Structural Analysis 1
ProfessorAmit Shaw
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Lecture 1
Introduction

Hello everyone. Welcome to Structural Analysis 1. This course is being offered as online certification course. An initiative by NPTEL. So let us begin our courseby expressing our thanks to NPTEL and of course to CET IIT Kharagpur formaking the arrangements.Firstlet me introduce myself. My name is Amit Shaw. I am an associate faculty in department of civil engineering IIT Kharagpur. You cannote down my email ID.

Throughout this course or even after that if you have anything to discuss, if you have any confusion need to be clarified, you are most welcome to write to me. But whenever you write to me please make sure that the subject of email you give this.

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It will be easier for me to identify those emails. This course is having around 12 modules. Eachmodulesaround 5 lectures. Each of which 25 to 35 minutes duration. We're going to start first module today. You see I will give you the syllabus of the course, reference books and the notesand other resource material.But since this is the first class, let us try to understand, what is the motivation of this course? Let us try to understand that, what exactly we are going to learn from this course?

And if you look at in your engineering curriculum there are many courses and among these courses, where thiscourse stands. How this course is related to those courses? You see the name of the course isStructure Analysis. So the word structure isnot new to us, right? I mean, onvarious occasions and various contexts we do use this word, structure. For instance we say some time something like themanagement structure of the company is like this.

We do say the social and economic structure of the country is like this. Sometimes we also say that the fabric structure of the textile is like this. So the word structure, we are familiar with, right? And we have used it in various contexts. Now if I see the dictionary meaning of this word, then it says,the arrangement of and relations between the parts or elements of something complex.

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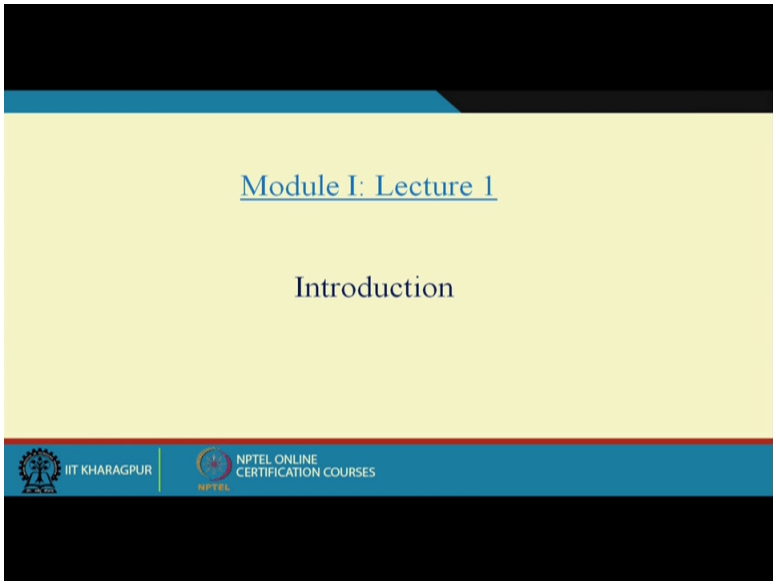

This definition is very general and it includes all the applications of the word structure engineering or non-engineering. But you at from engineering perspective, then probably the second definitionis closer. It says that a building or other object constructed from several parts. So for us structure or whenever we refer to structure, it means a building or other object constructed from several parts. Okay.

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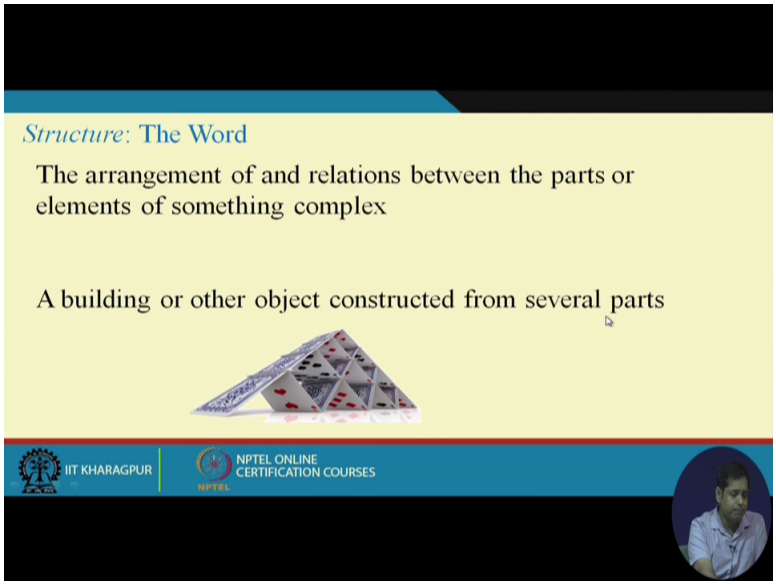

Now as we have defined the word structure, let us see some examples. Because there is a saying that one image is equals to thousand words. So what I am going to do is in next few slides I am going to show yousome examples for structures. Let us start withthe structures from ancient age.

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You know the concept of building structures was known in ancient age as well. Probably the idea of Structure Analysiswas not in the form that we have today. But they knew how to make structure as per their requirement and this is evidence from this figure, you see the first one is around 15000 years old. It is made of mammoth bone structure. And the second one is again 10000 years old and the third one 3600 BC.

And this is one of the some of the oldest freestanding structureand you can Google all these structure and read their history, howthose structures were made?So the concept of the structure was also there during ancient age.

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All wonders of the world, these are very famous structures.I have not given the name of these structures because they don't need any introduction, these structures. You see for any subject learning from history is a very important step. You imagine these structure were built during a time when the technology was not that advanced. The concept of understanding of material was not that advanced and in spite of that they could build these kind of structures.

Soyou must read the history of all these structures. How the design was done? How the construction took place? And definitely those informationwill help you to be a better structural engineer. Nowwellyou see this in the first rowyou see some of the structures which really common in country sideand this down, the second row, the structures which aresome of the well-known famous structures.

And now the structure is a mud hut, what you see in a village that is also a structure. And theworld's tallest building Burj Khalifa that is also a structure. A slum where many small houses, collection of many small-small houses, those are also structures. And this skyline that you can see, that is also structure. The Bamboo Bridge which is again very common in countryside that is also structure. And these kind of bridge is also a structure. So what point I want to make is to tell you the two extreme. And anything falls between this to this, all are structures.

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Wellmany animals are also great engineers too. You see these are the some of the structuresmade by animals. The first one is ant colony, then bird nest, then wild comb structure, then spider web, silk nest by moth and then termite colony. The first one is very interesting because you see there is an optimizationtechnique called ant colony optimization technique and that optimization technique is motivatedfrom ant colony, this kind of structure. If you look around, you can see there are many other structures made by animals. Here just I am showing you some representative figures.

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Well, as we all know nature is the best engineer. Some of the structures again created by the nature. Human skeleton is a great structure and for that matter skeleton of any animal is

structure. The next one isthe fish scales. The body of the fish itself is a great design because the body is made in such a way, the surface of the scale is made in such a way that it helps not only to allowthe fish to swim, it also protect the fish.

And here two important things to be (clea) noted. One is the arrangements of these fish scales. And if you take each fish scale separately and if you look into thestructureof fish scales, that is also very fascinating. Bird wings is a great, again a very fascinated structure created by nature. Then outer cover of snails. Tree root is again very interesting structure. You know the roots are such that it holds the tree to the ground and it also provides stability to the structure.

In fact (ther) now people are trying to make foundation of any structure very similar to theroot structure of a tree, to make it more stable. The anatomy of ant is again very interesting because you see ant can carry much-much more load then their weight. Andthe anatomyof ant actuallyhelps them to do that. And if you study them, people are trying to study the anatomy ofand try to make robot in such a way that it can carry more load. So these are again some few examples of the structure created by the nature. But if you look around you can see severalother examples as well.

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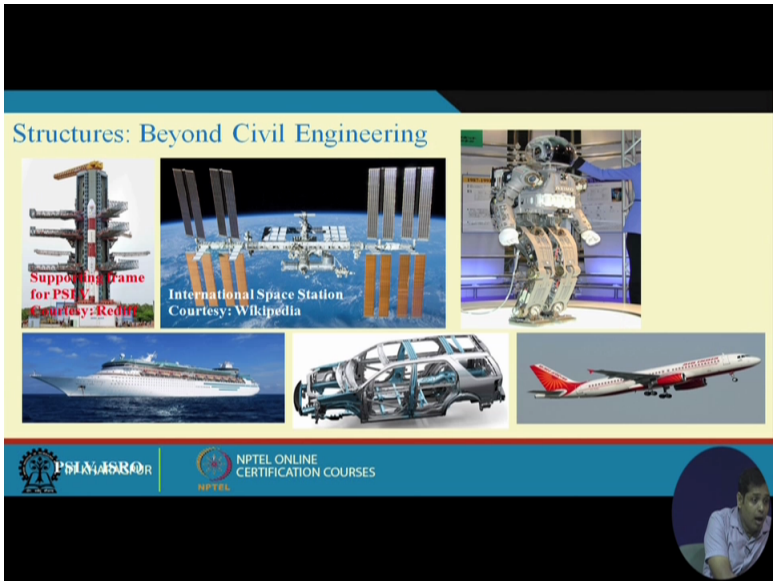

Okay. Some of the structures, you know the structure is not only associated with civil engineering. Yes, civil engineering we do have structure. But when we say structure, it is a very general. It is not only restricted to civil engineering. For instance, here the first one is again very well-known.It is the supporting frame for PSLV. That is also structure.

And this structure, when we have to create this structure, make this structure, we need to consider all the possible loads coming from this launcher. International Space Station, it is also a structure. It is orbiting in loweredorbit. And then robot, yes robot is again, the concept of structure mechanics is very important to make robots. In next lecture we will be studying degrees of freedom and we will see thatthese concepts of degree of freedom and constraint is very important in studying robotics.

Ship is again a structure, these are very well-known. The skeleton of any vehicle if you take, that is also structure. Aero-plane is also a structure. Again these are some examples but there are many moreexamples.

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Well, structure is everywhere you know. Some of the example that you have seen so faris very big. But very small things that we see everyday, they are also structure. And I am trying to collect some of them so that you can relate themto your daily life. For instance say, tripod of a camera is a structure. The see-saw, it is very (co) common in any children park. That is also structure. The jack, lifting jack is a structure. The dish antenna, that is also very common, is a structure.

You all might have use drafterin your first year engineering drawing. That drafter is also structure. The chair you're sitting on and watching this video or the table where the computers are kept,they everything is a structure. If you are sitting on a bench in your classroom, that bench is a structure. Cycle is a structure. Ceiling fan is a structure. Even cricket bat is a

structure. Then the collapsible gate, that is also very common, is a structure. The switch board, there are switch you can see, this switch is also a structure.

Scissor is a structure. Even the cloth hanger that is also a structure. You know the structure is everywhere. Nowbeforewe go further, here we I try to give you some of the examples. Some of thephotographsof structures that are famous and also some of the objects which cannot be associated with civil engineering. But they are also structure. Some of the objects we use in our daily life, when we see every day, they are also structure.

But again there is a saying that figure is demonstration. Demonstration is much better than figure. So I am going to show you some of the objects which are structure and there is a reason behind (obj). Those objects are having (pa) particular shape, particular size, particular feature and those features are not accidental. There is a reason for that and that reason can be explained through structure mechanics.

For instance, let us give you first example is an umbrella. You know you all are familiar with this umbrella. Now if I open this umbrella yousee this mechanism can be explained through structure. These ribs that you can see they are actually different kind of structure.

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So thisyou can explain through the knowledge of structure mechanics. For instancethis is a very fascinating example. You all have seen this coffee cup, right? Now if you see the rib of this coffee cup.I don't know that you can see it properly or not. This (th) it is folded outward. Yes, yes. This is folded out ward.

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This is folded outward. This is also not foraesthetic. There is a structure reason to this. There are two things important. One is it is folded and it is folded outward, not inwards. You go to any coffee shop, take any paper cup and you see this is a common feature that it is always folded outward.Now have you asked yourself, why it is folded outward? It can be explained through mechanic structure.

Now similar example again is aluminium foil. Many of you probably used this aluminium foil to carry food. You see what is interesting, you again see these small vertical ribs here.

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Okay. Again these are not for aesthetic. This provides stiffener. These are actually stiffeners.This make this entire container more rigid. So that you can hold it properly without considerable bending. So this is also from the concept ofstructural mechanics. Similar example, you take this water bottle.

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Water bottle again this vertical stiffenerthat you can see. Theseare again not for aesthetic. Aesthetic is one aspect but there is a structure reason to this. This provides stiffness. Make it more stiff.Now I will tell you one incident that few days back I was visiting one of my colleagues and I saw his 4 years daughter playing with building blocks. These are building blocks, okay?

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And she was making tower with this building blocks. And first she made a tower very slender, very slender tower. And when she tried to hold it and carry at it could not control and itfell down.

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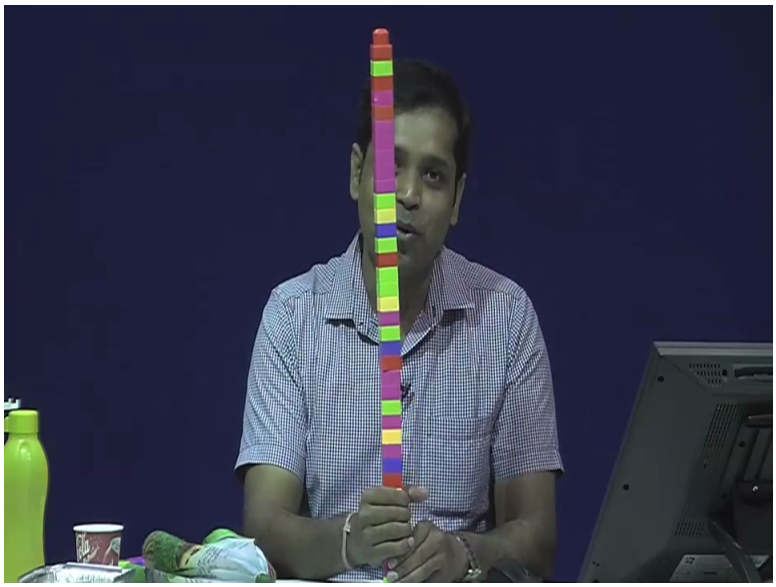

Then next time when she started making the tower once again, she made very small tower. Not that tall, not that slender and she carried it. I asked her, why are youmaking itthat small? Then she told me because if I make it more slender then it may fall again. You see the 4 years daughter could realize that if it is long then it may fall. But why it falls? That can be explained by structural mechanics. Now if I hold it like this it won't fall.

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So when a structure become slender then it becomes unstable.That can be explained through structural mechanics. This again some example. This razor that is also a structure. This you see this is a very common thing you can see on the dining table. This isa spoon holder. The spoon holder is also a structure.

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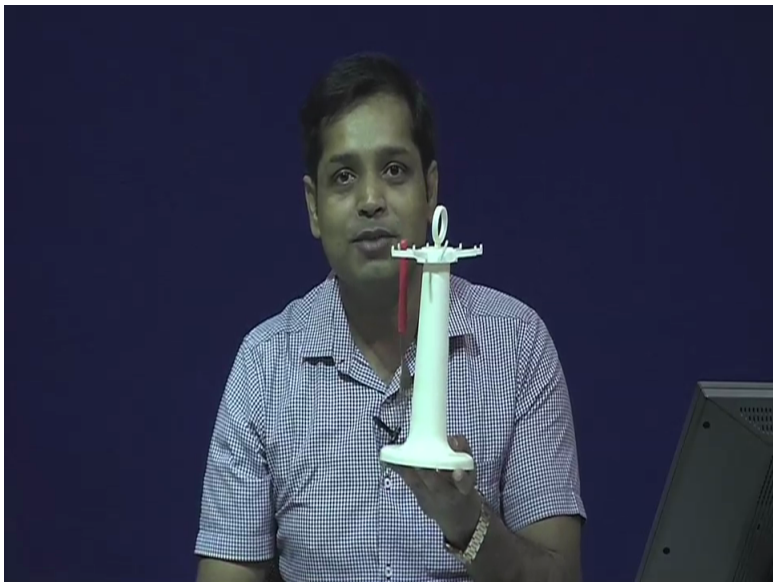

So what point I want to make it here is, we are surrounded by structures. Structure is everywhere. Only thing is we have to look at those object in a different way. Okay, now one of the important role of engineer is to build those structures, okay.

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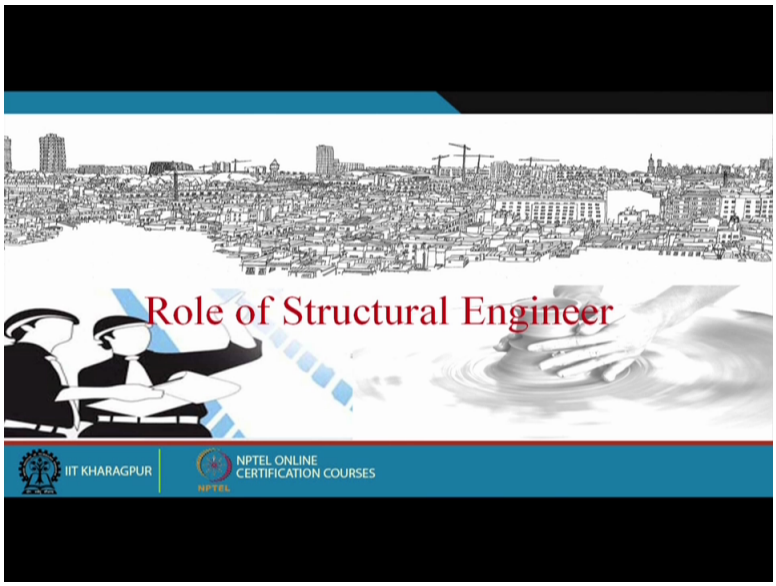

Now you know,building a structure is a process. Means there are many steps to be followed before we actually have the actual structure. And structural analysis is one such step. Now just to put it in more clear way,let me give you illustration. You see, consider this structure.

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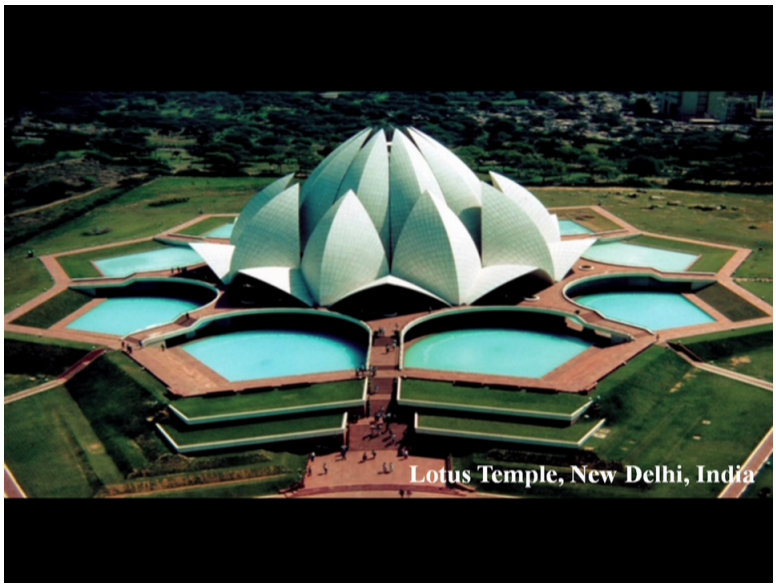

This is Lotus Temple, New Delhi. Again it is a very famous structure. Now suppose this is the final product, final structure which we need to build. Now what we are going to see is, what are the steps that we need to make this structure? Okay.

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Now, these are some steps. It always starts with concept of the structure, planning of the structure. As well as this structure is concerned, it is the architecture of the structure. Now

this is beside another reason why every architect must have some understanding of structural analysis. Now the first is always the concept of the structure, the architecture of the structure. Now once that model is ready, the architecture model is ready, what we need to do is, we need to understand feasibility of that model?

Means how the model, how the structure may respond when it is subjected to actual environment? And that step is analysis. And once the analysis is done then you need to design the structure. Design means,if you look at the structure, if it is a food, then design is a recipe for that food. You need to make the recipe for the structure. So that this structure can be constructed.

Now once the design is done then you need to translate the design in the form of a language that can be understood by the people who will be executing the structure or will be constructing the structure or fabricating the structure, right? And this language is design, this language is drawing. As you might have heard in your engineering drawing course thatdrawing is the language of engineer. Now this drawing goes to the construction site.

And where there are people involved who can read this drawing and execute the structure and finally you have the structure. So these are the steps need to be followed in order to construct it. These are the broad steps. There are some other steps as well, minute steps. But these are the major steps that need to be followed.Now you see it is not particularly for this structure. If you take any object which needs to be constructed or fabricated or manufactured, similar steps need to be followed.

There may be minor variation depending on the structure, but the essence of this steps remains the same.Okay, so this is what we are going to doin this course is this step, the analysis of the structure. We will be having design course in the subsequence semester. I believe you already have engineering drawing. Construction also you will be having in subsequent semester. So this is how you are analysis is related to other subjects that you may have in your engineering curriculum.

Okay, so what we have done so far is we havedefined structure, what is structure? Then we have seen some of the examples and through those examples we realize thatstructure is everywhere. Any small or big, many object can be can be called as structure. And one of the important role of an engineer is to build those structure. And building structure is a process. It needs several steps and structural analysis is one such step.Right?

Then naturally the next question comes is, what is structural analysis? We understand the structural analysis is a step. But what is structural analysis? Now next what we are going to see is what is structural analysis? Now instead of giving you a formal definition of structural analysis, let me tell you or explain structural analysis through a story. Okay.

This is a very old story, maybe more than 150 years old story. It is a very popular story. It is a popular nursery story. AndI am sure that many of you might have read the story when you were kid. But still I am telling you the story because story as such is nothing new in this story probably. Everybody understand that. But still this story will probably help us to look at this subject in a proper perspective. Okay,now the name of the story is three little pigs.

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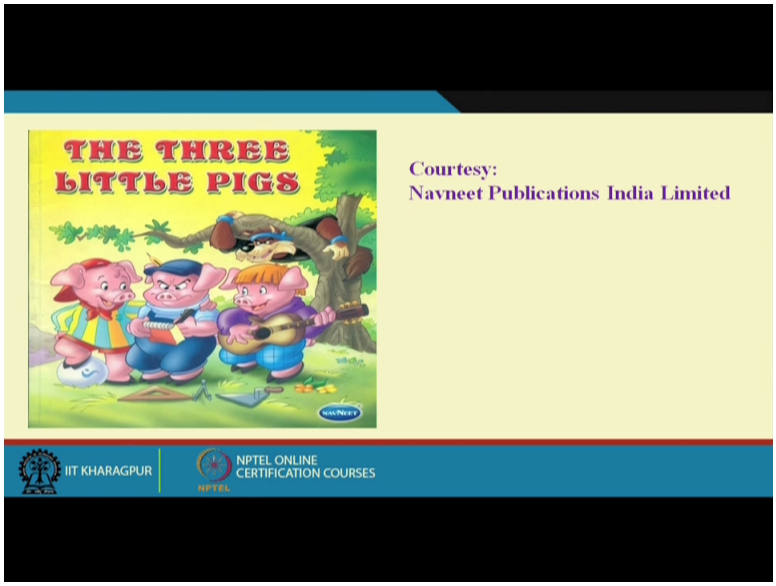

All the photographs I have takenfrom this book. All the scan copy of photographs taken from this book. Okay. The story was like this. There are three brothers. Okay. They used to stay with their mother.

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But when they are grown up they decided to go out and live their own and make their own houses. So theyrequested their mother to allow them to do so. And then mother said, yes fine no problem, you may go ahead and be careful.

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And now once they got the consent from their mother, they are very happy, they are very excited because now they are going to live their life on their own. And they are going to make their house. Nowthen one of these three brothers name is Curly.He was an engineer. Okay. Now hesaid other two brothers that, yes now we are going to make our own house. Let us spend some time to plan those house. Let us make the house strong so that we can protect us

from wildwolfs. But other two brothers were bit lazy. They said, no nothing doing, we will make the house asfast as possible and rest of the time we will play.

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So what the firstbrother did? The first brother collected some straw and made a straw house. Okay. He could make the house very fast and then he would play his guitar. He could play around.

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Now the next brother, he collected some wooden sticks and made his house with wooden sticks. Okay. He could also make the house very fast.

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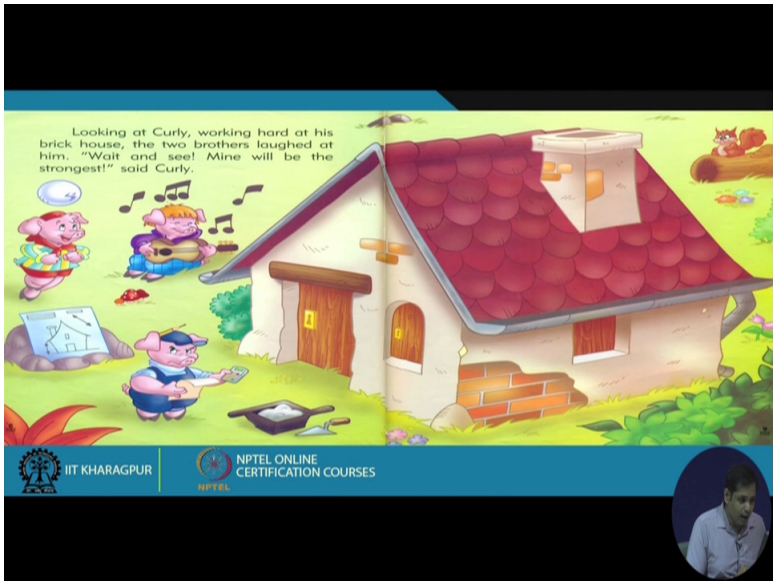

But on the other hand, the curly who was an engineer was busy in planning the house. Okay. And design the house and so he was taking a lot of time to make the house. And the other two brothers were laughing at him. And was telling him unnecessary he was wasting the time in making your house that strong. Our straw house and wood stick house is enough. But Curly did not listen to them and he went ahead with his plan. And finally hemade a housewith bricks and cement. Okay. Now they all made their houses. They are really happy now. They are excited. They were living in their houses. And now one fine morning they were playing and suddenly they saw one wolf coming.

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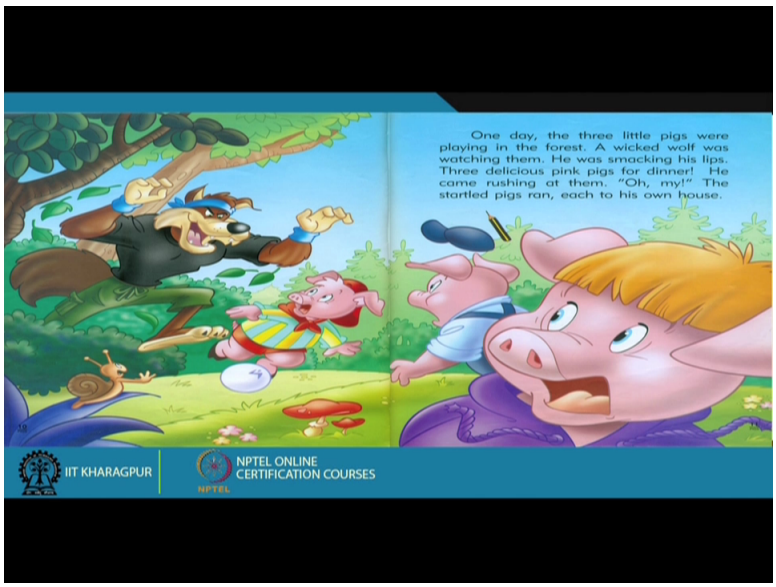

The wolf was watching them. They saw the wolf coming. And then what happened after seeing the wolf, they all got scared and they rushed to their houses.The first one went to his

straw house. The second one to his woodenstick house. And the third one, the Curly engineer, he went to his brickhouse. And the wolf followed them.

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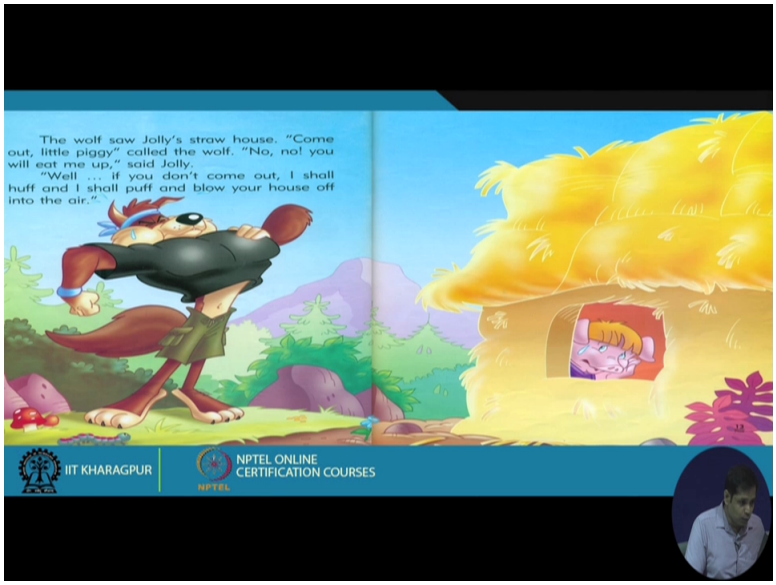

The wolf first followed the first one who was hiding in his straw house. But straw was nothing, it was not strong enough for wolf. So the wolfjust blew it off.

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And then the first brother realized that he is no longer safe there and then he rushed to the other brother who was taking shelter in a wood stick house.

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But again wolf followed him and wood stick house was also not enough, not that strong. So what wolf did is, then wolf blew the wood stick house as well. And again they realized that they are not safe.

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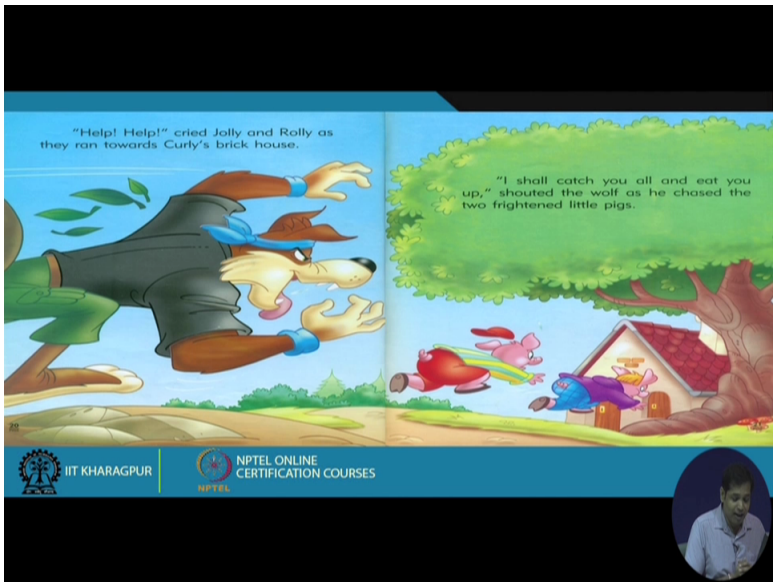

Then they rushed tothe other brother, Curly and took shelter there.

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And now the wolf was very overconfident and the wolf thought that he can blow off this house as well. And then wolf tried hard, but could not because that brick house was very strongas compared to the capacity of the wolf.

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And eventually he could not break the house and left. And thenall the brothers are safe and then finally Curly said to the other two brothers that please don't be lazy next time when you do anything.

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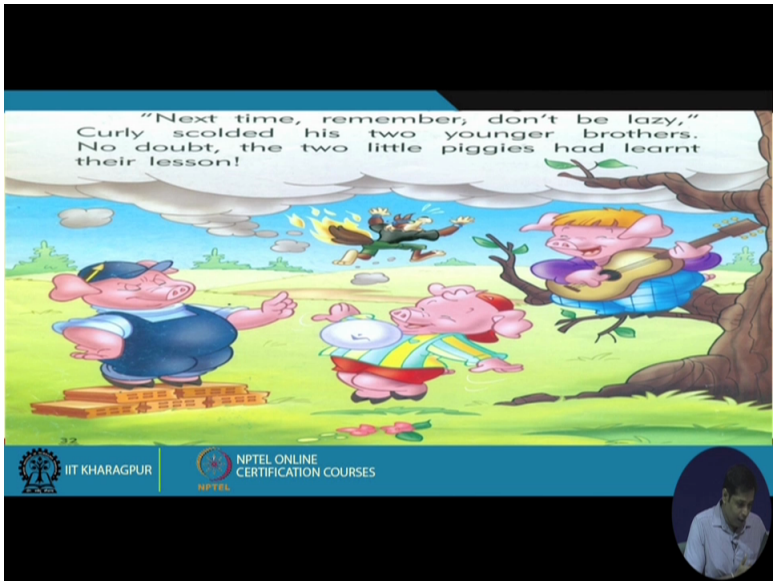

Now the story end here. There are many variants of the story. But the essence remains the same. There are other names of the story as well but I found from prospective of this course. This end is relevant. Now what we learn from the story? You see,oneis very obvious that we should not be very lazy in doing anything. We have to be very careful. Nowanother important thing we will learn is, again in totally you all know probably this, that when we make a house. Okay.

We have to make the house strong, such that it can withstand the attack from potential threat. For instance, in this case, had it not been wolf, had it been a small cat or mouse, then probably straw house or wood stick house would have been enough. And they would have been safe in those houses as well. But since here the threat is wolf, straw house and wood stick house is not enough. We have to make brick house. So the (ess) moral is very natural.

Now what you do is, you replace the house by structure and then replace these three brothers by us engineer and replace the wolf by threat. Okay. So then we can seethat we need to make our structure sufficiently strong such that it can withstand the attack of potential threat. Right? Now how do you know that up rightly? In order to make our house very strong, what we need to understand is, how the structure may respondwhen it is subjected to that threat?

If we find thatthe structure may fail when it is subjected to a particular threat, we can make our structure stronger. So that realization has to be there, isn't it? Understanding has to be there. Now structural analysis gives you that understanding. Structural (anjal) (under)

analysis is a process of understanding how a structure may behave when it is subjected to a particular environment or a particular threat? Now, thenwhat is structural analysis?

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You have a structure which is subjected to a threat and thenwe want to understand what will be the response of the structure. This is Structural Analysis. We will discuss more detail about different kinds of structures, different kinds of responses and different kinds of threats. But this is the Structural Analysis of the structure. Okay. And this flow is for any structure, any response and any threat.

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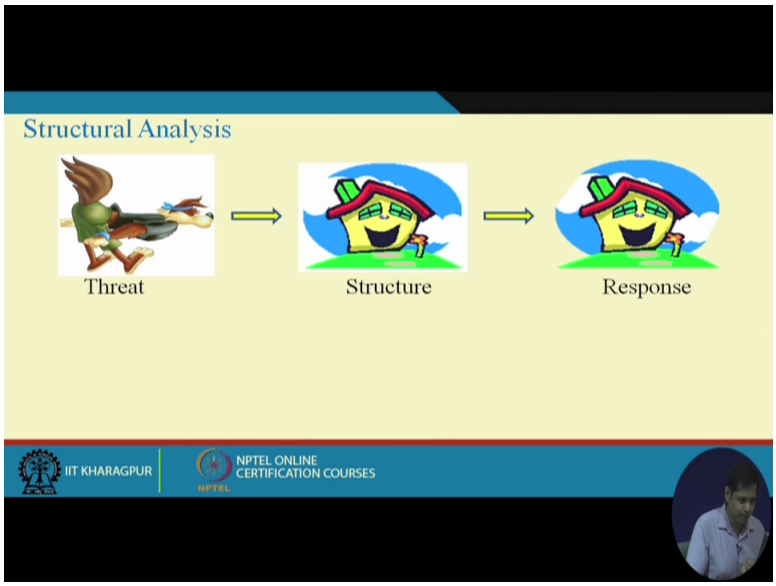

Now if we go from this, means you have a structure which is subjected to some threatand you are looking for a response, this is called forward analysis.

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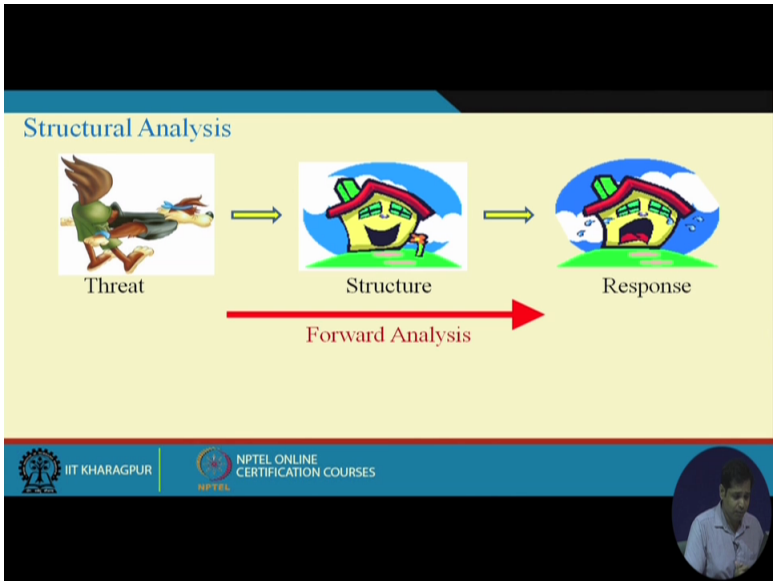

Now there are many instances. For instance, you have an existing structure which is builtmaybe 50 years or 100 years ago. You don't have the design of the structure. All the calculations are not available. Now you need to understandwhat will be the residual life of the structure? How long you can keep this structure as it is? Now here you have this structure, you probably know the response.

But what you want to know is,you want to inversely estimate what will be the strength of the structure or residual life of the structure? Okay. So forward analysis, input is threat and output would be response. And if you go like this, you have the response and you want to understand the properties of the structure,all the potential threat. This flow is called inverse analysis.In the inverse analysis, it is a separate course all together. What we do ininverse analysis, your input will be the response and output will be the threat or output will be the properties of the structure.

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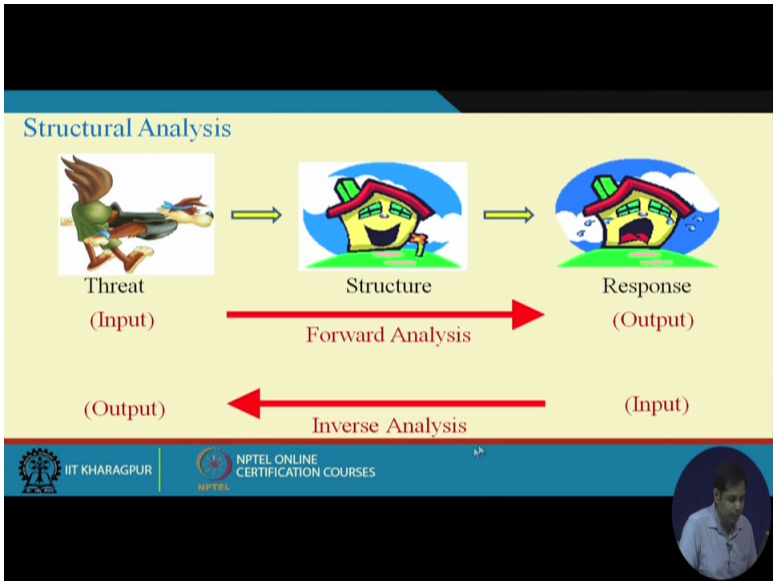

Now but in this course what we will do is, our focus will be on the forward analysis. Soin our case, structure subjected to threat and looking for the response.Now you seenext class we will start from this slide and we will see, what are the different kinds of structures? What are different kinds of structure? What are the responses we will be looking for? What are the different kinds of threats? And how these threat structure and responses can be idealized?

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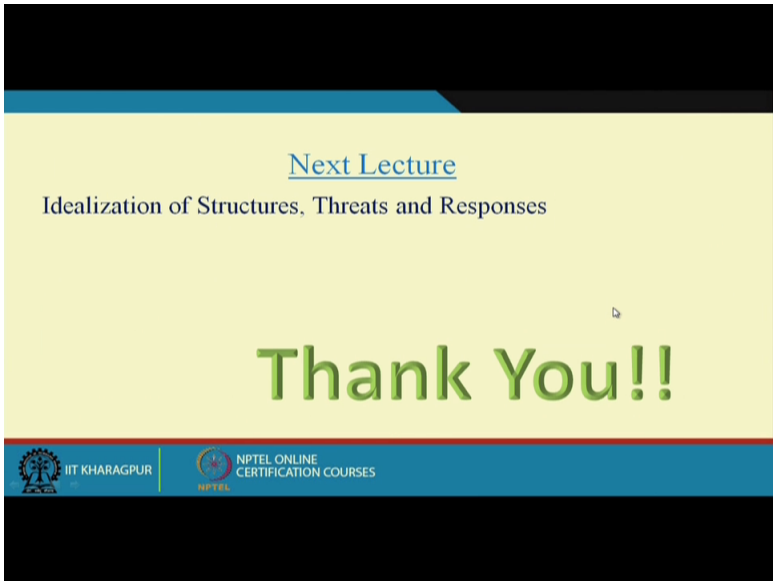

So next lecture will be idealization of the structure, threats and responses.Here we end our first lecture. Okay. Thank you very much.