Structure, Form, and Architecture: The Synergy

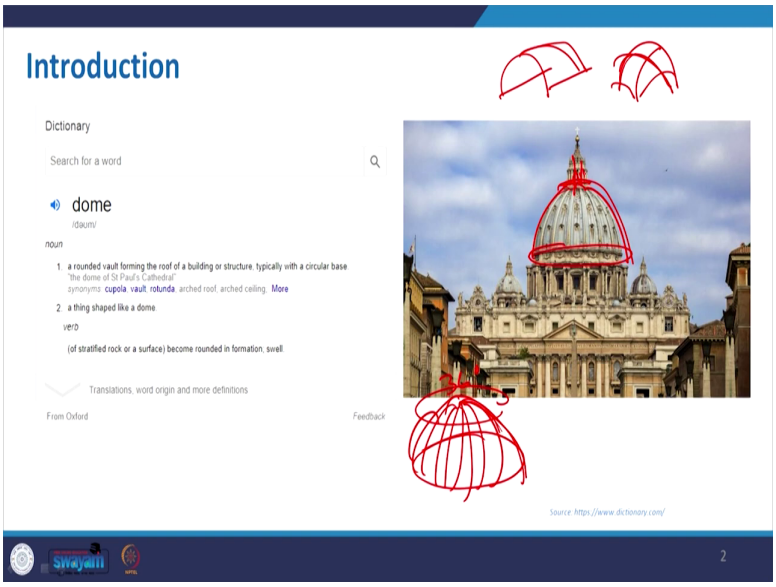
Prof. Shubhajit Sadhukhan
Department of Architecture and Planning
Indian Institute of Technology, Roorkee

Lecture – 24
Dome Structures

Hi, everyone. Welcome back to NPTEL online course on Structure, Form and Architecture: The Synergy. Today we are at lecture number 24 and we will be talking on Dome Structures. So, in the last lecture we have seen the you know type of vaults, their use, the fundamentals and we also came to know about the construction of a vault, it is basically a series of arches.

Now in this, we will also get to know about the evolve of that particular dome and it is again in this case like we have to take an arch and then we revolve it. So, we just rotate it 360 degree we can get to the shape or else we can just cut a hollow sphere and we can get it. So, we will get into this a dome and we will try to understand the materials, the use of that, different components of a dome, the purpose of using dome and then different types with some images some examples. So, let get started this lecture.

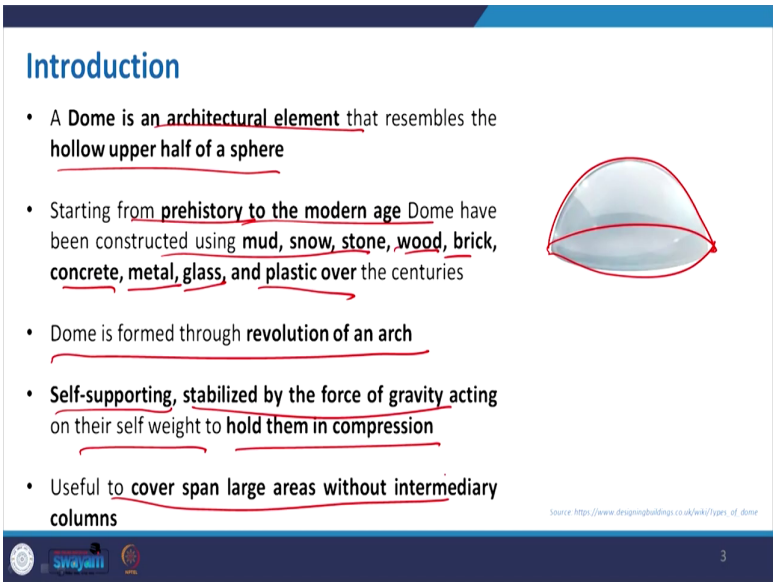
(Refer Slide Time: 01:35)



So, this is a very introductory slide. So, if you just search dome, the first in the Google so, what exactly the definition you will get from the dictionary dot com is a rounded vault forming the roof of a building or a structure typically with a circular base. So, what exactly it is like a rounded vault is basically when we create this space it is the vault even the cross arch vault is being represented like a dome and then it is normally being used and the circular base.

So, in this circular base I take a rise this is one arch and I just evolve it 360 degree. So, multiple arch like this we just tried to create and then basically whatever the form will get that is the dome. Like this is some example that is there with us; so, this is if you just try to simplify it. So, it is some dome not really having a very semicircular same semispherical hemispherical dome. So, like there is some other components added. So, we will come to that as well.

(Refer Slide Time: 02:53)



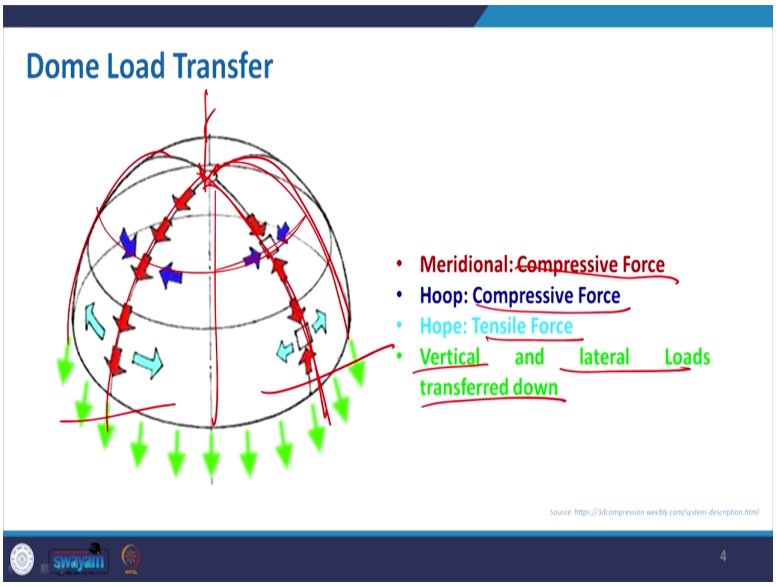
Now, here you can see a crystal dome in this. So, dome is a an architectural element that resembles hollow upper half of a sphere. So, that already explained. Starting from a prehistory to the modern age dome have been constructed using mud, snow, that we cannot ignore the construction of igloo that is basically the dome structure then wood, brick, concrete, metal, glass, plastic and now like anything. Even you know we all have played with the plastic ball or the some kind of a cricket ball. So, if you cut this that will be a solid dome, but we all are aware about this particular form.

So, dome is formed through revolution of an arch. Self-supporting, stabilized by the force of gravity acting on their self weight hold them in compression. Useful to cover the large span, it is again the same. So, starting from the dome that we can see in Taj Mahal or maybe the dome

that we have seen in Pantheon in Rome. So, it is basically helping us to have a column less structure.

So, vault doing the same purpose, but for the corridor or maybe a area of that kind, but dome being used for a larger span.

(Refer Slide Time: 04:23)



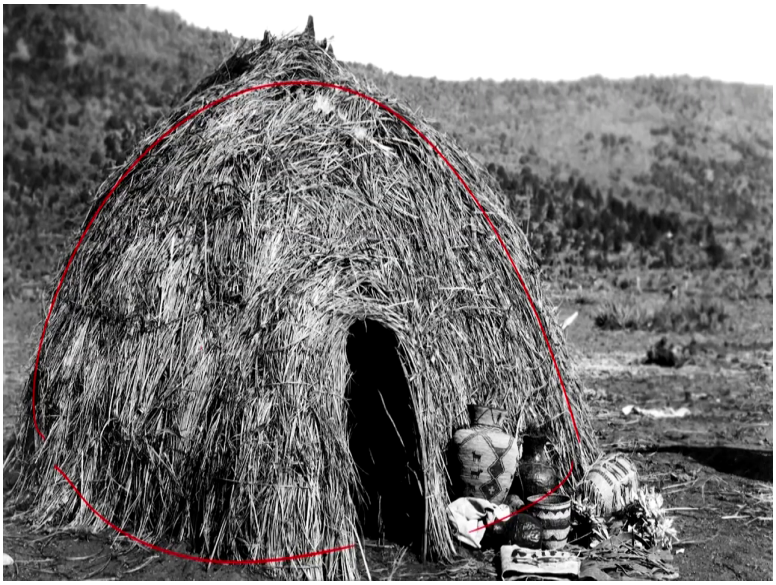
The dome load transfer, how it transfer the load so, let us understand this. And, here you get a schematic and corresponding color will have the indication the type of force that it is dealing with. So, the component that we have is basically these meridional portion. So, this are your meridional component of your dome and that is taking the compression.

So, basically if you take one you know maybe a plastic ball or something a ball made of a light material and you try to put the pressure from the top so, these fibers are always in

compression. Then, what you have the upper loop so, upper loop they will also try to compress. So, they will also be in compression, but the bottom surface when you press it ok. The bottom surface will always try to go away from each other and they that is why it is intention and then the vertical and lateral loads transferred to the down.

So, this kind of you know what we can compared with your latitude longitude similar kind of thing so, you have a series of compression and tension which can be dealt with the dome.

(Refer Slide Time: 05:47)



So, this is one example that I picked up. This is a dome made of some you know temporary wood and then the grass or something. It is very old a kind of practice to make this kind of structure, but the overall form is again a dome shape. So, it basically giving you a volume as well as like you do not need to really give much support in between.

(Refer Slide Time: 06:15)

Move on. So, this is some famous example and I am repeating this example in many cases because it is worth of repeating of its many features. We can explain many things with this the use of like this lighting is one component, but here the intention is to show you the dome. So, this dome is basically the dome for the pantheon and then here like it can accommodate the gathering. So, this is being used to have a like column less space.

(Refer Slide Time: 06:49)

This is something really I need no explanation the beauty of it, the aesthetics of it and the centralized dome. So, basically this is a type of dome we refer at the onion dome, we will come to that when we discuss it.

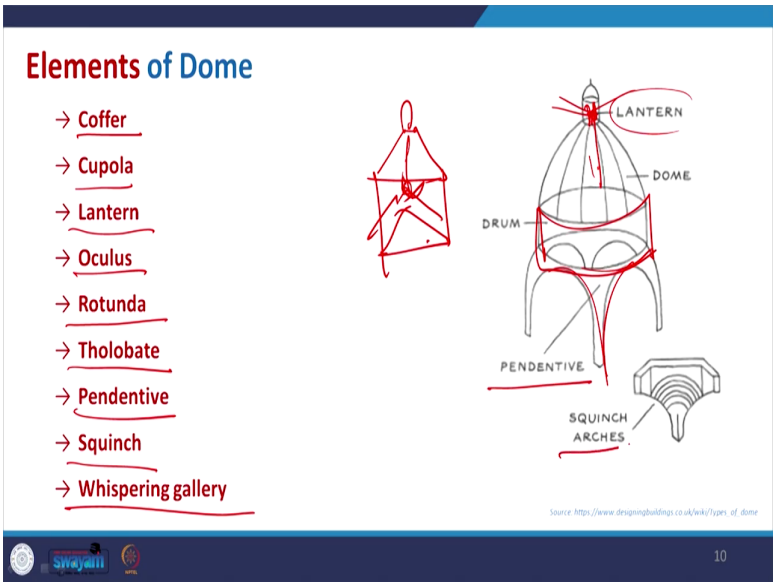
(Refer Slide Time: 07:07)

So, this is another application of the dome. This is your Hagia Sophia. So, here also you can see the series of dome in a different pattern. So, time to time from the history to the modern, the pattern of dome, the ornamentation of dome it differs. And, in the modern age also we can have something which is a pneumatic dome; that means, somewhere we also discuss; the typology the pneumatic means it is filled with the air and then create a form of a dome.

(Refer Slide Time: 07:45)

This is another example of a dome but here you can see that in state of your lattice and the hoop you have something different like a triangulation of that multiple triangles they form it. So, this kind of form is also called geodesic dome. So, we will also discuss this when the type of dome will be discussed in upcoming slides.

(Refer Slide Time: 08:03)



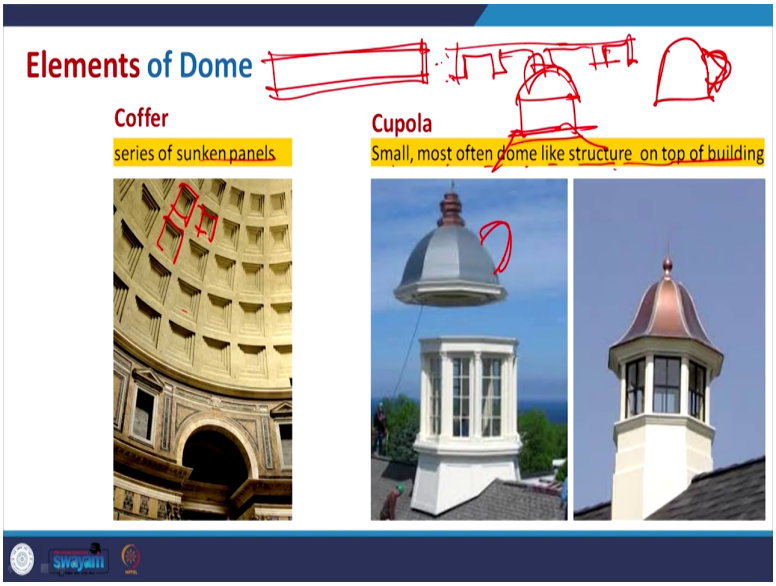
Now, coming to the elements of dome so, here you have some information which are little bit not similar to the vault component or arch. So, we have coffer, we have cupola, lantern, oculus, rotunda, tholobate, pin pendentive, then squinch and whispering gallery. So, what exactly they are? Though the names are little bit you know difficult to remember I know, but looking at the photo we will try to get to identify what exactly and I am sure that we can really get idea with the you know the some of the forms and the names and the what exactly it means.

So, before that in this it is very simple. So, the lantern is the upper part that you know the initial picture that I have shown here at the very beginning slide so, this particular portion is now referring as your lantern it is similar to that and not only looking at the shape, but it has a function as well. So, this will be used to create some puncture. So, light can enter to this and

then the interior can be getting some daylight. So, like when we have a lantern something like this we hold it and then there is a lamp. So, we can get the light it is something like that.

The cupola is the similar kind of a thing that we will do and this is basically when a dome to be placed on a you know a part of a cylinder. So, this is basically the drum shape. Then whenever you have to change like you have to place a different kind of dome on our square base. So, you have to make changes at that junction. So, pendentive will be form and squinch of arches that will be formed. So, let us try to discuss it.

(Refer Slide Time: 10:05)



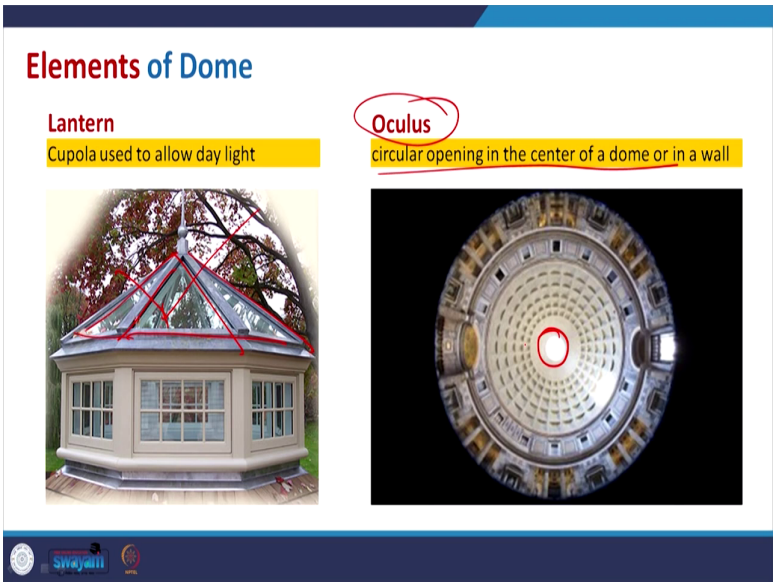
Now, coffer is basically the series of sunken panel. So, this is basically what you can see in order to reduce the volume of the self weight of the dome we can also have something like this. So, this is basically the coffer you know sometimes we call in this case it is the

component is called the coffer part of that, we also refer as the coffer ceiling. So, then where we can really reduce the volume of the you know concrete.

So, suppose this is a solid section and then if you use the coffer slab is basically something like this. So, looking at the you know load it can carry so, we can reduce this volume. So, this is basically the cross section I am referring. So, it being used in the modern building. Also the coffer is the terminology to just represent the series of sunken panel.

Then cupola is basically what we can relate with the cup. So, the shape if you just put the cup in this position, something like this, so, it is the small most often dome like a structure on top of the building. So, something like this you just put on top of it. So, in many buildings like where you have a very similar route pattern and top of that you can use this.

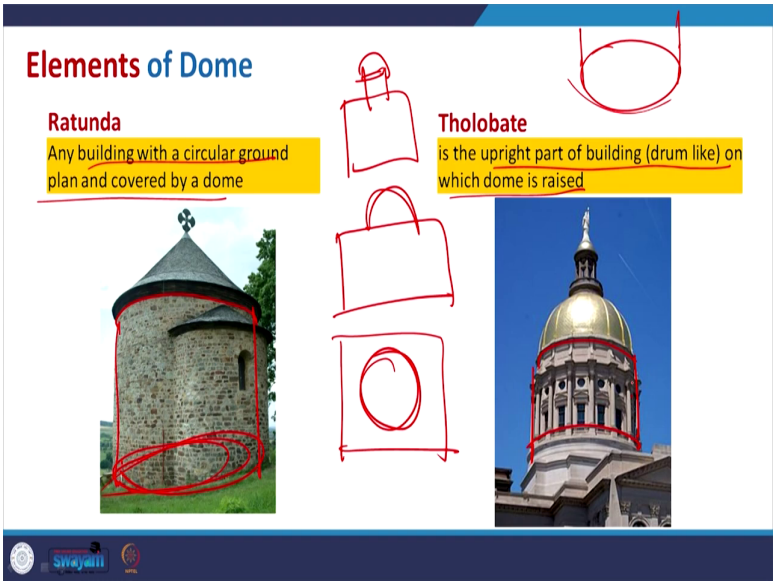
(Refer Slide Time: 11:37)



Move to that the lantern cupola used to allow the daylight it is a similar thing that the top of each the cupola in this case having the transparent glass so that light daylight can easily enter. And, not only the daylights sometimes even at nighttime, it can get a good you know lighting some ambience, good view of this particular building.

Now, coming to the oculus this is where the circular opening in the center of a dome or a wall. So, that we can see in again the example this is basically the view recreated from again the pantheon and this particular puncture. So, if you go back to the example of this so, this is basically the oculus.

(Refer Slide Time: 12:31)

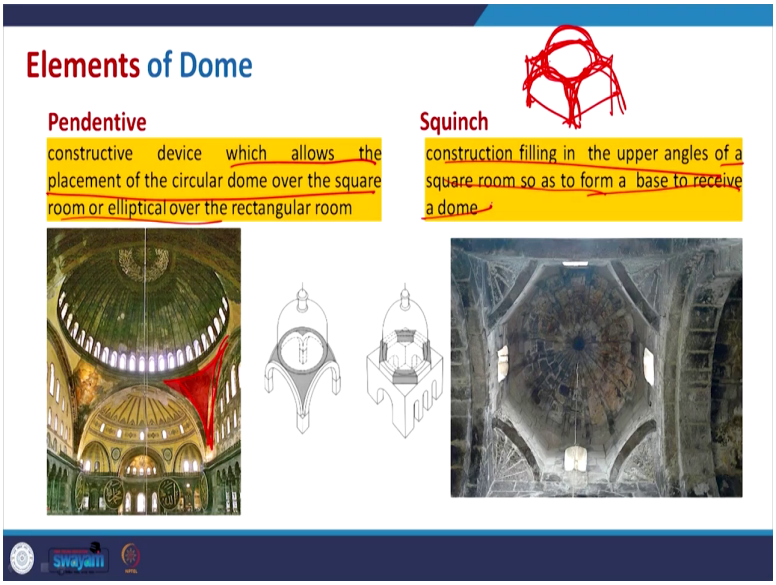


Now, what is Ratunda? Ratunda is basically any building with a circular ground plan and covered by a dome. So, in state of many buildings you will find that a dome is placed at the center. So, that it will look like something like these or maybe if you use some drums so, it

may look like this. But, here it is the same where the plan is itself a cylindrical form or it is basically the whole volume is a cylindrical form and the plan is circular. So, you can see if you just try to make the drawing of this is a circular plan and then in top of it you have this.

Then, coming to the tholobate, it is the upright part of a building drum like on which dome is raised. So, this portion is a basically the tholobate. Coming to the pendentive that this is basically also alternatively that we have seen it is called drum.

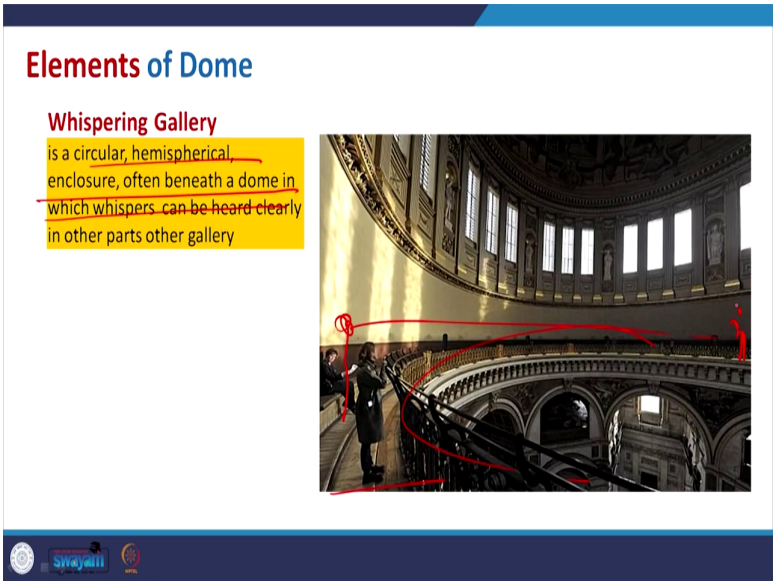
(Refer Slide Time: 13:19)



So, pendentive is basically constructive device which allows the placement of a circular dome on a square room. So, basically if you have a like some room like this and when you place the dome on top of it. So, it is basically you cannot you can take the midpoint of that, you can make the circle and you can make the dome, but now this particular portion to be managed.

So, in that case what we can do? We can just take out those material or we just create the portion we transform that portion and this particular puncture where form you will take out the material that will be your pendentive. So, this is basically the pendentive be created where the squinch is something were construction filling in the upper angles of a square room to form a base to receive a dome. So, again here some things we have to fill so, that is the squinch.

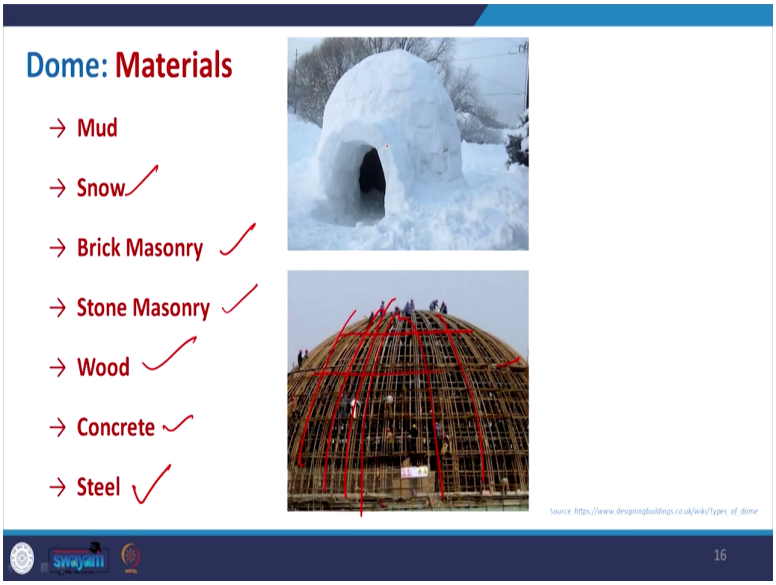
(Refer Slide Time: 14:35)



Whispering gallery is something where it is a circular or hemispherical enclosure often beneath the dome ok. So, it is basically a area where you can stand we have where we can you can go and which will help to whisper and if you just make a noise in this and that will you know take a surrounding sound and you can stand here and listen to this.

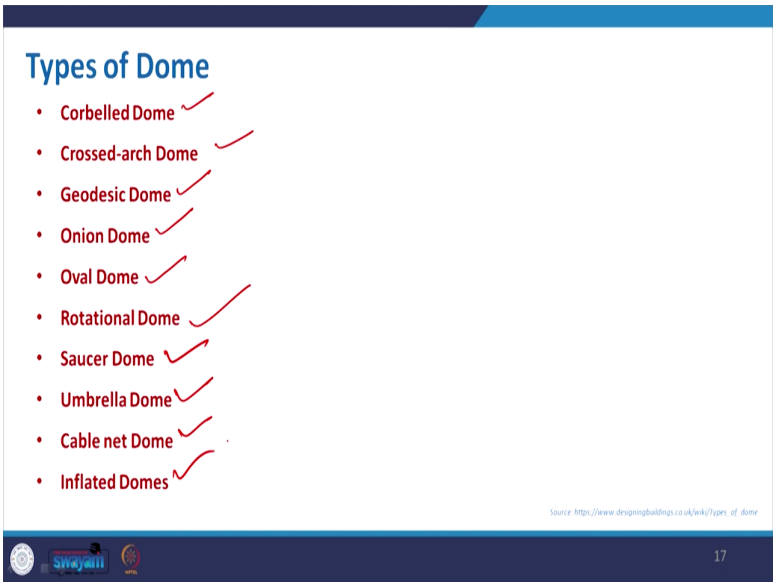
So, this is being there even in India this kind of things we can observe in your Gol Gumbaz in south. So, if you have visited that also you experienced this or else in upcoming days if you plan to visit you can get it and this is something which is also a part of a dome sometimes where we can create this kind of scenario.

(Refer Slide Time: 15:23)



Coming to the materials, so, as I already mentioned it can be mud, it can be snow, it can be brick masonry, it can be stone masonry, wood, concrete or steel and in this case you can see this being created a temporary dome being created with a bamboo. So, this is how beautifully they have been creating it and this is igloo being formed with the comprised block and then this dome been created.

(Refer Slide Time: 15:49)



Now, the types of dome. So, go to different search you will get different kind of list the dome. The my point is here I have a specified the domes which are very popular in nature, but definitely there will be some addition to this list and you I am really I will be happy to you know listen from you if I just missed out some of the dome and you can add on to this particular list.

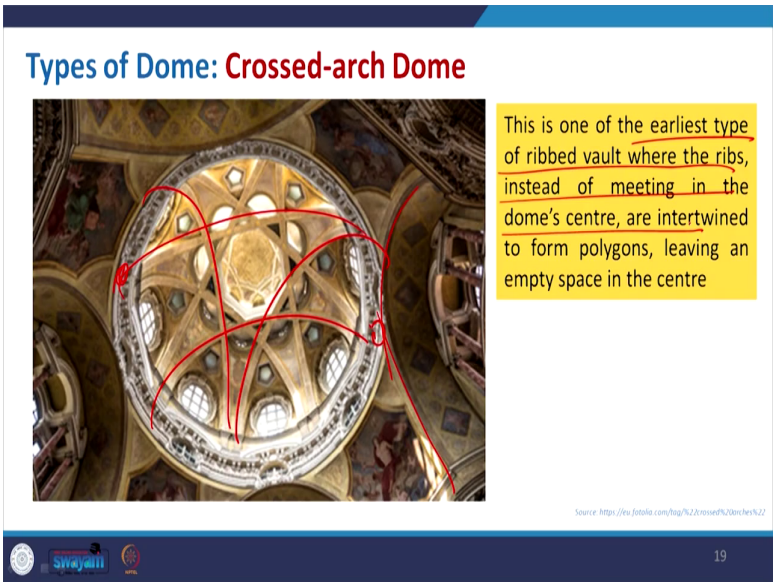
So, it started with the corbelled dome, crossed-arch dome which is also like a the ripped vault that we discussed; the geodesic dome, onion dome, oval dome, rotational dome, saucer dome this is really interesting, umbrella dome, cable net dome, inflated domes. So, what exactly they are and how to really remember? So, I will try to just relate with the terminology and your the vault.

(Refer Slide Time: 16:59)

So, let start with the corbelled dome. So, corbelled dome is basically where we put the layers of your brick or stone one after another ok. And, then we just take some kind of offset and we just create this type of you know hollow space inside. So, the more offside view it will look very like piramidical shape, but if you reduce this particular space between two layers. So, definitely it will give you the form of a dome.

So, this is something a very old kind of structure where without any mortar this being created and here it is something where in a temple this being again created to make a circular form and final ornamentation is a different thing, but basically out is the same. So, we take the span, we have like a particular cylindrical form and all. So, we just try to feel the first layer, then the second layer, third layer, fourth layer. So, likewise we will go for this kind of corbelled dome.

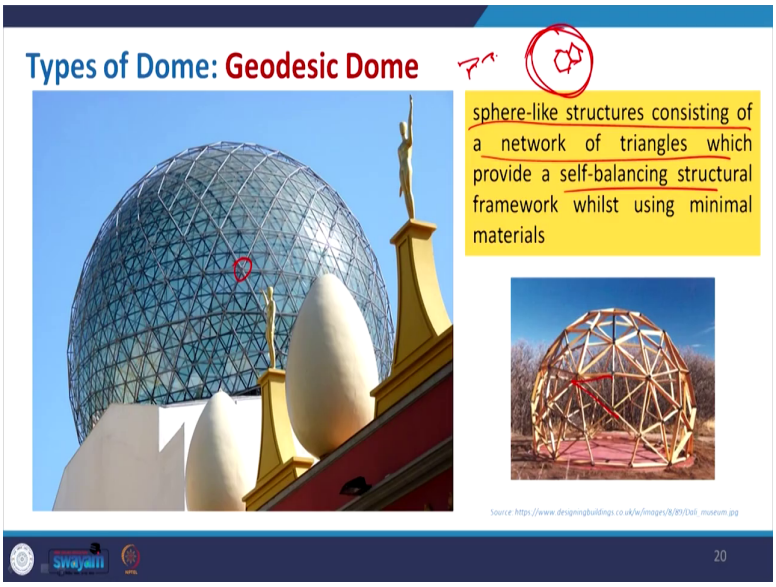
(Refer Slide Time: 17:57)



Now, the crossed-arch dome is basically where it is the similar that we have seen that multiple arches they are creating a octagonal shape or sometimes even more arches will give more polygonal shape and then this is being supported with some kind of you know wall or something. So, this dome being created is the crossed arch dome.

So, this one is one of the earliest type of ribbed vault rips instead of meeting the dome center are intervened to the polygons that we have also seen in that ripped and clustered vault.

(Refer Slide Time: 18:35)



Coming to the geodesic I have shown you one example a lit take this examples this is as a model where like triangle being placed one after another to create this kind of form.

Another example that I can give you the formation of the dome that many of us we also like played football or maybe we watch football. So, football if you see like basically it is a sphere ok, but in formation of this what we need? We need pentagons and then we need a hexagon. So, with one pentagon so, we just create the five hexagons and like that we create the you know these particular curvature.

But, instead of that if you use the triangle and we can just create this kind of volume. So, this is also very popular nowadays many such steel structure, geodesic dome being created. So, sphere like structure consistent of a network of different triangles provide a self-balancing between the structures. This is very useful; these joints are how it is being made those are very

crucial so, firm anchor how it is being placed to form this. So, the application of this kind of dome is quite modern and there are many examples that we can come across. So, this is one of them.

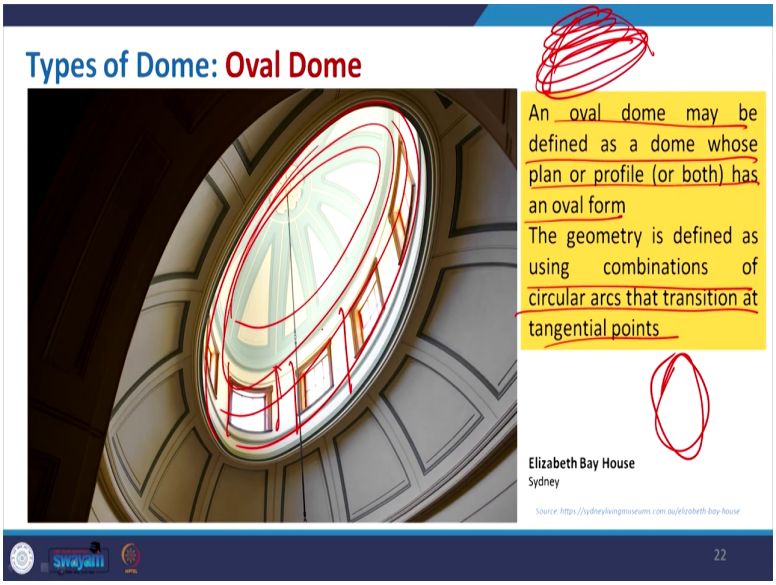
(Refer Slide Time: 20:11)

Coming to the onion dome is the easiest thing to remember we all know the onion and the shape is something like this. So, this is a white onion. So, the color may vary, but this shape I just place it here. Earlier I have given an example of Taj Mahal. Now, this is something like this. Even if you take example of the Disney land so, there also you get this towers and then the form is something like this.

Even we have something seen in those documentary video of Aladdin or some Disney movie. So, this is something where we can get it. So, this is basically the cathedral domes from Russia

so, where the form is being easily visible. So, it is look like a golden onion, but yes this can also be used as a form.

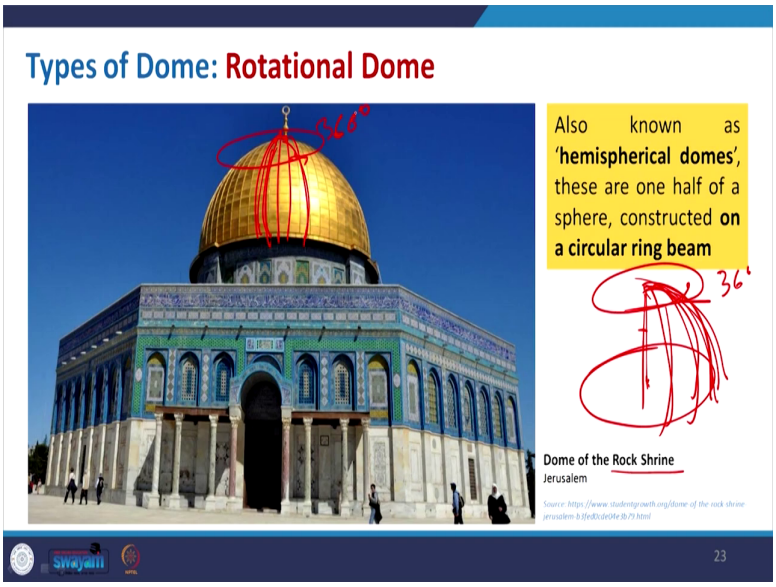
(Refer Slide Time: 20:49)



Coming to the oval as it is coming from in the shape of a oval so, like something like this. So, here sometimes for some interior space the change, the plan in state of a circle, the profile is the oval. So, basically a oval dome may be defined as a dome whose plan or profile has an oval form.

The geometry is defined as using combination of circular arch that transition at you know tangential points. So, basically in these case we have to reduce it like this. So, that we will finally, get the oval form on the series of oval. So, this is one oval, this is another one and this been connected to that sub plan here it is basically a wall and then on top of it we have this. So, this is oval.

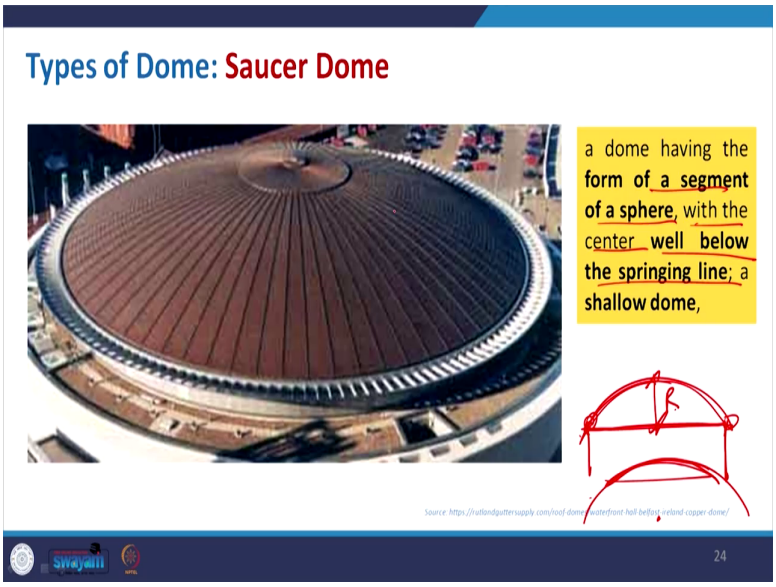
(Refer Slide Time: 21:43)



Now, coming to the rotational dome is basically where I have started like we take with one particular you know circular form and this is center you take a rise then you take one arch and then you try to revolve it 360 degree. So, after revolving whatever you will get is basically a hemisphere spherical dome if you take this arch like and the rise in that panel. So, it is basically the half cut of a sphere.

So, it is something the example that is from the dome of the Jerusalem Rock Shrine. So, here it is example of the rotation. So, rotating you know arch. So, if you find that if these are visible of few of the arches merging to a particular point if you increase more. So, basically it is starting from a point and ending to the same point the revolt of this. So, that is the rotational dome.

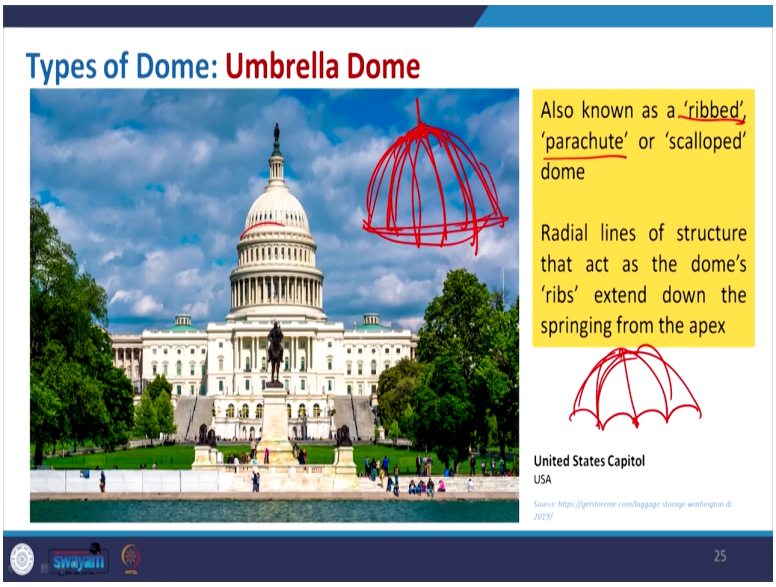
(Refer Slide Time: 22:49)



Saucer dome is basically where it is also referred as the segmental dome. So, we talked about the rise. So, this is your support and then whatever the height will get so, this is basically the rise. So, for the saucer dome it is a segmental. So, the rise is something which is not lying in this line maybe from you know some bottom of that and from there we make this particular arch. So, the center of this arch is basically below that.

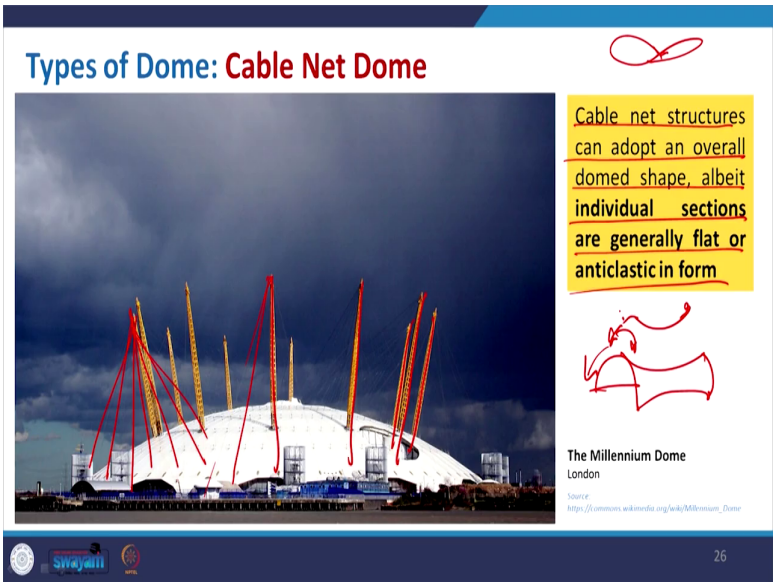
So, a dome having the form of a segment of a sphere with the center well, below the springing line. So, this is the line that we have talked about the springing line even in the vault so, this particular portion is the saucer vault. So, here you can see that how flat almost it is there. So, it is the saucer dome.

(Refer Slide Time: 23:49)



Coming to the umbrella dome it is also known as ripped or parachute dome. So, what exactly it is we know the form of a parachute is something like this and also the umbrella. So, where it is basically started with a very simple dome and then the ribbed will actually guide it to like take a form of this umbrella. So, this is a if you just take this example this is United State Capitol from US. So, it the example of this umbrella dome.

(Refer Slide Time: 24:25)



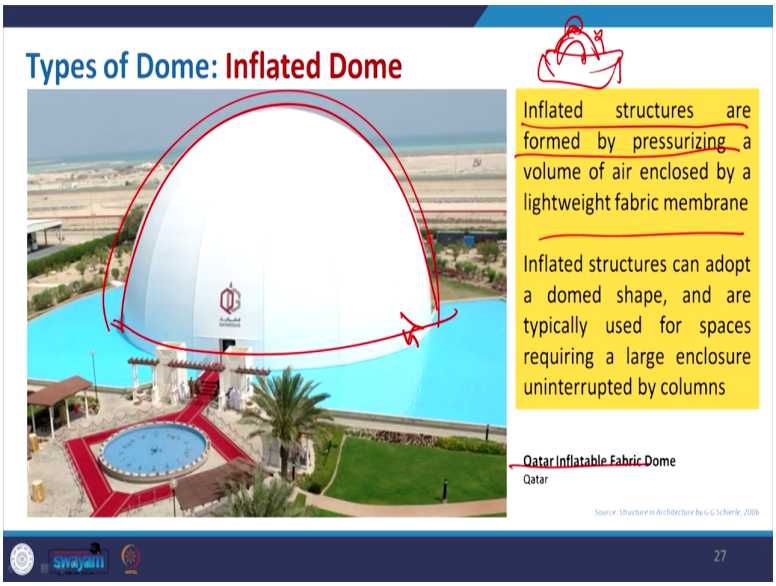
Coming to the cable net dome. So, it is also very important that this particular Millennium dome we have discussed earlier as well in when we discussed about that tensile structure. So, in this case this vertical members they are used as a compressive members and very finally, if you see these images so, they are fixed with some cables some multiple cables they are giving the tension and this is the fabric material. So, huge dome being created which very few number of such post or mast we refer technically the mast it is only taking the compression and the rest of the arch tensioned. So, with the cable this can also be formed.

The cable net structure can adopt an overall dome shape, albeit individual section are generally flat or anticlastic form. So, we have discussed the anticlastic thing, but again we are just discussing it. Anticlastic form is when the curvature of plain two curvatures of the plane they

are acting in opposite directions. So, basically I have given example of chips. So, it is sometimes you just take any example of chip. So, it is something like this something like this.

So, here I am trying to explain this with this example. So, this is anticlastic means you have a curvature of this particular arch like this and then you have curvature of the top like this. So, this is basically the anticlastic form that we will follow when we discuss the favorite structure as a form we will discuss in detail the anticlastic and synclastic curvature their advantages and disadvantages, but to understand it basically two curvature in opposite direction. So, this is from the cable net dome.

(Refer Slide Time: 26:21)



Coming to the inflated dome, can you guess the material of this dome? So, looking at the image from a distance it looks similar to a you know concrete dome, but it is not. So, this is

basically the inflated dome being created. So, inflated structure are formed by pressurizing a volume of air, enclosed by a lightweight fabric membrane.

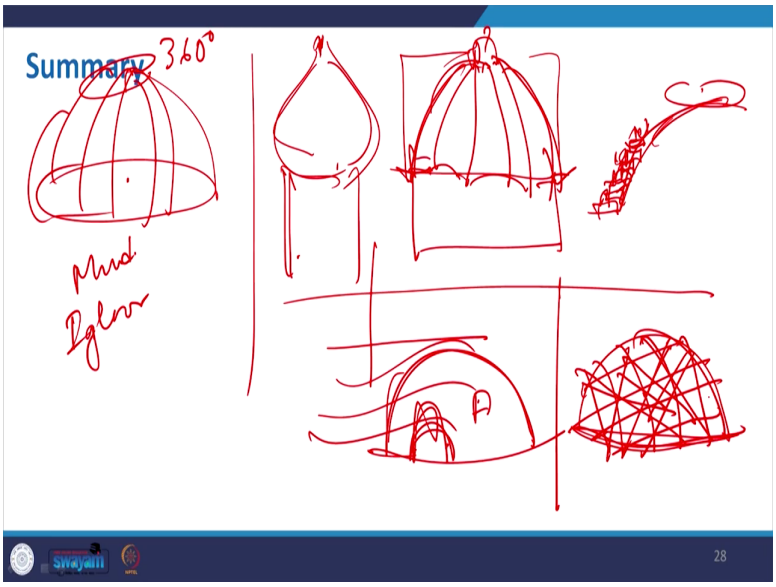
So, sometimes even I have given this cited this example before that for you know a game zone in a shopping mall or it may be a local fair. So, we will get something like a structure for the kids like you have a Mickey Mouse kind of things. So, people are jumping over it. So, it is nothing, but a membrane so, they put air inside this to give the form which is sells sustaining and adjusting automatically and when you release it will be just flat at.

So, this inflated dome being created. This is the Qatar Inflatable Fabric dome. It is a fabric being used, the air is used to give the form and it has been created. So, this is not the only for a structure even these kind of technique now being used to create as a shuttering to create the dome. Now, obviously, for this concave structure or the huge dome, unless you go for the core building is very difficult to make the shuttering at certain height, and also to maintain the perfect symmetry. So, what we need to do?

We can use take example of this kind of you know balloon kind of form and then we just put the pressure, we just cast the dome as we want or then we just take it out the we release the pressure, so that this is this will be formed very smoothly. So, this is a very good example and it low scale if you use this dome kind of structure they are again mostly taking the compression and at the bottom you know hoops you will get some kind of tension. This is also proven to be go to for our seismic zone.

So, in state of having rectangular this dome can be used for that even for the wind. So, they will also help to have a better air flow. So, taking the aerodynamics and oscillation and also this kind of shapes are being useful. So, not only as just the root purpose of any building as a decoration, even like for a normal structure as a building a low form structure we can also made. So, we will discuss on when we discuss about the structure that is preferable for such disaster zone area will come back again with this kind of dome form.

(Refer Slide Time: 29:09)



Coming to the summary, so, basically in this we have discussed about the dome and here it is like the basic dome being formed, like it is like half the section of your hollow sphere this is one idea that we had and the other one we discussed on the rotation. So, you have one arch and then you evolve it revolved it 360 degree and then we get the form of this dome.

We have also discussed about the material, the mud. I have also shown you some dome made of your some branches of the tree as well as some grasses to give the form and then also we discussed about the igloo which is made up snow and later on like brick masonry, concrete masonry, even the steel, even the cable and then the last example that I have shown you is just some air pressure. So, due to pressurized air so, inclination of these things being done and the type of dome that is a series of dome and, but we can relate it.

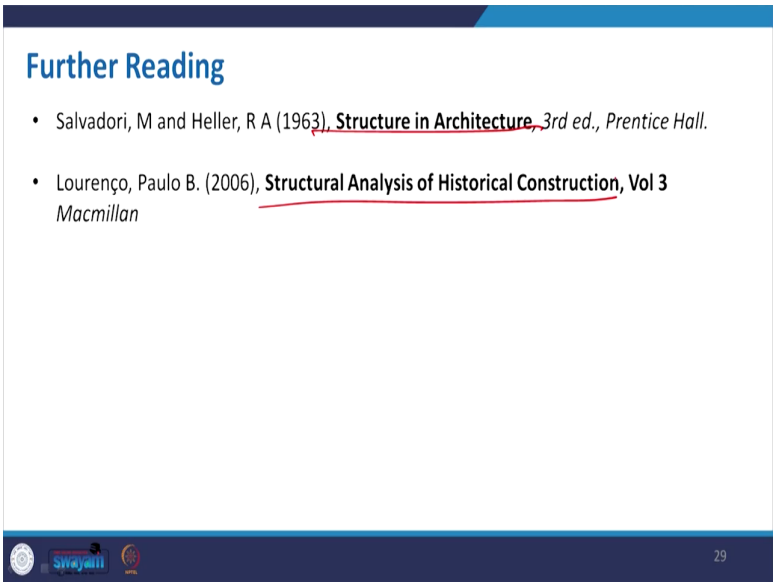
So, where the rotational dome we also discuss the you know onion dome that been used in Taj Mahal or even in the Disney land somewhere we have also seen that particular umbrella or ribbed thing that we have discussed for your what we call the Saint Peter's or maybe sometimes like the example have taken for the US State Capitol that is there and then sometimes the dome can be of your corbelled. So, where like you have to align those particular layer of bricks or masonry in so, taking some offset in such a way that it will create a form of arch and finally, it revolt and then we can get this dome.

Now, coming to the advantage of the dome definitely; taking the example of the pantheon. So, it will be used like it is very useful for covering a large span with minimum obstruction, but the disadvantage that we have that we cannot use the upper portion. So, that is where normally being used for the roof for the case and then like it can be easily formed and mostly it is like self-adjusting transferring the load to the support like this.

And, then the last point that we discussed that this kind of dome or curve form that is very useful for the windy area or outgoing planarian to tackle with that can also be used as a like small unit of as residence. And, then also we discuss in modern days in state of this a heavy construction we just go each some triangulation of your structure with the steel member and then we form the geodesic dome which is being used to create it.

So, we can we have some examples on that as well. So, this is the discussion on the dome and their uses from the history to the modern world, and there is no end of getting the example of that. Please do that exercise to put the more examples to this and if I missed out some of the category which is very predominant you can also suggest me in the forum we will get back to you that positively.

(Refer Slide Time: 32:49)



And, these are the some rating reading materials that been repeated so, you can go with that. So, these structural analysis of historical construction there you will in this book you will get some example of construction of dome and all how these being done. So, the main idea to discuss each type of structure one by one to get the advantage, their application, the type so, not only the structural form or they are capable to take more load, more span is feasible, but as well as the like the ornamentation that is also we need to understand because this subject is basically the synergy between the form, architecture and these aesthetics as well as the structure.

So, we should also take that point that how beautifully like ornamentation of world then the arches and then now the dome being created and we can definitely simplify that. We can go with the classical one or else taking the new materials and create some good form and that will

make a proper synergy without compromising the you know structural safety of our building, we can do some you know great creation with some new materials, new techniques and all.

So, again I would like to thank you for take part in this course and next we will be meeting on with a new discussion on the grid structures. So, moving from arch, baud and then dome and then we will discuss about the grid and their limitations and their advantages and then slowly move over to the membrane structure and other structural form that will be a useful you know a lecture that will help us to take a decision on the type of structure to be selected depending on the purpose and we can make the synergy between all these you know form architecture and structure. So, till then bye.

Thank you.