Structure, Form, and Architecture: The Synergy

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Lecture – 30
Pneumatic Structures

Hello everyone. Welcome back again to online NPTEL course on Structure, Form, and Architecture: The Synergy. In this lecture, lecture number 30, we will be discussing on Pneumatic Structure. Previously, lecture number 29 and you know few lectures before that, we have discussed the structure of spatial in nature and with different application for you know covering large span and also you know reduce the date load and all.

So, pneumatic structure is in the same category. Again, it will solve the purpose of covering last pen with minimum weight, but there are some few disadvantages as well. So, we will discuss in this presentation. It has a relation with the previous one like where we discussed about mid structure.

So, in one of the form that we discussed that inflatable that is the structural form being created just to with the air, pressure and that is one of the starting point of this pneumatic structure. So, let us start this particular lecture and go through the different example to understand the structural application in a better way.

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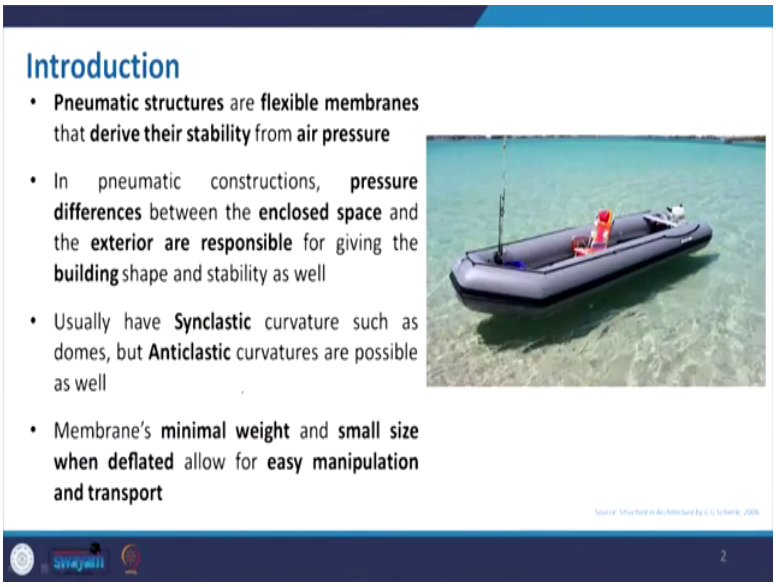

Now, before I read out anything from the slide. So, let us see this particular boat ok. So, we all are familiar with is some of us having the experience of using it or maybe we have seen somewhere in some documentary, some videos and movies. So, this is something where it is very you know thin material and when we put air into it, due to that air pressure, it creates a volume and it can float and it is so light so that it is stable as well.

So, the light boat, the light boat or maybe the light ring whatever we see this is having a similar principle. We do not need to go that far. Even we all are familiar with the balloons, during the birthday celebration or during any celebration, we have seen. It is basically a very thin membrane rubber material and when you put air.

So, it will get the volume and it will give a shape of like the way you desire like sometimes you can create the customized shape or a heart shape or maybe something a tubular shape or

maybe just a spherical shape or sometimes it may be egg shaped. So, that is one of the example of the pneumatic structure. So, it is actually the structure that thin membrane includes membrane that filled with the air and give the form and that also the stability.

So, due to the balance between the interior and exterior pressure difference, the form is in existence. The moment you release the pressure, it will be deflatable and deflated and then it will be just thin membrane; nothing else. So, here pneumatic structure are flexible membranes that I already mentioned that derive their stability from air pressure. So, two things; one is thin membrane and then the air.

So, if we combine the in a perfect combination, then you will get the you know the stability, the form. In pneumatic construction, pressure difference between enclosed environment; that means, the interior space and the exterior are responsible for giving the shape. So, this is the main fundamental of pneumatic structure. In this case most of the cases, the synclastic curvature means the doubling of curvature being used where the curvature is in the same direction.

That we have discussed in detail in the previous lecture like for the dome and other thing, the curvature like doubling if it is doubling of curvature, but they are in a similar direction same direction rather. So, these are synclastic, but anticlastic curvature being also been created. Thus, for that the purpose is something different, the system, the methodology will be different. So, we will try to cover that as well.

The membranes minimal weight and small size when deflate it; first of all, weight is minimal because thin membrane, you can see that the volume that being created that can be carried by one person ok, when deflated and you can fold it and you can put it in a bag a small size bag. So, this is the advantage of this and when deflated, it can be easily manipulate like you can give a enclosed form or something to carry and the transport. So, this is one of the advantage that we discussed at the very beginning of this presentation.

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So, before we go and discuss in point of the architectural buildings that or maybe any structure that use this; so, this is I think very familiar to all of us; maybe some of you have experienced it or maybe you just watch the kids playing over it. So, this is something which is very common in the fairground, where the kids they are jumping over it.

But what structure it is? It is a very perfect example of pneumatic structures, where these are perfectly stitched those color made in cloth and the air through air pump the air is inserted to this and it making a balance between interior and exterior air pressure so that it is giving a particular shape and as because it is placed in a coarse form.

So, there will be no such you know tolerance or something like a turbulence to this structure due to the heavy wind and all. So, people will jump and that is because it is for the kid. So, if you could accumulate I will say 10-20 kids. So, their weight is not that great so that it can

easily hold the load. So, this is one example of the pneumatic structure. So, from one particular part, it is a control pressure that we have to provide. So, it may be a continuous one or it may be just filled ones and then, if we can have a leakage proof material.

So, then we do not need to do it ok. Sometimes in the city, we that some weak size balloon that is flying over that and it is showing some ad of some company or something. So, again it is the structure that spherical volume or sometimes even not the balloon shape, it may be of a plain shape.

So, it plain shape something is floating on the sky to give a ad. So, these are example of the pneumatic structure, where the due to air we can get it. Even not only this made of cloth or maybe made of this plastic made of rubber material. So, let us take another example, it will be more clear.

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And then, we can understand in a better way that I was talking about this particular safety ring for the emergency purpose, we can use it. So, this is again a structure where the air is injected to that. Then, this is something where it is nicely depicting what I wanted to say that when it is deflated position, it is nothing by a small like very thin membrane very lightweight.

But when you put air to it, it is giving you the volume that you require; but if you release it, it will automatically be in its original position. But during this the deformation like here in this case of balloon, we have seen that many a cases like we blow up a balloon and we put it for 10 days or something and then, automatically it is coming back to this shape even it is closed. Because there is a very slow leakage through the surface and there will be permanent deformation.

But whenever you apply it with a good membrane or you know having good strength, so probably this will not occur. You can reuse that material in many places. So, for any you know temporary fair shop or something that you want to give any display area. So, we can take help of this kind of structure where air will be used as the main structural you know support to give and create the form.

Now, here this is now a days very popular and even in television, even in all you know different YouTube videos, even in your E-websites ok, ecommerce websites you will get that this kind of multi-purpose furniture's which is just made with some membrane and with the air you know inserted to this structure will give you the form of a sofa or the bed. So, this is something very important and when you just remove it, you can fold it and you can put it in a very concise and small area which is very much effective.

So, optimal use of these you know structural membrane or what the membrane structure with the air and all is very useful now a days. Now, coming to the general characteristics looking at this example that these are very common, I do not really think to you know you get surprised to know something about that something about that.

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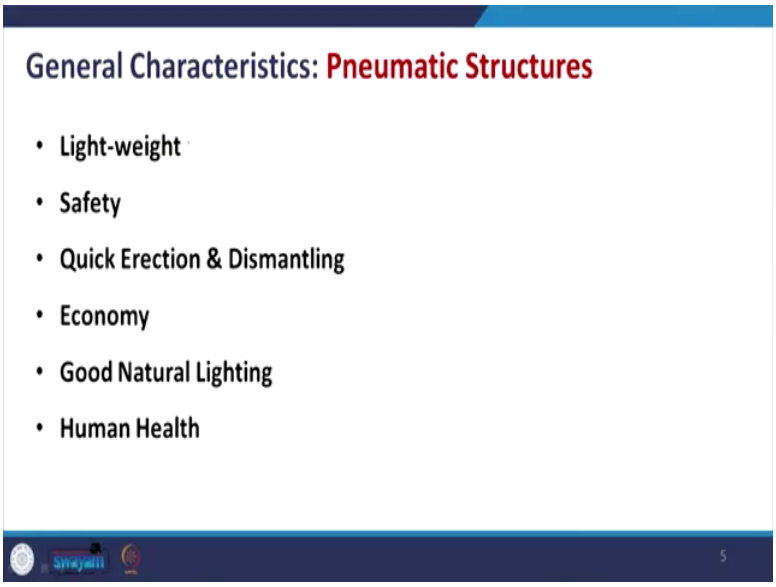

So, light weight, definitely it is very lightweight material because of the thin membrane and all. The safety point is another important issue and now, it will have two kind of answer to it. So, when it is a small scale, very close form application, so it is safe. Because it is just put to the air, so there will be not much dead load. So, collapsing of this structure will not really affect much.

But again, the safe when it is being applied in the open area and there is a heavy wind flow. So, then if the air is not properly maintained on corner or counter the additional force that sudden load applied to that structure that may cause some damage and that will not be very comfortable. Because the interior fixture and all the that will have some deformation.

The quick erection and dismantling is definitely the case. So, in case of the sofa, you perhaps if you have not done you just go through the video of this inflatable sofa or bed, you get that is a

very small like material folded material and there is a point that you just you know about the electric air pump and then, it will just you know inflate and then, they will create the volume.

So, slowly slowly it will give the form. So, it is very quickly can erect even that example I have given for the you know this particular facility for the kids. There also it is to be done. So, we do not need to transport the exact structure from one fair ground to the other. We can just remove the air and we can fold and we can easily transport.

Now, coming to the economy as because it is having very less you know number of support or very you know strong support. So, it is economical; obviously, so what you need? You need some anchor to hold it, to ground it so that it will not blow away with the air or something. Good natural lighting; if we use some translucent material like the membrane in membrane structure, we have discussed the translucency is one of the criteria to select the membrane. So, here it is true for this case as well because it is also the membrane.

The only difference there we have given support with the must and the tensile cable. But here its only the air. So, it is having the good natural lighting. The human health. This is the important case because for maintaining the shape you have to give constant air supply to this. So, there will be some pressure difference and who are insight to this structure, they should also be getting adjusted with the pressure of pressure difference from inside and outside.

So, we cannot really increase the pressure so much or you cannot make a vacuum so that it will get, it will put some effects on the human health; so, that you need to take care when you apply this kind of structure for any purpose. So, normally this kind of structure being made for like convocation hall or maybe sometimes for exhibition hall or maybe small kind of you know some interesting public places that I will show you some of the pictures of that kind. Now, coming to the components what exactly the components are? A typical components of a pneumatic structure is one is envelope.

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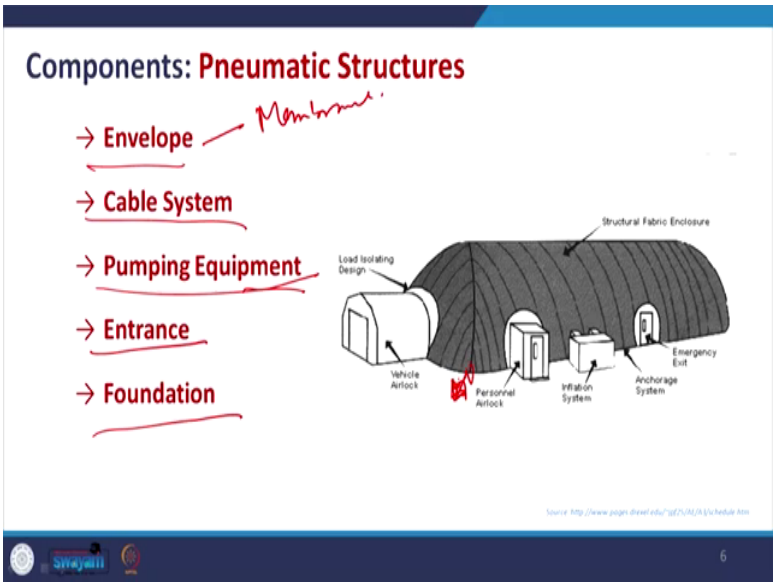

It is nothing but the membrane that we discussed earlier; the cable system that will anchor everything to that. The pumping equipment because the air is the source of making the structure stable so, the pumping equipment. Then, entrance we can create a balloon, but the main problem we cannot go inside it ok. So, in order to do that we have to have an entrance and that should be air locked.

So, that should not release your you know the pressure so that we need to take care of that and constant monitoring on pumping and overall pressure difference from outside inside to be maintained and the foundation, in order to make the stability. So, foundation is also required where like the endpoint maybe through cable, it is attached to a particular post or it may be with some foundation, initial foundation on main bias, we can just add on. Coming to the materials that can be used for the envelop is the membrane material.

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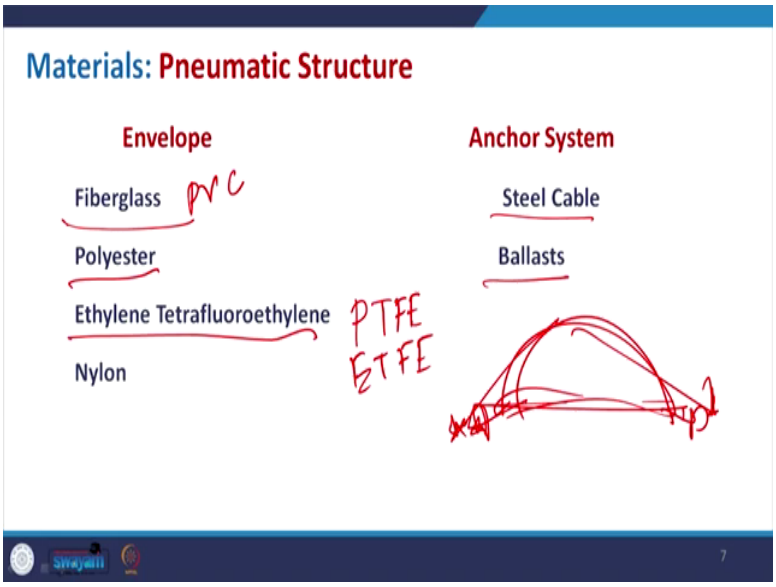

So, again it can go with the fiberglass, PVC fiberglass, the polyester, then ethylene or tetrafluoroethylene that where we have discussed about PTFE or maybe ETFE nylon. So, this kind of material which will have enough strength to carry and having good you know strength to width ratio that can give some advantage for this and for the anchor system, we can use the steel cables just to you know hold it.

So, we just hold it from a point and we just make a tie at the gent or you can use the ballast. So, where this can be supported with the temporary arrangement of you know few bags of cement or maybe it is a permanent post or maybe a very solid post being just elected there and getting connected with this structure.

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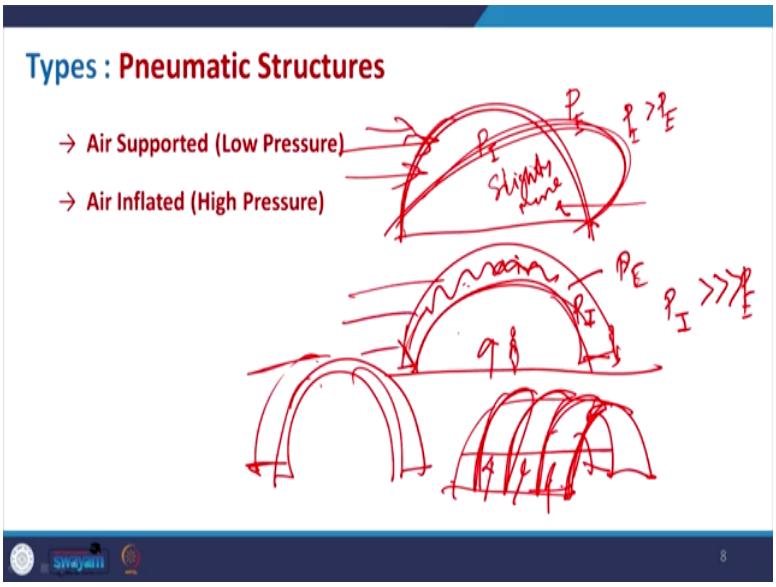

Move forward, the basic typology of pneumatic structure, we have two kinds; one is your air supported which is normally also low pressure and other is your air inflated. So, we will discuss one after another. So, low pressure means where normally before I go. So, we create with a single layer of the membrane and we put air and we get this volume right. In this case, the low pressure to be maintained. The pressure inside is slightly more from outside.

So, if it is P exterior and this is P interior. So, P interior is slightly more than P exterior and that is why it is holding the shape. But as because that will be habitable. So, we have to also take into consideration the you know pressure that one human can hold and that to be calculated. Now, where the air inflated is not a single layer. It basically the two layer of the surface ok, the membrane and air is not injected directly to the shape ok.

It is injected in the medium. So, between two layers, the air is inserted in this. It is basically very high pressure. So, if we consider this is as your P I within the system and P E. So, then P I is much much better than your P E and there is no effect on the human who were inside to this because it is within that. So, that this is giving better stability.

So, for that kind of inflated, we cannot have a continuous two layer. So, in order to give rigidity what we can do if I just want to draw a barrel vault like this. So, instead of a continuous one, we have the segment. So, individually we just you know put the air and then, we get this facility like this. So, this is making a cushion kind of thing in between if I make a cross section. So, basically it will be something like this. So, series of that is connecting each other is creating this particular air inflated or high-pressure pneumatic structure.

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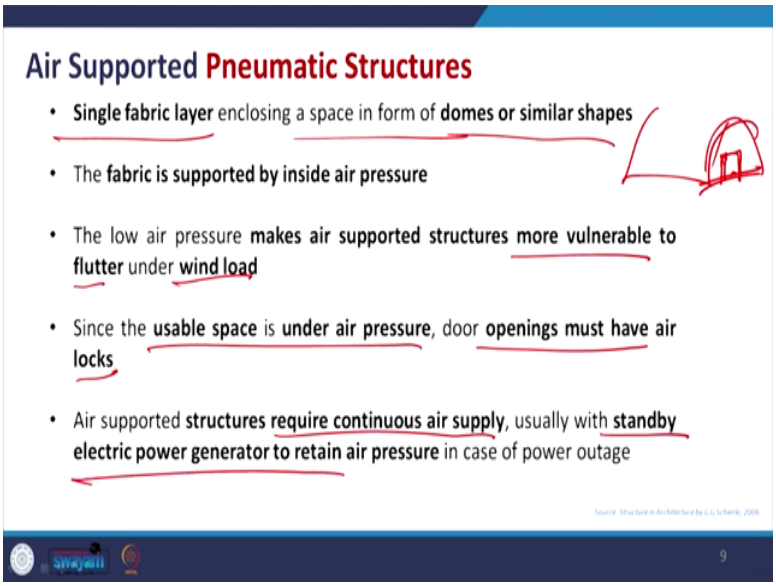

Now, coming to the air supported whatever we discussed, let us just go through this. It is single fabric layer enclosing a space in form of domes or similar shape. So, it can be of dome is very easy or else we can also go for a barrel. So, where like it is not the dome, we have and at the end we have a closed form and then the entrance to be made. The fabric is supported by inside air pressure; obviously.

The low air pressure makes air supported structure more vulnerable to the flutter or under wind load as because the interior load the air pressure is slightly more than the outer. So, if anything implied heavy wind blow and all. So, this will not really help. So, it cannot take hold of the volume. So, it will take different shape like this, which is vulnerable. So, in that case compared to that as because it is high pressure. So, it can hold it in a better way.

Since, the usable space is under air pressure, door openings must have the air tight air locks to prevent any leakage. Air supported structure require continuous air supply. Usually with standby electric power generator to you know run the fan continuously. So, that air is maintained because whatever the air loss from the opening the door or and that is why here we use the revolving door so that can be maintained.

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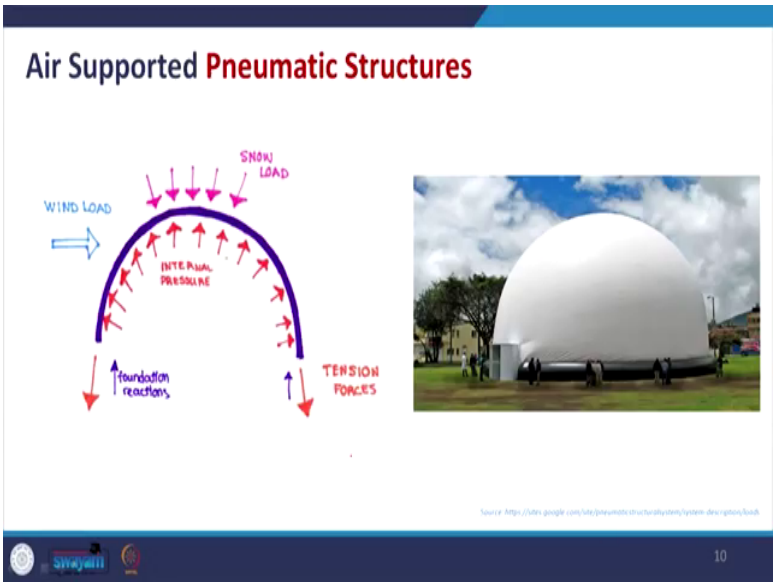

So, this is the example where you can see that how this is the entrance and this is the support grounded and this is a single air balloon kind of structure and this being made. So, here this is something that have picked up on the internet. This is very easily a very popular image that you can get and the source is given. So, you can get more information about that.

So, in this case you see that the structure the whatever the snow load or maybe the wind load. So, they can easily be drain off because of the synclastic curvature and the interior pressure is holding the overall shape and the wind load which is lateral which is really vulnerable, if we have a very little pressure difference and at the bottom it will have the tension.

So, like its all sales structure at the bottom, we get this tension force or tensile strength as that structural phenomena. So, it is not really different from that. It is also having the tension. Coming to the next category that is the air inflated pneumatic structure.

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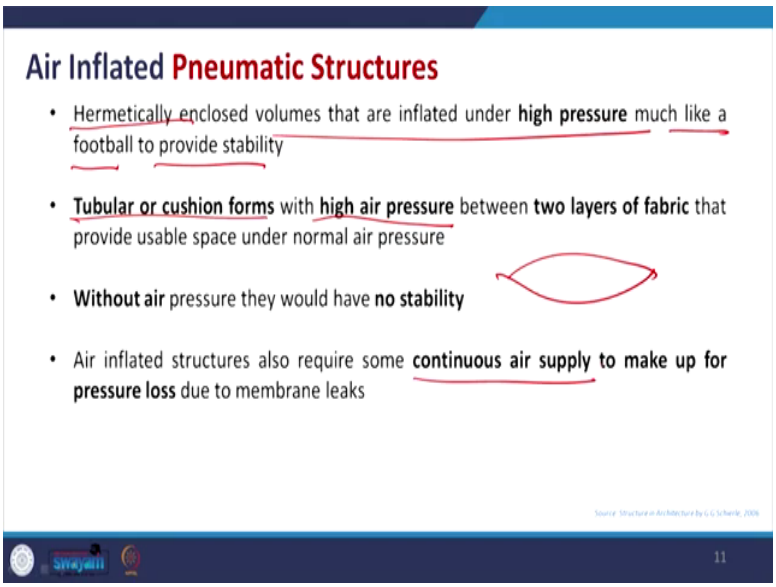

So, it is hermetically means the air tight. So, this is the property of the air tightness enclosed volume that are inflated under high pressure much like a football or to provide stability. So, it is enclosed. So, for football like this is a particular cell and input it. So, it may be any such you know balloons like structure. So, there are different cartoon characters, now it is available. So, you have to blow and then, there is a particular you know point. So, where you can enclose it and you can lock the air and it can give you the shape.

So, it is available like in terms of different cartoon character, different playing instrument and many. So, that is one. Then, the tubular or cushion form being created in this case and high

pressure is maintained. So, it is basically something like this. So, before we go further, let us show you this example, you are familiar with this facility as well. So, this is something I have picked up. So, these are the you know plastic ok, air pocket.

Here, I have just removed the air. So, it is very thin, I can fold it right ah. So, these are available when you order something from online. So, you can get this particular packaging. So, this is with very small space I can just hold it ok, its nothing. But at the same time, when I inject here, when I have not released the air, so it is giving a volume. So, you can see the volume and it can easily carry the load. So, this is very flat, but you can have similar structure where you can give some bend and all.

So, only with the air which is giving some cushion which will really give the shape will hold the particular shape. So, the difference between these two, they are of the same material, but only differences here it is I have removed the air and here air is within this particular plastic. We just keep giving this cushion. So, this is one example of this your air inflated pneumatic structure.

So, when is kept locked between two layers and now, without the air pressure they would have no stability that already I have explained with this where I can just crash it like this. The air inflated structure also require some continuous air supply to maintain the stability. It is same like during that particular process you know there will be slow leakages. So, in order to maintain that we have to put the air; not maybe regularly.

Even like I can give you the example of these are the cycle tube. So, when you pump it like if your tire, the tube is a very new. So, maybe it can run for another 2-3 weeks or maybe one month; but at the same time slowly when we do not use it, we put it somewhere in the sun and all there will be slow leakages. So, then again, we have to fill that with the air. So, this is a similar thing, but with the membrane, not with the rubber material or that I that I just mentioned.

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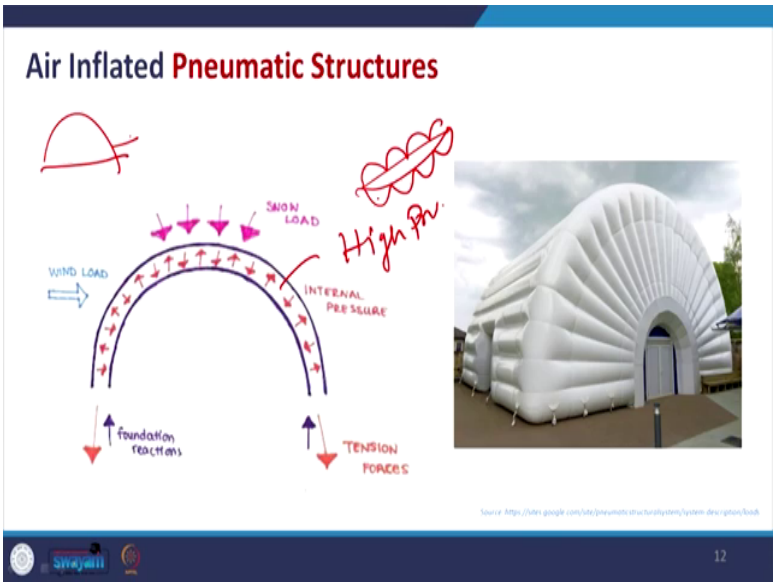

So, this is one example the difference between that you can get these different cushion and this example, you can get if you have used some cartridges laser print cartridges and all so that is inserted within some you know padded or something like you get a packet, where the outside you get this kind of air inflated structure. So, that it will give the proper cushion to the cartridge so that there will be nothing no damage during the transport and all.

So, in this case if you see that the only difference we get that two layers are there and then, the air is in between and they are balancing each other to this and here, we can get the high pressure compared to the other the exterior, the outside pressures and there will be no such impact on the human related thing. The earlier as because there was a single air, so that was the problem with the additional air injection or the creating the vacuum and all.

So, it is basically the putting more air into it not the vacuum. Vacuum will squeeze this down. So, when you want to dismantle you have to do that to get the what the vacuum can work, to remove the air from that.

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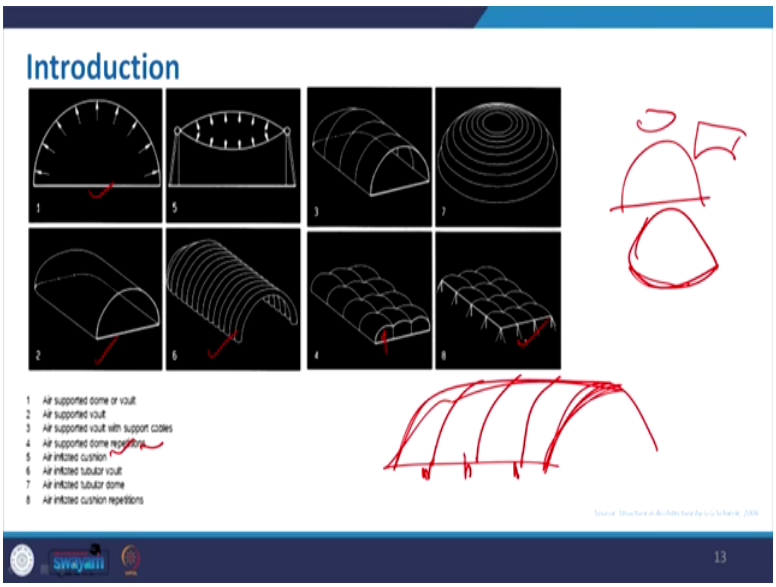

Now, let us have a quick taste on what we understand from this air inflated and then, you are supported. So, here are some pictures that is randomly placed and a number is lined you know given to that 1 to 8 and let us understand what are those like which category they are. They here the choices are only two; one is your air supported and one is air inflated.

So, just have a look into this and just try to give a answer and maybe spend another few seconds to it and then, I will show you the answers and you match how much correct you are and to know what exactly it is. I got your answer ok. So, now let us just check how much correct you are. I think most of you are 100 percent correct. So, let us understand this. So,

number one is called air supported dome and vault why? We should understand why, we should not believe on the text that is written.

So, as because this is single air and filled with the air so, it is in the first category. So, air supported dome and vault. The second is another one, but here it is the vault structure because this is something where we do not understand exactly the volume it the cross sections, it maybe something which is evolved and get a form of a dome or maybe extended that is you know vault. So, this is one the second was steeply a very simple air a single air is there. So, air supported.

So, I think you have both of the answers got correct. Now, coming to the three number 1. So, here it is something where air supported vault with support cables. So, what exactly like when you have a large structure and made of the three membranes, and each may sway and to give us some support. It is not the two layers, but we just tie it up with some cable.

So, we fix it so that it will maintain the shape. So, it is very useful tool that with the cable or rope will give this particular additional stability. So, that it will not sway or it will not deform much due to the wind. So, this is again the air supported wall with the support and then, this is similar the fourth one is the multiple dome of that again it is air supported.

Now, coming to the 5 is very clean and crystal, if you take this example it is similar to that if I hold it. So, it is giving the same shape and air is inserted here is locked between two layers. So, it is air inflated structure cushion and then, similarly when you just make multiple. So, I just made multiple of such and make a form and they are actually connected to each other. So, we will get the form of this number 6. This is basically your inflated vault.

And we can go with the number 7, where it is not in a wall direction, but in a concentric ring and it is forming a dome of air inflated and here it is a multiple dome, where the tool is being done. So, there is additional support. In this case the entire thing to be given, so it is very interesting to compare the 4 and 8. So, the top is same. But here it is single layers which is giving the volume of the wall as well as this is the base and here it is just the support.

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Coming to the example of this, so this is one example of that Inflatable Tea house, where the membrane is being made like this.

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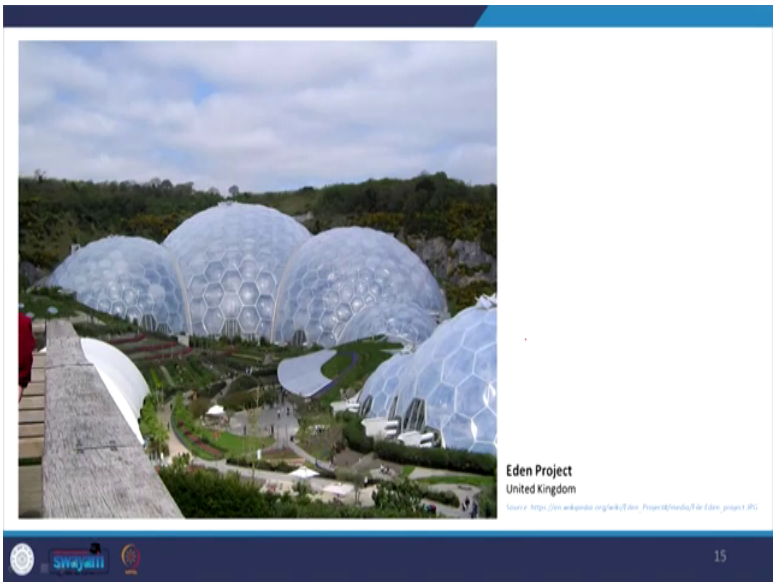

Here, it is the Eden project; basically this is made for our greenhouse for the botanical garden purpose.

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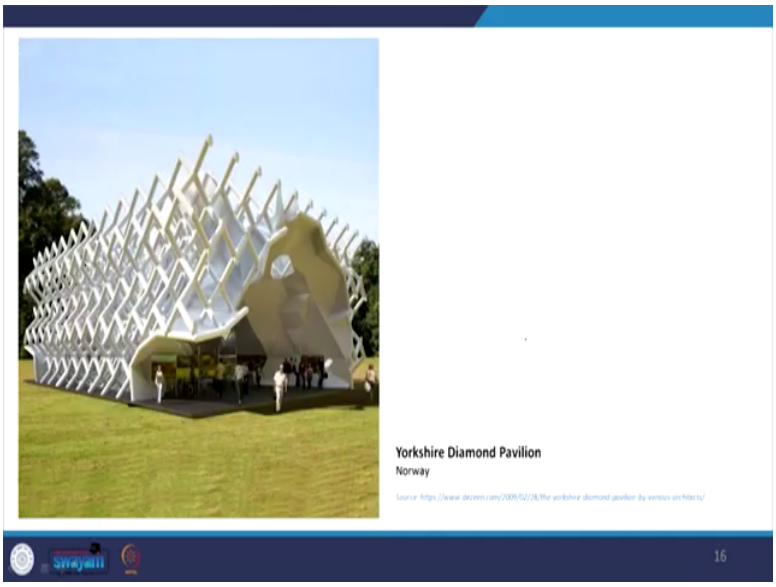

Here Yorkshire Diamond Pavilion; again these members they are actually you know filled with the air. So, in this case this example is for the air inflated. So, this members, they are filled with the air to give this form of this structure.

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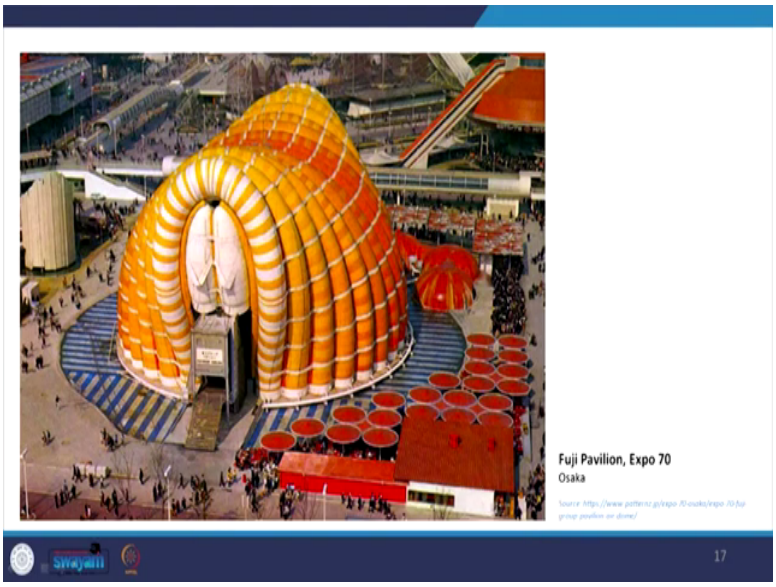

Now, come into the Fuji Pavilion and that too in 1970. So, this is something where again it is air inflated structure that club together and create this beautiful pavilion the exhibition space.

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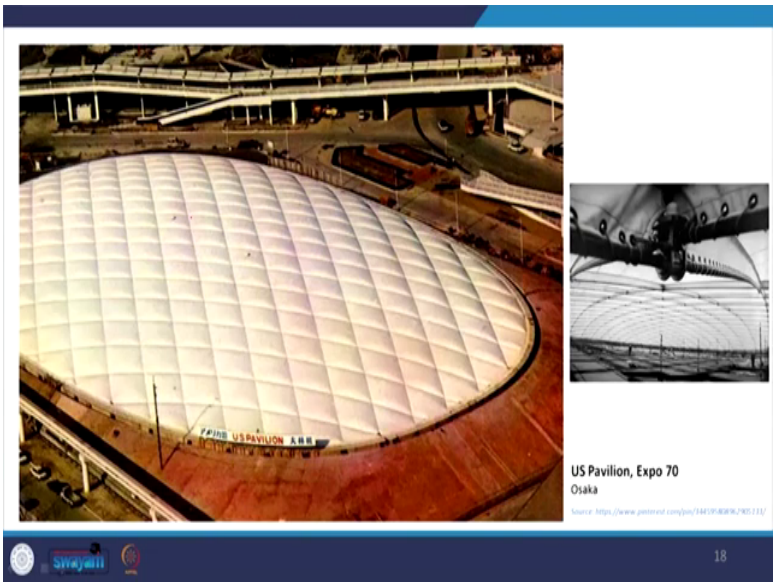

Similarly, the US Pavilion in Osaka in 1970, the same category here. It is the similar thing where the membrane being created and then, for additional support that being created with the support of frame; coming to the application of this.

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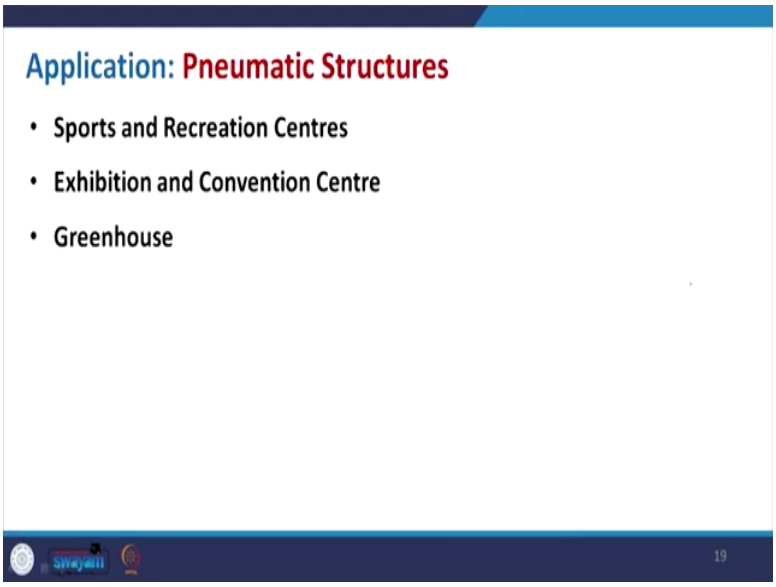

So, for the sports and recreational centers, exhibition, convention center, greenhouse whatever the examples we have seen, maybe for any other demonstration also we can get this kind of you know help.

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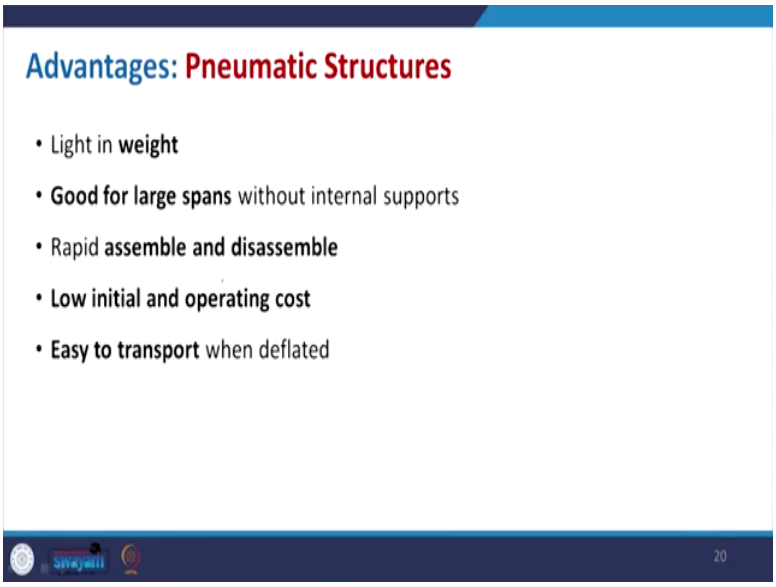

Now, coming to the advantage of that again, it is light in weight similar to the membrane structure good for large span without internal supports. Its true for all this spatial structure here. Rapid assemble and disassemble is definitely you inject the air and you remove the air, that is all. Low initial and operating costs as because of like hardly any such heavy materials being used there; easy to transport when deflated. It is a similar with the example I have seen that.

Suppose, this is the structure; if I want to put it in my pocket, maybe it will take much time; but I just deflate it, the same material and I can hold it. I can put it in my pocket. So, this is very simple example you can just enlarge the scale and you can get that the statement is very correct that we can easily transport when the overall system is deflated.

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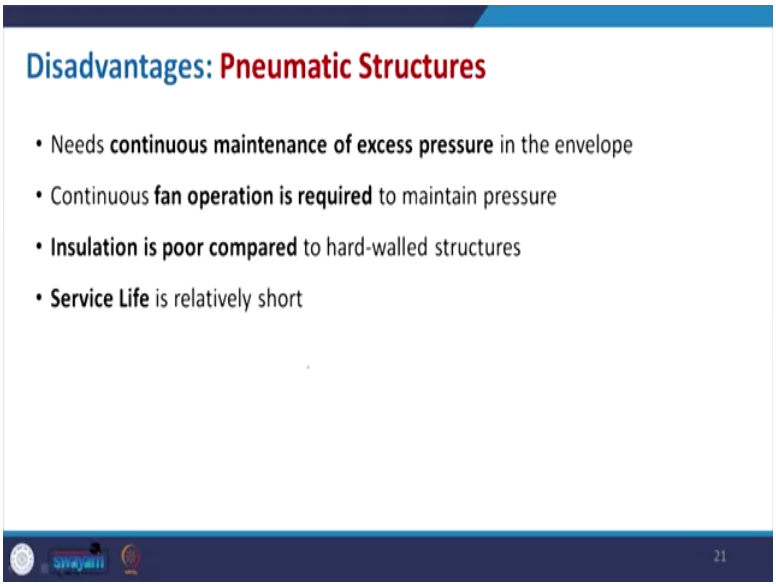

Coming to the disadvantages; yes, it needs continuous maintenance and excess pressure to maintain, specially for the air supported where you have to maintain the pressure in a controlled manner so that there will be no adverse effect on the human body, who are really you know enjoying the interior space. Continuous fan operation is required to maintain the pressure. So, a backup should be there. It should not be something like only it is supported based on the electricity supply. So, then that may create some problem.

Insulation is poor because of the thin membrane. Definitely, this has some resistance poor resistance to the thermal thing or something; but yes, definitely if we go for some good material that this you know poly tetrafluoroethylene or some coated material that can be taken into in a greater extent that can ease of some of the problems.

Service life is relatively short because each time you inject here and then remove. So, it will not have a lifespan of a concrete frame structure or meaning sales structure; but yes, for portable thing this is very useful and the probable application that may we think for like the rehabilitation center, where for the we have to locate many people to make and we have to erect it very quickly. So, we can transport this kind of material and we can create a state so that the people from the disaster area can be easily rehabilitated in that place.

So, this is the advantage of this pneumatic structure and can be applied. So, with some of the disadvantage and advantage, we should take a call what is our purpose and accordingly, we take a decision on which kind of structure to be adopted and the form. So, this is the end of this particular lecture.

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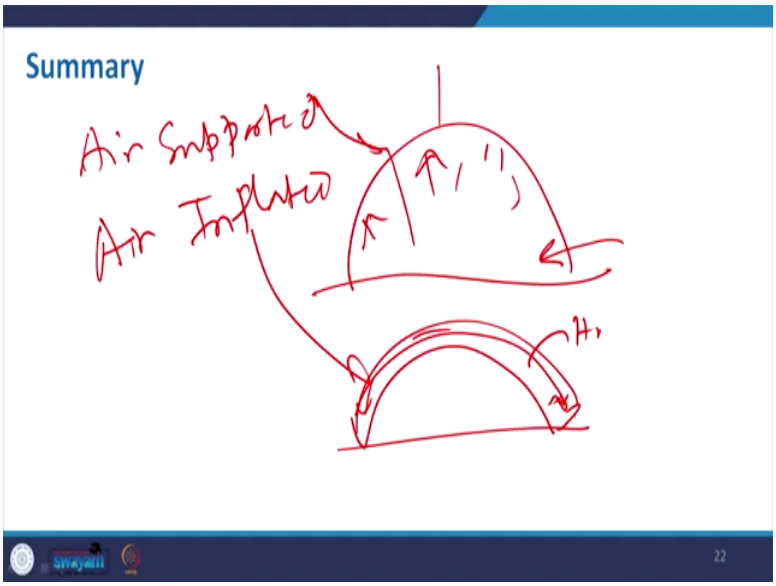

So, the summary is basically everything is explained. So, basic two type is your air supported and then, your air inflated. So, air supported is basically a single layer; air is inject and with the internal pressure, it is holding the every load and where it air inflated. So, two layers the air is actually locked in between two layers and very high pressure is maintained to create the shape and remaining the membrane characters is similar to that.

This is the application and application is already discussed in different exhibition hall, pavilion and this is the case and very light material, easy to transport, easy to assemble and disassemble. These are the advantages. With this I conclude here. This is the reading materials. Again, you can go through the web links given for the you know relevance slides so that you know more about this subject and get better idea, better examples, I have given some examples; you can also add more example.

You can give me that feedback, you can put it in the forum. So, we will discuss over it. With that we will move forward in the next lecture is basically lecture number 31 that talks about Structure and Architectural Forms in Windy Areas. So, now we will move through a specialized design for different kind of environment, windy or earthquake prone or flood time to time and we will discuss more on this lecture. Till then, I really thank you to take part in the course and we will be meeting in the next lecture.

Thank you.