Structure, Form, and Architecture: The Synergy

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Lecture – 23
Vault Structures

Hi everyone, welcome back to NPTEL online course on Structure, Form, and Architecture: The Synergy. Today we are at lecture number 23 and I will be discussing on Vault Structures, the type of vault structures, their advantages and before that like if we just recall like the past few lectures that we are focusing on individual structures, their you know pros and cons, application.

We have seen in the last lecture about we talked about arch as a structural form and how we can use it different kind of arch from, their connection, their support, the multiple use of diversified use of the arch in buildings, in window even in the bridges.

So, like that now we move one step ahead that is we are we will be discussing on the vault. So, before we start this particular session that we have certain idea about the vaults that being used in the history. So, it is basically if you take a paper and just try to fold it, roll it with something like this. So, this will become the vault and there are different types of vaults. So, we will discuss that in this lecture. So, let get started.

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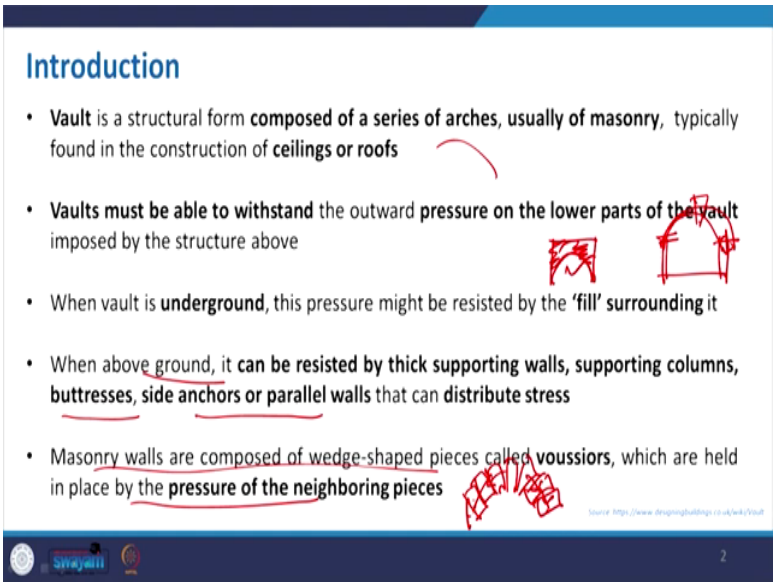

So, basically vault is a structural form that composed of a series of arch. So, if we consider one arch, then you just repeat the multiple number of arch that will create the form of a vault. And normally the construction it is the machinery construction, but definitely with advancement of technology, materials, nowadays even we can go with the steel structures some other materials can also be used to create this particular form.

The vault must able to be stand outward pressure that is very important. Suppose when you fold a particular plate, so, definitely the most of the part will be taking the compression, but where the outer part need to resist the pressure and that pressure will come from the date load from the top load, if it is imposed by the structure above. When the vault is underground sometimes we create vault to create the tunnel for the water supply, sometimes to create some path some tunnel for the transportation. So, underground may true.

So, in that case if you go with this tunnel, this pressure might be resist by some otherfilling. So, whenever we just view something like the tunnel is there and then this is the top portion. So, we fill this portion which will help this particular form to resist, but when it is above ground, then something where we will make just on top of a wall or something. So, that should be supported by the wall, so, that you know the concept is pretty similar with the arch we will have a keystone, then we have voussiors, then we have spring and mostly the symmetry will be maintained.

So, that will transfer the load to the supporting structure and that will go to the foundation that is the same concept. Then in this case also we can also support this with buttress that we have seen in some gothic architecture, those churches there the use of buttress to form like the support the arch and all these being used. Even sometimes the parallel walls or the anchors additionally tied to it can help to support it.

So, in two conditions when it is to be placed underground, so, that can be supported with the filling of materials like the example of the tunnel this one and the. So, again now what we just talked about which is above ground that should be supported either with the parallel walls, some kind of buttresses, some anchors. Then masonry walls are composed of wedge shape pieces with voussiors which are held in place to the neighboring pieces.

So, basically it is something where we can again take the example of the brick arches. So, this will keep pressure to the next and next will give pressure to the next and like this it will transfer the load to the support. So, it is very similar to the arch, but again the series of arch placing together in a linear direction will give you a form of a vault. But this is only a type of vault, we will come to that the type of walls and they revolve like how it evolved and the use of the same.

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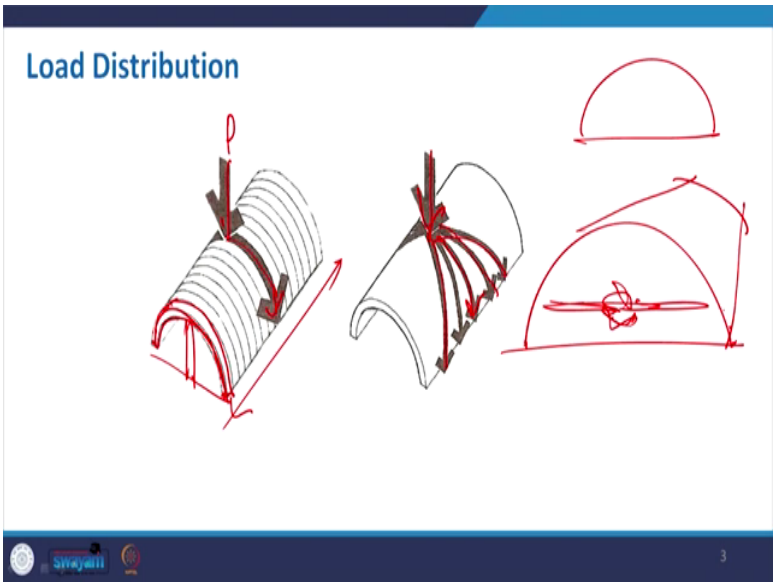

Now, what exactly we discussed last slide it will be clear now. So, what you can see that if you just consider this single part suppose, only we take this much these are basically a arch form may be made of masonry, may be of concrete. Now when you act like acts it individually we just place it one after another separately. So, each one of them is carrying the load individually applied load is applied here and it is being transferred like this to the surface and mostly it is in compression and when we make the vault is a continuous, you can get the resemblance between these two shape.

So, how it will be distributed? When you apply the load it is distributed based on the homogeneity of the material. Definitely the material should be homogeneous across there the thickness should be same across this particular vault then it will be distributed like this. Now the advantage is very simple like you can make some structure obstruction whenever you have

like have to have a like corridor, long corridor or maybe sometimes it is a gathering of many people.

So, we cannot really put columns in between which will make obstruction that we do not want as like the design, designer or architect then we can go with this kind of form. So, like that even most of us maybe heard of these hanger. So, normally being placed like to make it is to be made to you know put your plane aeroplane for the maintenance or something like that, sometimes even you know to make some convention hall. So, we are taking this kind of arch form and use the advantage of this vault.

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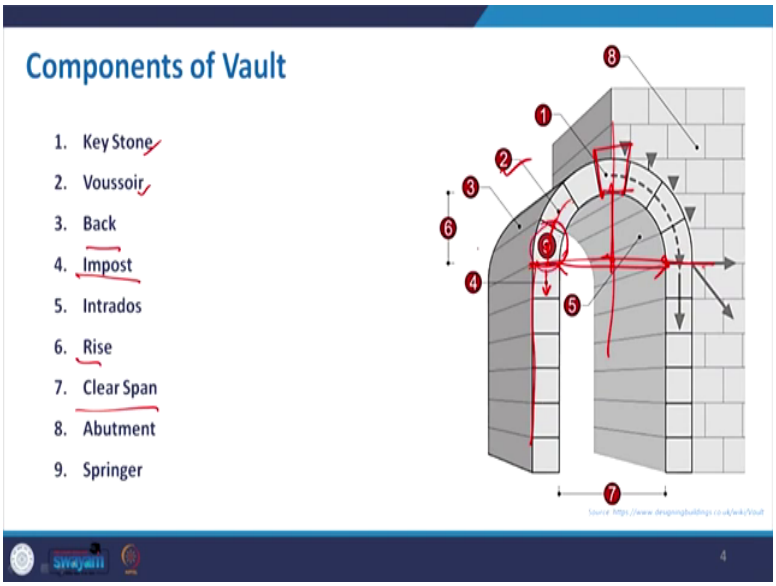

Now, considering the components of the vaults, some of the components are also similar to the arch rather most of them. Like keystone is the central like which to be placed at the center and the symmetry will be maintained across that. Then voussoirs are the stones number 2

which actually you know a series of voussoirs they will keep put pressure to the next one like this. Then number 3 is basically the back portion of that then imposed is very important element where like all these you know curved surface ends with and put the load on this vertical wall, then intrados is basically the interior surface. So, it is opposite to the back and then the rise that we know that it is to be calculated from your where the imposed end so, from that what is the rise. Then clear span is basically the span given to this then abutment is the support and also we have this springer where like it really convert transferred the last load to the wall.

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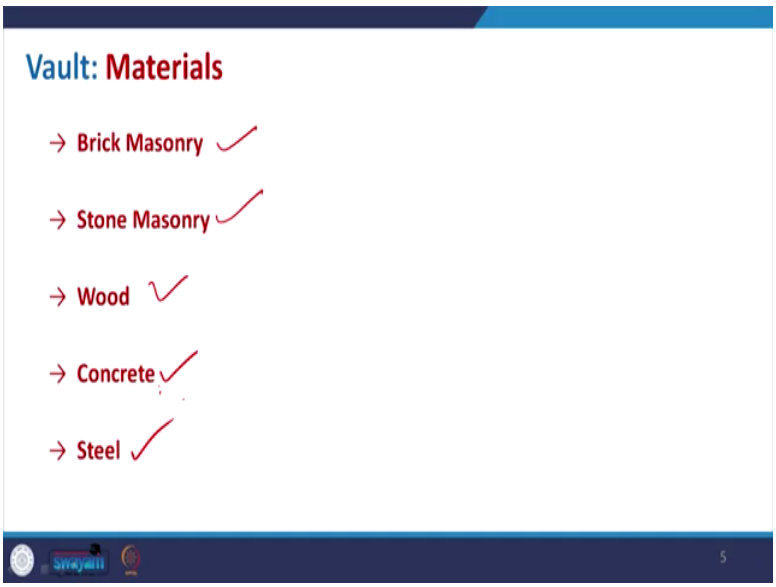

Now, coming to the materials, it is may be made of your brick masonry, it may be of stone masonry, sometimes we have also seen it is made of wood and then the concrete definitely after invention of concrete, we have actually made many such structure which earlier made,

but the brick masonry, but with very you know light thickness and to increase this and we used concrete and then steel is also being used to just take the form of a vault.

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Now, this is a these are the few pictures we will go through. This is again rebel masonry and you can see that apart from these you know the scenic beauty of this, if you focus on the structure in this basically this is the arch form and then these making a like manmade cave. So, this particular form you can see this span is quite huge and it is sustained with those you know rubble walk. So, this kind of vault structure is also present.

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So, coming to a complex one, where again it is the vault one and being placed for the corridor. So, normally it is been largely used to cover as a you know roof of the corridor and but here it is decorative. So, the columns being created and form their like there are different ribs or kind of you know what we call skeleton is coming up to hold this particular vault. So, this is one of the category will come to that as well.

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This is something similar to the previous one, this is for the corridor, but now this is actually inside a chapel.

So, how beautifully it has been done you can see that not only the vault form, but also the ornamentation that previously at the initial few lectures we talked about ornamentation of structure. So, here it is actually representing that kind of things. So, use of this arch and then the vault is making this space very you know beautiful and also structure resistible capable to you know reduce the number of columns to be placed to you know make a large span or large gathering to be accommodated in that situation.

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Now, this is something really you know giving a nice picture, this is a library and here the vault shape is being created, but it is with the wood that you can see that this been created with some wood material and again it is being used to cover that particular atrium. This space like you can see this is the ground floor it is double height. So, this span is being holding. So, no column is required in between and also it will give a ascetic view, when you make this curvature you know this arches and the walls. So, they will really create a nice environment.

Now, coming back to the as I told you that now it is also we can use steel or sometimes also the glass and steel combinations and other fabric material and steel combination.

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So, this is one example I have taken from a your station. So, in this case you can see this particular form is being created with multiple series of truss, but overall like you can get like the huge span without any column. So, this is one advantage to use this particular vault form, which is basically a series of arches.

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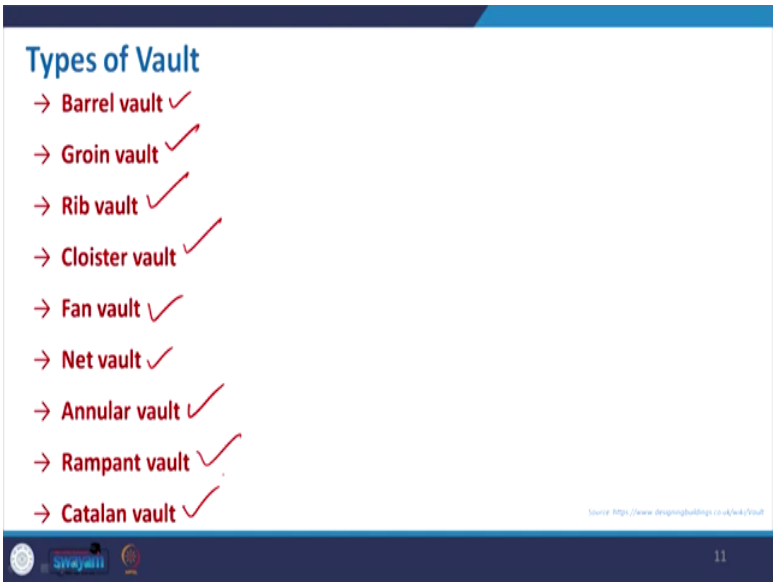

Now, coming to the type of vaults, so depending on some of the shape and other thing. So, there are many classifications. So, what I have picked up is basically the type of barrel vault and we will discuss with some image for each of them. The groin vault, rib vault, cloister vault then the fan vault you have then net vault, annular vault, rampant and then Catalan. So, what exactly are they and how they are different to look like we will go through it.

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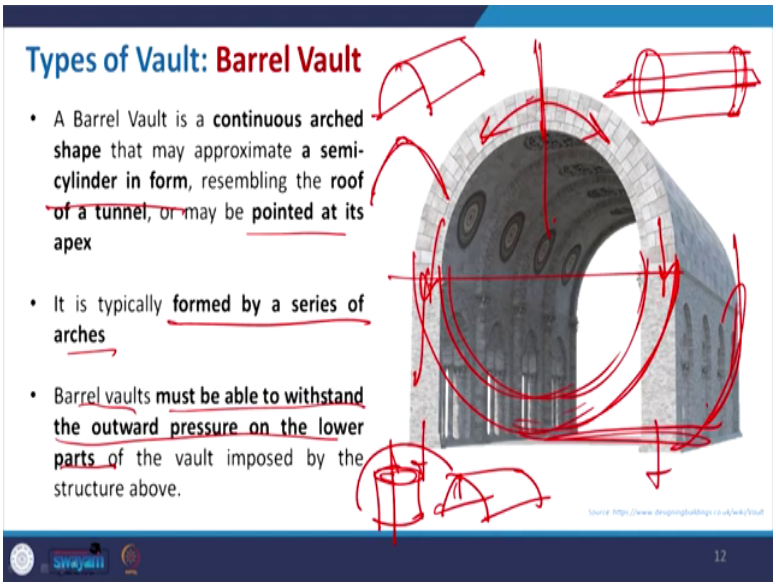

So, barrel vault is basically we know the barrel is if you just make a barrel position like this, it is laying on this and you just cut this with a section. So, we just cut in half piece and as because it is hollow. So, it will give a figure something like this right. So, this is basically the barrel vault and you can see this example it is basically the same. So, if we complete this image so, that is hypothetically give you the particular form of a barrel. So, this is called barrel vault.

Now, what exactly it says? A barrel vault is a continuous arched shape that may approximate to a semi cylinder form. So, this is very important. So, when we take a cylinder like this, we make a section and this is a hollow cylinder; obviously, and then you just rotate it. So, we will get this particular form. So, this is the barrel vault, this can be used as a roof of the tunnel as I mentioned when we just make the underground and maybe point it sometimes, even we will

not always get this particular thing in a semicircular form, sometimes you can also get the form even in some of the images we have seen that.

It is formed by a series of arches that is the common phenomena that is also there. The barrel vaults must be able to withstand the outer pressure on the lower part definitely when it actually coming to this so, that should take the load of this. So, again with the symmetry the load is being distributed both the side with the homogeneity in material that will transfer very systematically and then and that will transfer to the post imposed the abutment and then they will go through the foundation. So, these lows transfer.

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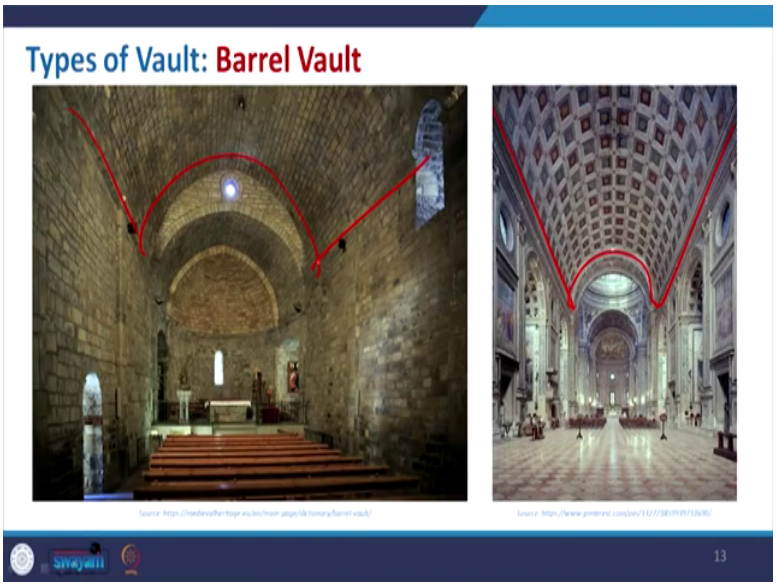

Now, coming to the example of the barrel vault, we have two pictures back to back here you can see it is the you know the stone brick masonry. So, where you can see that how it is being formed this vault, it is similar. This is quite simple like we can see the masonry the you know

layers of the brick, here it is the same thing, but apart from that the additional ornamentation is being done. So, different color, different you know height that being formed in this. So, it is again another use of this.

So, mostly this kind of vault being used in the gothic and then the byzantine that particular period, we will we can see that and gradually they will transform they have transformed from that you know old type of vault, will type of material and now slowly it will move towards some advanced material that will take that will retain this particular vault form, but like the materials the structural property they optimize it.

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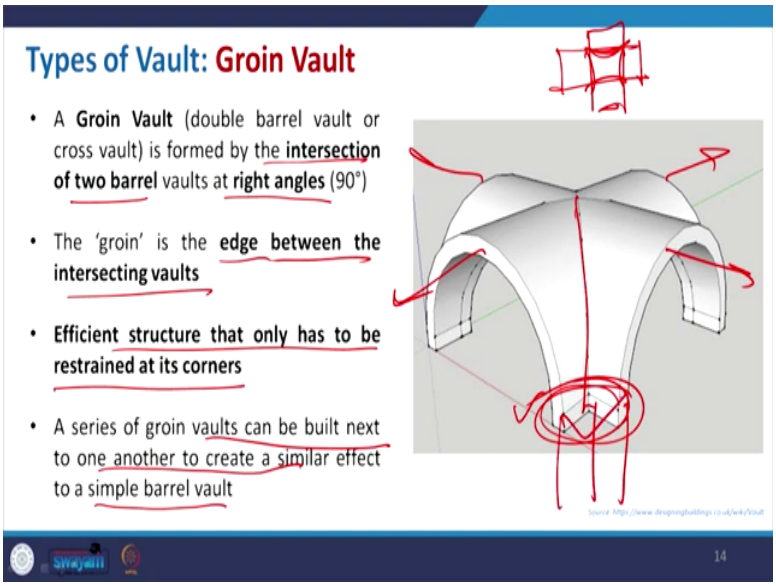

Coming to the groin vault, it is basically if you take two barrel vault and then you just make a penetration at 90 degree to each other. So, from top view if we just try to draw it so, it is something like that. So, this is basically the groin vault and if you can see this isometric where

it is making a form. So, sometimes for intersection of two corridor that roof can be created like this or making a post like this we can create it. So, that will give a few more intersection of the curvatures and that will have better visual (Refer Time: 17:17) and we will also see in the images.

Now, a groin vault or double barrel vault that already I mentioned is formed by the intersection of two valve vaults at right angles. This is the basic condition the groin is the edge between the intersection vault. So, basically this age that we get when they intersect as because they are in curvature. So, when they intersect also will form a intersection line as a curve. So, this is the groin, the efficient structure that only has to be restrained in the corners. So, they have to really make the structure in such a manner they can make this.

A series of groin vaults can be built next to one each other to you know have like the similar effect of a barrel vault. So, we can place one after another so, then like it will make a two barrel vault crossing. So, this can be extended further to get a view of the barrel vaults.

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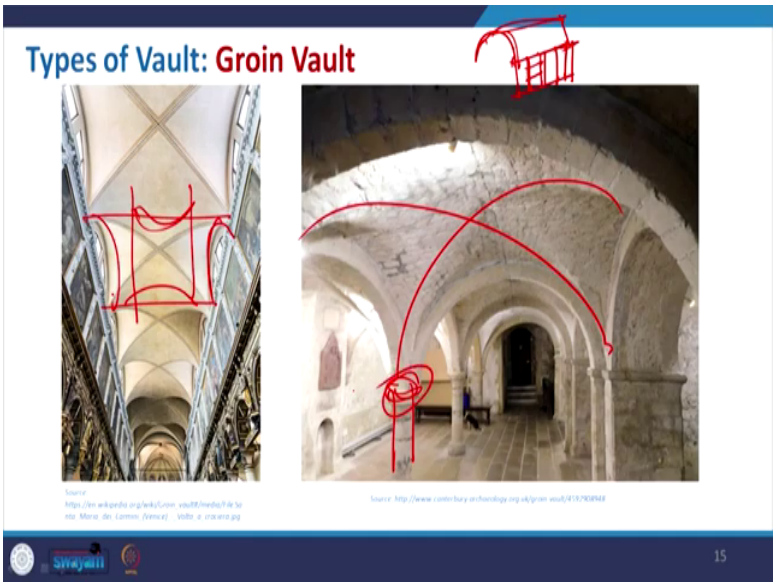

So, let us see what exactly it is, in this you can just try to understand how it is being made. So, like if you just take this curvature ok. So, this is one particular vault and then when you take this particular part. So, you will take this vault. So, the curvature is being seen this is from the inside in this is interior view of a groin vault.

So, this looks like this and something which is very simpler with your brick masonry, then also you can see the similar kind of curvature. So, you can see the edges that how they crossed each other. So, previously we have seen the very simpler form and now this is pointed and this corner is only being supported. In the barrel vault what was the different? Like in barrel vault the whole portion like as because it is to be supported a continuous. So, you need a wall or sometimes maybe it is supported with a thick wall in different parts of the section, we have seen that you know in this image that these arch being created it is being supported like this.

But for this groin vault only we have to support the corners. So, whenever we get these corners after intersecting two barrel vaults, we have to support this then rest of the things will take care with this form.

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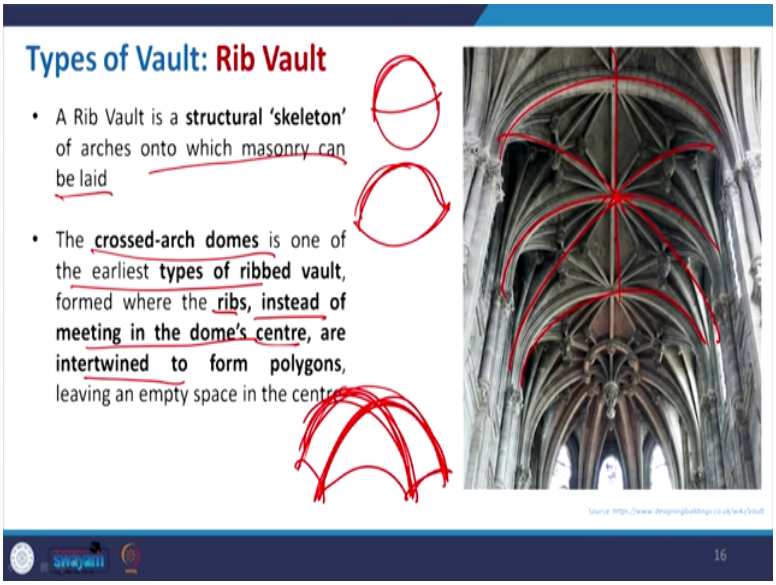

Coming to the rib. So, rib is similar to your skeleton. So, where the vault being created and that structure that on which the masonry work or your concrete work being done is basically a form of a skeleton. So, you can see that how beautifully with symmetry with a proper geometry experiment like this has been created.

So, rib vault is a structural skeleton of arches onto which masonry can be laid. So, what I just mentioned it is the same thing the crossed arch domes is one of the type of rib vault. So, whenever we make the curvature like this and then we give say we create this particular form with two arches and we just make some arrangement like we just connect those points with

some masonry, that will give a form of a you know what we call domes. So, we will be discussing that in the next of the type of domes and what exactly.

So, normally it is something like here we just started with the half portion of the cylinder that will be something in general the half cut of a sphere. So, that will be the dome. Then ribs instead of the meeting the dome center they intertwined to the polygon. So, different kind of polygons being made. So, this is one series and then you have a cross section. So, they are really maintaining a particular symmetry to distribute the load very you know uniformly evenly so, that the structure will remain safe standing.

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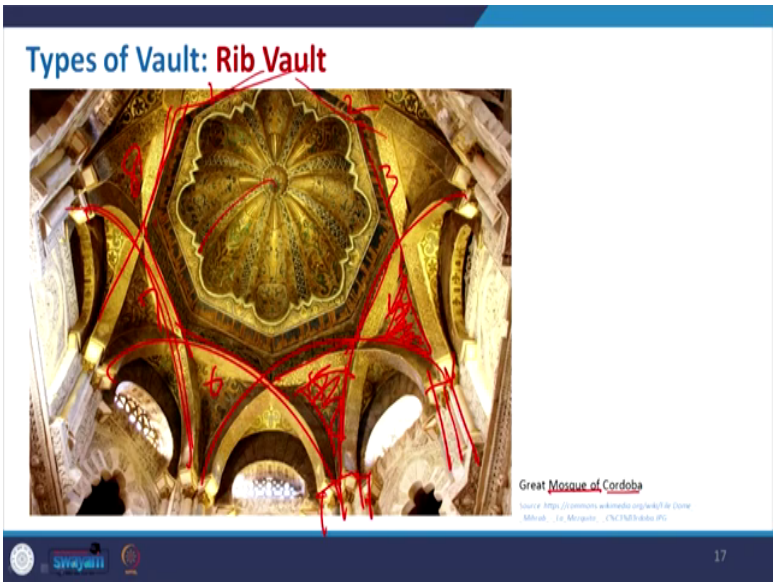

So, this is something really a very beautiful example that I have picked up this is a great mosque of your Cordoba. So, in this case you can get the essence that multiple arches like how they just make the connection, the beautiful geometries maintain to just create this

particular you know your what we call this dome inside this and then further decoration being made, but overall with this intersection of course, they are making a structure of octagon.

So, this is eight side 1, 2, 3, 4, 5, 6, 7, 8. So, octagonal shape being created with this curvature and it is in continuous mode. So, this kind of you know experiment like with the rib vault we provide like a beam like a curved beam being provided and on top really make it. So, these beautiful punctures that being created always this is giving a nice filling and with beautiful ornamentation that we have seen in the history the application is really fantastic to watch. Again with this number of arches as because we don t have a continuous wall or something like the barrel vaults, again we have to support this kind of corners with the pillars; that means, only the corner will be taken into consideration.

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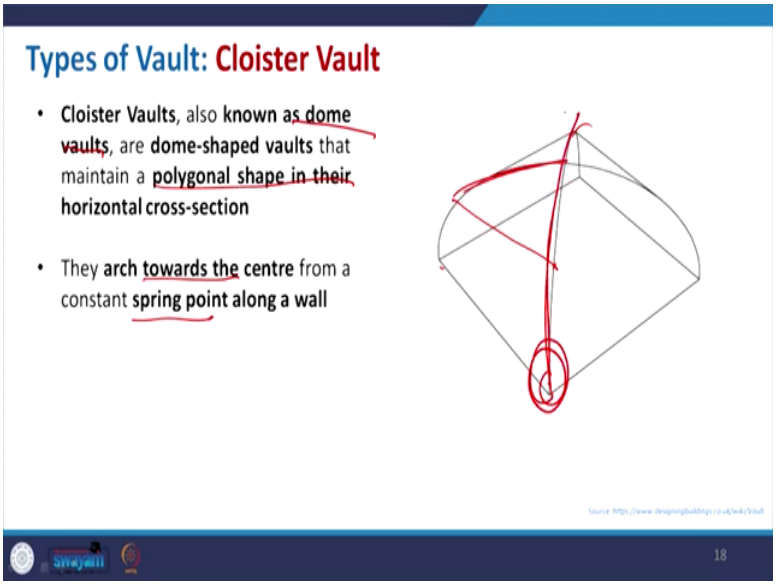

Now, come to the cloister vault. So, it is also known as the dome vault, it is basically the dome shaped and then basically different polygonal shape that will be created that I have drawn there. So, it is one arch and this is one arch and how they are connected. So, this particular portion is little bit flat and then when you go off, it will be even flatter. The arch towards like the center from a constant point to the you know spring point along the wall. So, this particular point is the spring. So, from there they coming to a center, they are meeting to each other to create this cloister vault.

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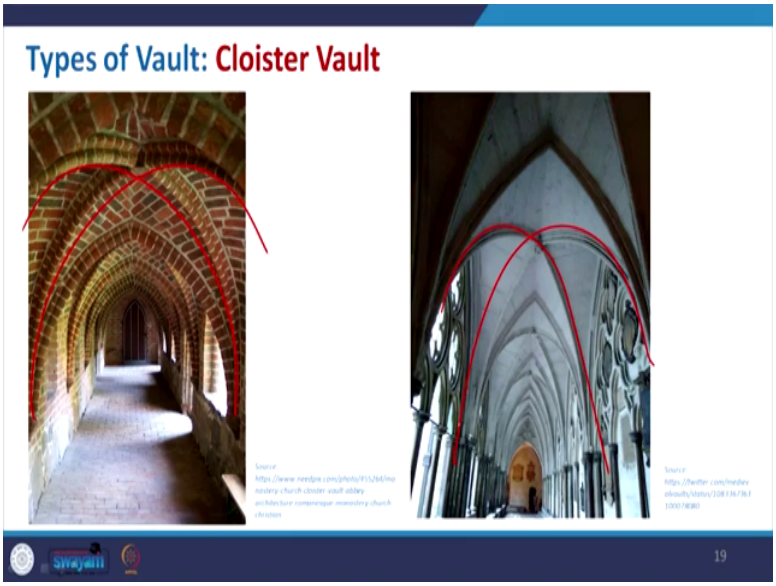

And this is the example that you can see that how it being formed. So, this is one arch and this is one also they are diagonally crossing each other, this is the same for here as well and they create this kind of vault. Again it is similar to the previous one, but here in earlier image we have seen that the ribs very predominant you are not.

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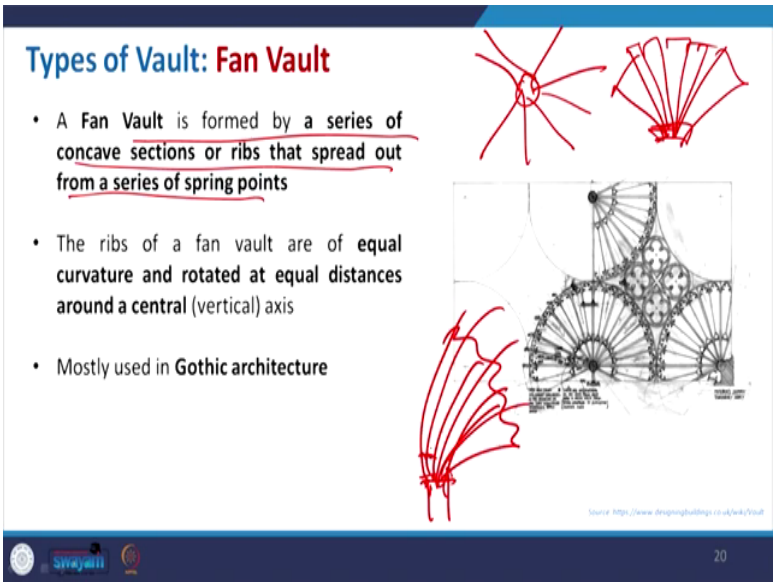

Coming to the fan vault and we all know fan we consider the ceiling fan or something were like with the center we have some blades and if you just increase it. So, it will give a fan shape, even the hand blown form of your fan is something like this that we gives. So, this kind of vault being created with proper geometry, this is some schematic plan I have picked up from the net, you can study more on this definitely going to the this like your website given. So, fan vault is formed a series of concave sections or ribs that spread out from a series of spring points.

So, starting from the point where like it ends. So, from their this spring point, this kind of ribs will created to create a particular fan form. And then the ribs of a fan vault are equal curvature and rotated equal distance. So, this is another geometry to be followed the difference the gap

between those curvatures they are maintaining with certain angle mostly used in the gothic architecture now, you can see how beautifully it being done.

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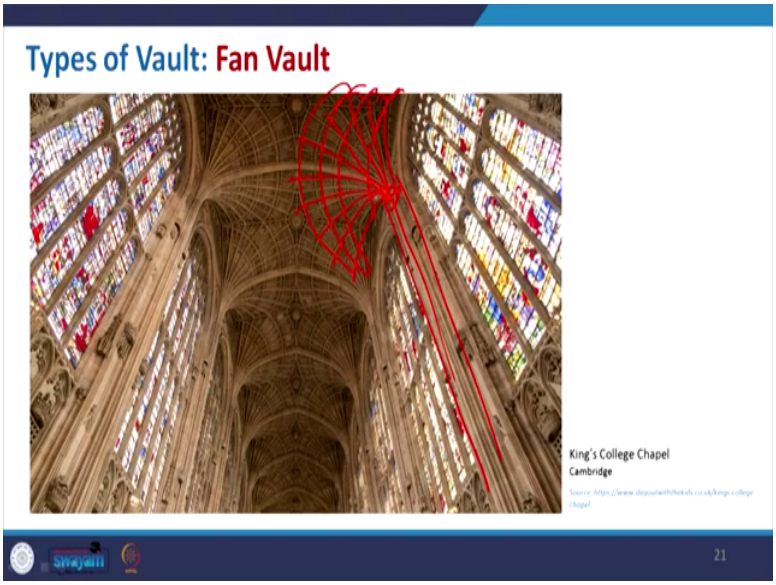

So, in this case again this is the spring area and then from there how like with very nicely with symmetry this being made. So, if I just take this particular portion and I just overlap the drawing. So, you can easily identify the type of vault. So, next time if you visit this kind of structure somewhere. So, you can easily identify the type of vault.

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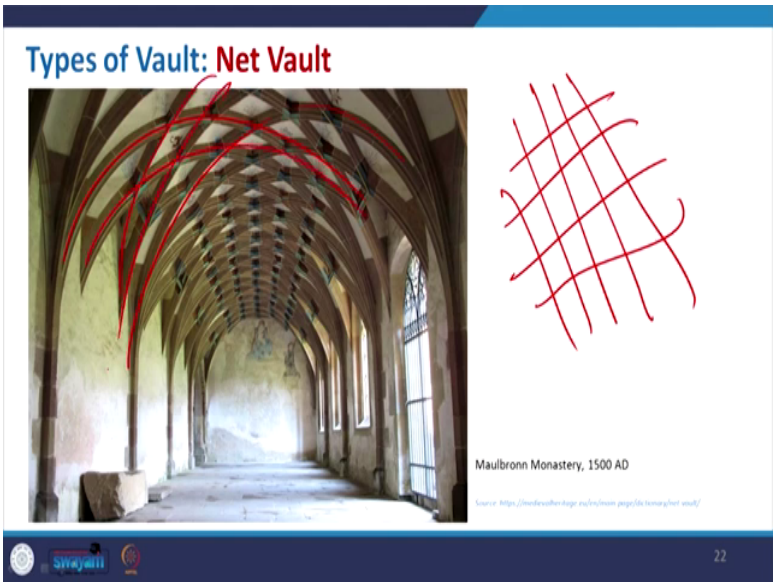

Net vault is something where net is we are much aware about different kind of nets. So, it is the same the shaker box and also multiple curvature they are just crossing each other. So, create this kind of you know net. So, this is example of the net vault.

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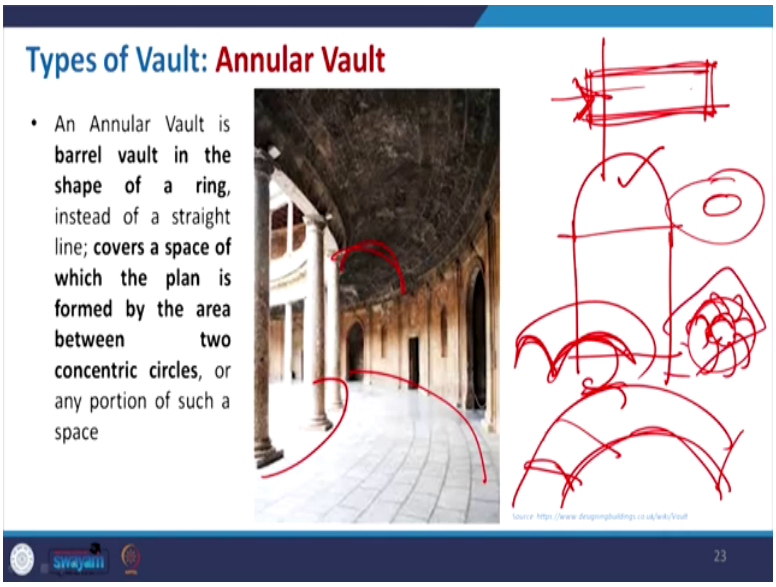

Coming to the annular vault annular vault is something related to the barrel vault, but barrel vault is you know you remember like it is being placed like these on a corridor right where the plan is something. You have the plan like very simple plan and on top of it you have this. So, if I try to get a section like this. So, I will be seeing like this, but in the annular form of vault in state of this straight rectangle, they have in some you know curvature. So, there means in this case if I take out the view so, you can identify that it is not very straight corridor, the vault that being created and evolved. So, that is basically is your annular.

So, for example, the easy example that I could give you to get this kind of shape that you know what we have that particular foot of donut type or maybe the vara. So, then you just cut that slice. So, you will get this kind of form. So, it basically the dome form, but it is again round it. So, this is something else or else you can take example of those you know plastic

balloons or what we call like what we safety aids for the swimmers and all so, that will also get similar kind of things.

So, we have a circular one and also we have curvature this. So, we can cut it like a cut this particular section. So, we will get this annular vault.

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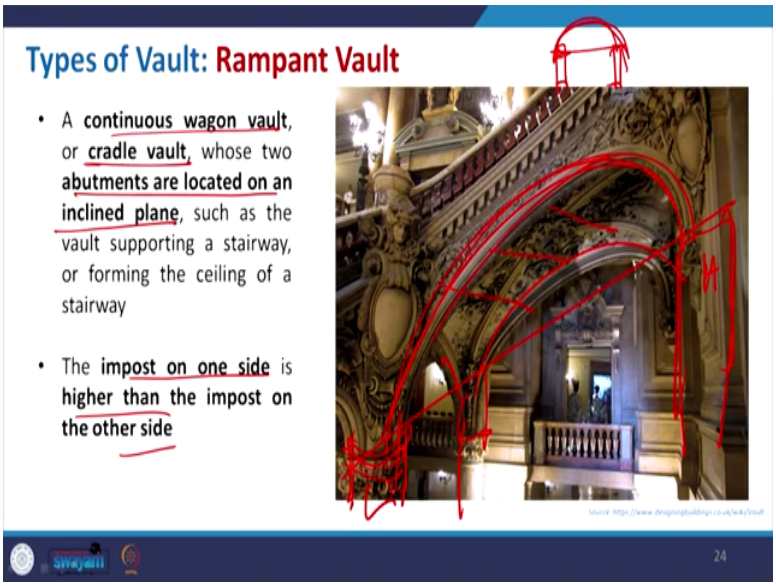

Rampant vault is where the symmetry is not maintained. So, a continuous wagon vault, cradle vault whose two abutments are located and inclined plane. So, in this case what you can see that in this abutments it is in the lower portion and here it is the upper portion and how it is connected is not really making symmetry it is in inclined form.

So, earlier whatever we have you know discussed they are all in aligned and the vault being created with that fan or your ribbed. So, this support is at the same level, but here it is not and

normally this kind of vault being used to support the staircase. So, here also you can get this idea that how it is being supported. So, this is basically a staircase. The impost on one side is higher than the other that just I have explained this is higher and this is lower.

I think by looking at the picture, it is more clear, like there is some very little scope to explain it because it is self expectory. So, what I suggest you for all these kind of example, you try to come up with some more examples and then you just share with me in the forum, then we can discuss over it and then we can actually you know increase the number of examples in each category and we will also confirm ourselves that whether we are able to judge a particular vault in the category or not.

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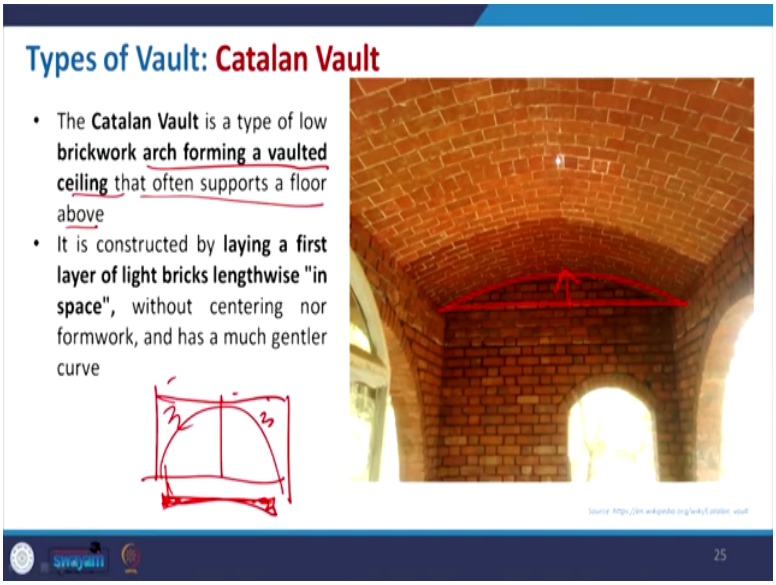

Now, the Catalan vault is something where the slope like the rise is very less, almost flat vault that we can say that here also if you just consider this particular art. So, rise is very less and

that can be this particular portion is being made with a brick and this kind of vault being used where the upper portion of the vault to be used. Because whenever you increase the rise it will give you better result, but definitely like you cannot really use this particular space unless you fill it with some materials or something like that ok.

But if you just make it almost flat. So, you can just use material minimum material to make it plain and you can use the upper storey. So, this is the example of the Catalan vault. So, what it says? Just let us go through this text the Catalan vault is the type of low brickwork arch forming a vaulted ceiling that often support a floor above that is already I explained. It is constructed by laying a first layer of light bricks, lengthwise and in space. So, it is being constructed one after another and you know this require very good expertise to really come up with so, that it will not really fall.

So, now we are coming to the end of this lecture. So, what exactly we summarize if we to summarize here.

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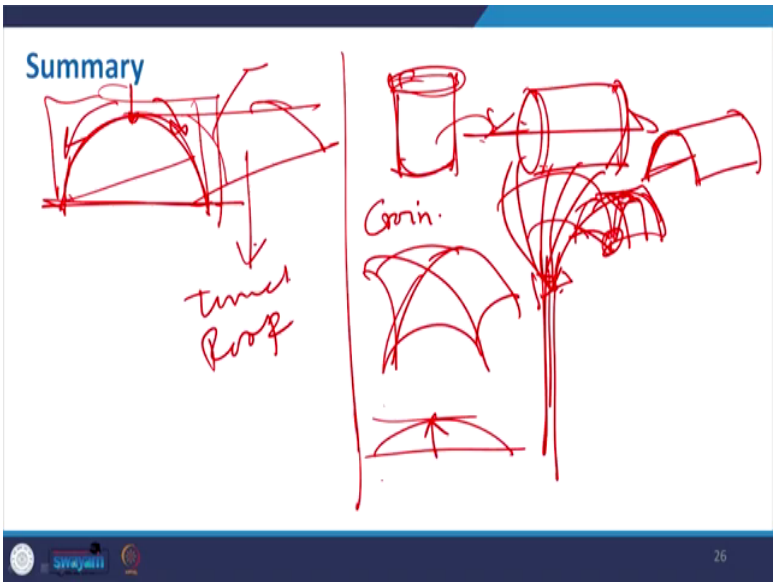

So, we started with the vault is vault is basically evolved from arches. So, the we know the property of arch and this in this arch from the keystone the load is being distributed and then we extend it ok.

So, that will become the vault and vault they are also capable enough to take care of the long span without much support vertical support so, that we can create the obstruction free space and then we also discuss about the material it is the similar material that we have used for the arches over the you know years like it started with the stone, brick, masonry work and then after that you know being like concrete being introduced to make this and then the steel glass that I have shown the example of railway station shade where this being used and then the advantage is this, and definitely for this kind of structure.

Sometimes if you go with very minimal slope and all the load on the you know shuttering or the temporary work being also reduced to this, but definitely when you have a huge arch and also shuttering will come into picture.

Now, also what we have discussed the application of the vault. So, it being applied like a tunnel, it may be a roof of corridor and sometimes it may be also used in a central hall like in charge and all that we have seen in gothic architecture and all. Then we have also discussed the series of vault types and then we started with very simple where it is the barrel vault and barrel means it is something look like this. So, then if you just make the position like make a rotation. So, this is the barrel and you just cut a section and then whatever you see is basically this.

So this is the barrel vault, and then we move little bit we moved with this and the intersection of two will give you the groin wall, then also we discussed that you know intersection of different arches and then creating the dome with a crossed arch dome or the you know we have the cloister vault, then we have the rib vault and also we have seen that at the corner for the groin vault and other thing where two a different vault intersecting them each other at 90 degree.

So, this basically the corner will be the crucial can be supported then also we discussed at the corner can support with some ribs in regular interval and creating a safer fans. So, that is a fan vault and the Catalan vault that we have used where the rise is very less. So, these are the most predominant types of vault being used and in it has diversified application like now it is also even for the corridor we just modified the materials and go for this kind of vault. Even we have seen one example of library where wood being used to create the vault. So, this is something in short vault will help us to you know make larger space, larger span without more obstruction the disadvantage whenever you have highe rise then the upper portion you cannot really use.

So, for that if you have to go for the low rise vault the Catalan vault, but there are other parameters as well. So, proper think proper shuttering is also required to make it and to make

it more stable and then the materials. So, this is overall like where we have discussed the vault structure similar to the arch and it is being useful being used from the history and also in the now present days. So, this is some lesson that we should get and we can apply in our design wherever we need some large span for the community hall or maybe something some big gathering we can go for it.

If I want to make it very interesting some central part of this, the room something interesting we can go with the fan vault or you know ribbed vault, but definitely for that we need very good geometry to be maintained with the good expertise in that construction we need good mansion.

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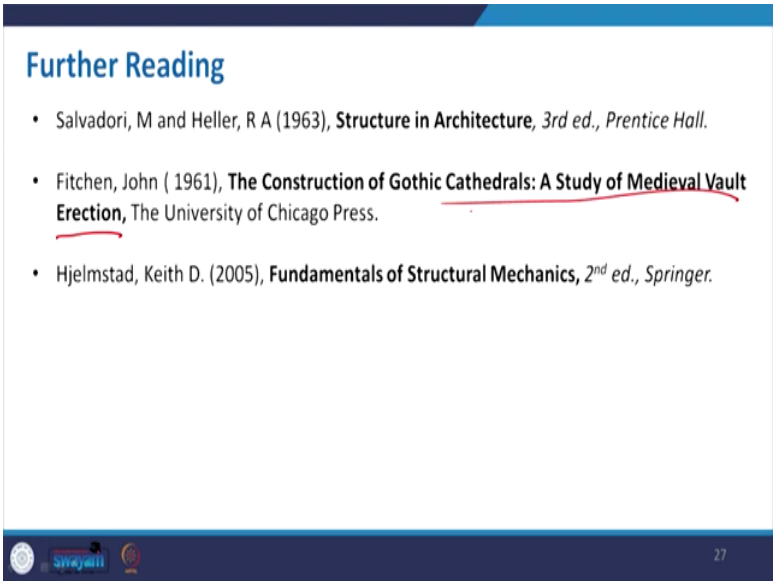

So, here we conclude this particular lecture. And these are the some of the material that being repeated, but this is a new addition to this particular vault study.

So, you can go through this book, you get more example the evolution of vault in detail and different history how it evolved in this book. So, with that I would like to thank you all to take part in this lecture and we will be meeting in the next lecture with dome structures. So, another discussion on the dome and they are like how it evolved and then the type of domes and their use. So, till then bye.

Thank you.