Introduction to Civil Engineering Profession
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Lecture – 11
Structural Engineering – 2

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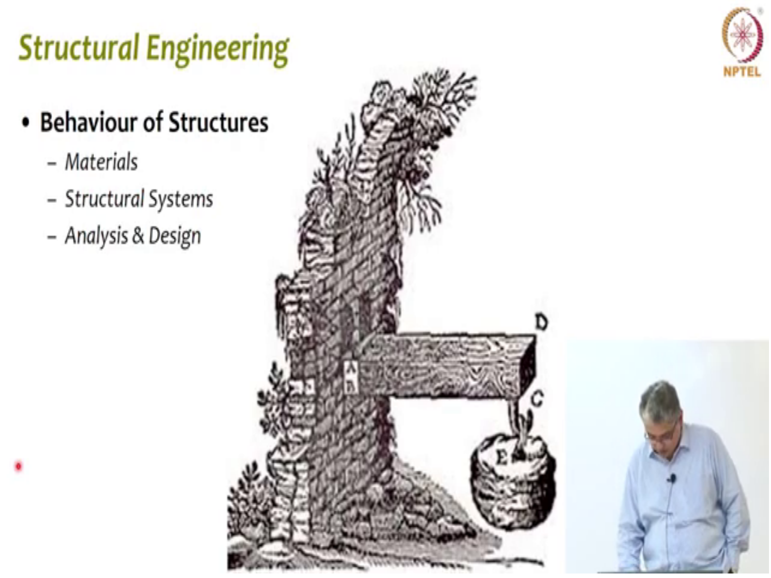

Structural Engineering and as I said I talk about structural engineering. So, my focus is always on structural engineering, but in general any engineering that you do, the focus is on understanding behavior; understanding behaviour of systems that you create and in terms of structural engineering, it is about understanding how a structure that you have created that you have built is going to behave. And for that three or few important things that we need to start understanding are the materials. When we went through those spectrum of structures, the photographs of all those structures, what we are trying to essentially tell you is that look how the construction.

Let us say take the example of a bridge, how it changed starting from 1000 to 2000 years back to what we are doing today and that change that transformation happened because of certain things. One of the key things that contributed to that transformation is materials right. We used to built with stones, masonry, then came concrete, steel right and today, we have more advanced materials and so on so forth. So, this is the very important thing.

And so, we need to understand some basic features about what this materials having, what as engineers what is it that we are looking for in these materials. Then of course, we will very briefly I mean we cannot do justice to all of these in just a 50 minute class, but some very interesting systems and then, we will talk about this basic thing called analysis and design and what is it that request to eventually make a structure.

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So, talking about materials, if you think of civil engineering as such we do lot of these, we used lot of these we starting from simple Thatch to Earth - Mud, Clay; then Stone, Wood. Wood is a very important material that has been used you know very successfully in civil engineering, then of course, Brick, Concrete, Steel and so on so forth.

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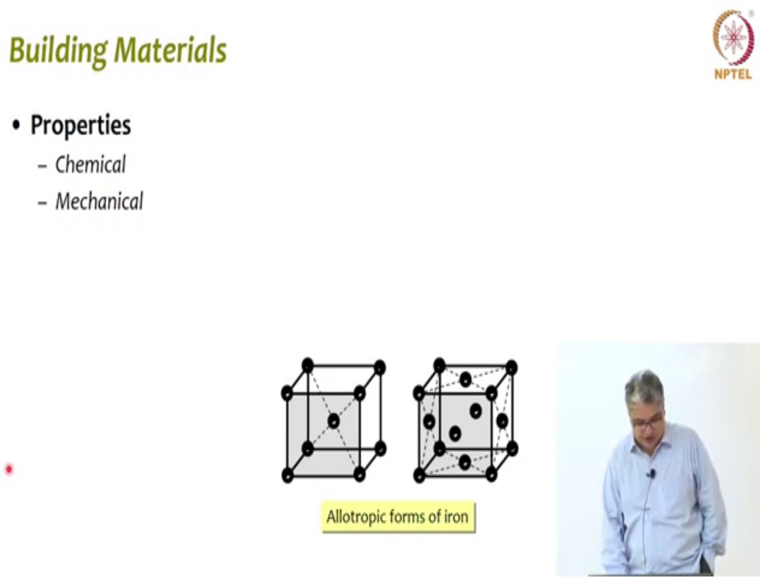

So, I will not go into the details of all these, but effectively what is it that we are looking for when we talk about materials, we talk about we are looking forward to understanding some basic properties. And the two fundamental things that we are looking for is chemical and mechanical properties of this. So, what do we mean by that? I mean how is that manufactured, if it is not a natural material a manmade material; what consequence are to be added to make that material is the first thing and then what properties help us actually create structures out of those materials.

So, chemical properties are very important. For instance what you are seeing is its steel is a very common material today we see right and that steel is made of starting from iron ore. But then, it has to be processed and then made into a form which we today can use in our construction and you see two different allotropic forms of iron which give certain basic properties to the steel, I will not go in to the details of it.

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But so, chemical properties are important, similarly cement and other materials that we are using; how do you what is the composition of different ingredients that gives a its characteristics. But talking about mechanical properties, again there are whole lost other mechanical properties which are the important for different cases. But the fundamental things that you must know about at this stage is what is called the Modulus of elasticity, Poisson's ratio which is nothing new. All of you have learnt about it in your physics and then, we talk about Strength capacity and Deformation capacity.

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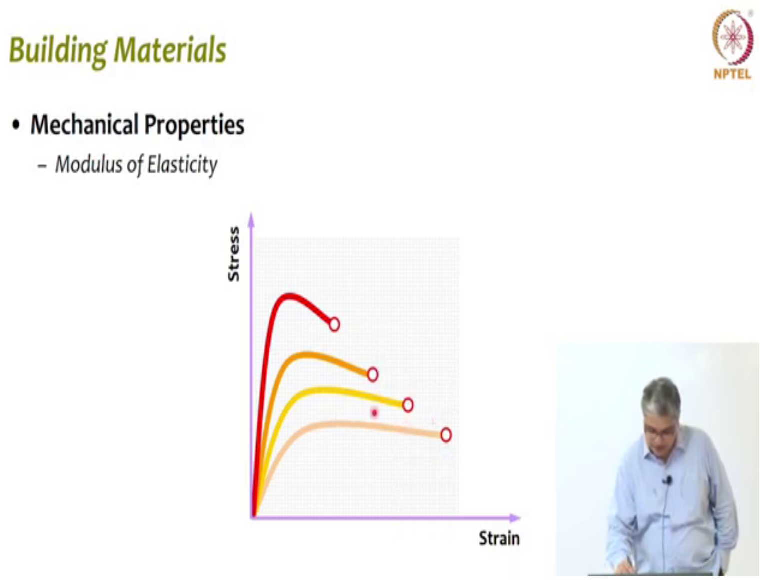

Let us see what this is. So, if you start with a material the first thing that we talk about is its stress strain curve right. All of you are familiar with stress strain curve from your school days. So, just to give an idea, I am drawing some stress strain curves, it does not matter what material, but just look at the nature of it. So, typically, what you will see is that as we start initially, there is a more or less linear elastic portion and then, it may touches a maxima in terms of the stress and then it moves and then, material moved by different deform or strain by different amounts. So, we can have things like that this.

So, modulus is this initial slope. So, a slope between stress strain curve. This initial slope is what is called the modulus of elasticity. So obviously, we are looking at different materials having different modulus of elasticity. For example, if we talk about steel since I started talking about steel, if you take steel the modulus of elasticity of all steels varies more or less between 200 to 205 to 210 GPa. What is GPa? Giga Pascal. Pascal you know Newton per meter square right.

So, similarly you can go and find if you look at different materials, you will see different materials have different modulus. Similarly, different materials will have different Poisson's ratio also. But more than that as structural engineers, we will be looking very closely at this value, the maximum stress that the material can handle and the maximum strain that a material can handle right.

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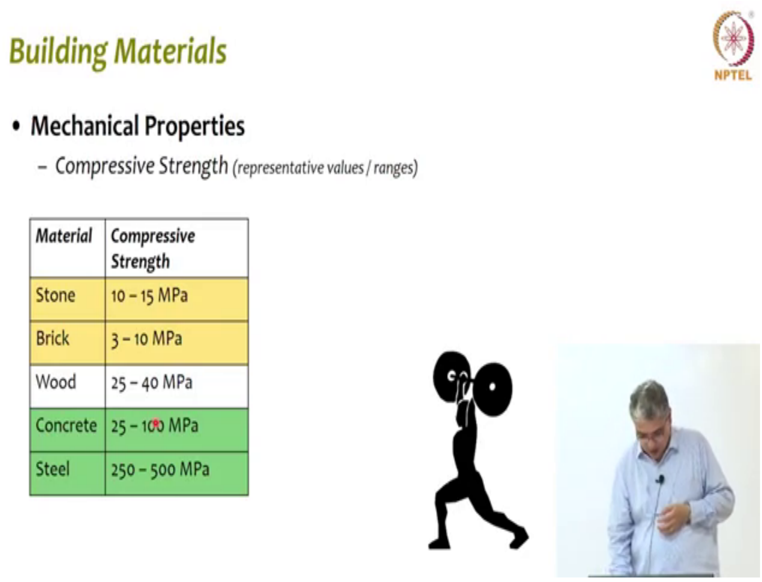

So, let us look at it. Just to give you these numbers are not you know a fixed numbers these are ballpark numbers approximate values just to give you an idea. So, when you talk about compressive, so, what is compressive? I have a system and I apply load. So, it gets compressed. So, the word comes from that. So, if you compress something; how much stress can it take? And what is stress? Load per unit area, from your physics days you know.

So, typically if you see here the masonry if the brick, it take some amount of compression. Stone; certain forms of stone, not all rocks, but certain forms can take something like this. Wood in a certain, but when used in a certain fashion will be able to take so much, but then we had a quantum jump. So, we have been using these for millennia; thousands even hundreds of years right and suddenly, only in the last century, we jumped from this to this. And so, you can see suddenly, there is a jump and then there is another jump here, if you see.

So, if we suddenly in the last 100 years civil engineering or structural engineering took a quantum jump in terms of how much load per unit area the material and therefore, the structure can take right. It helps us to suddenly expand the scale of our engineering. This is compressive.

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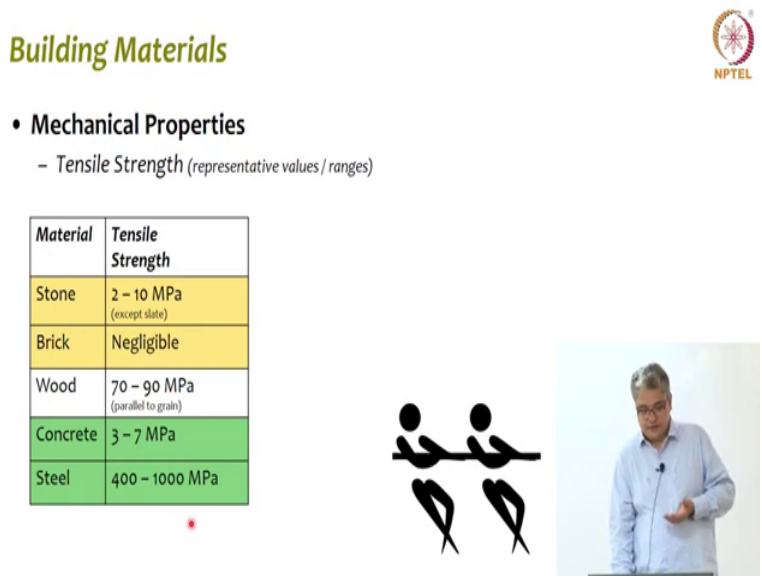

Material	Tensile Strength
Stone	2 – 10 MPa (except slate)
Brick	Negligible
Wood	70 – 90 MPa (parallel to grain)
Concrete	3 – 7 MPa
Steel	400 – 1000 MPa

If you look at tensile; now look at this. If you see brick masonry and all, it is very negligible and this is why we will see why in the past we had certain types of structures and today we have different forms of structures. Stone not much of a tensile strength; wood when used in a certain manner had this; but then concrete also look at this in terms of tensile strength; but steel as a material can really take lot of tensile strength.

So, we see the there is a basic difference in the material properties and we will keep this in mind that certain materials can take compression to an extent, but cannot take tension and certain materials can take both are good in carrying both tension and compression right. And this concept if we this if we understand, we will understand why we are building certain structures today using certain materials which we were not able to do earlier.

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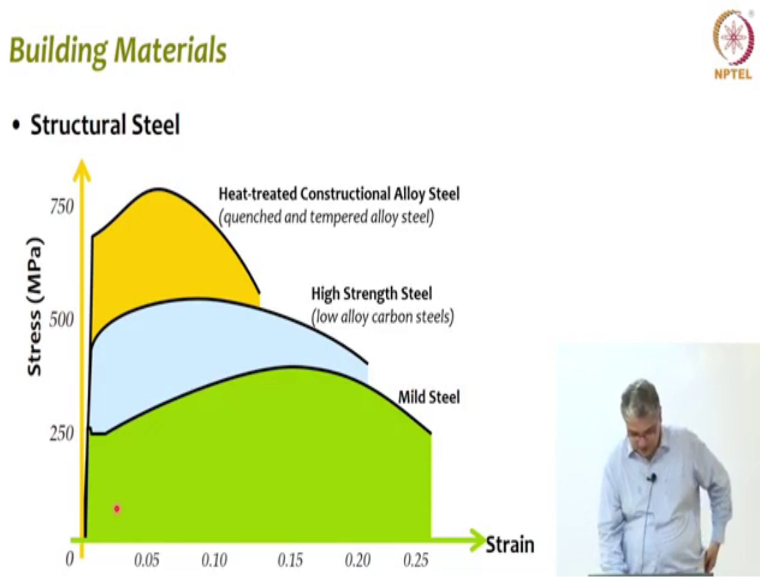

For example, if we talk about mild steel which has a certain mild percentage of carbon added to it and that is where the name comes from mild steel. You can have low carbon steel, mild carbon steel, moderate carbon steel or high carbon steel right. Typically, stress strain curve looks something like this. So, here you see that the strength is about 250 and typical concrete strength, we saw about 25, 30, 40. Today, we are making 100, 120 mPa. So, the strength is about one-third to half right and here if you see strain, I did not talk about the strain. The here it goes to about 0.25; that means, 25 percent elongation. Concrete, the strain will be something like 0.0025 0.0035; 100th of this.

So, if I take a material steel versus concrete, load wise concrete will take about half to one-third and deformation wise, it can deform 100th of what a steel can deform right. And if we talk about masonry, well it cannot even deform cannot even take what concrete takes. So, that is where we have to understand why different structures are being built with different materials. So, my what I will urge you to do is on this take this graph, on this you draw the you know stress strain curve of what concrete would be; what stress strain curve of what wood would be; steel stone would be; masonry would be? Now, this behaviour again changes; we saw in both tension and compression, they are not symmetry right.

So, your exercise would be to go back and take a sheet of graph paper and draw all these to scale and see how materials are very different in terms of their behavior. Same steel we can change the chemical composition or manufacturing process and create different strengths right. And one classic example that you see today is that we have steel which we know or iron which we know rusts and then we have stainless steel. So, we do something, we change the chemical composition a little bit so that this whole process we are able to create what is called stainless steel. So, go and find out what is it that is the added to make stainless steel.

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So, very interesting exercise right. So, basically what we are what I am trying to impress upon you is that material or availability of material is a very important role in deciding whether we are we will be able to build this tall structures, long structures that we see today we are eager to build right.

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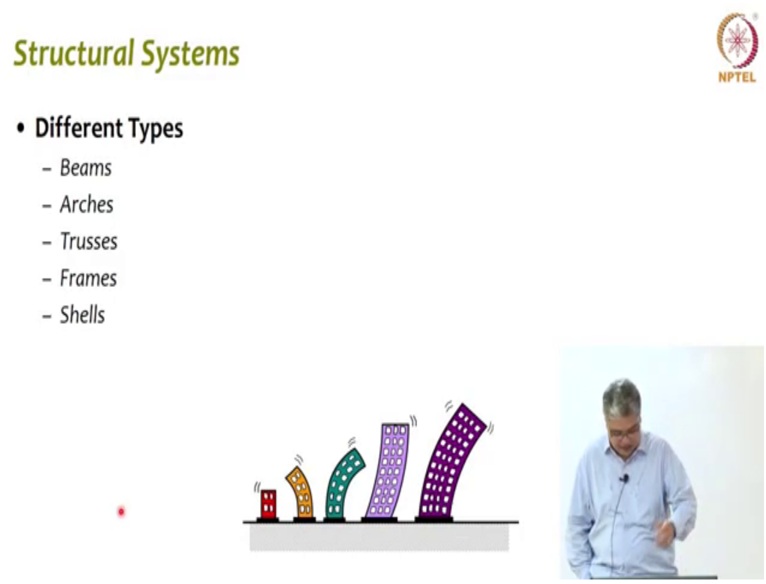

Talking of structural systems, there are different types of systems. Since starting with simple beams; we will see examples of simple beams; we will see arches, then we have trusses, frames, shells and so on so forth.

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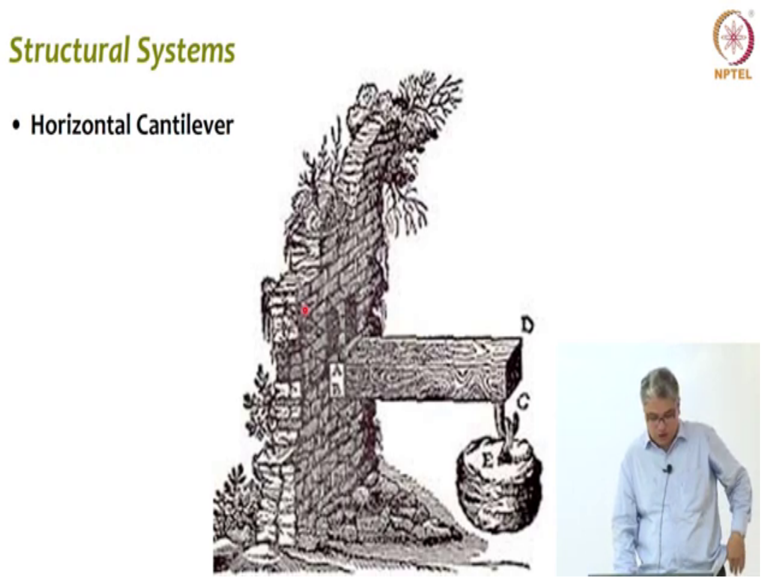

What you see here is a very simple example. What you see here is what is called a cantilever. What is Cantilever? It is like my arm which is projecting out from my body and imagine I am holding a load right that load is hanging. So, this weight is acting on my arm and something happens is happening to my arm. So, here is the cantilever; here is the load; here is it support and we need to understand what is happening to the system right.

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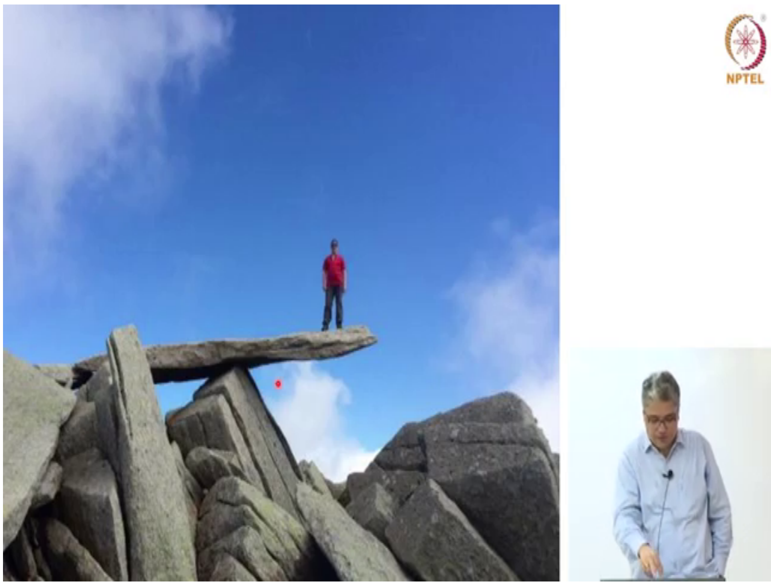

So, here you see the cantilever right. This is the cantilever portion, here is the load and something is happening here. So, I said our focus is to understand, would not just see and say oh beautiful picture, that is what we will do. We will appreciate all these beautiful photographs; but as structural engineer, we will try to understand what is actually happening within the system.

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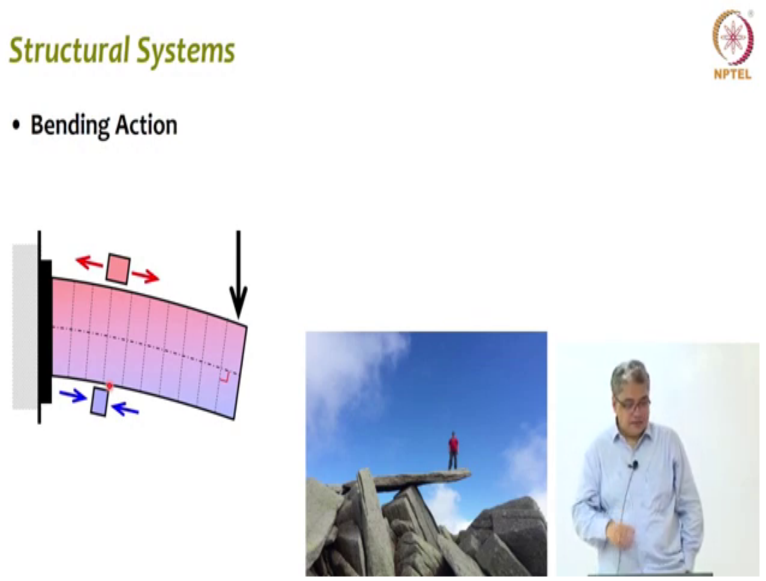

So, let us see. I am sure you will agree that if I go on increasing this load, my hand will start doing this. So, I can do one thing I can simply bend about this hinge or if I put it fixed, my hand will be strength and this you can do with the simple example like it you have an eraser, you tied bended you know putting a load on side hold it and you will see it will bend. So, when it bends, when it bends, you will see on one side, this side is getting stretched; whereas, the bottom side you will see it is getting compressed right.

So, when we say stretching, it is nothing but under tension and when I say compressing, it is under compression. So, now, think of what is the material it is made up of. If you have a material which is very weak in taking tension, what will happen? That material will fail, will break off and you will not have that system, you will not have that cantilever working. So, for this to work, two things has to happen; one the amount of stress, tensile stress or compressive stress must be less than the capacity of the material and the material the higher the capacity, the material the more the load that we can apply on the system right. It is simple in that sense.

So, we need material which is able to carry this tensile force as well as this compressive force. Now, if we have a material which cannot take any tension, then can you make a cantilever out of it? No; simple thing is that. That was a horizontal cantilever.

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All the structures that you see standing today, if you can just turn the reference instead of having your x y axis like this, put it like up turn it 90 degree and you see all these structures I see as vertical cantilevers, who is having some axial you know some load acting along the direction of gravity and some load coming on from the sides like wind load, wind pressure right and things like that. So, these are all vertical cantilevers. So, us when you talk when you now next time when you look at a building that building is nothing as simple as this or that rubber eraser which you are bending.

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So, as simple as that; only thing is scale is different, then actions on it are different. And we will have certain internal details to understand how that building can be designed and constructed. In nature, there are hundreds of examples of beautiful structural forms and structural systems. The simplest is a branch which is again nothing but a cantilever right. But if you watch carefully, you will see the branch is little thicker, wider, bigger when where its springs from and as it moves along, it becomes thinner and that is obvious because of you have learned some movement in your physics.

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So, if I put a load here, movement is only increasing and that is why that is the natural form which helps and that taking cue from nature, we have build beautiful structures using that same concept. This is the what is this? The Tower bridge right and if you see here, this is the deck. Its two parts of the deck which open up to lead these move though. And if you see here, so, now, it is neither horizontal one nor a vertical one; but in a some inclined position does not matter. But that is a cantilever which is supporting its load and you see this end is wider than this (Refer Time: 16:45) end. It is so, natural right; it is so natural.

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What you see here is construction of two very famous bridges and you see that these are the cantilever portions projecting out from this support. This is the twin one. So, two cantilevers projecting on from both sides. So, basically, they are supporting each other; balancing each other right. If I put one load on this side and nothing here, I will be tilting, but here slowly they are projecting on both sides and they are balancing each other right. Such beautiful concept, very high and engineering done using simple principles.

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And; obviously, we have this and we have this; beautiful right.

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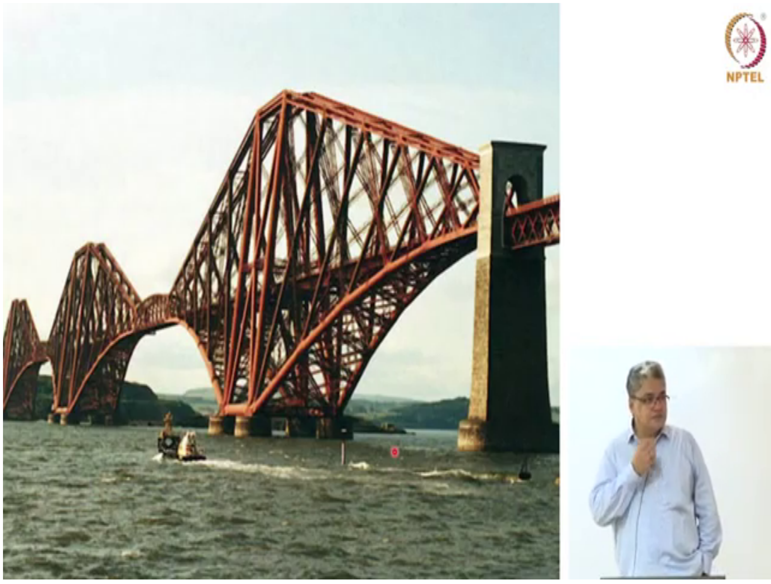

So, here you see a cantilever, here you see a cantilever, here is a cantilever and so, but watch this. This little fellow, what is that?

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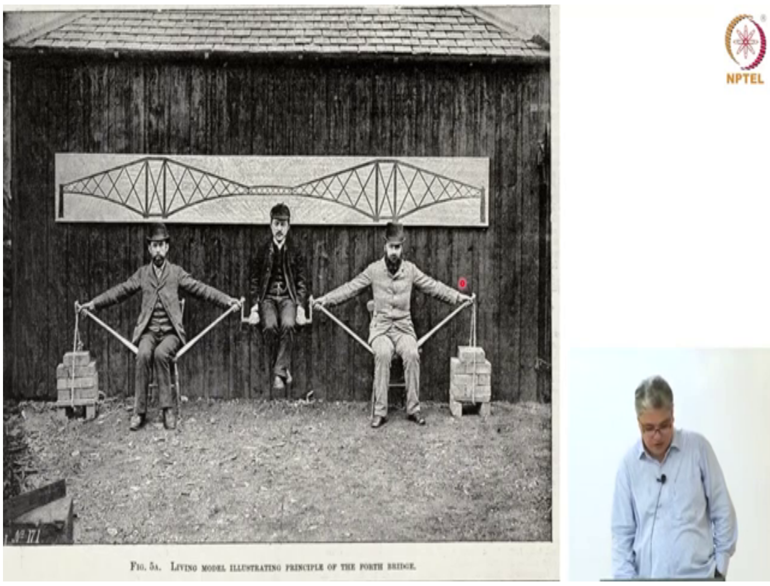

That portion, if you see is supported on this cantilever and this cantilever and it is actually a suspended one which is another beautiful form of system which is the simply supported system. So, this is a famous photograph, you will find everywhere and if you I will give you the links of all these photographs which are available on the internet.

So, you see this, this man is sitting on this which is the load on this part which is suspended from here. So, this is the cantilever which is this portion; here is this and this is the portion. So, if I look at this, this one this hand is in tension this strut, this is in compression and this man is causing bending of this. This is the simply supported span and these are the counterweights which are acting here, you know basically the other spans.

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So, beautiful concept; high end engineering done with basic understanding and that little portion in the middle which is the simply supported is actually the most common system that you will find right. What you see here is a bridge, but this bridge is made up of this individual segments. So, here is one segment which is followed by another segment, another segment and so on so forth. So, these are called the Piers which are supporting. So, one pier is supporting this left end of this segment and the right end of this segment and each of these are simply supported on these pier tops and this is what we called as simply supported beam; so, simple.

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The best example that we have seen for so many thousands of years; look at this, look at this bridging between two supports bridging the gap between two supports. The simplest form of structure that we have been using for ages now. And this essentially is what is called as simply supported beam. As you go to I will you know urge you go to the main our main gate, the out gate and you see the flyover right and there if you see you will see exactly those kind of things is deck in parts. So, rested on these piers right.

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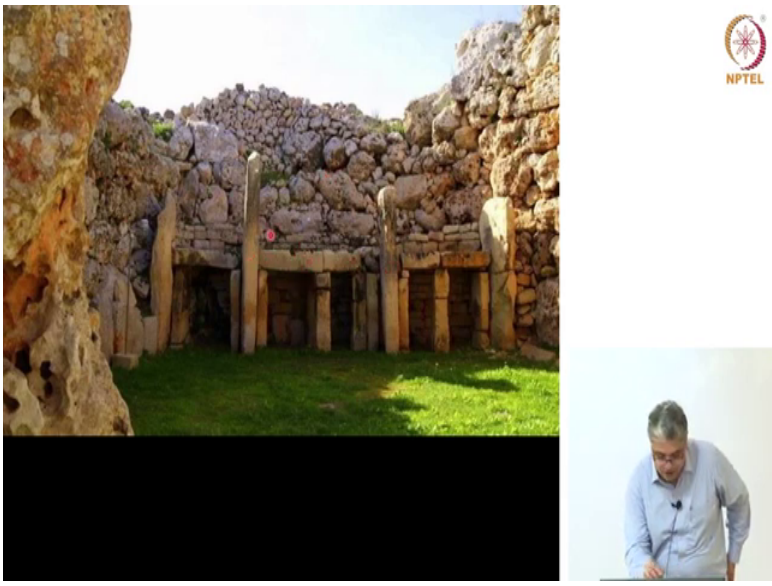

Go and have a look at it. And we have used this for thousands of years right, the famous caves of Malta, you will see this. You can see this stones. The simply supported beams supporting all these load and it is there.

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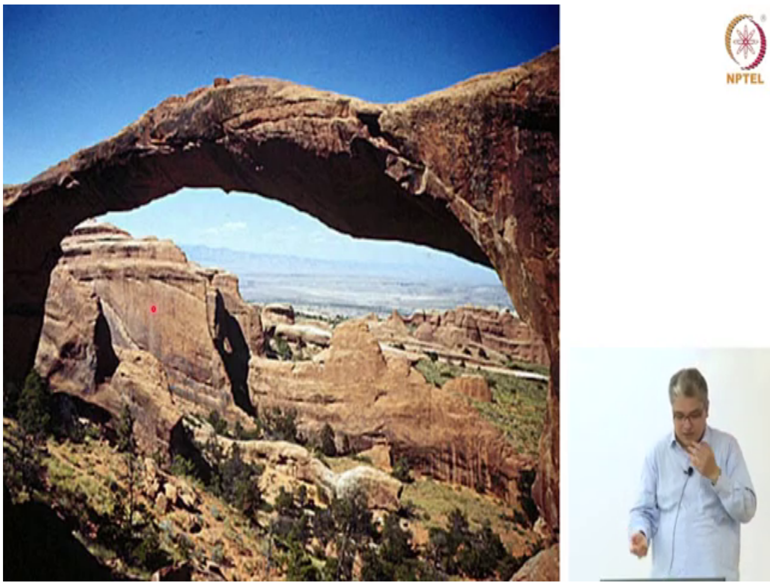

But this beams either this way or as a cantilever bends and bending means we saw tension compression. What if we have a material which cannot take tension? We cannot use that right. So, naturally we have seen these kind forms where it is not this way, but rather this way, what it does is this is what we called a arch.

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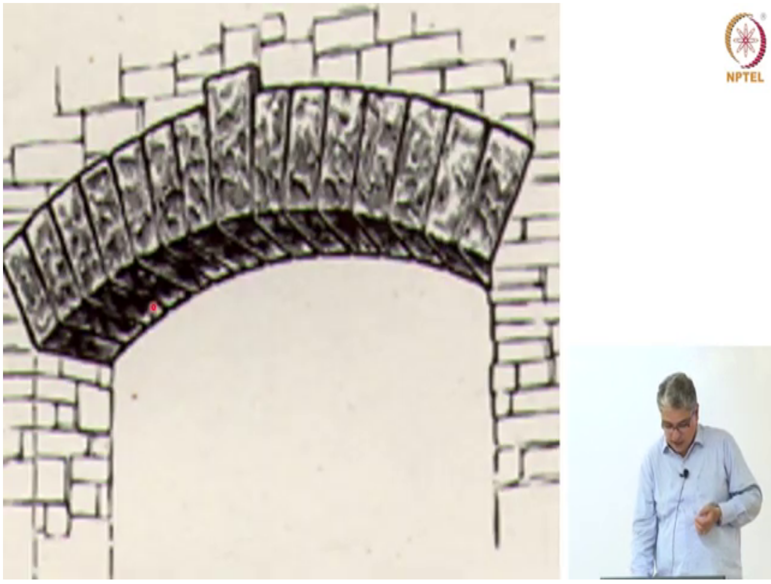

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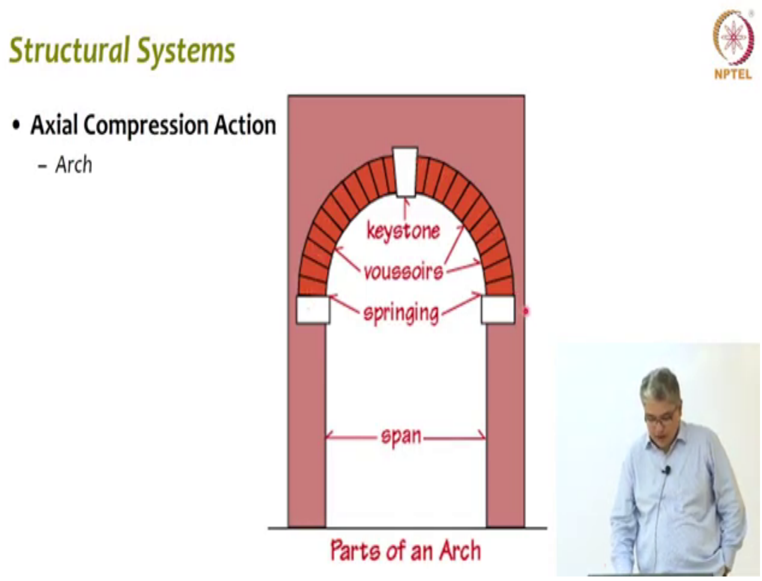

So, here you have a system, where the load flows directly to the supports through axial action. It does not cause bending as such.

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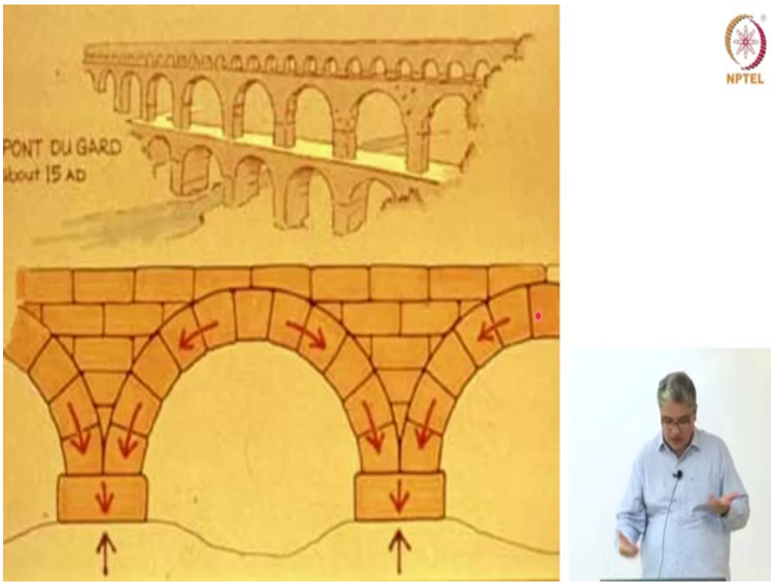

So, suddenly, we find that with this kind of a form we can even use materials which cannot take tension, which does not have tensile capacity.

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And no wonder, we built all these beautiful structures right. So, if you remember the earlier bridges were mostly this arch type bridges. They were not the simply supported bridges of the cantilever bridges. They are modern, but the old bridges are all arch type because they use materials which could means which were able to carry compression and this form enabled that kind of a system.

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Of course, to renovate it we had concrete we build stone you know so many arches and then 18 century when iron; this is the this is one of the earliest iron bridges, but we continued with that form right.

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18th century bridge and then, more recent concrete bridges. So, what you see is I want you to understand this systems. So, here is the deck which supports all the traffic and the load and that deck is supported on this arch beautiful arch, so be effectively all the load is transferred on this and this is what is supporting the taking all the load and when the load comes here, the load simply flows to the supports, simply flows to the supports right and so, the deck is supported.

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We took it one step further. So, what you see here? We see arch, but then the road is the deck is going through the arch. So, we have two different portions. This portion you see the deck is suspended from the arch; whereas, this portion it is supported on the arch. So, you can hold something support from bottom like this or you can hang it from top. So, we combined. Now, this is where creativity comes in structural engineering. You take a you have an idea you mix and match with other ideas and create new things and that is the beauty of structural engineering right.

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So, this kind of a thing where you can suspend a deck from a system is what we know today as the famous suspension bridges right. This is the Golden Gate Bridge. So, we talk about suspension bridges today. It is the beautiful concept. The whole deck, whole bridge so to speak is suspended from these cables and I did not add cable. We have beams, trusses, arches so far; cable is the another structural system. So, the whole thing is suspended from these cables which are supported on these huge massive supports.

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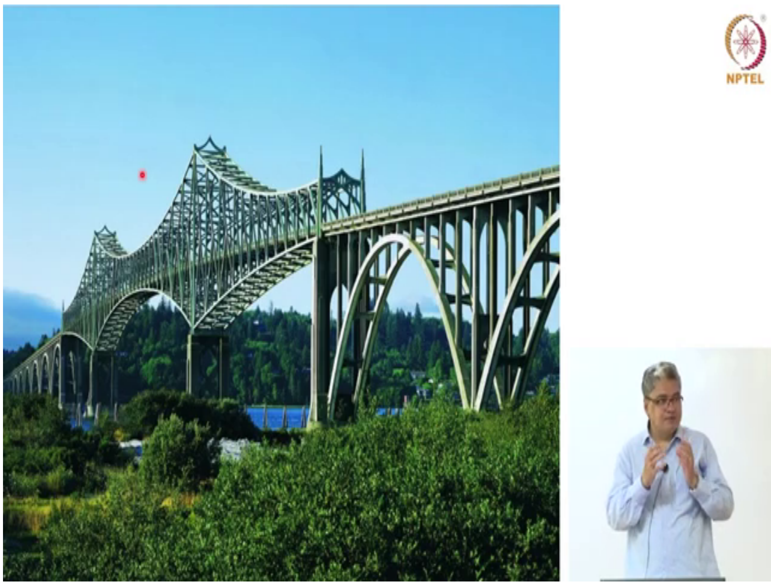

So, as I said we mix and match and we create new situations. So, you have a truss bridge and you have arches here, you have a all these all the systems put together and you create iconic you know structures create beautiful structures out of them starting with simple idea.

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Talking of simple structures, you can create a simple shade like this and of course, what you see here going like this are bracings for support for stability of the system and a truss systems are very you know useful in creating such bracings. What you see is this bracings can be massive depending on what you are talking about. So, here you see a braced kind of a eccentric system.

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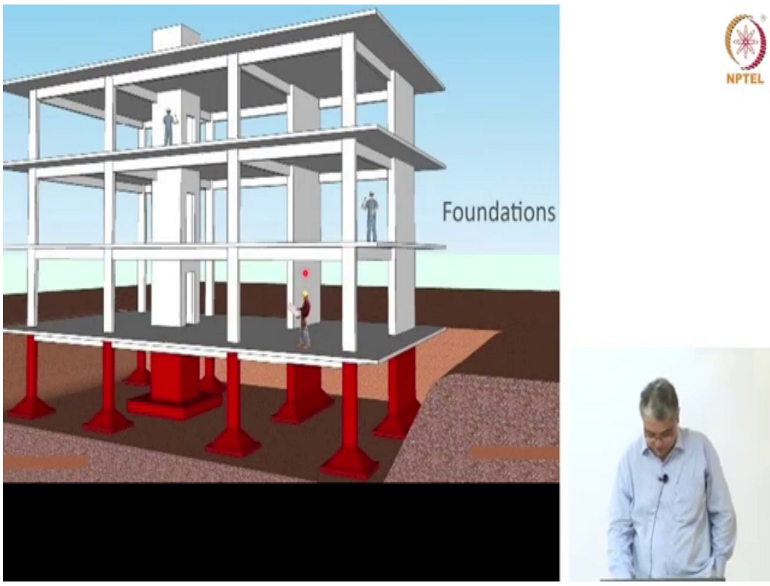

But more common system that at least in your undergraduate days, you will have to learn and understand is how we create this simple structures like buildings today right. So, if you look at a building system, here you have the foundation; then, the what goes in a vertical direction is what is called a column and then you have this horizontal members which are connecting each of these columns called beams and then of course, you have the flat surface on top of which the floor, we call is what is called a slab right.

So, when I am standing here or a person is standing here, his load goes through the slab in to these horizontal members called beams which then transfer it to this vertical members called columns and they transfer it back to the foundation and finally, to the soil. So, at least this simple thing is what we will try and teach you and how to design how to make this structure happen. In this, we also see another system which is called these are like walls, this is a much bigger wider than these members. So, these are walls. So, you can have walls and frame action all going together and so on so forth.

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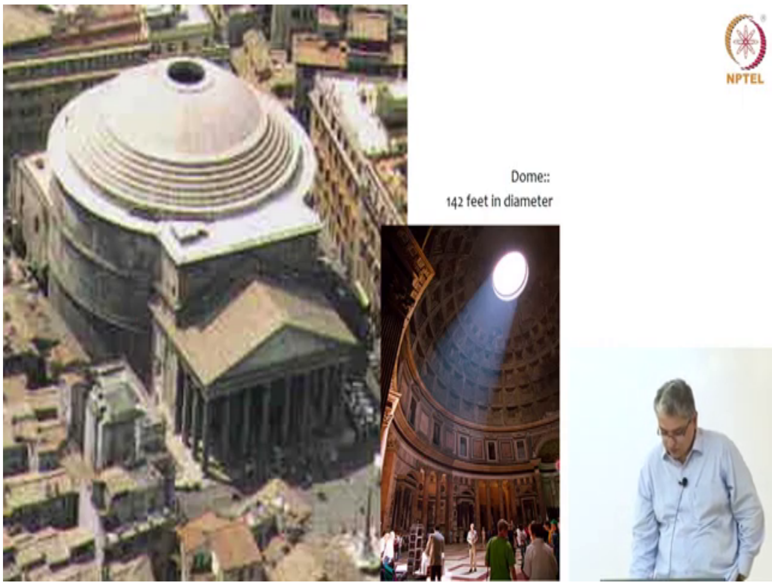

But going back, this flat surface the flat roof or the flat floor that you saw, you will see if you go to your hostels and where you have large spaces; small rooms you have a flat roof. But if you go to a very large hall you will see different. That slab, that roof is not just a flat system, but something more has to happen. Sometimes you will find ribs and even if it has to be even more; then obviously, we see that these kinds of systems do not work. We go back to that arch action, but in three dimension and this is what we created as domes. So, a famous dome which is 142 meter. So, again all the load directly flows to this support, this wall and from inside you see this and this is what we created thousands of years back.

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60s, we created a stadium with a cover and you can see from the top, the system looks very similar, but look at the number now; staggering number right and this was possible with slight modification of the system. This is actually this is a inside view.

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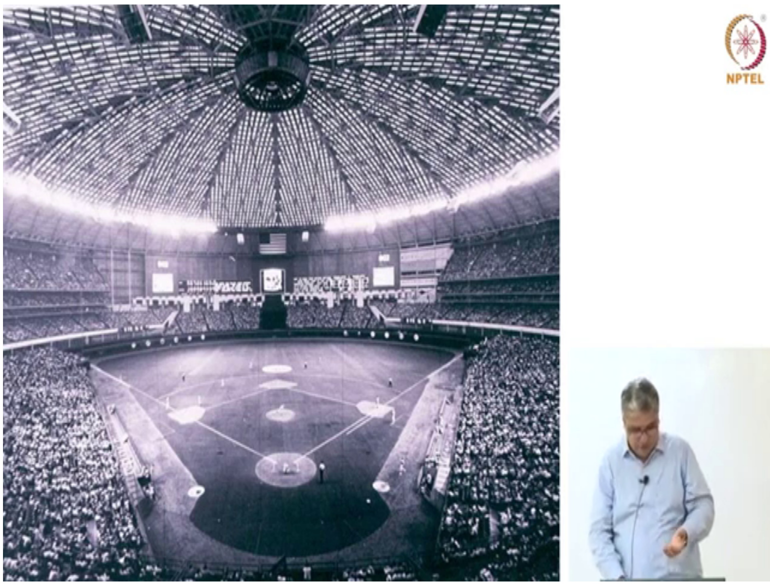

So, we are not able we are not creating a dome as such, but we are creating a system with different materials, where we kind of replicate that action to the extent possible and then, transfer load and essentially cover larger and larger area.

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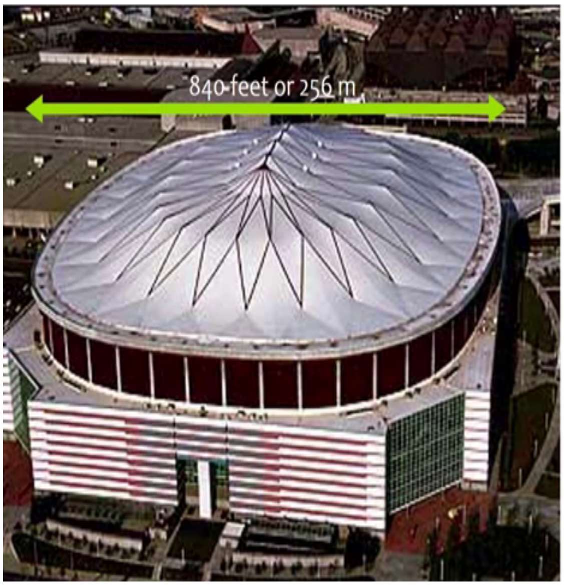

And then of course, we have this. So, this obviously, cannot be done with materials that was used 2000 years back and if the system also structural system also is different and we need to understand how do we create these systems. And that brings us to the next item which is analysis and design right. We have to analyze the system to understand how a load applied to the structure is going to eventually get to the soil which is going to support all the loads and that whole process is analysis and design.

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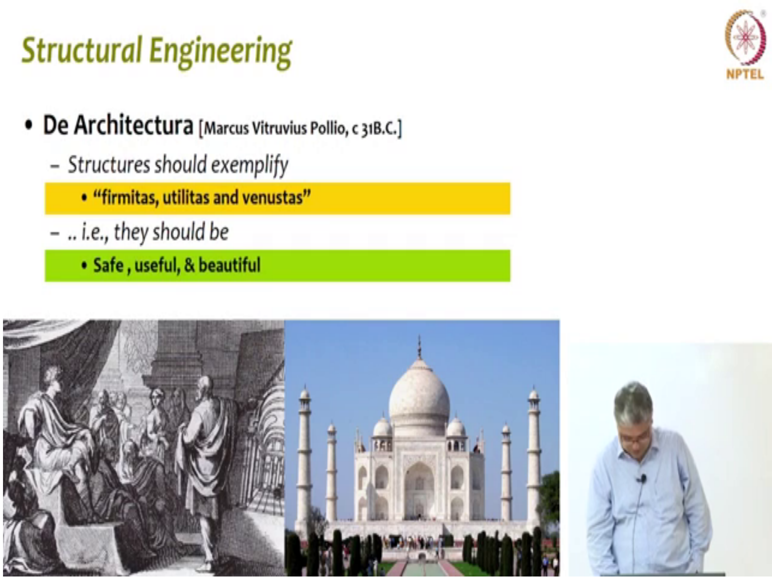

So, we saw this. So, our objective was a structure must be safe useful and beautiful.

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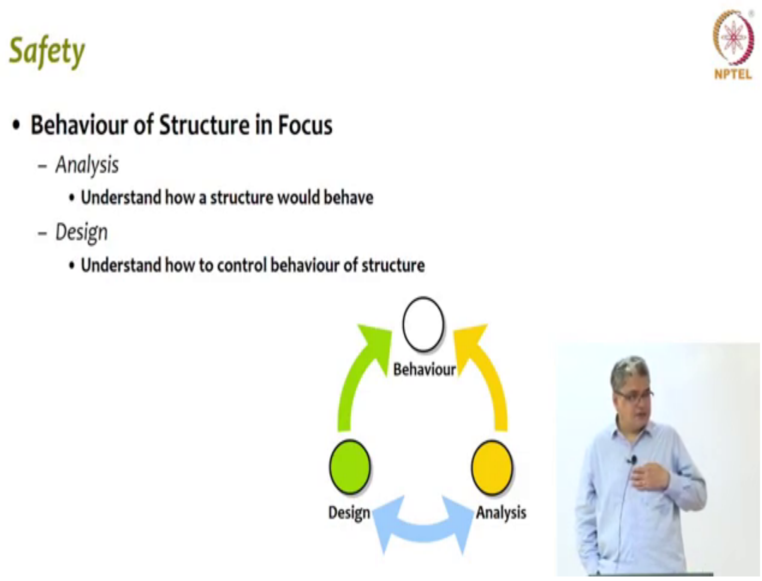

So, what is safety? Safety is understanding the behavior. If we understand behavior, we will ensure that that structure continues to you know stay there and do the work that it supposed to do without itself failing or causing injurial harm to others. So, analysis is that process which helps us to understand how a structure would behave and design is that process which helps us to control the behavior. We want the structure to behave in a certain way. So, we control it through our activities as designers, as structural engineers right. That is the process of design and analysis is we analyzed how the structure once we create it, how it is going to behave and that process is analysis.

We will stop here for today and we will continue this discussion tomorrow and we will take it forward from here. So, essentially what we have discussed today is materials, you got little exercise today go and find out; draw those stress strain curves on the same graph steel, concrete, masonry so to speak compression tension. We touched upon very briefly on two or three basics structural systems. This whole process of analysis and design and then, what structural engineer is supposed to do we will discuss tomorrow.

We will stop here for today.

Thank you.