, either that, the translation, will be there, in X or Y direction, so you see here, I am considering, Z direction, as the vertical direction, however, X and Y directions are in horizontal plains. So, in case, the force, because it is dynamic load, it can be vertical, it can be horizontal, from any direction, it can come.

So, if, due to the presence of dynamic load, this block, if it is undergoing the translation, that is if the movement, is taking place along X or Y direction, or the movement is taking place in horizontal plain. Then, the shear stresses will be induced, as compared to, the compression, which was there, when it was subjected to the vertical load, so two type of things are there, in one case, the compression at the base, of the footing was induced, and in another case, in case, when the block is undergoing translation about X and Y axis, the shear stresses are induced at the base of the foundation block.

The nature of equivalent spring, stiffness will be different in each of the different modes of vibration. Obviously, when it is subjected to compression, at the base of the footing, the property of the soil, or the equivalent spring, with which you have replaced the soil, it will be, different and in case, the translation is taking place, then in that case, the spring constant will be different.

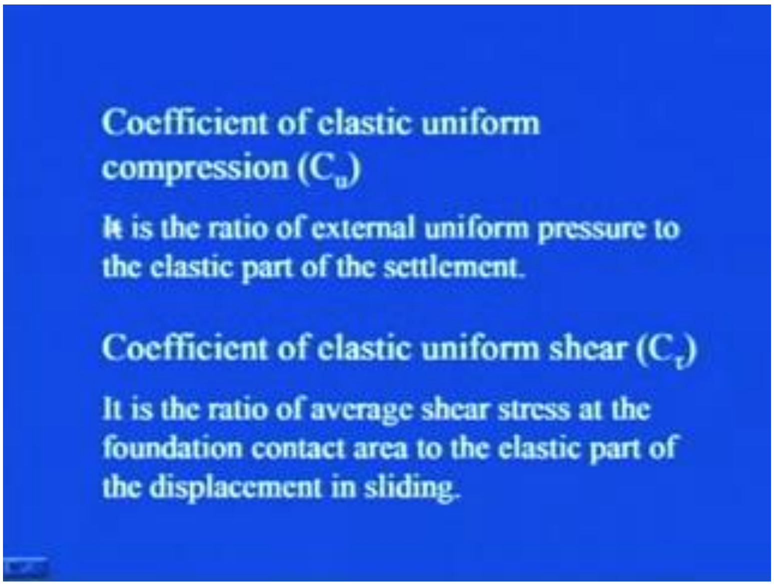
(Refer Slide Time: 08:19)

So, as X and Y axis are interchangeable, there are basically four different types of, equivalent soil spring constant, which are of interest for the purpose of analyses. So, you see, the number of mode of vibration, different number of mode of vibration, different will be the equivalent stiffness of the equivalent spring, by which you are representing the soil. So, whatever, is the mode of the vibration, one corresponding value of, spring constant of the soil, will be there.

If it is compression, that spring constant will be different, if it is translation along, X or Y axis it will be different. So, corresponding to the various mode of vibration, four different type of equivalent soil spring constants are there. Let us, try to see, one by one, that what exactly are they, what is the physical meaning, physical interpretation of them, how you can determine them, using different techniques, so the first one is coefficient of elastic uniform compression.

Second is, coefficient of elastic uniform shear, third is, coefficient of elastic non uniform shear, and the fourth is coefficient of elastic non uniform compression, so these are basically, four types of equivalent soil spring constants.

(Refer Slide Time: 09:45)



First, let us see, that coefficient of, elastic uniform compression, we represent it as C subscript u, that is C u, how we define it as, that, it is the ratio of external uniform pressure, to the elastic part of the settlement. Wherever, we talk, in terms of spring constant, you know, that it is, the force required to cause unit deformation, so that is, what is there, this is also a kind of spring constant, so it is the ratio of, external uniform pressure to elastic part of the settlement.

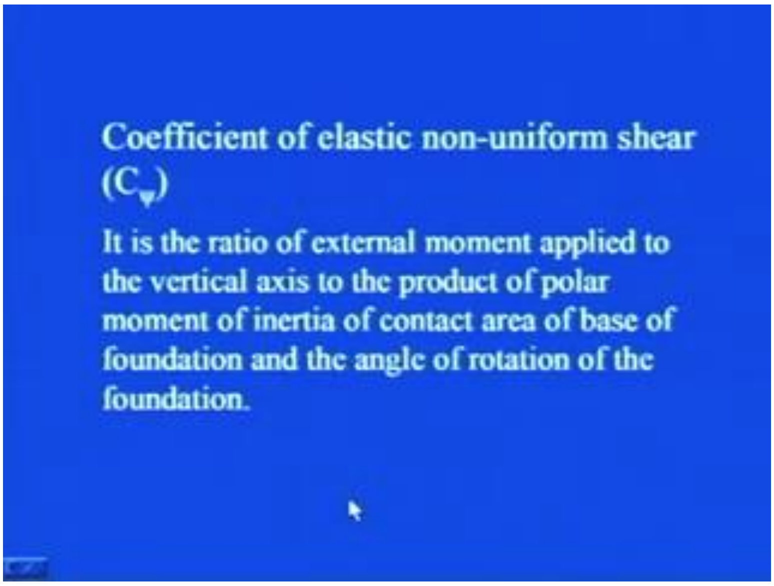
So, when you divide it that means, that you are talking, that force per unit deformation, so what is this force, in this case, it is the external uniform pressure. And, what is the that settlement, is the elastic part of the settlement, as we were discussing, in case when we were discussing, that pile foundation, then we have discussed that, what is the elastic and plastic settlement, so in this case also you will have elastic settlement as well as the plastic settlement.

So, in case of, elastic uniform compression coefficient, you it is the ratio of, external uniform pressure, to the elastic part of the settlement. Then, second one is, coefficient of elastic uniform shear, we represent it as C tau, tau is in subscript, and it is defined as, that it is the ratio of, average shear stress at the foundation contact area, to the elastic part of displacement in sliding, see, it is not compressing right now. So, it is the translation, which is taking place, either in X or Y direction, or X along, X or Y axis.

So, wherever, there is translation we have seen that, there will be, development of shear stress, at the base of the footing. So, in that case, if it is subjected to the translation, along

X or Y axis, in that case, this equivalent soil spring stiffness is defined as, coefficient of elastic uniform shear, where it is the ratio of the average shear stress, which is generated at foundation contact area, to the elastic part of the displacement in sliding. In, above case, it was elastic part of the settlement that was a vertical compression however in this case, it is the displacement in sliding.

(Refer Slide Time: 12:22)



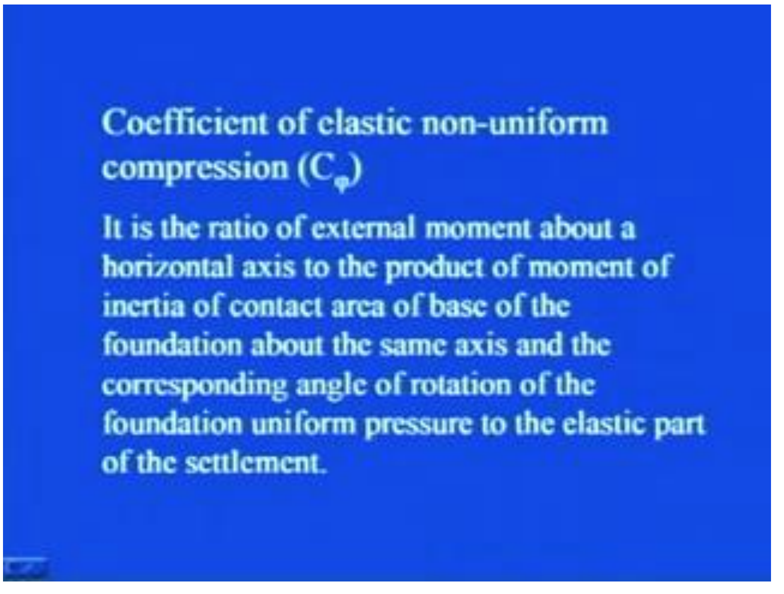
Third one is, coefficient of elastic non uniform shear, we represent it as C psi, it the ratio of external moment, applied to the vertical axis, to the product of polar moment of inertia, of contact area of base of foundation, and angle of rotation of the foundation. You see, if the vertical X and Y axis are horizontal axis, and Z axis is the vertical axis, if the external moment, which is applied, to the vertical axis, then in that case, what will happen, you have the block, area of the block foundation.

So, you can get, the polar moment of inertia of the same, and then, you take the ratio of, that polar moment of the inertia, to the angle of rotation of the foundation. You, see that, I told you, that spring constant is the force to cause unit deformation or deflection, when the force is causing, the deflection, that is, in case of compression, you have seen that, it is, it will be the vertical compression, in case of, the translation it will be the displacement in sliding.

However, if any system or anybody is subjected to a moment, there will not be any translation there will be rotational moment, so that is what is happening here, that, it is subjected to external moment and so. The resulting deformation will not be the translation, but the rotational one, so that angle of rotation of the foundation, so you have, why you find out, the spring constant, equivalent spring constant.

Then, you have to take the ratio of external moment, which you are applying, to the vertical stress, to the product of polar moment of inertia of contact area of the base of foundation, and the ratio with angle of rotation of the foundation.

(Refer Slide Time: 14:29)



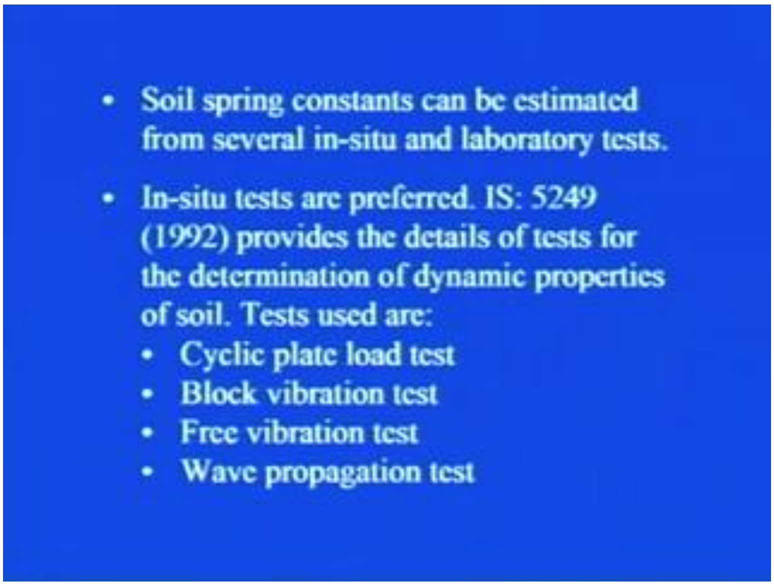
Then, coefficient of elastic, non uniform compression, this is represented by C phi, phi is in subscript, it is the ratio of external moment, about a horizontal axis. See, in the third case, it was about vertical axis, to the product of, moment of inertia, of contact area of base of the foundation, about the same axis, and the corresponding, angle of rotation of the foundation, uniform pressure to the elastic part of the settlement, as it was there, in case of, this non uniform shear, exactly in this case also, it is subjected to external moment, but about horizontal axis.

So, you have to take the ratio, as per this particular definition, to determine to obtain the coefficient of elastic, non uniform compression. Now, how you can determine, these spring constants.

(Refer Slide Time: 15:36)

Let us, try to see that, that how we can determine, this equivalent soil spring constants.

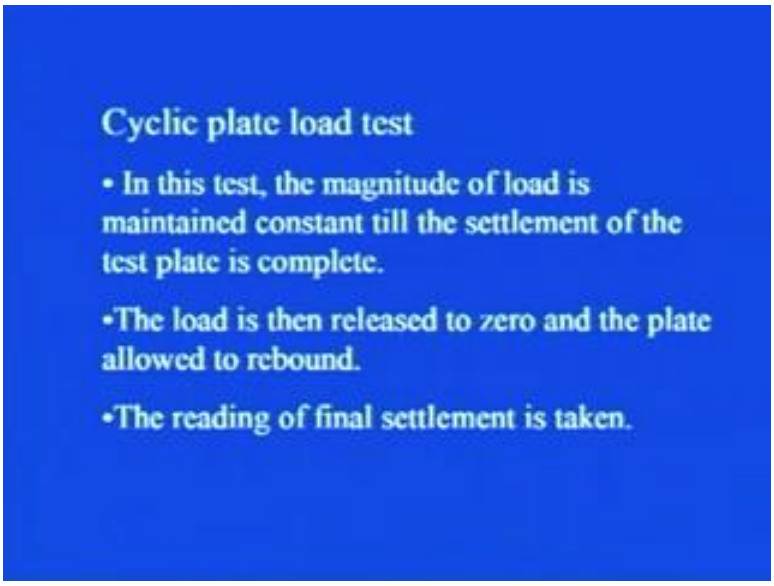
(Refer Slide Time: 15:40)



So, the soil spring constant, can be estimated from, several in situ and lab tests, in situ tests, they are conducted in field, however, lab tests obviously, as name suggest, they are conducted in laboratory. So, in situ tests are preferred, because they represent the real situation, which is exactly existing in the field, and which, will be the, they will be represent, representing the exact condition, that the foundation or the soil foundation, system will be subjected to.

This IS code, that Indian standard code of practice is there, and its number is 5249, that is IS 5249, 1992, provides the details of test, for the determination of dynamic properties of soil. What are these tests, these tests are cyclic plate load test, then block vibration test, free vibration test, and wave propagation test, let us, try to see, that what exactly are these tests, how they are conducted, what are the different guidelines, given in IS code, and how you can analyze the test data, to obtain or to estimate, this equivalent soil spring constants.

(Refer Slide Time: 17:08)



So, first we discuss about, the cyclic plate load test, in this test, the magnitude of load is maintained, constant till the settlement of the test plate is completed, as you see, as the name suggest, that it is cyclic. And, since the dynamic loads are coming into picture, obviously, you have to go for cyclic kind of loading, so this is in situ test conducted in the field a plate is there, a foundation a representative plate is there, so wherever, you have to conduct that particular test.

You, have to put the arrangement, at that particular depth, and then the loading arrangement, is made in such a manner, that loading as well as unloading, can take place, So, whenever, you apply a load, you obviously, on the application of that load, the soil beneath, that plate, will be, deflecting or the some settlement will be, taking place. So, you have to, give sufficient time, that that particular settlement has been stabilized, it is not further settling.

So, for that purpose, the magnitude of the load is to be maintained constant, till, the settlement of the test plate is complete. That means, that the, whenever, the further settlement of the test plate, is not occurring, then only, you can increase or decrease the load, in case of loading, or in case of unloading respectively. But, till the point, the test plate is settling, you have to maintain the load on the test plate, the load is then released to zero, and the plate allowed to, rebound.

So, first is, once you have to load it, to some particular load, then you have to unload it, so after loading, let us say, for the first cycle, after loading, you have to maintain, that load, till the test plate is stopped settling. Then, from that particular point of time, you have to go on withdrawing, the load from the test plate that means, that you have to, unload the test plate, so in that particular process, you will be, removing the load in some steps.

So, in that case, the load will be released to zero, and obviously, due to the elastic, some of the elasticity, which is present in the soil, the test plate, will have the tendency to rebound. Although, the settlement, which has already occurred, the resulting settlement will not be zero that is it will not be recovering, whole of the settlement, but some part of the settlement, it will be recovering, and that part of the settlement is called as elastic settlement.

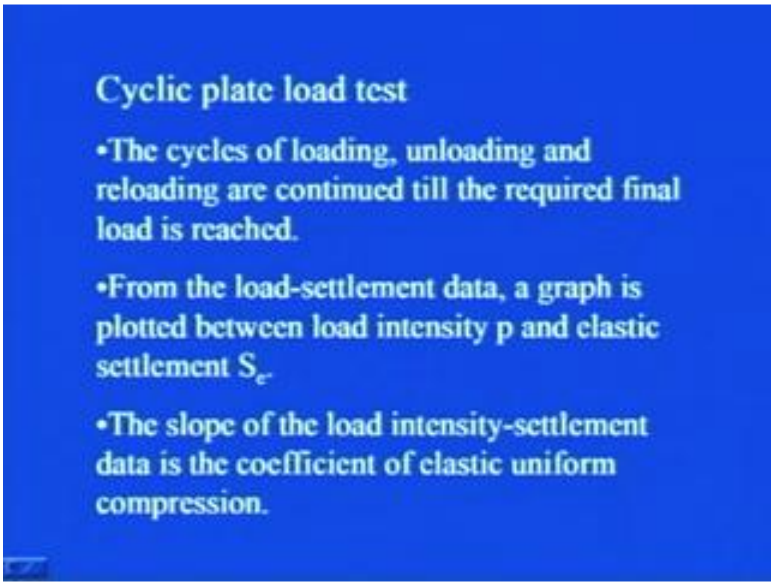
So, then, when this test plates is allowed to rebound, you can note down that, once this rebound is stopped, you can no note down, that particular reading of the test plate, that is that particular settlement. So, that is there, that the reading of final settlement is taken, the load is then increased to, next higher magnitude of loading, and maintained constant, till the settlement is complete, which again is recorded.

So, once you have loaded, and then you unload it to zero, then further loading takes place, and exactly in the similar manner, as you did for the first loading cycle, you have to do. For the second loading cycle, that whatever, is the maximum loading intensity on the test plate, corresponding to that obviously, the plate is going to settle, so you have to maintain, that such loading intensity, till the time, test plate stops settling, so till the point, it is settling down, you have to maintain, that particular load.

And, wherever, that settlement stops, you have to note down, that reading, then the load is, then further reduced to zero, and the settlement reading is taken. As, it was done, in case of, first unloading cycle, from the second loading cycle, you go on withdrawing the load, such that the load on the test plate becomes zero, and in this process, you must allow the test plate to rebound. Because, whatever, is the elastic settlement, or, due to elastic nature, it will have, the tendency to rebound or to recover some of the settlement.

So, that particular settlement reading is also to be taken, and then further the next, increment of the load is applied, again this procedure is repeated.

(Refer Slide Time: 21:51)

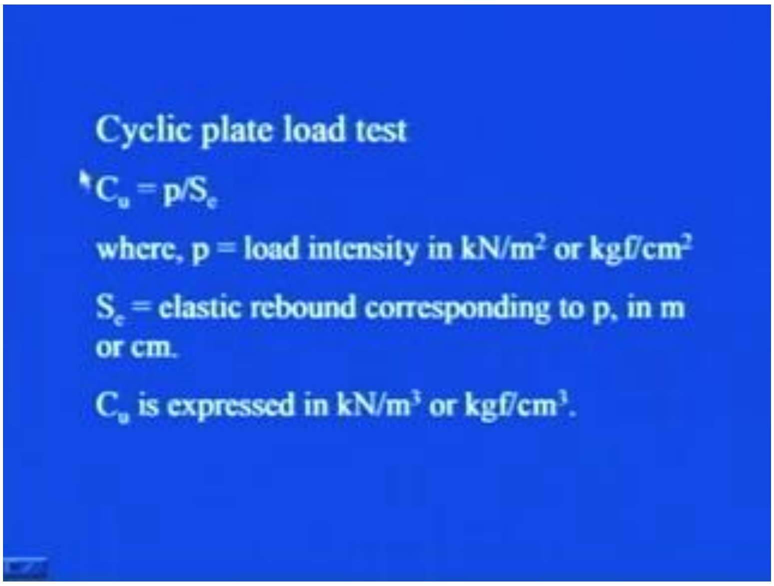


The cycles of loading, unloading and reloading are continued, till the required, final load is reached. So, you see, either the final load is reached, this IS code has given the provision, that what should be this final load, till the plate fails, you can see, you will be having, one particular condition, in some loading cycle, that the plate, will not be taking any further load, or the failure will be represented by, excessive settlement of the plate, so there till that particular level, till the failure of the soil, which is around the plate, you have to go on loading, unloading and then reloading again.

From the load settlement data, a graph is plotted, between load intensity p, and elastic settlement S e. You see, whenever, we were allowing the plate to rebound, to what extend it has rebound, we have noted down, that final settlement, so from there, we can get, the elastic settlement, because whatever, it has recovered, that is a part of the settlement, which is elastic, remaining is plastic settlement, so the elastic settlement, we can get corresponding to, each loading intensity.

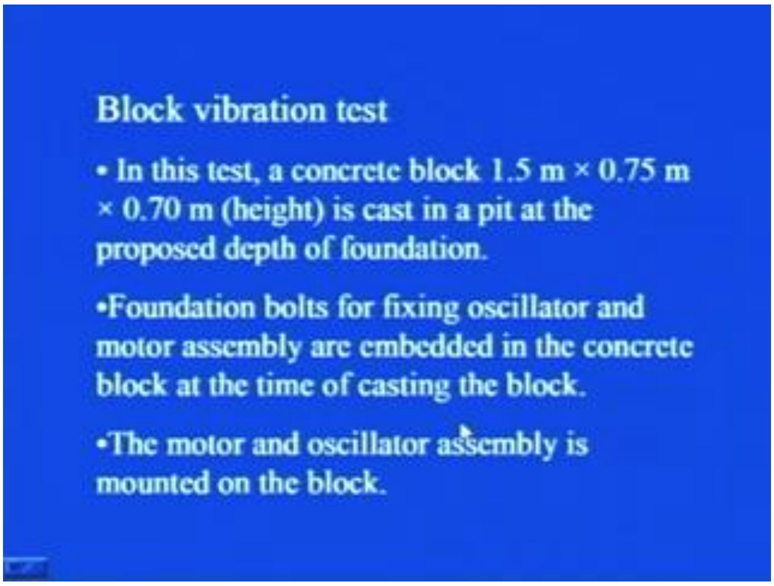
The slope of the load intensity, settlement data is the coefficient of elastic uniform compression. So, from the load settlement data, directly you will be getting, this load intensity p, verses elastic settlement, and the slope of, this particular curve, will give you the coefficient of elastic uniform compression. So, you I hope, that now you understood, that how you can get the coefficient of elastic uniform compression, using cyclic plate load test data.

(Refer Slide Time: 23:52)



So, here, you see, that C u was the coefficient, which we are intend to find out, is equal to p by S e, where p is the load intensity in kilo Newton per meter square, or kg force per centimeter square. S e is elastic rebound corresponding to p, in meter or centimeter then your unit of C u will be kilo Newton per meter cube or kg force per centimeter cube, you have to be consistent as far as, the units are concerned, if you are using this IS units, kilo Newton per meter square, and meter, you should use or in case of CGS, you have to use this kg, force per centimeter square, and centimeter for elastic rebound.

(Refer Slide Time: 24:38)

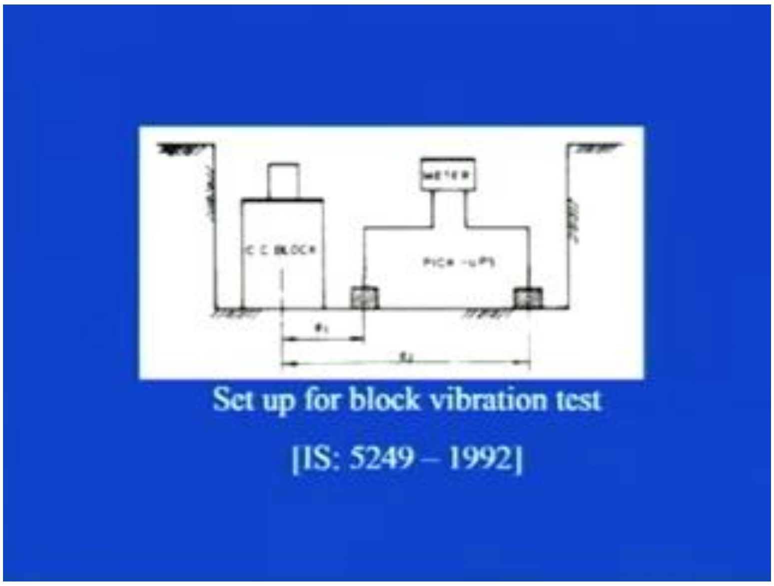


Now, this was all about, the cyclic plate load test, so cyclic plate load test, gives us, the coefficient of compression that is elastic uniform compression that is C u. Now, let us try to see, that how this block vibration test is conducted, you remember, that we talked of four tests, first was cyclic plate load test, and the second is block vibration test. In this test, a concrete block of size, 1.5 meter, 0.75 meter and 0.70 meter, which is the height of the block, is cast, in a pit, at a proposed depth of foundation.

So, wherever, you are planning to place the foundation, at that particular depth, you can create a pit, till that particular depth, and there on that particular depth, the concrete block, which is, of this, these dimension is casted. Then, foundation bolts, for fixing oscillator and motor assembly are embedded in the concrete block, at the time of casting the block. So, while you, cast the block, the bolts, because you know, that oscillator and the motor, they will be performing there, because it is machine foundation.

So, you have to fix the bolt, while you are constructing, that particular block, so that subsequently, you can fix oscillator and motor, to this concrete block. The motor and oscillator, assembly is mounted on the block. So, we have the fixing arrangement, we have the bolts for that, so you with the help of those bolts, the motor and the oscillator, they are fixed on the block.

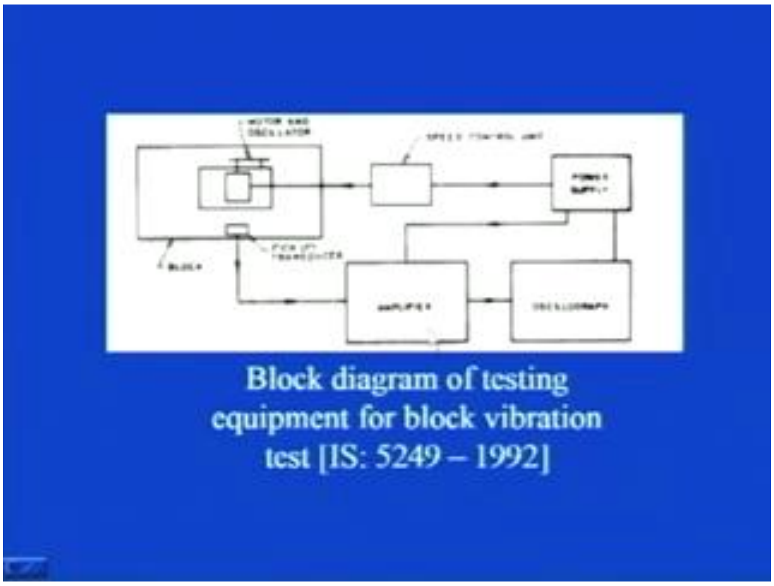
(Refer Slide Time: 26:31)



You can see here, that it, is the test pit, this is the figure, which has been taken from IS 5249, 1992. So, this IS code, if it is available to you, you can directly get, this particular figure from that, IS code, so this is, this shows the set up for, block vibration test, as I told you, that it is to be conducted in, a test pit. You see, this is the test pit, that is, at this particular depth from the ground surface you are planning to place the foundation for, that particular machine.

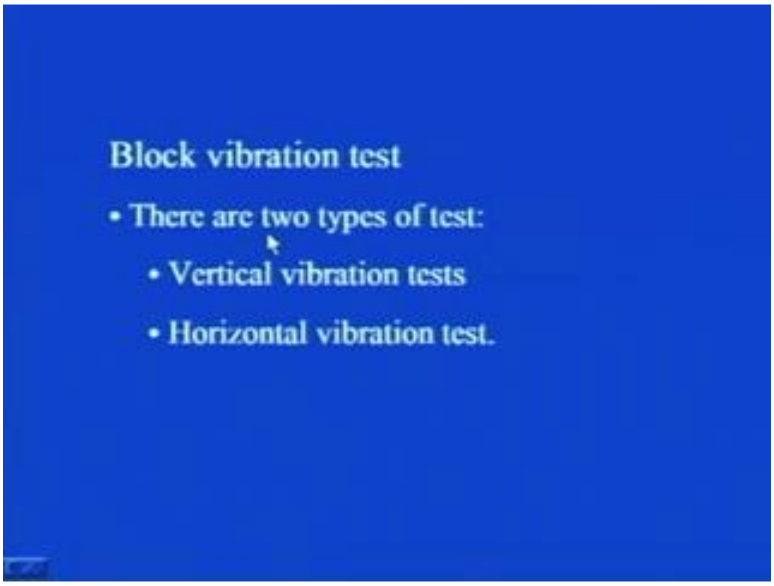
And, here you see, a cc block, that is concrete block, has been casted here, and on top of that, this assembly of oscillator and motor has been mounted. However, these are to take, the readings for this block vibration test, that we will see, right now.

(Refer Slide Time: 27:31)



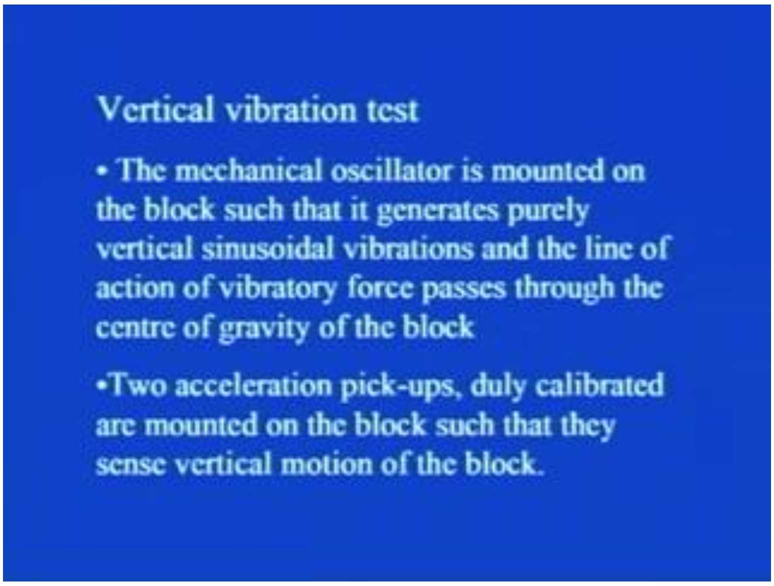
Then, this is the block diagram of testing equipment for, block vibration test, this is again has been taken from 5249, 1992, that is IS code, it is this concrete block. So, you can have a look that, how it looks from the top, so this is the concrete block, on top of that, this is the motor and oscillator, which has been mounted, here is the amplifier, here is the power supply, this is speed controller unit, so and here, it is transducer, to take the reading.

(Refer Slide Time: 28:11)



How, it is done, that there are two types of tests, that is one is vertical vibration test, another is horizontal vibration test, so what exactly, these test are, and what are their salient features, we will see one by one.

(Refer Slide Time: 28:28)



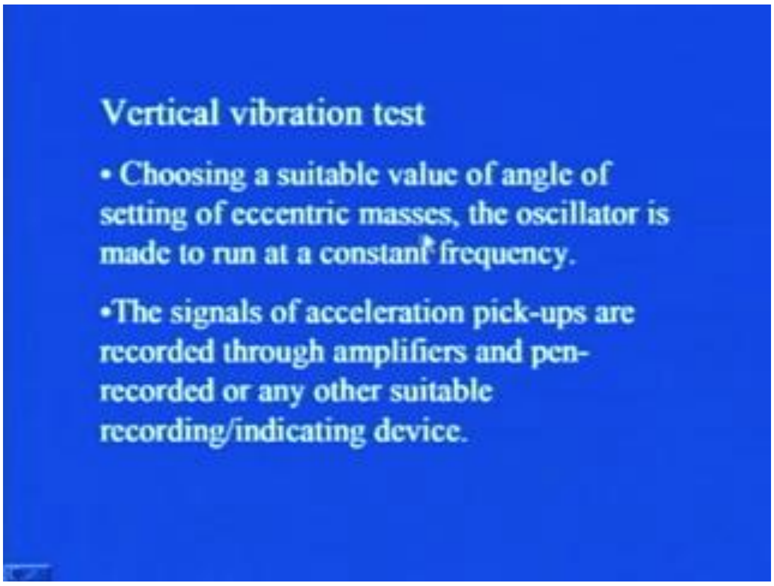
That first, let us see, that vertical vibration test, the mechanical oscillator is mounted on the block, such that it generates, purely vertical sinusoidal vibrations, and the line of action of vibratory force, passes through the CG of the block, that is centre of gravity of the block. As, the name of the test suggest, that it is vertical vibration test, so the mechanical oscillator, which has been mounted, on the concrete block, it is mounted in such a manner, that it generates the oscillation in vertical direction, that is vertical sinusoidal vibration, and its line of action, that is it will be creating the external force, which will be acting on, that particular block.

So, you see, as the name suggest, that is vertical vibration test, the mechanical oscillator, is mounted on the block, such that it generates, purely vertical sinusoidal vibration. So, in case of, vertical vibration test, which the whatever, is the oscillations, which is getting generated, that has to be essentially, vertical sinusoidal vibration, and the line of action of vibratory force, passes through the centre of gravity of the block

So, the whatever, is this mechanical oscillator, which has been mounted, we have to make sure, with the help of these, calibrated transducers, that it is, generating purely vertical sinusoidal vibration. And, this particular line of action of this external force, must coincide, with the center of gravity of the concrete wall block, on which, this oscillator has been mounted, then two acceleration pickups, duly calibrated are mounted on the block, such that, they sense vertical motion of the block.

So, to note down or, to have the, if knowledge, that what exactly is the vertical motion of the block, how it is taking place, this acceleration pickups, are also mounted on the block.

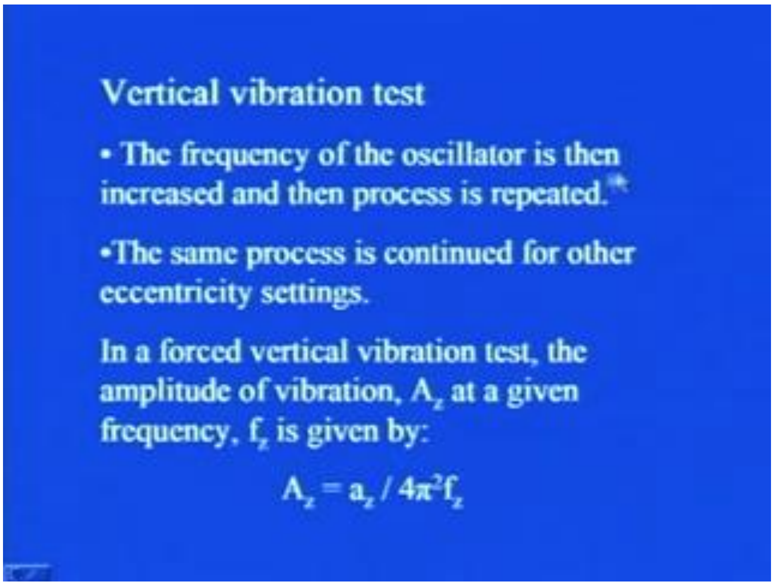
(Refer Slide Time: 30:48)



Choosing a suitable, value of angle of, setting of eccentric masses, the oscillator is made to run, at a constant frequency. So, little this thing, eccentricity of the masses is there, so for, that particular value of, angle of setting of eccentricity masses, the oscillator has to run, at a constant frequency. For one particular eccentricity, it the frequency of the oscillator, should not be different, the signals of acceleration pickups are recorded through amplifiers, and pen recorded or any other suitable recording indicating devices.

So, the signals of acceleration, then after that, it is being converted, that is, first the test is conducted, whatever is the data, that you collect, and then you have to analyze. So, for that the signal of the acceleration pickups are, recorded through amplifiers or pen recorder or any other suitable device, so how they are being analyzed, afterwards we will see here.

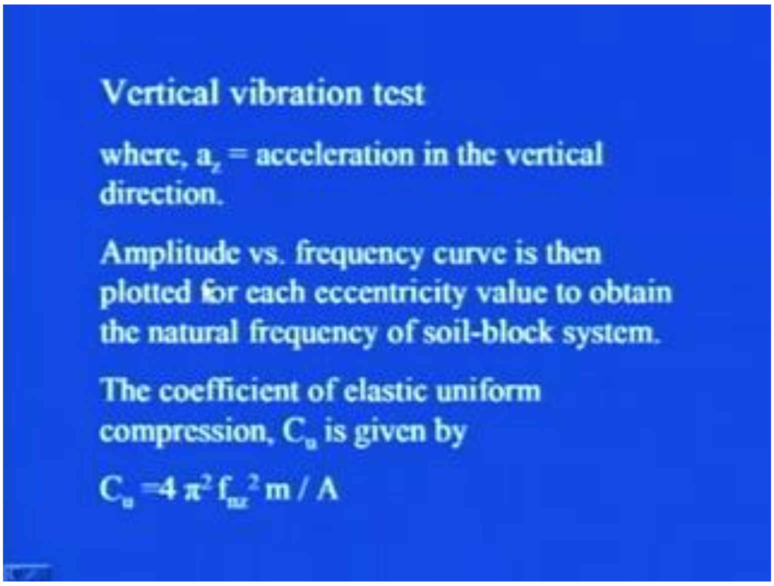
(Refer Slide Time: 31:57)



The frequency of the oscillator is then increased, and the process is repeated, so you see, first for one constant frequency, the experiment was conducted, and then this frequency was increased, and the whole experiment was repeated again. So, the same process is continued, for other eccentricity setting, so you pick different, different eccentricity setting, and choose particular constant frequency, throughout that, and then, you can go on conducting the test, and go on recording the, response of acceleration pickups.

In a forced, vertical vibration test, the amplitude of vibration, that is A z at a given frequency f z is given by, A z is equal to small a z divide by 4 pi square f z.

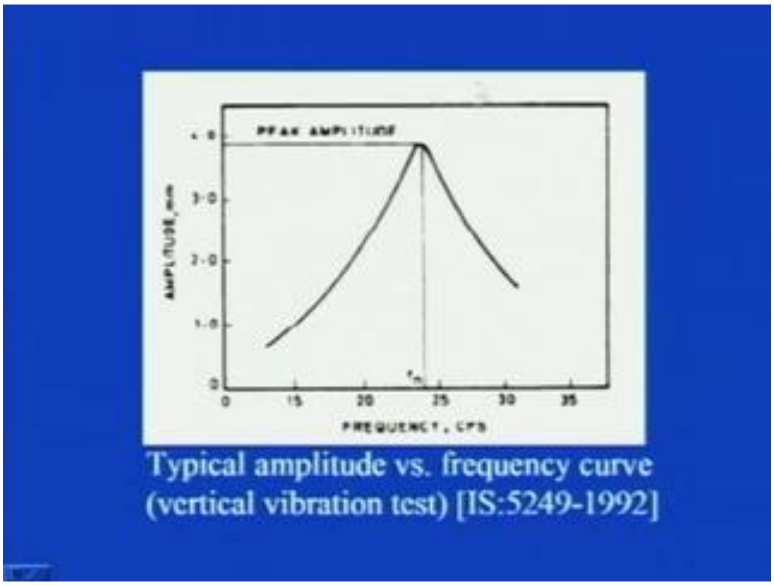
(Refer Slide Time: 32:49)



Where this, a z is acceleration in the vertical direction, you see, you were recording the response of acceleration pickups, that is how, you will be able to, get this acceleration in the vertical direction, then amplitude, then once you know this, a z you can get ((Refer Time: 33:08)) this amplitude. How, amplitude verses frequency curve, is then plotted for each eccentricity value, to obtain the natural frequency of soil block system, we will see, with help of one figure, that how it is obtained.

But, from this particular expression ((Refer Time: 33:25)) once this, a z is known, and at a given frequency, so this is also given. So, this, you are measuring from the response of acceleration pickups, so once this, and this they are known, A z can be known, and then, this amplitude a z verses frequency, frequency is known, is can be plotted for corresponding eccentricity values, so the coefficient of elastic uniform compression, using this vertical vibration test, can be obtained as, 4 pi square f n z square m by A.

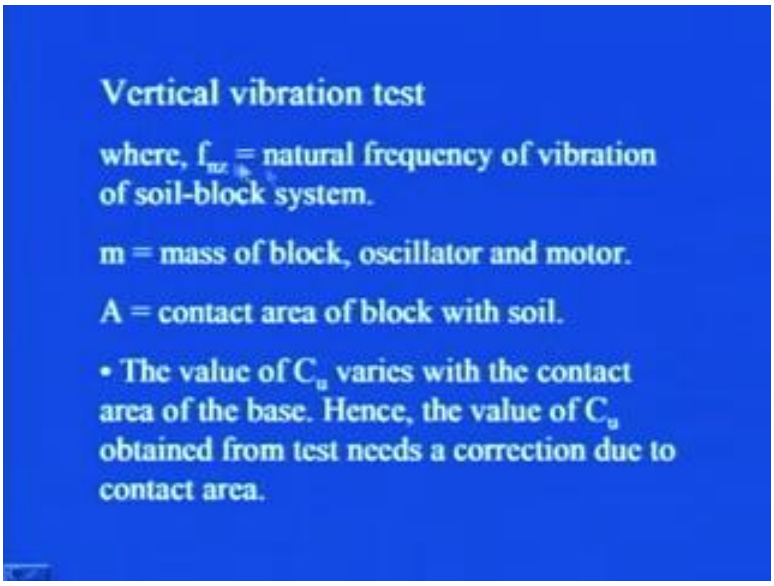
(Refer Slide Time: 34:06)



Now, you see here, that you have plotted, amplitude verses frequency curve, this is for one typical eccentricity value. So, that is why here, I am writing as, typical amplitude verses frequency curve, so for one particular eccentricity value, you can get, this amplitude for corresponding different frequency. So, what will happen, when the frequency is less, first it will go on increasing, and then it will attain, a peak value and after that, it will go on reducing.

So, corresponding to, that peak amplitude, whatever is the frequency, that, frequency is f n, that is the natural frequency, which we are interested to find out. (Refer Slide Time: 34:57) To know, here you see, for to know this C u, we need to know this f n z, so that is what we are finding out by, this particular response.

(Refer Slide Time: 35:08)

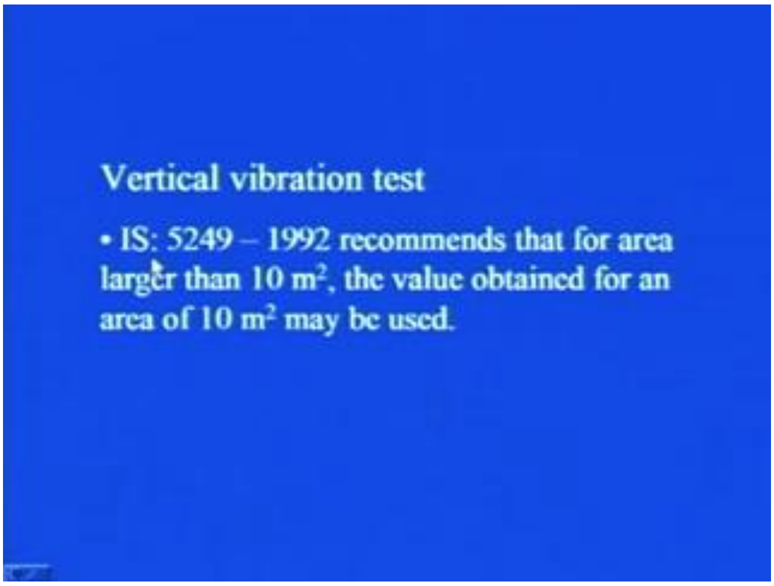


f n z is natural frequency of vibration of soil block system, m is mass of the block, oscillator and motor, A is area of contact of block with soil. So, from the response of acceleration pickups, you can get the acceleration, that is a small a z, and from there, you can find out, the amplitude corresponding to the different frequency f z, by using, that particular expression, as I showed you just now. So, once you know that, what exactly, is the amplitude corresponding to different frequency, you can plot them for, different eccentricity values.

So, if we concentrate on any typical amplitude verses frequency curve, then we see that, first the, this it goes on increasing, and then, once it attains a peak, amplitude, then the curve starts duping down. So, that frequency corresponding, to the peak amplitude is called as this natural frequency of vibration of soil block system, which we want to find out. So, from the test, we can get this f n z, and then subsequently we can get, that C u value.

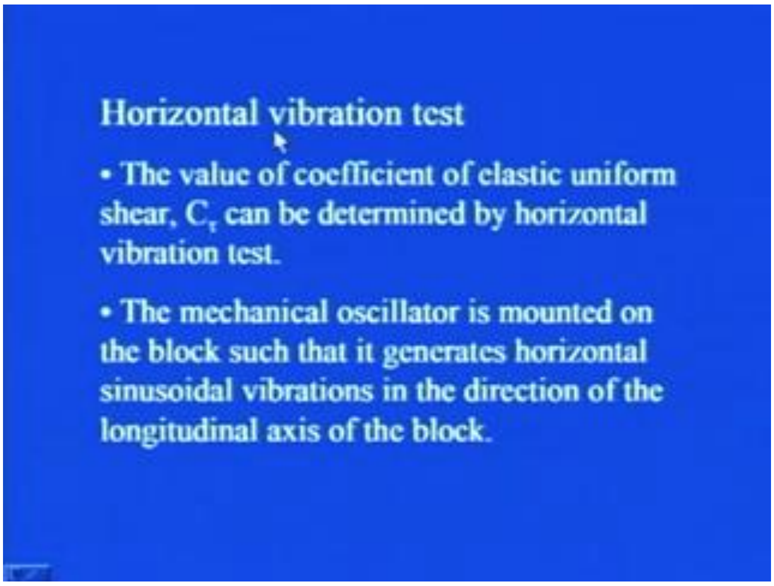
The value of C u varies with the contact area of the base, as you have seen that, the expression of C u area was coming, mass was coming, so all these are the factors, on which, this C u value will depend on. Hence, the value of C u obtained from test, needs a correction, due to contact area, see, this C u is the property of the soil, that is the spring equivalent, soil spring constant, so that should be, independent of this contact area. So, to make it independent of the same, some corrections are to be made.

(Refer Slide Time: 37:16)



What are they, that IS code recommends, that IS 5249, 1992 recommends, that for area larger than, 10 meter square, the value obtained, for an area of 10 meter square, may be used. So, if the area of contact of, that concrete block, with the soil, is more than 10 meter square, then you have to restrict, that area to 10 meter square, if it is less than that, you have to use, that corresponding value, but in case, if it exceed, if it exceeds 10 meter square, you have to restrict the value, to 10 meter square.

(Refer Slide Time: 37:56)



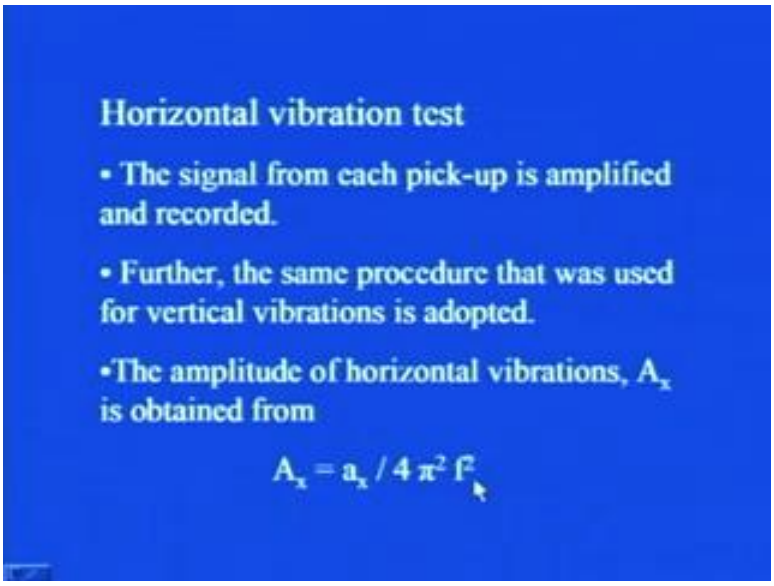
Now, this was all about that, how you can find out, the coefficient C u, using vertical vibration test. Now, let us, try to see, that how we can, get constant using horizontal vibration test, so as the name suggest, horizontal vibration test, and as we were discussing, that when the translation motion is there, along X and Y axis, that is along horizontal plain. Then, we can evaluate, the coefficient of elastic uniform shear, which we were representing as C tau.

So, this can be determined, by horizontal vibration test, the mechanical oscillator is mounted on the block, such that it generates, horizontal sinusoidal vibrations, in the direction of longitudinal axis of the block. In previous case, we saw that the, we saw to it, that oscillator, which has been mounted on the block, is generating purely vertical sinusoidal oscillation. However, in case, of this, horizontal vibration test, that the, oscillation should be, horizontal sinusoidal vibration, and that to in the direction of longitudinal axis of the block.

So, we have to make sure, while mounting this mechanical oscillator, that it should be mounted in such a manner, that it should generate, only horizontal sinusoidal vibration, in longitudinal axis of the block, in that particular direction. So, in this case also, as it was there in case of vertical vibration test, three calibrated acceleration pickups are mounted on the block, one each at top, bottom and middle, along the vertical center line, of the transverse face of the block.

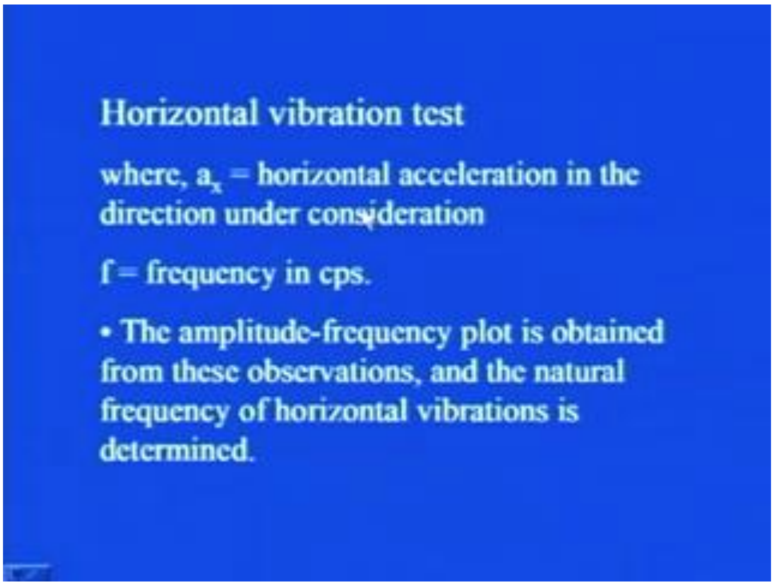
So, as to sense the horizontal vibration, because whatever, vibration has been created, using this oscillator, that has to be recorded. So, that is being done, using this acceleration pickups, so that, it response, can further be analyzed to obtain this constant C tau. The oscillator is excited in steps, starting from at rest condition, so earlier, it is, at rest, there is no excited state, in the oscillator, and then, it is excited in steps, it should not that, at in one go, it is excited, in steps, it has to be excited.

(Refer Slide Time: 40:31)



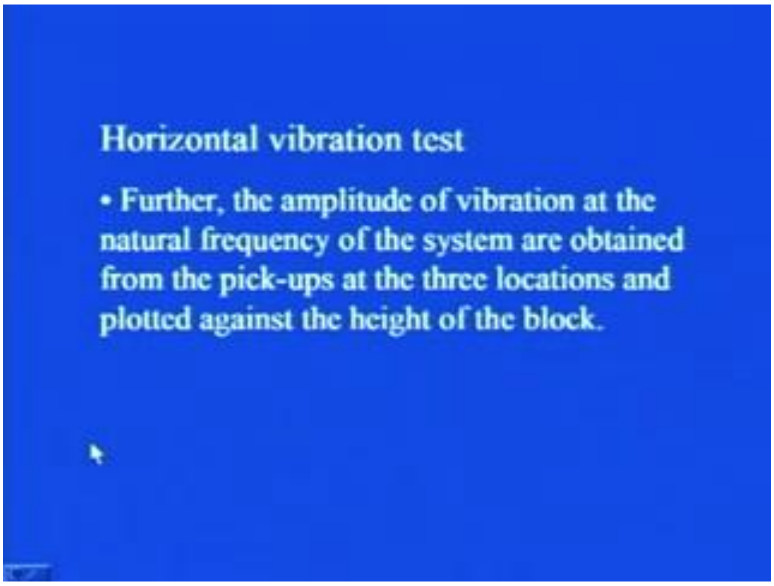
The signal from, each pickup is amplified and recorded, so that we can analyze, this particular data. Further, the same procedure, that was used for vertical vibration test is adopted, in this case also, so once, this is there, so you fix up an, eccentricity setting value, and then you get, the value of acceleration, you find out the amplitude, you then plot amplitude, verses frequency curve to know this, of this frequency of the system. The amplitude of horizontal vibration, that is A x, is obtained from, small a x divided by 4 pi square f square.

(Refer Slide Time: 41:11)



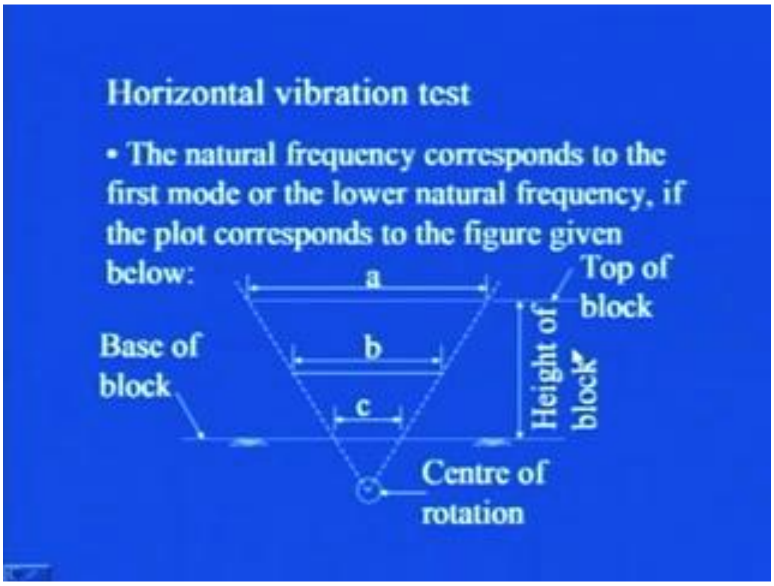
Where, a x is horizontal acceleration, in the direction, which is under consideration, because in horizontal direction, it can be, any in horizontal plain, there can be, n number of this direction. So, you whatever, direction, that in, which you want to, find out the spring constant, in that particular direction, you have to measure this acceleration, where f is the frequency, in cycles per second, that is cps. Then, as you did, in case of vertical vibration test, in this case also, the amplitude frequency plot is obtained, from these observation and the natural frequency of horizontal vibrations are determined.

(Refer Slide Time: 41:58)



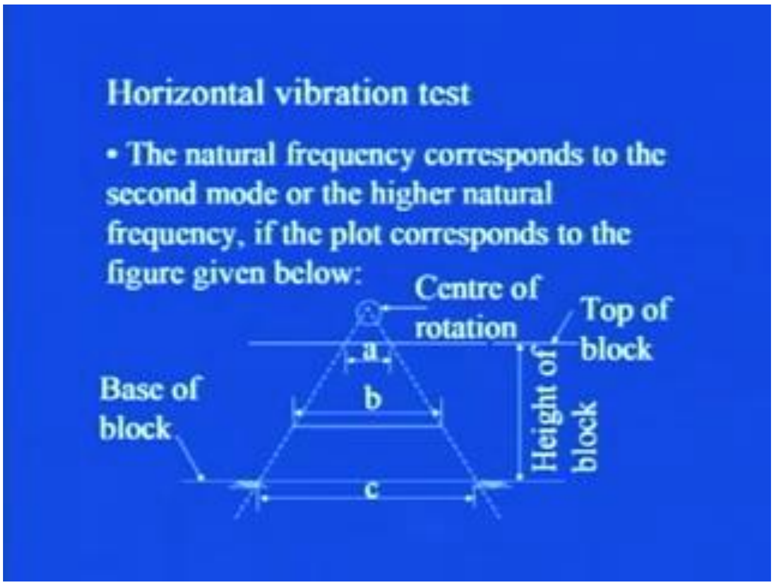
Exactly, on the similar lines, further, the amplitude of vibration, at the natural frequency of the system, are obtained from the pickups, at the three locations, and plotted against, height of the block So, the amplitude the vibration, at once, we you know the natural frequency, you can note down the amplitude of the vibration, then you have mounted, the pickups, acceleration pickups, at three locations, at it top, middle and the bottom, so that, you can plot, against the height of the block.

(Refer Slide Time: 42:34)



Now, the natural frequency corresponds to, the first mode or the load natural frequency, if the plot correspond to the figure given below. So, you see, if I am plotting. it with respect to height of the block, this is what is the response, this is the center of rotation, then, this is top of the block, this is base of the block, where here, it is in contact with the soil. So, if the condition is like that, that this amplitude is go on increasing here, in this particular case, so the natural frequency, will correspond to the first mode, or the lower natural frequency.

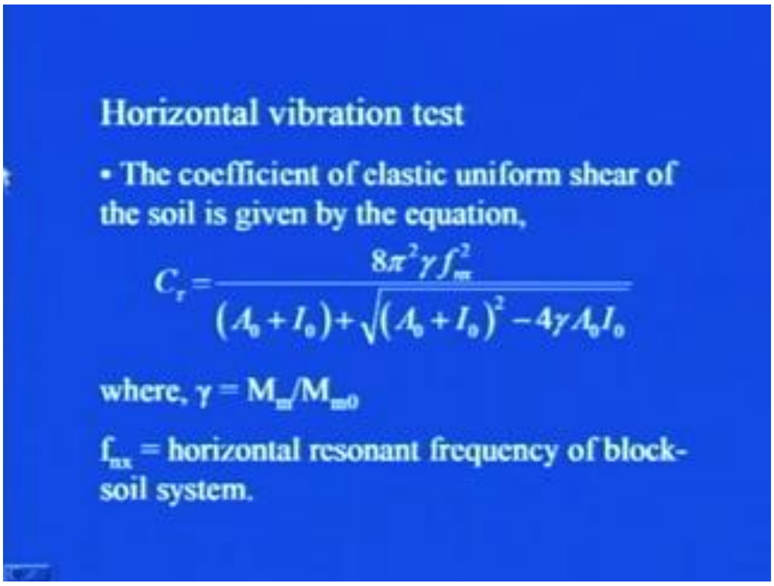
(Refer Slide Time: 43:16)



However, if the case is reverse that is like this, centre of rotation is here, this is height of the block, which we are plotting the variation, with this is top of the block, and you see that the variation is, in this manner. So, in this case, it is the, the natural frequency corresponds to the second mode or the higher natural frequency, if that particular plot corresponds to, this particular type of figure.

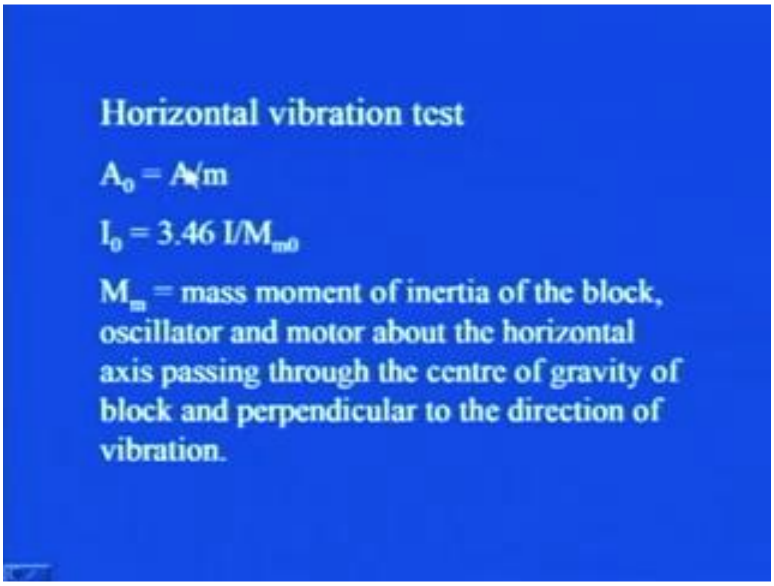
So, in earlier case, it was the first mode, so from that figure, we also can make out, that whatever natural frequency, that we are, we have obtained, is corresponding to first mode or second mode, or whether it is, lower natural frequency or higher natural frequency.

(Refer Slide Time: 44:00)



Then, how we can find out this, coefficient of elastic uniform shear of the soil, it is given by this equation, where it is 8 pi square gamma f n x square divided by, A naught plus I naught, plus square root of A naught plus I naught whole square, minus 4 gamma A naught I naught, where gamma is defined has M m divide by M m o. What exactly, are these we will see, in subsequent slides however, this f n x is horizontal resonant frequency, of block soil system.

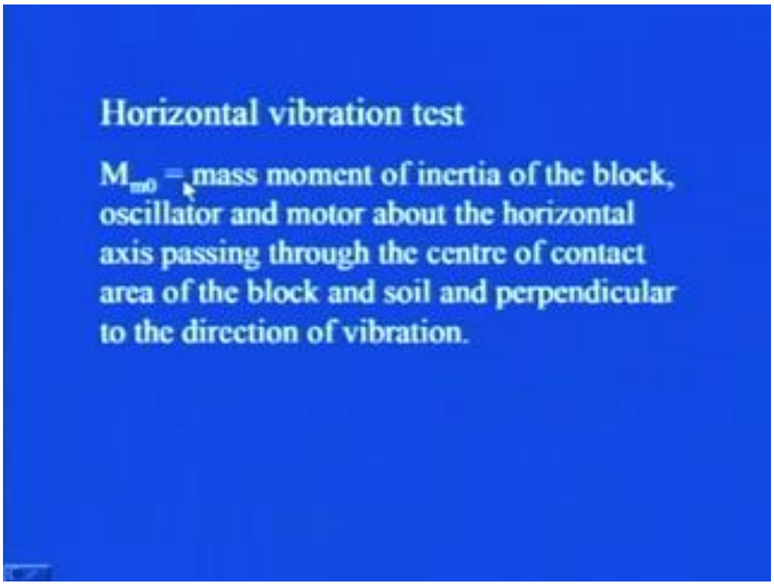
(Refer Slide Time: 44:42)



A naught is A by m, A is you know, area of the contact, at the base with soil, M is the mass of machine oscillator and that block, then I naught is equal to 3.46 I by M m o. That is M m is mass moment of inertia of the block, oscillator and motor, about the horizontal axis, passing through the centre of gravity of block, and perpendicular to the direction of vibration.

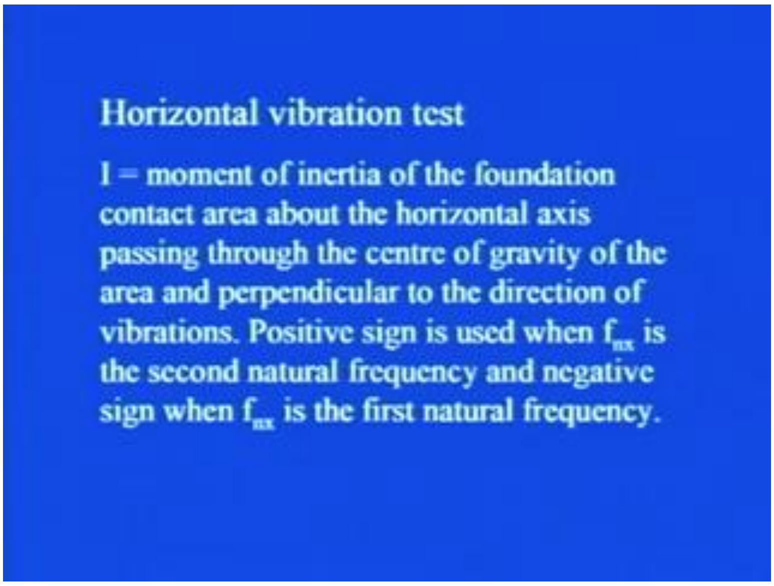
Since, the vibration are getting generated, the oscillator has been mounted in such a way, that, it is generating purely horizontal sinusoidal vibration, and that is why, the whatever is the horizontal axis, which is passing through the center of gravity of the block, obviously, the direction of the vibration will be, perpendicular to that.

(Refer Slide Time: 45:37)



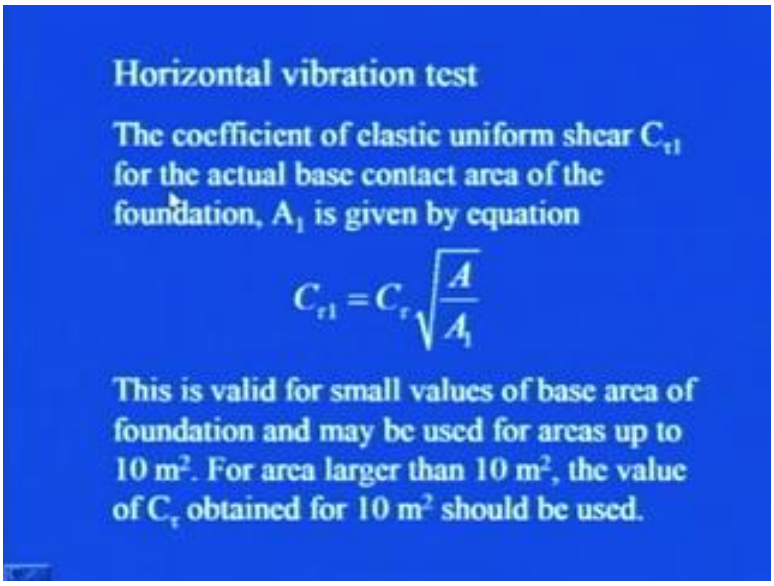
Then M m o is mass moment of inertia of the block, oscillator and motor, about the horizontal axis passing through, the centre of contact area of the block and soil, and perpendicular to the direction of motion. M m was the mass moment of inertia, about the horizontal axis passing through, the center of gravity of the block. However, this is, the mass moment of inertia of block, about the horizontal axis, which is passing through, the center of contact area of the block and soil, so that, you must keep in mind where, this I is moment of inertia, of the foundation contact area, about the horizontal axis, which is passing through the, center of gravity of the area, and perpendicular to the direction of vibrations.

(Refer Slide Time: 46:15)



Now, in this case, the positive sign is used, when f n x is the second natural frequency, and negative sign, when f n x is the first natural frequency. So, just now, we saw, that using this horizontal vibration test data, we can find out, whether it is lower natural frequency or higher natural frequency, or whether it is, first mode or the second one. So, once we know then corresponding, you can assign the sign, so positive sign, for second natural frequency, and negative sign, for first natural frequency.

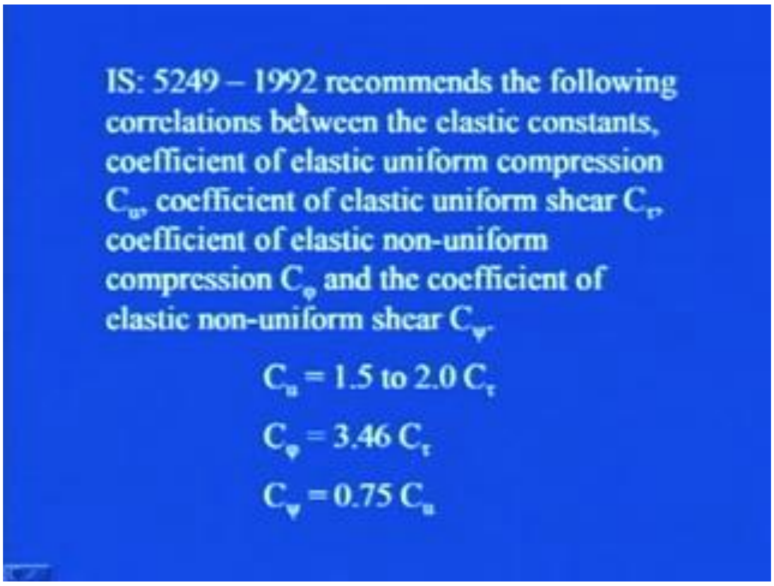
(Refer Slide Time: 47:09)



Then, the coefficient of elastic uniform shear C tau 1, for the actual base contact area of the foundation A 1, is given by, this particular equation, that is C tau 1 is equal to C tau square root of A by A 1. See, A is the area of that block, but it is, just modeling the foundation, it is not the exact size of the foundation. So, for that, correction we need to apply, so that is, what it is, this is valid for a small values of base area of foundation, and may be used, for areas up to 10 meter square.

For areas, larger than 10 meter square, the value of C tau obtained, for C area to be equal to 10 meter square should be used. So, as the case was there, in vertical vibration test, exactly on the similar lines, here also, the area restriction, of 10 meter square, is there. So in case, the area of the foundation base, contact area is more than 10 meter square, then you have to take, the that area value, as 10 meter square, and then go ahead, with the further calculation.

(Refer Slide Time: 48:29)

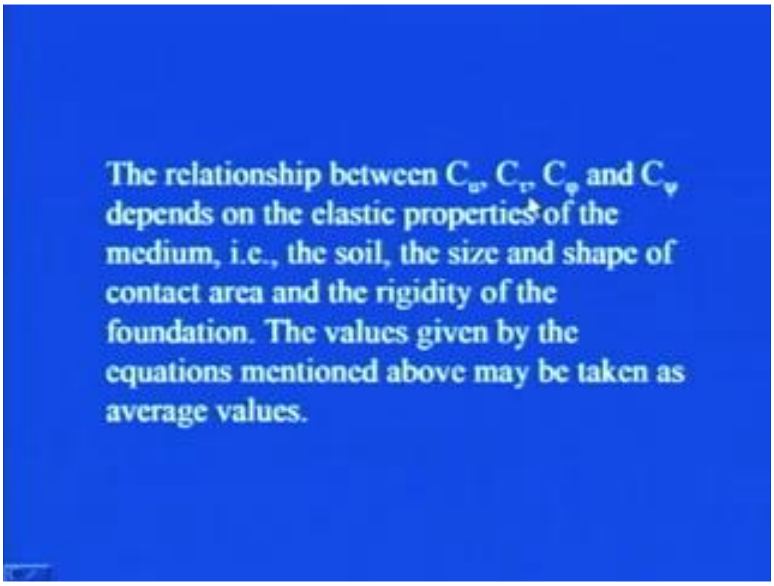


Then IS 5249, 1992 recommends the following correlations, between the elastic constants, coefficient of elastic uniform compression C u, coefficient of elastic uniform shear C tau, coefficient of elastic, non uniform compression C phi, and the coefficient of elastic non uniform shear C psi. As, C u is equal to 1.5 to 2 times C tau, C phi is equal to 3.46 C tau, and C psi 0.75 Cu, see many a times, it is not possible to, conduct let us say, either of the test, may be it is possible to conduct cyclic plate load test, but that, vertical vibration test, or horizontal vibration test is not possible to conduct.

So, what happens is that, you conduct any of the test, get at least one value of this constant, then empirical relations are available, to correlate that. So, let us say, that if you got, the value of C tau, using horizontal vibration test, then in that case, by applying, this or using this particular expression, you can obtain the expression for, or the value for Cu. Once, you know C u, you can find out the value of C psi, and C tau is known, so you can get the value of C phi.

So, these are just the correlation, empirical correlation, based on the experience of different, research workers and the experience of different practitioners, engineers.

(Refer Slide Time: 50:14)



The relationship between C u, C tau, C phi and C psi, depends on the elastic properties of the medium, that is, in this case is soil, the size and shape of contact area, and the rigidity of foundation. The values given by, equations mentioned, in the previous slide, may be taken as average value, since there, they are not being, obtained from some, mathematical means, or some established mathematical method, they are an empirical results or imperial expressions.

So, that is why, while you use, these expression, they just give you the representative values or the average values. So, today, we saw, that how you can analyze block foundation, we saw various aspects that two theories are there, that linear weightless spring theory, and then the theory based on, theory of elasticity. Then, we started with, that how we can go ahead with the analysis, using the first method, that is a spring method, and in that one, we saw, that we need to know the soil property, because we are modeling the soil, using the springs.

So, we need to precisely know, that what exactly is the, property of the spring, and then we saw the, depending on the mode of the vibration, the property of this spring will be changing. So, the question is, that how we can get the property, of the spring, that is equivalent spring, with which we are replacing the soil, so after that, we saw that, how we can find out, these properties, there were four type of basic constants, or a spring constant, equivalent spring constant, that need to be evaluated.

And then, we saw that, how we can do, using cyclic plate load test data, that after that, we saw vertical vibration test and then horizontal vibration test, we saw the methodology, that how, one how all the four this constant can be evaluated, by conducting these in situ or lab test. Then, we discussed about, some of the empirical relations, which are available, because many times, it may not be possible to conduct, all type of test.

Let us say, if we have the result of one type of test, then we should be able to get, the rest other coefficient, for spring. So, we will be discussing, this aspect, further in the next class, with the help of few examples, and then we will, see what exactly, is the effect of damping etcetera, on the analyses of the block foundation.

Thank you.