Structure, Form, and Architecture: The Synergy

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Lecture – 17
Compressive Structures

Hello everyone welcome back to online NPTEL course on Structure, Form and Architecture: The Synergy. Today we are at lecture number 17 and it is all about the compressive structures. Before starting this lecture if we just recall our previous discussions, that we have discussed about different structural arrangements and as well as different materials and then also we discussed different kind of force acting on structure. So, based on that like, we can classify a particular structural element into category. But we have to remember one thing that may be a structural arrangement we will have multiple such you know force resisting power means the structure may also take compression as well as tension.

But looking at the predominance the most of the elements of that arrangement is taking which kind of force and resisting against which kind of applied load is basically the basis of making this classification. So, today in this lecture, we will be knowing about the structure, where the maximum component or the major component of that arrangement will deal with the compression force and that is why we call it compressive structures. So, let us start that.

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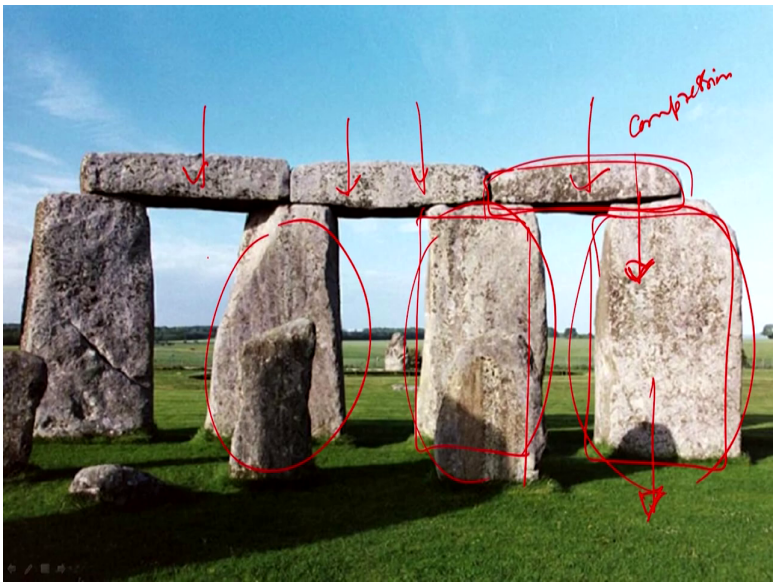

So, at the beginning that I would like to show you this photograph that also we discussed when we discussed about the evolution of the structural system, from prehistoric age to the modern age. And you know that present day and this is the example of the stone hinge where it is basically a megalithic structure, where they used to this particular stone slab up standing and they support this particular stone on top of it.

So, looking at this the behavior of this vertical stone, basically all the date load of this all the load of this particular stone being transferred through this stone slab and it is transferring to the ground. So, in this case this kind of arrangement where this external force is trying to compress in your object, we know that this behavior is called compression and that stress developed here is again the compressive stress.

So, we can say that this element like this particular wall you may say or maybe the extended column, we can also say depending on the position they are basically the compressive structures. And this is like a very basic structural arrangement the wall slab kind of relationship is there. But in now you know in the modern age also we also you know go for this kind of compressive structures.

Basically we will see in the subsequent slides that for compressive structures you use the machinery or concrete as material and the use of this kind of compressive structure was so prominent in Greek and roman architecture and later on even in the gothic with a flying buttress and all. So, we will have some slides on that we will discuss to that.

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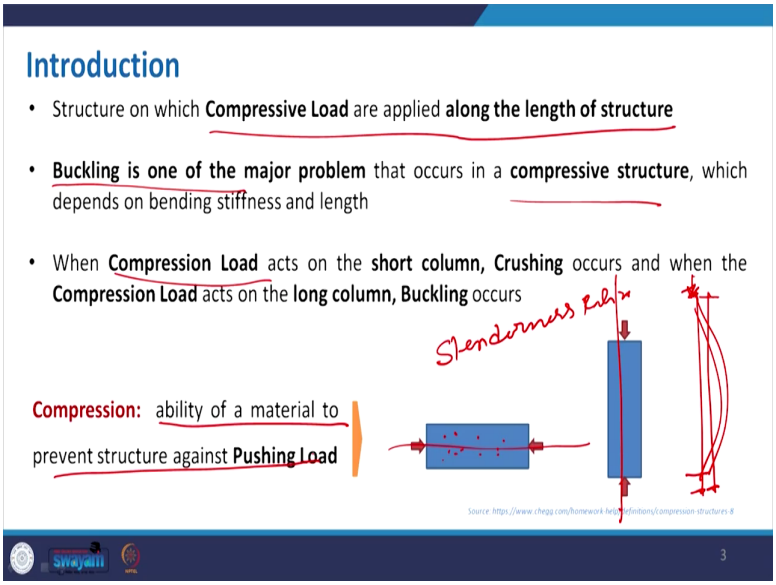

Now, to start with the structure on which compressive load are applied along the length of the structure. So, we also discussed in the lecture that the principal axis the major axis based on

that whatever the load applied on that. So, the material keep depending on the density and the strength and the hardness they will react to that. So, in this case also this is the major axis in this case, this is the main axis and the load applied to it is basically giving some compression. So, all these particles, if we consider at that micro level that they are trying to compress they are coming close to each other. So, basically compression taking place and that in kind of structure compressive structure we presumably see that the load is compressive load.

Then along with that buckling is one of the major problem that occurs in the compressive structure which depends on the bending stiffness and length what exactly the buckling. So, if you can recall that we also discussed that whenever like you have a long column, so applying load on it initially it will try to compress. But if it is having higher length and consider in compression to the cross section, so also we refer that as your slenderness ratio. So, basically that is the ratio between the cross section and the length of the structure. So if it is too narrow, suppose the length is quite you know much more higher than the cross section; then applying the load along with the compression it will give a bending so this is called buckling.

So, for compressive structure this is a problem, if you have you know pore in this slenderness ratio. When compression load acts on short column, so basically that time crushing happens. So, it will try to compress and move and when it is applied to the long column then buckling will happen.

So, what is short column and long column. So, short column is depending on the height and then long column again this basically the ratio. When we have like quite much higher length compared to the cross section of that then we refer that as a long column and short column is just where we get something you know the proportion between the length of the column and the cross section of the column, they are not that much you know having the ratio higher than that.

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So, in that cases suppose we roughly consider so, we can consider this as a very short column and may be something like that this is little bit a long column. So, you can see that though the cross section of this two thermocol that I have is same but the length that differs. Now the action of crushing when you apply load on top of it, it will try to compress and then this is basically result in for the higher load it will go for the crushing. So, whenever we do the test with the you know concrete block, the compressive stress we will develop like we will see those kind of development of cracks and it is crashed.

But when we apply for a like long column where again I am repeating that when the length is quite higher like proportionately higher than the cross section of that, so then applying loads you can if you see carefully that when I applied load on it, so it will try to bend. So, first it compress then it will try to bend. So, this particular property is called the buckling. So, if our

material is not having good stiffness and also buckling failure will be the problem, so we have to take care of that.

Now, we all know so just to have a recap what is compression, compression is the ability of a material to prevent structure against pushing load. So, whenever push the load both the cases one is from the up right direction and we can also put from this you know horizontal direction. So, these are the compression. So, then based on this initial discussion what we found.

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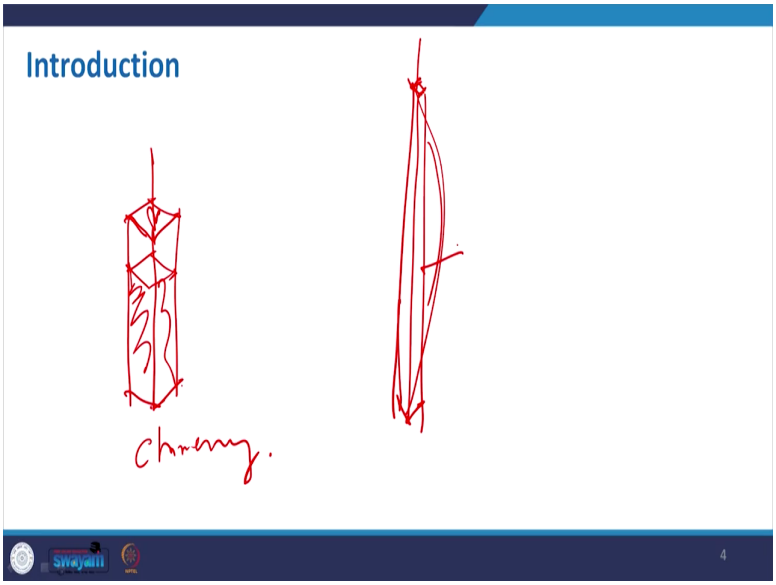

So, whenever we have say short column, so then if we apply load it will get shortened and then finally like it will crash. So, crushing is your phenomena. But when you have something like this where maybe you have very thin cross section and then this is something like a very long column.

So, when you apply load on that it will try to bend so buckling will happen. So, depending on that position and that particular principle, so we have to select our structure accordingly. So, that it will sustain again the applied load.

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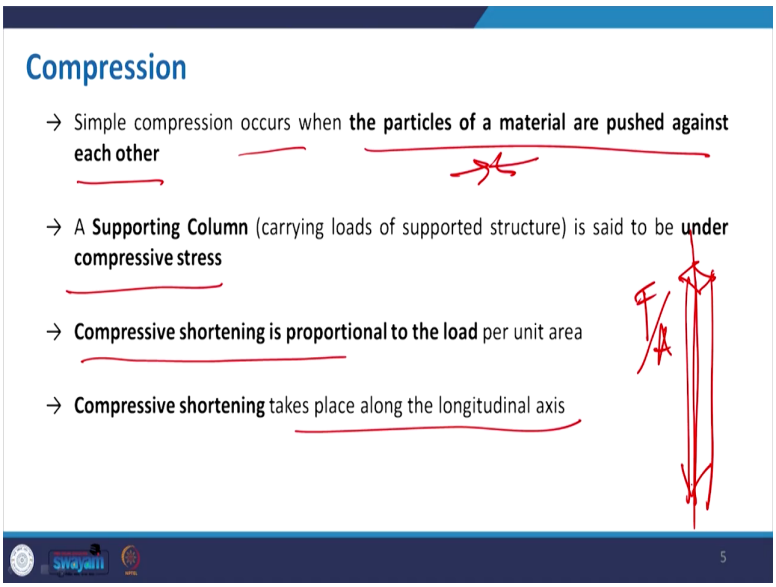

Now, to discuss more on that the simple compression occurs when the particles of material pushed against each other, that we say that they are trying to come close to each other ah. A supporting column is one of the examples which is basically under the compression, compression you know compressive shortening is proportional to the load per unit area and that is why no buckling will happen.

When you have a like very small area so then stress will be you know even more. So, we know that it is F by A. So, definitely cross section will play a role. So, compressive shortening takes

place along the longitudinal axis yeah definitely like when it applied. So, most commonly it is to be done through the center of this particular member.

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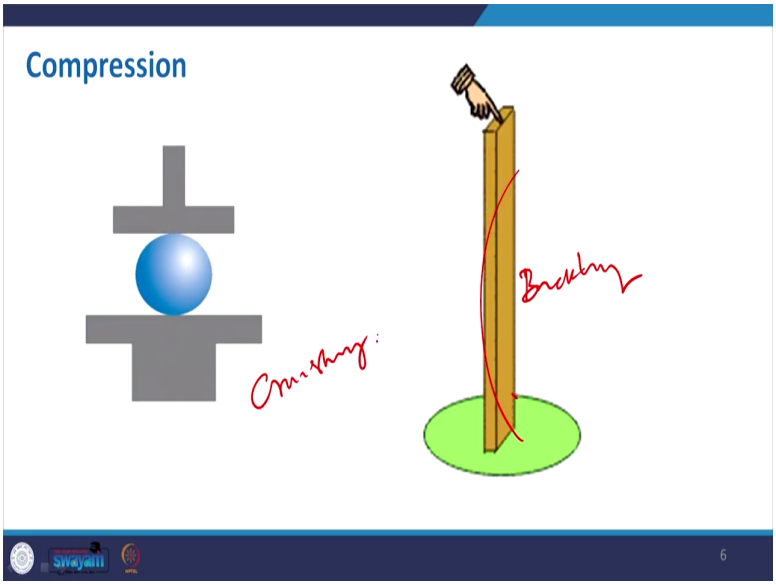

Now, here we have two jeep images. So, it is basically showing what we say that in a compressive stress that how cracks develop. So, after compression it will go to the ultimate stress that it can hold and then after that it will break. But the other case if you see this is a kind of example of a long column, where you have like quite more length compared to the cross section and then on applying load. So, it will have a buckling. So, in this it is your buckling here it is crossing.

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Now, move forward to the material that ah being used for that one is the Masonry. So, masonry here this is a representative picture where brick being laid on the cement sand mortar. But like we also discussed previously that masonry can also be done with the block stone block, the mortar can be lime surkhi mortar or a nowadays after invention of cement; it is cement sand mortar. Concrete without reinforcement here it is basically I am talking about the plain concrete. So, plain concrete is having good compressive strength. So, if you use a concrete block so it can really give you a enough strength the compressive strength.

But you know sometimes you know for like some high rise structure of where the span is more or the height is more, then probably simple concrete will not really take that. Because then you know as we discussed that because of the slenderness ratio because of the height of the structure. So, buckling will occur so then for in order to prevent that bending we also need some support to control to resist again the tension developed during this bending. For that this

concrete is not good and that is why we add steel to it as reinforcement, which is good steel as a material which is good for taking tensile load and then the combination of both can really do some good ah. You know support that we that can give us good support to make more number of storey building and make our structure more shape.

So, that is why the machinery and concrete they very good are in compression, but poor in tension. So, use of steel is for that reason to you know make a balance between carrying compression which will be taken care of by a concrete itself and then we the tension will be taken care of the steel member.

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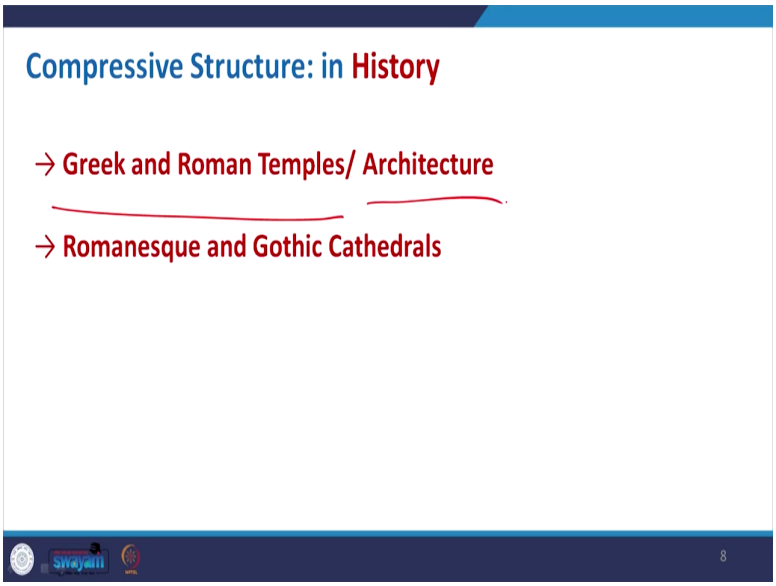

Now, if you see the application of that then as I mentioned in the beginning of this lecture, that in Greek and roman temples and assembly halls so use of these compressive structures are

very predominant. Nowadays also you can see those few of those historic building still, they are you know of that you know standing and you can actually refer to them.

Then after that also in the Romanesque and the Gothic architecture where normally you know for the church and cathedral the used is as a buttress and all. So, these are very predominant later on like it is shifting to was the steel or the reinforced concrete structure. So, not really the compression is basically then taking care of the other you know force as well. Now if you broadly classify like compressive structure.

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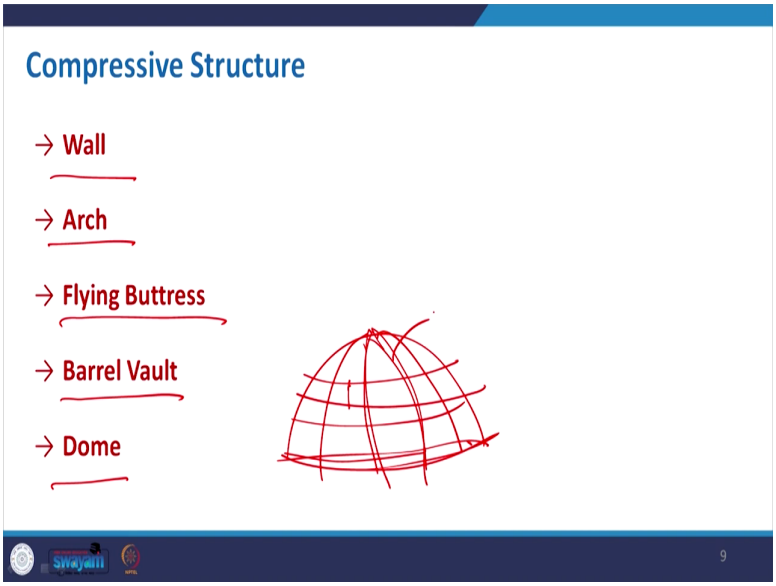

So, like we can have wall arch flying buttress barrel vault and dome. But again I am telling you like looking at the major elements of that system which is acting in the compression load or which is resisting that compressive force, based on that this classification has been done. But

at the same time if you take example of the dome, so dome also it is not really that everywhere we will get this compression.

Mainly you know when we discussed about the dome will find that this compression is basically tracking for this meridian and when we are taking care of this you know hoops tension and compression both will develop will come to that only, when we have this kind of system in detail.

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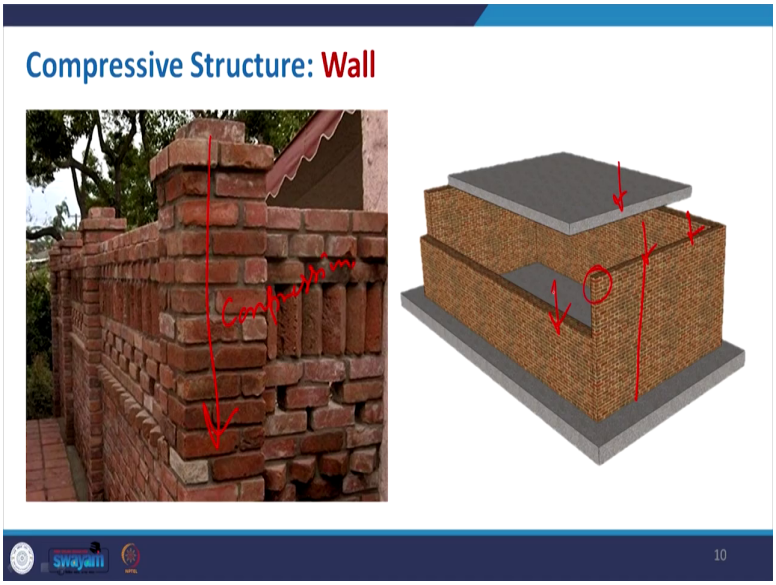

So, come to the wall like wall may be used as a building envelope or it may be a load bearing wall or maybe a boundary wall. But basic principle is that like the load is transferred vertically through the axis and this particular portion is in compression.

So, in this case there is no such tension. So, majorly it is in compression so it is one example of the compressive structure. Here also if you make load bearing you know structure the load of the slab is transferred to the wall to the foundation. So, this is another example that already we discussed earlier, again we are you know taking this example of the load bearing wall normally being used. Like in you know some of the old buildings, where you have a higher thickness of the wall and wall will take the maximum load. Because then now we shape to the frame structure where the concrete columns and beams are preliminary taking the load and walls are being used just to make the partition. So, in this case wall act as a compressive structures and taking the load.

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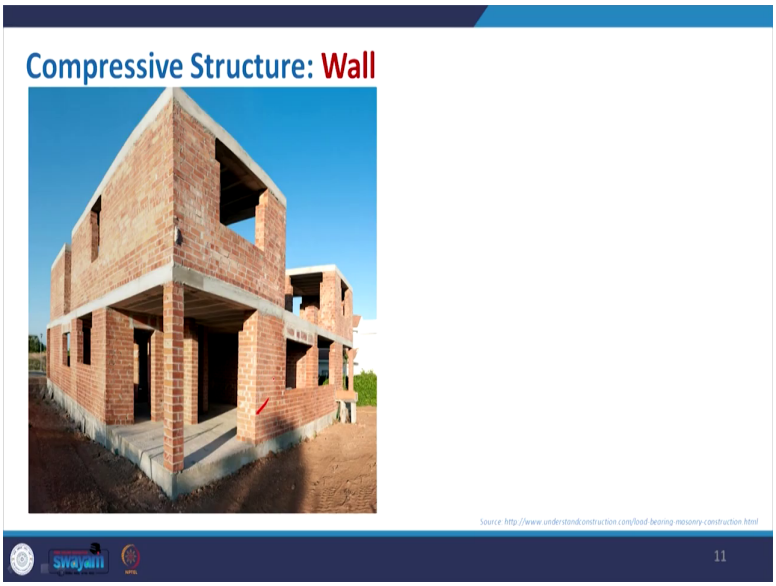

Now, this is another example like this is the load bearing structure mate. So, the slab the load of the slab being carried by this wall and this transferred to the you know, the foundation. So, this is another example of the compressive structure and wall.

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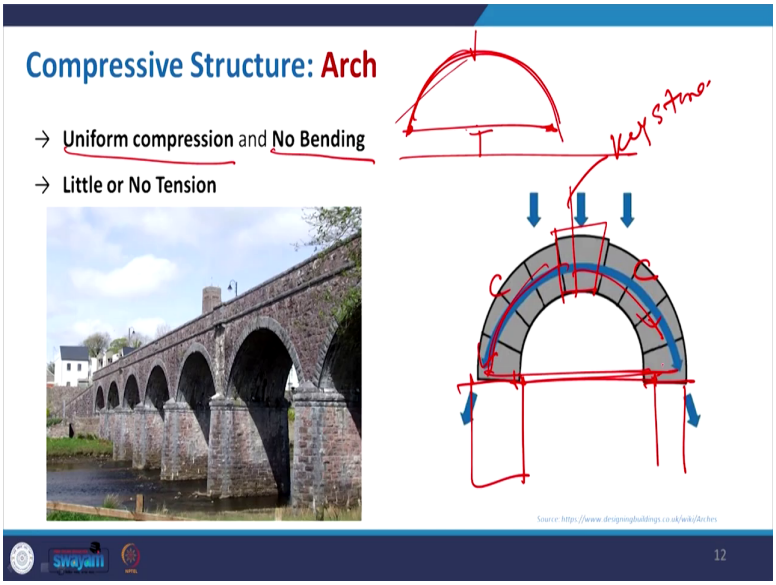

Come to the arch, it is very useful you know structure and you know the use of this arch is basically spread in various type of construction. So, it here you can see this is just being used for you know breach and in many historical building that has been used to create the huge door or sometimes the corridor.

So, in this case also like if you take the arch as a component will also have a detail lecture in upcoming you know detailed lecture, planned for this whole course on arch there will try to know different kind of arch construction and all. But in this case, in short if I say that you know in the arch form it is mostly a semicircular in this particular form and it is symmetrical.

So, the main stone that also we refer as a key stone. So, whatever the load applied on this surface they actually you know spread over that and you know that create compression and they transfer it to the support.

So, this is the overall transfer of the load through the arch and the load that been carried out is fully compression. So, in this like arch is the very good example, where uniform compression we can see and there is no bending on that. And sometimes you know the second line of this particular slide that little or no tension it depends and suppose if we link this particular arch the support.

So, you know basically if I try to put the pressure, so you just do this thing like you just try to make one arch and you just use something the rubber band or something like this. So, the moment you put the pressure, so it will try to be flat and then it will you know elongate. So, basically so when you press it so it will elongate, so here tension will be developed. But in this case there is no such attachment so it is full compression. So, sometimes also you know you know some truss you where arch being used so we get this particular tension.

This is again another beautiful example of the arch how it being formed and the main beauty is with a symmetry and that is why like it will also make the structure you know in equilibrium, so that how they distribute it in the supporting structure. Now come to the other category that we mentioned in the gothic cathedral and all the use of the flying buttress.

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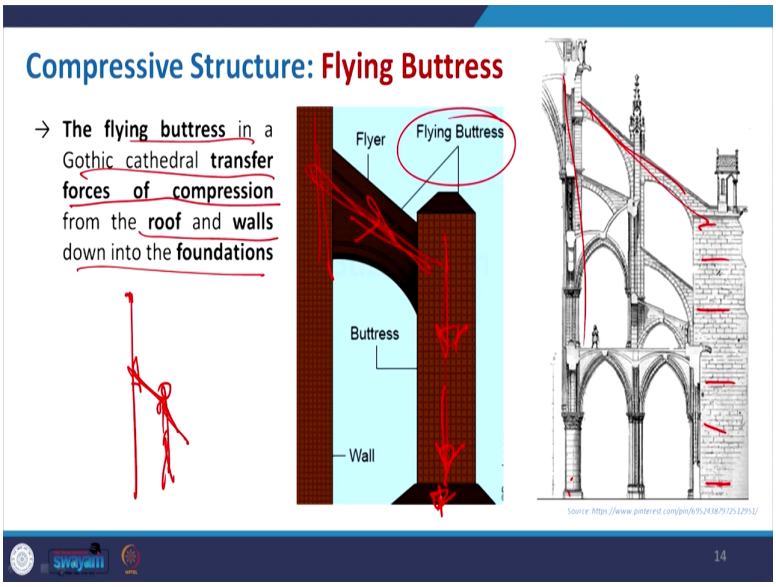

So, basically it is something like you have the main structure and someone is giving you the support ok. So, something like that one has to hold it. So, the load of the roof and the wall is being transferred to the flyer and then you have another supporting wall which together making the flying buttress, it is again in compression. So, it is something you know you can say that having relation with the wall and but you have a connection with the fire, so that it will transfer the load.

So, you can see here also like how this particular you know load bearing structure being again supported the huge mass and with the flyers. So, the flying buttresses in a gothic cathedral transfer force of compression from roof and wall down to foundation. So, basically whatever the load is there that to transfer to the flyer and then go down go down and finally transfer to

the foundation. So, this is very important kind of you know compressive structure being used in those cathedral and all.

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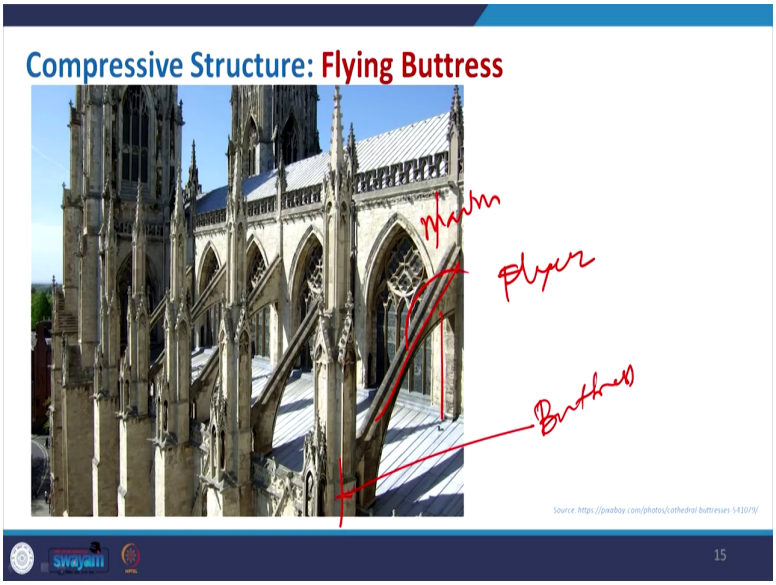

Now, in this case this is another example like earlier it was just a symbolic one, now you can see that in this cathedral how it is when been made. So, this is the main structure and then now you have for this flyer and then down to that this is connected with your buttress ok. So, how it is being supporting this building?

So, this is again very useful you know compressive structure being used and if you just consider like the building materials. So, basically either stone block or the bricks they being used and masonry was the technique. So, they put the bricks one by one in the mortar bit and then they create this kind of structure.

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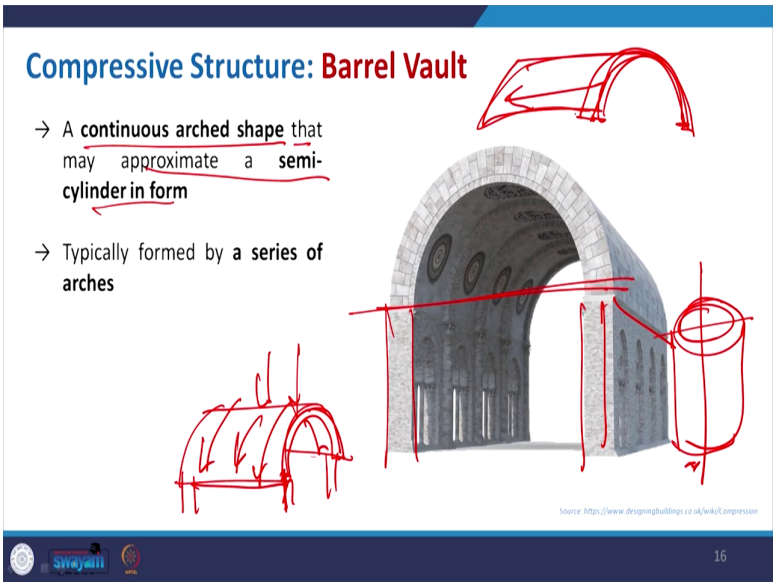

Now, next to that is another kind of compressive structure is your barrel vault. So, in barrel vault normally it is something that you can see that this is a stretch arch form. So, previously we have seen that arch it is a compressive structure so it will have a thickness and then if you try to stretch it so basically that will give you another like what we can say that hollow semi cylinder kind of form.

So, suppose you just have a cylinder hollow cylinder and you just cut it like this or maybe like this. So, whatever the form you will get is basically your barrel vault, now here also as because it is having similarity with your arch so the transfer of load through compression. So whatever the load applied on it so that will be transfer to the supports. So, normally it is being supported by some wall some load bearing wall and all normally being used for making corridor and used

as a rooftop in many of the buildings. So, a continuous arch shape or maybe the stretched arch whatever you can say in this that may approximate to a semi cylinder in form.

So, we are talking about this much as a semi cylinder and it is being supported to the wall. Typically formed by a series of arches yeah definitely it is a continuous series of arches that is making this form and it is the compressive structure on that nature. Now if you see that how beautiful ah you beautifully you can use that and here also you can see some ornamentation.

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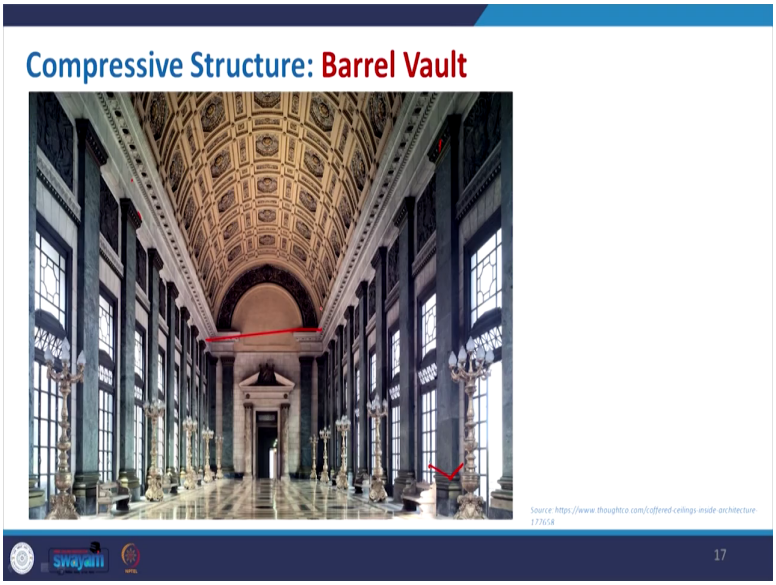

But looking at the point of the construction, so it is again being supported and to this particular you know beam and then being you know this you know support. So now the advantage of creating this yes, you can create some span and definitely you know this is one of the vaults type that we discussed Barrel vault. But there are other kind of vault where you can like use to multiple such barrel vaults to form a different kind of vaults.

We will also have a discussion on the vault section; one particular lecture will be on that aspects. So, then we will see that how different kind of vaults acting together. But considering the compressive full like maximum of the you know structural component which are dealing with the compressive force of so barrel vault is one of them, which is extended arch form and then that transfer the load to the support in where there is no tension or maybe very you know minor tension somewhere where it is being attached or closed.

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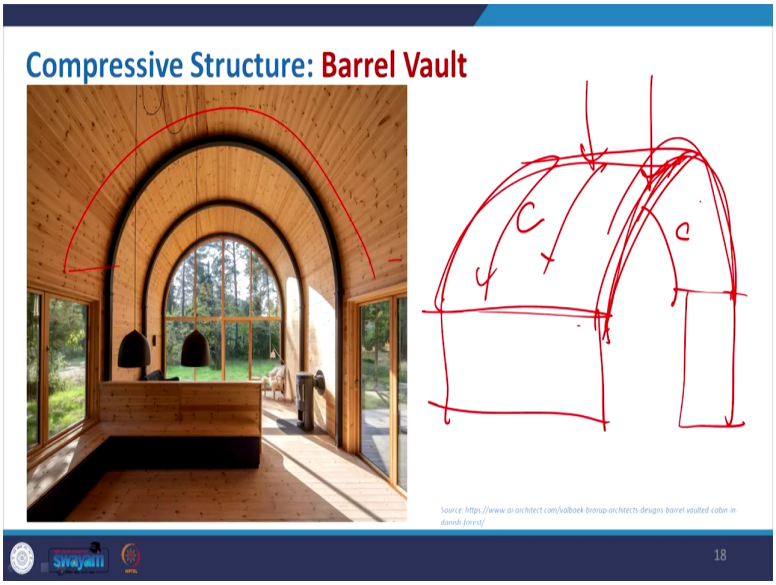

Now, that was one example with many structural ornamentation. But if you see this is another example of that vault where it is very nicely been done by the architect, where you can create a very smooth and a very good span management you can do with application of the barrel vault where you can simply you know make something like you know hanger kind of support or

something. So, that can give you this you know advantage of putting this. So, the compression is the main force which are taking care off.

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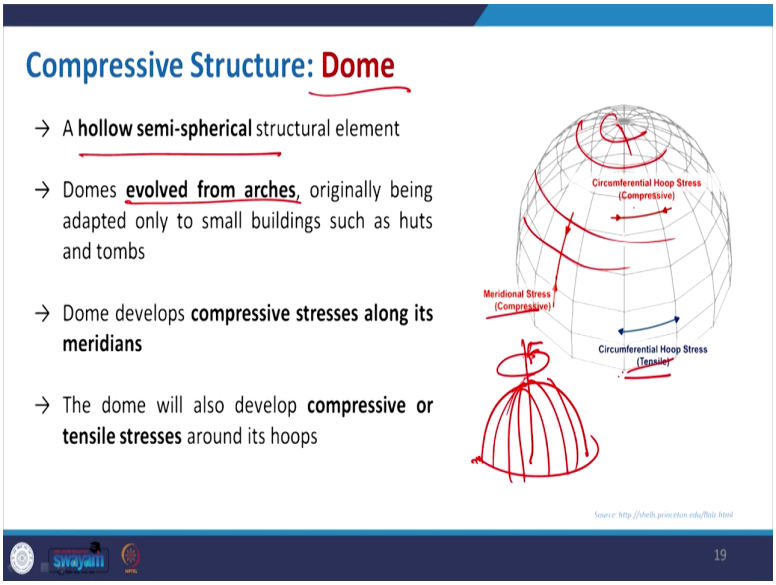

And now come to the other category that is the dome. So, earlier in the vault what we have seen that is extended the series of arches the form that barrel vault and here it is basically a hollow semi spherical structure. But it we can say the evolved from arches.

So, what is evolve? So, if you have one arch and you access. So, then give a rotation give 360 degree rotation of this string. So, it will basically give you the multiple arch is starting from each other. So, we give you the form of this dome. And as because we know the basic fundamentals with the arch that we started with this discussion you know in a previous slide. So, there the main you know ah the load is of compression type, so here also it is the same. But in this case what as I try to mention that when you have this dome, so whenever you take

these you know meridional you know stress. So, in this case it is in compression so they are trying to get very close to each other.

So, in this case if you see that this is compression. But at the bottom they will try to go out from each other, so in their hoops the tensile force being developed. At the top when these particular hoops are tried to get course closer. So, compression takes place here so in this case dome if we just take as example. So, majority of that is basically the compression, but slightly definitely at the you know circumferential hoops they are taking tension in that and at the top where they are close together. So, then circumferential hoops they are taking your compression. So, this is again a very useful structure, but earlier when it was used specially for making a small you know hut or a rooftop.

But now because of you know some improvement in the material, then use of the steel as reinforcement. So, this expanded like in a big structure. So, not only to cover you know top of any particular room or part of the building, it is basically can cover the whole lot of building or the entire area and create beautiful column free column less place on that.

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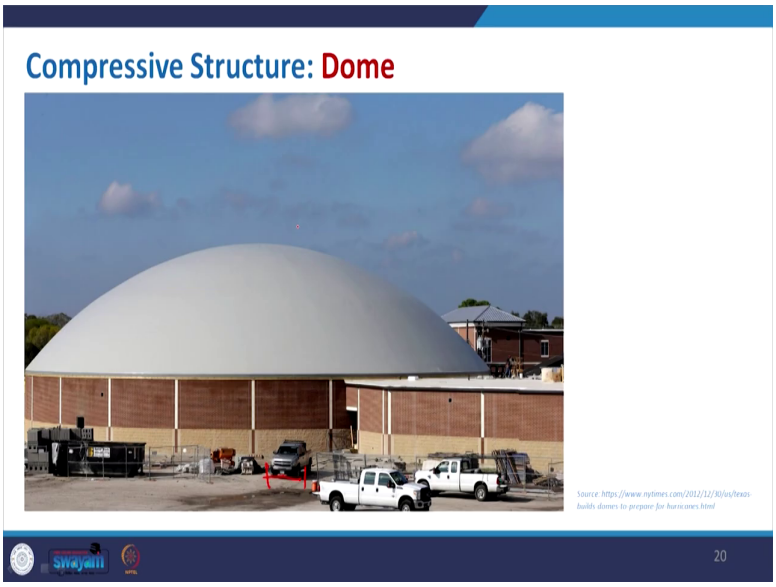

So, this is another example this is basically gymnasium for a school where you can see that you know RCC dome how it is being used to cover a huge pan. You can imagine taking this as reference of the car width this is a huge pan being used and it is not the case like being used in the present day, but also we have seen this kind of use of dome in the history.

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So, this is basically the example and this is very rear view, normal you know I have referred this building specially but not this view most frequently. So, this is basically the you know Pantheon from Rome. So, in that if you see that from outside, so again it is giving this particular form of the dome which is being constructed taking some good framework and the you know concrete was used to make this dome. So, this is again another good example of the compressive structure.

So, here it was used in the roman architecture and the earlier example that I have shown you. So, this is in the modern age, definitely the earlier one only with the compression or you know compressive material with the concrete only. But here the steel use of steel and the reinforcement, you know made it successfully you know implemented for the purpose.

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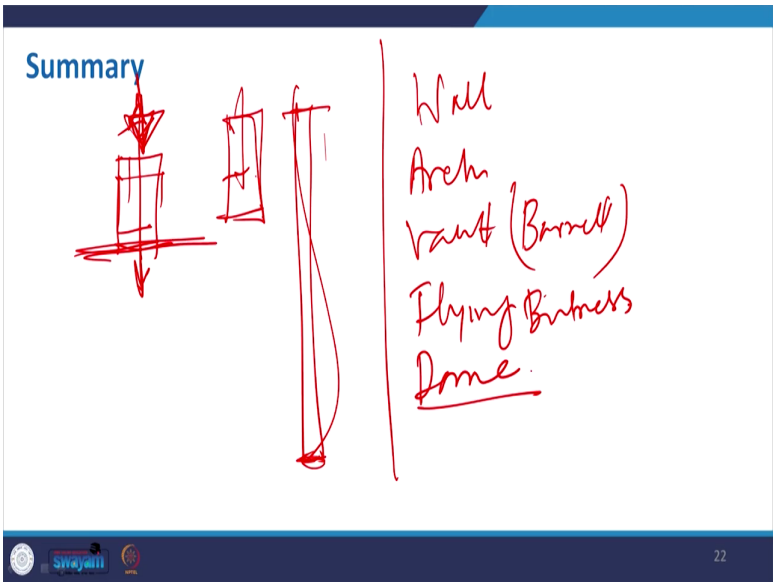

Now, if you just make a summary quick recap. So, what we have learned that compression is basically it is acting to the main or major axis, where the load applied to it ok. This is the base and then load applied to it is basically try to compress it try to crush it. Whenever you have like short column or something where the considerably your length of the column is not that much bigger than the cross section so crushing will take place.

And in place of that if you have a larger height and compared to the base then buckling will take place and then based on that also we discussed about the different types of compressive structures. So, started with wall then the arch then the stretch it arch as vault especially, the barrel vault and then we also discussed about the flying buttress being used in those gothic cathedrals churches. So, basically these are the type where again I am saying he the load they

are taking, the major component of this kind of structural system are taking compressive load that is why they are categorized in this compressive structure group.

And last but not the least that we discussed about the dome and depending on the material and the technology. We can also vary the span of the dome where mostly it is taking the compression, but definitely are the circumferential hoops they are taking tension as well.

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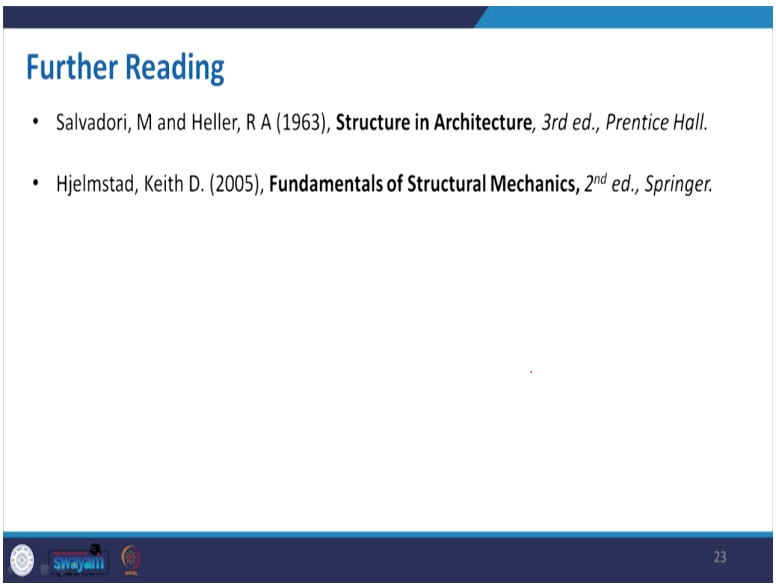

So, here we conclude this particular lecture and these are the starting materials that you can go through and also you can go through those website links that I have given in respective pictures. So, study more about that and can give me some feedback on it. So, next we will be discussing about the tensile structure, where again like the similar to the compressive structure. So, here also the structure will discuss, mostly they will be taking tension either they

will take like a little bit compression or no compression. So, we will be discussing that in the next lecture and thank you all for taking part in this particular course.