Soil Dynamics
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Lecture - 1
Introduction & Theory of Vibrations

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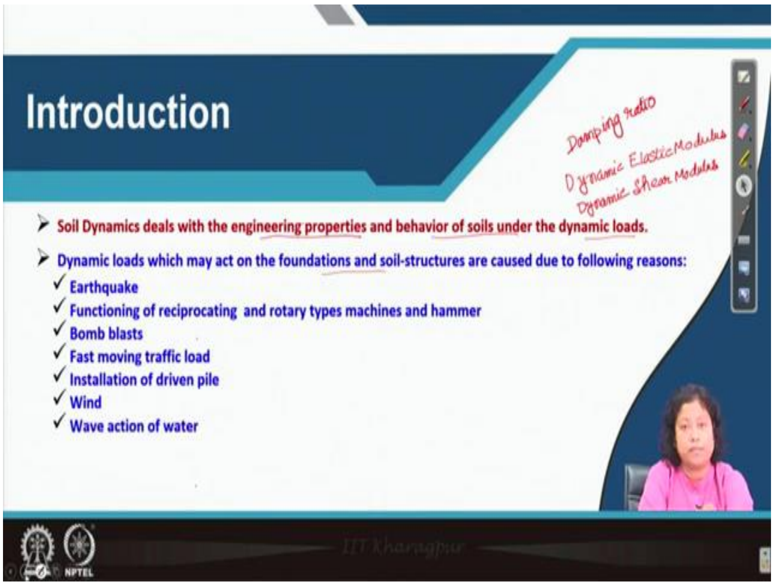

Hello friends today this is the first class of the core soil Dynamics. So, in the first class, we will study, we will first be introduced with the subject soil Dynamics and then we will study the theory of vibrations, a few fundamental elements of the theory of vibration.

So, let us start why we will study soil Dynamics? Basically soil Dynamics deals with the engineering properties, you can see here, soil Dynamics deals with the engineering properties and behaviour of soils under the dynamic load.

Now, the question what engineering properties basically are required for soil Dynamics or when we are dealing the dynamic loads? These engineering properties are first is your dynamic elastic modulus, the second one dynamic Shear modulus, other than that we also find out damping ratio of the soil. So, these are the engineering properties, there are several other properties also which we will come to which we will discuss due course of time.

So, what is dynamic loads? Or what is the reason for these Dynamic loading? So, Dynamic load which act on the foundations and soil structure are caused due to the following reasons, first reason is earthquake, first reason is earthquake. So, we all know in our country every decade we find at least three to five earthquakes having magnitude more than five in the Richter scale, so this is one of the main reasons or one of the main cause of dynamic loading.

The next reason is the functioning of reciprocating and rotary types machine and hammer. Next reason is Bomb Blast, then fast moving of the vehicle and its load, then when we install the driven pile, it also causes vibration of the ground surface, other than these wind and wave action of the water can cause the dynamic load.

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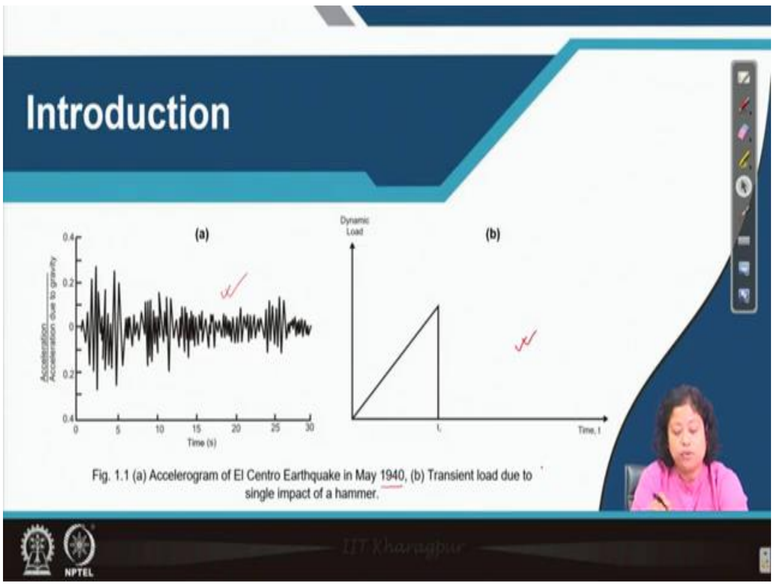

Now, in this figure we can see different types of dynamic loading, the first figure here you can see the Accelerogram of one earthquake which occurred in 1914. So, in this figure we can see the dynamic loading is a earthquake loading is kind of random vibration or produces random vibration to the ground. Next one is the transient load which is caused due to a single impact of one hammer.

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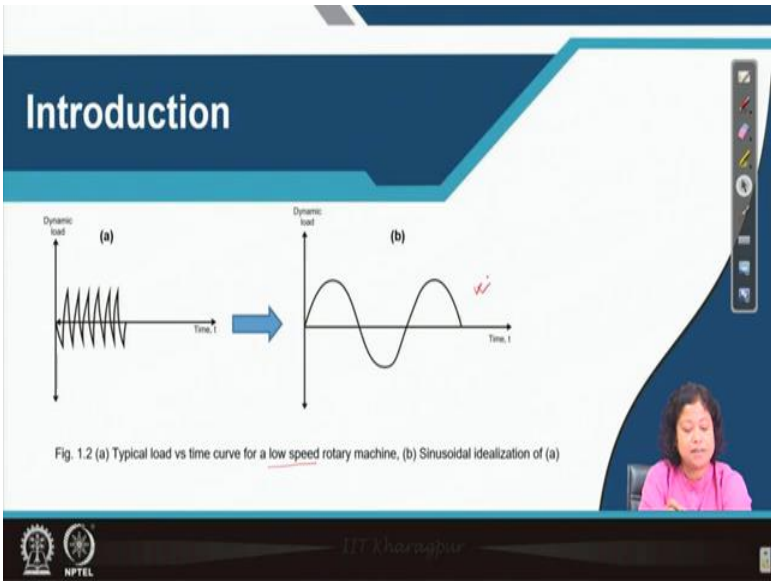

Come to the second picture here we can see the typical load versus time curve for the low speed rotary machine and the next figure is the idealization of the previous one. So, this is the idealization of the figure a.

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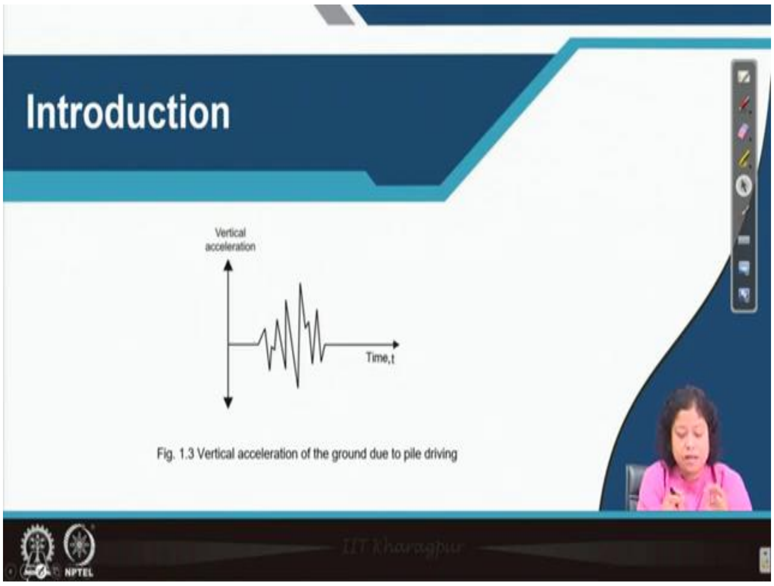

Now, in this slide we can see the vertical acceleration of the ground surface during the installation of the pile, pile means due to pile driving.

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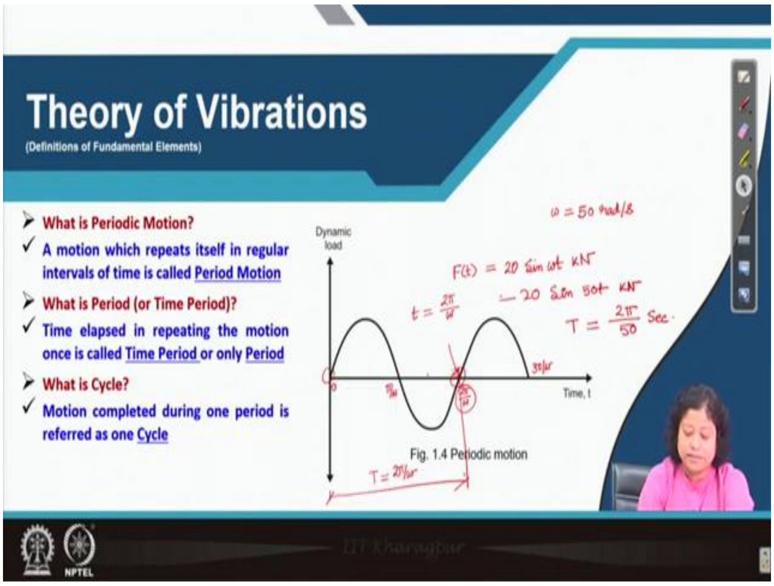

So, with this introduction of the different types of dynamic loading, now we can start our discussion on the theory of vibrations. The first thing which comes in our mind is what is periodic motion? So, periodic motion when we are saying it is a motion which repeats itself in regular time interval. So, let us take an example, in this figure what we can see, this figure basically shows load versus time curve for one vibration.

Now, in this case we can first this is a typical sin curve, so we can express this load, let us take F t, let us take it as F t is equals to 20 sin omega t in kilo Newton. So, t means at the beginning it is 0, here the value of t will be Pi by Omega likewise here the value of t will be 2 pi by Omega and so on.

So, when we see this diagram what we can note from here, the pattern of the load versus time curve from 0 to Pi by the Omega time repeats after 2 pi by Omega time, when t equals to 2 pi by Omega that time the same pattern is repeating. So, it is a typical example of a periodic motion. Come to the next definition which is time period or sometime we called it as period also. So, what is time period here? Definitions says, the time elapsed in repeating the motion once is called the time period, sometime as I said we called it also only period.

So, in this diagram from 0 to 2 pi by Omega time there is no repeat of the motion, however, when t equals to I can say t equals to or greater than 2 pi by Omega or I can write it as when exactly t equals to 2 pi by Omega that means this time, what is happened, is the motion starts to repeat its pattern, so the time from 0 to 2 pi by Omega that means this interval is called the time period. So, in this case time period is 2 pi by Omega.

We can take some value for Omega also and based upon that value we can let us take omega is 50 in Radian per second. So, F t will be nothing but 20 times sine of 50 t unit is in kilo Newton. So, the time period in this case will be how much? It will be 2 pi by 50 in second. Now, come to the next one what is cycle? So, the cycle is motion completed during one period, so motion completed during one period means from here to here, whatever we can see in this picture that is referred as the one cycle.

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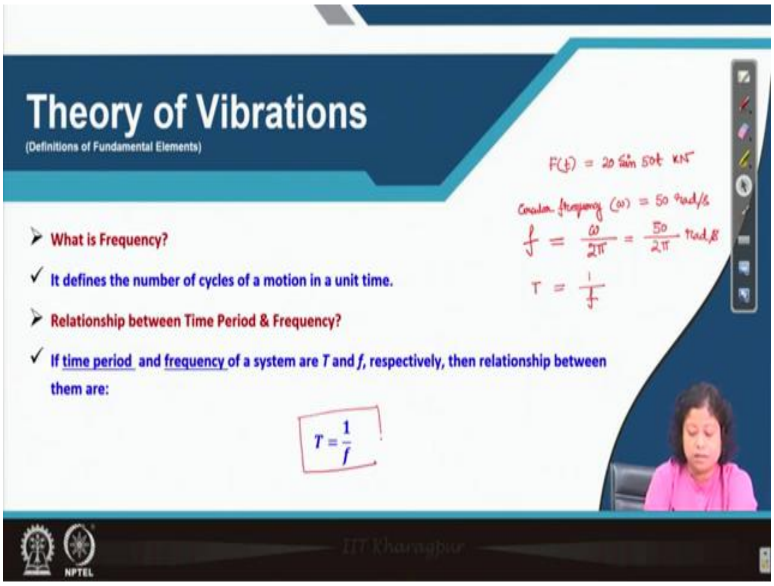

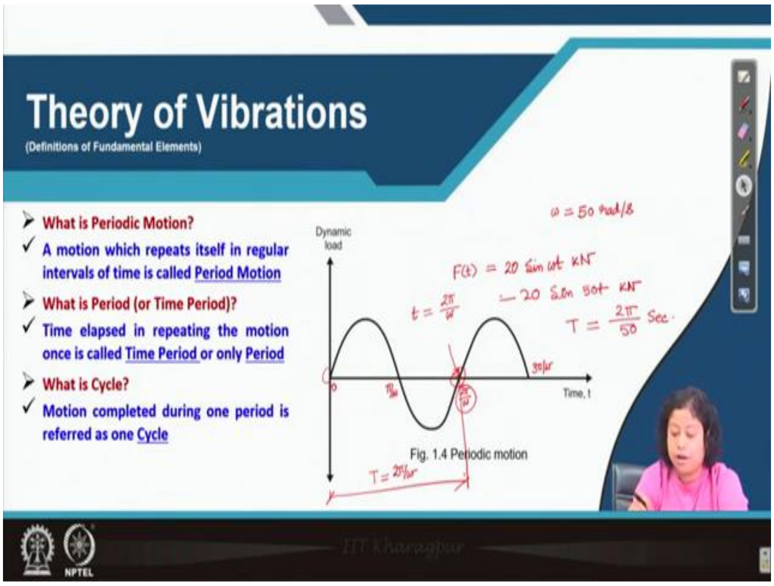

Next what is frequency? So, when we are talking about frequency, first just I am going back to the previous slide here Omega is also a frequency, but Omega is called circular frequency, now when I am talking here frequency I am not talking exactly Omega, but there is correlation between Omega which is circular frequency and this frequency, this frequency we can take both the same also as per definition.

So, it defines the number of cycles of the emotion in unit time. So, if total we know the time period from that we can calculate the frequency. So, let us take the same example that F t is equals to 20 times sin of 50 t in kilo Newton. Then what will be the first thing what will be the frequency? So, first one is circular frequency in this case, so the circular frequency Omega is 50 in rad per second.

Now, then the frequency if will be equal to or Omega divided by 2 pi which is in this case is 50 divided by 2 pi in radian per second. Next is what is the relationship between time period and frequency? So, time period if we note t is the time period and F is the frequency, then t will be equal to 1 divided by f. So, here you can see the relationship which is given T is equal to 1 divided by f.

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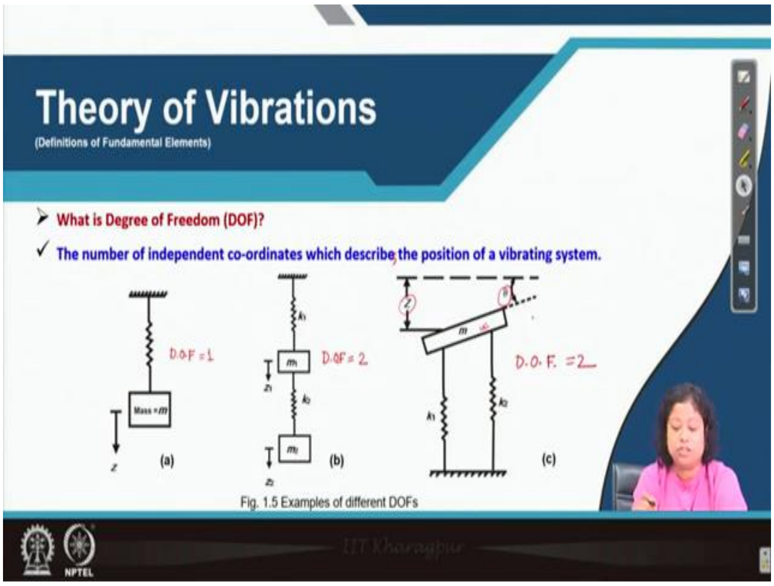

Come to the next slide, next term which is very important for us is degree of freedom. So, what is degree of freedom? Let us see the definition, "the number of independent coordinate which describes the position of a vibrating system is called the degree of freedom." I am repeating it once again, "the number of independent coordinates which describes the position of a vibrating system is called the degree of Freedom."

Let us take a few example to clear the understanding, in this figure a mass is attached to a spring and spring is and the thing is suspended from the fixed support. Now, when system will vibrate how we can describe the motion of the mass in? The mass m is vibrated in the vertical direction in this case, so we need only one coordinate which is in the Z direction upward or downward, so the degree of freedom for this case is 1.

Now, take next example, in this figure what we can see there are two masses, one is m1, the other one is m2 and these the mass m1 is connected to the spring k1 and k2, whereas mass m2 is connected to the same to the spring k2 only. Now, when the system will be vibrated that time we need to describe the motion of mass m1 and mass m2. So, we need in this case two independent coordinate, one for m1, the other one for the m2. So, the total degree of freedom for this system is 2.

Now, take the next example, so in this case what we can see mass m is placed inclinedly and connected to the two springs, of course the length of two springs are springs is different. So, the two springs are k1 and k2, so because of this orientation what we need actually, here we need two independent coordinate to describe the position of this mass m, one is z and the other one is the angle theta. So, for this case also degree of freedom is 2.

What is the difference between figure 2 and figure 3? In figure sorry figure B and figure C, in figure B there are two masses each mass requires one independent coordinates to describe its position at the time of vibration, whereas for the case figure C what we can see there is only one mass, but because of its orientation and connection to the two springs it requires two independent coordinates Z and Theta to describe its position during vibration.

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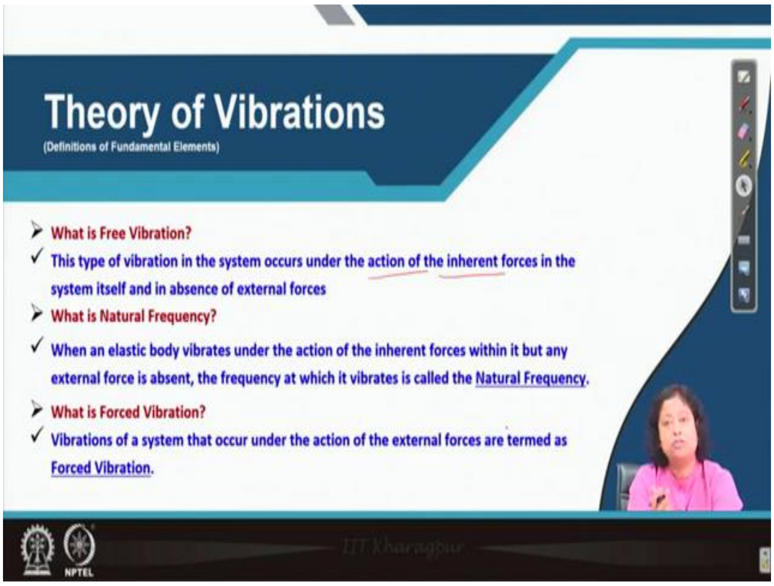

Come to the next slide, now the question what is free vibration? So, as per definition, this type of vibration in the system occurs under the action of the inherent forces in the system itself and that time any external force will be absent. So, just take an example suppose I have switched on a machine and immediately switching on I have switched off, now what will be happened, because of the inertia of the machine, it will vibrate for some period of time.

So, what we can see here? The vibration of the machine after switching off is an example of free vibration, I am once again reading the definition "free vibration is a type of vibration which occurs under the action of the inherent forces present in the system and in absence of the external forces." Now, during free vibration the frequency of the system is called as the natural frequency.

So, we can also define it as when an elastic body vibrates under the action of the inherent forces within it but any external force is absent the frequency at which it vibrates is called the natural frequency. Next is forced vibration, so forced vibration is the vibration which is caused because of the action of the external force.

So, the vibration of a system that occur under the action of the external forces are termed as forced vibration. Now, take this previous example of the machine as long as switch is on switch of the machine is on what will be happened, machine will vibrate and that kind of vibration is because of the external energy or external force, so that vibration is called the forced vibration.

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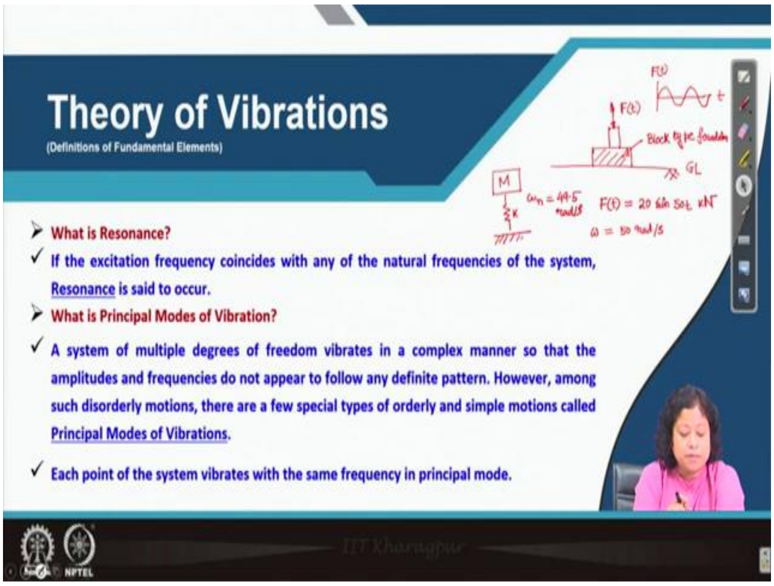

Come to the next definition, what is resonance? This is another important term which we will see which we will find throughout this course. So, let us see the definition, "if the excitation frequency coincides with any of the natural frequencies of the system, then it is said that resonance will it is at resonance frequency" or I can say it in another way resonance is said to occur when the excitation frequency coincides with the natural frequency of the system.

So, let us take one example, let us take this is soil domain, this is the ground surface, so I can write this ground level just for the sake of simplicity we are taking one block type foundation resting on the ground surface, so this is our block type foundation. Now, when a machine is resting on it what will be happened? During the when machine is switched on it will vibrate, so I can draw F t versus t by this curve also.

Now, if F t is defined by 20 times sin of 50 t in kilo Newton that means the frequency operating frequency in this case is 50 rad per second. Now, under free vibration suppose we have calculated the natural frequency of the system, if the natural frequency of the system, system means in this case how we will represent the system, the total mass of the machine and foundation together will be the mass by a mass m and the soil will be represented by some spring, so that have stiffness k.

Now, if we will find out its natural frequency, let us take its natural frequency is your in this case it is 49.5 rad per second, so it is very close to the operating frequency of the machine. So, in this case we can say resonance is occur, you can note here the magnitude of Omega n which is the natural frequency of the system and the frequency of the operating frequency of the machine are not exactly same, but very close to each other.

Now, next question which is important for us is what is principal modes of vibration? So, let us see its definition, "A system of multiple degrees of freedom vibrates in a complex manner and as a consequence the amplitudes and frequency do not appear to follow any definite pattern, but among such disorderly motions we can see a few spatial types of orderly and simple motions which are called as the principal modes of vibrations." Now, each point of the system vibrates in this case with the same frequency in principal mode.

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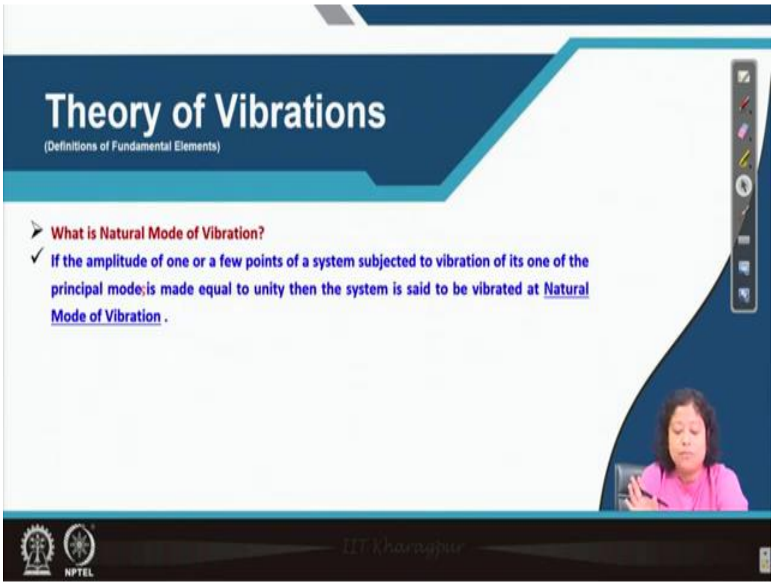

Come to the another definition, which is what is natural mode of vibration? So, already we know the principal modes of vibration. Now, "if the amplitude of one or a few points of a system subjected to vibration of its one of the principal mode is made equal to the, equal to unity then the system is said to be vibrated at natural mode of vibration." I am repeating just the definition what is natural mode of vibration that I am repeating only.

So, if the amplitude of one or a few points of a system subjected to vibration of its one of the principal mode is made equal to unity then the system is said to be vibrated at natural mode of vibration. So, we have hundreds suppose principal modes.

Now, among these hundred principal modes, if I can find one principal mode for which the amplitude of one or few points of the vibrating system is equal to unity, then we can see that the system is vibrated at natural mode of vibration.

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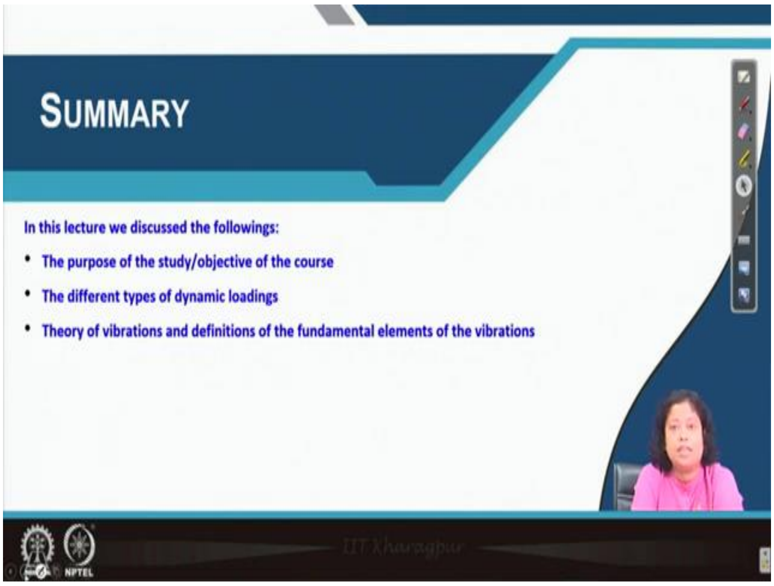

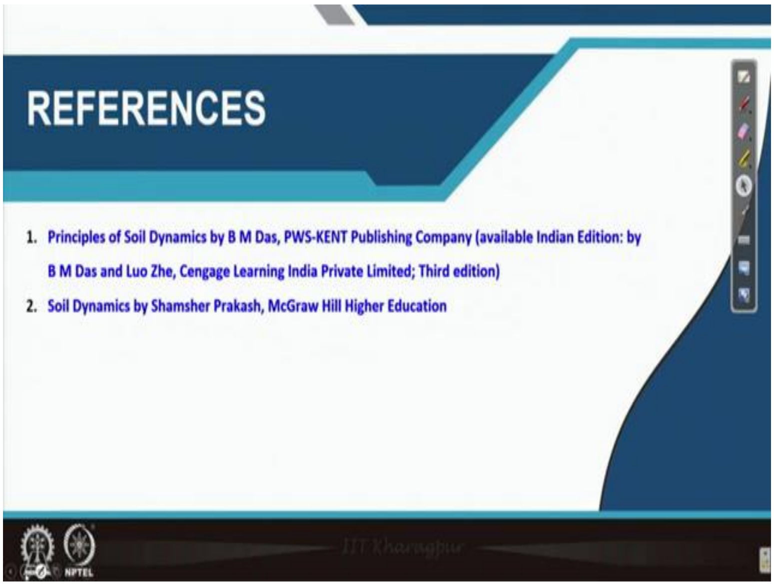

So, now we can conclude today's lecture one, so in today's lecture what we have discussed? We have discussed the why we will study the subject soil dynamics that means what is the purpose of the study or what is the objective of this subject.

Next the different types of dynamic loadings, we have learned there are different types of dynamic loading, one earthquake loading, then machine loading, then we have seen when fast moving vehicle passed that also causes vibration, then when driven piles are installed during its installation also ground is vibrated. So, there are several reasons and different types of dynamic loadings.

Then what we have studied? We have studied definition of a few fundamental elements of theory of vibration, like what is time period, what is exactly periodic motion, then what is time period, then what is natural frequency etcetera. So, here we can see the references which we have used for this lecture. So, thank you we will meet in next class.