Structure and Architecture
Lecture 3

Tent

The picture you see on the screen is of a simple tent. Let us try and defend what a tent is. A tent is a shelter consisting of sheets of fabric or other material draped over or attached to a frame of poles or attached to a supporting rope. While smaller tents may be freestanding or attached to the ground, large tents are usually anchored using guy ropes tied to stakes or tent pegs. A tent is very simple. Take two poles, attach them firmly to the ground. Once you attach them firmly to the ground, tie a rope through both the poles, once that is done, we should put a sheet of fabric, any other material on top of the guy rope making it a conical structure or a prism like structure. Pull the fabric apart, pin it to the ground using pegs, you get a tent. If you see the tent, they are essentially two important parts. Obviously, you see the fabric which is the blue colour in the image, the one on the top. Second part is the frame. Here, interestingly the frame is made by this rigid pole which you can see right in the middle of this picture. Any tent will have these two parts. This is a modern camping site, where these are modern tents that have the extension of the same concept of a fabric pulled over a particular pole or a structural frame. A fabric may be made from any material including cotton, nylon, felt and polyester. If you could see, traditionally cotton tents are over used. In cotton tents, it is admirable that wet cotton is more waterproof than dry cotton, I'll explain why. Take wet cotton for instance, a wet sheet of cotton material, the advantage lies in the micropores in the cotton yarn with these pores being covered with water droplets, this forms a waterproof layer. Traditionally, people also used to use paraffin, wax and other materials to make it more waterproof and modern day materials also used Silicon impregnation or polyurethane coating on top of this.

When canvas is being stitched, when two pieces of canvas are being stitched, there are these minute holes that come out of the stitching and these holes traditionally allow water to come inside but modern day stitching methods have different sowing methodology that also have water proof techniques.

Next, is the frame. The frame is the one that provides structural support. Some designs use rigid poles, typically made of metal or wood. Other designs use semi-rigid poles typically made of fibreglass or sometimes of special metal alloys, steaks or screws maybe used to fasten the tent to the ground. These are the stakes. Sometimes the guy ropes pull outward on the poles and help shape the tent or give it additional stability. These are the poles, pole number 1 and there is a pole number 2 right here which we are not able to see because the tent fabric is covering that. There is a guy rope, this blue color rope is passed and pulled outwards, they are the ones that actually help shape the entire tent. Using these steaks, this guy rope is attached to the ground firmly. Now, this tent fabric is put over the guideline and pinned again with stakes on all the corners. These little pegs or stakes, can be made of metal, can be made of plastic, wood or any other suitable material. This is a generic, simple way to make a tent. Now let us see how does a tent work structurally. If you look at tents, they are the exit opposites of arches. If you see arches, we learnt in the previous episode that, if you put a load on top of the arch, the primary load is taken by the key stone and from the key stone the weight of the above material is transferred on either sides. From one stone to another, the load gets transferred from the top till the bottom of the arch with pure compressive strength, there is no tension on the arch which is why arches were discovered early and it is one of the best forms of structural expression. Whereas, the tent is an exact opposite of what an arch is because tent is a pure tension member whereas arch is a pure compression member, except for the tent pole which has slight compression on it. All other parts of a tent are all completely tension members. The Guide wire, they are pulled apart and then they are pegged onto the ground. The tent fabric, put onto the guy rope, pulled on either sides, on all the four corners so that they can be pinned onto the ground. In that way, every part of the tent is a tension member.

There is another concept called tensegrity which we need to understand at this point of time. Tensegrity is an important concept which we should learn at this juncture. It was a concept which was formed by architect Buckminster Fuller, in the year 1960. This concept is also called tensioning integrity in simpler terms, it is also called 'floating compression'. It is a structural principle based on the use of isolated components in compression inside a net of continuous tension, in such a way that the compressed members(usually bars or struts) do not touch each other and the prestressed tensioned members usually cables or tendons delineate the system spatially. Tensegrity structures are usually more of these struts and are arranged in such a way that none of these struts actually touch each other. It is essential that we understand this because a very simple or rudimentary form of a tensegrity structure is what is expressed in the form of a tent. There are two poles which act as struts, don't touch each other and these struts are entangled in the guy ropes, the fabric, the other elements that make the tent, this is how the tent structure is formed. Tensegrity is actually an advanced principle which I am giving you an insight about because this juncture has a micro level of tensegrity structure.

These are the different types of tented structures. These type of tented structures on the left are called A bell tent, they were predominantly used by the British during the early wars and this tent on the right is a Kohten tent. Kohten tent is a typical German way of building a tent. Here, this tent on the left is a Sami/ Goahti tent or Laavu tent which is used by nordic people. Nordic people are people who live in the Scandinavian region, they have access to wood, sticks and skin. This tent is made up of skin and wood. One on the right is called a Finnish Loue tent. This tent is not a completely covered tent, it covers only one side of the tent and on that side, it is usually the side where the wind flows. A Finnish Loue tent does not cover the entire perimeter of the area. It cover only one major side. Usually the side where the wind blows from because in Finland the winds are very harsh. Even if you build a fire, the fire is bound to get extinguished by the cold winds that blow. You need a Finnish Loue tent to keep the fire burning and so that the fire does not completely get extinguished by the winds. A Person can comfortably sit or sleep beneath a Finnish Loue tent with the fire burning right next to him, giving him some warm comfort. A Finnish Loue tent is very simple, it has only three parts. There is one pole which is kept at an angle and the fabric is stretched onto either ends and it is penned using kegs, here and here.

This tent on the left is a Tibetan Nomadic tent and this tent on the right is something which is very common to us. It is called a Pandal. We have seen Pandals in India for a very long time now, during festivals, during processions, during weddings and a lot of other ceremonies across India. All we need is a typical garden that we could turn into an ideal wedding spot, into a fair, an exhibition centre or as a place where a religious function is being held. Such is the specialty of a tented structure. A tent could typically comprise of one or two people or it could be as vast as it could contain thousands of people. Even a circus is traditionally conducted under a tent, its called a circus tent.

This tent here is a very interesting tent which is called the Sibley tent. It was designed by a person called Mr. Sibley. This is a very different tent from what we have seen earlier because this tent usually is constructed over a tripod. All the other tents require a guy rope but this tent does not require a guy rope, it is put over 24 little pegs and the fabric is stretched and the other thing is covered and right in the middle of this tent, you could start a fire, put a tea kettle or heat something over it. Usually the top of this tent is covered with a little structure that allows the smoke from the fire to release.

Let us look at larger tent like structures. Larger structures like this, this is the picture of Denver airport, it is inspired from a little tent and the whole structure of the airport is comprised of many such tents but this type of a large structure are not called tents anymore because tents are typically small. These structures are now called tensile structures. Another big example would be the O2, the Millennium Dome as seen in the picture. This building was designed by Sir. Richard Rogers, this is in London. This was constructed by tensile fabrics, the fabric is stretched over these members and henec, this entire big dome was formed, this is also a tensile structure.

We were talking about the principle of Tensegrity and this bridge 'Gunpla Bridge' is the largest tensegrity structure in the world, it's in Australia. Look at how the tendons, the struts, at how the tensile members are arranged here. Each member will never touch another member and look at how the entire bridge has been formed. Such an engineering marvel. This is one of the few places where true architectural geniuses and true genius structural engineers make.

Bridge

Let us move on to another interesting subjects called 'Bridges'. A Bridge is a structure built to span physical obstacles, without closing the way underneath such as a body of water, valley or road for the purpose of providing passage over obstacle. There are many different desigs for many different purposes to be applied in different situations. The picture on the right is the Iron bridge, the first ever bridge made of iron. Hence the name, Iron Bridge. If you have been wondering how bridges were built earlier, think about the smallest and meanest little stream that you have crossed on your recent trip to the Jungle. If you have been to the jungle, the stream is about is 2 feet wide, so you can't do a long jump and cross it if it's more than 2 feet long with all the materials that you are carrying, at least not for little children and aged people. How do you cross that little stream? Take a log of wood from nearby tree or area, put it across the stream, walk over it. Look at the pictures, they are simple series of planks arranged in this fashion could span this entire area easily and this material is made of one single material so that one single material structure is called homogenous structure and hence the entire structural integrity is unquestionable. For a reasonable weight like people, one or two people can easily cross the bridge in one go. Such is the simplicity of very basic rudimentary bridges. These bridges don't have a specific name but they can be referred to as span bridges. If you want a name, you can call them as span bridges, but other than that, they don't have a very specific name as such. Look at some of the early bridges, the picture on the right is a living rude bridge in Meghalaya, if you look at the evergreen forests in North Eastern area, in Meghalaya and Shillong area, there are these bridges made from roots and vines from the trees and the trees and roots are living. The bridges that span small, tiny rivers here, tiny strings, the bridges themselves are living. You'd be able to see the entangled mess of all the root, bridges, that are present, people can walk very easily on top of these bridges. Now, let us discuss different types of bridges, structural classification of different types of bridges. Based on structural classification, bridges may be of many types. We have always been looking at these types of bridges and we can easily recognize these bridges once we see. The simplest of this type is the Beam Bridge. A beam bridge is nothing but what we saw in a rudimentary bridge here. This is also a beam bridge in a way because this is a single platform of homogenous material that is being kept over two supports, so this log of wood here acts as a simply supported beam. This is also a type of a beam bridge. This is the beam bridge, there is a water body down and these are the two ends that need to be bridged and this black thing here is the beam that we are talking about. Typical beam bridges could be like these. These are columns and beams that connect that these columns. On top of these beams, your trains, railroads, roads, they span the entire sea, oceans; they are bridges across oceans and rivers. This is another beam bridge which is built across a road, look at the supports on the side and the beam.

The next type of bridge is the 'Truss bridge', which is a very common type of bridge because a truss is a very easy element to build especially with little steel members. All the members in a truss can be easily mass produced in an industry and the connections are very simple and can be designed easily. Trusses can take huge loads when it comes to integrity and structural strength. Let us look at a few Truss bridges. There are different types of truss bridges, there is a War and trial, Verendian trial, a lot of types of Truss bridges and these are a few of them.

The next type of bridge is called a Cantilever bridge, a Cantilever as discussed earlier in our previous episodes, is when an element is supported on one side and free on the other side. This type of bridge has two cantilevers, one on this side and another one on this side. Here it is supported on this side and it is free on the river side. It is supported on the peer and it is free in the middle. Examples of Cantilever bridges are these. If you'd notice the fourth bridge i.e the picture in the middle, this is a support, here is the truss and this little part here is actually cantilevered from these bridges. Hence, this is called the Cantilever bridge. If you see how this bridge works, this is how it works. These are the two Pile ons, this is a simple truss, this middle portion here is a cantilever portion. The loading pattern is pretty simple here, all these green colour members have compression acting on them, all these red colour members have tension acting on them. Look at these green colour members, these pile ons are purely compression member and these bottom arms again have compression because there is load acting on either ends. These top arms are on tension because there is load acting on the ends. In this Cantilever, all the cantilevers are always such that there is tension in the bottom and compression on the top. This little part is cantilevered from these two portions.

The next type of bridge is called the 'Arch bridge'. Arch bridges have been around the world since time and memorial. Ever since an arch was invented or conceived, arch bridges have existed. It was simple, easy to build, easy to replicate and it was best used for democratic kind of a structure because if you want to use a large number of people to build a bridge, you cannot have all engineers because engineers are very few people and since they had a lot of labourers, it was easy for them to replicate since they had to design only one particular thing and it can be replicated n number of times. This is another reason why the Romans, the ancient Romans built a lot of these arch bridges. They built bridges over water, aquadecks, they built bridges so that little chariots and horses could pass through. They built aquadecks so that water can be transported from one part of the country to another. Let us look at a few examples of Arch bridges.

Next type of bridge is the 'Tied Arch bridge'. It is also a type of an arch bridge but from this arch the actual bridge portion, the place where the person walks or the car moves is actually tied to the arches. Let us look at examples here, this is a tied arch bridge.

The next type of bridge is the 'Suspension bridge'. We did see a suspension bridge earlier in this episode. We saw how ropes were suspended from a thicker rope and that is how the whole bridge is supported. Let us look at examples, the most famous suspension bridges of all is; the Golden gate bridge in San Francisco. These two things are called the Pile ons. From these pile ons, there is this major rope that runs like this. From the major rope, there are these little ropes which actually keep the bridge up. Other examples of suspension bridges. Suspension bridges can be built to span a very long distance. Look at the distance, this bridge spans. Next type of bridge is called the Cable Stayed bridge. There is tiny difference between a cable stayed bridge and a suspension bridge. In a suspension bridge there are two pile ons and there is a major rope which is connected between these two structures like this. This is very similar to the guy rope we saw in tented structures except for the fact that the pylons are very far apart than in a tented structure and in a suspension bridge you see this rope but in a cable stayed bridge, you don't see that rope except that these pylons are comparatively larger than what we saw in suspension bridges. There are cables from the top of these pylons which actually pull the bridge up and allow it to stay in place. It is the cable that enables the bridge to do so, hence the name 'The Cable Stayed bridge', you see examples of cable stayed bridges, a very famous bridge called Mila which is not in the pictures here, Mila designed by Norman foster was also a cable stayed bridge. Let us look at other types of bridges, a very interesting type of bridge is a moveable bridge. Usually when a bridge is built, it is built on top of water and the water is also used as a means of transportation. Usually boats and ships move across waters and large rivers, so these waterways also cannot be disturbed. So when you put a bridge on top of a river, it kind of obstructs the movement of ships and bridges. How do you work this thing around? If you want to work around this, what we need to do is, build a bridge that's editable, that can be moveable from one place to another or can be changed such that both roadways and waterways can happen via the same bridge. The famous London bridge is a moveable bridge. If you look at this bridge, it is actually a tilt bridge wherein this part if you see, is the pedestrian path and when a ship moves, this bridge looks like this, else this entire thing rotates and rests on top of this so that this entire thing could be a pedestrian path across the river. This is another movable bridge.

This is the famous 'Rolling bridge' designed by Thomas Heatherwick of Heatherwick studios, this is built across a very small puddle of water here and this bridge looks like this when it is used by people, this bridge looks like the third picture on the right when it is used for movement of small boats and this is how it looks in the picture in the middle when it is tracting.

The different types of moveable bridges are; the Curl bridge which we saw right now. The bridge curls itself to form this kind of structure. Next type is the Drawbridge, something which we saw in the famous London bridge. The bridge is pulled apart so that a boat can pass through. Next thing is the 'Fold Bridge', the bridge folds just as it is shown in the picture. This is called the 'Lift Bridge' where the bridge is lifted so that a boat can pass through. Next is a 'Roll bridge', where in if there is weight acting on that bridge, it acts as a little seesaw, so that a boat can pass through. Then we have the 'Submergible bridge' in which the whole bridge is submerged under water when boat has to pass through and then the bridge comes up for roadways. Next is the 'Swing bridge' which we saw earlier in the previous slide, when a boat wants to pass through, the bridge swings so that the boat can easily pass through. Next is the 'Table bridge' where the bridge rises on tables, to let the boat pass through. Then we have the 'Thrust Bridge' which retracts itself. Then we have the 'Tilt bridge' which is again something we saw in the previous slide.

These are some of the 'Future' bridges' in the world. Look at all the future possibilities that we have, it only gives us a firm belief that the future is definitely ours.