Structure, Form, and Architecture: The Synergy

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Lecture – 25
Grid Structures

Hello everyone. Welcome back to online NPTEL course on Structure, Form and Architecture: The Synergy. Today we are at lecture number 25 that is Grid Structure. So, far we have seen different kind of structural form and their uses in building forms as structural material or else to just make the form and we have discussed about comprehensive structure, tensile structure, dome and now we are coming in a part where we will discuss about the grid structure. Though these grid is very commonly known as some you know very commonly we can say the rectangular pattern the square block and all partially, this is the same thing that we will be talking about. So, let us start this particular lecture.

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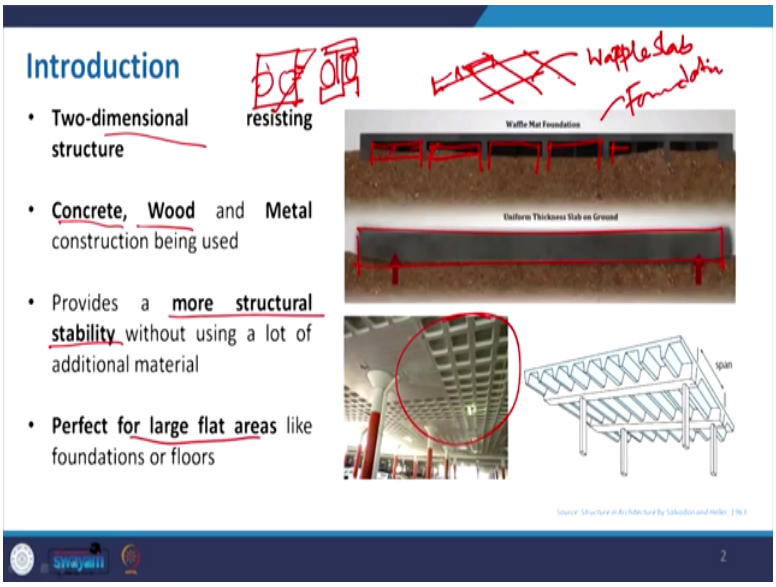

So, basically if you see in this slide that grid is a 2 dimensional resisting structure. So, what exactly it is for that we need to know about the one dimensional structure.

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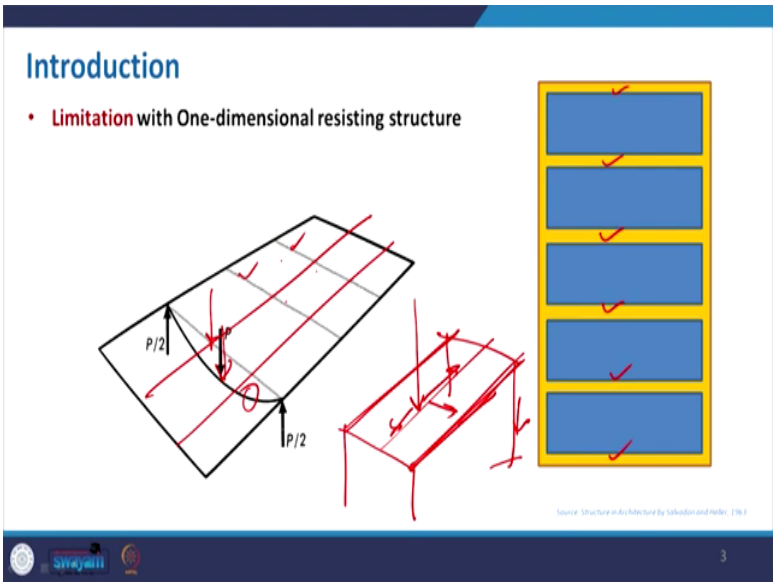

So, I take to the next slide then again I will come back to the first slide. So, whenever you have a frame structure a flat slab structure, so, basically what you have? The number of columns and then the slab the load applied on the slab then distributed and transmitted to the column and column will transfer load to the you know lower floor and then to the foundation. So, that is the phenomena. But in this particular case, we have to like give this particular beam in one direction in one dimension is given either in x or either in y.

So, here if you see this is a rectangular slab and the beams are provided parallelly to that. But the problem with the one dimensional arrangement is whenever you give a point load, the corresponding beam will get more deflection and there is not much you know deflection in other parallel you know beams. So, that is why sometimes these will not really act you know

very efficiently or we will find that we are we have to restrict our self to reduce the span of the room to have this.

And in order to overcome that we may add some of the members and we just make grid form. So, then on load applied, so that will be distributed in more you know in a more better way. So, coming back to the slide first slide, so, here exactly this is what said that it is 2 dimensional not in one direction, but both the directions we have the beam. They are you know interacting with each other.

So, whenever there is a point load so that can be easily distributed. This kind of structure can be applied for the foundation where the surface is very flat and also as ceiling or your floor. So, for the foundation, so here if you look into this picture, so, the first so the bottom one is basically a solid slab as foundation base. But here it is basically if you see that in this case it is not the solid one, but it is improved. So, basically it will have particular grid structure and it is having some thickness.

So, once we you know say these thing as waffle slab. So, this will not only reduce the you know material, but also it will increase the efficiency of the structure. So, one particular discussion when we discussed about efficiency of a structural form then we have seen that whenever we take one solid rectangular section, So, maximum bending that occurs in the outer fiber, whereas, at the you know center there is less amount of stress. For that we can improve it we can make these as I sections.

So, we can easily remove this particular portion of the solid section and improve structural section to make it cost effective and also when you reduce the material remember that that will also reduce the date load. So, that is advantages. So, like we taking that concept this grid structure being formed it need not to be orthogonal or you know mutually perpendicular grid that always you know vertical and horizontal line they are crossing each other at 90 degree, but sometimes also we get different kind of you know relationship between horizontal and vertical members that we will discuss in a upcoming slides.

Talking about the material the concrete wood or metal that can be used and these are the materials like we can use for creating different shapes. Then it is providing more structural stability without using a lot of additional material and you can compare this to figure where you can easily identify that reduction of the material between these 2, but solving the same purpose to make the stability it is also effective for the large span. That earlier we have discussed when post beam column that if we want some large span so we have to increase the depth of the beam or we have to place multiple number of columns. But multiple number of columns essentially blog the space, but when we require to have these column lists then the way is to increase the depth of the beam if we go with the frame structure.

But there are other alternatives like we can go for sale structure, we can go for dome structure, but if we confined ourselves with a very straight forward flat structure then this a waffle slab or these grid structure can help us where both direction you know cross beam can help us to increase the span that required for let us say you know ballroom or maybe a party room maybe a conference hall etcetera. So, here you can see another picture of the same thing where the large span being supported and normally this kind of structure being used in parking maybe in a public stations airport.

Even earlier I have shown one example of you know Mumbai airport where this kind of a waffle slab being used in a different format. So, we will also discuss that with picture. Now here the limitation with one dimensional as I already have mentioned, but here if you again see that though they have some parallel members which are drawn with the black color these are parallel beams that is getting you know giving support to the upper slab.

But due to a point load the deflection on this particular member which is black color bolt is taking much deflection and there is considerably very less effect on the others whereas, if we make the grid. So, that can be distributed more efficiently.

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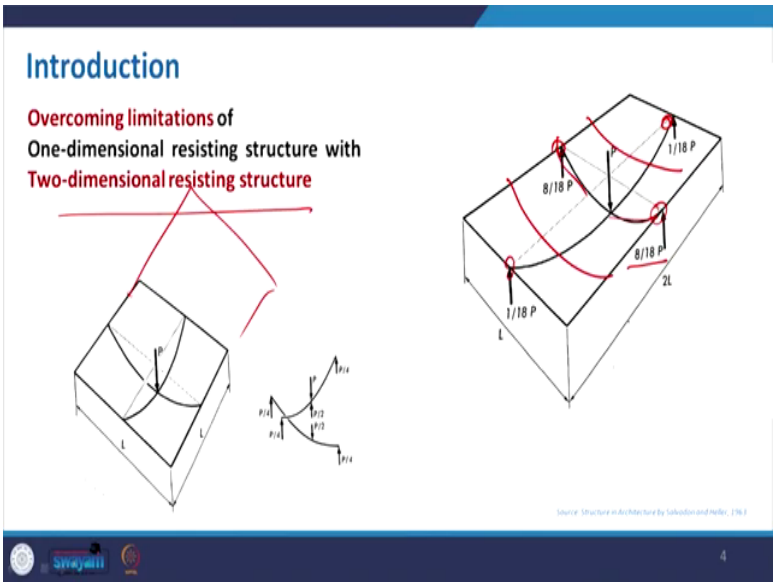

Now, coming to this slide, it is basically showing the overcoming limitation of this one dimension with the two dimensional. So, now, how we get the idea of the grid. So, now, here it is both it is a square form and grid being placed where l by 2 into l by 2 is one particular grid and as because the length has same and the it is making 4 square out of a big square of having a site l. So, the distribution of load in all the cases it is equal P by 4, but the moment we just make it say rectangular and in that case depending on the shorter a corner and the further corner the load will be distributed in a different manner.

So, load will essentially distributed to it is the shorter side. So, here you can see the 8 upon 18. This is basically the load that will be transmitted to the this particular you know support and where at it is less. And if you increase the number of this you know shorter site beam then probably this load again be distributed further.

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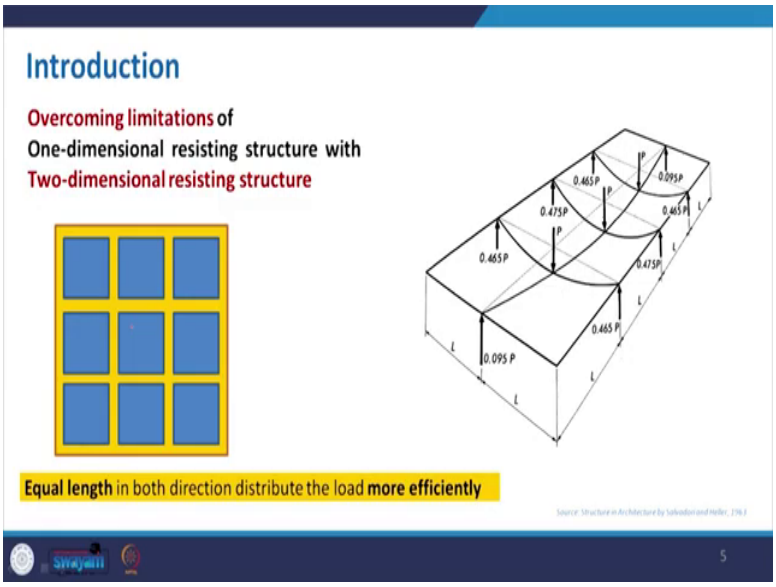

So, here you can see that the similar picture now being distributed more evenly. So, it represent that when we go for the equal length in both direction distribute the load more efficiently equal length can distribute. So, here if you just consider this is a square of equal length and then it has being divided by 3 by 3 grid of equal size then any point load anywhere will be distributed more efficiently rather than any other form.

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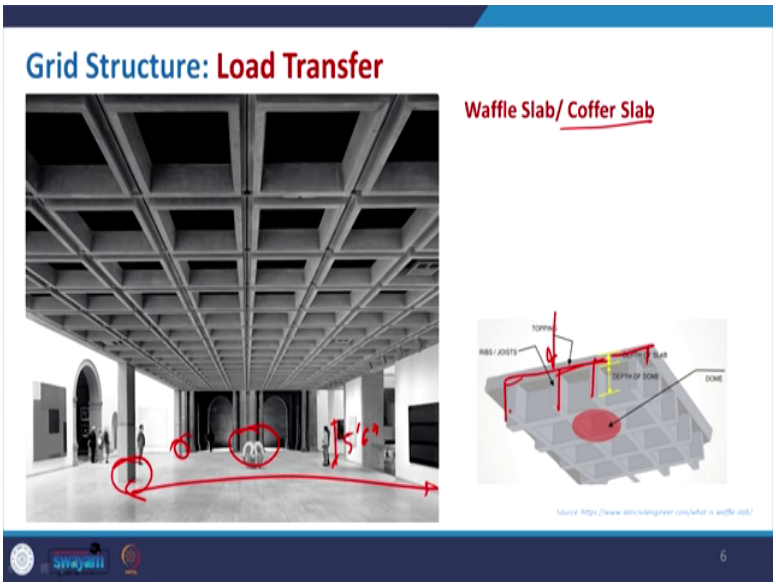

Now, coming to the load transfer how it will transfer the load already we have seen with the schematic. This is some image where you can see that here you can identify a column there you get another one and here at the end. So, this span is considering the human scale of say maybe 5 feet 6 inches.

So, this will have a good span which is been supported with the waffle slab or sometimes also referred as the coffer slab. So, any load you know given on that that will be distributed through this particular support and at the end. And the more efficiently you make that grid the distribution will have that efficiency.

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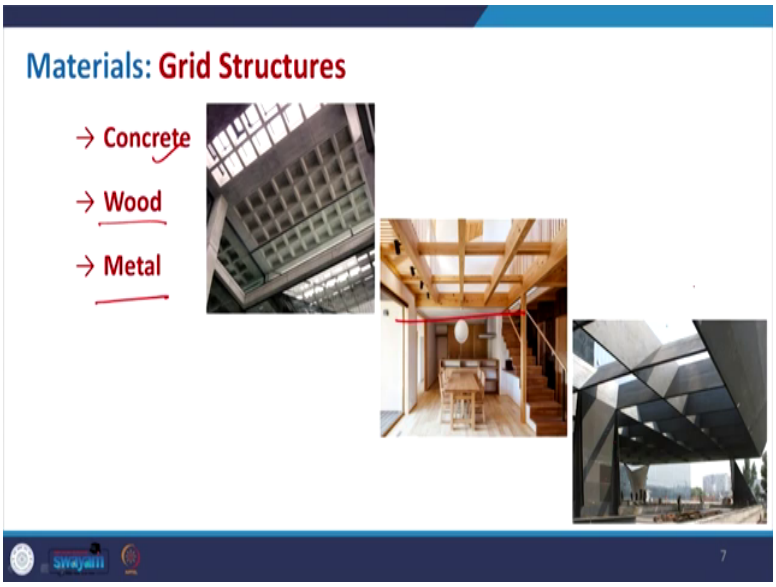

Now, coming to the materials to be used for the grid already have mentioned that RCC reinforced cement concrete can be used wood can also be used to make some you know structure especially in interior it will make something which is structure is structural stable as well as esthetically pleasant. And metal grid is also being used for the industrial project as well as some of the cases where you know some office buildings or some shopping malls they have used this kind of structure.

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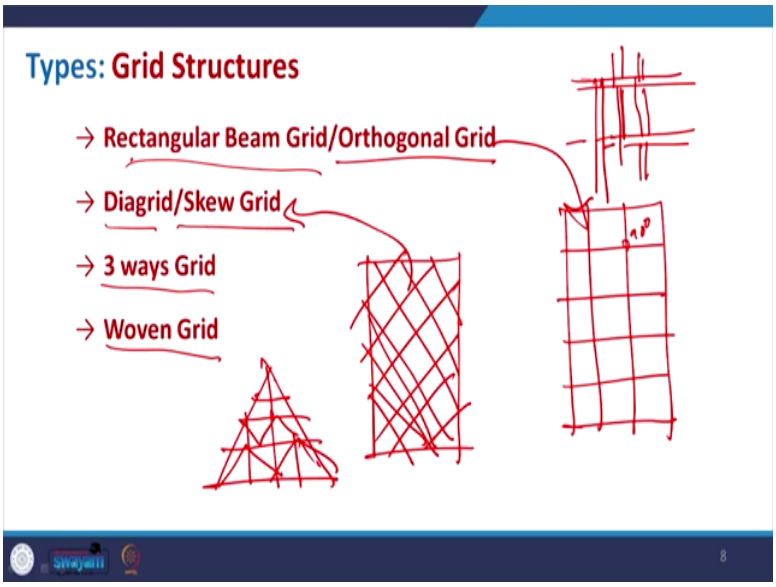

Now, coming to the type of grid structure depending on the arrangement of the grid it can be classified like rectangular beam grid or orthogonal grid then diagrid or skew grid 3 way grid and woven grid. So, what are those. So, taking this terminology rectangular it means the grid will be in a very rectangular pattern and orthogonal means that horizontal and vertical members they are making say 90 degree angle.

So, this is orthogonal grid diagrid where it is basically not parallel to the in support. So, it will have some diagonal or angular member. So, this is basically your diagrid or skew grid and it may vary you know uniformly or maybe sometimes it can be something where a irregular grid may form. 3 ways grid is basically referring to the grid of your triangle where you know triangulation will take place so that it can develop the grid pattern.

And woven grid is basically something where like it is coming from the weep. So, you have some kind of interlacing about the between the object. So, here in this case if I try to draw it. So, it is something like this. So, they are interlocking each other ok.

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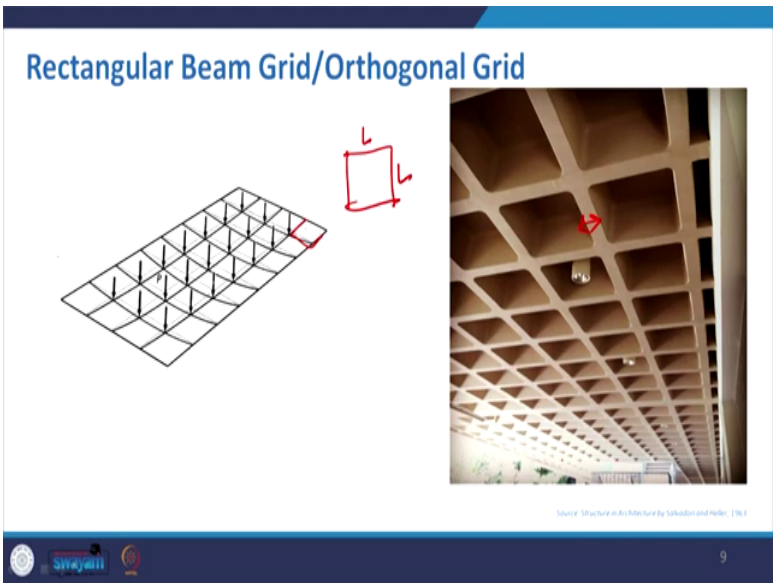

So, I will also show with the images. So, rectangular grid beam or orthogonal grid where like if you can place your beam and this particular grid so that each will form a square of say equal length. So, that will be more effective.

So, here you can see how it is being made and for these also you do not need really a very you know high thickness. You can reduce it can be of thin thickness, but it can able to hold this much. So, many buildings in the government buildings are earlier for their canopy they have used this kind of rectangular beam grid or orthogonal grid.

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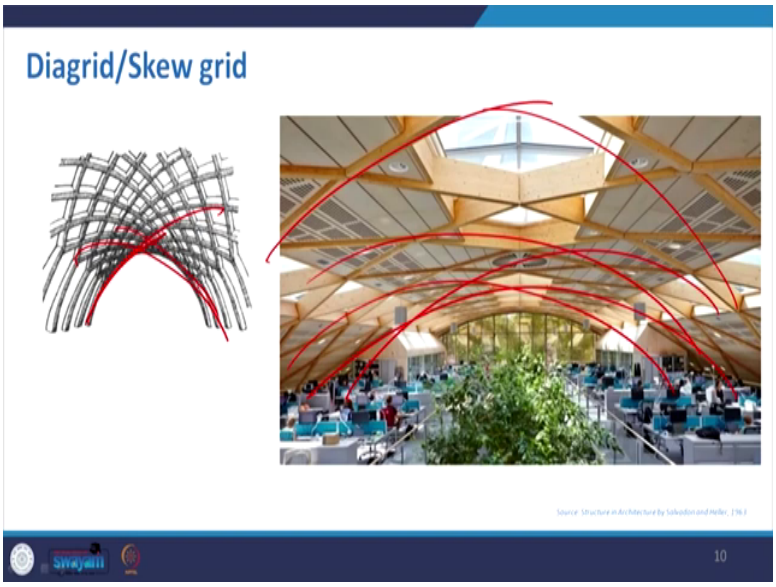

Proceed with a the diagonal grid here you can see that it is in the something where the you know grid being placed in a form of arch and they are crossing each other. So, it is not very state. So, each will have some crossing nature and that is forming this particular grid. Again it is being used for a public like a well you know this is the office area where you can see the cubicles and also this roof been created.

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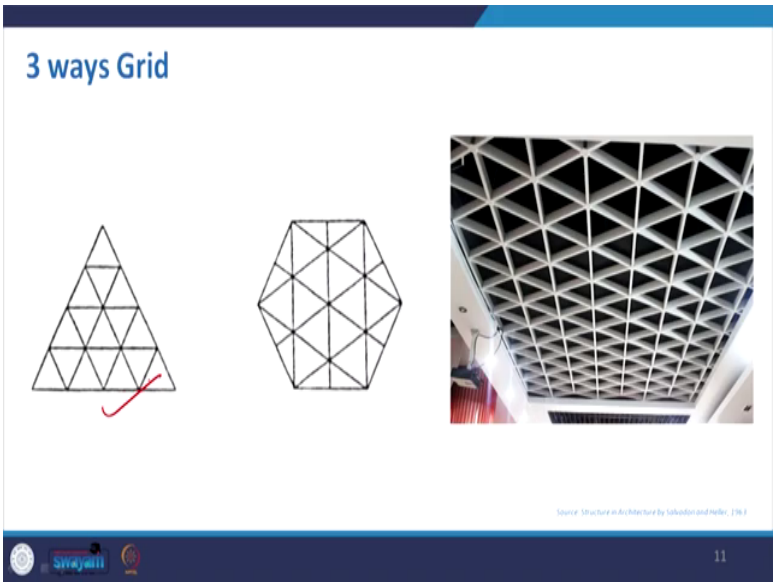

Coming to the 3 ways grid as I mentioned that, it will make a formation of your triangle or hexagonal shape for the roofing.

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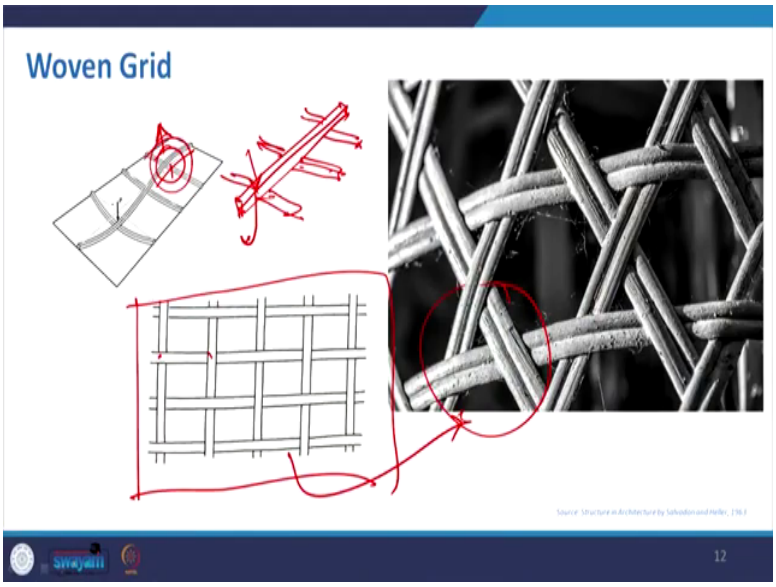

Now, woven grid at as I mentioned: So, this will look like something this the interlacing take place. So, if you consider this image the concept image it is basically the woven grid. Now in this case, why it is a more effective than the previous one? Here you can identify if you see this image before deflection. So, you have one particular beam at the top and then you have other members just below it. So, they are not in the same plane; so, one place after another, so, in that case if a load is applied where it is been shown.

So, the deflection will take place here that can create a pressure on the other junction and that can you know result in some upliftment of this particular structure whereas, here if you put the pressure, so, this upliftment the tendency that can be covered up with this. So, whenever this is interlacing most of the buckets we see a made of plastic or made of say bamboo there this kind

of wind structure being followed. So, in a building perspective also we can go for this kind of wind structure which will reduce the upliftment tendency of the structural member.

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Now, let us just go through some of the images where this waffle slab or coffer slab being used maybe sometimes in structural purpose sometimes also with structure the ornamentation and especially in the period of roman architecture and then next (Refer Time: 16:37) by that time along with the structure so they also focused on the ornamentation.

And here is one of the example where decorative coffer ceiling being displayed. So, you can easily identify those grid which is making this vault and I am sure that if you followed the earlier lectures there where we discussed about different kind of vault. So, this is basically a barrel vaults, but here the ceiling being made with the coffer ceiling.

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And these needs no introduction. So, this is the dome the roof of your Pantheon. So, here also you can see how the coffer slab reduce the material of the dome. So, that is why also it is reducing the date load of the dome.

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Coming forward this is at Santa Maria, Rome. So, here also you can see that how decorative it is along with the structural material is more of the decoration.

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Now, this kind of a structure nowadays we can see in many public stations as I mentioned. So, here also this is also referred as your ribbed structure where again the orthogonal grid being just given a form of you know arch and then it is been placed. So, this the material the upper material maybe of some transparent translation material to you know get the daylight during daytime or else it can be of the concrete or any other material to just cover it.

So, this is being useful and you can see that the span the main use of the arch and these waffle slab construction essentially reduced the amount of material here and also it is helping out to get a nice aesthetic very clean and visually pleasant structure as a roof and here you can see that the same material being used as wall and roof. So, this is basically again a vault form structure, but here the orthogonal grid being used.

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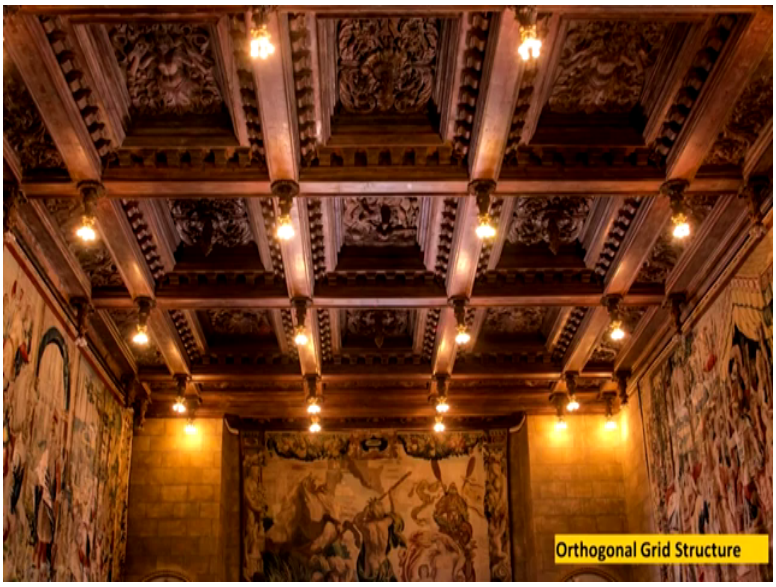

Coming to another one again it is made of some wooden for interior the wooden grid and you can see the decoration how beautifully it been placed and it is also covering a good span. So, without any vertical support here how it is being supported.

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And this is the example from your Mumbai International Airport. There you can find this kind of waffle slab. So, here also you can see you can identify the span how big it is though it is just a rented picture, but at the actual picture also will get the similar thing about this kind of arrangement. So, very nicely very beautifully executed waffle structure at Mumbai international airport.

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Coming to this is the Metropol in Italy Metropol Parasol. So, here also the grid is something which is known or we can call an unorthodox and here different curvature being formed with different geometry and the structure is being optimized with the reduction of this.

So, this is basically giving us since very you know a dynamic flow of you know some something which is giving our sense of flow. So, this is a open area planning a closed form not a closed form architecture.

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Now, coming to the grid structure again it is a your lord Lodytel Communication Development Center. So, here also you can see that this particular cantilever and it is having a good span that can be easily you know covered with this gird or waffle slab. So, this is a advantage of the waffle slab that being used where like the building can be of a rectangular shape. It can be of some curve shape, but this will help to distribute the load effectively and at the same time it will reduce the amount of material from the section it is improvement of the section and also can be used for the large span.

Now, so as to allowing the service which is very important for the flat slab also we put the reinforcement and then also we try to make the fall ceiling to cover it, but as because it is getting a depth and sometimes like if that can be done with the mold and especially these being designed.

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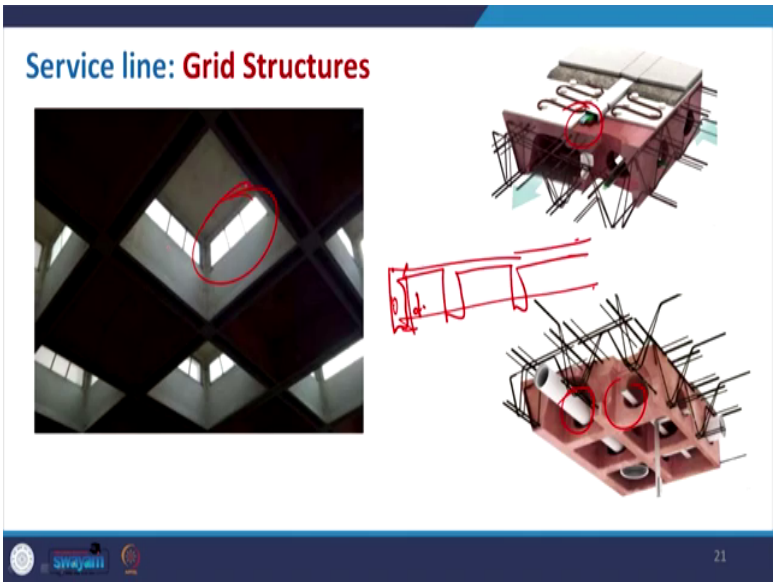

Then all the services can be fixed within that. So, this is one example where the pipe aligns can go and here also you can see the electrical fittings how it can be adjusted within that section. So, that with the depth of the waffle slab that we referred the depth of the waffle slab means whenever we have this kind of you know grid structure so this is the depth. So, within that depth we can able to put all this you know services.

So, that it can give a nice look from the outside. At the same time that can be also used to create some skylight for some public area where the large span is being covered. So, this is another useful you know application of this waffle slab.

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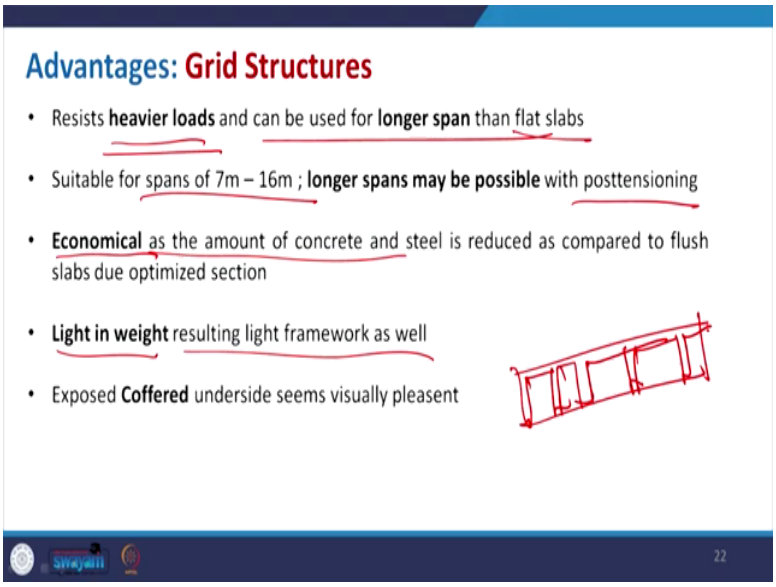

Now, coming to the advantages of that resists heavier load and can be used for longer span compared to the flat slab. For long span solution there are many. We can go for arch, we can go for your dome or shell structure, but compared to the flat slab if we go for the grid slab or grid structure that can be used for the longest span. Suitable span up to 7 meter to 16 meter, but can be extended if we really go for post tensioning and take will care of that. Economical as the amount of concrete and steel is reduced compared to the your solid section light in weight resulting in the light of framework.

So, different definitely when you reduce the section cross section then this can effectively reduce the framework. Export coffer slab also looking visually pleasant we can you know put some lights. So, that it can create some you know nice environment from interior.

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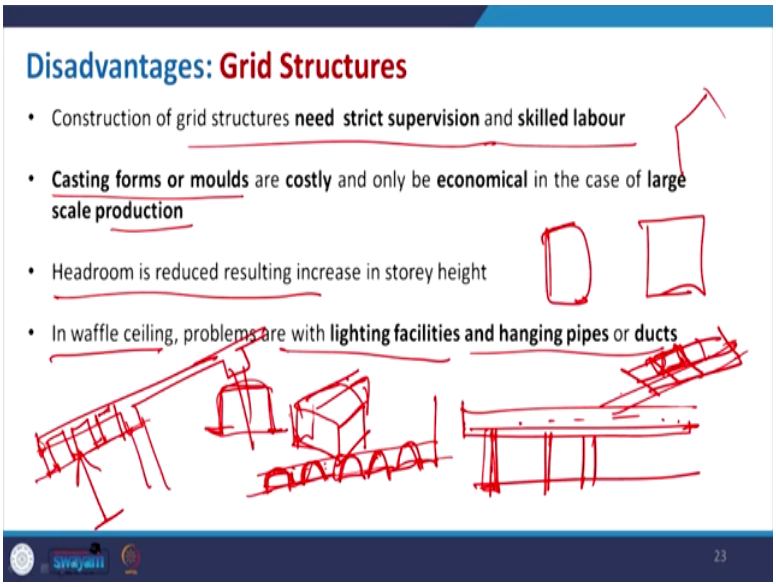

Now, coming to the disadvantage construction of grid structure needs strict supervision and skilled labor. Definitely proper execution is required not only the design, but also during the execution the proper alignment of the reinforcement and the form work. Specially it is required to be very accurate to get the desired result. Now casting of that formwork or molds to get this particular form: So, suppose when you make the centaury for the flat slab it is very simple. We give a horizontal member and the vertical props and we lay the concrete, but for this we what we want. So, we need some mold which is basically look like this and we place one after another and then we put the reinforcement on top of it and we fill it.

So, basically if we try to convert this. So, your formwork now look like this. So, all these members is basically all these molds we will placed one after another and then we cast. Now this is very costly item because that to be customized. Depending on the size of the grid depending on the size whether you need very sharp finish or you need something rectangular

or sometimes you need something hexagonal or diagonal leave like suppose rectangle your triangle or maybe hexagon so you have to customize it.

So, then it will not be economical unless it will have a large production. So, for a large number of uses if the mold will have repetitive use and all then it will be economical. Head room is reduced. Definitely when you go for this instead of flat slab whenever we use flat slab has continuous beam. So, sometimes we just provide the beams to give the support, but for your waffle slab this is more regular this particular repetition though the thickness is less. So, effectively the height head room from the in the measured from the speed of that particular waffle slab to the floor getting reduced so that you need to provide little bit more height. So, the you know the story height, the building height will increase in this case. In waffle ceiling problems are with the lighting facility and hanging pipes.

So, lighting facility means which are to be placed. Suppose as because we have this kind of pattern like only from the bottom we get this particular grid and so we are restricted to put the light within that a particular gap or else it will create problem and also for the hanging pipe services or duct.

If it is not in build the way like I have shown in the services that how you can put all these services within the waffle slab construction then it will be a little bit tough and it will look ugly if it is not being properly executed. So, that is one of the disadvantage. So, coming to the end of this particular lecture.

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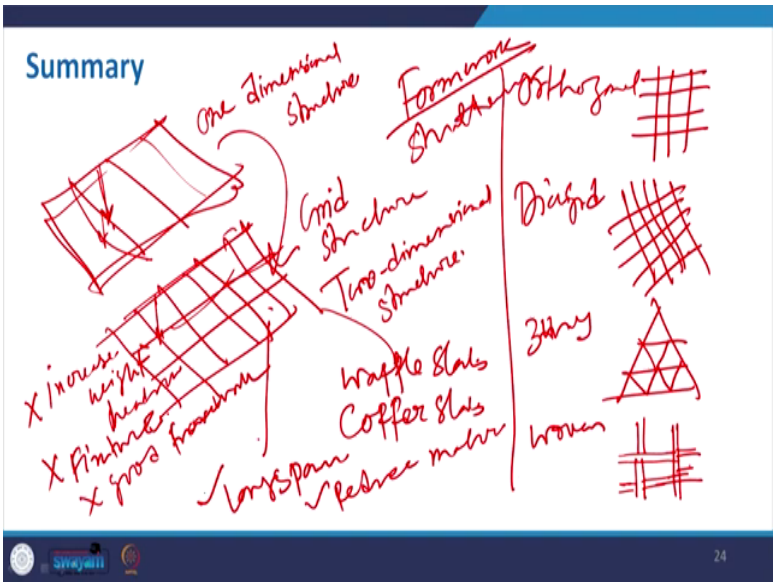

So, basically if we summarize. So, we start with one dimensional slab where the parallel beams are acting only one direction, but due to any point load. So, the defection of this beam will be more compared to the others. So, effectively the distribution of the load will not be that much effective compared to that when you move to that the you know grid more number of grid. So, the load distributed will have some effect and it will be distributed with more number of you know site support that will be distributed. So, this is the advantage of a grid structure and it is also called two dimensional structure and this is one dimensional structure right.

So, this is also referred as your waffle slab construction. We can use this or also we referred as the coffer slab. In the typology we have orthogonal where it is very rectangular rectilinear form we may have diagrid. So, where it is not perpendicular. So, we have something like this. Then we have a 3 way that is basically making this kind of grid and then last, but not the least the woven where we have seen like something like this on the bucket and all. And advantage

or disadvantages already we discuss that definitely it can hold the long span ok. Again reduced reduce material these are the advantages and disadvantages what we have the increase in height or maybe head room then also the problem with the different fixture like lighting and all.

If it is not being included in the section itself and definitely it needs good framework for a good form work ok. Formwork is also a that we have discussed earlier. Formwork is basically also referred as the shuttering of the structure and also skilled labor. So, with this also we have seen the examples. Normally these kind of structure being applied where large span to be covered with the less number of columns, less number of material and the useful application in the you know airport in parking area etcetera some convention hall as because this waffle slab also looks very beautiful from inside.

So, that can be used for the decoration for the you know even for the small building like even for the restaurant and all and wood, timber, concrete that can be used. It was used in history with ornamentation and now also I have given you example of Mumbai airport then the other example from the public plaza that is from you know Italy. So, that is basically the use of this grid structure.

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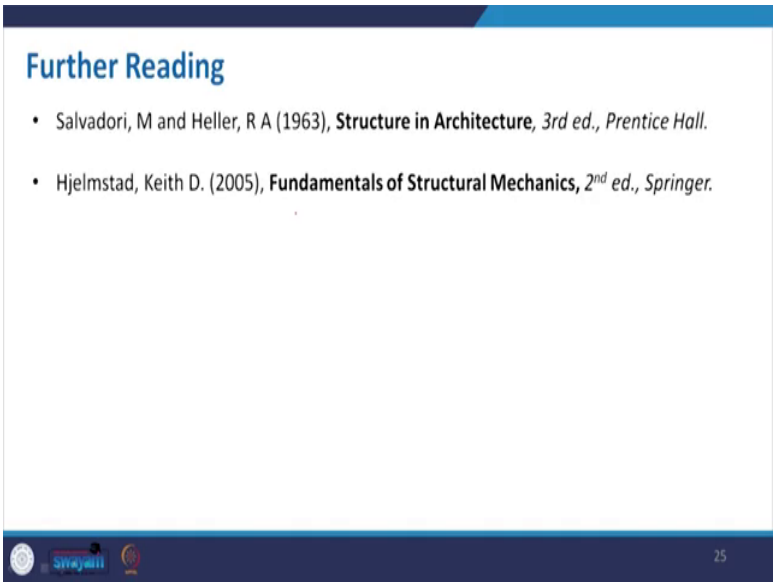

So, with this we conclude this particular lecture. These are the study material that already been given in other presentation, you may go through these books and also you go through the links given for you know different pictures, different stories where you can get more information from that. With that I conclude here. So, next we will cover the shell structure and we will discuss about different application of the shell structure, type of shell structure. So, till then I again you know we very much thankful to you to you know attend this particular course and we will be meeting again on lecture number 26 that is on shell structure.

Thank you.