Soil Dynamics
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Lecture – 1
Introduction

Welcome to NPTEL phase two video course on soil dynamics. My name is Deepankar Choudhury, I am from department of Civil Engineering of IIT Bombay, Mumbai. Let us look at the slide here; as I have mentioned just now, course title is soil dynamics. This is the first lecture of the course.

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This course contains several subtopics and basically the entire course is subdivided into number of modules. We have divided it into total 7 modules and under each module we have subtopics, which will be covered in about 40 lectures of each one hour duration. So, let us look at, discuss the contents once again. The first module of this course is introduction, in which we will talk about scope and objective of the present course; that is on soil dynamics, nature and types of dynamic loading importance of soil dynamics study. In the second module, which is on vibration theory, we will cover vibration of elementary systems degrees of freedom. Then single degree of freedom system, un damped and damped free and forced vibrations.

Forced vibrations, due to support motions rotating mass and constant force oscillators, dynamic magnification factor, phase, non-harmonic forced vibrations like step loading, impact loading, any arbitrary loading etc. Then concept or Duhamel's integral, then vibration isolation, vibration measuring instruments and finally, introduction to multi degree of freedom systems or MDOF systems. Then, we will move to module 3 of the course, which is on wave propagation. Under module 3 our subtopics will be elastic response of continua, in one, two and three dimensional wave equations. Waves in unbound media waves, in semi-infinite media waves, in layered media seismic waves, characteristics of P wave, S wave, Rayleigh wave and love wave, estimation of epicenter of earthquake by using different methods like travel time method, three circle methods.

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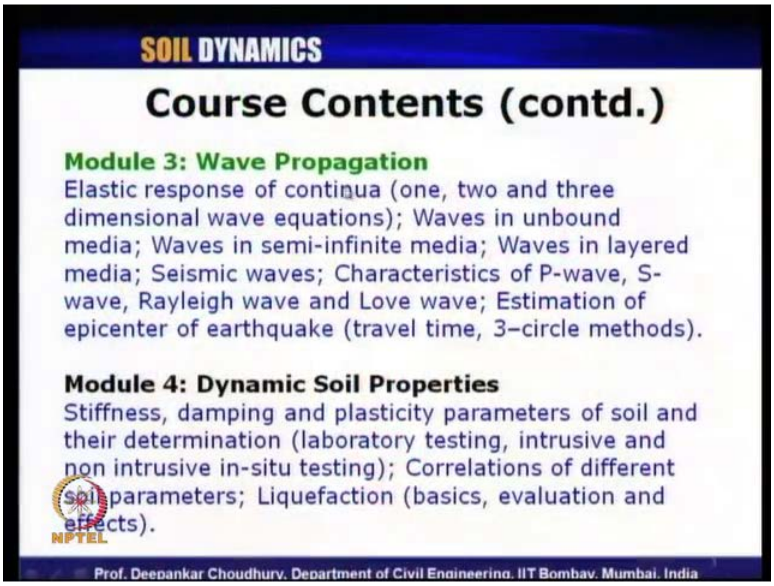

Then, we will move to our next module which is module 4, that is on dynamic soil properties. Here we will cover stiffness, damping and plasticity parameters of soil and their determination in laboratory, as well as in field. That is intrusive and non-intrusive in situ testing, correlations of different soil parameters, liquefaction and basic of the liquefaction. Then evaluation of liquefaction and their effects will be discussed in this module 4.

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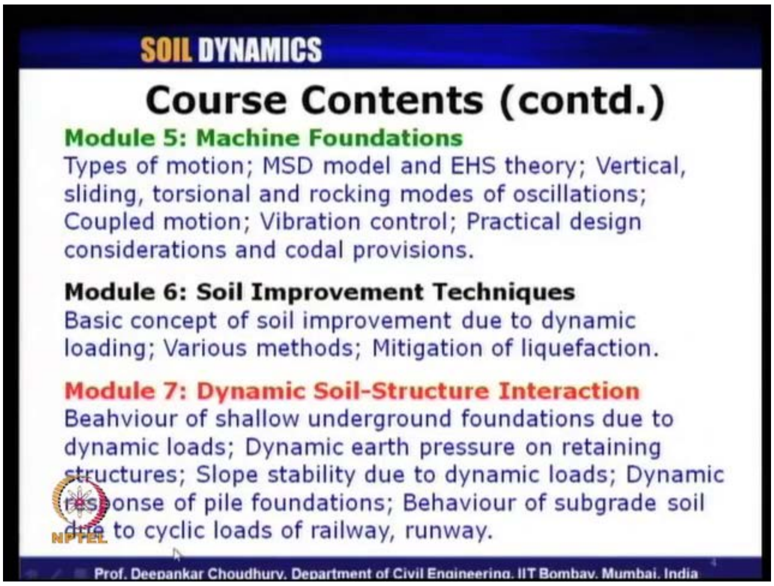

Then, we will move to our module number 5, which is on machine foundations. The subtopics are types of motion, mass spring dashpot model, or MSD model and EHS theory or elastic half space theory, vertical, sliding, torsional and rocking modes of oscillations, then coupled motion, vibration control, and practical design considerations and codal provisions. In the next module 6, we will cover soil improvement techniques. In this module 6, the subtopics are basic concept of soil improvement for dynamic loading, various methods mitigation of liquefaction and our last module for this course is module 7, which is on dynamic soil structure interaction.

Here, the topics will be covered like behavior of shallow underground foundations, due to dynamic loads, dynamic earth pressure on retaining structures, slope stability. Due to dynamic loads, dynamic response of pile foundations, behavior of sub grade soil due to cyclic loads of railway, run way etcetera. So, these are the entire contents of the course on soil dynamics. For this, NPTEL phase two and the related text and references for this course are listed here.

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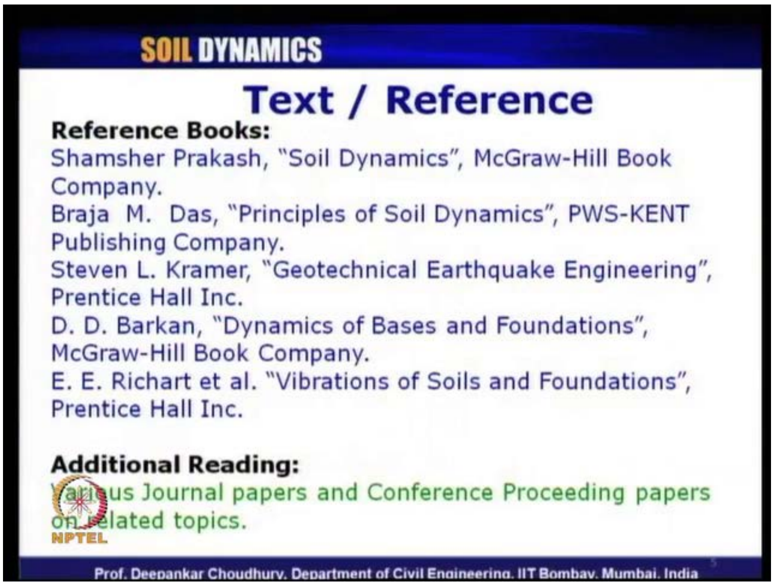

Like reference books, one can follow for this course are by Shamsher Prakash on soil dynamics McGraw Hill book company, by Braja M Das principles of soil dynamics PWS Kent publishing company, by Steven L Kramer geotechnical earthquake engineering prentice hall, by D D Barkan dynamics of bases and foundations McGraw Hill company, E E Richart et al vibrations of soils and foundations prentice hall. There are many other reference books available on the similar topic, I have just listed a few of them in this slide. One can of course, follow several others beyond, whatever is listed here. For additional reading, various journal papers and conference proceeding papers on the related topics will be covered. During this course material to update ourselves with the latest research output on this topic.

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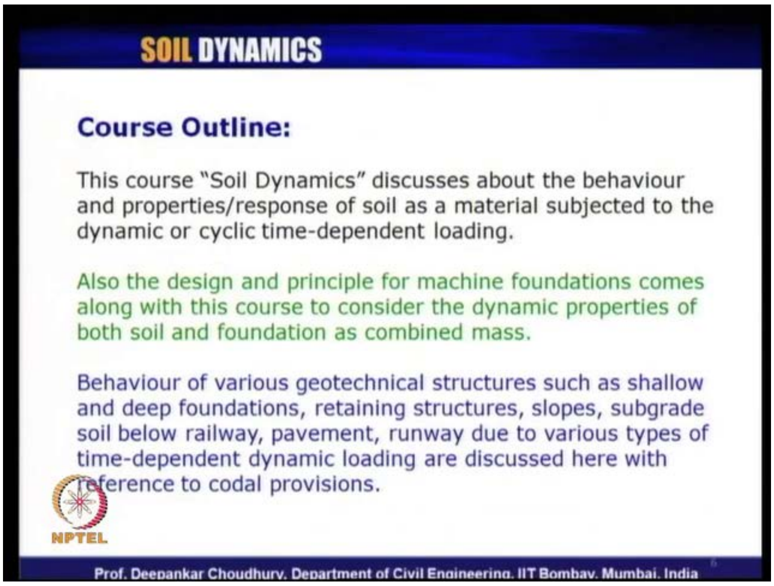

The course outline is prepared in such a way that, this course on soil dynamics it will discuss about the behavior and properties and response of soil, as a material which is subjected to dynamic or cyclic time dependent loadings. Also, we will see the design and principle for machine foundations comes along with this course, to consider the dynamic properties of both soil and foundation as combined mass system. Then, behavior of various geotechnical structures such as shallow and deep foundations, retaining structures, slopes, sub grade soil, below railway pavement, runway due to various types of time dependent dynamic loading will be discussed with reference to variable possible, the codal designs provisions available for this topic of soil dynamics. Then, let us see, what is our target audience for this course soil dynamics?

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If we look at here, the audience or target group for this present course will be very useful to all the undergraduate students, who are mostly in their final year of undergraduate course curriculum of civil engineering. Post graduate students who are studying both geotechnical engineering or structural engineering and also to the mechanical engineering students, who are related to the problems on dynamics. Then for researchers, then teachers, consultants and for practicing engineers, these courses will be very much useful. There is one pre requisite to understand the concept of this course, on soil dynamics and that pre requisite is knowledge of basic soil mechanics or fundamental geotechnical engineering is necessary. May not be a very high level soil mechanics, but only the basic soil mechanics knowledge is required to understand further the contents of this course on soil dynamics.

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Regarding the contact details, as I have already mentioned my name is Deepankar Choudhury, I am coming from department of Civil Engineering of Indian institute of technology IIT Bombay, which is located at Powai, Mumbai. This is the pin code in India and this is my postal address, anybody can send any postal mail to this address and can reach me. Also I can be reached by telephone, these are the telephone numbers, my office number as well as my residence number and this is the fax number by which I can be reached. The best way in today's world to reach me is by email. These are the two email IDs of my institute, which I access frequently and I can be reached very easily by using these two email IDs. To know more about the my research work my teaching and other professional academic and research activities, one can see the url, which is located in our institute department website.

So, the link is provided here, one can see into this link to know more about the instructor of this course on soil dynamics. Now, let us start this course with our first module, which is introduction. So, this is our module 1. We are starting with for the soil dynamics with introduction of the course. First let us see, why this course is essential to learn or to study? So, basically we want to see, what is the objective of the study of this soil dynamics course? Why one should know this course?

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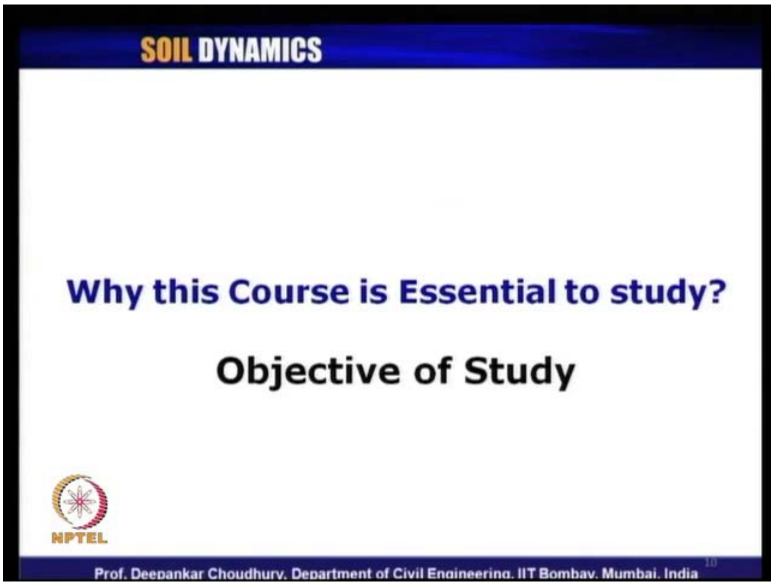

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Let us go through some figures, then we will clearly understand why it is needed? This picture shows that some portion of the soil. It is flowing as if it is not a soil, but as if it is a liquid or as if it is fluid material. This phenomenon, when the soil behaves like a fluid is commonly called liquefaction, soil liquefaction. It can occur due to various reasons, one of the reason is earthquake and for any other dynamic or cyclic loading also this soil liquefaction can take place. So, if such disasters or such situation happens in soil. Suppose, if we have a building or a structure constructed on this type of soil, on which an application of any kind of dynamic load, say earthquake load. The soil behaves like a fluid that is no longer it is a solid material, which can withstand the load of the super structure or the structure constructed on top of this soil. It will be simply as if we have constructed the structure instead of a solid material on water. So, if the design considerations is not taken care of properly which in most of the cases will not be because we are initially designing the structure to withstand on a firm soil. But due to application of some dynamic loading such as earthquake loading, if it flows like a fluid then our structure is seriously in danger. That is the reason, why we should study this course to know about the entire behavior of the soil, under this kind of dynamic loading.

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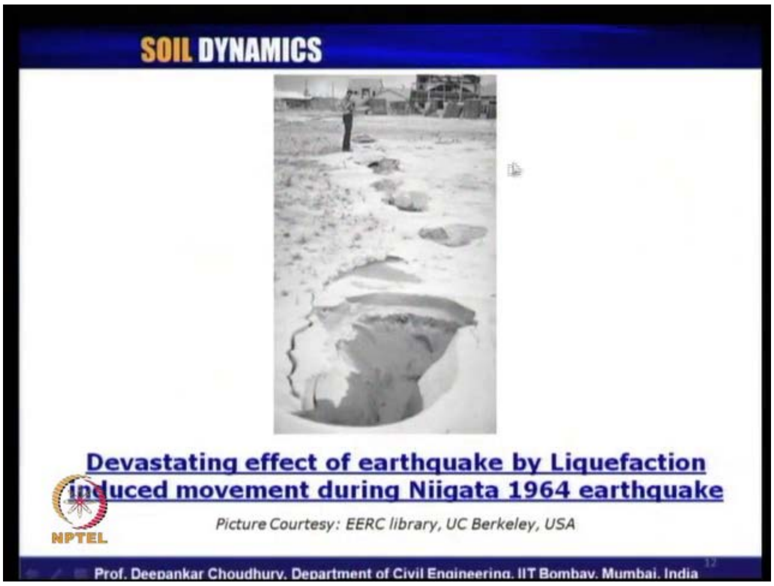

Then another example, let us look at the slide here. The picture courtesy is from EERC library of U C Berkeley this shows devastating effect of earthquake, by liquefaction induced movement during the Niigata 1964 earthquake. We can see a very big pot holes have been found on the soil. Due to the liquefaction what happened, the soil in these region has flowed to some other area. That is why such big pot holes have been created. So, we can imagine if any structure would have been constructed on top of it definitely that again would have been in extremely danger. So, to know all these behavior we must understand the dynamics of the soil material under this kind of dynamic loading.

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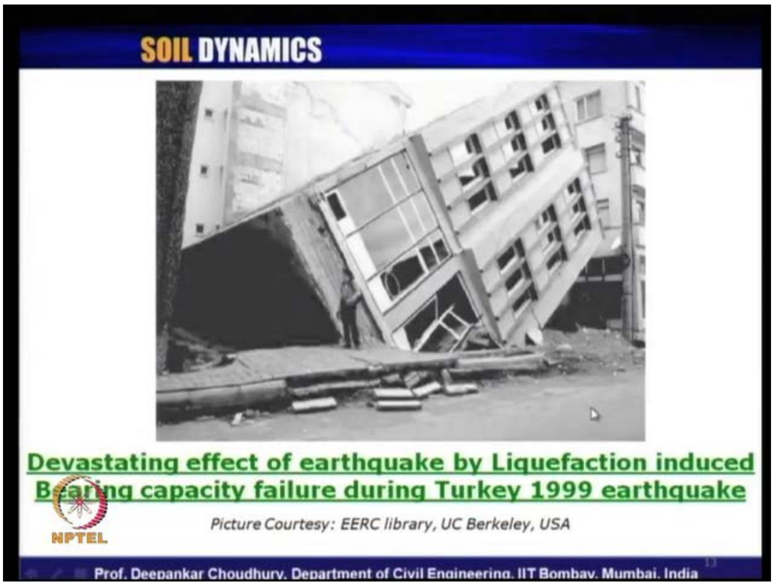

Another picture, which is also taken from EERC library of U C Berkeley, it shows devastating effect of earthquake by liquefaction induced bearing capacity failure during the turkey 1999 earthquake. We can look at this building, what it shows during the earthquake? Loading the super structure or the structure above the ground, whatever was constructed that was not damaged because there is no failure of the column or beam of this building. Because super structure was very nicely constructed, taking considering all the dynamic loads etc.

However, the main culprit in this case is again soil. The behavior of the soil under that kind of earthquake or dynamic loading was not considered properly or it has been liquefied in this region. That is why, what happens though the super structure was constructed very nicely, but because of the foundation failure, the entire structure has toppled down like this. It again shows the need to study the course on soil dynamics. In spite of knowledge in the other topics of dynamics. Suppose, those who have already taken the courses like structural dynamics or machine dynamics or aero dynamics, they know what are the basic concepts of the dynamics. But why this course on soil dynamics is so special for us? These are some of the examples of severe failure, which needs the study of knowing the dynamic behavior of the soil material separately.

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Another picture, which is again taken from EERC library of U C Berkeley, it shows the devastating effect of earthquake on the slope. That is on stability of the slope during Nevada 1954 earthquake. The land slide or slope stability problem arised and all the failures have taken place for the slope, due to the earthquake loading. So, that again needs the knowledge of the soil mechanics and the rock mechanics etc to understand the behavior of these material under the dynamic loading.

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Another devastation effect, this picture shows the devastating effect of earthquake on pavement foundation failure during the 1960 Chile earthquake. This picture is also taken from EERC library of U C Berkeley. We can see there is huge differential settlement of the two parts of the pavement sub grade material, which is basically a soil material. So, the sub grade failure has occurred during the earth quake. This part of the pavement somewhat it has bulged up or hived up little bit. This part has collapsed or come down excessively and there is a differential failure between these two levels of the pavements. This again needs the study of behavior of the sub grade material, which is essentially the soil.

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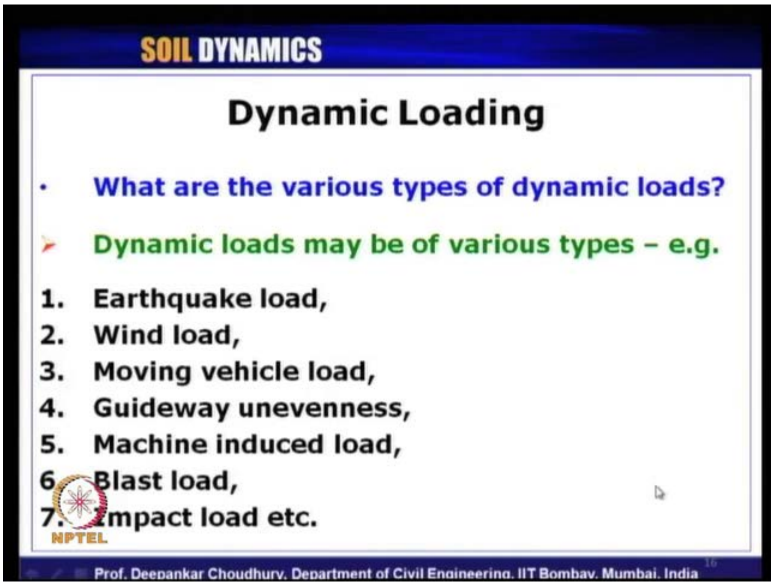

Now, we have understood why we should study this course on soil mechanics, through these various examples of practical failures of several structures and super structures during different types of dynamic loading. Mostly, I have shown the earth quake loading which is one of the dynamic loading. There can be several other types of dynamic loadings also, for which the failure can occur. So, let us see when we address any problem on dynamics what is that meant by?

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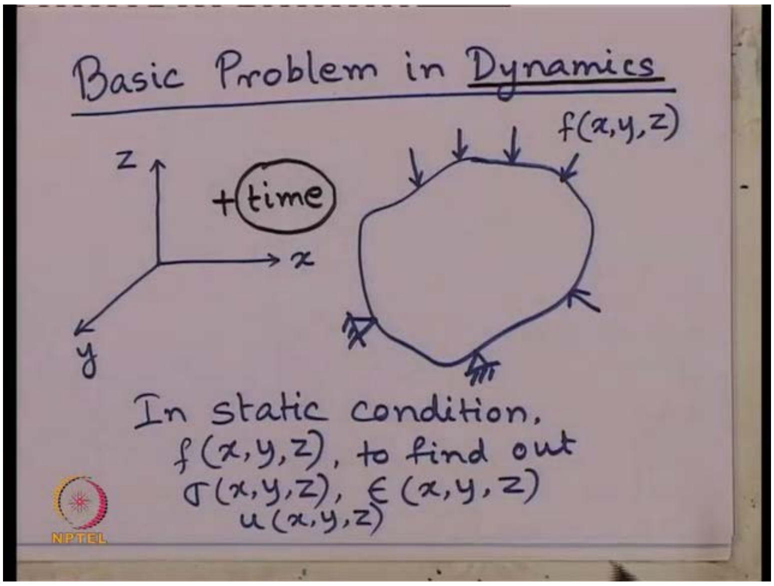

So, basic problem in dynamics, how it differs from the problems related to our static problem? Suppose, we have axis system in the space, what we generally considered a three-dimensional case of x, y, z co-ordinate, co-ordinate system, three orthogonal co-ordinate system. If we take any rigid body subject to any rigid body subjected to various types of loading and support conditions. So, in static case what we are interested to know in static condition, whatever loads are applied to the system. Suppose, these loads are f of x y z, so these are functions of this coordinate system of x y z.

We have the loads in terms of x y z, we want to find out the stresses, which are again function of the coordinate system. Then strain on the body which are again function of the coordinate system or we can find out the displacement of the rigid body, which can be again function of the coordinate system. When we are talking about problem in dynamics, what is the major difference from the problem in static? One additional parameter gets involved when we talk about problems in dynamics. So, along with these coordinate system, now the additional parameter is time. So, if all these applied load and the corresponding results like stresses, strain, displacements are function of time, then we say that we are dealing with problem in dynamics.

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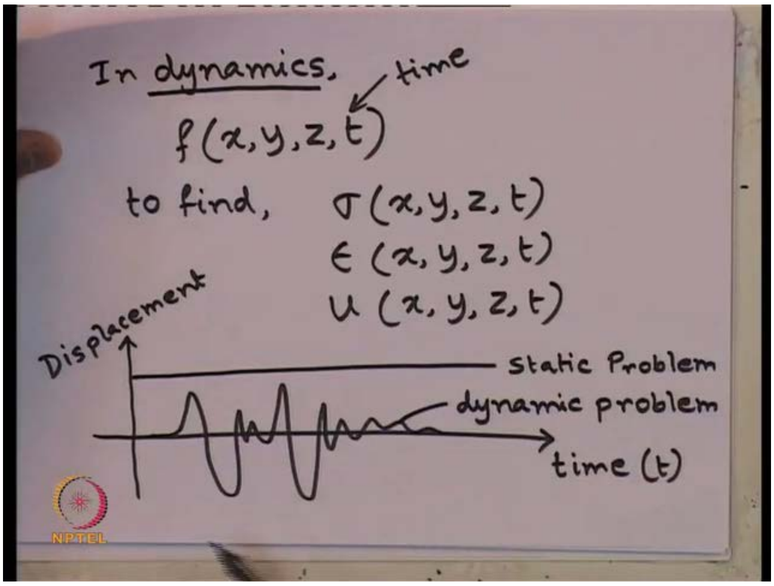

In other words, in dynamics we have applied load which can be a function of the coordinate system. Time and we can find out the results of stresses in the body strain. In the body and displacement, in the body, which can be function of the coordinate system x y z and the additional factor which is time. So, this time additional factor is required to deal with problems in dynamics, when we are comparing the similar problem in statics. So, suppose if we want to plot with respect to variation of time, the behavior of say displacement in the case of static problem, it will remain constant. So, this is static problem. However, in case of dynamic problem, it will be a function with respect to the static. It will be a function of time, so this is some variation with respect to time.

We will observe in case of dynamic problem, so when we want to compute say total displacement of the system, we should superimpose one over other. That is the actual complete displacement will be about this access, to give us the complete static and dynamic displacement, which is varying with respect to time. So, in this way time variation means, we are dealing with problems related to dynamics.

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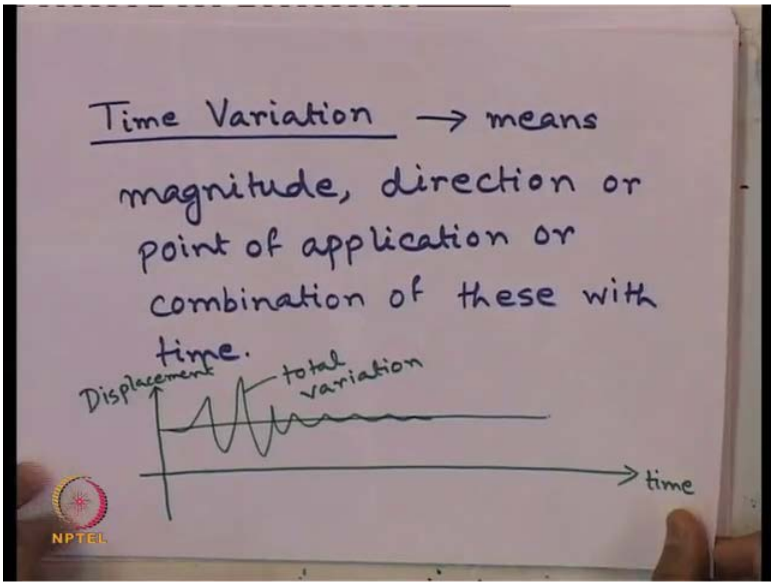

So, let us say. So, let us see how this variation of time means? So, time variation means it varies both in magnitude direction or point of application or combination of any of these three parameters. What does it mean? So, if we say that force is dynamic, that means force varies either in magnitude or in direction or in terms of point of application or any combination of these with respect to time. Similarly, for displacement similarly, for stresses and things like that, so that actually means the dynamic problem. So, when we are combining the two effects as I have mentioned just now, the variation with respect to time for the displacement will be something like this as the total variation.

So, this is total variation in which this constant line is for the static problem and this variation with respect to time is for the dynamic problem. Now, let us see what are the different types of dynamic loads because we know now, any load which is varying with respect to time can be called as dynamic load. So, let us see what are the time varying load? We know and which we can name as dynamic load.

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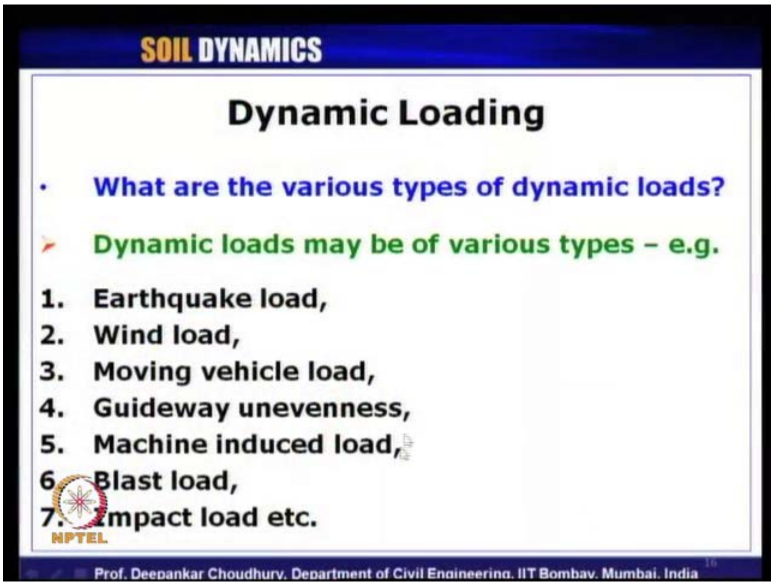

Let us look at the slide. So, dynamic loads may be of various types. For example, some of the examples are given earthquake load is a dynamic load because this load varies with respect to time. Wind load is also a dynamic load because here also it varies with respect to time. Moving vehicle load, when any vehicle moves on any road bridges etc that load is nothing but a dynamic load. Then another type of dynamic load comes from guide way unevenness. What is guide way unevenness? There can be several undulations on pavements, runway etc because of those undulations. When any vehicle is moving on those pavement or runway it may experience additional jerking, which is due to the additional dynamic load coming because of the movement of the vehicle on those uneven pavement or uneven runway.

So, that is called guide way induced guide way unevenness induced dynamic load. So, we will see later the application of this kind of dynamic load also. Then another type of dynamic load is machine induced load. When any machine is running or moving, the rotating component of the machine or the applied loading on the machine because of those movement it can induce the dynamic load. Then of course, blast load is another type of dynamic load because here also the load varies with respect to time. Impact load is another example of dynamic load. Now, after looking at these that is all these loads are time varying, and they are dynamic load, can I ask one question? Are all time varying loads dynamic? If I ask this question to anyone.

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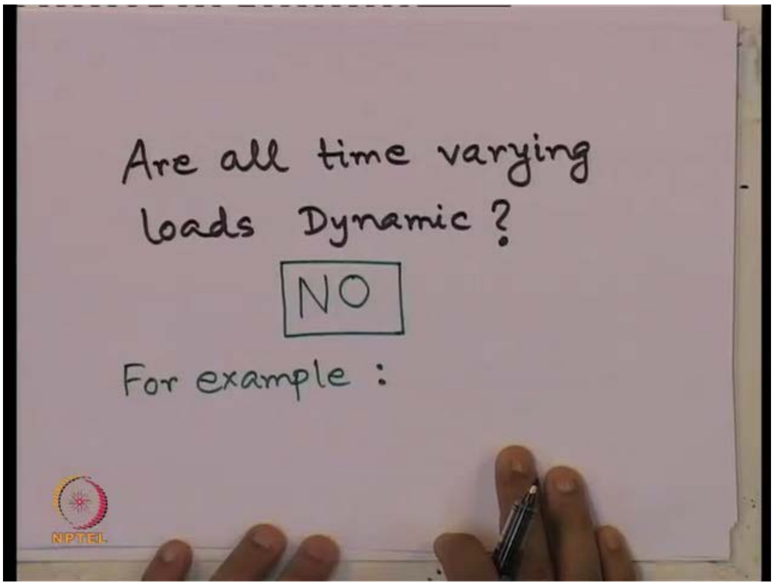

So, what should be the standard answer? Just now we have seen that any load which is varying with respect to time are dynamic and we have given the examples for that, but does it mean that it is always true? That is if we consider any type of load which is varying with respect to time can we say it is a dynamic load? Answer will be no. All time varying loads are not dynamic. So, for example, suppose at a particular point when the classes are starting say at morning 10 o clock, the room is filled up with students and teacher. Then the class is getting over at say 11 o clock and all the students and teacher vacates the room. So, in this case in that room at 10 o clock there was some loading, but with variation of time that is at 11 o clock there is no load acting on that room. Can we say is it a dynamic load?

No, because we know this type of loading is called live load, it is not dynamic load, Though it is varying with respect to time. Another example, in the morning the over head overhead tank are where in a any apartment it is filled up with water or in a student's hostel in the morning overhead tank is filled up with water. And by noon time, the overhead tank is almost getting empty because all students or all users of the apartment have used the entire water of the tank. So, does it mean that from morning to noon due to the variation of time there is change of load in the overhead water tank? Does it mean is it a dynamic load? No, again it is a live load. So, all time variant loads are not dynamic load; some more examples, excavation work or any construction activity.

When we are excavating soil in at any particular location and dumping it in another location. So with respect to time of excavation, the load at one place is reducing where we are excavating and in another place it is increasing where we are dumping that material. Does it mean that that it is a dynamic load at both these places? Again answer is no. These are live loads. So, when we considered the loads reacher time varying in nature are dynamic, it says that loads are considered to be dynamic. Only when it creates a vibration in the system on which the load is acting, unless it creates a vibration it cannot be a dynamic load. So, even though we can have several types of time varying load, it can be live load or some other kind of load. As we have given the example just now, but it may not be necessarily be a dynamic load. So, what that event vibration means? what do we understand by vibration?

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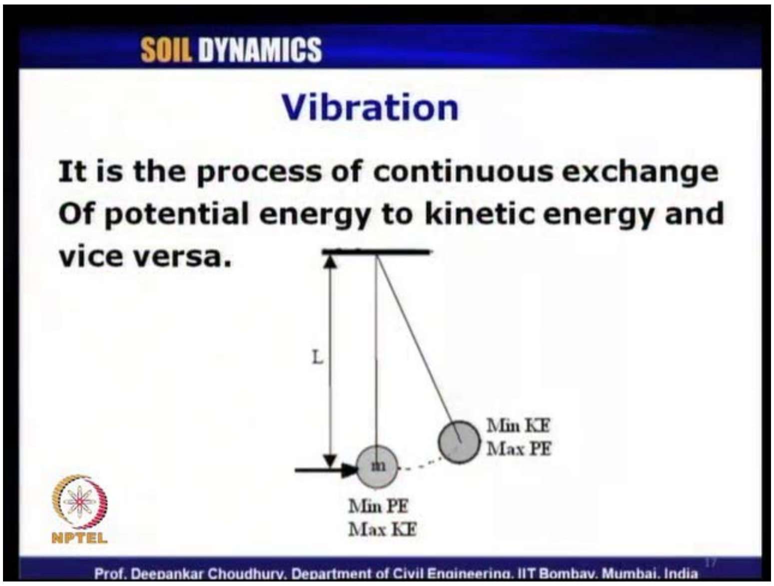

Let us look at the slide. Vibration it is the process of continuous exchange of potential energy to kinetic energy and vice versa. So, in any system, if there is continuous exchange of energy from potential to kinetic energy or from kinetic energy to potential energy due to the application of sometime varying load, then we can say the system is vibrating and then it can be considered as a dynamic load. A simple example is shown through this pendulum a simple pendulum, which is having a mass m and a string inextensible string of length L is attached to it, which is assume to be as mass less. When we apply some force on it or dynamic load on it, it starts vibrating like this. What happens when it is, when the mass is at this position it is having minimum potential energy. But maximum kinetic energy and when it goes to this position, it can have minimum kinetic energy and maximum potential energy. So, what happens during the process of vibration?

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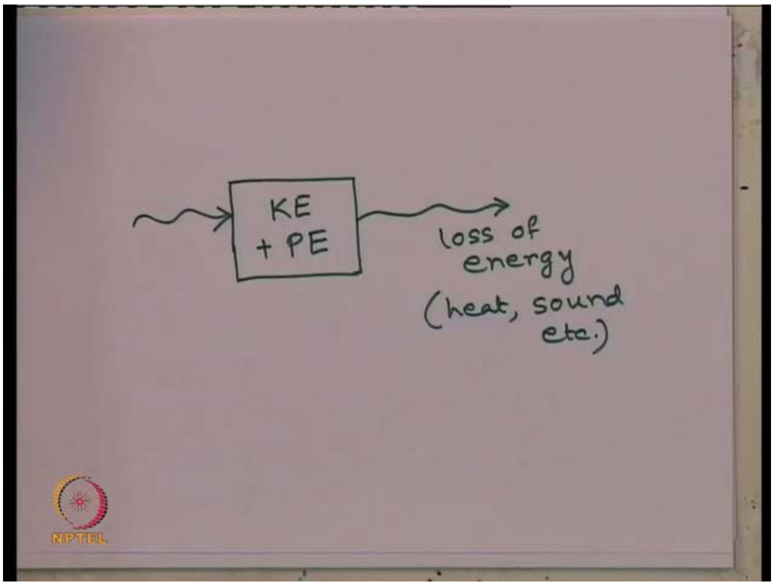

It is due to the application of the dynamic load on any system. We are having kinetic energy plus potential energy, some of it should remain almost constant in any system, unless there is any loss of energy. So, there can be some loss of energy also during this process of vibration and that loss of energy can be in terms of heat sound etc. Now, let us give some definition of some standard terms, which are useful in the theory of vibration.

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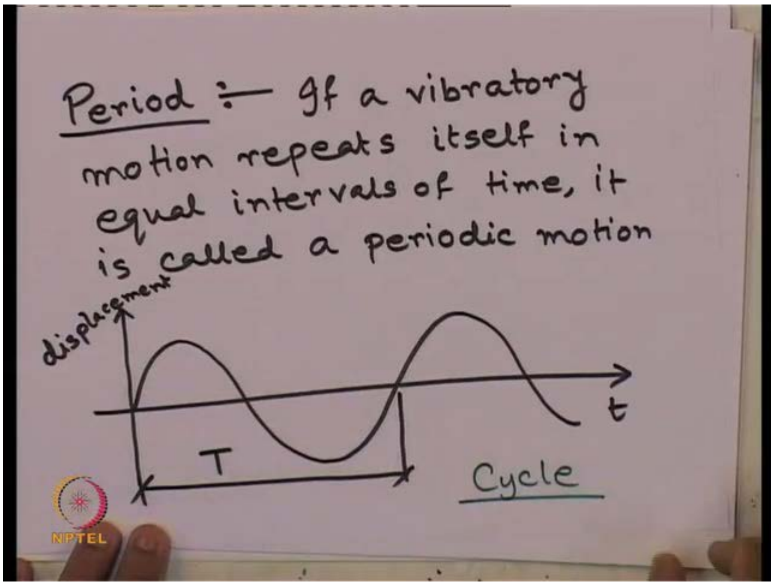

One is called time period or period of vibration, what is period of vibration? If a vibratory motion if a vibratory motion repeats itself in equal intervals of time, it is called a periodic motion. The time elapsed in repeating the motion, once is called as period. So, let me repeat it, if a vibratory motion repeats itself in equal intervals of time, then it is called a periodic motion. So, with respect to time suppose we are plotting the displacement of that vibrating body. What it says? This vibratory motion it repeats its motion after equal intervals of time. So, after this much of time capital T, the motion is again repeating the same motion is getting repeated. So, this time to repeat it once is called the time period or period of the vibratory motion and what is called cycle in this context.

We can mention another terminology, the cycle of vibration means the motion repeats under the motion repeated after a particular point is called cycle. So, from here to this point is called one complete cycle. Let us now define another parameter, which is called frequency.

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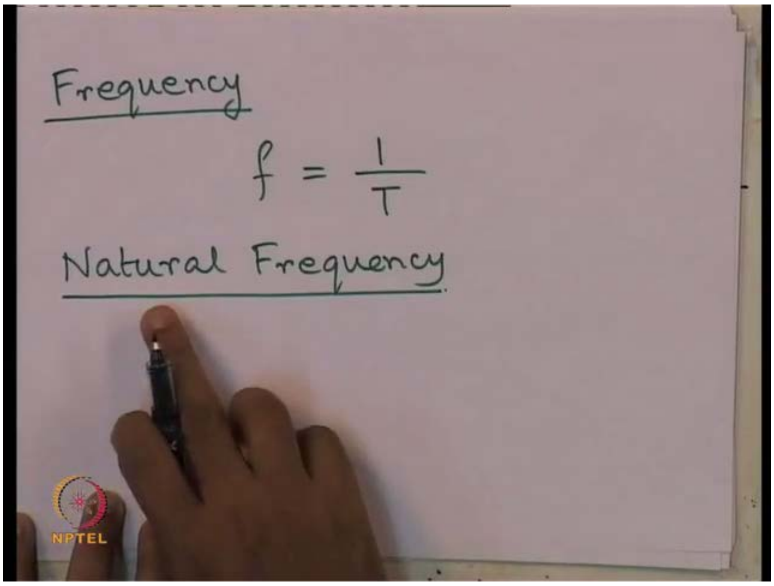

What is frequency? It is nothing but the number of cycles of motion in unit time is called frequency of vibration. So, frequency f can be written by 1 by T, that is number of cycles of motion in unit time. One unit time is called the frequency of vibration and what is natural frequency? The natural frequency of vibration of an elastic system, is the vibration the natural frequency of an elastic system, which vibrates under the action of its inherent forces. In absence of any externally applied force the frequency with which it vibrates is known as natural frequency. Now, let me tell you that, what happens in dynamic problem? The work is getting stored in the form of potential energy and kinetic energy.

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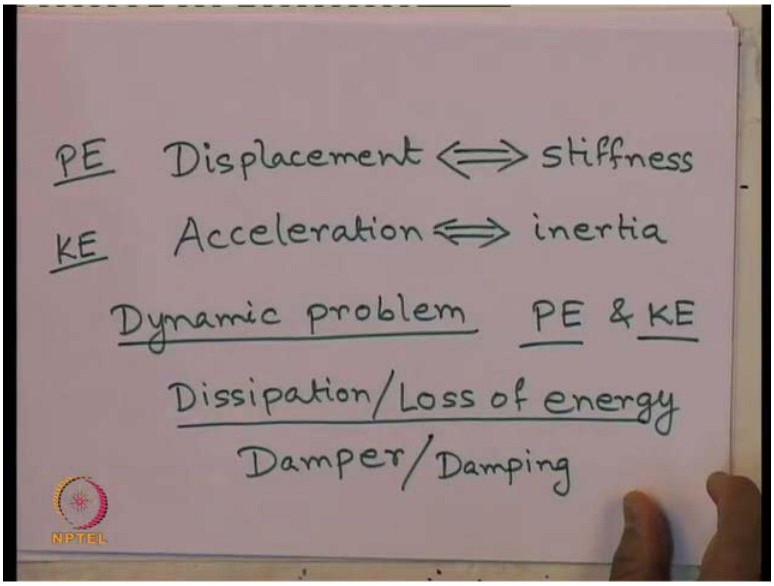

So, the displacement is related to the stiffness of the material and acceleration is related to inertia of the body, during any dynamic problem which we are considering where potential energy and kinetic energy are involved. So, to take care of these two issues, the displacement has to be related to the stiffness and acceleration has to be related to the inertia component. So, it relates to the kinetic energy component and this one relates to the potential energy component, during the exchange of potential energy to kinetic energy and vice versa for vibration. Now, when we have the loss of energy, so the dissipation or loss of energy that can be represented by some damper or damping.

So, damping is the property by which this dissipation or loss of energy can be represented. So, just now as we have seen when we have any system which is vibrating due to any input of the dynamic load. There will be continuous exchange of potential energy to kinetic energy. There will be some loss of energy in form of heat and sound. This can be represented by acceleration and inertia part. This can be represented by displacement and stiffness part and this can be represented by dissipation damping part. So, these are the basic three components of vibration.

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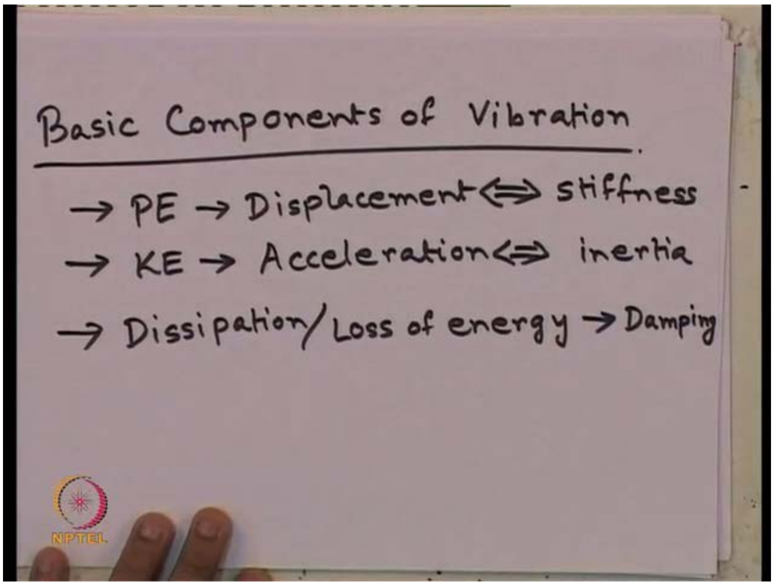

So, if we list… So, basic components of vibration of any system can be represented by potential energy, which is represented by displacement. It relates to the stiffness of the system. Kinetic energy which is related to the acceleration, which can be related to the inertia component of the system. The third one will be the dissipation or loss of energy which can be represented by using damper or the property, which we can mention is damping. So, these are the basic three components of any vibration. So, one can easily see the load is called dynamic load, only when the vibration occurs. That means exchange of potential energy to kinetic energy or with a loss of energy, then only the applied load can be called the time varying load can be called dynamic load.

If it does not create any of these three, mainly this first two, the dissipation or loss of energy can be optional, but it must create this exchange of potential energy to kinetic energy in any system. Then only the time varying load can be classified as dynamic load. If it is not, so then that kind of time varying load we cannot say as dynamic load. So, that ends our discussion on the first module. End of module 1, introduction to this course on the soil dynamics. So, from this study we have seen, why we need to study this course? That is what is the necessity to study the soil dynamics course specially apart from other dynamic course? What are the usefulness in practice for them and we have seen what do we mean by dynamic load?

What are the different types of dynamic load? All time varying loads are not essentially dynamic load, unless they creates some vibration in the system. Vibration will be continuous exchange of potential energy to kinetic energy and vice versa. There can be some loss of energy or dissipation of energy, that can be represented by a damper or a damping system. Potential energy can be represented by the stiffness component, which is related to the displacement of the system. The kinetic energy can be represented by the inertia of the system, which is related to the acceleration of the system.