Structural Analysis 1
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Lecture 2
Idealization of Structures, Threats and Responses

Hello, welcome to the second lecture of Structural Analysis 1.

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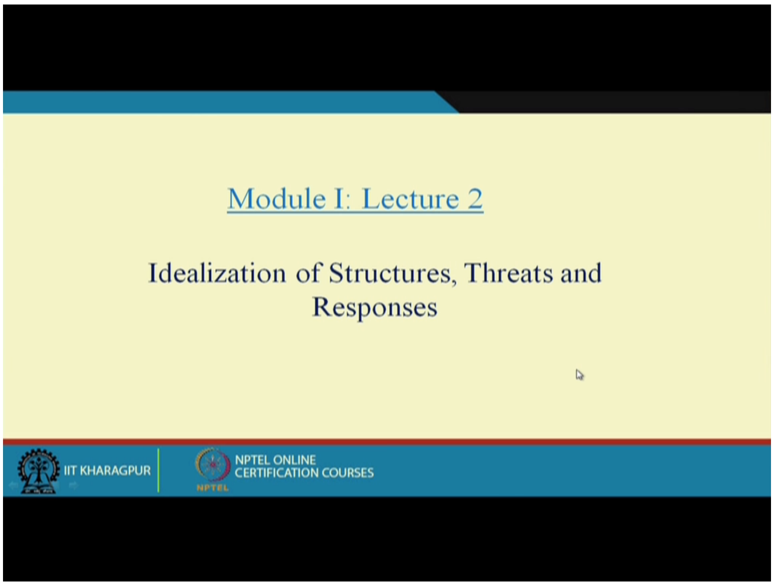

In this lecturewe are going to see idealization of structures, threats and responses.

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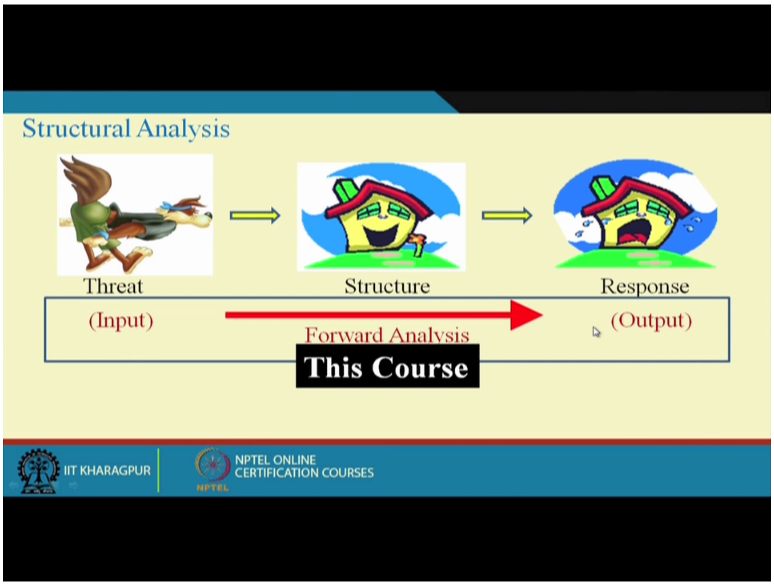

If you remember the last class, that was our endslide, right? We discussed that structuralanalysis is essentially a step to understand the behavior of structure when they are subjected to any kind of threat. So this is the flow called structural analysis. Now what you are going to see in this lecture is, what are the different kinds of threat we may have? What are the different kinds of structure we have? Andof course, what are the responses we are looking for? Okay. .

At the end of the day, irrespective of any engineering discipline, what we want to study is, we wantto the nature, right? Nature is governed by certain laws, certain rules. We want to understand those rules. And then with that understanding we try to find out the solution of ourengineering problems. Okay. Now, when you do that process that is also a step. For instance, if you take any physical system, this physical system could be anything.

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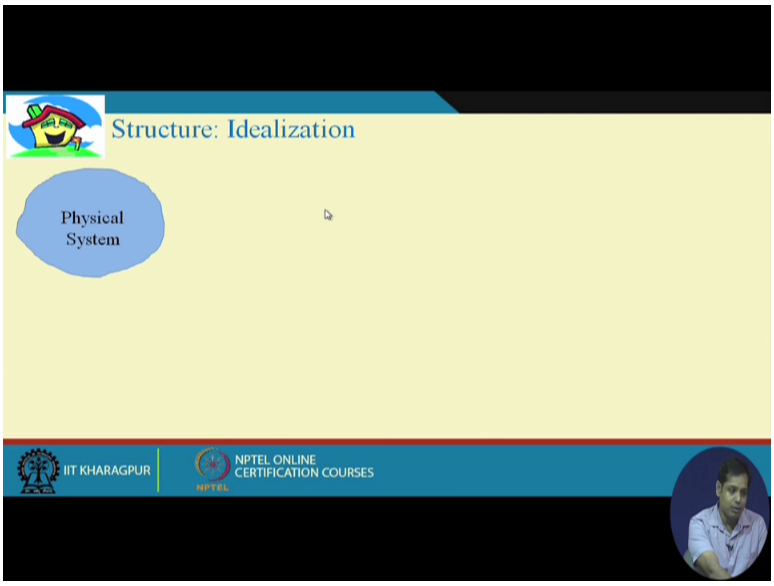

It could be a structure,I will give you some examples of some physical system. Now this physical system is very complicated, very complex. So dealing with the physical system exactly the way it is, is very difficult. So what we do is, instead of taking the physical system as it is, we take an idealized physical system. We take an ideal, simplified model of this physical process. Okay.

And then try to analyze this simplified process. Now these idealization of the physical system should be as close as possible to this physical system.

Now again, this idealization depends on what exactly we are looking for thisanalysis. If ourrequirement is different,thenour method of idealization or idealized model of same physical system will be different. Now once we have the idealized system, then we try to represent this behavior of this system through some mathematical model. This mathematical model could be in the form of integral equation, may be in the form of differential or algebraic equation. But those equations must represent the idealized physical process. Okay.

Now once we have this mathematical model ready, then what we will do is,we solve this mathematical model.So this process is true not for only structural analysis. This process is true for any analysis. It is pet of the discipline. Any problem we solve or try to solve, we generally (appro) follow the similar approach. First, idealization of the system. Then equations, model of this equation, model representing the idealized situation and the solution of the model.

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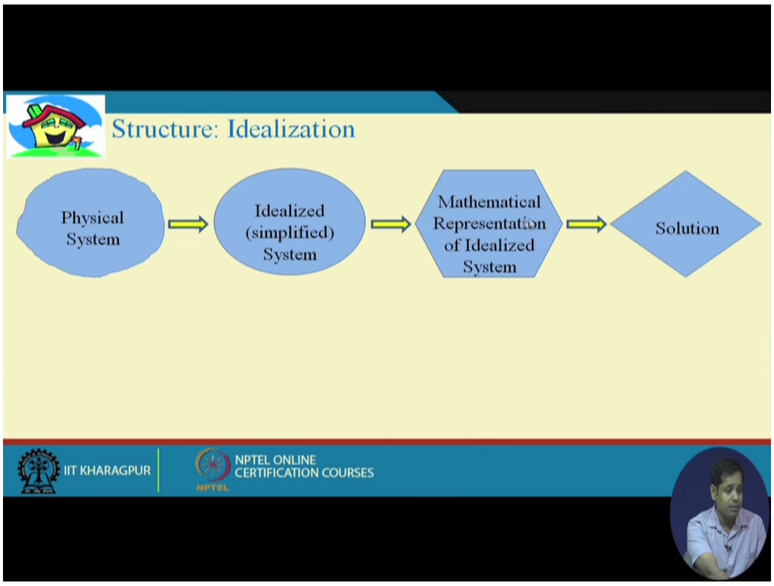

Just to make it clear let me give you an example. Suppose I want to study. If a ball is dropped from a certain height, what I want to study is,how the velocity change over time as it falls? And when it reaches the ground what will be the velocity of that object? Okay. Or at any particular time distance travelled by this object. So this is the physical process.

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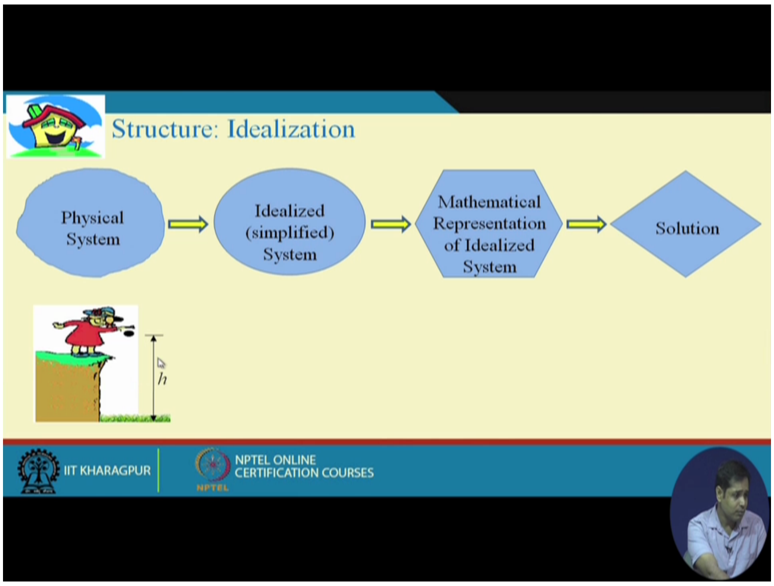

Now what is the idealized system? This is the idealized system of the process. And this is the ball with mass M and this is falling on the gravity G and now at the initial point Y0 and the final when it reaches the ground Y is equal to Yf. At t is equal to zero, you can have if it is not free fall, if you give some initial velocity, then there could be some initial velocity as well. Now this is the idealized model of this physical process.

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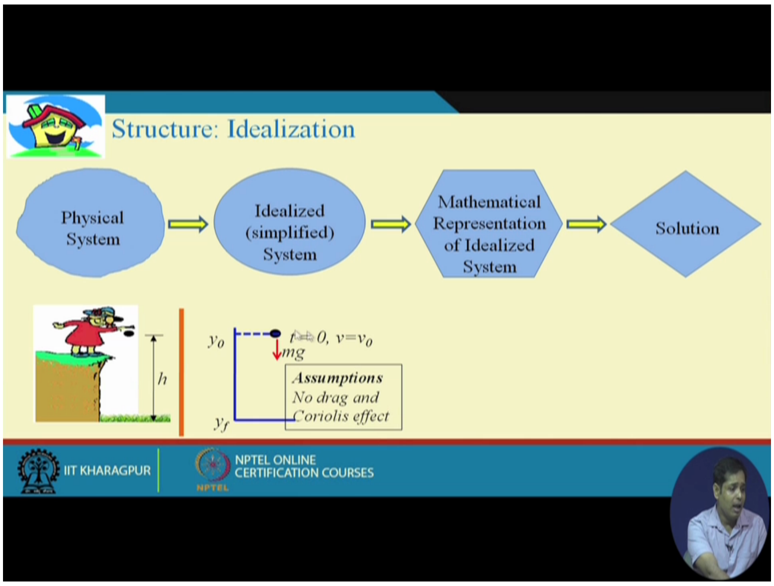

Now you see, what are the simplification we have made? When we say that this represents the physical process,that representation is based on certain assumptions. As far as this problem is concerned here one of the major assumption is there is no drag and Coriolis effect. There is no drag force from here. And since there is no drag force then what happens if you drop a steel ball and a feather they will reachat the same time. And then there will be no Coriolis effect. Okay.

Now this physical system is based on this assumptions. Similarly you take any system, when you idealized it, that idealization has to be based on certain assumptions. And assumptions of any process is very important. Because you know it is the assumption which are the limitations of any model. So when you simplify a system, when you are working with a model, you must understand what are the assumptions behind that model?

And understanding of that assumption will help you to know what will be the limitations of this model? Because wherever that assumptions are not valid, the model cannot be applied. So in this case, this is the limitation. If for a problem the drag force and Coriolis effectis important, then you cannot really have this.You need to consider this in your model.

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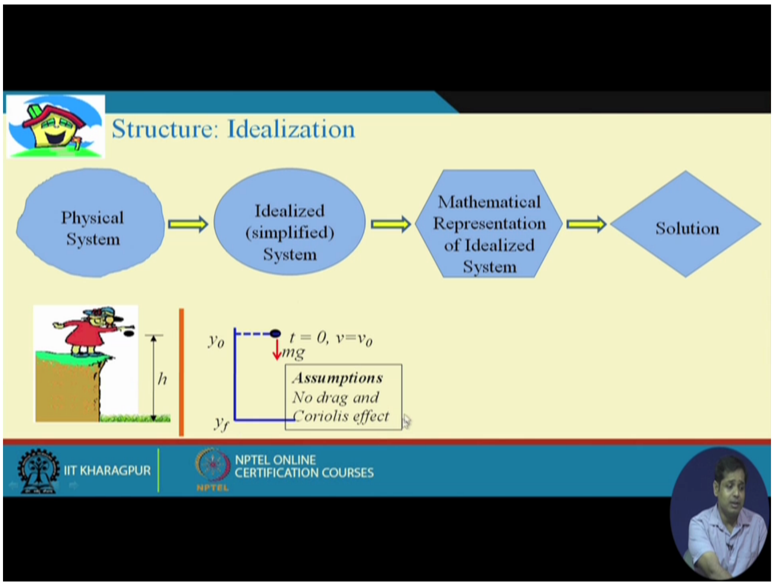

Now once you have idealized the system,next step is the representation of this system through some equations. Okay.

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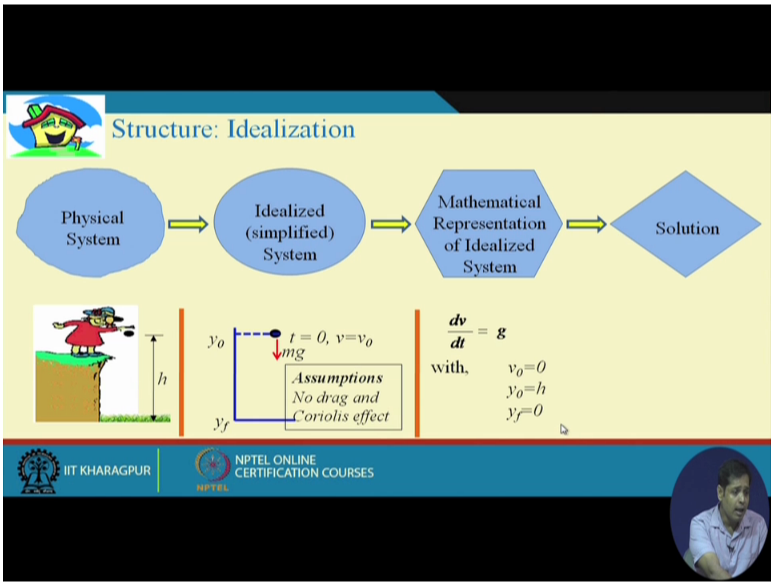

Now this can be represented by this simple equation. Now this is the governing equation and this equation is subjected to this initial conditions. Okay. Now once this model is with us, then next step is to solve this model, solve this equation with this initial conditions. And finally solution of this equation is this.

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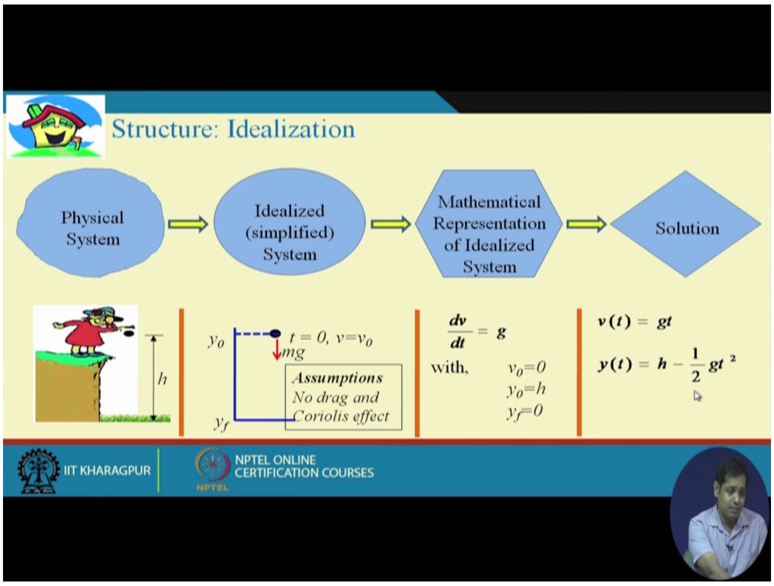

So if we see, this is the solution of this model. Now, how accurate this solution is for this physical process? It depends on assumptions at various stages, various steps. Because you have some assumption from physical system to idealized system. And because of that assumption you were slightly deviating from the physical process. Now from the simplified model when you represent the mathematical model, here also this mathematical model is based on certain assumptions. And that assumption will have to this deviation.

And finally when you solve this mathematical model, there are many cases you will see that close sum solution may not be possible and you need to go for some approximate solution. And even in structural analysis, towards the end of this course you will see thathow some will introduce some of the approximation method for solving structure. So during this approximation also there will be some assumptions contribute to this deviation. So you must not take any solution for granted.

When you have a solution, please check the physical process and understand, what are the assumptions at every step? And if those assumptions are applicablefor your case then your solution is valid. Then you can go with the solution. But if you see that these assumptions are not applicable, not validfor the case you are dealing with, then you cannot take thissolution for granted. And that is true not only for structural analysis. That is true for any analysis. Okay.

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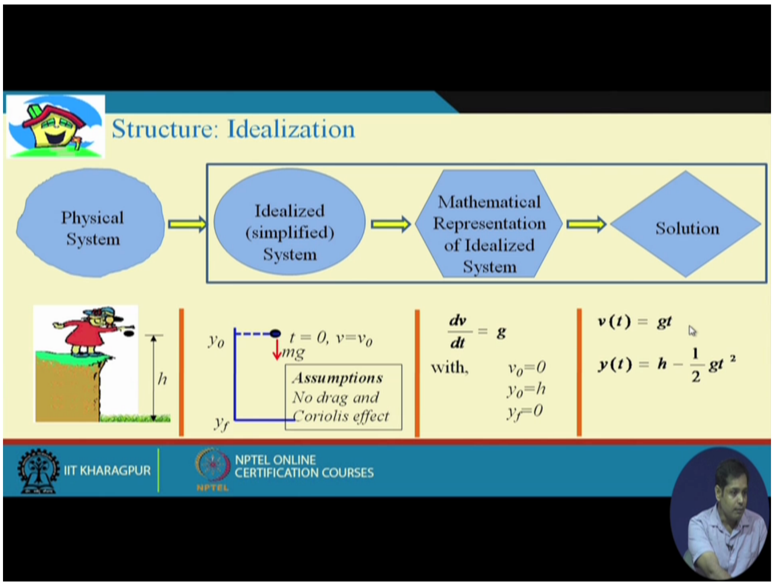

Nowwhat we do is, analysis essentially means,what we do is, in this course is this process. Okay. So today we will see how the physical system can be idealized? What are the idealization of physical system? And then next lecture on, will only concentrate on this part. And every problem we will start with the simplified model, the idealized model of the actual physical process. Okay.

So for today we will discuss from this step to this step and then next and the rest of the courses, we will be concentrating on this part. We will always start with this idealized system. Okay.

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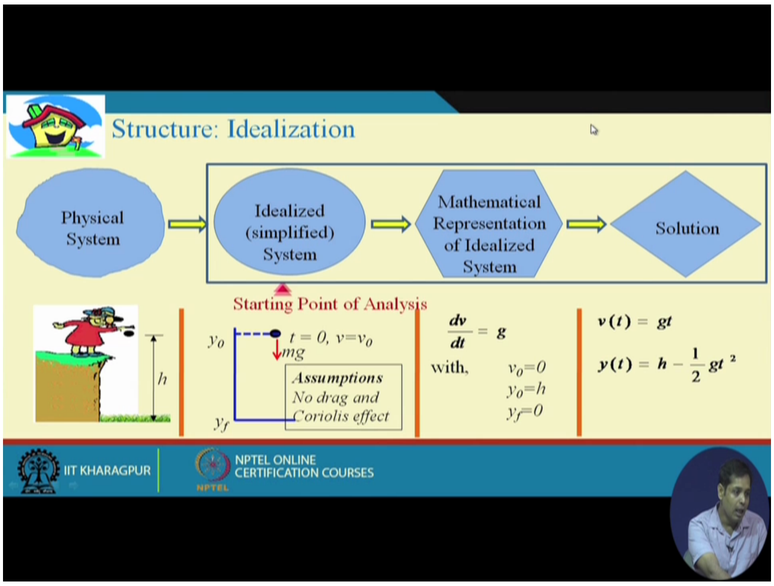

Now you seethere are three components involved here. One is the structure itself and then another one is threat and the responses. So when I say that you need to idealize this system, you need to idealize everything. You need to idealize the threat, you need to idealize the structure and you need to idealize the responses as well. Now let us see how the structure can be idealized. Now you see this is an example. This is a tall chimney. This is actual structure. Now this is the physical process and this is the simplified model of this physical process.

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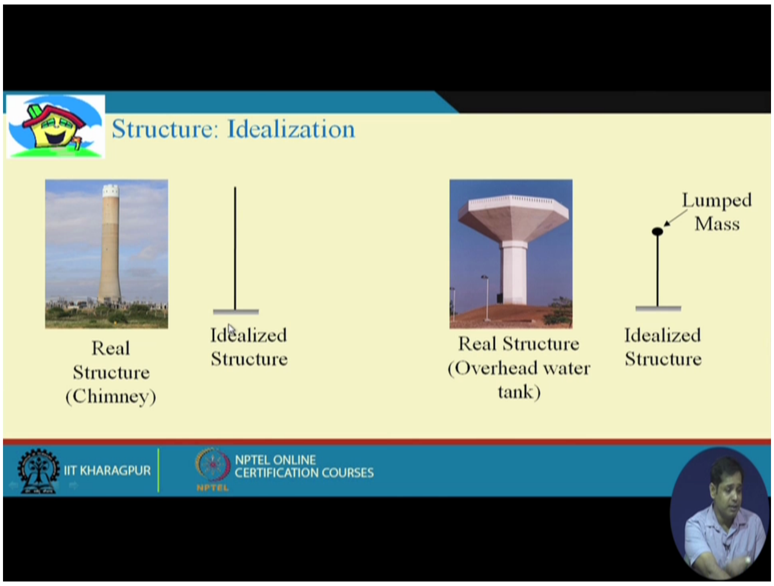

Now what are the assumptions here? Now the assumption here is, if you see this chimney is very long. The cross section of this chimney is very small as compared to the length of the chimney. So if it is such, then this chimney can be treated as one dimension.It is a line. Now this chimney is fixed to the ground and this line which is an idolization of this chimney. It is fixed to the ground. So here two things are idealized. One is the chimney itself. It is simplified as one dimensional line element. And the support, that is idealized.

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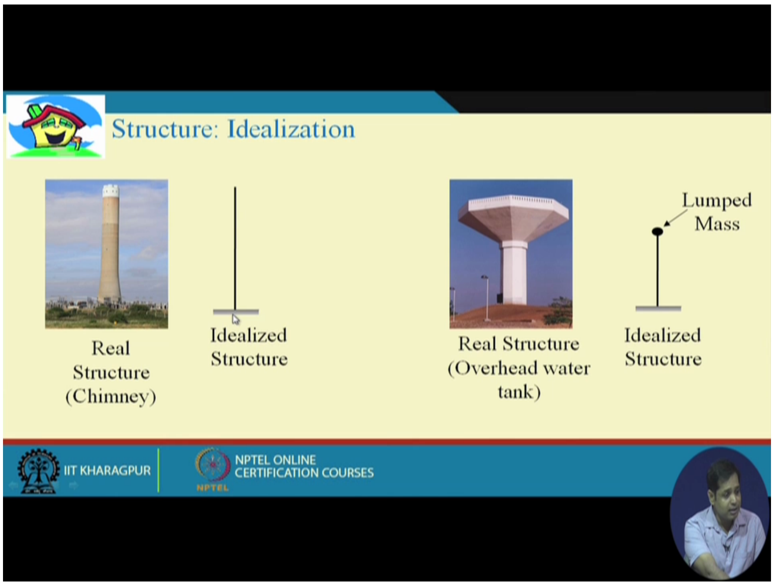

We will discuss more on support in detail, but this is a fixed support. This line is fixed to the ground. Now suppose the similar kind of structure,butit is an elevated water tank, you know. Now up to this it is very slender, similar to chimney. The cross section is very small as compared to the length of this part of the structure.

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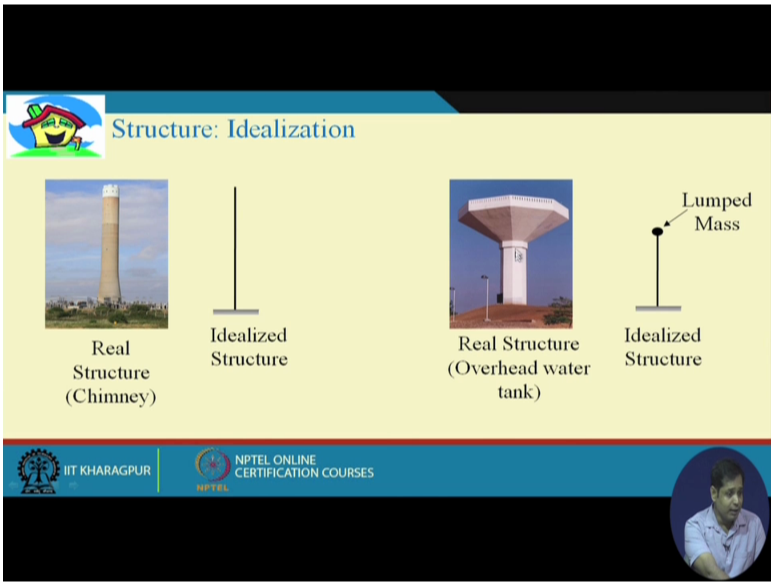

But then after this part there is ahuge tank. Now the weight of this tank is huge. So what thisstructure can be idealized as?You have a line element, which is an idealization or idealization of this. And then which is attached to mass, the mass of the entire thing. So this is idealization of this structure. Okay.

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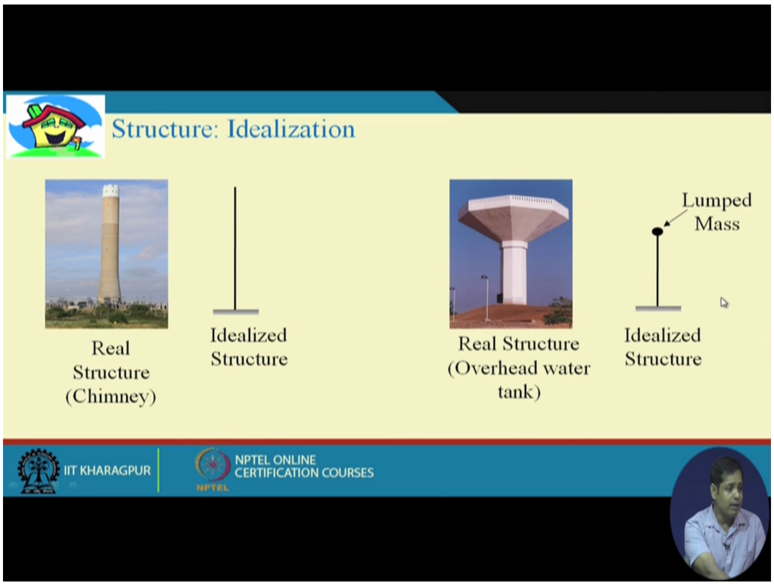

Now let us see some more.This is a truss, okay. Now this is the real structure. I will show you the model of truss so that you can better understand the different jointsand the members or the assemblyof different components of this structure. Now this is the real structure and this is idealized as this. Now again if you look at every member separately, the one dimension is very small as compared to the length of this members.

So every member is model as line element. And this is essentially the collection of some slender member. Some member havingone length is larger as compared to other two. This is idealized as collection of some one-dimensional element, one dimensional member. Now again the support are, it is the idealization of the support. Now when we talk about structural analysis, the analysis needs to be performed on this idealized structure, not on this.

And therefore we have to be very careful from this step to this step. Your idealized or simplified structure must be as close as possible to the actual structure.

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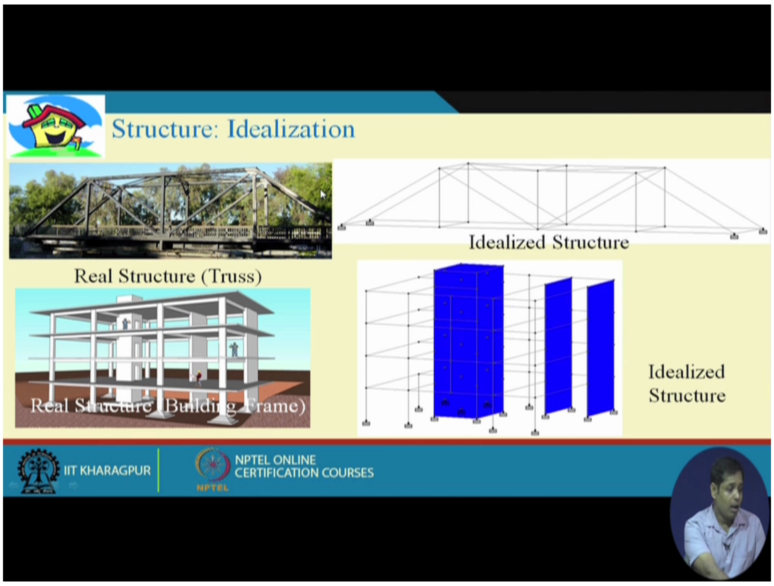

Now again take another example, this is building frame and which has columns,slabs, thenshear walls. We will discuss details about columns, slabs and shear walls. And this is the idealization of the structure. You seethe columnsare model as vertical lines. Then the beams are model as the horizontal lines here. And the shear wallsare modelled as model as plates. And then another important thing you can see here, the slabs are not modelled here. We will (dis)see later thatin many cases we really do not need to model the slab.

And whatever load you have on the slab that can bejust directly distributed on the floor. But in many cases where, depending on the response you will be looking for, you may have to model theslab as well. So this is and idealization of this structure. Again it is very important when you do this step from actual structure to idealize structure, you have to be very-very careful. And the analysis needs to be performed on this idealized structures.

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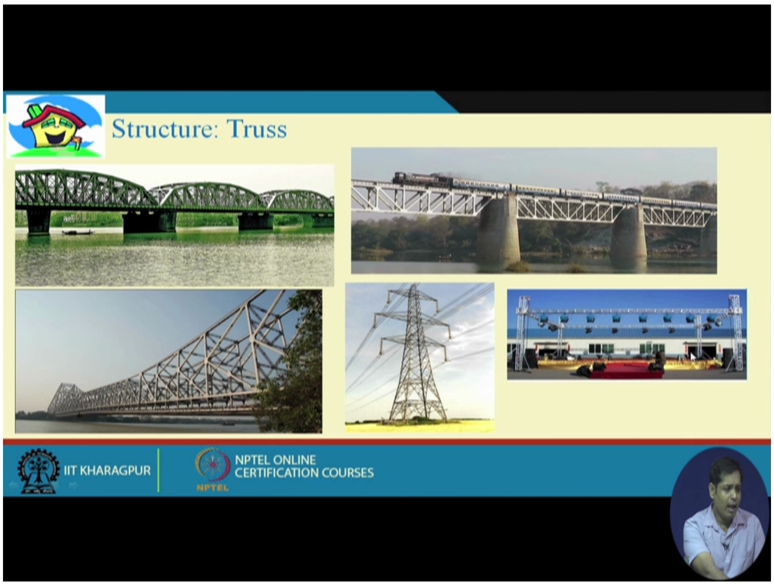

Now there are mainly in this course, we will have two kinds of structure we will talk about. One is truss and one is frame. How structurally they are different? Truss and frame, we will discuss in detail. Now this is some example of truss. Truss is a railway bridge, this is a transmission tower and then this is, you might have seen thatduring any function or any this isa supporting arrangements where you can keep yourlights or any other orchestra system that you may need.

So this is also a truss. But important thing here is you see all these structures are three dimensional structure. In fact we are living in a three dimensional space, right? So all structure is essentially three dimensional structure. But what we do here is, we will idealize them as two dimensional structure and perform the analysis on those two dimensionalstructure. But that is not our restriction.

The reason why we perform analysis on two dimensional structure because through two dimensional structure we can demonstrate the concept. We can learn this concept and once we learn the concept then similar concept can be extended to any three dimensional structure, okay.

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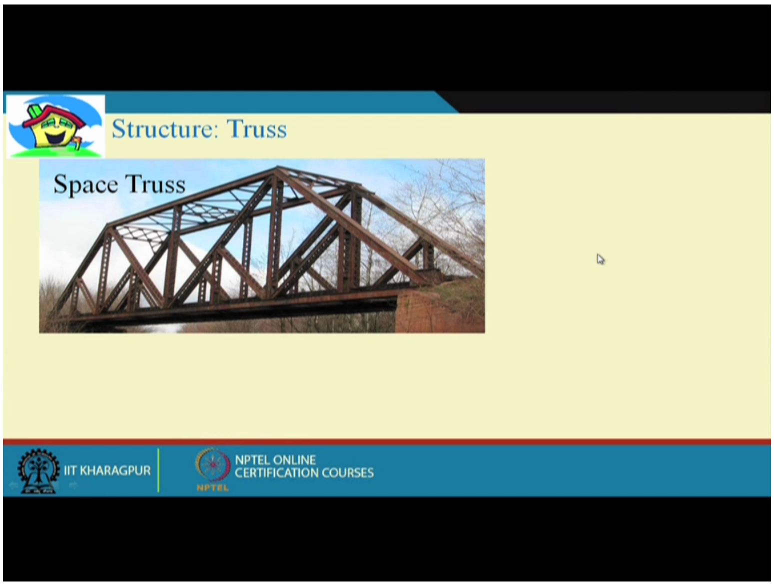

Now you see this is the actual structure. Now you see the actual structure made of, if you take this is one system and another system, the replica of the system and this two systems are connected through some members.

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Now see this is one system and thensimilar truss you have there, this one.And then these two trusses are connected through cross members. What we do is now we demonstrate our concept, the structural analysis concept through this.

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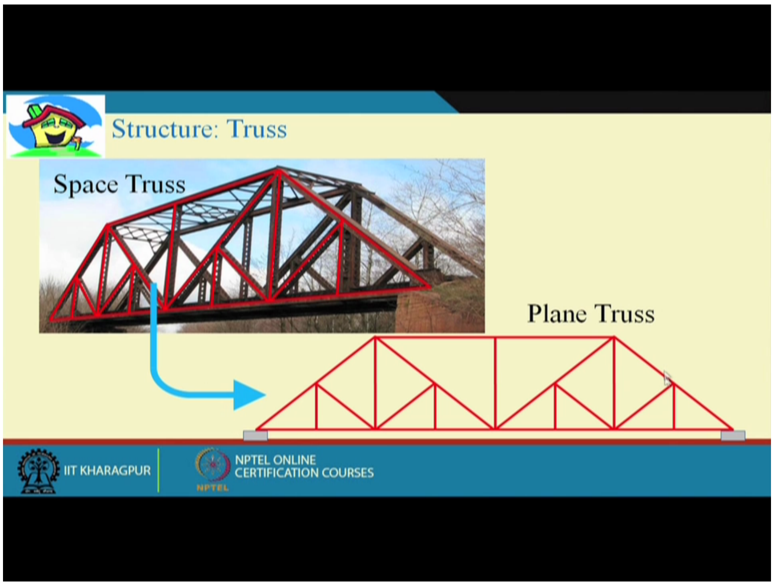

So this is a space truss because it is in three dimensions. And this is a two dimensional idealization of the space truss. And this is called plane truss. And we will perform analysis on this plane truss. If time permits later we see how the concept you learn in two dimensionalproblem can be extended to three dimensional problem.

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Now this areframes. Structurally they are different from trusses. And how they are different from trusses? We will discuss thatindetails. Now again if you take this frame, consider this frame.

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This is a space frame. Now again you see this frame essentially, if you take this is one representative element on this frame. And then you have mirror image of several such elements. And those all elements are connected together. So this is one component and this component you repeat those component and then connect those components together, you will have this space frame.

What we will do now is, we will instead of considering this as a space frame, we will take just one element of the space frame and perform analysis on this on this frame.

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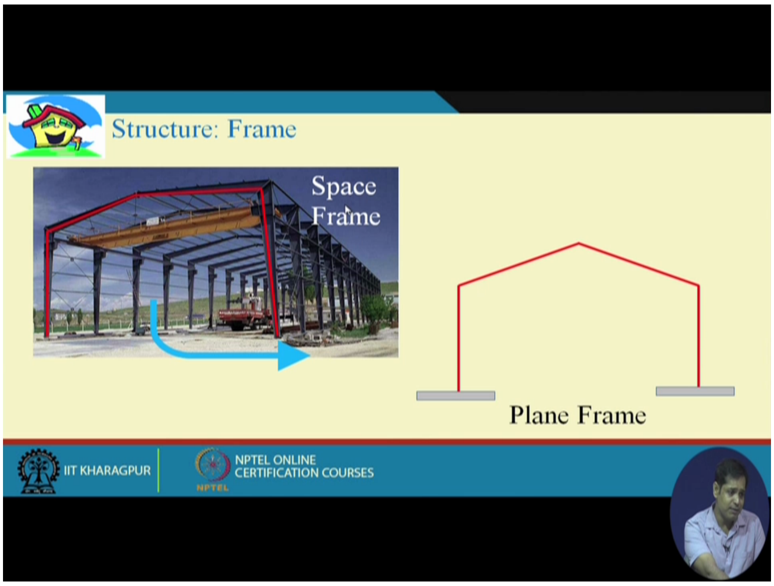

So this is a space frame, this is plane frame. Again this is not our restriction. We will be doing that just to demonstrate the concept. Once we learn the concept of structural analysis, we will see how those concept can be extended to three dimensional problem. Andtheseframes are supported at the ground, fixed at the ground. And this is the idealization of the support.

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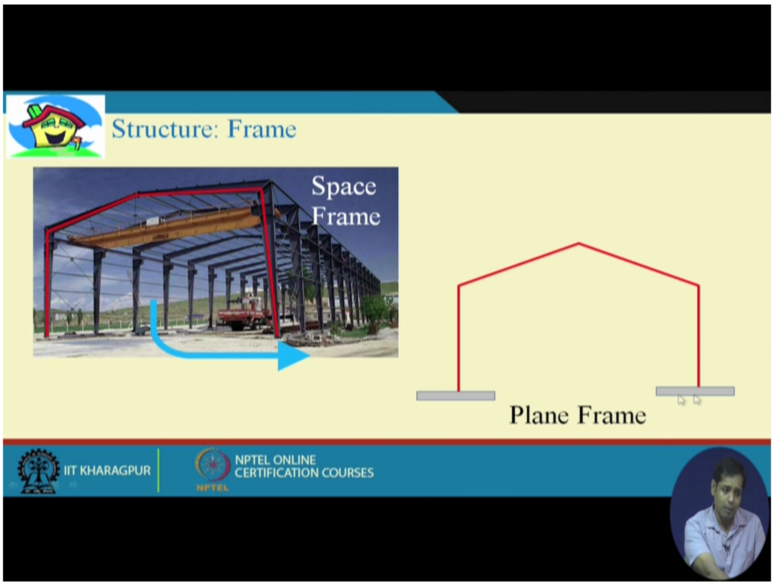

So essentially what we do is, two kinds of structures we will discuss here. One is called truss and one is called frame. For the time being you take the term truss and frame for granted. We will discuss detail, how the trusses and frames are different and structurally different? But in this case we will be considering two different kinds of structures, truss and frame and that too plane truss and plane frame. But again as I said earlier, this is not the limitation.

We will extend once we learn the concept. We can extend it to three dimensional problem as well. Now this was the idealization of the frame. Now let's see what are the idealization of threats? You know when any structure is subjected to actual environment, it is exposed to actual environment,it is subjected to different kind of loads. What I'm going to do on this slide is,I am going to show you some of the loads that we consider during structural analysis.

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The first load is called the dead load. Which is the self-weight of the structure itself. Andthen live load. Live load means the loads which are live, right? For instance here, if you take a building,then the self-weight of the building is the dead load. Now other than the self-load of the building you have the load from the occupants of the building, load from the furniture.

If you take a bridge then in addition to the cell fate of the bridge, the vehicle moving over the bridge, passenger moving over the bridge, this vehicle and passengers they exert some load on the bridge. Those loads are live loads. So these two, dead load and live load are the most common type of load that we consider in any structural analysis and design.

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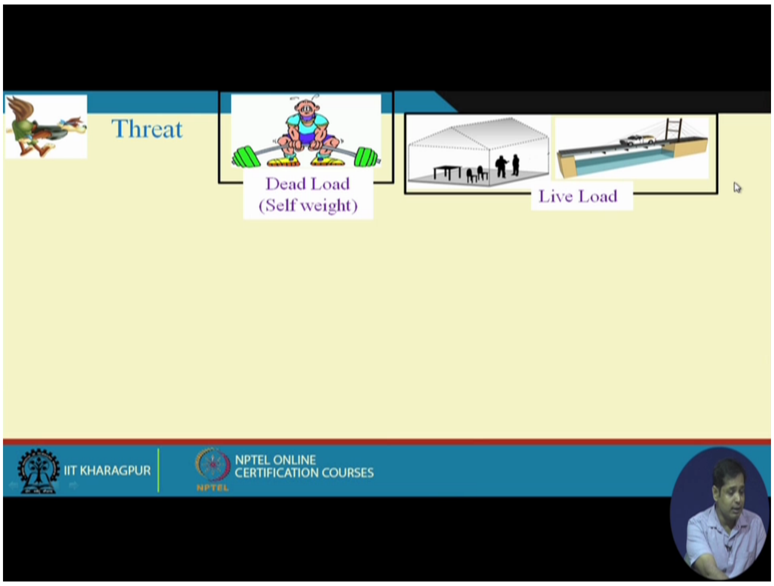

Now then we have earthquake load. Earthquake, you all are familiar with earthquake. Now that also needs to be considered. If you are making a structure in the area which is prone to an earthquake. then we can have wind load,especially for very tall structure, we do consider wind load. Wind has very significant effect on the structure.Then we have earth pressure. If you take a retaining wall which retain soil, then the soil can exert some pressure on this retaining wall. That also need to be considered while analyzing retaining wall and designing retaining wall.

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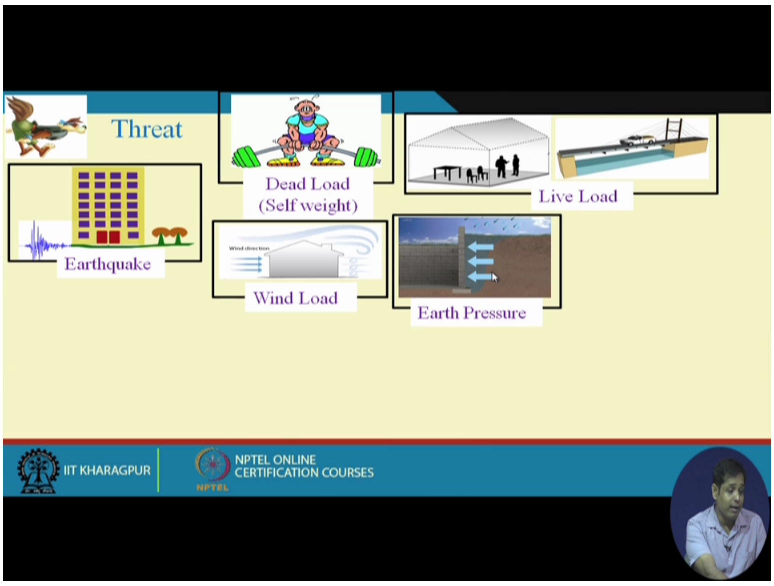

Then we can have water pressure as well. If you take any dam,then the water can exert significant pressure on the dam. That pressure needs to be considered. Then you have snow load. That also depends on the location. If you find in an area thatthedeposition of the accumulation of the snow on the roof of a structure may produce the increase the load on the structure. That load also needs to be considered while analyzing the design of thosekinds of structures.

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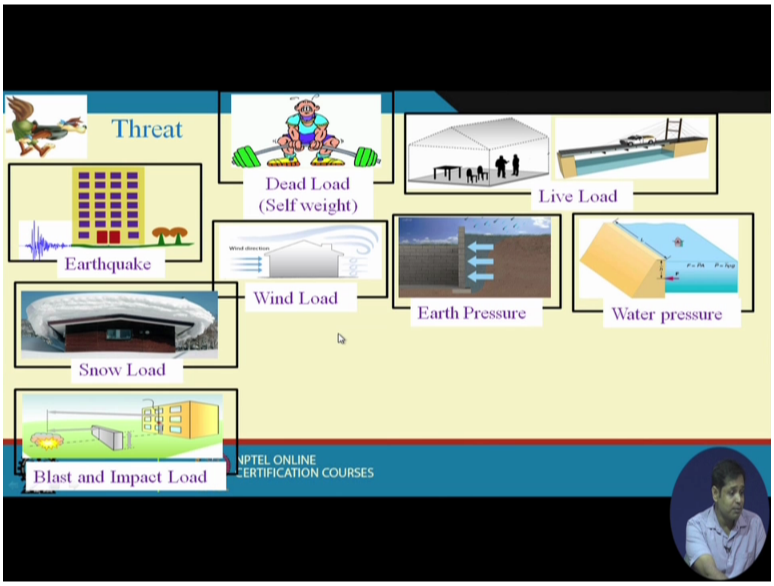

We can have blast load. Again these kind of loads are very special load. I mean you are designing very important structure which may be subjected to impact or blast. That also needs to be considered. Then offshore structures, yes almostall offshore structures are exposed to wave and current load. And actually this is the one most significant threat on offshore structures. When we are designing offshore structure, we need to consider the load from the wave and current.

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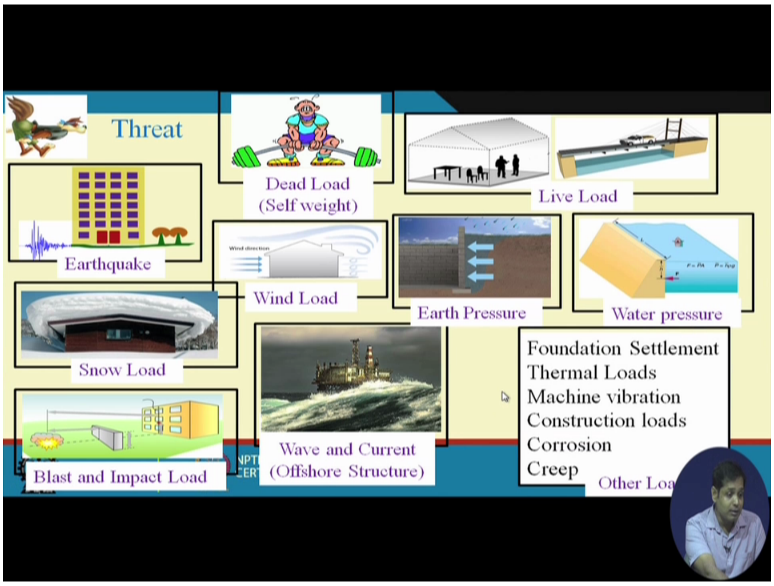

So in other than all these loads, apart from all these loads, there are few other loads which are important and needs to be considered. Again whether or not you consider thatload.

Thatdepends on the purpose of the structure. The second, foundation settlement. Effect of foundation settlement we will discuss later. That's why you put a star mark right now here.

Then thermal loads due to change of temperature, your temperature may effect expansion and contraction then that expansion may or contraction may inducesome load on the structure that needs to be considered. If you think that is asignificantpart of your threat. Machine vibration, if you are making a structurefor a machine then vibration of the machine needs to be considered. Then construction load, during construction also you can have different kinds of loads.

That needs to be considered. Corrosion or creep, so you can Google it or you can see any books to understand what is corrosion and creep. But these are the some loads that need to be considered. So these are some of the threats that need to be considered when you design or analyze a structure.

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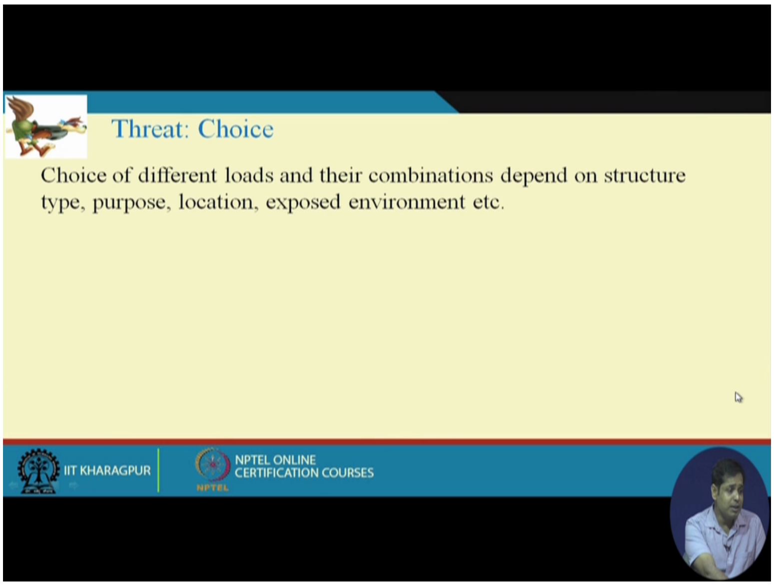

Now in this slide what I gave you, I gave you different kind of threats. But it is not necessary that you consider everything when you analyze a particular structure. These are the common threats that you can have. But depending on the structure you need to choose the kind of threats. If you see the dead loads and live loadsare more important than any other loads, then you may ignore all other loads. For instance, suppose the choice of different loads and their combination depend on structure type and purpose and location on the structure.

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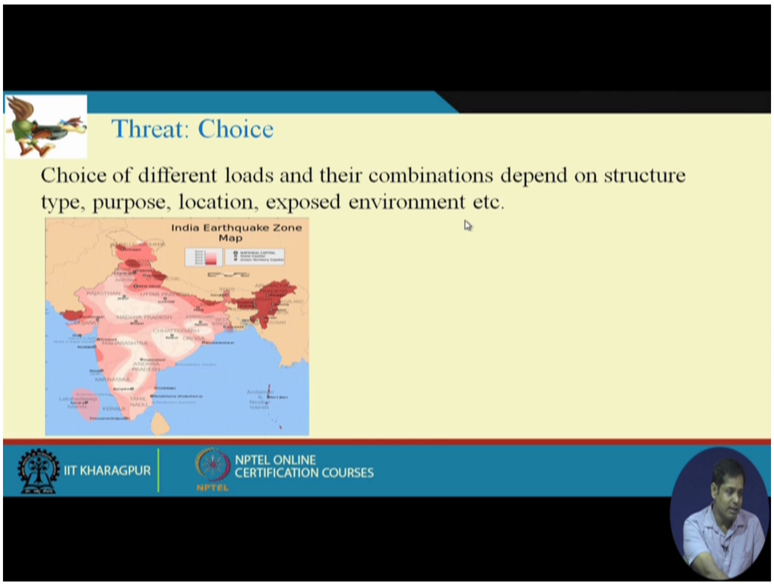

For instance you see this is the earthquake zone of India. And this map shows you that which are the places which are prone to earthquake. These arethe places where the probability of having earthquake is more compared to the lighter part here. Now naturally if you are building a structure here, you need to consider earthquake load. But when you are constructing a building here, then earthquake load may not be thatsignificant. So whether or not earthquake load to be considered, that again needs to be decided based on the location.

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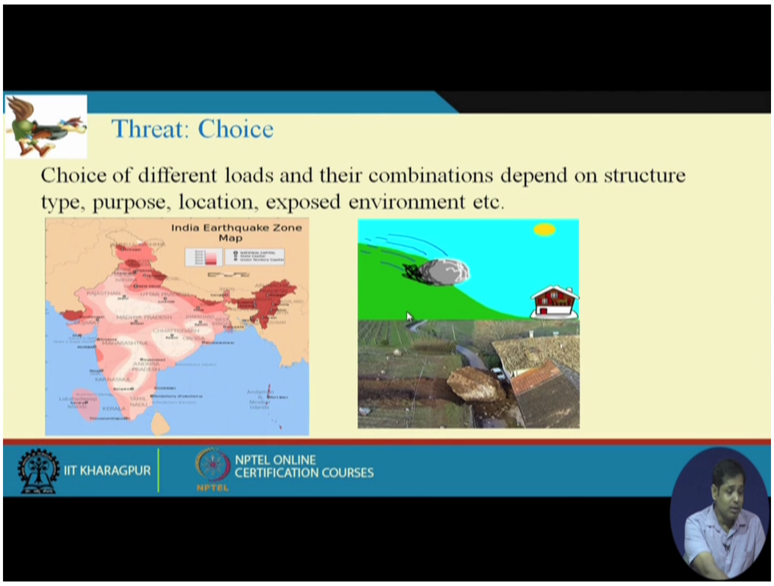

Now suppose this is one example, there are many hilly areas that rolling stoneis a very common problem. So what happens, stone rolls around from the hill and hit the structure which can cause damage to the structure. Now if you are making a structure in those areas, then the impact from this rolling stone needs to be considered. So in a nut shell the point what I want to make is, we have different kinds of threats, different kinds of loads.

But what are the loads to be considered, that depends on the location of the structure, purpose of the structure, importance of the structure and based on this we need to consider the threat. Now next is the idealization of the threat.

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What we have discussed so far is different threats, right?Now let's see how the threats can be idealized. For instance for self-load, take this structure. This is a cantileverpart of the structure. Now you see this structure can be idealized as this. That we have discussed how the structure can be idealized. Now the self-weight,this (stru) portion of the structure has some self-weight and the self-weight is distributed over the entire length.

And this self-weight can be idealized as a uniformly distributed load on the structure. So this line is the idealization of the structure and this arrows, you can see, that is the uniformly distributed load which represents the dead load of the structure.

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Similarly if it is earthquake load, it can be shown that earthquake load can be idealizedas horizontal load at different stories. If we move from the ground this magnitude of the load increases. So what happens here?Here thisgreat structure that you can see, that is the idealization of your actual structure. And then these arrows which has the horizontal forces on the structure, this is your idealization of the earthquake load. So this problem is now idealized as this.

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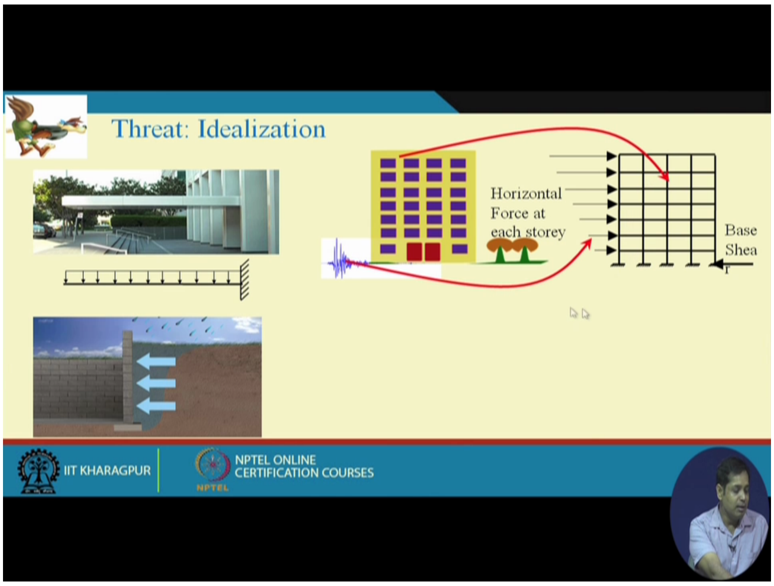

Similarly the Earth pressure if you take, this is the retaining wall which is subject to Earth pressure. Now it can be idealized as this. The vertical line you can see, that is the idealization of the retaining wall. And thistriangle distribution, that is the idealization of the Earth pressure on the retaining wall.

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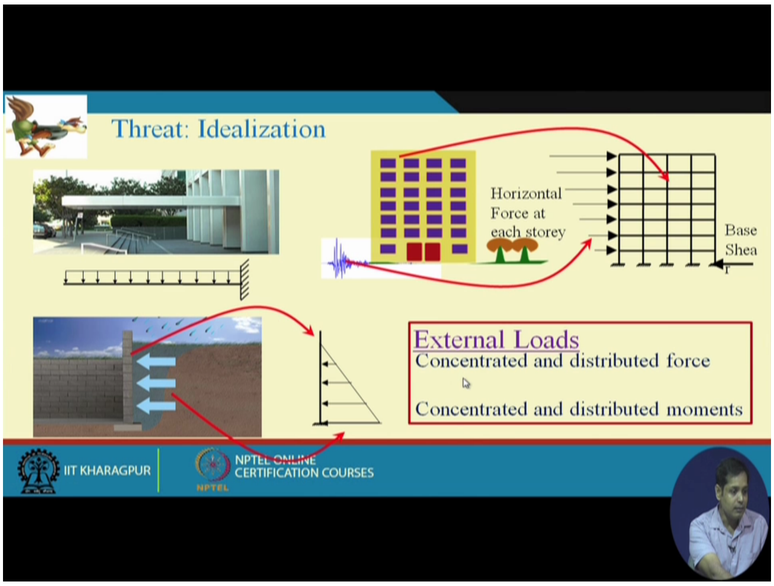

So one observation from this example is, any kind of load, whether it is dead load, earthquake load or pressure or live load, any load can be idealized as some concentrated or distributed forces or concentrated and distributed moments. So now whatever threat we consider, instead of considering the threat as it is, we translate that threatintoconcentrated or distributed forces or translate the threat into concentrated or distributed moment and apply those forces on the structure and analyze it.

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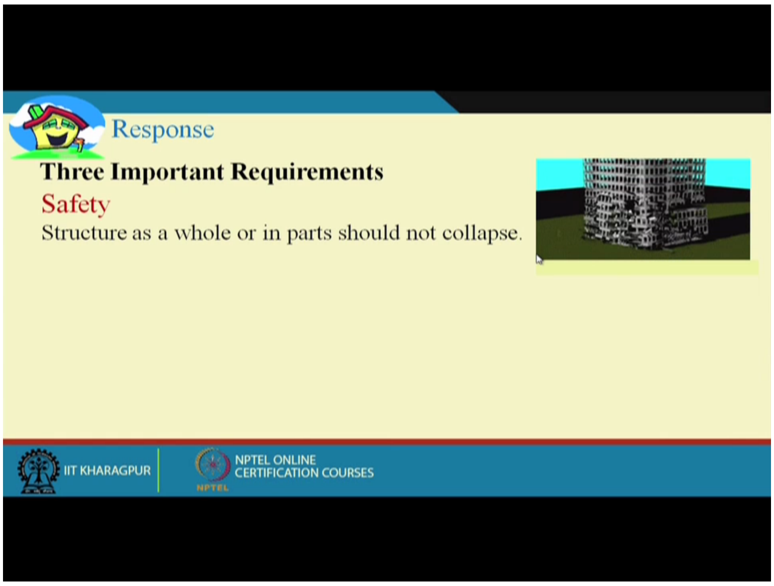

Now next the response of the structure, we will see in the design course, there are three important consideration for design. One is whatever structure you make, your structureneeds to be safe. Means the structure must not collapse under the action of load. So safety is the first requirement.

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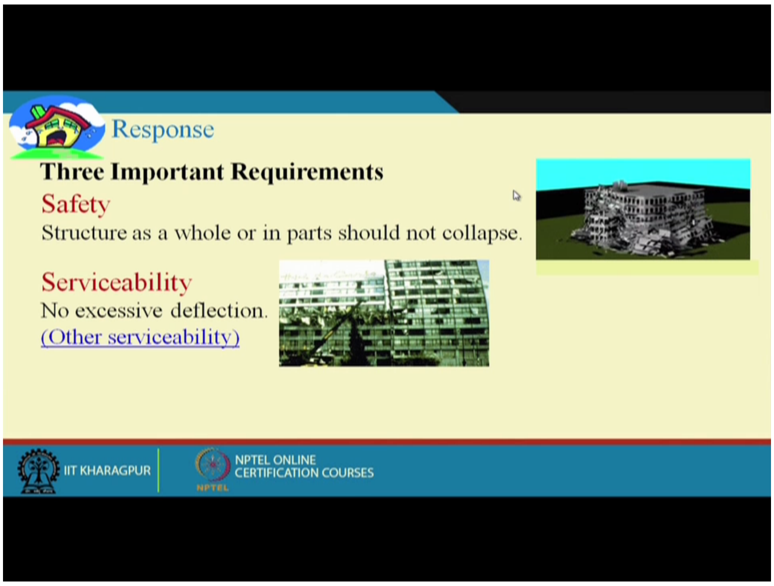

And second requirement isserviceability.Serviceability says that one of the serviceability is the no excessive deflection. The structure may not collapse but the deflection of the structure isvery high. So the is a purpose of the structure is not solved. There are many other serviceability requirement as well.

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For instance, the durability. You said the structure must not have excessive cracking. You see this structure is still safe but because of this cracking the purpose for which the structure was made, it is not being served. Again overall stability of the structure, still the structure is not collapse, but it is not stable. Again the fire structure that is also another serviceability requirements. But in this course we will not considered the durability cracking and all these serviceability requirement.

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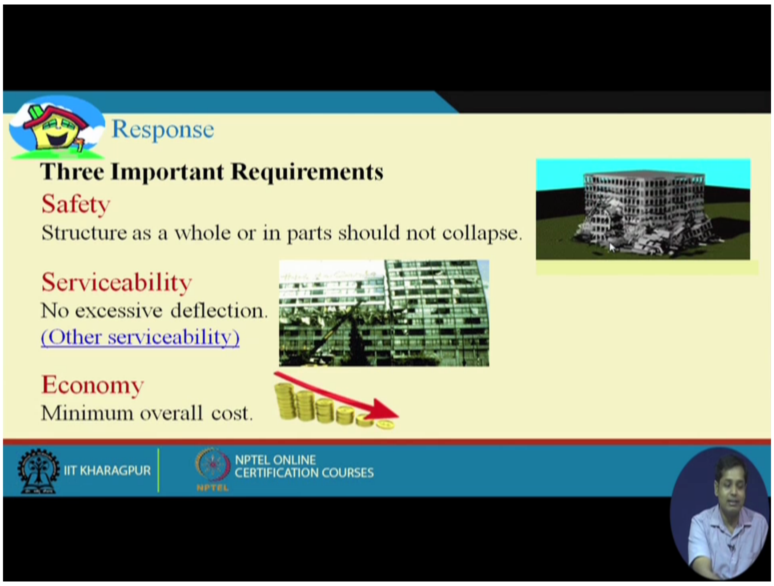

What we will do is, we will concentrate on serviceability related todeflection. And last but not the least, the economy. You want your structure to be economical. So essentiallythe design of the structure is an optimizationwhere we come up a design which is safe and serviceable and economical as well. Now then what are the responses we will be looking for in this course? Two major responses. One is the responses related to safety and responses related to serviceability. Economy is not something weare going to discuss in this course.

Now responses related to safety means what will be the internal forces in structural component. You know, every structural component has certain strength. If the stress or force in the structural component is more than its strength, then the structural component fails. So it is very important to understand what arethe internal forces in structural component? So our first response that we will be determining from structural analysis is internal forces in various structural components. And the second response will bethe deflection. Means the structure has to be serviceable. So deflection is the serviceability criteria that we will be considering in this course. So our response will be internal forces anddeflections.

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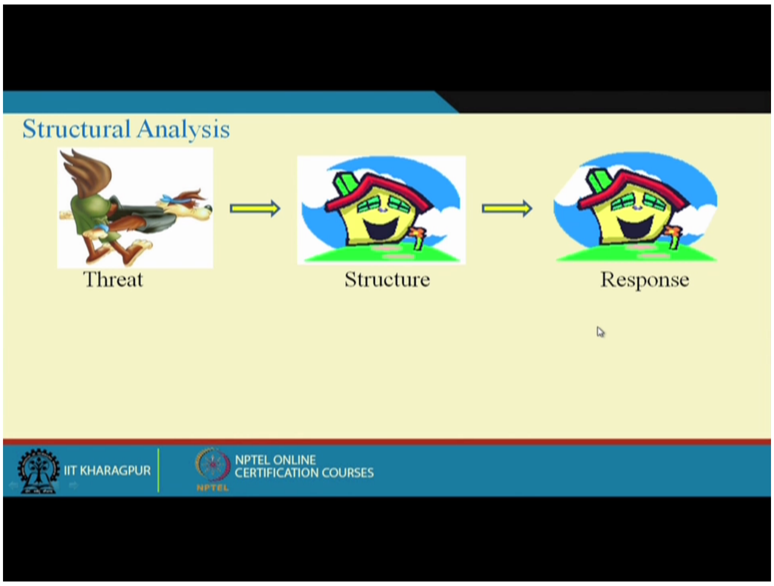

So justquickly summarize. So this is the slide we started with today. And then we discuss the idealization of threat,structure and responses. Let us summarize this. Threat is essentially, you have different kind of threats.

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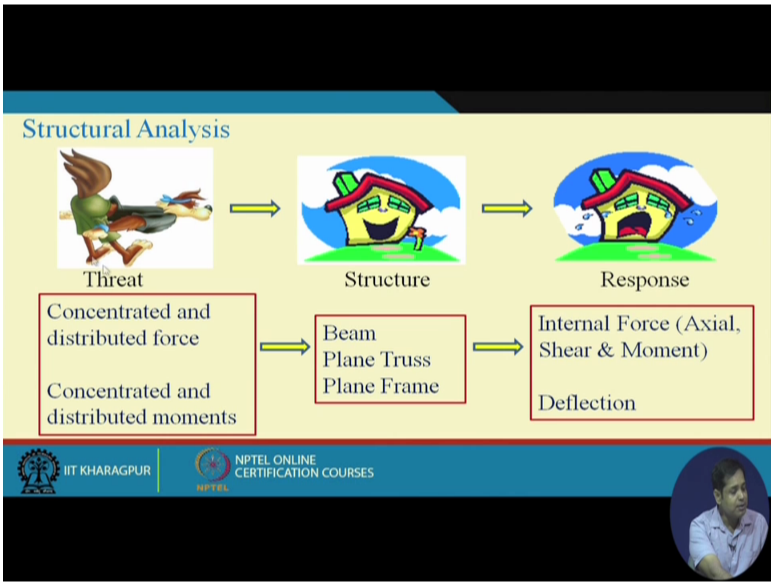

But we have seen that all the threats can be translated into concentrated and distributed forces and moments. So for usthe threat will be concentrated and distributed forces and moment on the structure. The structure is plane truss and plane frame. We will discuss this concept with plane structure but the same concept can be extended to space truss and space frame as well. And thenresponses. Response is two responses. One is related to safety and one is serviceability.The responses will be internal forces. Internal forces could beaxial force, shear force and moment.

We will have more discussion for this in the next class. And then the deflection. And what you will do is,you have already had mechanics course and probably some strength of material solid mechanic course. Where you probably have some idea about bending and shear force in beam. What we will do is, we will review those concepts in first module itself because these are the concepts which are usefulin the rest of the classes.

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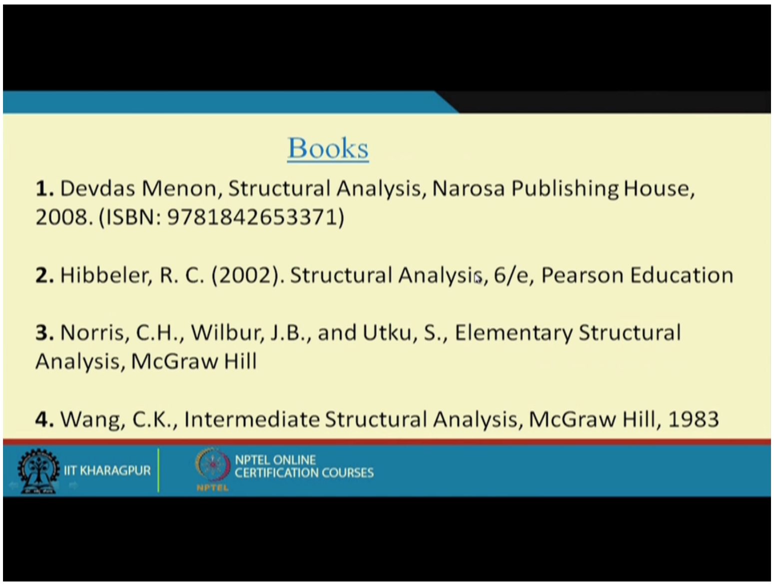

So, but you know, no amount of lecture can compensate reading from books. Reading from books is very-very important. Andyou must have a copy of these books. These are the some reference books that will be considering in this course. And many example that we will solve here will be taken from these books. Either solved or some exercise problems. Okay, then here we stop.

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Next lecture what we will do is, next lecture we will discuss the degrees of freedom, supports and support reactions, static equilibrium equations, determinate and indeterminate structures and we will see how the equilibrium equation can be used to determine support reactions? Okay, see you next class. Thank you.