Structure, Form, and Architecture: The Synergy

Prof. Shubhajit Sadhukhan
Department of Architecture and Planning
Indian Institute of Technology, Roorkee

Lecture – 18
Tensile Structures

Hello everyone, welcome back to NPTEL online course on Structure, Form and Architecture: The Synergy. Today, we are at lecture number 18 and in this lecture we will be talking about Tensile Structure.

So, like the previous lecture we discussed about compressive structures, where we have discussed about different you know form like arch then vault then flying buttress which are like mainly taking care of the compressive load and now in this lecture we will be talking about those structural arrangement or structural form that are mainly taking the tension taking care of the tension force or we can relate it to the tensile stress and again as we discussed earlier that this classification is based on like the predominance of which kind of force being acting on that.

So, we have same structure will may have something like a compression or some bending stress, but predominantly it is taking care of the tension. So, based on that, this presentation or this lecture is designed. So, let us start this particular discussion.

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So, in this particular picture what is like visible is basically a very beautiful bridge and to be specific this is called suspended bridge, suspended Cable Bridge. So, what exactly it is that we will discuss in this lecture, but one particular thing that you can see that in this case the cable being used and they are in tension.

So, these cables they are taking care of the tensile load of this whole structure and this is that is why the cable suspended bridges are coming into the category of tensile structure.

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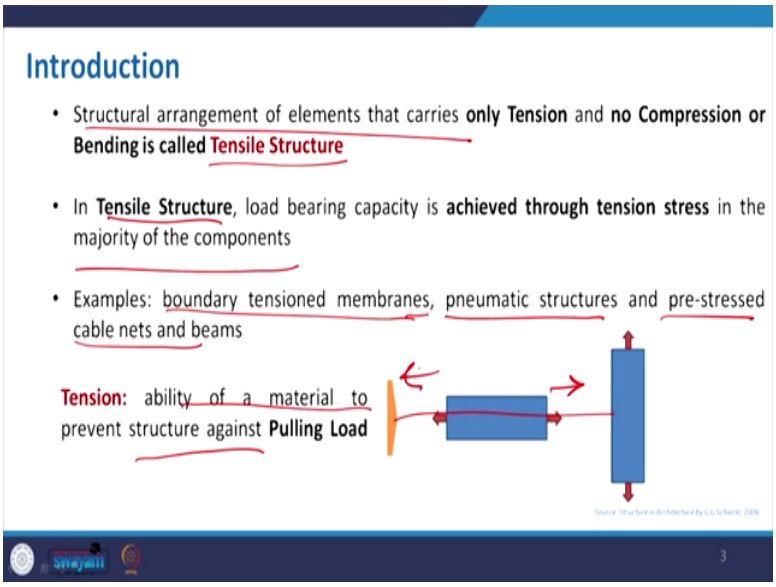

Now, if you see that like the concept of tensile structure, so, here also the structural arrangement of element that carries only tension, no compression, they are called to like tensile structure at the same time along with no compression there will be no bending as well, but there are some structure that we will discuss that where a component may be a minor component that are taking the compression as well.

The tensile structure, load bearing capacity is achieved through tension only and the majority of the component. As we mentioned keep on saying that the majority of the component of a structural arrangement they are dealing with the tension tensile stress. Now in this the boundary, the example of that that is boundary tensioned membranes is one the tensile fabric structures is alternative we can say the pneumatic structure we discussed earlier that is also considered to be your tensile structure then you have pre stressed cable nets or beam.

So, the cable net structure normally being used we will see that this being used for you know making the roof or the stadium where you use the membrane to make the structure light, so, how they are supported with the cable nets and the cable beam. So, tension is basically the ability of a material to prevent against the pulling load. So, when you pull. So, in comparison to the earlier example which looks very similar, but in this case again it is acting on this axis, the main axis, but in this case it is basically the pulling, the other one is on the pushing.

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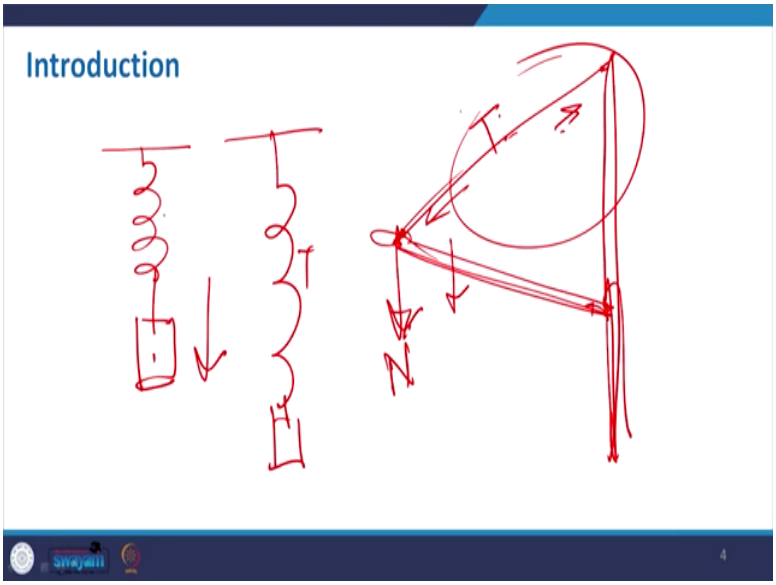

Now, in this case what are the changes that normally takes place in tension? So, if you take the example of a spring, so, basically if you add load, so, it will try to expand and you will see that it is elongated. So, the tensile stress developed within this material. So, this is one now at the same time like you just try to hold a particular structure ok, maybe a roof or maybe particular cantilever and you just use a cable to hold it. So, in this particular member this cable member

what essentially, so, it will have some load, so, if you apply load to it then in this member what is the phenomena will be developed.

So, it will try to turn ok. So, it will always try to go this side. So, this is basically you know this member is in tension. So, this cable is acting to hold this member. So, this arrangement specially, the major members which are taking care of you know preventing that structure from collapse is taking tensile load. So, this is again a tensile structure.

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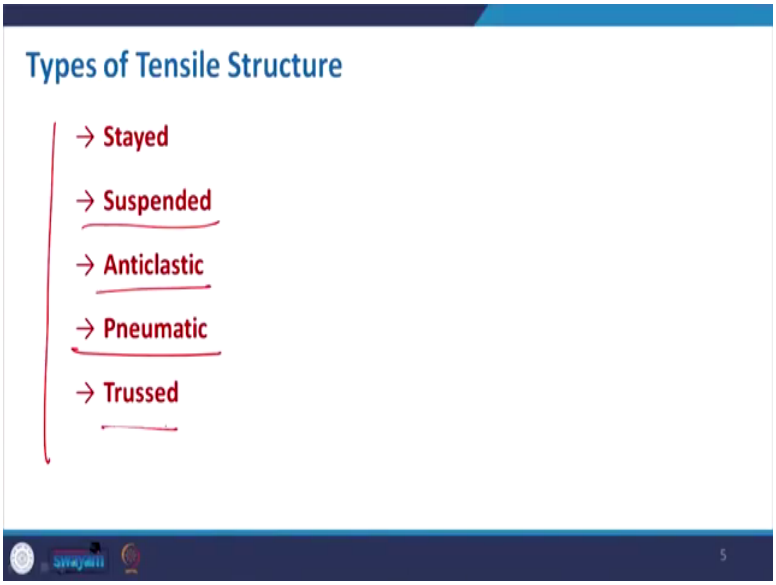

So, based on that principle how it is being supported and how load are being carried out for tensile structure, it is being classified in 5 category. One is the stayed you know cable we can say, the other one is the suspended the initial picture that I have shown of your bridge is basically of the suspended category then there is a category called anticlastic. So, this is some term that we need to understand very clearly.

So, basically anticlastic is that it is a structure making of the curvature, but with two curvature acting in opposite direction, two different direction we have this curvature. So, we will discuss that in that particular slide, what is anticlastic. Then pneumatic is basically the structure made of like with the pressure of the air that can form is basically the pneumatic structure and trussed sometimes we can go with the you know cable trussed and also we will discuss that as well.

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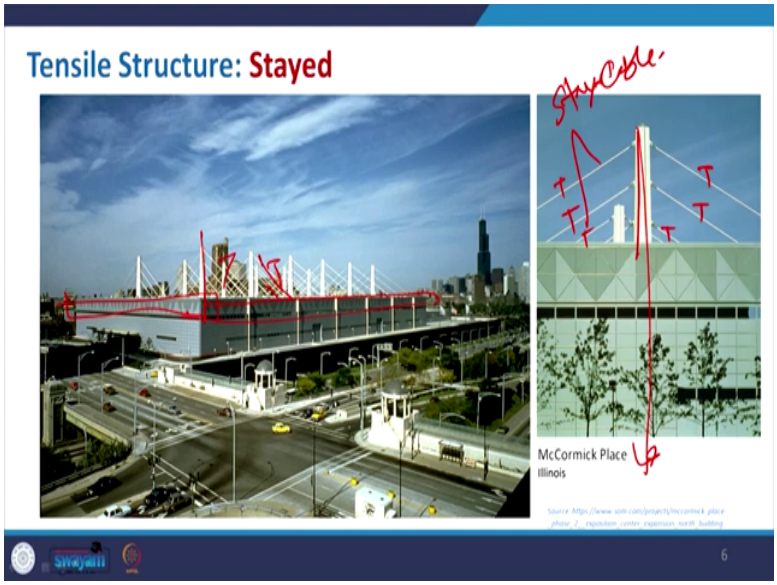

So, in this stayed tensile structure basically, the whole mass you know the roof and other things they are being supported with the stayed cables. So, these are if you see in broad, so, these are basically your stay now stay cable.

So, they are taking care of this and you know in all these members, so, which actually support they are developing tension, but at the same time as I mentioned in this particular bar the mast

sometimes we say, so, basically they are carrying the load to the ground. So, these will take compression, but predominantly if you see the overall arrangement, so, it is basically coming under the stayed cable structure. So, this is one kind of a arrangement and this is again you can see a modern building. So, there stayed tensile structure being used.

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Take the other example. So, it is again showing that you have this kind of arrangement of you know of the rails or the beam which are being you know connected with this particular masts. So, this is again the stayed cable where tension is developed on this.

So, basically this is another you know kind of setup into the category of stayed tensile structure.

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Now, considering that two, we have another example this is the Millennium Dome in London, the huge structure this membrane structure creating some space and in this case also if you see that this mast are placed to as a compressive members and all this particular roof in connected with you know the stayed cable. So, it is taking care of the form and the overall structure that been made. So, these all are in tension.

So, overall this arrangement is called stayed tensile structure, stayed cable tensile structure.

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Come to the suspended one. So, in this case we started with the Golden Gate Bridge that image and here it is another image of that where you get all these you know vertical members which are giving support, but the main support being give it with this particular cable, so, which is in tension.

So, in this case these all tensile cables like this all also trying to take care of the tensile force that been generated in this particular bridge. So, the load whenever there is some imposed load on this they are putting some pressure to the structure and that being taken care of by this cable which is suspended from a running cable. So, this is the example of the tensile structure. And why it is called to tensile because the majority of the you know elements in this whole system they are taking the tensile force and they are resisting the and that is why the name it is.

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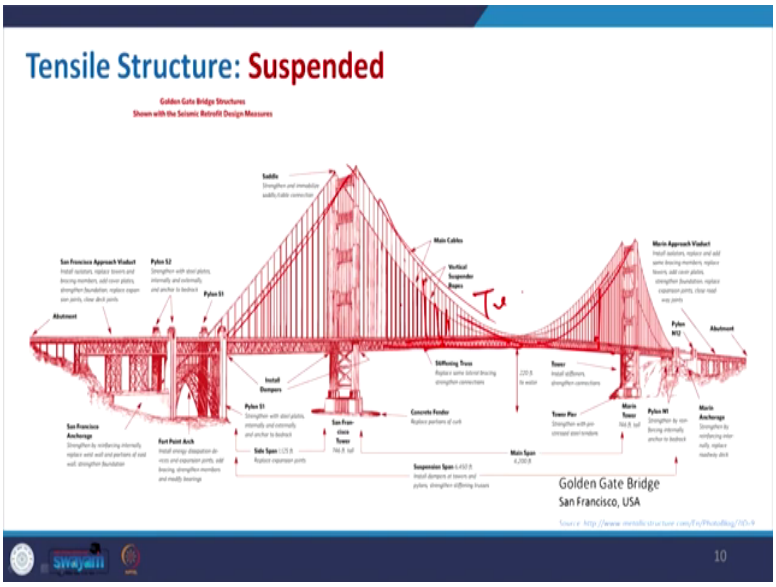

So, if you see this, like this is the overall the structure where like they have shown in this like different component how they are making this structure stable, but our concern is to know these the main cables and the vertical you know what we call vertical suspender ropes which is taking care of this.

So, the whole member like whole support with this members are specially taking care of the tensile force being developed due to the applied load for the main bridge. So, the structure that being made on top of for the main bridge or the carriageway where the vehicles and people are moving. So, these are responsible to taking tension and it is suspended tensile structure that we can say.

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This is another example with that Clifton Suspension Bridge in Bristol. You can see that the like how this has been made. It is pretty similar to look like the Golden Gate Bridge, but this is another example into the same category.

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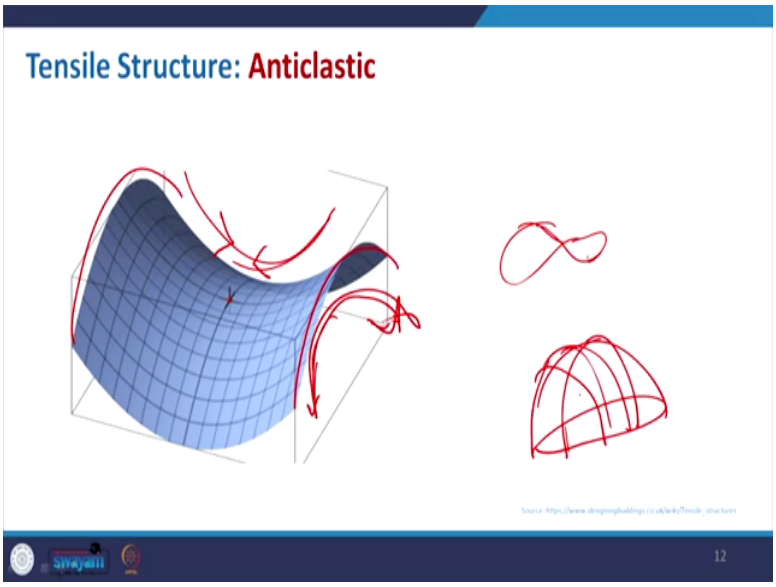

Now, this is very important the anticlastic. So, as I mentioned that this is basically plane having curvature, but in opposite direction. If you see in this case and you can sometimes relate with like very easy example that I can give you is basically, if you go and purchase some potato chips. So, many of that chips is giving this particular form. So, what exactly this is that means, that here if you see the curvature in this ok, so, you have curvature in this direction and at the same time you have curvature in this direction.

So, the same plane being arranged where two curvature having you know the opposite direction. So, this is very much you know important and to know for the anticlastic. The opposite to that is synclastic where all the curvatures, say for the dome all the curvatures from later xyz whatever the axis involved all the sides, it will give you the similar kind of direction.

So, in this case it is in opposite direction. So, it is anticlastic and this can be achieved through different kind of parabolic hyperbolic or parabolic hyperboloid kind of form.

And if you see some of the work done by architect Felix Candela, so, then you can get all these example like even in oceanografic building or in some other buildings of that type will get this kind of anticlastic curvature where it is being used with the you know tensile stress and this can be also formed with the membrane or fabric, not only the concrete with the fabric also we create it and we will have some pictures on that too.

So, in this case if you see like the application of anticlastics.

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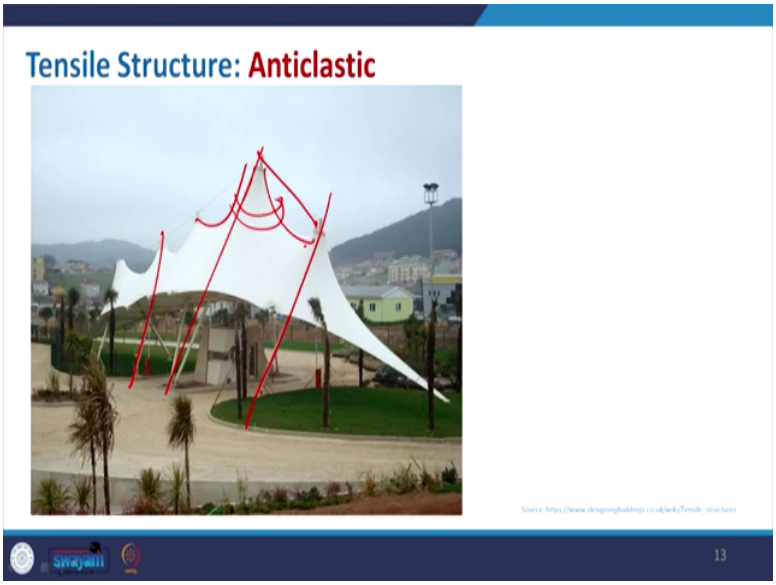

So, here also you get the curvature, one is like this and the other one is just getting the support to the bottom. So, again it is being supported with the cable and you have some mast

compressive members as will which will take those load to the foundation. Take the another example.

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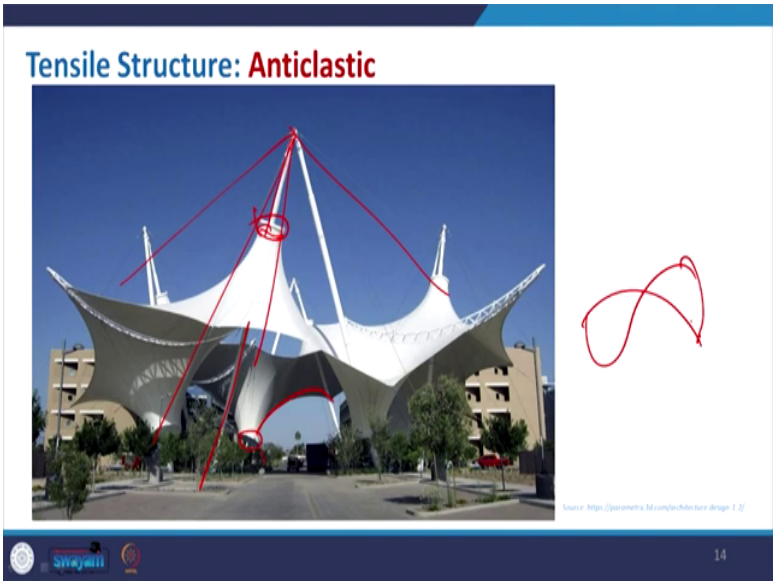

It is basically a conical shape fabric structure then this is basically from the state Arizona University Campus. So, in that case also these fine you know like cables they are taking the main load and you if you see the curvature also here, you have a different kind of you know arrangement somewhere this corn is upside sometimes it is in the downward direction, but we are getting the curvature in different manner. So, it is basically again you can resembles with the example I have given.

So, the two curves that they are acting like their direction are different then that is why I call it is anticlastic.

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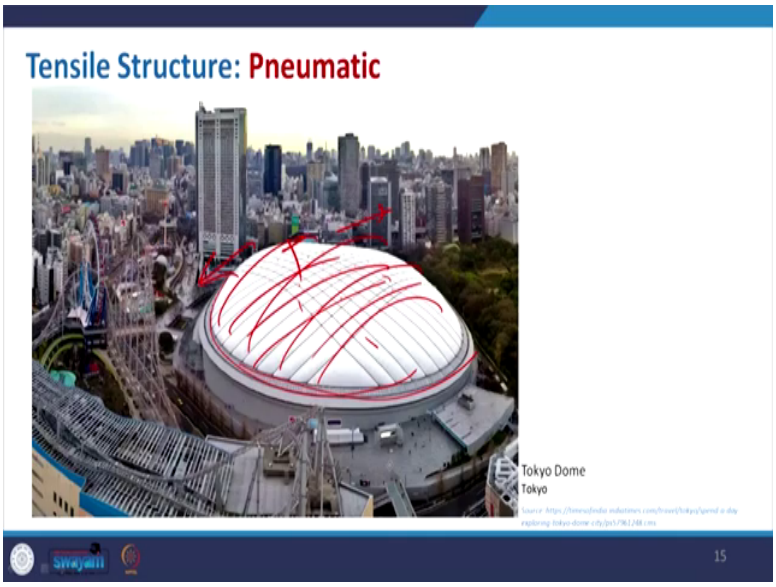

Now, come to the pneumatic structure. Pneumatic structure is basically what I mentioned earlier that this structure is formed with the help of the air. So, air is injected through like very thin membrane structure and which will give you the form. Here also like it is giving some kind of form where it is being, so, light and normally took over some you know area and you have to make your success super light. So, then you can go with this. So, this is the Tokyo Dome, where this particular you know activity place is been covered with this pneumatic structure where air is used to give this particular form and being supported like this is get connected at the top and those particular you know members these cables they are just keeping and the proper shape of this structure.

So, this is again another example of the tensile structure where mainly those portion due to the air blow and also these will try to expand. So, go away from each other. So, tension being developed at this point. So, this is example of the pneumatic structure.

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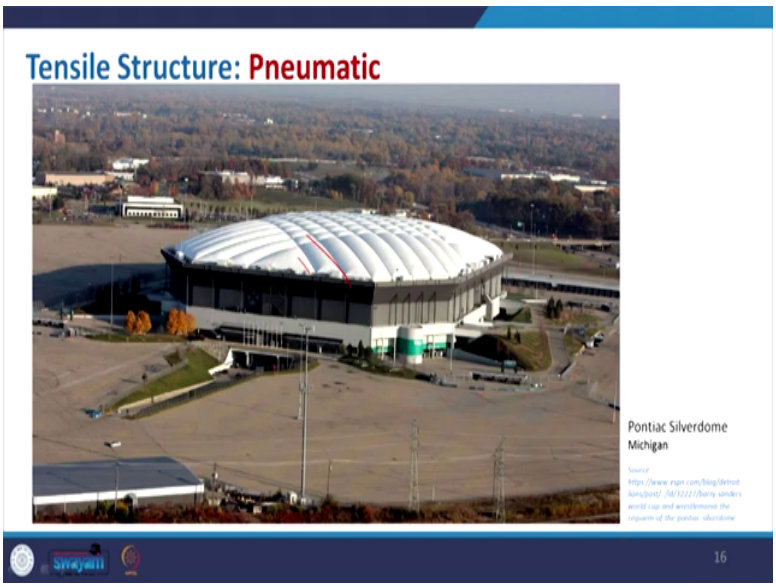

This is another pneumatic structures being covered in a football stadium, but later on it being dismantle, but this Pontiac Silverdome in Michigan. So, this is the same like that Tokyo dome.

So, in this case also you get like this particular division to just give the form so that it will take the proper shape, so that can act with. So, this is again another example of the tensile structure.

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Now, come to the tensile truss trussed structure, so, where in stayed of this cable and stayed cable or suspension we use the trussed. So, what is truss?

So, far we have seen some of the examples and we will also discussed more on the truss. So, it is basically something like the arrangement of the structural member in a triangular form which will be much more effective to you know distribute the load applied load on it and it actually managed this with some you know load transfer with; some member will take compression, some will take tension and then they will actually balance it and maintain the static equilibrium.

So, that is very important for making a truss. So, in this case again, the cable being used. You can see this is a like Oldenburg Stadium in Germany, where like again it is a membrane

structure like all other again the curvature if you see that you get this anticlastic form which is actually taking care of all this load applied on it, but it is being supported with a truss system.

So, you have a you know cable and along with that to complete that truss, you also have something which is very you know small cross sectional you know cables which is making the form. So, this particular truss that being formed and taking the fabric and the to cover it up. So, it is making tensile structure, but in this category of trussed.

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This example is another one of that, but here it is in state of the cable trussed, it is the normal trussed being used where the cover is being made with again the fabric, but overall like the trusting being made and you can see that at the top also in order to you know take this particular structure stable and all. So, those mast being created and this is getting connected at different points.

So, that it is holding the overall balance and all to maintain it. So, again with this cables and all, it is giving that tension and it is coming under the category of tensile structure, but along with all these truss it is coming into the trussed category. So, this is a very useful information that we are getting in this particular lecture.

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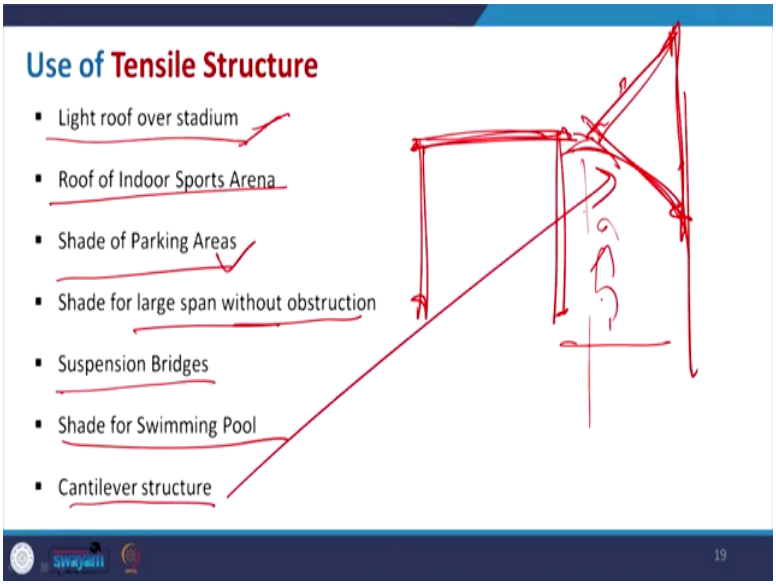

So, what we have seen now based on that we also would like to know the uses already depending on the variety of the application of the tensile stress that it is really helpful to make the light roof over stadium or any like it may be a open kind of stadium just to cover the spectator area or else we can also use it in a form of pneumatic structure to cover up the whole space like whenever we have anything called your indoor sports stadium something like for to be made for like this Tokyo dome or the other one that we used like that we discussed that is for to cover a football stadium.

So, this is one like use of the tensile structure, again that the roof of the indoor sports arena that we discussed. Then sometimes not only like took over the huge span. Sometimes in order to you know make it very light for the parking areas or any you know to any sided area in the open plaza and all, we can also have this kind of tension and fabric structures which will really make our thing column free.

Say for example, if we have a like a vertical member a roof. So, you have to initially support it with two members, but at the same time the advantage with a structure like then you can go for something like you just use a tension cable with a mast and can create this with a very light material. So, that this portion is column free, you can use the you know you can maximize the use of that space.

So, this is for the parking areas. Then come to the large span without obstruction that we have seen specially, where we have seen that Millennium Dome, the what is really a we know covering very huge space with the stayed cable and those mast. So, this is also useful there to go for the particular you know covering up at the large span in you know inner structure. Then the important thing that we started with that is also this kind of tensile suspension cable structure being used to make the bridges, sometimes maybe the cantilever sometime some you know making some temporary structures of that nature which is very useful to carry all the load with the suspension cable and the supporting cables the vertical suspended cables which will help the main cables to take the load.

Then sometimes maybe we have seen in many Olympics in you know games that the swimming pool is been covered, there also we use this tensile structure and as we mentioned that we can also go with this cantilever structure. So, this is about the use of that tensile structure. Now, if we want to just summarize this particular you know fact that in this we discussed about the tensile structure.

So, what is the tension there?

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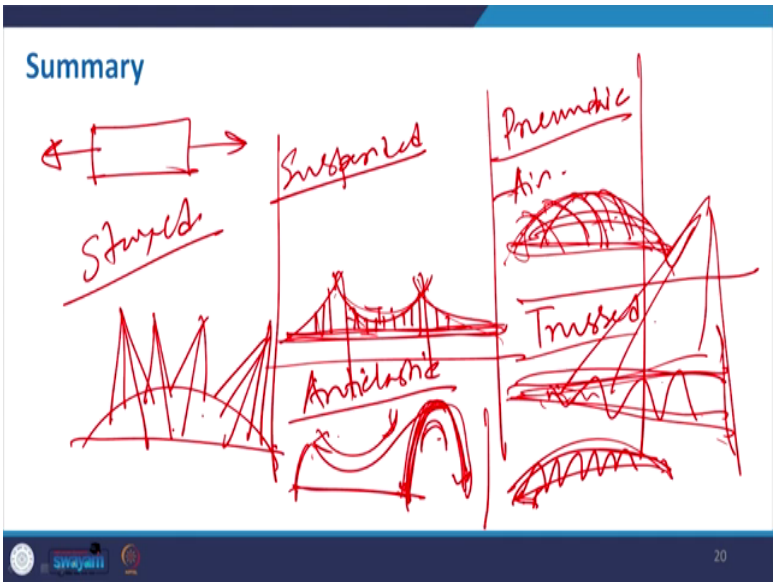

So, whenever any object is giving some you know pulling load, so, they will try to expand and the internal strain that developed, it is basically your tensile stress. So, depending on that like the structure which the main most of the members of that structural arrangement is taking care of this tensile load is basically the tensile structure. So, depending on the position and the member used and the type of you know what we call, the way they resist the load against the applied forces, so, then we have some category. So, we started with the stayed cable, where like the example that I have given with the Millennium Dome with the large span is being divided there are some support as a compressive member and the whole group being supported to the stayed cable.

So, this is one example where it is being supported with the mast and the stayed cable. So, this is the arrangement of both, but the earlier the next one that we discussed that is the suspended one. Suspended one, we discussed about that particular golden bridge where the main cables

and the suspended verticals members, they are taking care of the load implied on this particular bridge. So, whatever the load of the traffic, whatever the load of your you know vehicles, people, dead load everything is taken care of this suspension cable. So, this is again a full of you know tension those members are intension and they are able to cater the you know purpose to hold it. So, this is again the suspended structure. Then what we discussed is basically one of them like we pneumatic.

So, in pneumatic structure it is basically you use the air and you give that pressure. So, your structure will make a form of a dome or something and then with the cable you can give a shape to it. So, this is also being useful to make some portable structure or make some you know convention hall or convocation hall, a last span where also it is similar to your the dome Millennium dome, but here the whole thing being done through air pressure management and with some cable to just give the shape. So, it is in the pneumatic form.

So, this is again very important. Then also we discussed about the trussed. So, some of like, some of the examples that we have seen in a stadium that where the fabric structure that being used, so, in that case like the cable trussed you know trussed being used and they hold it the structure with the other cable, but along with that in state of the stayed cable for trussed kind of tensile structure, so, they have use the truss as a member. We have seen another example also, where the roof of the stadium the football stadium is just supported with truss and then it is the membrane to make or reduce the weight of the structure then the other one that we discuss very important one that is your anticlastic.

So, anticlastic means, we have given example I have given example of the chip. So, basically wherever you have such kind of you know structure where like you get this particular shape, where the plane is basically a plane if you just gives the curvature to give the form where both are having some you know different direction the opposite direction.

So, here you can get that it is giving some direction of the curvature and here it is something different. So, this kind of hyperbolic, parabolic or hyperbolic paraboloid form being used and many work being done by Felix Candela and then later on many such structural engineers and architects and we have some good buildings that like oceanographic building and other

building where like it is taking the load of the tension. But, this is not only being used for the concrete structure we also have seen that this being used with the membrane structure and we have seen that how that can be done. It can be done with a conical shape; it can be done in a wavy shape.

So, different kind of fabric tensile structures will fall into this anticlastic tensile structure category and we will definitely discuss those you know fabric structure in one particular lecture in detail where we will also see. So, there the our focus will be on this fabric structure and the component, but considering the load it can take it is of tensile type.

So, that is why we discussed in this particular chapter. So, 5 types of tensile structure broadly that we used, but apart from that as we discussed in the previous lecture that even in the compressive structure like dome, there the circumference hoops they are taking the tensile structure, so, tensile load.

So, basically, the tension and compression and bending they are acting in like in various kind of arrangement of structure, but some of the structure where the tension is very predominant, sometimes the bending is very predominant, sometimes maybe the compression is very predominant and depending on the classification happen.

So, this is all over that tensile structure and I have given a very few of many such a beautiful tensile structure example and I ask you to just you know exchange that particular list you also put the examples of each of these 5 categories, so that things will be clear and we will exchange that in the forum or in the discussion section that how this can be classified in which category of tensile structure or compressive structure.

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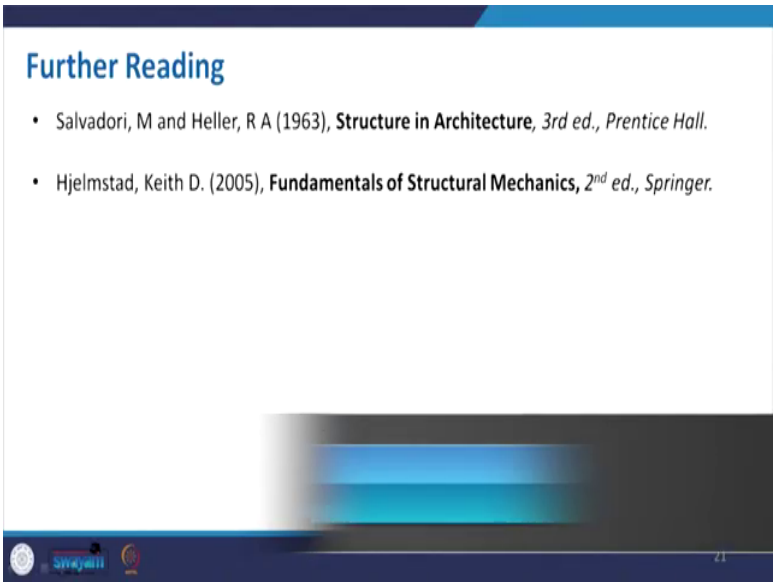

And these are the reading materials, he same reading materials you go through it and if you want to know more about the examples and their different you know you know theory background and the material being used to construct that, you can always go through those links I have given in each of the slide.

So, with that I conclude this particular lecture and we will move forward to the lecture number 19 that is all about the load bearing structure.

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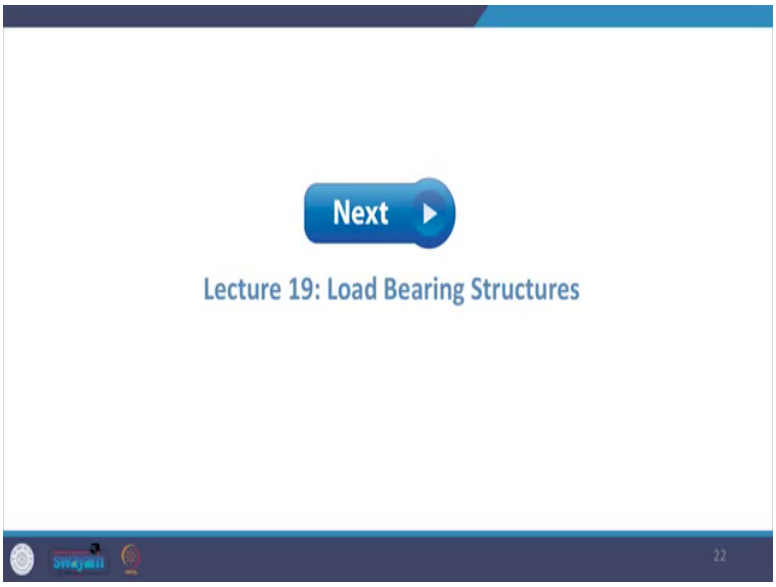

So, we will be discussing different load bearing structure in that lecture and before I conclude I really want to thank you all for taking part in this course and like we will be waiting for the next lecture, till then bye.

Thank you.