Structure, Form, and Architecture: The Synergy

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Lecture – 16
Structural Typology

Hello everyone. Welcome back to online NPTEL course on Structure, Form and Architecture, The Synergy. Today, we are at lecture number 16 and in this we will talk about the Structural Typology. So, in the last lecture, we have discussed about different material and their you know pros and cons, and also we discussed about different properties. So, looking at their property and then advantage disadvantages, so time to time we develop different structural arrangement.

So, in earlier lecture we have discussed about like post column, post slab, wall slabs, so this kind of different structural arrangement that bring in practice and we create the overall structure. So, in this it will be another interesting lecture where we just you know discussed about different type of structures and then this lecture will be basically a summary or may be a you know what we can say that a very brief introduction to different type of structural system and slowly we will pick up one by one and we will discuss on that and their application.

So, let us start this particular lecture. So, if you like try to make structural category, so it is very tough. We cannot really have a single category of a structure because you know when we discussed about the structural form that time also we said that structural form is something like not really giving the clear picture its better the structural system because building may have more than one such structural system.

So, one may be predominant, but the other is also important as well. So, looking at that position, looking at the material used, so in this particular lecture we try to divide it in 5 categories.

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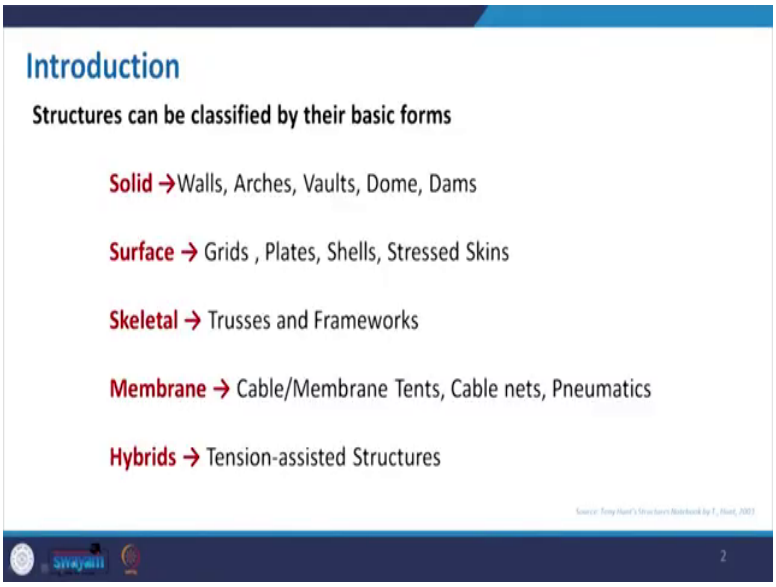

What are those categories? The first one is a solid type structure, ok, the second one is surface. So, then we talk about something having lower thickness and then the skeletal is basically similar to the skeleton. So, the given the back bone and then the remaining part of you know overall building is just to protect the environment or making privacy and etcetera like the frame structure and all.

Then also there is a category called membrane structure where we normally will be talking about the you know tent, the cable, some pneumatic structure will discuss on that. And the skeletal it is the framework and the truss different kind of truss, we will also discuss each of them in separate lecture to know more about that, like how they really helping us, like how they deal with the applied load where the compression will develop, where the tension will develop, how it will act against the bending and the shear.

So, we will also discuss on that. But for this timing we just try to figure it out. So, when we talk about the solid so, we just can collect it with the wall, then the arch and the vault and then you have your you know what we call the dam. And then the when we talk about the tension assist structure, so it is hybrid. So, not coming into the single category it may be something like which is the hybrid of multiple such structural system.

So, we use the membrane, we use the like some skeleton and then we just make a fusion of that. So, that is basically what we can say the classification into the category.

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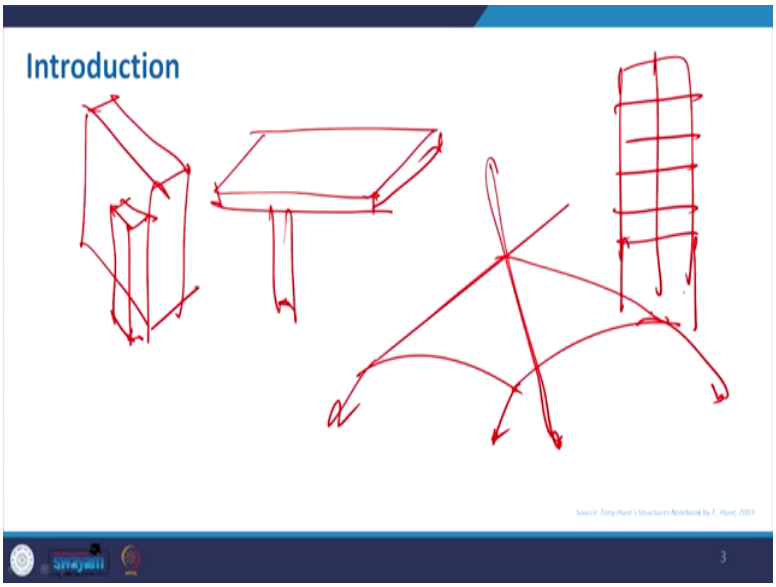

So, in this before we really go, so solidity. So, it may be what we just told, like this is the walls the wall structure, then you can support it with some batteries in you know like you know earlier in history we have used it when you talk about a like the surface. So, we are talking

about different you know please or the slab or you know the connection between your column, post slab kind of combination.

So, this is another typology. When you talk about the membrane, so basically we are talking about to different you know membrane structure which is anchored some here and may be supported with the mast. So, this is in this category. And then if you go for a like the skeleton structure, so it is basically the frame that we make the composition of your horizontal and vertical components. So, let us discuss with some examples. So, it will be clear to us.

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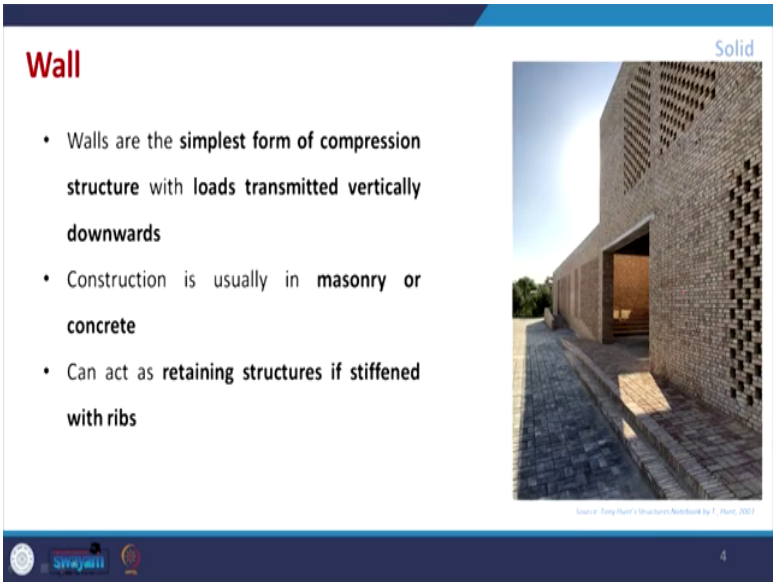

So, in this wall are the simplest you know form and basically it is the compressive structure and the way they will transmit the load is basically you know towards the gravity. So, whenever we create any building and also finally, whatever load imposed on it we will transmit

to the foundation, it has it may be the safe foundation for the load bearing or the isolated if it is something made of the you know other type of foundation.

So, it transmit the load vertically downwards. The construction is normally the masonry or in concrete, so when we talk about the brick wall or the stone wall. So, it is related to the masonry. So, they put brick or blocks on the motor (Refer Time: 06:31) and they form this particular structure. And can also act as a retaining structure if we properly ribbed it with the reinforcement. So, nearly where we want that retaining structure may be at the bank of the river or may be somewhere in the hilly region where to protect the landslide.

So, wherever we require, so similar kind of retaining wall can also be used. The sheer wall can also be used in this category if which basically is showing a mass and a solid profile sectional profile of the structure and hence it is coming under this solid category. So, here you can see a example random example that I have taken. It is mostly the world you know you know the nice masonry work that create all these you know openings and all. So, over all aesthetically it is looking very pleasing as well as it is also solving the purpose of the structure.

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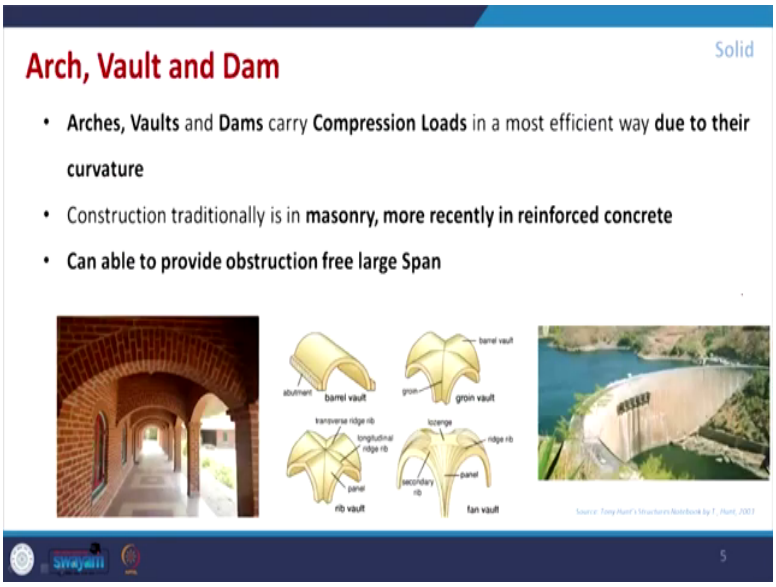

Come to the arch fault and dam again arch is again a very useful like what we can say the compressive structure where due to its curvature it transfer the load. So, load is very well transferred and because of the symmetricity, symmetry of this arch it will transfer the load to the you know the supporting column and then it transmit the load.

So, as to with the vault where we can also get this kind of you know compression mainly in this category, and the semi true for the dam where it is being built very huge and it may make of something like concrete, the retaining wall or maybe sometimes in earlier it is just like a masonry. So, it is under the profile of the solid structure as a typology.

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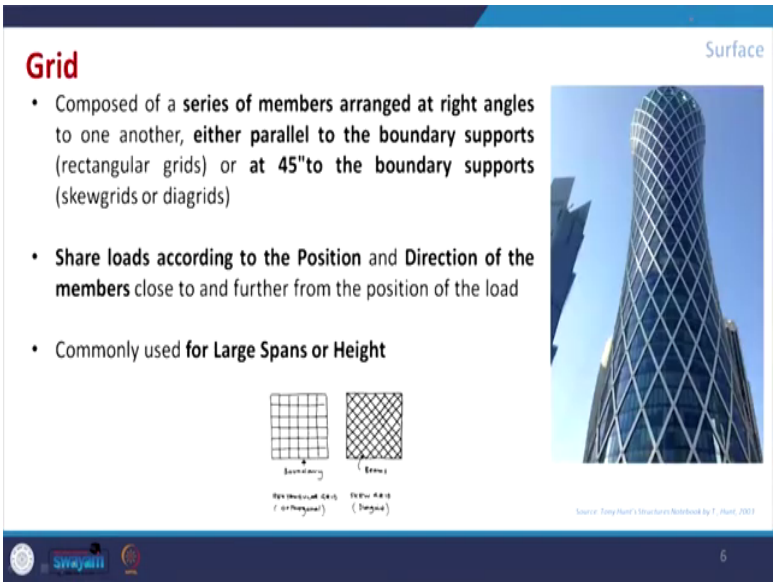

Now, come to the surface one in this basically it is not that much solid. So, what grid says, that it is a series of members arranged at right angles to you know one to each other to form the grid, ok. So, it is arrangement, but depending on the arrangement we may have a regular or rectangular grid like this or maybe we have something which is cute and sometimes in 45, so that may be a diagonal grid. So, basically whenever we design a building, so we design the beams, layout support to the column in different way out.

So, we make the grid and this grid you know this particular frame structure will really help us to make multi storey. So, in this grid will decide about the span and also it decide the direction how load will be transferred. So, the share, it shared the loads according to the position and direction of the members which are close to it, which are away from it.

So, if I take say one squares slab in a grid, so basically if load is imposed here, so how it will be distributed is basically distributed like this. So, it will transfer the load to the beam and it is very you know very systematic manner. If the material is very homogeneous and all the columns designed to support it are equal in size, so it will also be distributed very uniformly provided that it is uniformly distributed load.

But whenever this point load it will self adjust to it position. So, it is also can be used for the last pan where this grid can be formed and then also for the height. So, here you can see one of that like how grid been used in this structure.

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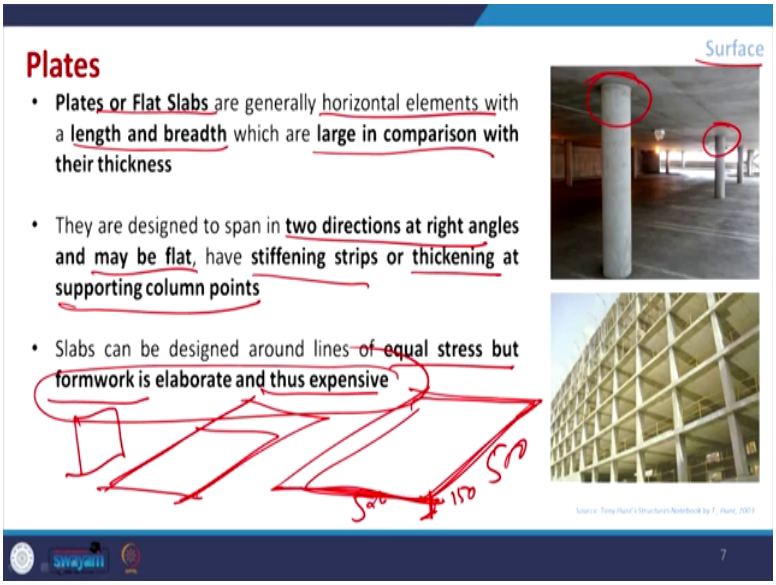

Come to the second example a under the surface where it is basically showing about what we discussed earlier also that is your post slab connection. So, you can see that there is no such beam or something just you the slab is resting on the post or column. So, plates or flats slab

are generally horizontal element as because we call it slab and with the length and breadth. So, this is we just define it with certain area and its large in comparison to the thickness. So, this is how you can define it.

So, whenever you know think about say 10 with say 5 meter by 5 meter grid, so thickness is compared to that is 150mm, ok, so where it is 5000, 5000. So, it is like that even it can be higher based on the requirement and the material used. They designed to span in two direction at right angles and maybe flat.

So, sometimes you know it is how you go for it, like it may be something we call we will come that like the one way slab or two way slab and depending on how we design this particular thing like length is too big or maybe it is having equal share all the side like square is form, and then stiffening strip and you know the thickening at the supporting column points that will also determine the characteristics of this plate.

Slab can be designed around lines equal stress, but formwork is elaborate and thus expensive. So, we can really go for this kind of grid, but basically if that means, in the proper calculation, that competition to be done and then also we have to decide about the formwork or the supporting work during the construction when the concrete and other thing is in is initial setting in the semi liquid form, then we have to take care of this.

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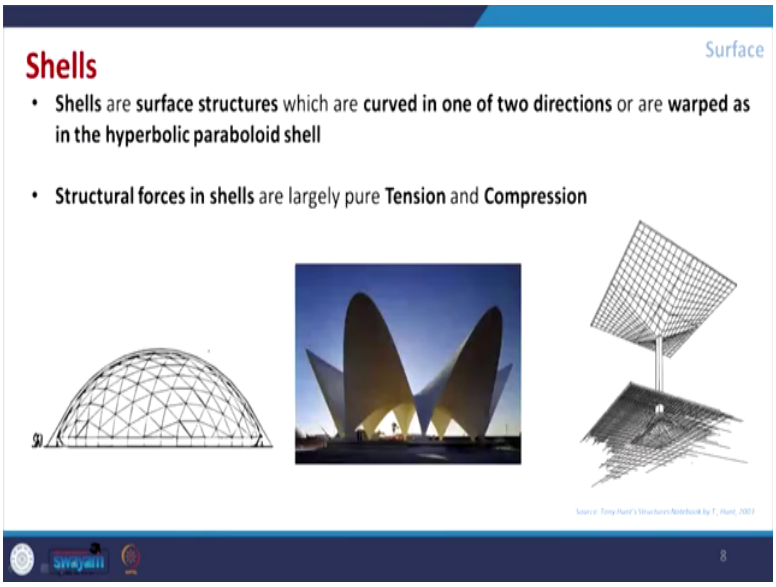

Come to the other surface category when again the thickness of you know that particular form is so negligible compared to the span it can cover. So, shell or the surface structure which had curved in one or two direction, so like it is may be of say something we just bend a piece of paper in one direction like this, ok. If I draw it correctly, so something like this.

So, we just bend it give a form of a halt, so that is one or it may be like two directional where we think about you know in this case that one curve is in this side the other one is this side. So, like we play with the parabolic hyperbolic or hyperbolic paraboloid form that you know if you find the work of helix candela we find that kind of use of the curvature.

So, in that this curvature will help us to also you know resistor load implied on that and also it can crease the huge span and also like due to the thin you know this particular shell can help

us to design. So, you can also think of a dome where it can developed it. So, in this case a like the hyperbolic paraboloid shell being used in many buildings that we can see.

The structural forces in shell are largely pure tension and compression. So, basically in this case what we have that a surface where this will be in compression this portion and then at the bottom one it will developed engine. So, it is to be understood like if you take a particular you know such kind of domical shape and you just put pressure on that or you take one eggs.

When we discussed about the shell structure I will really show you some of the experiment at a small scale that how we understand where tension and compression will take place. So, this is another typology under the surface.

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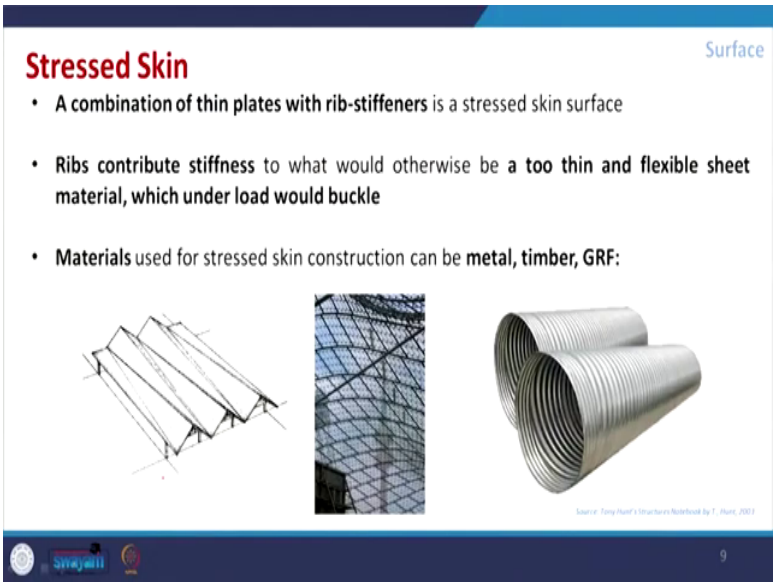

Now, in this case this is surface where it is the stress skin. So, what exactly; it is basically not a flat one, but it is relate to something where we already have seen like the folded plate. So, already it is a combination of thin plates like how you and the ribs or increase the steepness of that material.

So, it may be some corrugated you know metal pipe or it may be something where it is a membrane kind of structure. So, ribs continue contribute steepness and also like what we can get out of it the you know thin and flexible sheet that can also you know we you know acting better due to the applied load.

So, depending on the material, availability and the purpose will pick up these kind of stressed skin. So, here what says; the materials used for stressed skin construction can be metal, timber or GRF. So, basically in this case like wherever we can really do this experiment, but at the same time we can also use the you know concrete in this case, but properly it should be ripped or reinforced in this case. So, it is again from the surface example.

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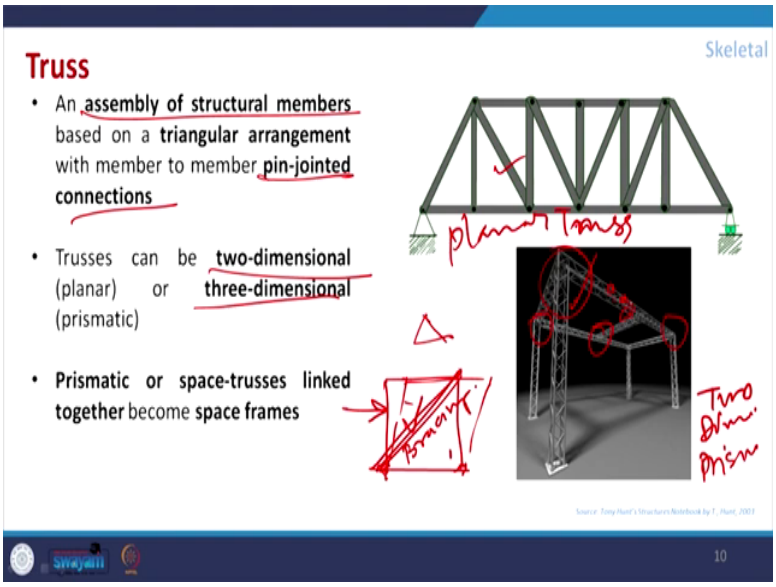

Now, come to the skeleton. So, this is a very useful you know component under that that is the truss. So, truss is basically assembly of structural members, ok. So they are joint together and mostly they are joint together with a pin joint, and this is to be formed in a triangulation form. Because, to start with suppose we have a portal like this where they are fixed, so on applied load what happened that it will try to you know get a deformation.

The moment we put a diagonal, ok, so automatically these due to this triangulation, so it will be more you know it will develop more resistance again applied load and this particular arrangement the bracing we call, help the structure to get you know beta stability.

Trusses can be two-dimensional, like normally this kind of two-dimensions truss been used for the factory or some old historic building and it may be three-dimensional and then we call it prismatic and when it is two-dimensional we call it planar. So, here this is the example of

planar truss and here it is true two-dimensional you know or prismatic. So, here you can see this basically you know this kind of structure where the cross section if you see that will give a form of a prism.

So, form that it is derived as prismatic, so for any cultural event some concert you know you must have seen this kind of arrangement where with the minimal area this is so stable. So, this is one. So, prismatic or space truss link together, so when we use this 3D cross it will give a form of space frame. So, space frame is another important you know structural typology being used to have a light roof and especially for a gathering or maybe station or an airport.

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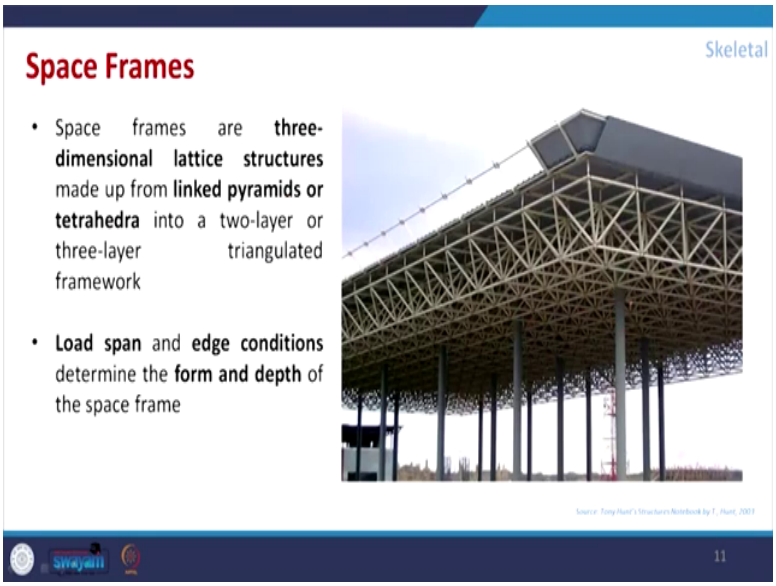

Now, in this case a like this is a one example of the space frame. You see like how they are joint to each other. The load transfer of this space frame how the transfer is complicated to be

designed very accurately and you know then you have to apply it and there are few supports, so that you can see that the how much span and the height it can cover.

So, space frames are three-dimensional lattice structure linked pyramid or tetrahedra. So, basically tetrahedra is where all is you know (Refer Time: 19:29) they are equidistant to each other. So, that is one important. And it is giving a very good stability in state of a pyramid of different height and all.

Now, load span the edge condition determine the form and depth. So, definitely like how you really try to fix it up, how you transfer the load based on that this will be designed. So, this is another skeleton structure typology that being used for the building.

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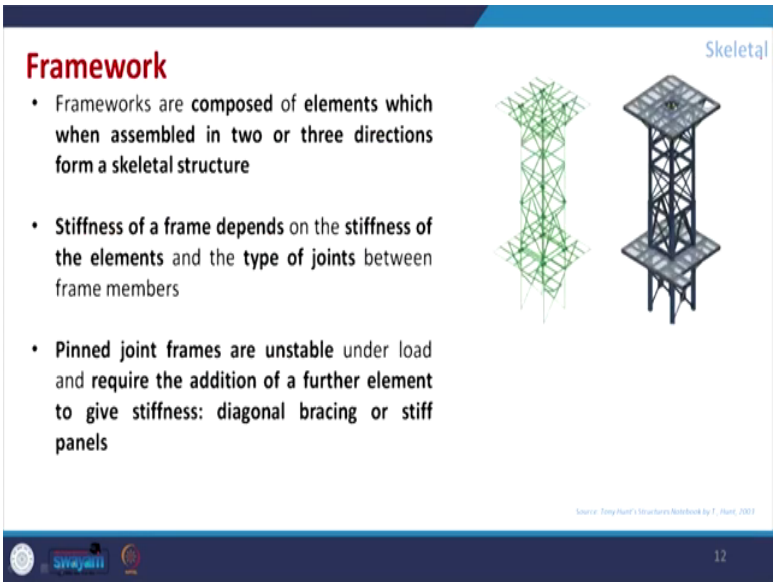

Now, come to the framework. So, here again it is a composed of materials which assembled in two or three directions. So, we just try to make a box, so it may be something like we just connect this part and then this part or maybe they are connected to give more rigidity, more stability with this bracing.

So, stiffness of a frame depends on the stiffness of the element that we used. So, how you use this particular material and like this member or this element to that system that will determine the stiffness. The pinned joint frames are unstable under load and require the addition of further element to give stiffness like diagonal bracing.

So, what we discussed, like we can have a frame like this just simple frame and they are pin joint, so they will definitely deform and then if we add this, so it will be stable. If you go for a cross bracing, so it will be more stable to that. For high raised buildings its lateral force is concerned due to the wind and again due to the seismic act activity the oscillation, so this lateral movement of the structure you know it is very important for high rise, but for specially considering the wind blow at higher you know altitude, so this kind of bracing to the framework. So, definitely help us to come up with better solution to resist our building against that kind of applied load.

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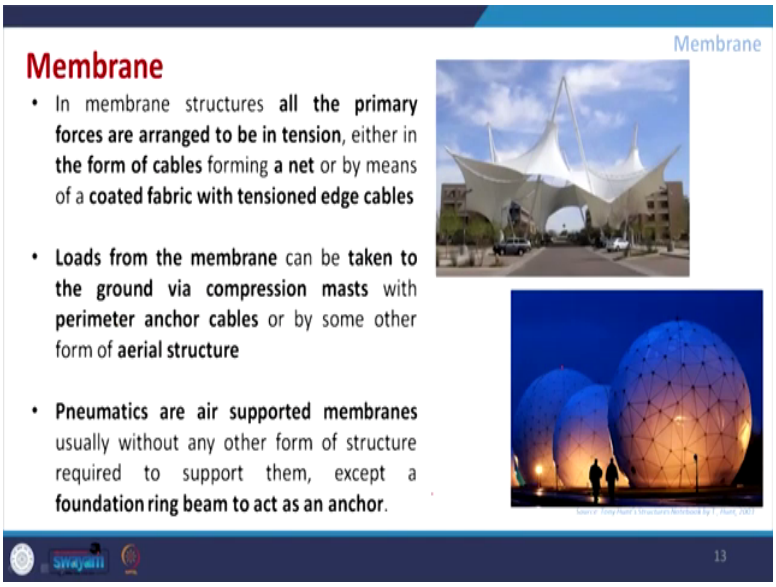

Now, come to the membrane, this is a type where it is already being discussed and this example from the (Refer Time: 21:46) state university campus being so repeated, so nice construction with you know some kind of you know cloth like material. So, it is fully given the tension. So, with this you know tensile cable and this you know the mast that use is at only act as the compressive members.

So, in membrane structure all the primary forces are arranged to be in tension through the cable and the form cables and or a net and coated fabric with tension edge cable. And whereas, the load from membrane can be taken to the ground via compression mast. So, this is the compression mast. So, they have used in several points and others all members all these coated fabric is basically intention.

Now, a compare to that the other category in the membrane structure that is the pneumatic structure where like air or some kind of liquid being pooped. So, for pneumatic it is most commonly the air supported membranes and they do not really need any other support or in his form. So, they will be created. So, you put the air and many of us we have seen such kind of pneumatic structures especially in a you know fairground or something for the kids that we find a Mickey mouse or something student a jumping on top of it.

So, it is basically a cloth or such fabric and we just inject air into it and give the tentative forms. So, this is another kind of membrane where you know the thickness of the material is nothing, but to create the form the huge space is very vital for us. There are some you know disadvantage of these about the hide restriction and in the reaction against other forces, but definitely it is one of the very you know portable structure that we can develop.

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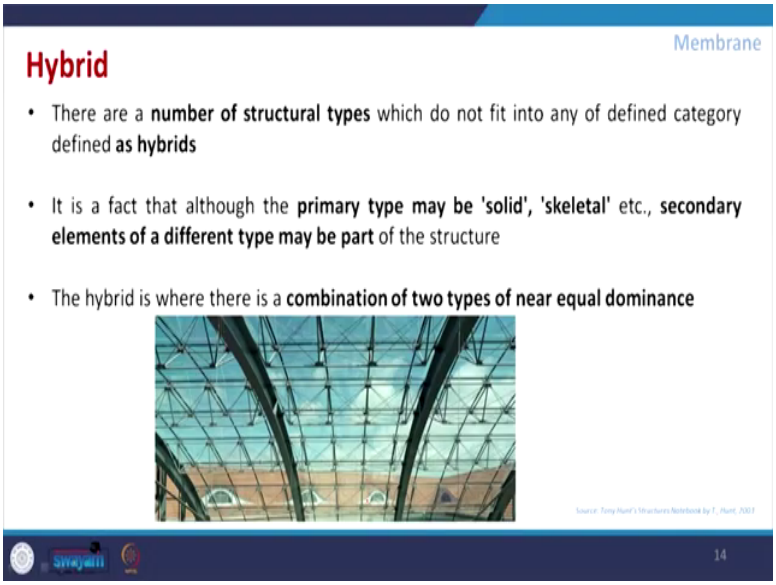

Now, come to the hybrid structure. So, we in this the hybrid structure basically where the number of structural types do not fit in the category that membrane or the (Refer Time: 24:05) like we said solid or the skeletal. So, that is coming into the hybrid category.

It is a fact that all the primary type may be solid or skeletal, but secondary elements of different type may part of the structure. So, we cannot really distinguish output abstraction in a single category. So, same example can be given in multiple category, but looking at the predominance of a structural system of all structural systems being used in this building, so we put in the category, but in hybrid there are more than one is basically the dominance.

So, here it says the hybrid where there is a combination of two types of near equal dominance. So, if you see this structure that here this particular you know glass space frame being used and as well as this still you know frame work being used. So, both are complementing each other. So, here it is coming under the hybrid category.

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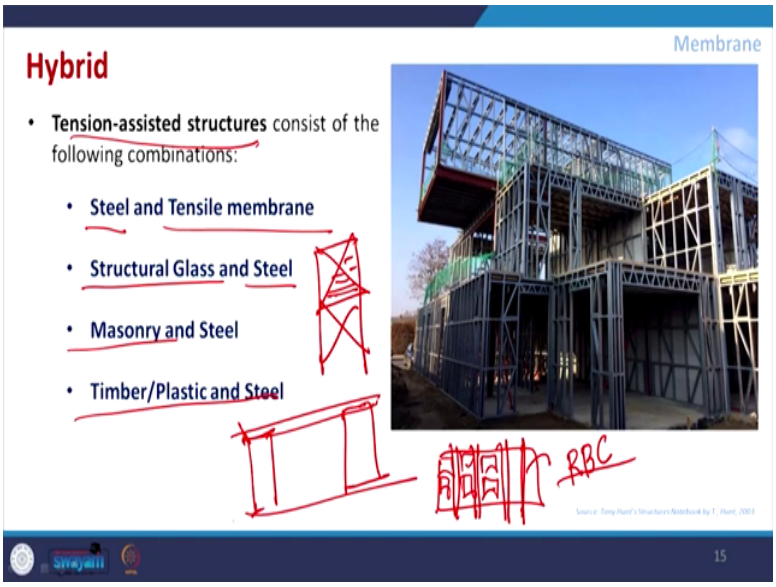

So, in that there are probably you know compositions like what we can call the tension as his structures. So, this is basically it may be a steel or tensile members. So, only steel being used as like post beam and then the cable is being used to add some membrane kind of structure to it. Then you may have the structural glass and steel as a combination. Here you can see what exactly like it is being still being used with other.

So, then in this also the masonry and steel can also go together, ok. So, this is something like where you have seen like in earlier phase that we make the masonry with the break and all, we do not really cause to the slab with a concrete or something we just use some eye section so on top of the wall of a building of the masonry with the put this eye section in layer.

So, basically if I draw the plan, so many eye sections are running parallelly and on top of it we put the tiles and that puts some you know lime concretes to make something like what we also

can call the reinforce break concrete or something or the other. So, it may be something like where we use the timber and still together.

So, in particular lecture we have discussed about like how we make the you know timber as a structural material and we make the whole building with the you know timber materials a beam column, the bracing and rest of the things that filled up by the masonry. So, it is again a combined structure. So, even in the load bearing case, so we put both together. So, this is something where like we go for making it very hybrid structure. So, this particular thing is under hybrid.

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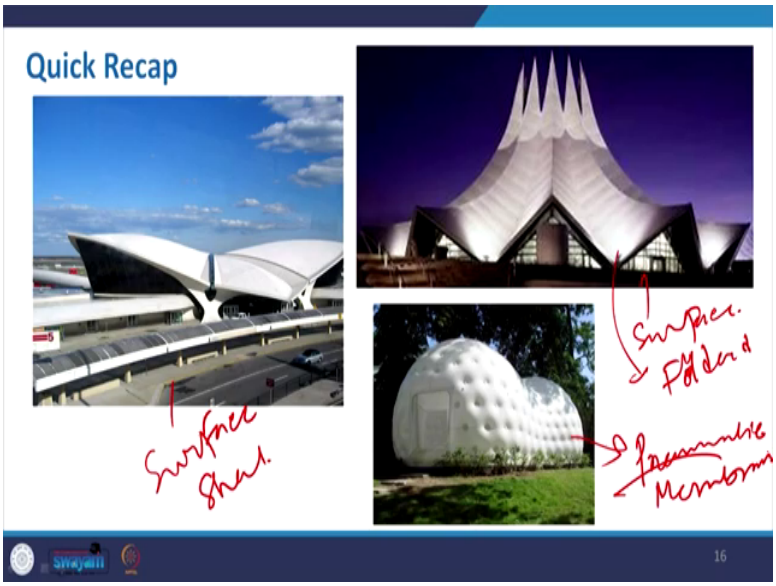

Now, to have a quick recap in this portion like let us just try to understand on this predominancy of this structure. So, if you use this particular example (Refer Time: 27:29) terminal building, so it is coming under I just give you some you know few seconds to think

on it and then let us just match whether we are on the same track or not. So, take some 5 seconds and just quickly just figure it out, ok.

So, I think all of you can give right answer to that. So, it is basically compared to the it is coming under the you know shell structure, thin shell structure and it under the category it will come in the category of surface. So, surface and shell. This is again surface, right. So, it is again surface, but in this case it is basically the folded plate and this is something looking very you know attractive.

So, it is based on the air. So, it is pneumatic. So, it is pneumatic structure and the category is your membrane, right, so ok. So, these task is done. I think all of you have answered in a similar fashion, so let us take another set.

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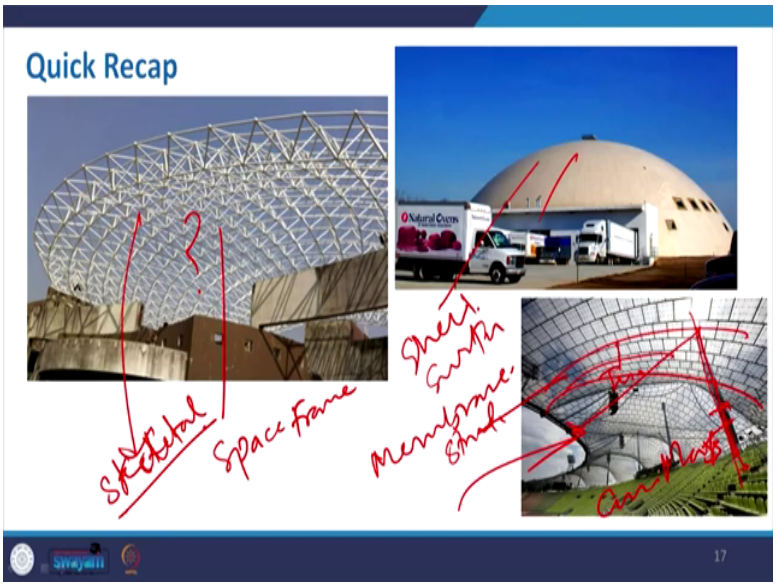

So, in this case what we see like what exactly it is. Yes, it is basically the space frame, right. So, space frame is basically coming under your skeletal structure, fine, very fine. Again this is something which is made of some concrete rainfalls and getting the dome. So, again it is coming under shell structure, and then also it refer to surface because of the thickness of that particular you know which thickness is very less compared to the span it can cover.

Now, here it is something like can you recognize this particular picture I you have used a couple of time this earlier. So, this is the Olympic stadium from Munich, and we discussed on the ground of making a light structure. So, it is again if you see that, there is post, and then the cable, and then it is basically the membrane that are looking you know this is much prominent. So, it is again a membrane structure, where it is basically give in tension and then all this load transferred to the ground through this compressive mast, ok.

So, it is compressive mast. So, we know this thing. So, now, your task is to really find some buildings that you see in your day-to-day life or maybe you have come across through different you know platform in a book or maybe in a some website. So, you just try to figure out then just put them in the category. So, make exhaustive list and share with me, so that will discuss on that in the process.

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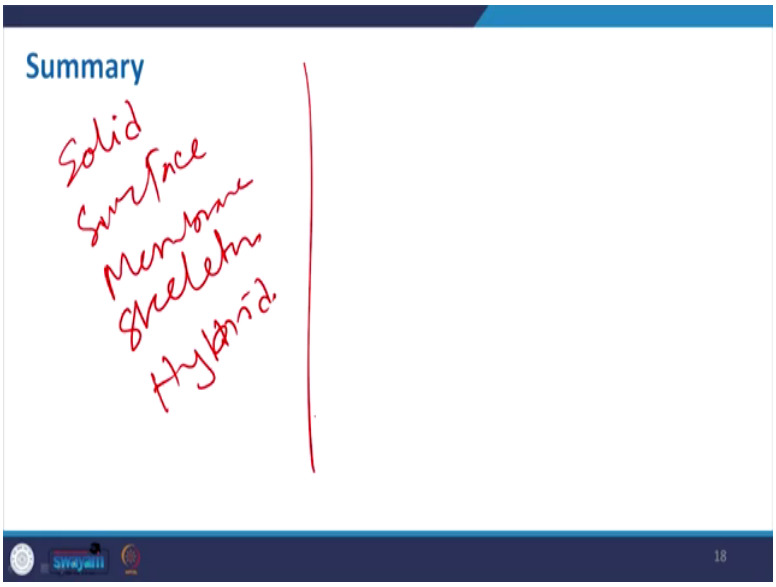

So, this is what that we discussed about this, but again the you know summary what we can say that though we have the category of solid, then you have this you know surface, then you have this membrane, then you have skeleton, then after that you also discussed what we like have this is basically the hybrid, ok.

So, this are some general form, but you know we cannot really give a single name to a building because it may consist of multiple structural system. So, but predominance looking at the predominance which is coming up in front of you will go for that. So, your task is to find or give put that building that you search for or you have already noticed in different platform to clap into together.

So, again I really thank you all to take part in this course. And, now will be you know waiting for the further discussion of each of individual structural mem; like components on that and

before that you can really go through the books that I have referred which are very useful to get more examples and also help to you know develop the idea on the discussion that we have. So, next we will discuss some compressive structuring, and till then again I would like to thank you.

Bye-Bye.