Structural System in Architecture
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Lecture No -34
Flat Plate and Flate Slab Structures

Welcome to the NPTEL online certification course on Structural Systems in Architecture. We are in the week number 7 that is the module 7 on Tensile and Plate Structure. This is the 4th lecture on this module. Today our topic is the Flat Plate and Flat Slab Structure.

The basic concepts to be covered under this lecture are:

- Introduction to Plate Structures
- Major Classification of Plate Structures
- Flat Plate Structures: Structural concept, Failure mechanism
- Flat Plate Structures Advantages and Disadvantages
- Application of Flat Plate Structures
- Introduction to Flat Slab Structure
- Advantages of Flat Slab Structures
- Applications of Flat Slab Structures

The tentative learning objectives are:

- To outline the structural concept of plate structure.
- To differentiate between Flat Plate and Flat Slab.
- To illustrate the types and parts of Flat Slab.

So, let us introduce the plate structures. Plates are thin flat members. Any three-dimensional object has the width, the length and the thickness. So, the thickness is very, very minimum compared to the other two dimensions; that is the plate, or we can say that this kind of a geometry is called as plate structure. Structural stiffness of the plate structures is much higher than that of usual RCC slab. The plates are designed to resist the bending moment and shear stress. By changing the geometrical layout of the plates, can design to make the more moments. This is one of the very, very important structural concept of the plates. We change the geometrical shape, geometrical layout of the plate intentionally to increase the stiffness values so that way it can be take more moments. It is also used as a solution for long spans. The last point is very interesting and very important; unlike the shell and tensile structure, which just now we have discussed, plates are flat and the floor above it can be habitable.

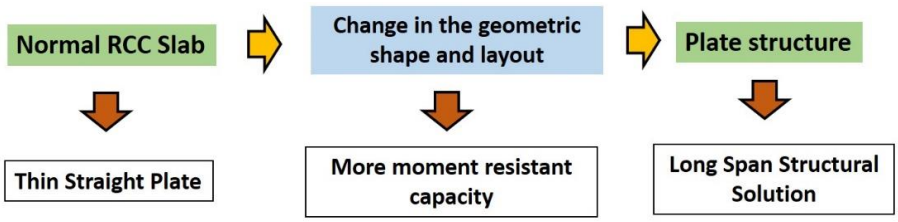

Figure 1 : about flat plates

The Plate Structures comes under Surface Active structure systems. The resistance against bending moment develops: Compressive, Tensile Stresses in addition to Shear Stresses. There are two different mechanisms and their combinations are set according to the direction of the acting forces:

- Slab Mechanism: If the acting force is directed at right angles to the surface.
- Plate Mechanism: If the acting force is directed parallel to the surface.

Now, if we see the classification of plate structures, then broadly it can be classified into four type. However, some books say it is to be of three types. Any way we will see here where is the confusion or difference of this confusion.

The first one is called the flat plate structure; flat plate structure a system of flat plate and column only; there is no beam. The second one is called a flat slab structure. It is almost alike and some of the books some of the literature says that both these two are same.

Here if we see it in details, the flat slab structure has only plate and the column; there is no beam. Whereas, in case of flat plate, there will be the plate and column with capital, here also there is no beam. The third one is the waffle slab or the grid slab structure; it is also called as a coffered slab structure. This is a system of slab and closely spaced beams. So, there are columns but basically the slab and very closely spaced beams are there in both the direction or maybe sometimes in one direction. The fourth and last one is called the folded plate structure. It is a system of plates with different geometrical shapes and folds.

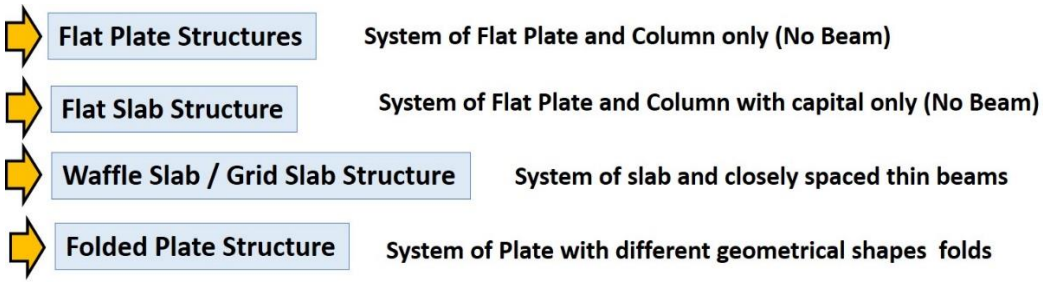

Figure 2 : classification of plate structures

In this particular lecture we will discuss about the first two; the flat plate and the flat slab structure. We will discuss the folded plate and the waffle slab structure in the next lecture.

Now, what is a flat plate structure? As I now understand it is a beamless construction or beamless system, where a plate is directly supported by the column or a pillar. It is used for the short or medium or moderate kind of a spans, which can be almost about 6 to 8 (15 feet to 25 feet) in the limiting value of this span. The live load is most normal kind of a live load of 3 to 5 kilo Newton meter. As you know, the 3 kilo Newton to 5 kilo Newton meter is almost like a residential live load, not very heavy. So, it is very simple to construct. It requires very easy layout of form or column, that is why it can gain a speedy construction. It is suitable for the apartment buildings and for moderate spans and loads are relatively low.

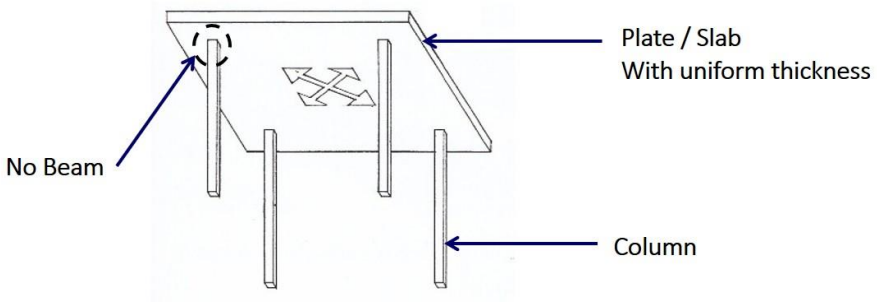

Figure 3 : a flat plate

In Figure-3, it is a schematic diagram of a flat plate. There is no beam; columns are actually strike directly to the slab or plate.

So, there are some photograph taken from internet, as shown in Figure-4.

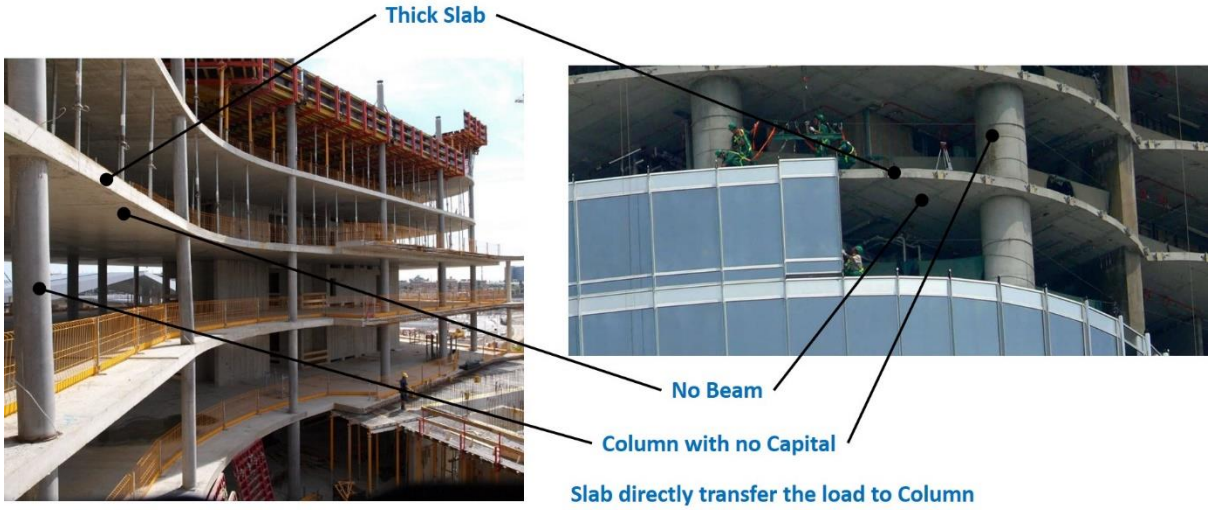

Figure 4 : the flat plate structures

If you see these photographs, you have columns, you have a very thick plate but with respect to the other dimension this thickness is very simple that is why this is called a plate structure; and there is no beam, no column capital, just the column is flushed with the slab.

But if I do so, it is nice to see a flat plate structure; because it is same beamless it is very, very I mean it is a very clean kind of a construction or maybe it is aesthetically also very clean but there are some problem of the serviceability limit or serviceability and also due to some kind of structural problems. Flat plates are prone to shear failure and this kind of shear failure will going to occur pyramidal wedge-shaped kind of a failure will going to occur. See Figure-5.

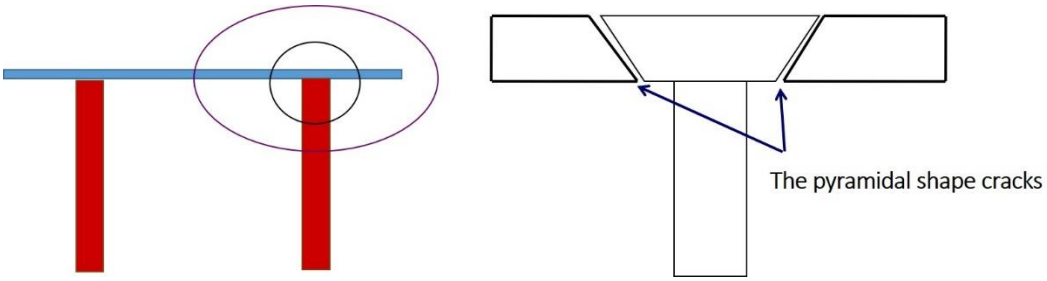

Figure 5 : shear failure in flat plate structure

This particular shear is called either one directional shear or a multi or two directional shear. The punching shear is the typical problem of the flat slab, punching shear is something like, if you put a very heavy load in a very small area of a material or an object which is thin, then it will punch because of the heavy load on a very small area. That portion of the other object with a thin object will be punch out. Punching Shear is a typical problem in flat plates. The shear stress near the columns may be very high, requiring the use of special forms of slab reinforcement. At exterior columns, where shear and moment transfer may cause difficulty, the design can be improved by extending the slab past the column in short cantilever.

So, as we understand this failure of the flat plate is because of the shear and shear is potentially very high in stress in the connection between the flat plate and the column. So, this shear failure is one way or sometimes it is two way. If you see one-way shear failure, almost 45º inclined cracks will be appear in two opposite sides of the column. This kind of failure of slab is uniaxial direction and it is called as a beam type shear failure. But there is two-way shear failure also. Inclined crack occurs across the entire width of the slab in all the four sides of the column. It involves a truncated cone or pyramid-shape surface around the column due to biaxial shear. The angle of inclined face or pyramid shape surface varies 20º to 45º. It is also called Punching Shear Failure.

Those are the failures; but definitely there are some advantages of Flat Plate Structures. Some of them are:

- Easy workmanship, formwork installation and Reinforcement placement is easier.
- Flexibility in room layout: freedom in placing partitions, flexibility in gaining room sizes, the false ceiling can be omitted.
- Controlled building height can be achieved through minimizing structural depth and reduced floor to floor height.
- Prefabricated welded mesh can be used as reinforcement.
- Speedy construction.

Some disadvantages of Flat Plate Structures are:

- Span length is medium, not applicable for very long span, of more than 25'.
- Critical middle strip deflection beyond the serviceability limit.
- Higher slab thickness to control shear stress within limit.
- Not be suitable for heavy loads, leads to punching shear failure.

If we see the applications, the it is used in: Warehouses, offices, then the small parking lots, auditoriums, residential buildings, industrial buildings and of course the industrial buildings too.

In Figure-6, you can see one example of application of Flat Plate System. It is the parking lot, Terminal-2, Chhatrapati Shivaji Maharaj International Airport, Mumbai.

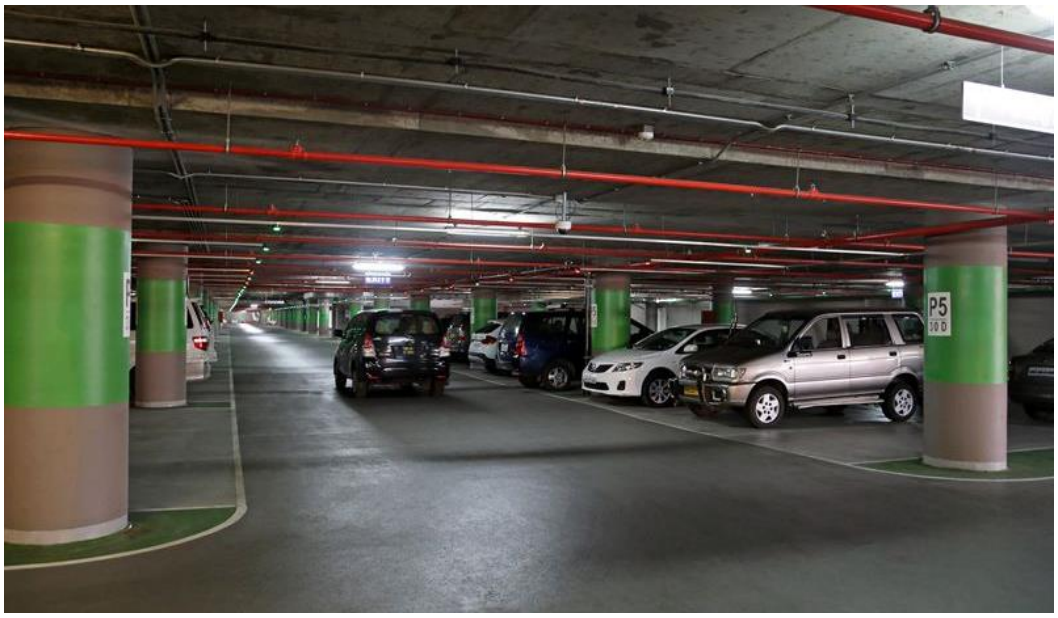

Figure 6 : parking lot, Terminal-2, Chhatrapati Shivaji Maharaj International Airport, Mumbai

So, next let us discuss about the flat slab structure. The flat slab structures are as you know is another type of beamless structure; but in this type we have a capital on the column, and sometimes we can also go with the drop slab or sometimes the both. Now, the things change. The span increases to, 20 to 30 feet instead of 10; and the overall a little bit of increment in the

live load 4 to 7. Here, also we can go with that very simple formwork. As capital is introduced, it will be definitely going in to increase the shear strain capacity, also give you a lot of protection against the punching shear. Widely used for storage warehouses, parking space, below grade structures, theatres, factories, mills and shopping complexes.

So, flat slab structure is of three types:

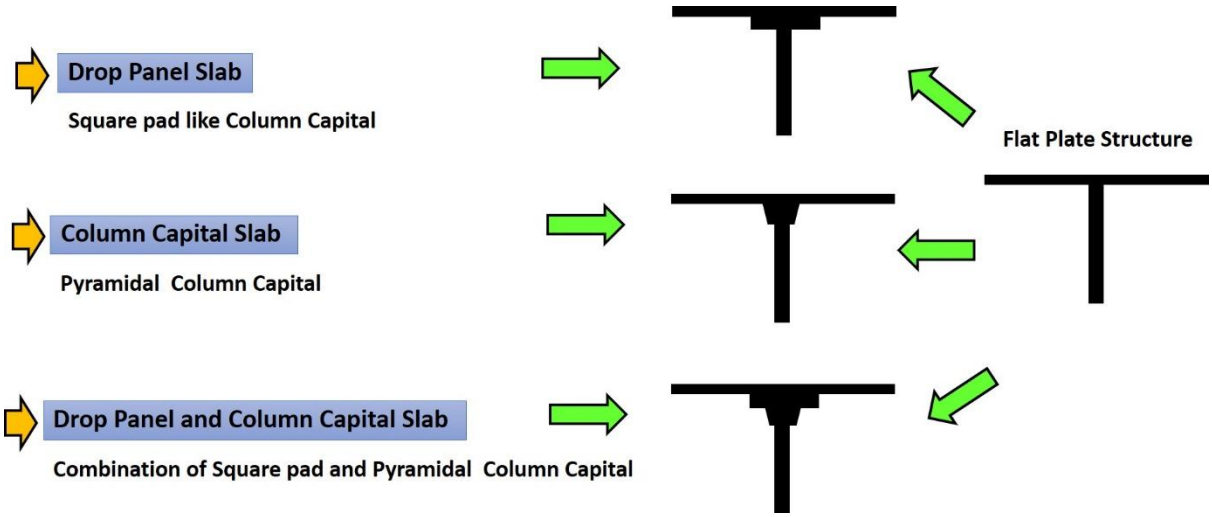

Figure 7 : the three types of Flat Slab Structure

One is called drop panel slab, in this the column capital is of square pad like shape. The next is column capital slab, where the column is with a pyramidal shape capital. The third one is drop panel and column capital slab; where the column capital is a combination of square pad and pyramidal column capital.

The flat plate has some problem of punching shear; so, that there are three improvements with the supports or capitals on top.

Figure 8 : images of the three types of flat slab structures

So, the flat slabs sections with the drop panel is something like that a square pad which is called a drop panel is introduced in between the column and just below the slab which essentially going to increase the effective thickness of the slab at that particular area. Where there will be a load transfer, if there is a stress concentration that punching shear or the beam shear will

destroy your thickness on the overall portion. So, as it is now thicker definitely the stress will be less as you know that when the effective area is going to be high.

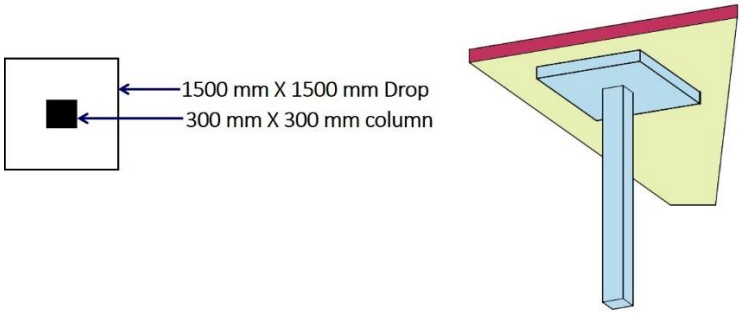

Figure 9 : flat slab with drop panel

So, in this case we can think of a 300 by 300 column with that 1500 that is mean that means 1.5 meter by 1.5 meter of drop.

So, in case of the flat slab with the column capital, so instead of the flat drop panel we can go with a pyramidal capital. Based on intensity of shear stress developed at the slab-column junction the size and shape of column capital is designed. It increases the shear strength of the slab and reduces moment in the slab

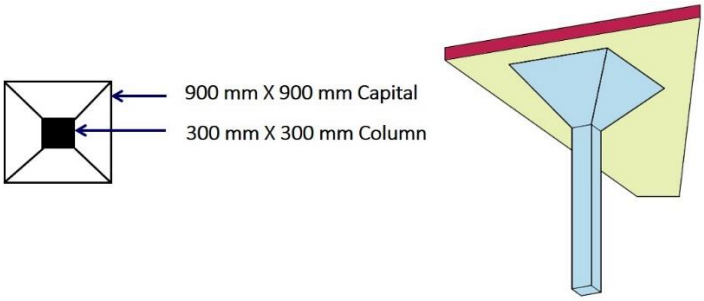

Figure 10 : flat slab with a column capital

The overall influencing area is reduced a bit instead of the 1.5 meter, we can go with the 900 by 900 capital and column size remain suppose the same 300 by 300. Again, the same effective increment in the slab thickness will occur near to the stress concentration area.

The third one is the drop panel with the column capital, if both are taken into account. This is some of the hybrid kind, where we have a drop, we have a column capital.

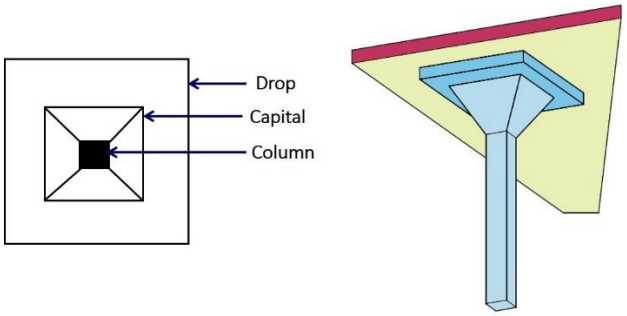

Figure 11 : flat slab with column capital

This increases the strength of the slab.

So, if this is a particular section in Figure- 12, then the slab thickness is almost about 200 mm, which is a little thicker then with our normal RCC slab and this drop area which thickness is again going to be additional 100 to 150 mm and there is a column capital whose width is almost equal to 1500.

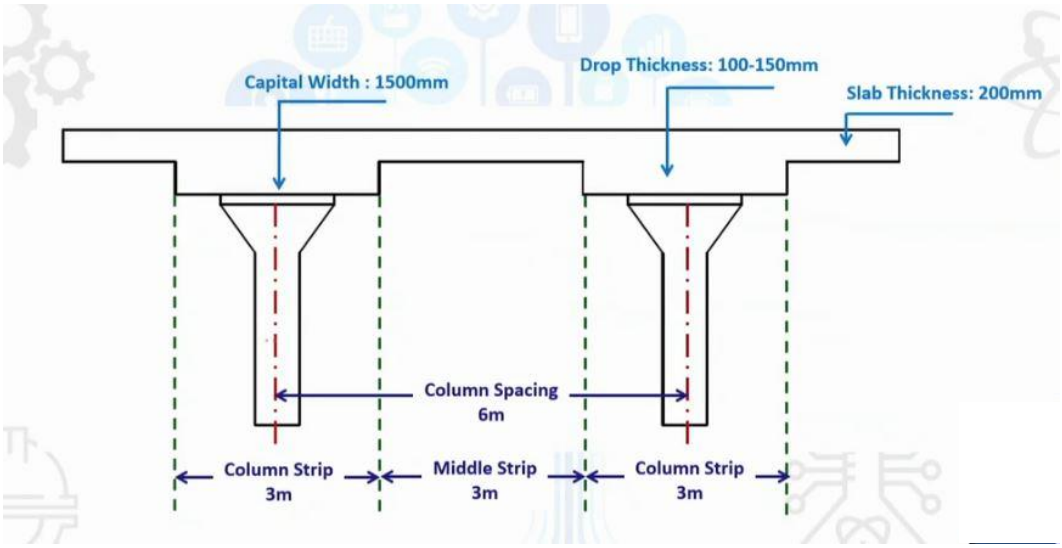

Figure 12 : section of flat slab with column capital

So, in this suppose the column spacing is 6 meter and this column strip will be of 3meters, 3 meter and 3 meters. On this this column strip portion, the portion of the slab will be governed by the shear and this part again 3 meters in between the column, the middle strip 3 meters will be under bending. We have to actually see that, if I want to increase the spacing of column up to say 10 meters of this span, so we have to see that there is an increment of course all these things. I mean, if the spacing is too wider, then the bending will be too high. So, I have to increase the column strip and moderately reduce the amount of the middle strip such a way that both the bending and the shear comes under control.

To do that, while we will bring that from 6 meters to 8 meters; 8 meters to 10 meters 10 meters or to maybe 11, or 12 meters, you may go maximum and then you cannot actually be able to adjust that particular column strips and middle strip. Because, if it is more than 10 or 12 meter or so then the overall geometry of your this drop and column capital will be uneconomical, and secondly it may not result to be very useful or may not be that much functional as it will have huge drops in peripheral areas of the column.

The advantages of flat slab structure:

- The general and punching shear can be totally eliminated in flat slab structures.
- A wide span structural system can be achieved with higher floor to floor clear height.

- Architectural design flexibility can be adopted.
- Building height can be controlled by eliminating the beam.
- Easier and economically viable shuttering can reduce the construction cost and time.

If we see the application part, then it is more useful because it does not have the beams. It os mostly used in parking lots or multi layered or multi-level parking spaces, where beam sometimes is a problem. If you remove beams, so you may actually introduce one more level car parking over here. There are some images of parking spaces:

Figure 13 : Multi-level car parking at Chandigarh, with drop panels

Figure 14 : Parking, Palma de Mallorca City Centre, Spain

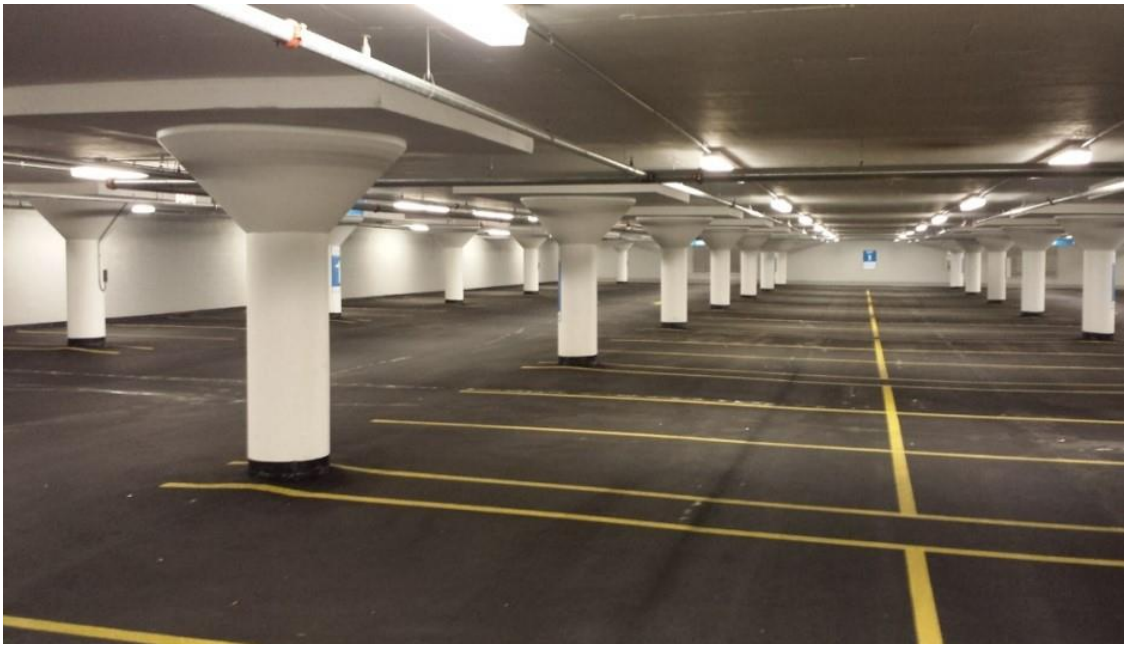

Figure 15 : Millennium Lakeside Garage in Chicago

The flat slab structures can mostly be used for parking, railway stations, bus stands etc.

The references for this lecture have been taken from:

- **Structure Systems** by Heino Enge, Hatje Cantz Publisher
- **Structure and Architecture** by Meta Angus J. Macdonald, Elsevier Publication
- **The Structural Basis of Architecture** by Bjørn N. Sandaker, Arne P. Eggen, Mark R. Cruvellier, Routledge
- **Building Structure Illustrated** by Francis D.K. Ching, Willy
- **Structure as architecture: A source book for architects and structural engineers** by Charleson, A. Elsevier/Architectural Press.

In conclusion I must say that:

- Flat Plate and Flat Slabs are the two types of Column- Slab combination, generally adopted for functional and architectural need of the interior.
- The system is beam less and gives clean interior.
- Adding drop and capital flat slab increases its relative stiffness w.r.t flat plate.

This is the end of this lecture and in the next lecture we will go to the waffle slab and the folded plate structural system. Thank you very much.