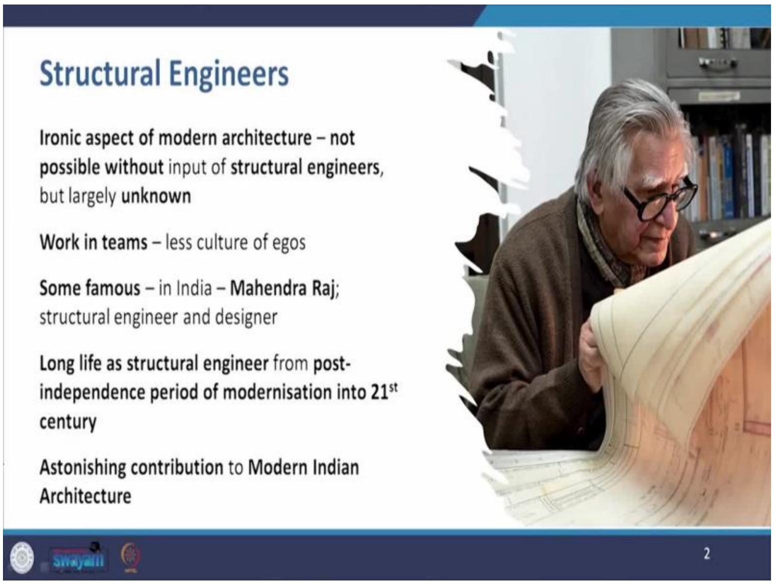
Modern Indian Architecture
Professor P. S. Chani
Department of Architecture & Planning
Indian Institute of Technology, Roorkee
Lecture 33
Structure: The works of Mahendra Raj

Hello students, today we will go in a slightly different direction. And as we are nearing the end of this series, we will look at the topic of structures. And we will focus on the works of probably the most important structural engineer to come out of India one of the most iconic and that is Mr. Mahendra Raj.

(Refer Slide Time: 00:48)



Now, structural engineers their work is seen but they themselves are not seen as much. Whenever we talk of architectural projects, iconic buildings, it is generally the architect who is mentioned and the structural engineer is someway, sometimes relegated to the background. It is an ironic aspect of modern architecture, it is not possible without the input of structural engineers to make these amazing buildings we see today. But they are largely unknown.

Whenever we talk of amazing buildings today, we remember the names, the names come in front of us of Frank Gehry or Zaha Hadid, the Norman Foster or in India we talk of Charles Correa or the young upcoming architects and firms. But where are the names of structural engineers who gave those dreams wings made them into reality. A Burj Khalifa or a Taipei 101, or any of the high rise skyscrapers that we were discussing in the last session could not have been possible without the ingenuity of the structural engineers.

Many of the amazing iconic buildings like the Heydar Aliyev center by Zaha Hadid or even the Guggenheim Museum in Bilbao, by Frank Gehry, or the Guggenheim Museum in New York by Frank Lloyd Wright could not have been possible without amazing structural engineering in the background. It is very rare to find the combination of a person who is both an amazing architect and a structural engineer.

For example, Frank Lloyd Wright himself or somebody like Antony Gaudi, to a certain extent Frei Otto. So, there are people like that, but generally, since the entire industrial revolution, when these professionals got divided up, the structural engineer is one of the team members in the design of the building.

So why, one of the reasons why they are not so well known is probably because they work in teams. And there is a less culture of egos in the structural engineering or the civil engineering profession. And some of the famous ones have really become well known, along with the architects and in India that certain engineer happened to be Mahindra Raj, who is both a structural engineer and an amazing structural designer. He had a long stint as a structure engineer, right from the post-independence period in India, of beginning with the modernization of India, including that in architecture, all the way into the 21st century.

And he is an astonishing contribution that he has made to modern Indian architecture. Some of the most iconic buildings that come to your mind. Many cases the structural engineer behind them would have been Mahindra Raj.

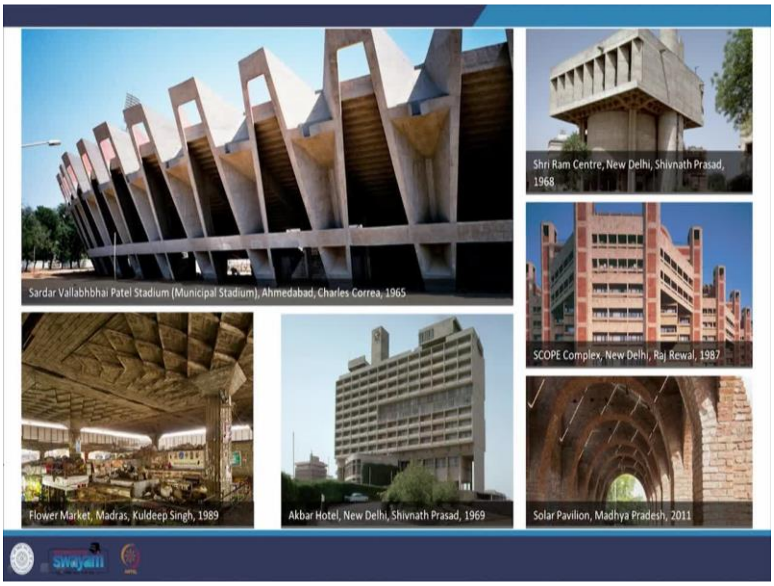
(Refer Slide Time: 03:48)

So this long string of long life from 1924 to 2022 and a very interesting journey. He began as a structural engineer, as a part of the upcoming city of Chandigarh and he worked with the team of Corbusier and his architects. And he made genuine contributions in that there are anecdotes that you can read about and his education. For example, here the Masters that he had did in US, Minnesota was actually an outcome of his desire to learn more deeply about structures, post his experience in Chandigarh.

So here is a man who followed his passion to be a structural engineer. He was also a person who truly understood what the architect's vision was, and how to bring that vision to reality. Notable works that we find in his oeuvre is Hall of Nations, Pragati Maidan in New Delhi, Salar Jung Museum in Hyderabad, IIM Bangalore, Tagore Memorial Hall in Ahmedabad and he worked with a wide array of architects starting from Corbusier to Kanvinde, Steinn, Doshi, Correa, Ranjit Sabikhi, Jasbeer Sawhney, Ajoy Chaudry, Raj Rewal, Kuldeep Singh, many of them he partnered with.

And a whole range of works like I said, think of an iconic building and in many cases the structural engineer behind is Mahindra Raj.

(Refer Slide Time: 05:22)



Sardar Vallabhai Patel stadium 1965, Sri Ram center that we have studied by Shivnath Prasad in 1968. Then there is Kuldeep Singh Flower market in Chennai in 1989, Akbar Hotel in New Delhi 1969, SCOPE Complex whereas Raj Rewal 1987, Solar Pavillon in Madhya Prasesh in 2011.

(Refer Slide Time: 05:43)

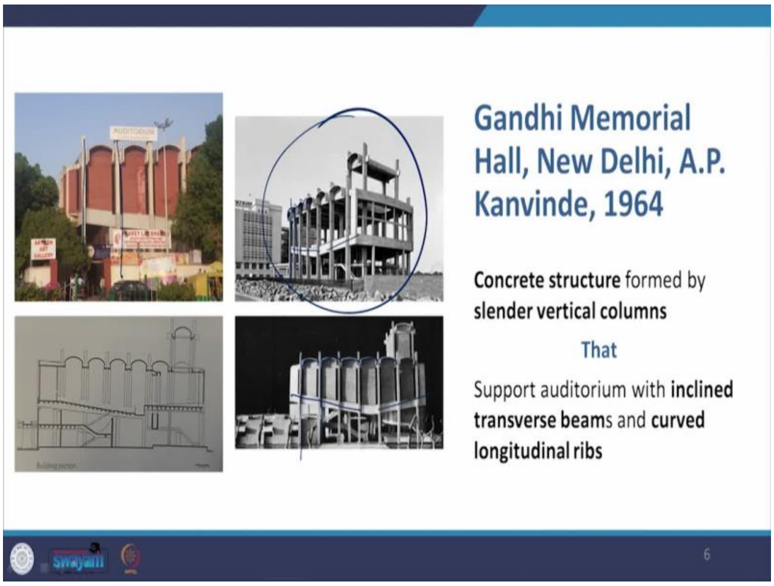
Or the Prembhai Hall in Ahmedabad by B. V. Doshi in 1974, National Science Center by AP Kanvinde in 1994, Vidhan Bhavan in Bhopal in 1994 by Charles Correa, Salvacao Church by Charles Correa Mumbai 1977, IIM, Bangalore by B. V. Doshi 1983, and the British Council Library in New Delhi Charles Correa 1991.

So, both in the expanse geographically working in different parts of India, as well as the timespan from early 60s all the way into the 21st century. So, let us look at some of the examples to understand the innovativeness of Mahindra Raj, before we begin looking at these works, I would like to make one thing about him clear.

Mahindra Raj works under tremendous constraints as a structural engineer, the kind of forms that he evolved the kind of innovations he brought about in his buildings, within the constraints of all somewhat primitive building industry, not having the kind of mechanization that was available in the West, not having the same degree of same finish and quality of building materials, not having the same kind of labor force, which is highly skilled and restraints of not being able to use for example, steel in his buildings as much as he would have wanted, which was so readily available at the time in the West.

So, when you look at these works, that I will show you keep these points in mind, that here is an engineer working with severe constraints in the Indian environment, particularly in the 60s, 70s, 80s era. So, when we come to the Gandhi Memorial Hall in New Delhi, which was designed by A. P. Kanvinde in 1964.

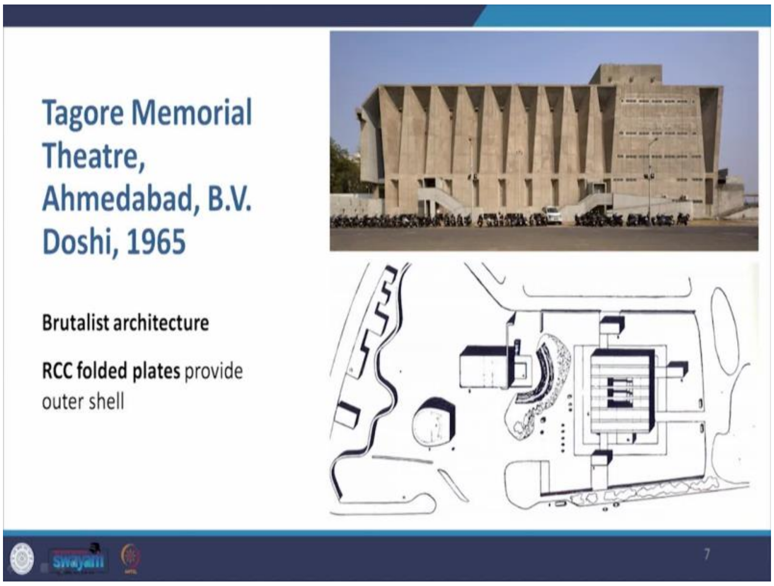
(Refer Slide Time: 07:42)



It is a concrete structure, when you this is the overall structural frame that was created. And it is made about these slender vertical columns. So, if you look at these columns here, these slender vertical columns, in this model also you see them here. And when this is supported the, the support the auditorium with the help of these inclined transverse beams that you see here. And you can see them in the overall skeleton of the building. And then there are these longitudinal ribs that you find at the top here, which help in creating the roof of the memorial hall.

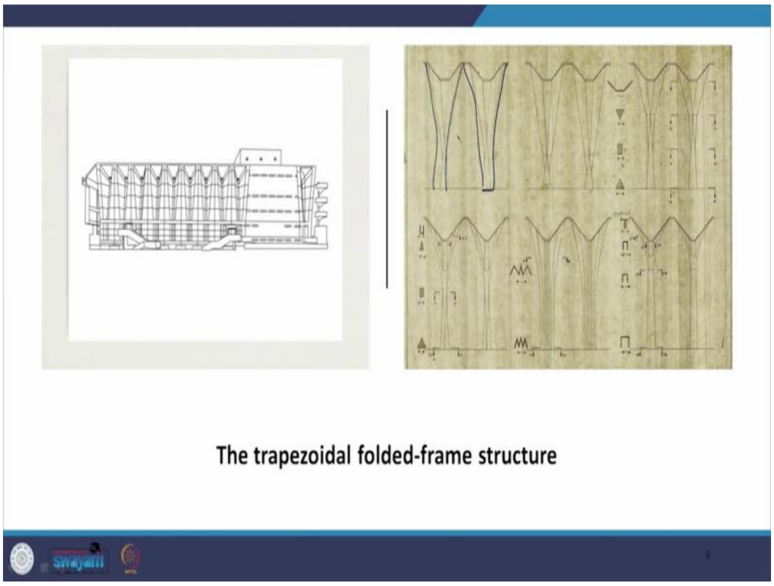
So, this engineers simple structure in concrete, infilled by welding material led to this memorial hall in 1964.

(Refer Slide Time: 08:37)



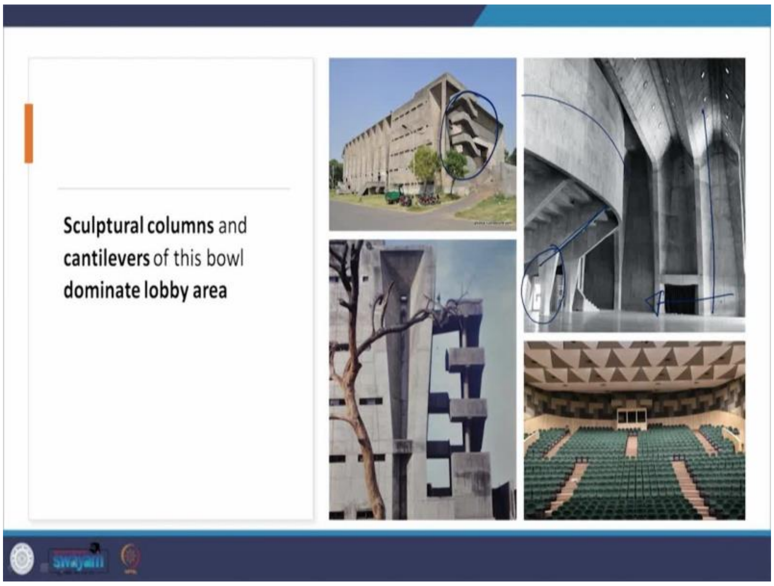
And then, the brutalist work of Tagore Memorial Theatre in Ahmedabad in 1965 by B. V. Doshi made up of RCC folded plates, which was even in the west something of a unique structural innovation even at that time. And so, this RCC folded plates provide the outer shell of this hall of this theatre.

(Refer Slide Time: 09:00)



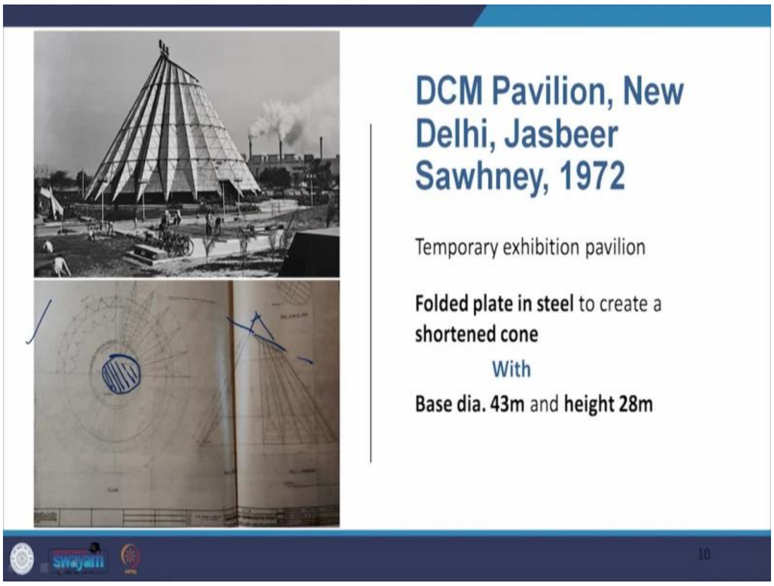
And there are these, these folded plates out trapezoidal folded frames as you can see, this is the trapezoidal image that you get out of it, the somewhat trapezoidal shapes that you get out of it.

(Refer Slide Time: 09:16)



And these are sculptural columns and cantilevers within the building that you find in the main auditorium, the main hall is cantilevered out as you entering into the lobby area, this is a vast high space in brutalist raw concrete and you have these amazing columns, sculpturing columns over which the hall has been cantilevered out and this dominates the lobby. There is also the freestanding staircase, which was a well-known feature at the time. We have seen it in IIT Delhi and there are other buildings where we have the freestanding staircase coming from the developments of Chandigarh by Corbusier.

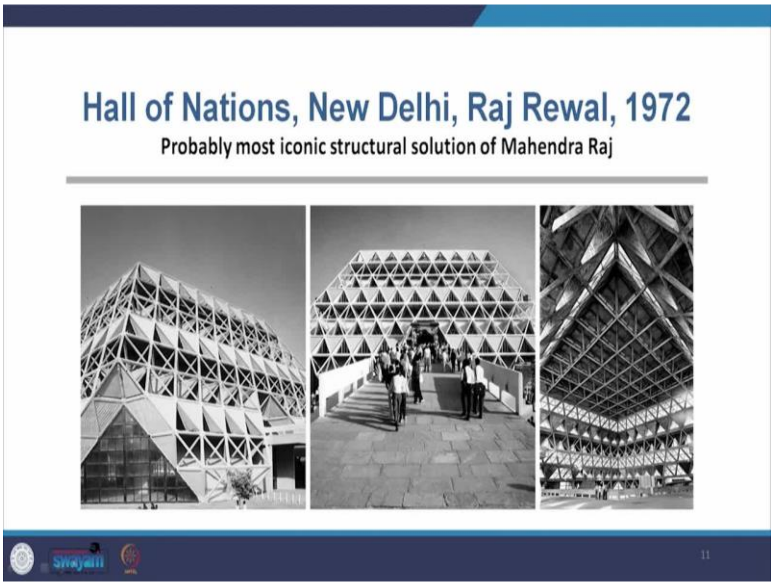
(Refer Slide Time: 10:08)



Then again we have folded plates, not in RCC, but in steel. So this was in the DCM pavilion in New Delhi, which was designed by Jasbeer Sawhney in 1972. It is a temporary exhibition pavilion having folded plates in steel to create a shortened cone, that means the cone has been sectioned off from the top. And the base dia of this cone of folded plates is 43 meter and a height of 28 meter.

Now, the drawing that you see, I am sorry, it is not very clear, because directly from the book of Mahindra Raj, this is a very typical drawing that you would make in architectural graphics of a sectioned cone, where this is the section area of the cone and the cone has been sectioned here, this would have been the cone that part has been removed. And this is the section line here and you can see the sectioned are and this is something that you would draw in your graphics class. So, fundamental geometry that is that you learn in first year in graphics has been the is the background of the DCM pavilion.

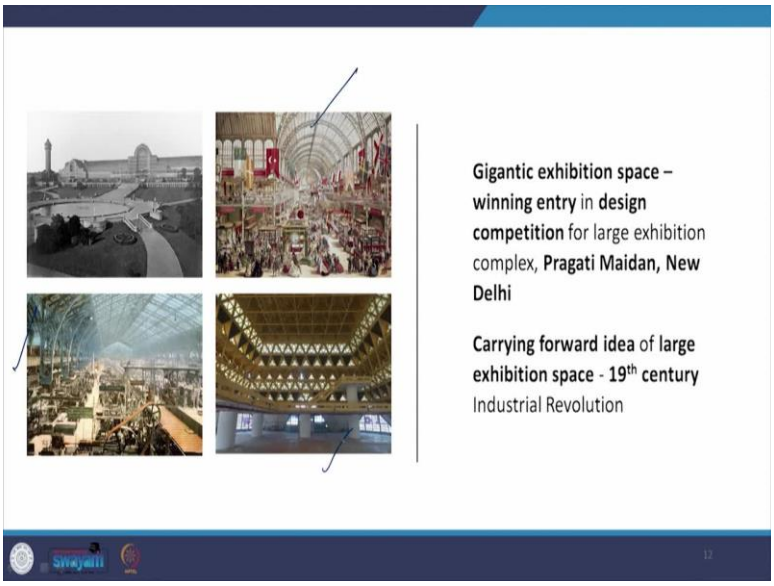
(Refer Slide Time: 11:23)



Now, there is a connection between these three projects, the folded plates in RCC of Tagore Memorial Hall, followed by the folded plates in steel of the DCM Pavilion and the DCM pavilion being a sectioned cone and then, or rather a frustum and then we come to the Hall of Nations at Pragati Maidan by Raj Rewal in 1972, which is supposed to be probably the most iconic structural solution of Mahindra Raj, and that really established him and gave him an international identity, this work became world famous.

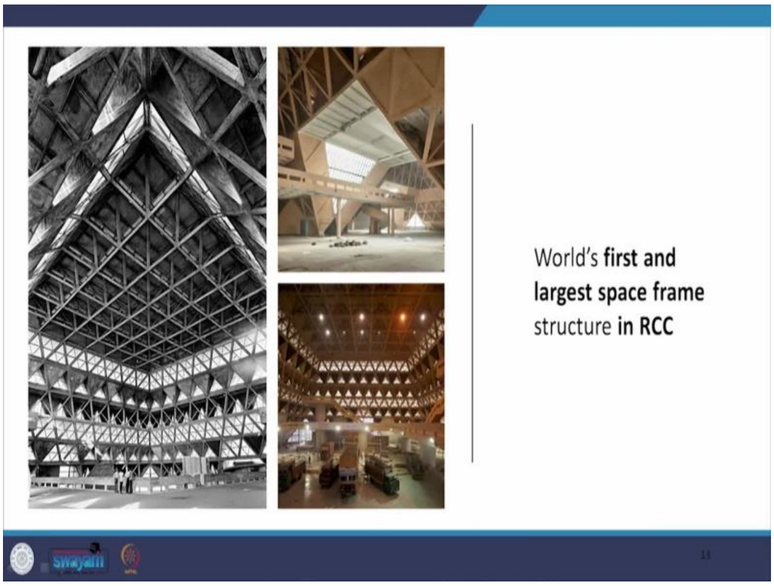
And we will see the reasons why this work was an offshoot of the idea of gigantic exhibition spaces, and a gigantic exhibition space was needed at the Pragati Maidan. There was a design competition for that, and this was the winning entry. And this was carrying forward the idea of very huge exhibition spaces, that it started rising post industrial revolution in the 19th century, with great exhibitions like that, which was held in the Crystal Palace, and then there was the exhibition around in Paris, where we have the picture of the Hall of machines.

(Refer Slide Time: 12:46)



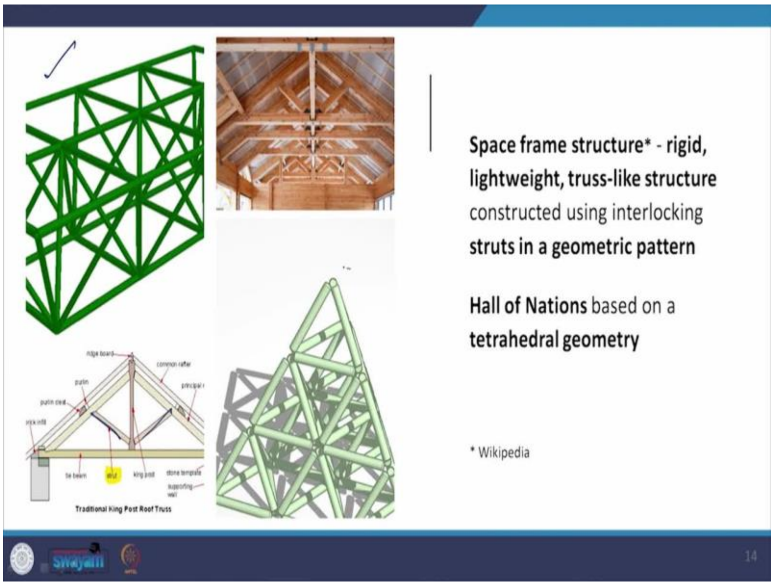
This is the Crystal Palace, very gigantic exhibition spaces and this is carrying forward of the same idea the large exhibits can be displayed.

(Refer Slide Time: 13:00)



Now, this happened to be the world's first and largest space frame in RCC. Space frame are already being built in the west geodesic dome, many other examples are there.

(Refer Slide Time: 13:15)

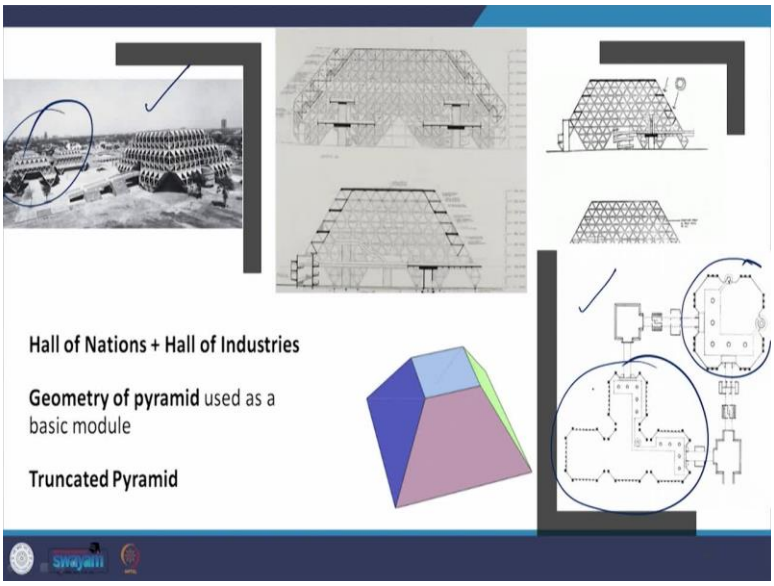


And these were being built in the West, but they were being built in steel or aluminium sections. So, the space frame structure is a rigid, lightweight truss like structure that you see here in which these truss that you see for example, these are the truss they are interlocked with each other in a geometric fashion. And in the case of Pragati Maidan. This kind of tetrahedral geometry has been developed out of this, but the only difference in this picture that you see and that of Pragati Maidan is that first of all the pyramids that you see here the individual modules, it was inverted and secondly that it was square based pyramid there is this happens to be a triangular based pyramid.

(Refer Slide Time: 14:12)

So, here we have the various types of space frames that are visible around us today. There is the geodesic dome, and this is a vault in space frame is a flat roof in space frame. This is an example that you can find in a center that was designed I believe, by Norman Foster in England, and then you have the Heydar Aliyev center with a curvy linear firm that is possible because of the space frame.

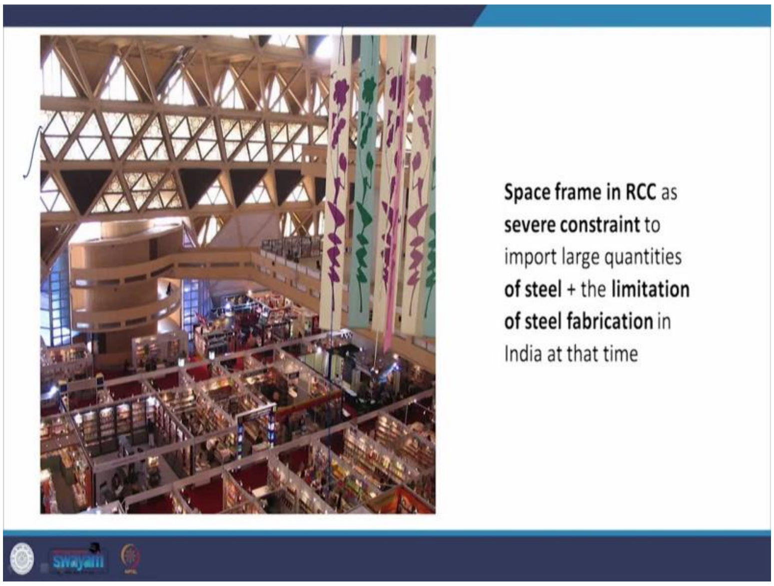
(Refer Slide Time: 14:44)



Now the entire complex that was designed as a winning entry included the Hall of Nations and there were smaller units called the Hall of industries. So this is the hall of nations and there are smaller units, the Hall of industries and these had the geometry of a pyramid, but a pyramid that has been truncated that the top part has been cut off. So, these are truncated pyramids used as the basic module in the Hall of nations. This is the plan layout, this is the plan of the Hall of nations and then these are the Hall of industries.

Now, you can see that they are all column free spaces, they are gigantic column free spaces, so, that they with complete freedom in exhibiting the products of various varieties within the space.

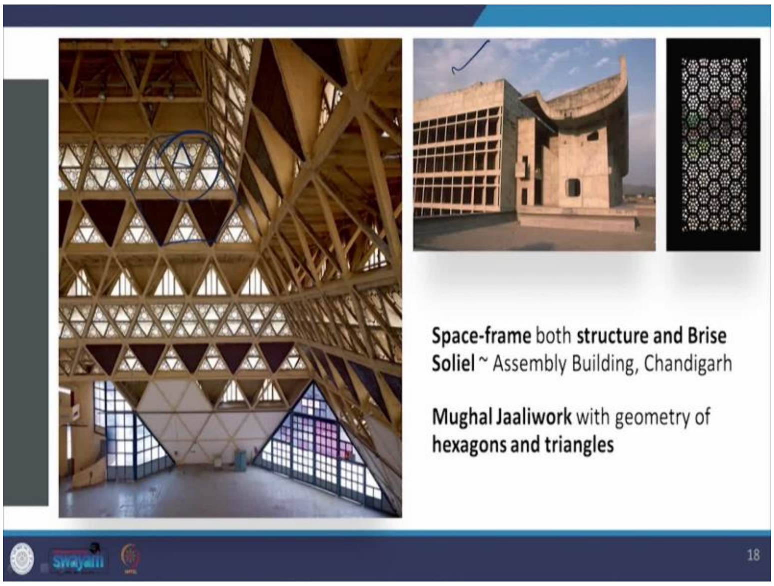
(Refer Slide Time: 15:39)



And this is a picture that shows you how amazingly this space can be used, there are a series of exhibition spaces that are housed here within the Hall of nations and the even the height becomes useful. So, the space frame was an RCC because of the severe constraint or of importing large quantities of quality steel to manufacture it in India, along with the limitation of steel fabrication at that time in India.

Therefore, the architect Raj Rewal and Mahindra Raj decided to make this in RCC and thus came up an iconic structure, which is the first and the largest RCC space frame in the world it was built and became and got international fame to both the architect and the structural engineer.

(Refer Slide Time: 16:38)



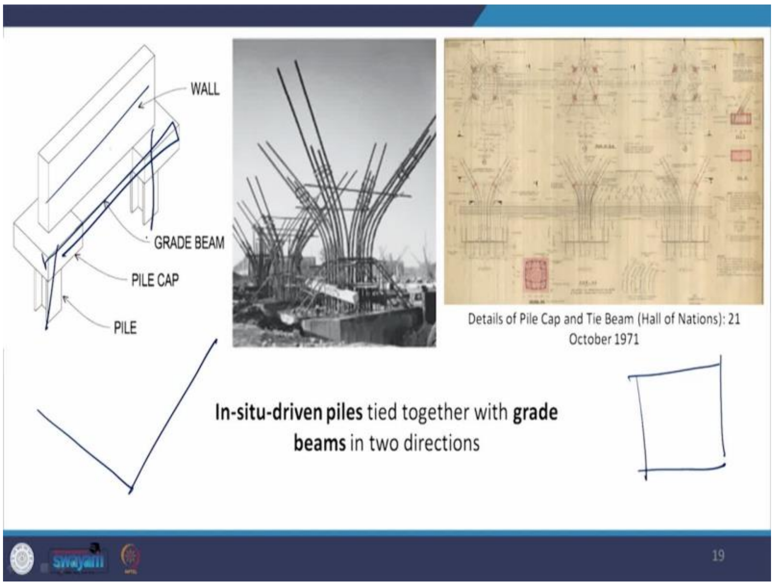
Now, in this case, the spaceframe of the Pragati Maidan or Raj Rewal pointed out that this happened to be both the structure and the sun breaker or the brise soliel. In the case of Corbusier's building like the Assembly Building in Chandigarh, the structure was separate and the brise soliel was mounted on the building. So, the brise soliel was not a part of the structural system.

Whereas in the Pragati Maidan, in the Hall of nations, the structural system of the that is a truncated pyramid, itself served as sun breaker or brise soliel. The second was the idea of borrowed from traditional architecture. When we look at the Hall of nations, we do not remember critical regionalism we do not seem to have , this is a very modern looking building even by global standards.

But look at it carefully and hear what Raj Rewal says that it has the Jaali concept in it. So if you look at it carefully, it has the jaali concept but obviously on a very huge scale. And the hexagons and triangles of individually have been borrowed and incorporated. So you see there is the hexagon and then there are the triangles within it. And that is creating a massive jaali.

So the brise soliel is a part of the structural system, the brise soliel is a derivation of the jaali and this leads to this amazing volume.

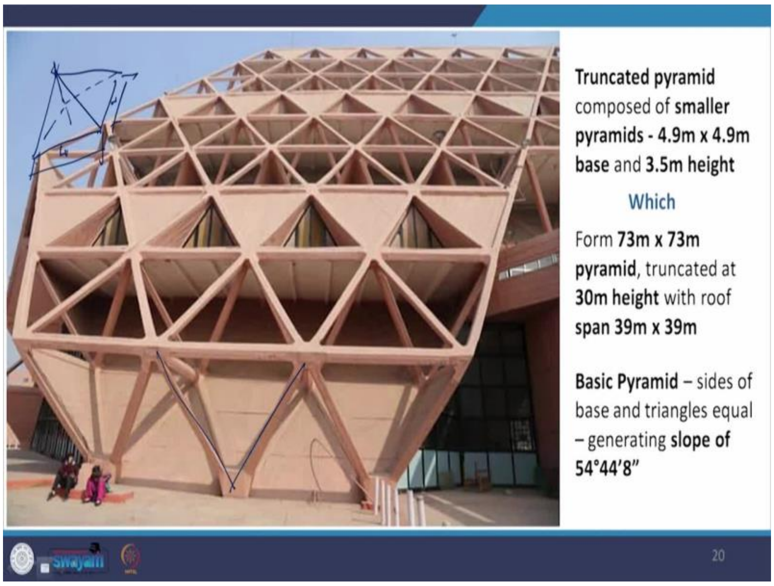
(Refer Slide Time: 18:10)



Coming to the structure which was the part the role played by Mahindra Raj. It has in situ piles that are tied together with grade beams which are running in two directions that is a both in the x direction and in two perpendicular directions and thus to create the base of the Hall of nations. Now, what is a grade beam, grade beam means that which transfers the load of the structure above rather for example, the wall above to the piles below.

So, if this is the wall, it transfers its load to the grade beam and the grade beam then transfer load to the piles, because the piles were cast on site, then the grade beams were installed above it or cast above it and this was a homogeneous casting composite, they were tied together with the grade beam and then over it a superstructure came up.

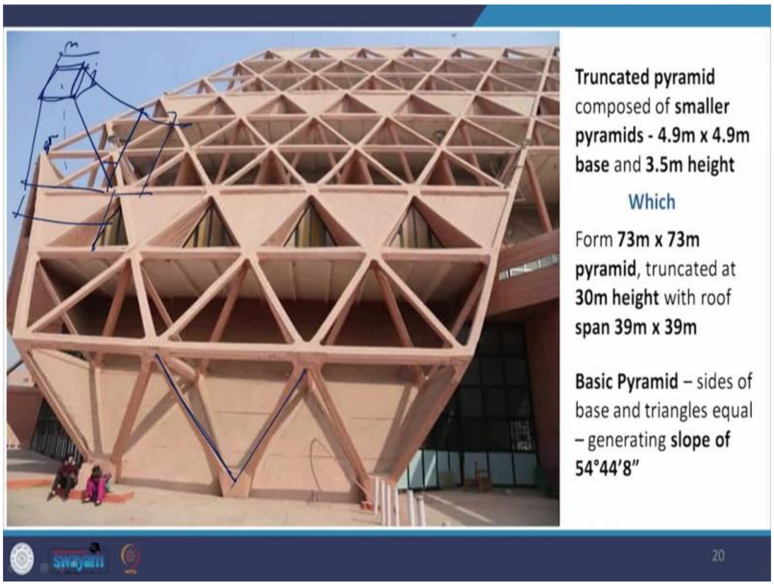
(Refer Slide Time: 19:11)



Now the truncated pyramid itself is composed of smaller full pyramids like these are pyramid and starts with an inverted square based pyramid. Now these pyramids are 4.9 by 4.9 meters. So if I were to take an example of a square based pyramid to draw it for you, this would be a square based pyramid and therefore, this is 4.9 meters and this is 4.9 meters and the height of the pyramid this height is 3.5 meters.

Therefore, this leads when we keep on multiplying it this leads to a form of an overall pyramid of 73 meters by 73 meters, which is truncated at 30 meters height and the roof span is 39 meters by 39 meters. So, what we have is that we have the pyramid.

(Refer Slide Time: 20:19)

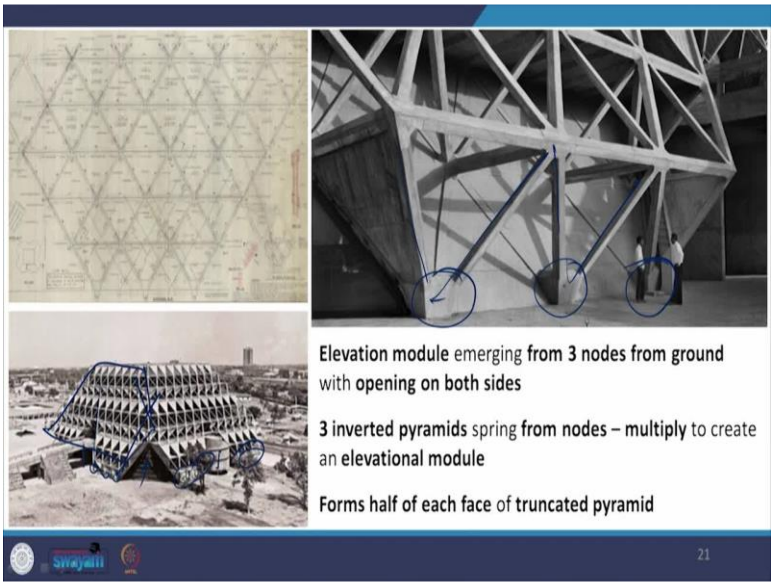


If I can just show it to you again that we have the pyramid, which is truncated and here we have the 73 meters by 73 meters within it there are the smaller pyramids of 4.9 by 4.9 meters and 3.5 meters height.

This 3.5 meters leads to a total height of 30 meters at which the pyramid has been truncated and at the top level this is 39 meters by 39 meters. So, the basic pyramid the other thing is that all the lengths that means of the triangular faces of the pyramid, these members and the base member are all of equal lengths that is 4.9 meters. And this because it is an equilateral triangular square based pyramid, it leads to generating a slope of 54 degrees, 44 minutes and 8 seconds. And this being the slope of this square pyramid, as we keep on mounting, it automatically generates the slope that we see in the Hall of nations.

Now, the same thing on a smaller scale is there in the Hall of industries. And because it is again a square based equilateral triangular pyramid in the Hall of industries, that also has the same slope. So, the slope is consistent for the Hall of nations and the Hall of industries. And it is an automatic offshoot of using this kind of a square based pyramid.

(Refer Slide Time: 22:00)

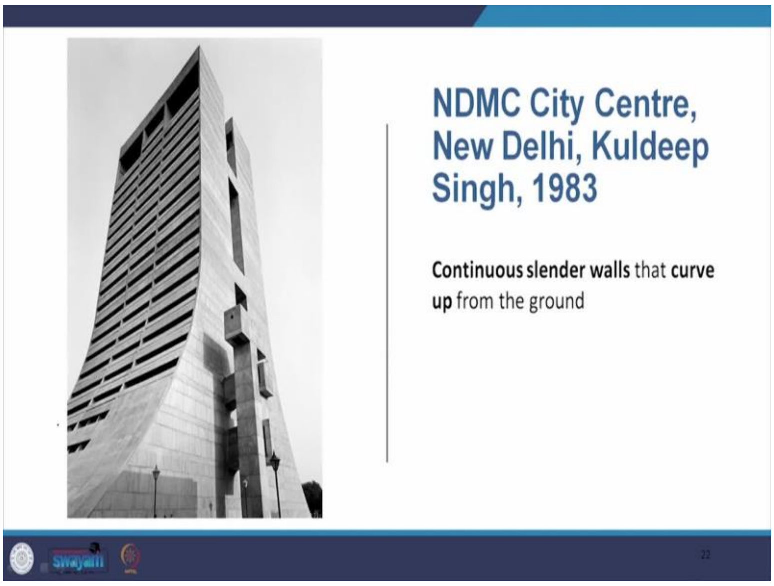


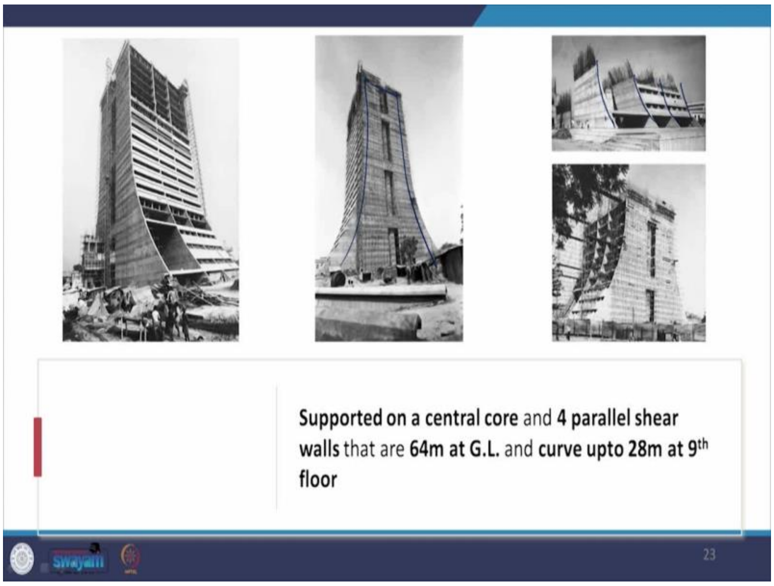
Now, the elevation module in itself is emerging from these 3 nodes or the ground. And then, so, if you see it in the overall built form, these are the 3 nodes with openings on both sides. Now this is consistent, we again find 3 nodes here and the 3 nodes here and with openings on both sides. And so, it is consistent throughout.

Now, these three inverted pyramids spring from these 3 nodes and thus begins the rise of the truncated pyramid thus they multiply to create an elevational module. Now, there are two such elevational modules on each phase that means in this phase, there are two such elevational modules that are put together. So, this is a very interesting modular system, starting from a small square based equilateral triangular pyramid springing from these 3 nodes rising up to a height of 30 meters and with an angle of 54 degrees something as it rises up, the 2 elevation modules are formed that combined together to form one phase and thus there are these four phases on all the sides, which are identical to each other.

Amazing structural system created by Mahindra Raj worth the iconic status that has that was given to it.

(Refer Slide Time: 23:35)





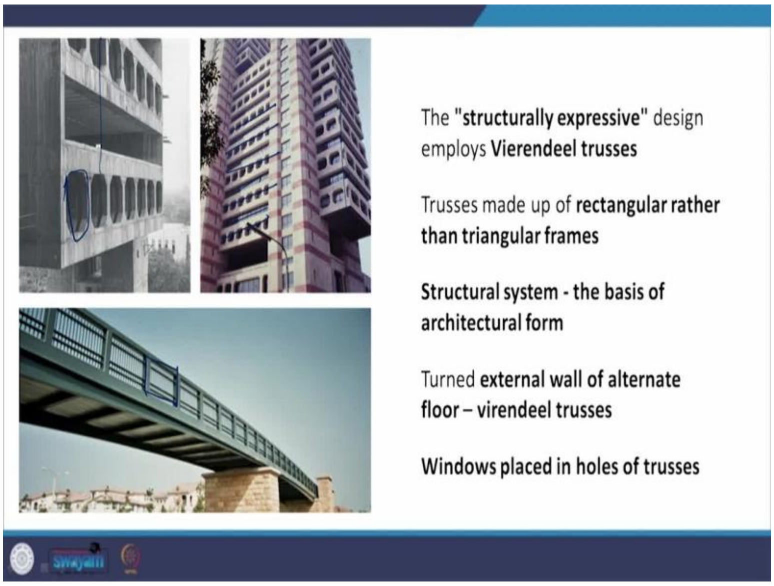
And then we have the NDMC city center, which he collaborated with Kuldeep Singh in designing in New Delhi and this was also very iconic firm, which is something which was related to structuralism. Because what it has is it has got independent the structural elements become the ornament of the building, for example, the freestanding staircase here, and the entire building is brutalist in raw concrete finish, whereas these continuous slender walls that curve upwards from the ground and they are supported on a central core with 4 parallel shear walls, where are the shear walls, we see the 2 shear walls on the outside, one on the side and on the other. And then when you see the construction, this is 1 shear wall 2, 3 and 4.

So 1, 2, 3, and 4 shear walls, which are curving up from 64 meters with at the ground level to 28 meters with at the ninth floor. So that is how this amazing building was put together. Now, I have shown this project earlier also, whether smaller units of this also created next to it. Just as the Hall of nations has the Hall of industries, this NDMC building has a smaller unit adjoining it close to it, which is also following the same rhythm and structural format.

(Refer Slide Time: 25:12)

Then there is the STC, the State Trading Corporation building in New Delhi by Raj Rewal in 1988 having 22000 or 22000 square meters of office space, hotel, cinema, museum, art gallery, OAT, shops and the shopping center happens to be the focus of the cultural, social and commercial life.

(Refer Slide Time: 25:32)



Now, what it has is something called Vierendeel truss what is a Vierendeel truss? Vierendeel truss is different from this triangular truss in that in the triangular truss, you might have seen there are these triangular elements in the Vierendeel truss these elements instead of being triangular in the truss, they are rectangular. So, that leads to Vierendeel truss or even Vierendeel girder and these trusses are made up of rectangular rather than triangular frames. The entire structural system of the STC building is based on this architectural firm or rather this structural system.

Now, the external wall of alternate floors is in this Vierendeel truss. So, if you look at the building facade, every alternate floor you have seen these Vierendeel trusses one on this side and one on the other side. Thus, enclosing these alternate floors and intermediary floors do not have the Vierendeel truss, they are automatically generated in between these alternating trusses.

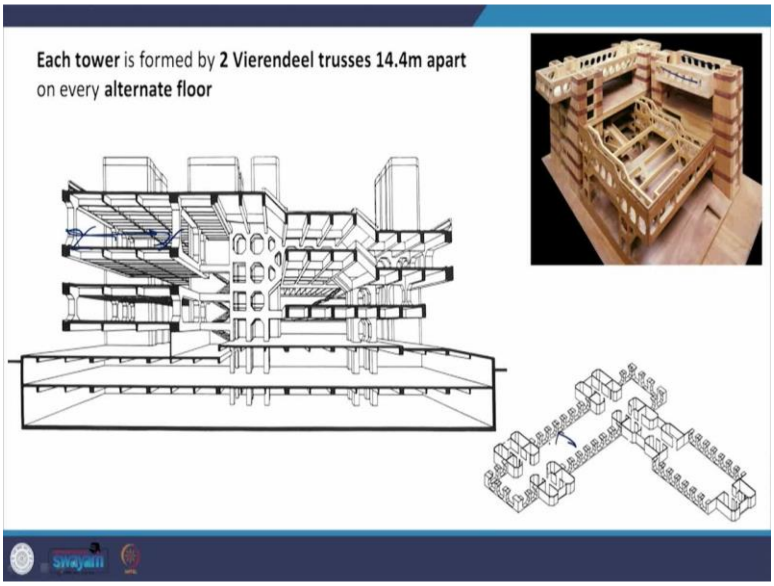
And thus we have these alternate trusses you can see in the close up and the truss itself has been cut out with these octagonal cutouts these windows which are octagonal cut out. More or less kind of a square shape or rectangular shape indicative of the Vierendeel truss. Now, the building is having 3 heights in it there is a 23 and an 18 and a 12 meter high tower.

(Refer Slide Time: 27:05)

So we have the 12 meter high, 18 meter high, and the tallest is the 23 meter height tower, and this is supported and cast-in-situ piles. The Vierendeel trusses are cantilevering outward 6 meters from the end, these are the shafts of the building, the shafts have been provided. As you can see these are the vertical shafts of the building service shafts of the building, which are located 23 meters apart from each other. So this is 23 meters. And then again, this is 23 meters.

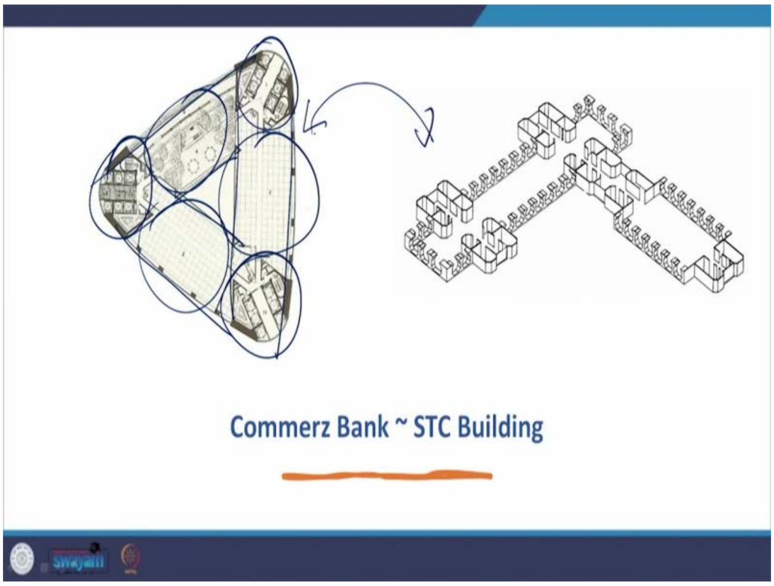
And then you have the Vierendeel truss on this side and on this side. This is approximately 14.4 meters. And what you get is this expansive, column freeze floor space for the offices. Permits these column free spaces for flexible internal planning.

(Refer Slide Time: 28:08)



So there here we have it again, as you can see, these are the Vierendeel trusses, or you can see here in the perspective, one point perspective section these are the Vierendeel trusses on both sides with 14.4 meters apart from each other 14.4 meters apart. And there are on every alternate floor.

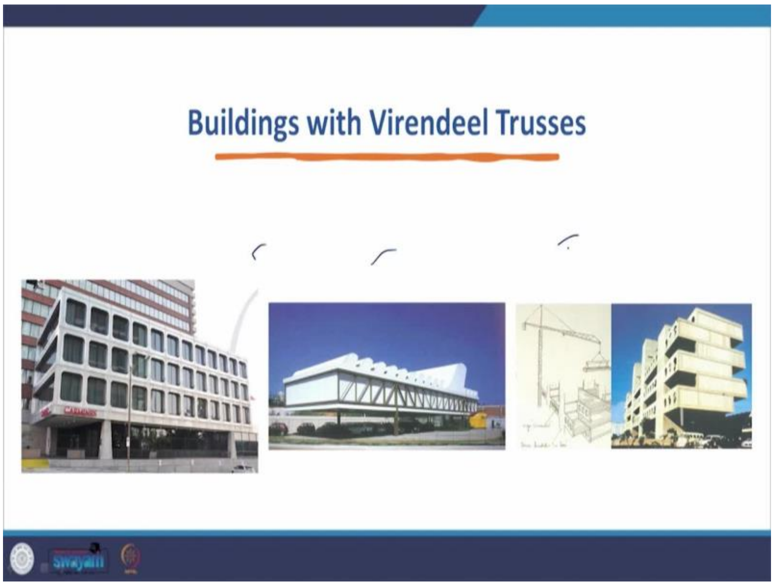
(Refer Slide Time: 28:25)



Now I will drop a comparison between two buildings, the Commerce Bank in 1997, by Norman Foster, and then earlier than this was the STC building that was in 1988. And in the Commerce Bank, the Vierendeel truss was used in that these are large Vierendeel trusses, which are holding the Commerce Bank like, it is in a triangular form. And this is column free space, this column free office space, column free office space. And just like in the STC building, the service cores are on the periphery in the Commerce Bank. And it also has sky gardens.

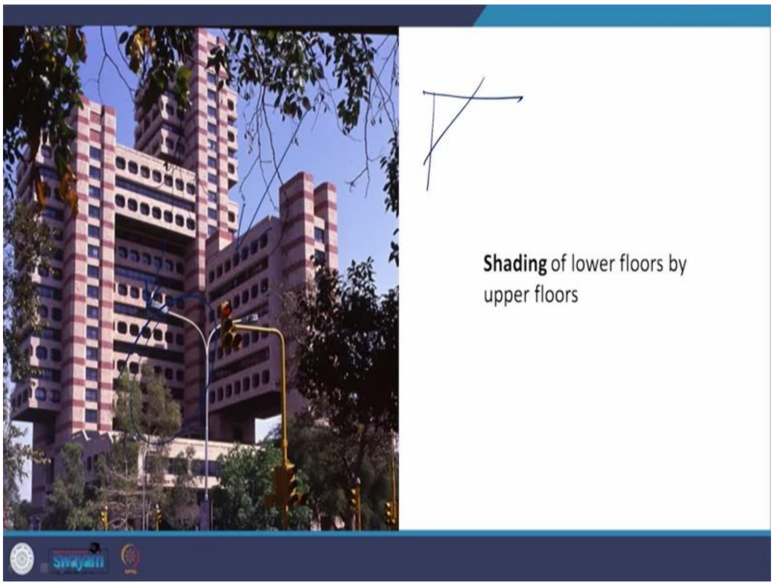
As you remember I told you in the presentation for search for a new architecture in (())(29:19) vision of morphogenesis. Sky gardens are provided in the Commerce Bank. So the idea between of these two buildings is very similar using the Vierendeel truss.

(Refer Slide Time: 29:34)



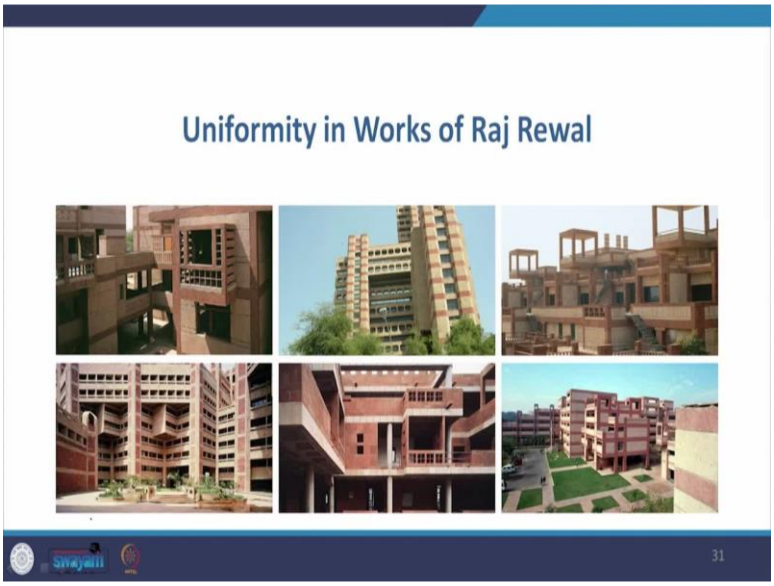
Now there are other buildings that have come up with Vierendeel trusses globally. These are a few examples that you see where, Vierendeel trussses have been used.

(Refer Slide Time: 29:44)



Now the other aspect of it is cantilevering of the or I am sorry, not cantilevering, but projecting the floors above so that shading happens to the floors below. And in fact that is also an aspect of mutual shading happening because of this kind of arrangement. So, you also found some mutual shading happening in the facade. And overall the cladding that Raj Rewal did here is with sandstone, which is reflective of the traditional architecture of North India.

(Refer Slide Time: 30:21)

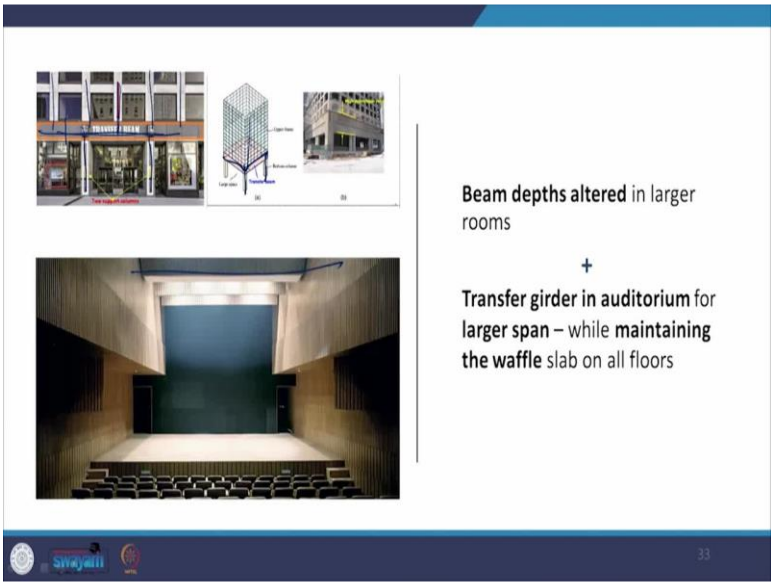


In fact, we find this uniformity in the works of Raj Rewal in various works that you see and all these works are in Delhi NCR, and all of them have this sand stone finish. And generally they are of 2 colors. There is a darker one and lighter one in which is used in all these various buildings.

(Refer Slide Time: 30:42)

Then there is the Alliance Francaise project that was done in New Delhi by Stephane Paumier and Anupam Bansal the firm of SPA design in 2004. And this earlier, was supposed to have a multiple structural system that the architect had come up with, because of the varying spans in the building. But when Mahindra Raj came on board, and he unified the system, and made it more efficient and clean and more attractive, by providing these pre cast waffle slabs that you see here, I am sorry, the picture is not very clear, but these are the waffle slab panels that have been provided. Each of the panels is 8 meters by 10 meters.

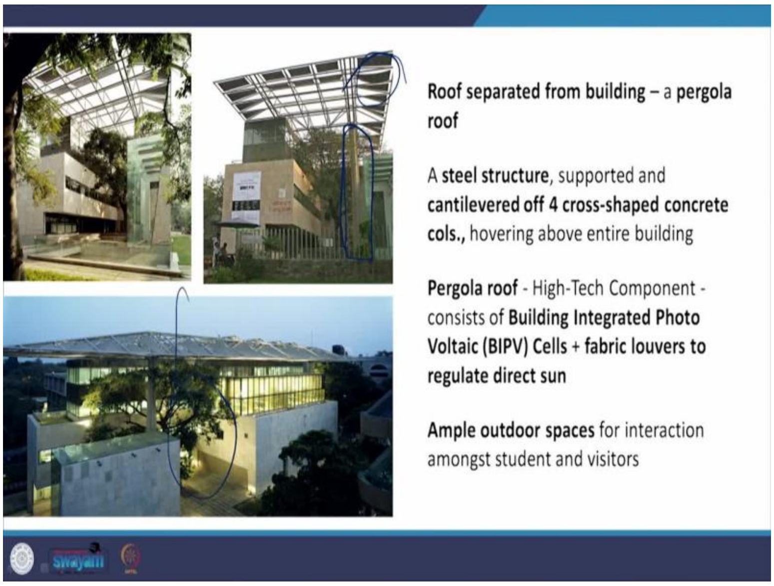
(Refer Slide Time: 31:31)



Now, not only that, the other things he did was that he altered the beam depths in the larger rooms, and then he provided transfer girders, that were need it to provide a large column free space in the auditorium. So, what is a transfer girder? Transfer girder or a transfer beam in a sense is that you have the structure above, these load is coming down, but then this load at this level you require a problem free space. So, you have a much deeper beam, it is having more width to span this thing, the higher depth to span ratio, and as a result of that, it carries the load of the structure above and then transfers it to the extreme column.

So, for example, if this is the building, and this load is being transferred to the grade beam here and here and then it is transferred to these the peripheral columns and taken downwards. So, the grade beam is very important to do to create this kind of column free space at a given level. And thus you find these grade beam provided to create the auditorium space.

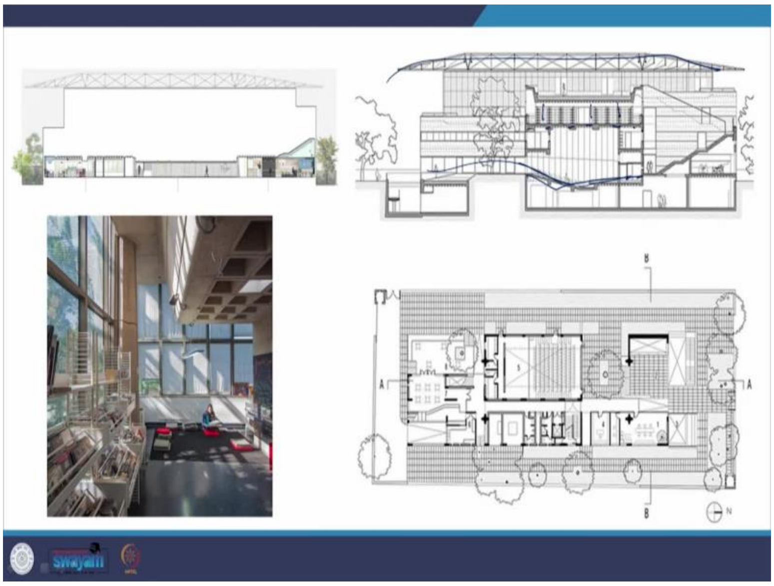
(Refer Slide Time: 32:52)



Now, another interesting thing they did was that they separated the roof from the building and it is a pergola roof it is extending outwards cantilevering outwards and it is becoming a pergola, it is a steel structure. And because it is cantilevering out the roof itself as a separate unit it is standing on 4 cross shaped as you can see here, 4 cross shaped concrete columns are supporting this roof. And the pergola is a high tech component because it is made up of building integrated photovoltaic panels and BIPV panels that help in generating solar energy or electricity from solar energy rather and the fabric louvres as you can see, and this together work to regulate the direct sun.

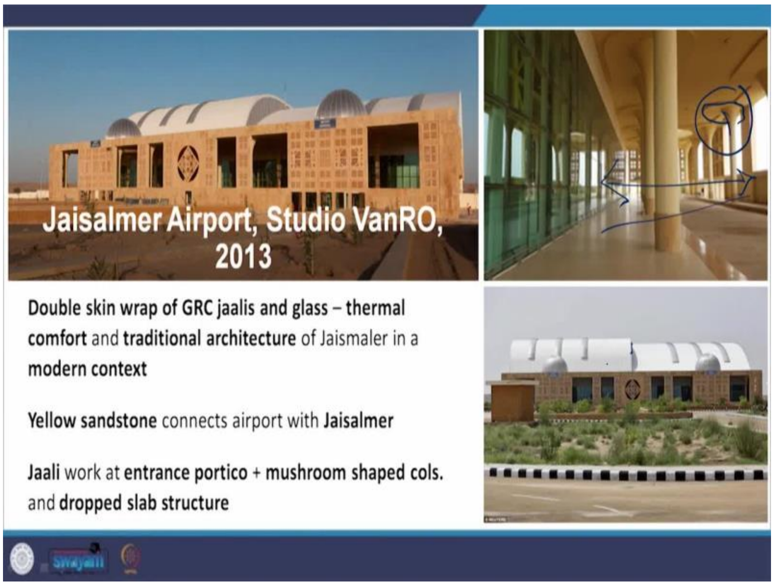
Now, there are also ample outdoor spaces that are created which are under this massive pergola where interactions can take place between students and visitors etc.

(Refer Slide Time: 33:56)



These are the drawings section shows you the amazing spaces that have been created the auditorium within as you can see, these are the grade beams in the section these are the grade beams that you can see which are taking the load of from above. And thus the auditorium is created. And this is the massive pergola steel roof structure which is somewhat independent of the building.

(Refer Slide Time: 34:22)



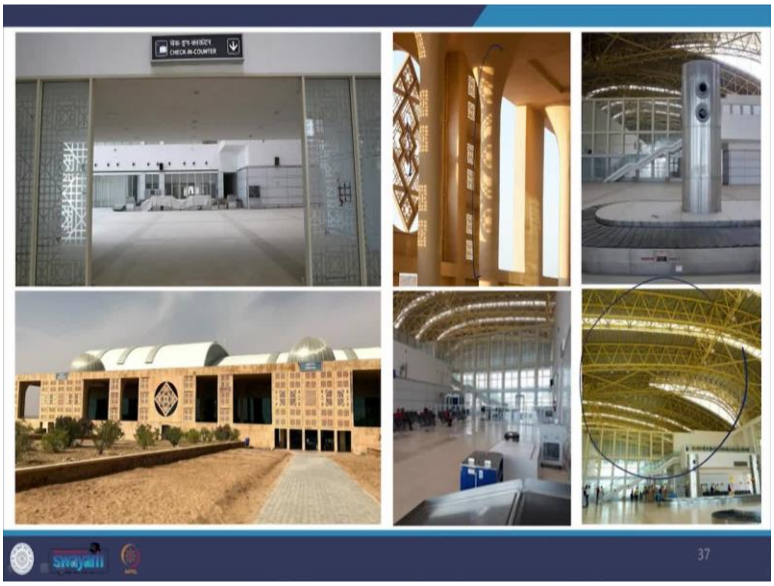
And then we have the Jaisalmer Airport by Studio VanRO in 2013. It has a double skin wrap of GRC jaalis, glass reinforced concrete jaalis and glass itself to provide thermal comfort and also reflective of the traditional architecture of Jaisalmer in a modern context.

Now, yellow sandstone has been used which is reflective of the material available in Jaisalmer. It connects the identity of the airport, the Jaisalmer. So the architecture is the identity of Jaisalmer the outward appearance in terms of jaalis, etc and the use of material. Now, the jaali work at the entrance portico and the mushroom shaped columns and the dropped slab structure have been provided here at the entrance.

This is a very large space that has been provided and thus the solar glare does not penetrate into the airport. Now, what is a dropped slab structure that Mahindra Raj is used if you look very carefully, here, this is the mushroom column. You see in a flat slab, the beam is not there the slab is directly being carried by the column, but in that situation the column can punch into the slab, to avoid that from happening, a dropped slab is created you can see very neatly here, a dropped slab is created underneath the flat slab and then there is the column. And that prevents it from punching into the flat slab.

And that arrangement has been done besides you see in the roof form, which is a barrel vault more or not exactly barrel vault it is a vault and we will come to the section to explain why I am not referring to it as a barrel vault. There is a gap created here that brings in light from the top, that is the skylight.

(Refer Slide Time: 36:26)



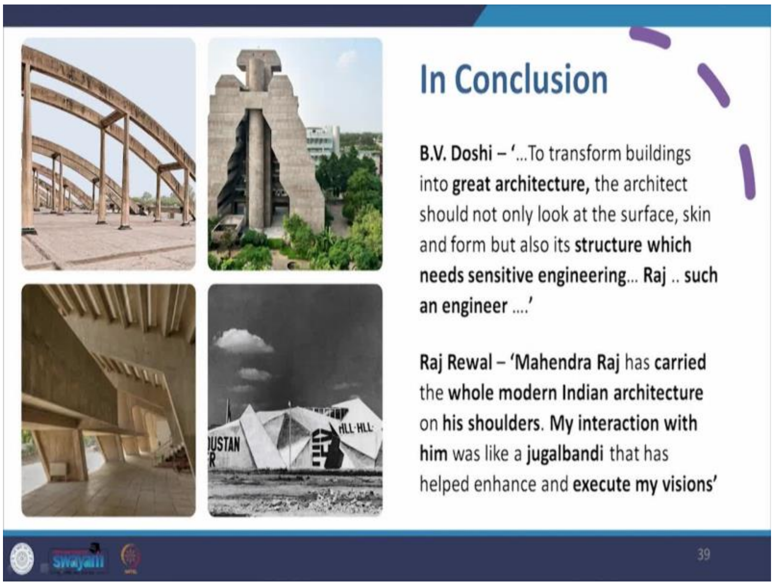
These are some of the views of the airport, these are the mushroom columns and these this is the jaali work on the outside. Now, this is the frame of the roof and we look at that what is it.

(Refer Slide Time: 36:39)

Where these 10 asymmetrical trapezoidal steel arches that have been created. This is the drawing of the arch and the trapezoidal part is that as they go up, they take a kind of a trapezoidal shape. And they have a span of 66 meters from one spinning point to the other. And this from the airport roof and it is said that it is also reflective of the rise and fall of the sand dune of Rajasthan. Along with that the arches themselves the stun arches, you can count the stun arches here that interconnected in between by these 4 triangular cross trusses.

And as a result of this, this cross trusses help to contain the horizontal forces that can come through an earthquake that come through the wind that come through temperature variations, they account for that. So this entire structural system was evolved through Mahindra Raj consultants.

(Refer Slide Time: 37:46)



In conclusion, seen by all these buildings, what do we see? One is the chronological range coming from the early modern period in India in the 1960s, all the way till 2013, 2011, 2013. So this is a very vast period, when we saw the rise of modern architecture in India, all the way to today.

Not only that, we see the different regions in which the structures have been built, I have only looked at a very few for a summary. There are many others that in different parts of the country, and the architects that he has worked with some different architects who have associated them in designing their iconic structures, all the iconic architects you can name today, at one point time or another, particularly of that era of the 60s and the 70s have had a structure that they had done along with Mahindra Raj.

So B. V. Doshi says in conclusion, to transform buildings into great architecture, the architect should not only look at the surface skin and form, but also its structure, which needs sensitive engineering and Raj was such an engineer. Raj Rewal says that Mahendra Raj has carried the whole modern Indian architecture on his shoulders because of the longevity of his work and his interaction with him.

That or other Raj Rewal says my interaction with him was like a jugalbandi that has helped enhance and execute my visions. Such was the amazing contribution of the structural engineer. Now, we are not here to deify or to glorify one man no, that is not the purpose. The purpose is to tell us the importance of structures in making very amazing and interesting buildings.

The vitruvian triad comes to mind form, function, structure. All three are important to come up with a good building, but in this case, the structure is done so sensitively and aesthetically because it makes a major contribution to the aesthetic of the building. And that is what a structural engineer or a sensitive structural engineer strives to do. That is what Fazlur Khan tried to do when he came up with the idea of different designs, structural designs for skyscrapers.

So that is why a Sears Tower looks so beautiful, or the John Hancock Center, which is tapering towards the top looks so beautiful with its cross bracing, because Fazlur Khan devoted himself to sensitive structural engineering. I will conclude here and we will begin in the next session with looking at a search for a new architecture. Thank you.