Structure and Architecture
Lecture 5

Large Span Structures

Take a look at these pictures on the screen, these are very simple rudimentary structures that we have all seen and experienced. We have even seen structures like these in the earlier videos. Look at the first image, you see a small shack with run down walls, makeshift doors and a small roof on top of that, an abandoned setting. In the next two images, we look at wooden structures, small wooden cabins which are made up of wood that are made up locally, with roofs, make shift arrangements and in the fourth image, we are looking at another similar kind of structure. If you try and analyze these earlier structures which we have been designing. The requirement of ancient structures were small. We used structures predominantly for domestic use, living, eating, praying, a very small amount of activities which did not require allotted space. Later when we moved on higher up the ladder of civilization, we required places where people need to gather and discuss ideas to govern their civilization. We needed a congregation space, that space needed to be bigger because we needed more people who needed to gather there. Then we needed larger religious spaces because we don't want just a few people in our religious buildings anymore, we wanted large number of people so that we can show to the world, the religion we follow is a mighty religion and that there are a lot of followers. Our belief system took us from one level of religious following to another level of religious observance. We wanted bigger churches and other bigger places of worship. Then, our civilizations moved on.

This picture is the view of an indoor stadium. Take a look at this picture too, this is a place where an aircraft, is coming to park after a flight. This is where maintenance, repair and overhaul of the aircraft was done. They are called hangers. Take a look at these spaces, these are large entrance lobby spaces of great large public buildings, the one below is the lobby building of an airport terminal, where you need to have a large number of people there. If you look at these pictures, if you compare the previous four pictures that I showed you to these pictures, you will realize that our needs have changed as civilization changed. We wanted large spaces so that we can accommodate larger people in congregational areas. Our transit hubs kept growing, we needed larger railway stations so that great many stations can come, great many people can be transported via trains. Our airport terminals became more bigger, our cultural needs also grew along with our transport needs. We needed large auditoriums for our cultural pleasures, we needed stadiums to watch and spectate great games. We needed auditoriums where large number of people can be addressed by one single person. Theatres, malls, shopping areas, markets became bigger markets, bigger markets became supermarkets, supermarkets became hyper markets and now we have huge malls. Our civilization has grown,

our needs have grown too. We also needed spaces where we can store a large amount of things, a warehouse, a storage unit, cold storage. These are the structures that require interestingly,enormously large space and volume.

Some of these spaces needs to be column free. By column free I mean that the space should not have any pillars or columns inside. Imagine, you are in an auditorium watching your favorite movie. Unfortunately you got the seat right behind this huge column, how sad would that be?, you would not be able to enjoy the movie. That space in the auditorium, that space in the movie theatre, that space in a vast space, needs to be column free. That is why when we got the need of large span structures.

These large span structures span increasingly longer, wider, bigger and sometimes tallers when required. Let us look at what large span structures are. Human need increased and demanded spaces that fitted their requirement. Requirements grew from simple domestic needs to mass storage spaces, supermarkets, hypermarkets, malls, auditoriums, theatres, airport terminals, aircraft hangers, etc. But how large are these large span structures. The moment you say large, large denotes a big space, how large are these structures.

A structure with a span larger than 20m, can be regarded as a large span structure because this is the kind of structure that is usually very difficult to achieve conventional rcc structure. Conventional RCC structure is the one with beams and columns, we have discussed about this in detail in the previous episodes. There is a famous thumbrule which most engineers would recommend without designing the depth of the beam if you want to find the required depth of the beam required in a particular area. There is this thumb rule that states 'the depth of the beam should be approximately l by 10 or l by 12 where l is the effective length of the span between the two columns that the beam is supporting. l is the distance but the depth of the beam is approximately l by 10 or l divided by 12. We see a structure with a span larger than 20m is regarded as a long span structure because imagine RCC structure of 20m wide will have a beam depth of assuming l by 10, 2m. 2m will be the depth of the beam that spans 20m approximately. It could be less, it could be more. If the beam size is 2m and the volume, the ceiling height needs to be more bigger because we need to accommodate a 2m deep beam. If the room has mechanical ventilation, different requirements for lightings, if the rooms needs sprinklers, conduits, carry pipes, conduits and other service related elements, if you need cctv cameras, if you need other service related components which are to be fitted on the roof. All of these must be accommodated on the roof within the false ceiling. None of these can actually pass through a beam in normal circumstances. If there is a conduit that needs to pass through a beam, the structural engineer needs to design the beam with a hole which is increasingly difficult. If we are not doing any kind of special consideration, we need to take the conduits, the air ducts, the other pipes, cable trays, everything beneath the beam that will occupy some

amount of space. The false ceiling itself occupies some amount of space. Together if you are designing a 20m wide shopping mall area, your services would come close to about 1m and your beam depth is approximately 1.6 - 1.8m. The total unusable space is close to 3m from the finished floor above to the bottom of the false ceiling. The space which is not technically being used for habitation is close to 3m. We cannot afford to spend 3m of height, every floor for non-habited space. That is why, we needed long span structures to reduce the depth of the beam to make sure that your unusable space is at a minimum level.

Types of Large Span Structures

Types of large span structures - Rigid element structures, Suspension structures, Stayed structures and Pneumatic structures. We will look at each of these structures in detail with examples. Let us look at the first type - Rigid element structures. Just as the term describes, it has elements that are solid, elements that can span large distances, there can be many types of rigid element structures where walls or thin components of plains, rigid thin plains are used to support the large space. The second system is called the arched system where we use the system of an arch to support a large span. In our earlier video, we saw that arches can take immensely large amount of loads when properly designed. We also saw that, in an 'Arched system' compressive strengths are the only thing that matter. The tensile stresses are negligible in arch systems. This arch system when properly designed can take large loads, can span bigger distances. Cathedrals of Europe, Gothic cathedrals, Renaissance cathedrals, they were all built with arches. The next type of system is called the 'Portal frames' where this is the kind of system which is long, where there are different kinds of frames at equal regular intervals, they are three sided things and there is a roof that covers the entire structure on top of it. Then we have, 'Space systems' which have a lot of Frames which are mostly three dimensional, multiple framework that are interlaced together to form the space systems. Then we have the 'Triodetic systems'. Triodetic systems are where element or one or more of the elements are flattened and bolted and connected with other elements so that the whole joint is stable and rigid. We have the regular vault and domical roofs. We saw in detail about vaults and domes in the previous episodes. Vaults are nothing but an arch when extruded, it becomes a vault. We saw the different types of vaults; Barrel vault, Groin vault, core patted vaults, six patted vaults, fan vaults. Domicile roofs are nothing but arch which is rotated by 360 degrees, we saw classic examples of domicile roofs. Domes have been used in history to span enormously large distances and the concept of domes is now being used by modern engineers and architects to span even larger expanse. I will go to examples and explain how the system actually works in the upcoming video. In this video, we will just be looking at different types and will learn the different elements that exist in different types of structures. These are the different types of rigid element systems, moving on, to the next system which is a suspension structure system. Suspension system is again divided into two types; Cables and Membranes. A cable suspended

structure could be a plane, a double layer or a space cable depending upon how the joints are made. Depending upon the number of cables, how the cables are connected with each other. In Membrane suspended structures, it is about how the members are arranged or how the member is rolled upon to get the structure in a single stable position. It can be cylindrical or in an ellipsoid shape. If you look at the pictures, you can see different cables and how they are connected. This is a fork swaged socket, this is a thimble where the cable is rolled and tied up here, this is a U clamp and these are other types of clamps which can be used in other membrane types of structures. Next type of structure is the 'Stayed Structures'. This is divided into two types, they can be rigid or suspension structures. The picture on the left is of the hanger building, the picture on the right is the Olympic stadium in Munich, Germany. We looked into the difference of stayed structures and suspension structures in the earlier videos in bridges. Right now if you have doubts about stayed structures and suspension bridges, you might have to go back to the previous video, video 3 where we dealt with different types of bridges. We looked at different types of bridges and the difference between stayed bridge and a suspension bridge. This works in pretty much the same way. It is the same concept which is being used in a large span structure, instead of a linear spanning structure. The difference between a linear spanned structure and a regular large spanned structure is a bridge that only requires people to move from one point to another point, usually over a river or over something which cannot be crossed with ease. Bridges are usually thin whereas large span structures have the same length to achieve but also wide enough so that large number of people can be gathered in that particular area. An olympic stadium is a very great example of that particular type because again, a large number of people can gather to spectate a particular event. Moving on to the next type, we have 'Parallel cable structures' where if you see the two images, these are the cables that support the roof. In this diagram, you can see that the cables pull in so that the structure can be maintained at this level. Same thing happens here too. The cables are pulled in so that the structure can be maintained at this level. Same thing happens here too. The cables are pulled in so that the structure is maintained at this level. These are called parallel cable structures. This is another type of large span structure where the cable structures are formed by an arch. Starts out with simple arches like the ones here, planned section again. You can move on to producing complex forms by arranging simple arched structures from complex forms to more complex forms to more larger, bigger areas, it can be used to span large amount of areas. If you look at the classifications, we have classified the large span structures based on function. When the size varies, when the width varies, height varies, volume varies because based on function every space needs to have a different space dimension, different volume, different heights and different dimensions. Based on the different heights, different dimensions, based on the volume, the type of construction that is required also changes. For a normal 3m by 3m room, RCC roof would be ideal. The roof could be made of any material, even wood, stone, even brick. Bricks when arranged in a herringbone pattern, on

wooden logs placed at regular intervals can also become a roof. For smaller structures where height is also small and the spans are also smaller, we can use large number of materials. We have a variety of materials that can be used to span smaller structures. But when the size increases, when the volume increases tremendously, we require more complex methods to solve it, that is why we have different complex structures. Take a look at this span, again a different kind of cable structure is formed by an arch. Here, in both the pictures, you have a similar arch arrangement and the picture on the top, you have panels that are being used as roof covers, mounted on top of the arches thereby forming a big space, this kind of a space, this kind of volume is ideal for aircraft handlers. If you look at the picture below, the framework is the same, except that the height of this arch is greater than the other, the systems are the same but the roof element instead of putting panels directly on top of the arches, they are suspended from the ceiling, from the arches, that is how this ceiling has been formed. This type of structure has been used for warehouses, can be used for auditorium purposes, the advantages of the bottom image structure over the top image structure is that if the structure needs to be air conditioned, the volume of air conditioning required in the picture below is much lesser than the volume of air conditioning required in this image. It is another reason why the height of this arch is more than the height of the other type. Using the same skeleton, the same construction methodology, we can now see how different typologies of buildings can co-exist under the same type of structure. Moving on to the next type, this type is called tented structure. We saw what are tented and masted structures in our earlier videos. This tented and masted structures are used in number of ways to span large distances. This is an example of pneumatic structures. Trusses are also used to span large spaces. Folded plains are an excellent example of how large span structures can be formed. If you look at paper, if you want to span or support loads with paper, it is very difficult. Paper are bendy but the same paper can be used in a different way, if the paper is folded in a proper fashion. This can be used to take enormously large loads. Imagine two thin slices of paper holding up a book like this. Well that is the magic of structural engineering. Then we have shell structures, which are again used to span large areas. We have come from spanning large areas by arches and early cathedrals to spanning larger forms such as this to great span structures, interesting steel structures.