**Solid Dynamics**
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**Lecture - 56**
**Isolation of Vibration (Part 1)**

Hello friends. Welcome to the course Soil Dynamics. Today is the first class on, isolation of vibration or we can call it as also vibration isolation. So, today, we will see what are the different types of vibration isolation that we can use and the mathematical background of those isolator or vibration screening.

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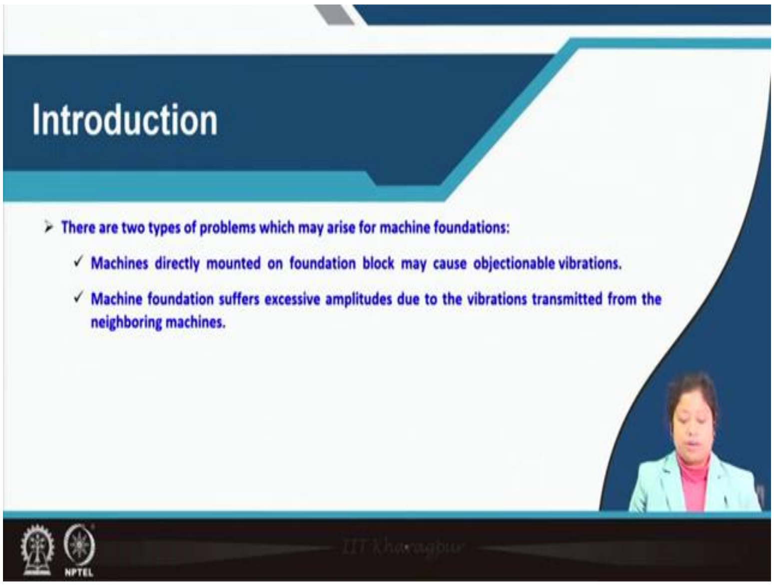


So, basically, what is happen, there are two types of problems for which we need to provide, we need to provide isolator. So, what are those two types of problems that come from machine foundations? First one, machines directly mounted on foundation block may cause objectionable vibrations. So, that vibration can create trouble to the machine as well as to the foundation itself.

So, the second case of problem or second type of problem, you can see here machine foundation suffers excessive settlement or amplitudes due to the vibrations which is transmitted from the neighboring machines. So, suppose in a lab or in a factory there are two machines, which, one is both are probably a very precise equipment. Now, one machine suppose undergoes excessive amplitudes then what will be happen?

That may cause trouble for the other machines, which are kept in the factory or the laboratory. Probably the machines, the machine which causes excessive amplitude may be designed for that, so that mean that excessive amplitude of vibration may not create trouble to the concerned machine itself, but it can create trouble to the other machines kept in the factory or laboratory. So, we need to know what are the solutions for these two types of problems. Let us see the solutions then.

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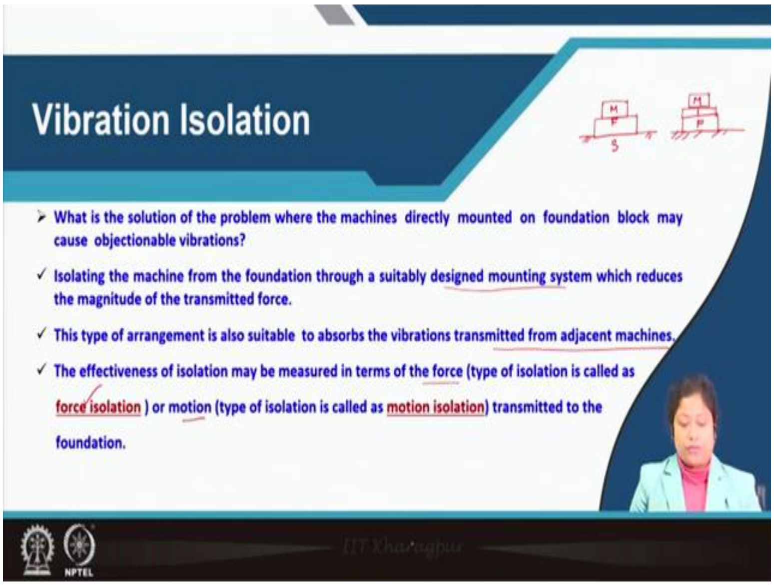


So, the first case what is the solution of the problem for the machines directly mounted on the foundation and causing objectionable vibration. Machine may be okay for that vibration but foundation may not be, that is also possible. So, for that foundation and soil, so for that case what do we do? Isolating the machine from the foundation through a suitably designed mounting system.

And that can reduce the magnitude of the transmitted force. So, if I will draw here, let us say this is machine, initially it is mounted on this foundation block which is resting on the ground surface. So, this is machine, this is foundation, this is soil. Now, if the machine causes excessive, as I said if the machine causes excessive amplitudes of vibration, then what we can do, we can put one isolator here, on the top of the foundation.

And then, so this is foundation, this is isolator and this is machine. In this way we can reduce the magnitude of the transmitted force to the soil foundation system. This type of arrangement is also suitable to absorb the vibrations, which are transmitted from the adjacent machines. Now, the effectiveness of isolation can be measured in terms of the force or in terms of the motion of the ground or transmitted to the foundation.

So, in this case the, if we consider the effectiveness of isolation in terms of the force, then the type of isolation which is used is called as force isolation. Similarly, if the effectiveness is measured in terms of the motion, then the type of isolation is called as motion isolation. So, in short we can say that force isolation means it reduces the amplitude of the force or vibration in terms of force which transmitted to the soil foundation system whereas in case of motion isolation, it reduces the amplitudes of displacement of the ground surface.

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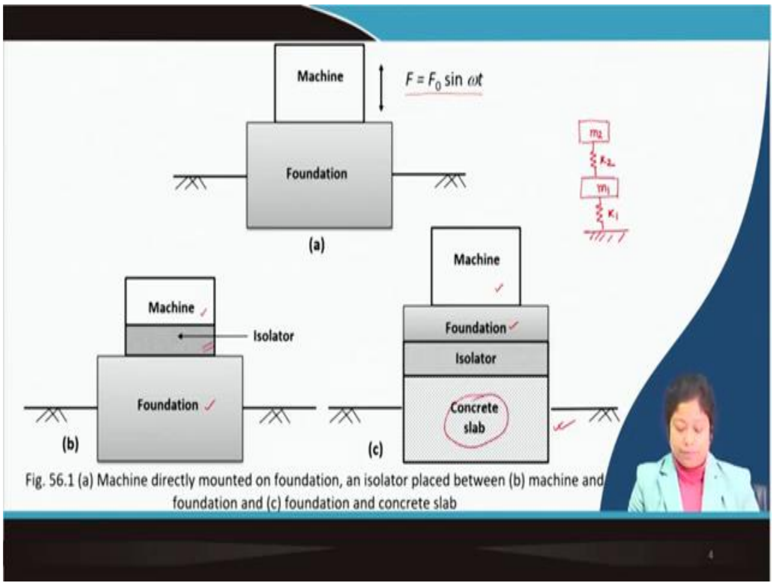


Now, which I have already drawn that you can see here, so machine is resting on the foundation and foundation is in this figure it is partly embedded to the soil, which is more realistic case. So, in this diagram you can see machine is producing dynamic force magnitude or I can say amplitude of dynamic force is F0 and omega is its operating speed. So, in this case if we encounter excessive vibration then what we can do?

We can put isolator in between machine and foundation which can reduce the amplitude of vibration. Also, what we can do, instead of choosing option b, we can choose the, this option where isolated is provided in between foundation and the concrete slab. So, the difference is that generally we can model this type of problem by two degrees of freedom system where there are two masses and we need to represent the isolator and the soil.

If we are assuming soil is infinitely extended elastic medium, in that case we need to use stiffness for the soil as well, and that time m1 and m2, we need to select carefully. If we are considering b, suppose this is m2 connected to spring k2, which represents the isolator and m1, it is connected to spring k1 represents the soil. Now for case b, m2 includes the mass of the machine only where and m1 represents mass of the foundation only. For c, m2 represents the mass of the machine and the foundation together, whereas m1 represents the mass of the concrete slab.

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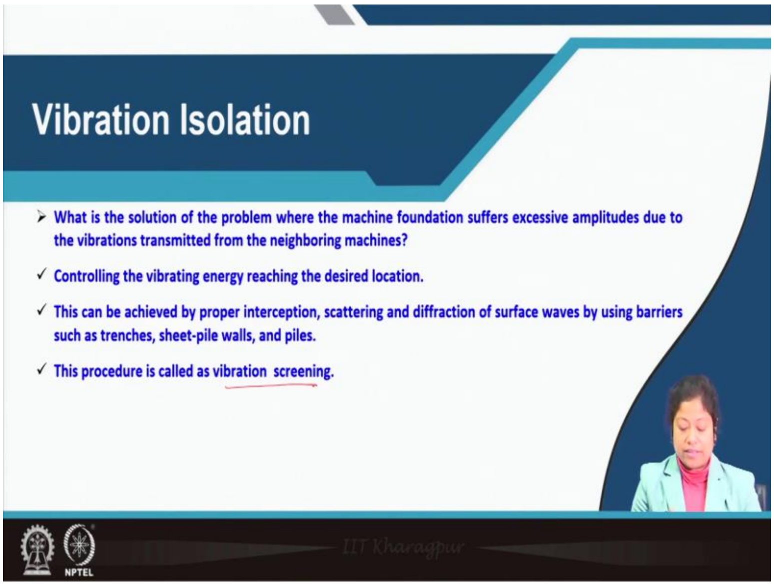


Now, in vibration isolation what is the solution of the problem where the machine foundation suffers excessive settlement or amplitudes due to the vibrations transmitted from the neighboring machines. So, in that case solution is to control the vibrating energy reaching the desired location, so before reaching it to the desired location we need to control it.

So, for that what we can do? We can use proper interception scattering and diffraction of surface waves by using barriers such as trenches, sheet-pile walls, and piles. And this procedure is called as vibration screening. So, basically in this case isolator acts as a vibration screening.

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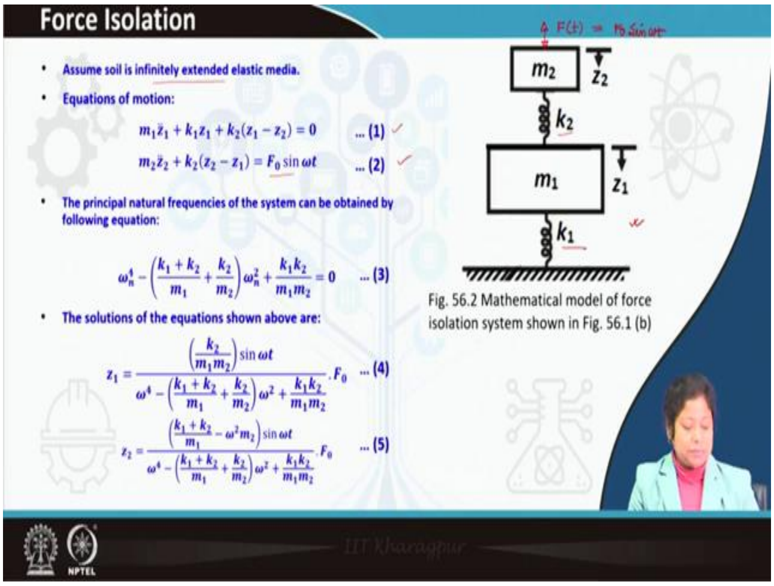


So, let us consider the case of force isolation, that means in this case excessive force is generated in the machine and consequently, the when we will measure the effectiveness of the isolator that should be done in terms of the force transmitted to the foundation. So, here you can see figure 56.2, so m2 and m1, these two masses m2 represents the mass of the machine, whereas m1 represents the mass of the foundation. k2 represents mass, sorry, stiffness of the isolator, whereas k1 is the stiffness of the soil. Of course, in this case we are considering that the soil domain is infinitely extended and it is of elastic media.

So, if we will draw the free body diagrams for mass m2 and m1, we know we will get these two equations of motion. So, here if you see the, in the equation to right hand side there is a term which is F0 sin omega t, so basically this machine is under the vibration FT, which is equal to F0 sin omega t. Now, we have already seen how to get the solution. So, after solving these two equations what we can get?

We can find out the principle natural frequencies of the system, so for that we need to solve equation 3. After solving equation 3 we need to find out z1 and z2, which are the displacement of the mass m1 and m2 respectively. So, z1 is you can see in equation 4 and the solution for z2 is shown in equation 5. So, here all the terms are known to us, so I am not explaining it.

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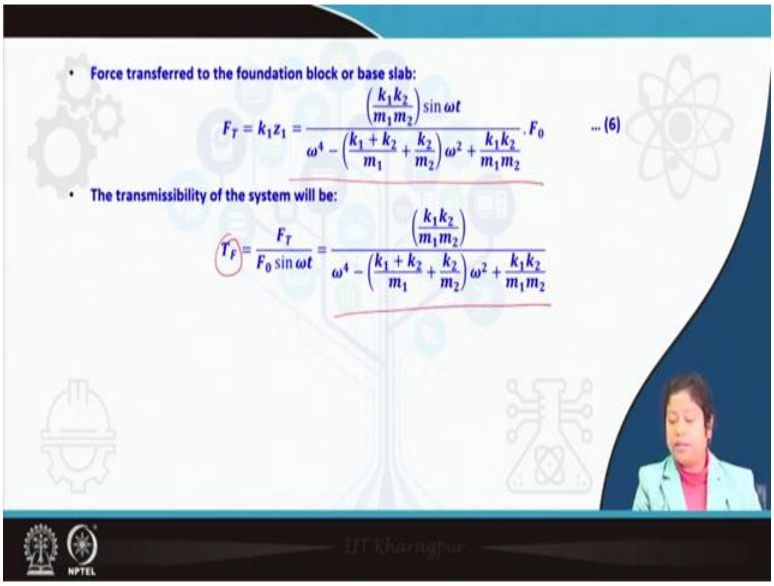


Now the, what is, how do we measure the force that is transmitted to the foundation block or base lab? So, the force transmitted to the foundation block or base slab, if we call represented by FT that is equal to k1 times z1. So, if you put the expression for z1, which we have already seen, then FT can be written like this. So, here omega is the operating speed of the machine, m1, m2 known, k1 k2 known.

Now, after calculating f t that means the force transmitted to the foundation we can measure the transmissibility of the system. So, the transmissibility of the system TF is equal to FT divided by F0 times sin of omega t. So, FT is shown in equation 6 and, then if we divide equation 6 by F0 sin omega t, what is left that you can see here in equation 7. Now if, so here you can see there are several terms. So, earlier we have seen how to take m1 m2 and k1 k2.

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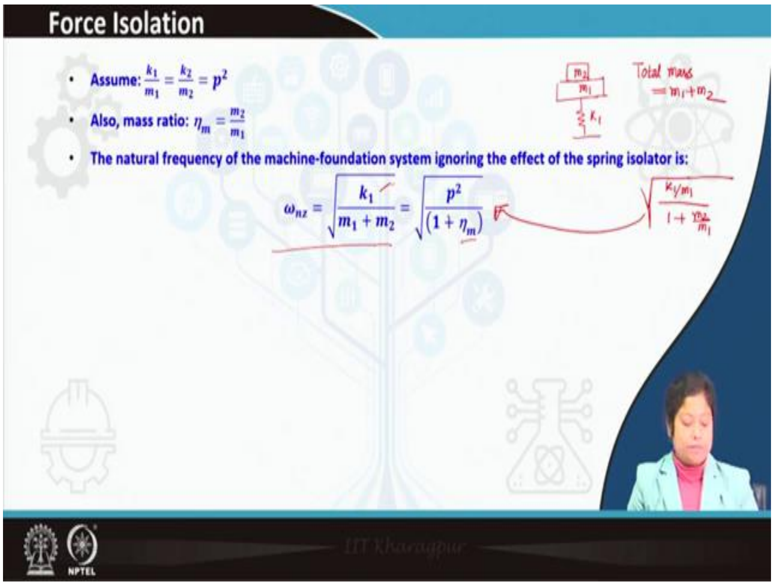


So, the similar kind of exercise now we will do here. So, first thing we can assume k1, k1 divided by m1 is equal to k2 divided by m2 and that is equal to p square, that means p is equal to square root of k1 by m1 or square root of k2 by m2. Here what is assumed the ratio of the stiffness to mass is same for the, I mean, k1 by m1 is equal to k2 by m2. Also, we need to assume that the ratio of the two masses that means m2 divided by m1 is equal to eta m.

Now, with this what we can do? We can, the natural frequency of the machine-foundation system ignoring the effect of the spring isolator can be written. So, that means we are not considering the isolator, we are just considering this is machine, which is resting on the foundation and foundation is resting on the soil. That means for soil we are taking k1. So, now in this case total mass is how much?

This is total mass means in this case it is m1 plus m2. So, from this we can find out the natural frequency as shown here. Already we have assumed that k1 divided by m1 is equal to p square. So, k1 divided by m1 p square and m1 by m2 is equal to, sorry, yes, m1 by m2 is equal to 1 divided by eta m. So, basically if this expression I can write like square root of k1 divided by m1 plus m2 divided by m1. Now, here you can see m2 divided by m1 means eta m and k1 divided by m1 is equal to p square, so that from this we can get this final form. So, let us give it a number 8.

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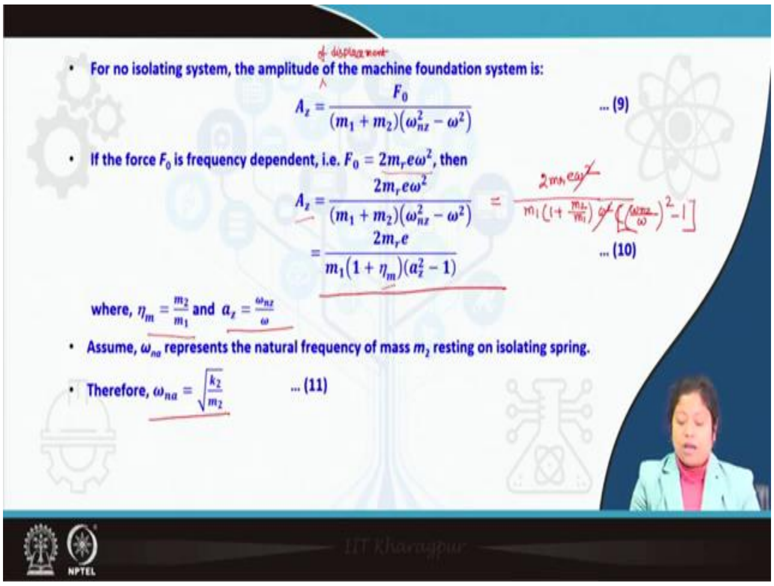


Now, for no isolation system that means once again the machine is directly resting on the foundation or placed on the foundation. So, that time what will be the amplitude of machine, amplitude of the displacement for the machine foundation system, Az better, I should write amplitude of displacement or vibration of the machine foundation system. Then it is already we know Az equal to F0 divided by m times omega nz square or…

Sorry, F0 divided by m times omega nz square minus omega square. So, omega nz we have already calculated which is equal to square root of k1 divided by m1 plus m2. Now, F0 is known and m1 plus m2 means total mass, so we can find out Az for the no isolating system. And some cases Az is, Az may exceed the permissible value of the settlement. So, in this case if F0 is frequency dependent then we know how to represent F0, so that is done here.

So, finally we can then write Az is equal to 2 times of mr times e times omega square divided by mass times omega nz square minus omega square. Now, here we can write this equation, so one step I am writing for you, so here I will take m1 out, then it is 1 plus m2 divided by m1, likewise I can take omega square out of this bracket, so it is now omega nz by omega square minus 1.

So, if we will consider omega nz by omega is equal to Az, that means I can write here Az is equal to omega nz by omega. Actually, I think it is already written in the next line. Yes, it is already written. So, I am, so here you can see, now omega square is present in numerator and denominator and this is non-zero quantity, so I can write it, both can cancel each other and now for m2 by m1 we can write eta m that is mentioned here.

And for omega nz divided by omega we can write this one. Then the equation 9 can be represented by equation 10, which is shown here. Now, here if we assume omega na represents the natural frequency of the mass m2, which is resting on the isolating spring. Then what we can write for omega na? Omega na then is equal to square root of k2 divided by m2. You can see here in equation 11.

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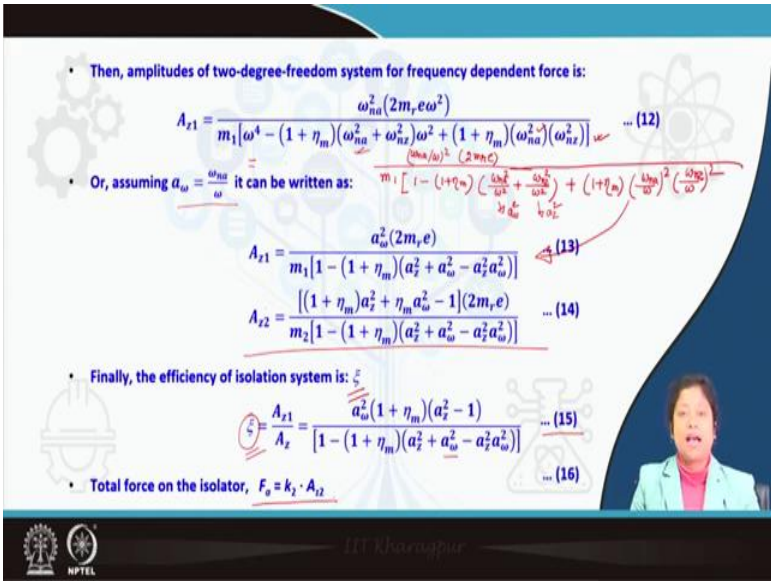


So, then the amplitudes of the two-degree freedom system for frequency dependent force, what we can write its amplitude is equal to this one. Here what is omega na and what is omega nz that we have already seen and what is eta m that is also known now. So, after knowing the expression for Az1, what we can do, we can now assume this omega na divided by omega is equal to a omega.

Now, here you can see there is home one omega na and also you can see, here also there is another omega na, so this one and this one. So, what we need to do? If we will divide it by omega square then what is the, then we can get this expression. So, basically what we are doing, we can take in, from this expression we can, from the denominator if we can take this omega to the power 4 out of this bracket, then here we can write omega na square divided by omega square and here also we can write omega na square divided by omega square.

And since omega to the power 4 is out of this bracket and if you see the numerator, there is one omega square. So, what we will get in the denominator, they are is a term omega square, so actually what I can do, I can just write one step here itself, so what I am saying here, I am taking omega to the power 4 out of this bracket, then what is left that I am trying to write. So, here I can write it as omega na divided by omega square times 2 mre.

And here I can then write mr times 1 minus 1 plus eta m. Now I have taken omega to the power 4 out of this bracket, that means here there is omega square, so I can write this expression as omega na square by omega square plus omega nz square divided by omega square plus 1 plus eta m. Here I can write omega na by omega square times omega nz by omega square.

Now, I think you can, it is easy, now I think it is easy to follow, so here omega na by omega that is equal to a omega that means this is a omega square whereas omega nz divided by omega is Az, so this is Az square. So, finally from this we can get this expression, which is written in equation 13 and for Az2, okay, it is better. I just delete this line. Now for Az2 we can, we can express Az2 in terms of which is written here in equation 14.

So, after doing Az1 and Az2, finally we need to find out the efficiency of isolation system which is xi here and that is the ratio of Az1 to Az. Az1 is the amplitude of displacement for the foundation and Az is the amplitude of displacement when there is no isolation in between machine and the foundation.

So, Az1 when there is an isolation in between machine and foundation and Az is the case or the amplitude of displacement when there is no such isolation. So, the ratio of these two amplitudes is the efficiency of isolation system and that can be expressed as shown here in equation 15. Now, generally what is happen? Generally, the permissible amplitude is provided, it may be 0.2 millimeter or 0.25 millimeter, that is mentioned.

And for the system of without isolation you can calculate omega nz and from that you can calculate Az. So, when you know Az1, when you know Az, you can calculate this efficiency and then you need to write equation 15, where what is the unknown, the unknown quantity is a omega, which is the ratio of omega na divided by omega. Now, what is omega na? Omega na is square root of k2 by m2.

That means the natural frequency if we think it or I should not use the what natural frequency, so a omega is the, ratio of omega na divided by omega and omega na is square root of k2 by m2. So, it depends upon the mass of the machine and the stiffness of the isolator. So, if you know this left-hand side, then using equation 15 you can find out a omega because Az is known. What is Az here? Omega nz divided by omega.

Eta m also known, which is m2 divided by m1. Only unknown parameter is A omega which you can calculate from equation 15. And after calculating a omega from that omega na and from that k2 what you can find out, you can find out the total force that the isolator can take, which is this one k2 times Az2. So, in this way we can, this is the maximum force that the isolator can take. So, in this way we can design the isolator.

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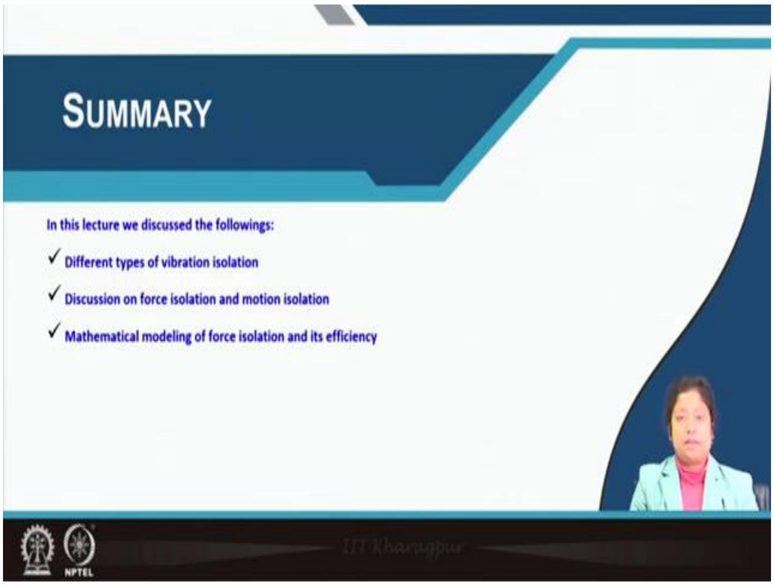


So, come to the summary of today's class. So, in this class we have discussed different types of vibration isolation, what is force isolation, what is motion isolation, that we have discussed. Then we have discussed the mathematical modeling for force isolation and how to express its efficiency and the settlement, etcetera.

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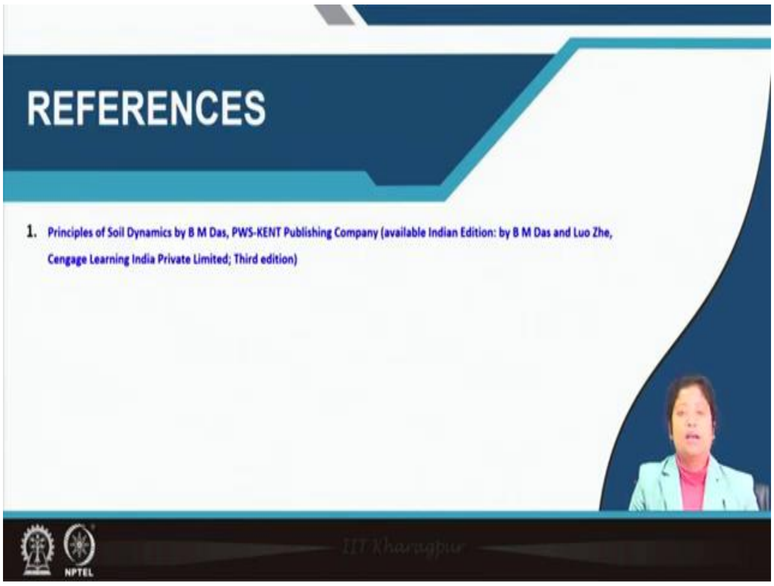


This is the textbook which can be referred to find out the different mathematical form, for an example, Az1, Az2 or how to solve the 2 degrees of freedom system, etcetera. So, with this I am ending today's class, thank you.