



Art Museum in São Paulo, Brazil



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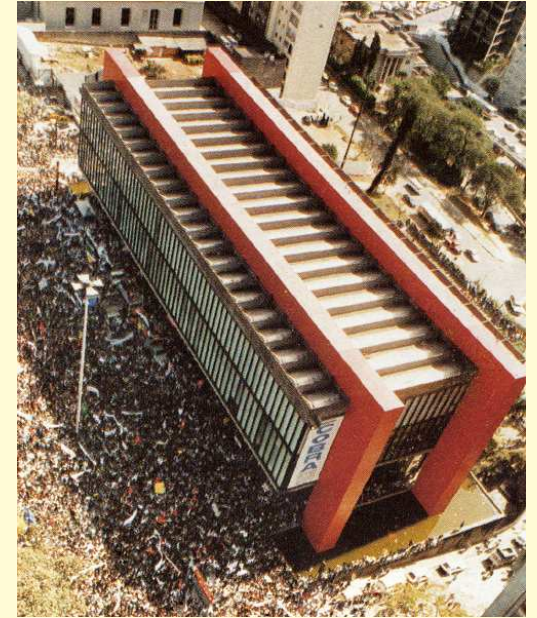
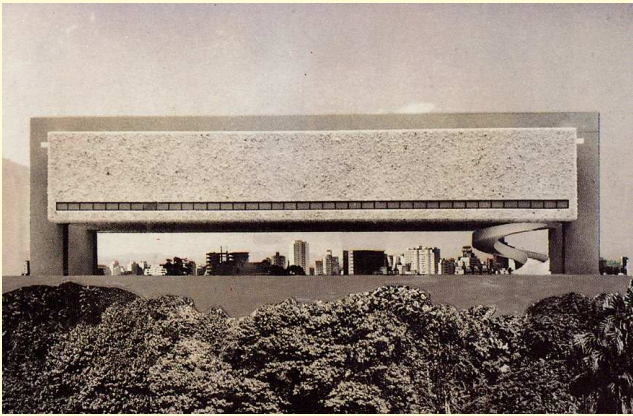




Art Museum in São Paulo, Brazil

Lina's most known project was the São Paulo Art Museum (1957-68).

Lina wanted to leave an open area in the center of São Paulo for social events.



The Art Museum



Art Museum in São Paulo, Brazil

The Architect

Lina Bo Bardi

Structural Engineer

José Carlos de Figueiredo Ferraz

Designers Involved



Art Museum in São Paulo, Brazil



Lina Bo Bardi was an Italian architect born in 1914 who traveled to Brazil in 1947. She was already a well-known designer in Italy when she arrived in Brazil. Her husband, Pitro Maria Bardi, was an important Italian journalist who dealt mainly with the arts. He was invited by Assis de Chateaubriand to come to Brazil to become the head of the art museum. Assis also invited Lina to design the art

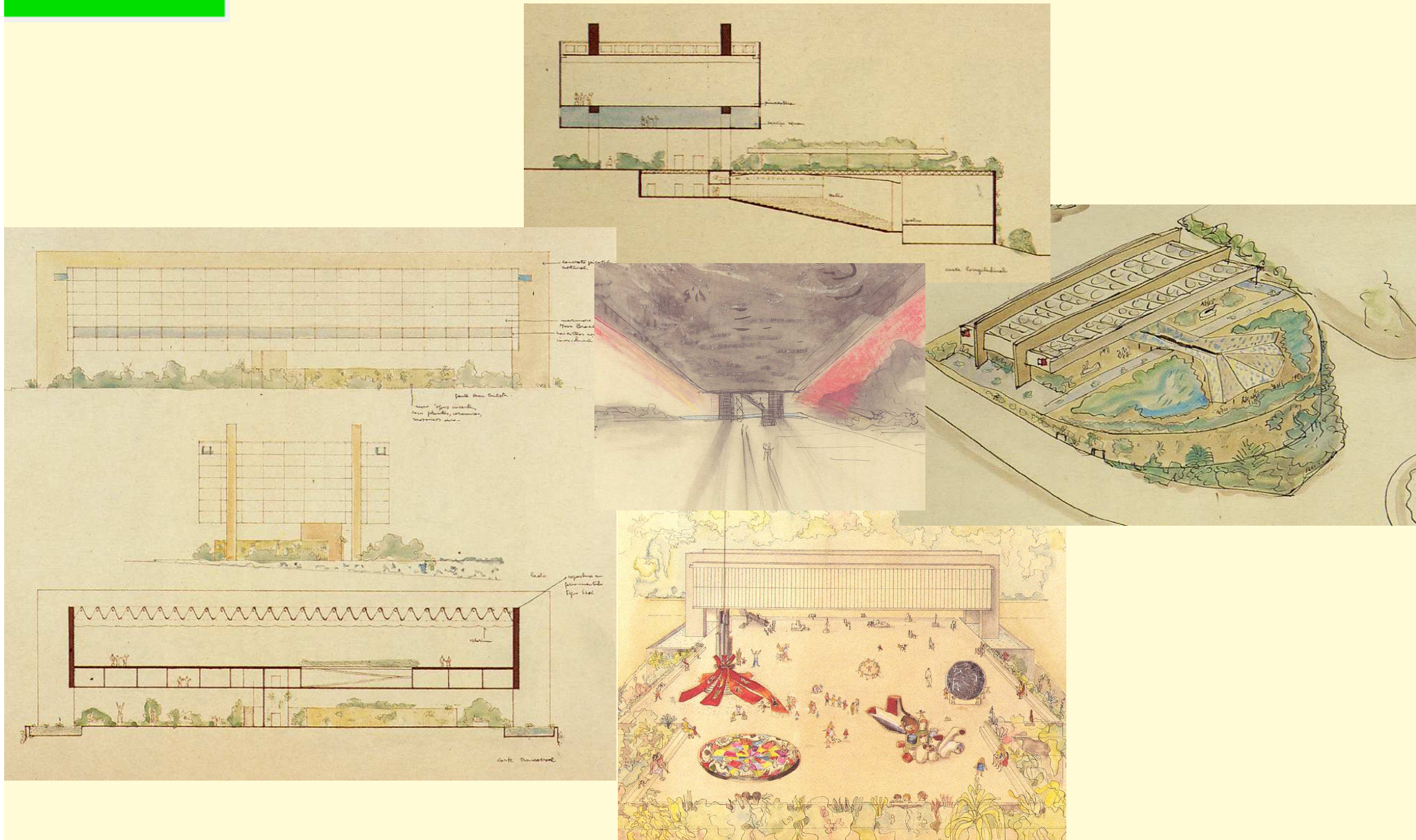
museum. She lived in many different cities of Brazil, and five years later she and her husband naturalized themselves as Brazilians.

When designing the museum, Lina intended to create a design of simple architecture with a strong social context. The simple architecture was directly emphasized in the use of the raw materials, such as concrete, and used in the way of simple rectangular forms.

The Architect



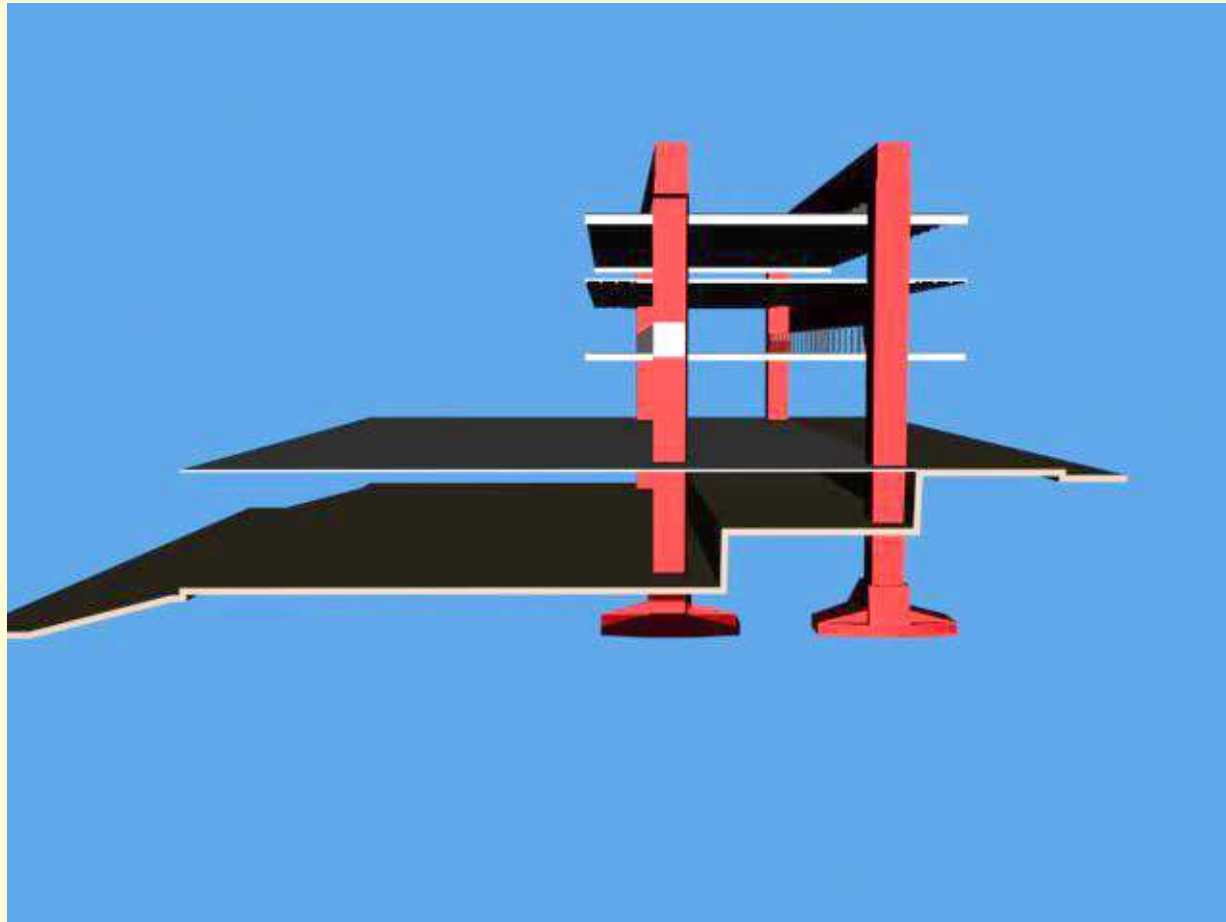
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Schematic Design



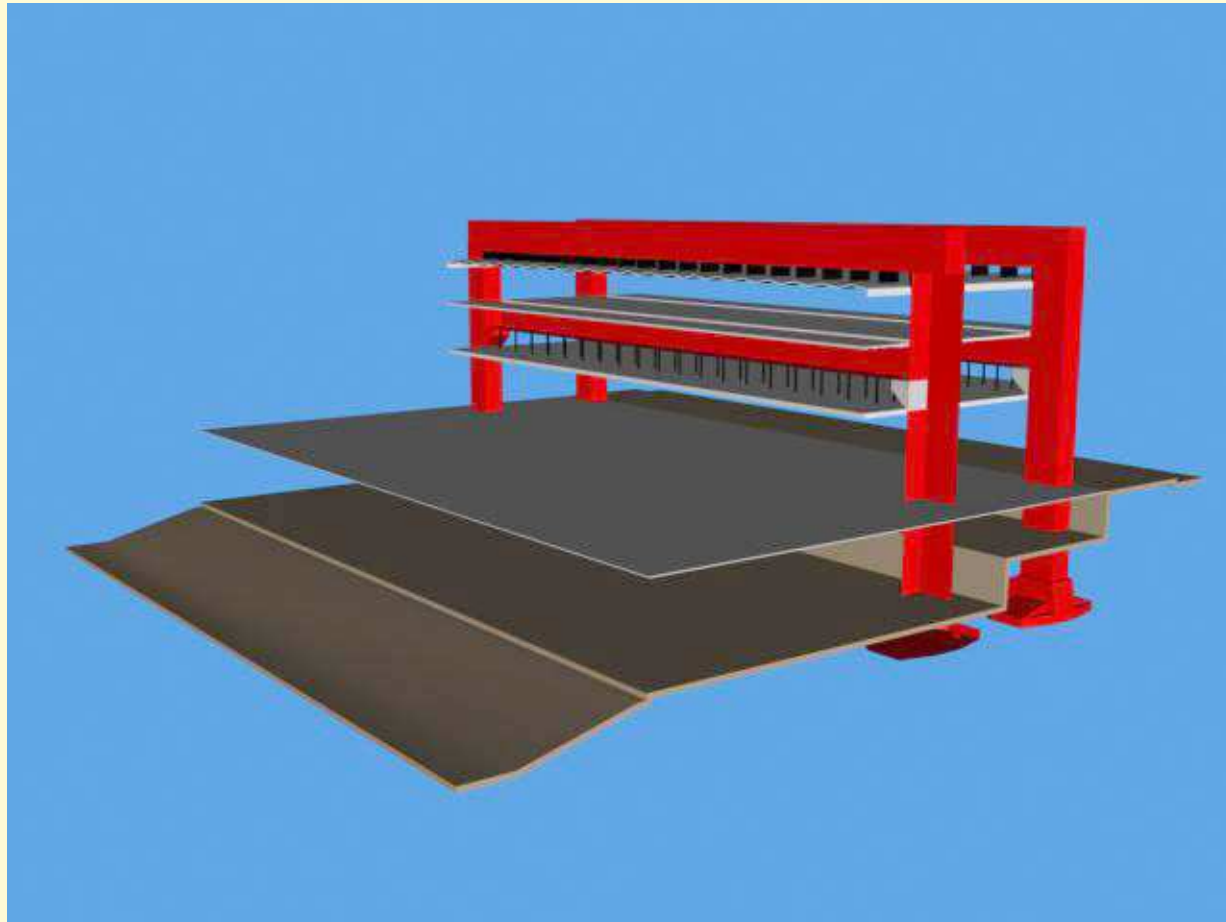
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3D Model



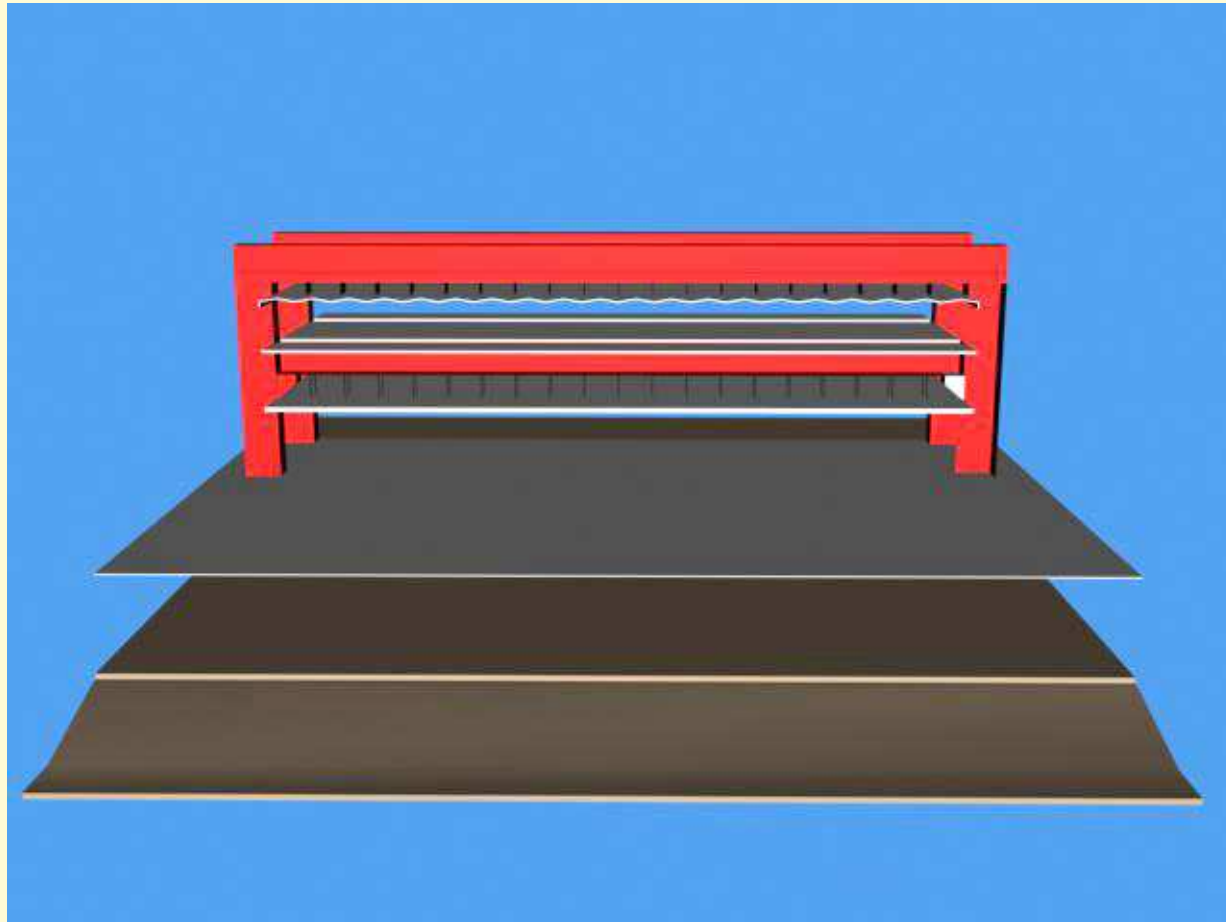
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3D Model



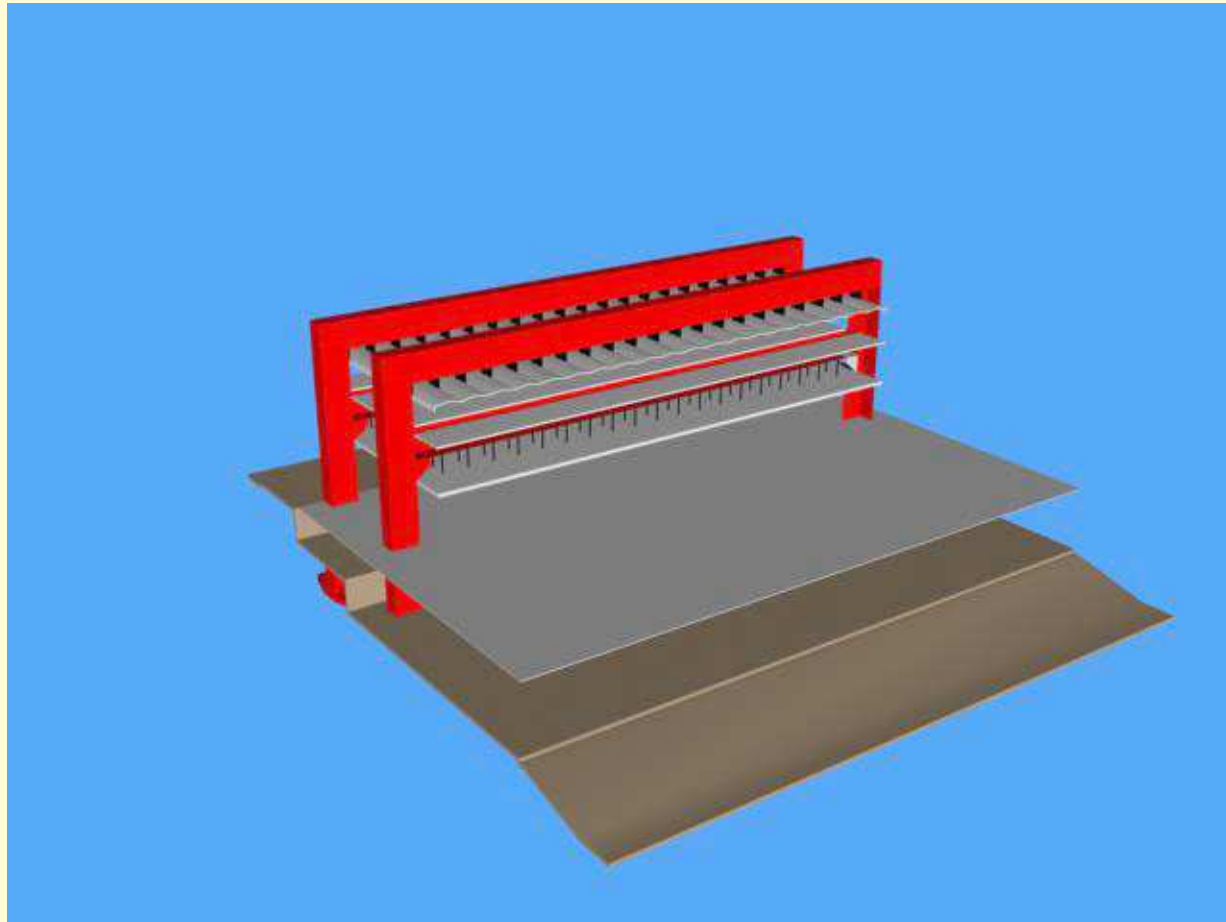
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3D Model



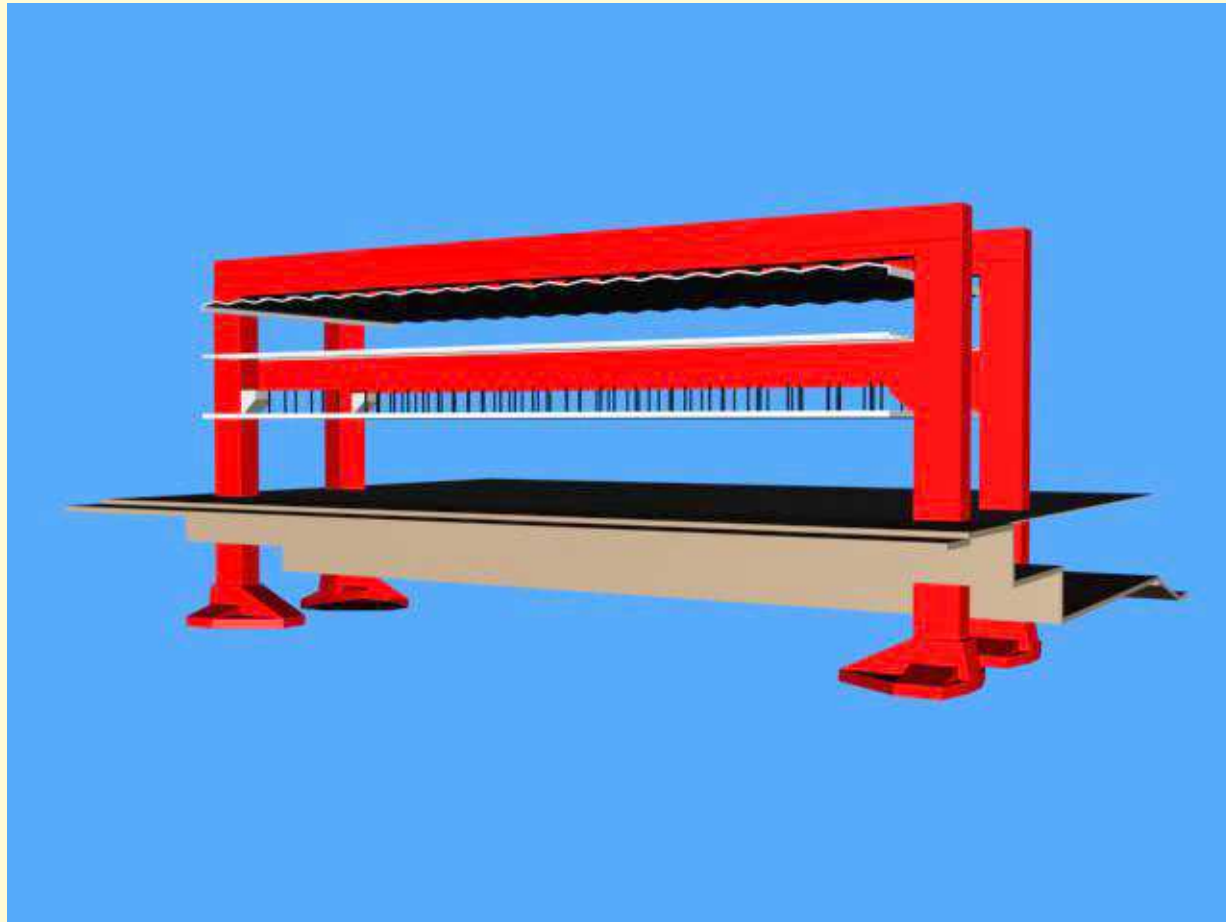
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3D Model



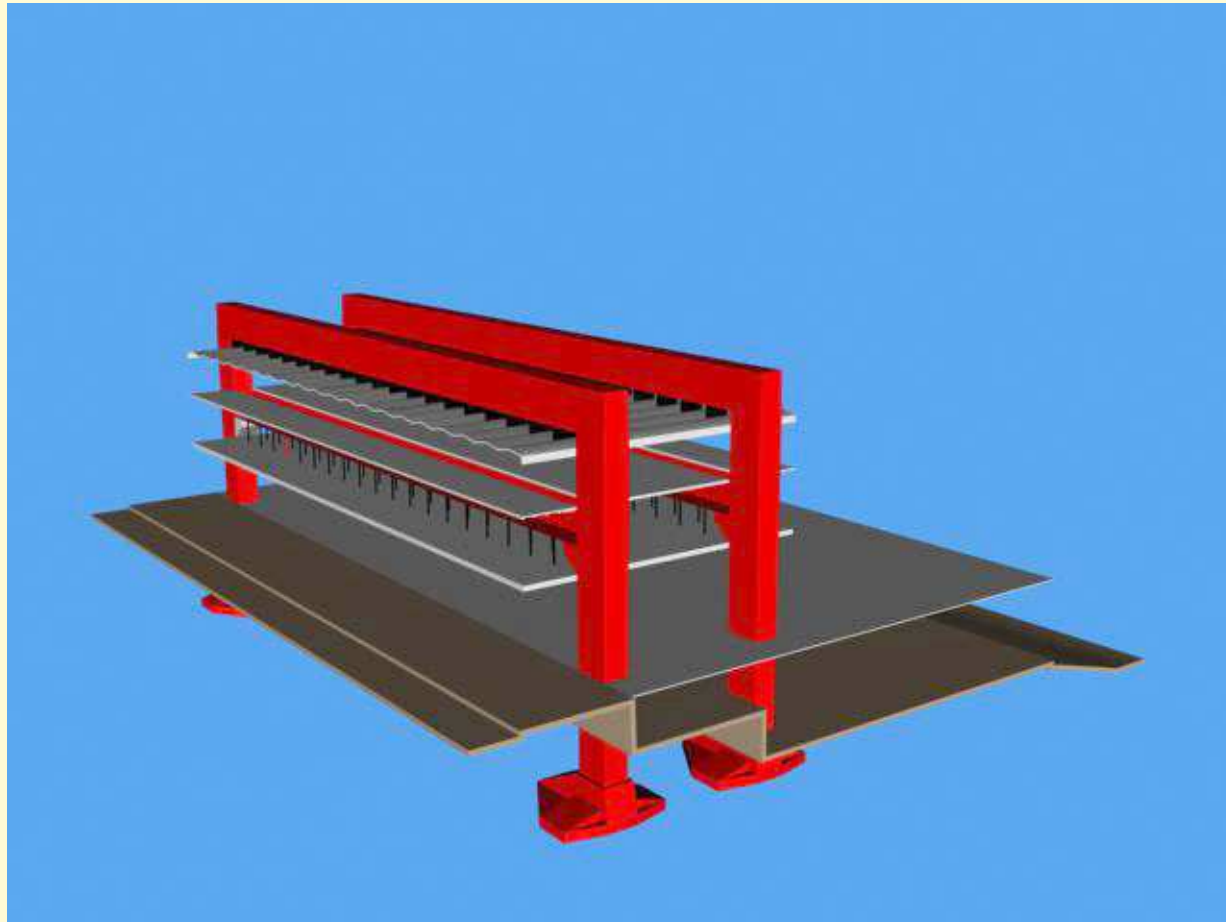
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3D Model



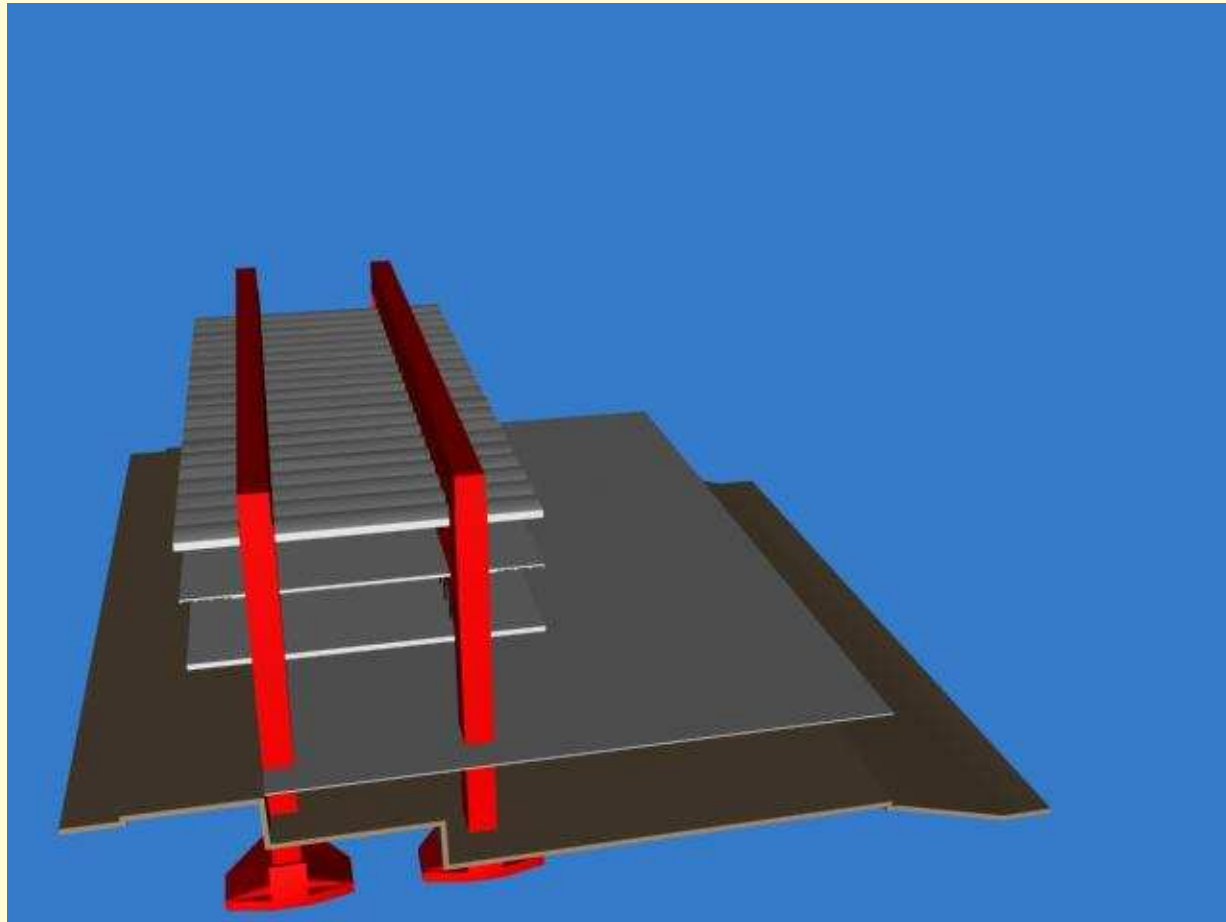
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3D Model



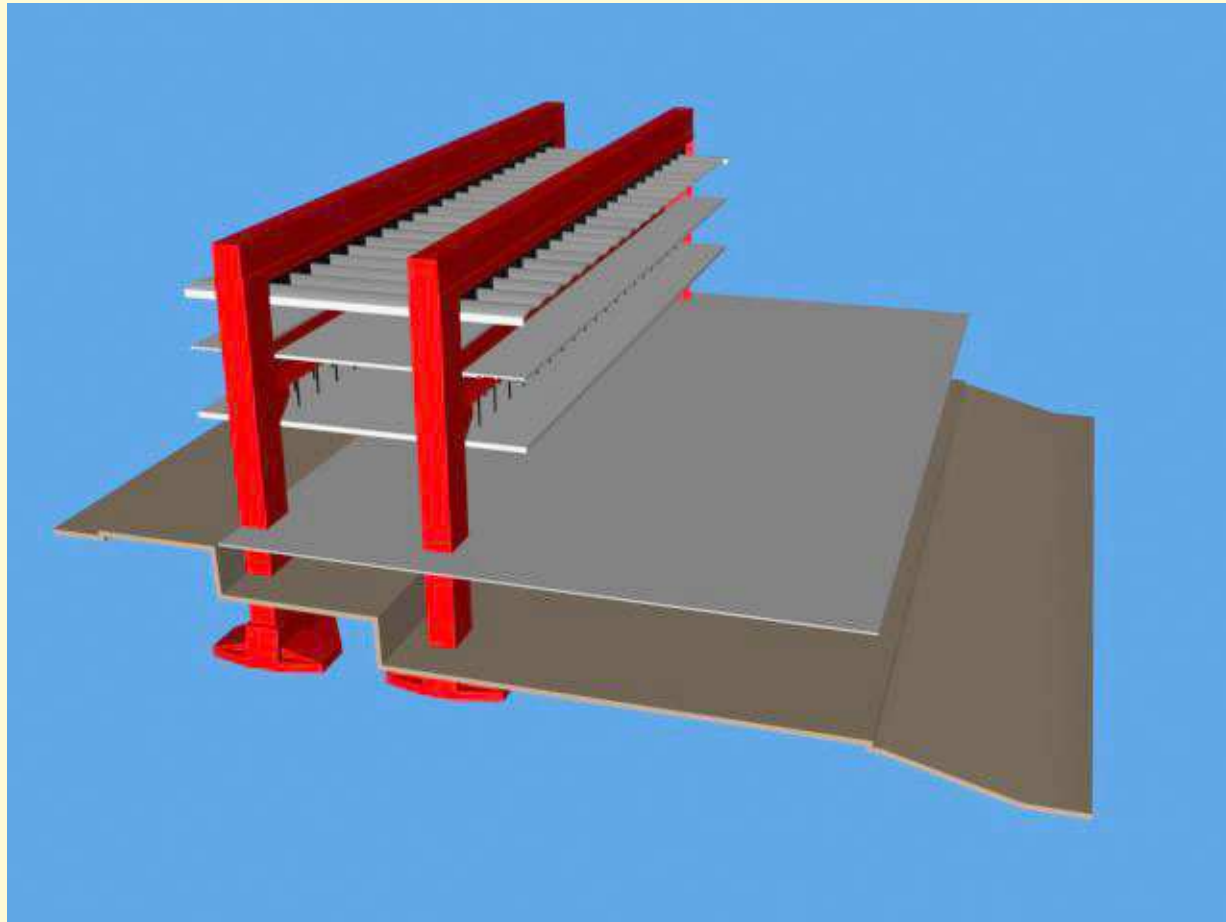
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3D Model



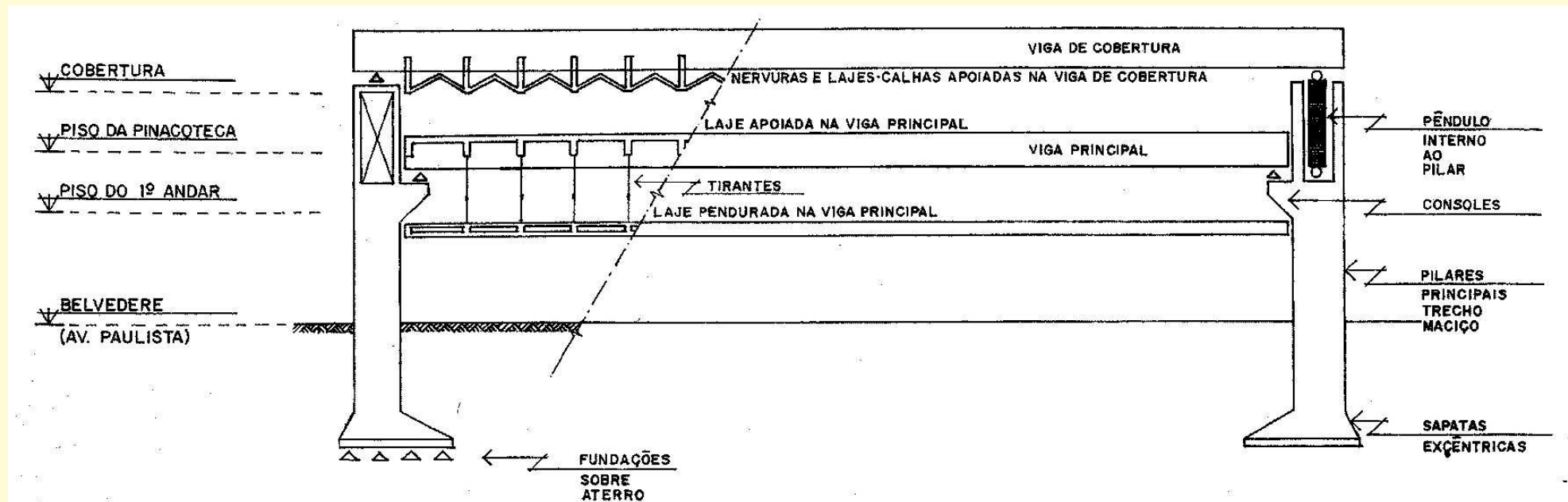
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3D Model



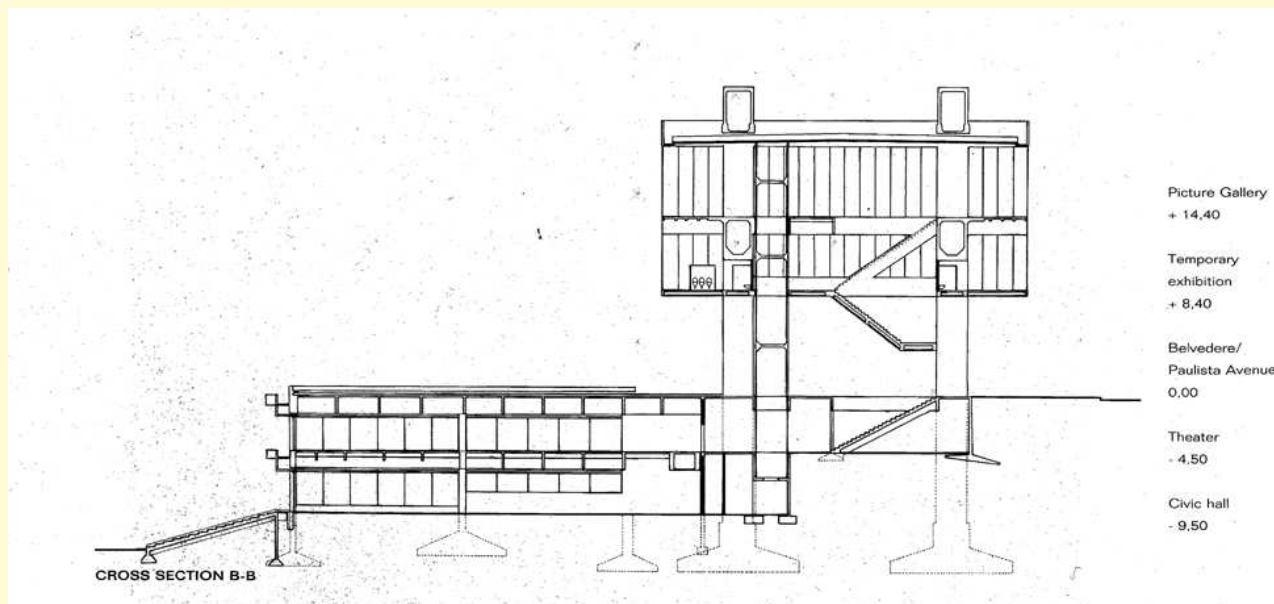
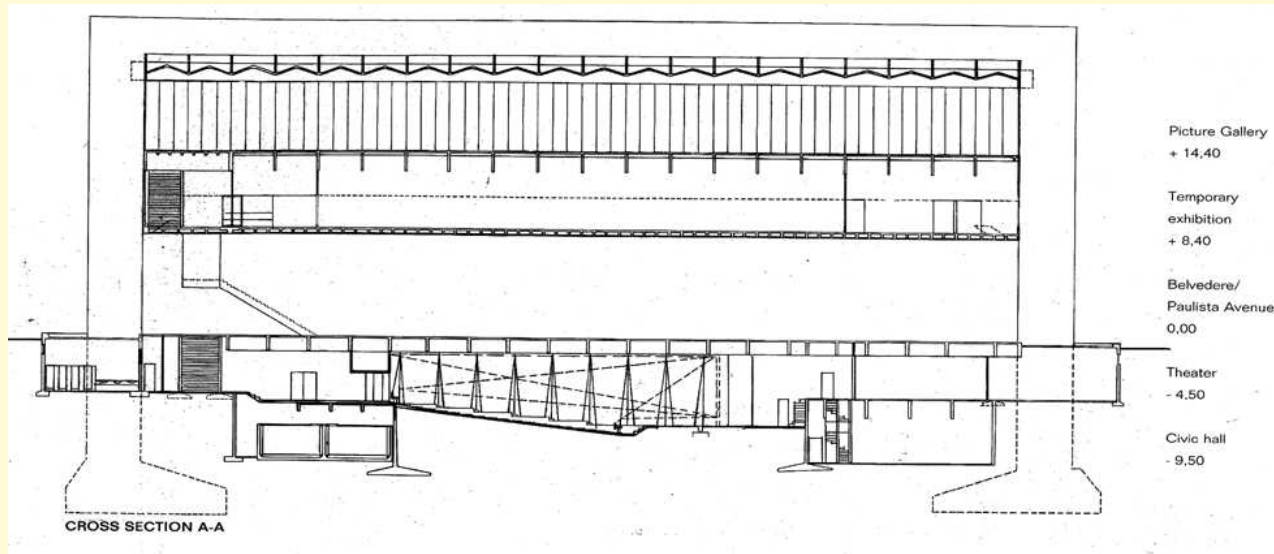
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The Structure



Art Museum in São Paulo, Brazil



The Structure



Art Museum in São Paulo, Brazil

The audacious structural design had construction characteristics similar to bridges. The museum would hang itself from two frames leaving a 75 meter (246 ft) span above the ground level. This design justified the use of post-stressed concrete and column beams.

The rectangular block is located 8.5 meters (27.88 ft) above the ground level. 4 columns and 4 beams compose the structure. Each 2 columns and 2 beams form a frame with articulated beams of 70 meters (229.6 ft) and 3.50 meters (11.48 ft) high.

The Construction



Art Museum in São Paulo, Brazil

At the street level, to keep the Paulista Avenue open, 4 hollow columns with the dimensions of 4 x 2.5 meters (13.12 x 8.2 ft), and with the exposed beams above of 2.50 x 3.50 meters (8.2 x 11.48 ft). At the level of 8.40 meters (27.55 ft) above ground level, a 50 cm (1.64 ft) thick waffle slab is supported through cables by the two middle beams, which are 14.50 meters (47.56 ft) above ground level.

At 14.50 meters (47.56 ft) above ground level, there is another 2100 m² (6888 ft²) grid slab with cantilevered sides of 5 meters (16.4 ft) with a thickness of 30 cm (1 ft). Doubled steel cables support the inferior slab by the exterior side of the beam.

This slab at 14.50 meters (47.56 ft) above ground is heavily loaded and supports the inferior slab. A live load was calculated at 500Kgf/m² related to the exposition material and general public at critical situations.

The Construction



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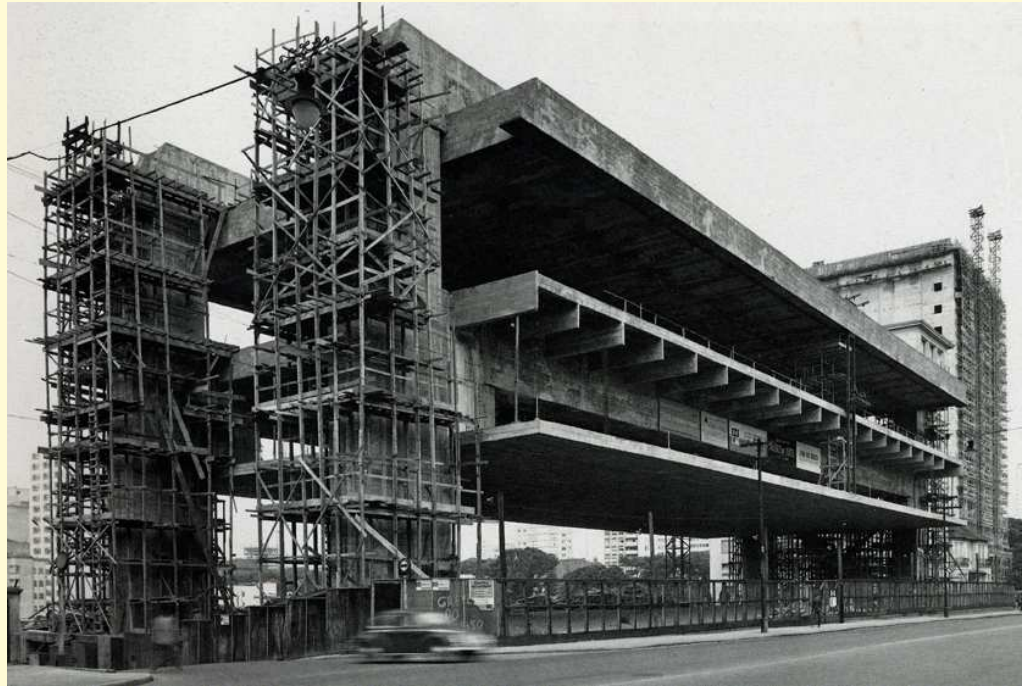
Post-tensioned beams supported by the side columns resulted in smaller horizontal members that can resist the bending moment. During the construction, the chamfered corner in the beam and the column connection were used for tensioning these structural members. At the final moments of the construction, the horizontal and vertical members were connected resulting in a rigid frame and the corner was completed with concrete. The vertical elements were post-tensioned, as well, to resist the bending moment acting on the beams..



The Construction



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The middle beam is hollow, with 25 cm walls (10 in.), and exterior sections of 2.5 x 3.5 meters. At the superior part, there is a compression table of 5.15 x 0.35 meters all along the 70 meter beam. The inferior part was thickened to support a compression of 10,000 tons-force with 122 cables composed with 40 lines at 5 mm (1/8 in.) thickness each. These beams were under a bending moment of 20,000 tons force resulting in a supporting reaction of 1,200 tons force.

The Construction



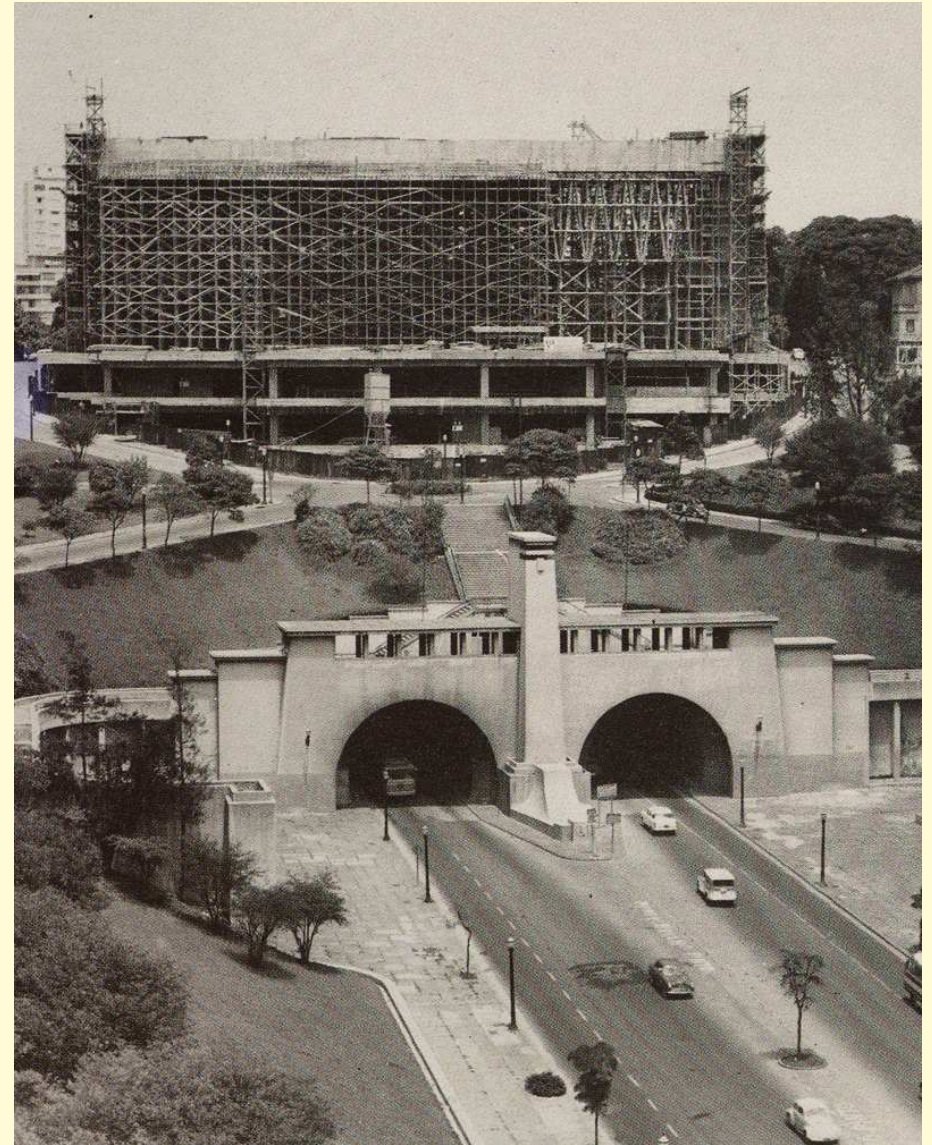
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Part of the foundation was located only 8 meters (26.24 ft) above the highest point of one of the tunnels. Construction plans were analyzed and prototypes were built to study how this structure would affect the tunnels.

maximum column load: 2,250 tons

foundations surface area: 10 x 12.5 m

concrete volume at the lower foundation: 1000 cm³



The Foundation



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A double-surface tube surrounds the cables. Hydraulic jacks with capacities of 120 tons were used to stress the cables, and then a cement glue was poured inside the metallic tube resulting in the cable-tube adherence. Care was taken to minimize the friction between the steel and the tubing. The steel used was CA-50, and the concrete quality was controlled by an on-site lab.

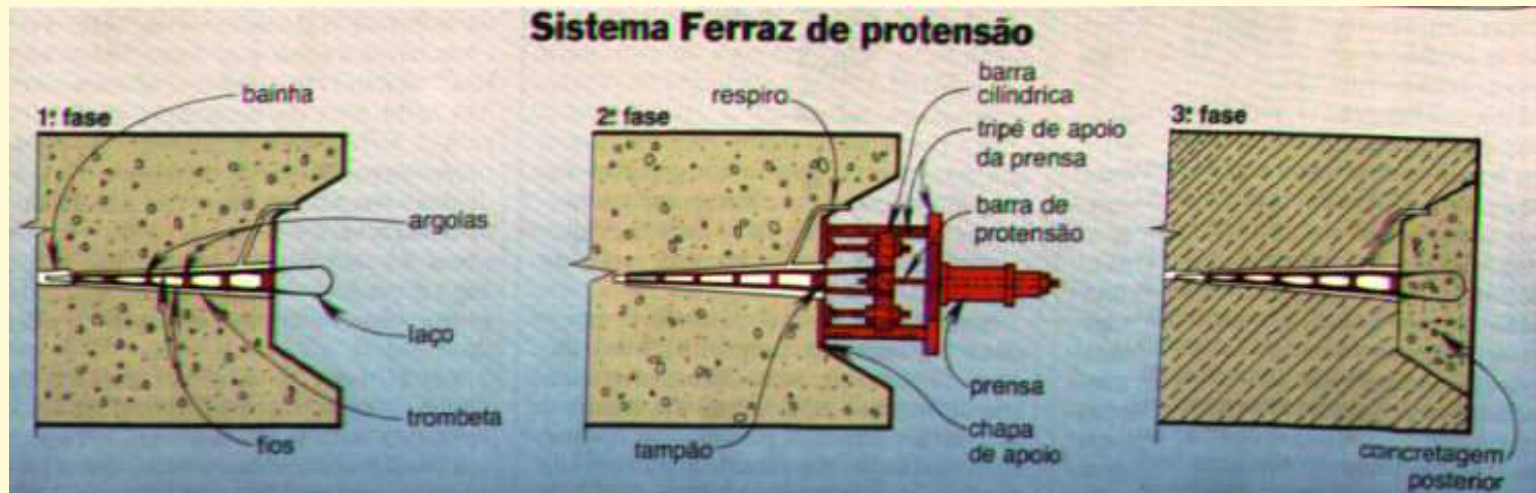


The structural engineering professor, José Carlos de Figueiredo Ferraz, used lines with a 5 mm thickness to compose the steel cables.

Post-Tensioning



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The beams' weight reaction over the support system can reach 1,000 tons (a value big enough to create friction problems while tensioning). This friction could transmit a horizontal force to the vertical elements, which were not designed to receive such load direction.

The engineers came up with a creative solution: a neoprene piece was located between the beam and the column over a metallic base. Through a whole left on purpose at the beam, oil was poured manually alleviating the friction at the horizontal and vertical elements. Without this caution, the post-tensioning could have caused the columns to collapse.

Post-Tensioning



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The minimum of 28 days compressive strength should be 3 times larger than normal concrete;
The maximum size of the concrete aggregates should be no more than 19 mm;
Mild increase in the concrete's temperature during the hydration process;
Small shrinkage;
Texture compatible to exposed concrete;
Industrial scale concrete with an affordable price.

Average rupture tension strength by 28 days: 56.3 Mpa
Average rupture tension strength by 7 days: 45.6 Mpa
Coefficient of Variation: 10.9%

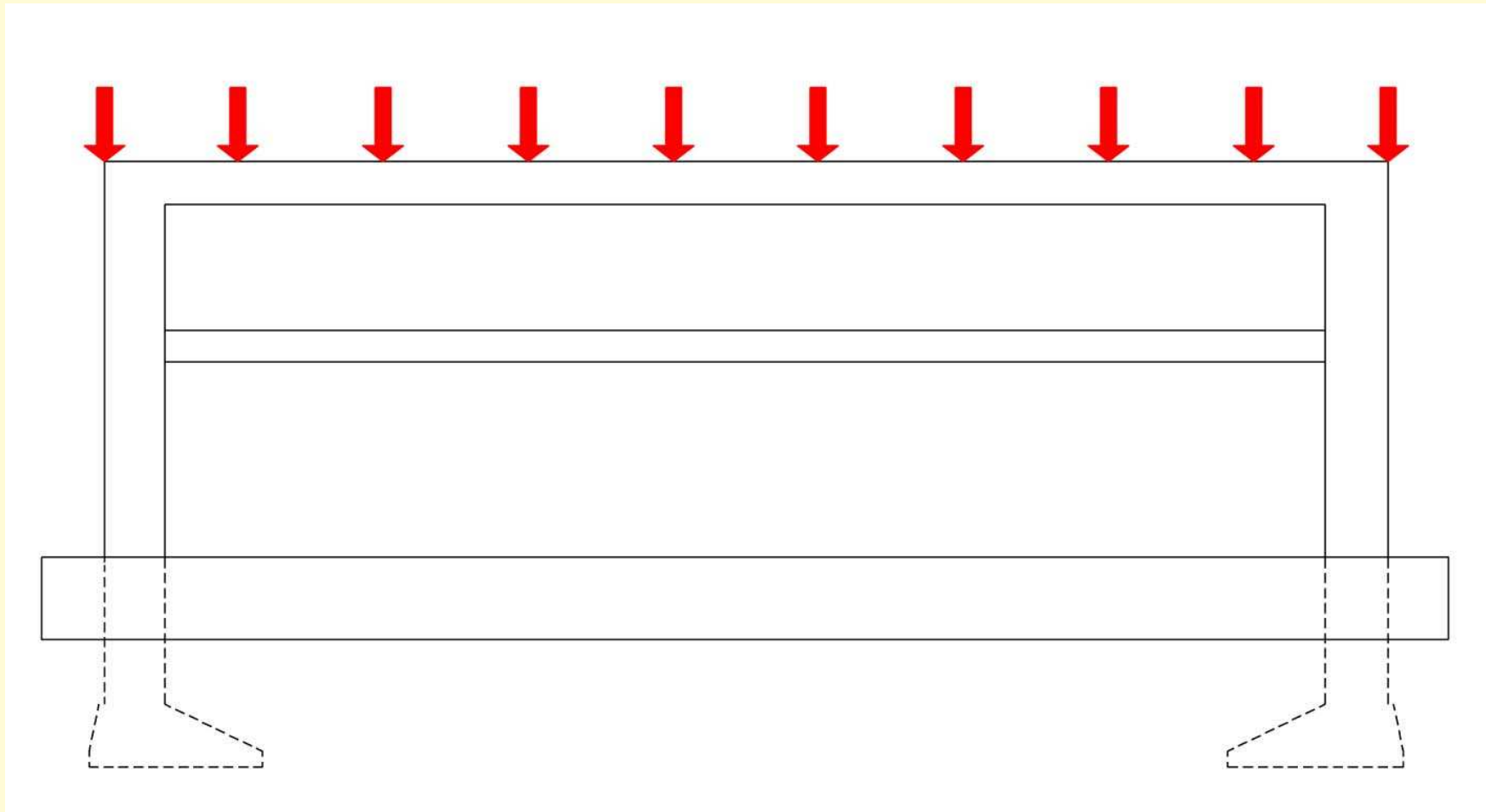
Amount of concrete used: 9,000 m³
Average weight of concrete used: 2,500 Kg/ m³

Concrete Characteristics



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Distributed load – weight of top beam

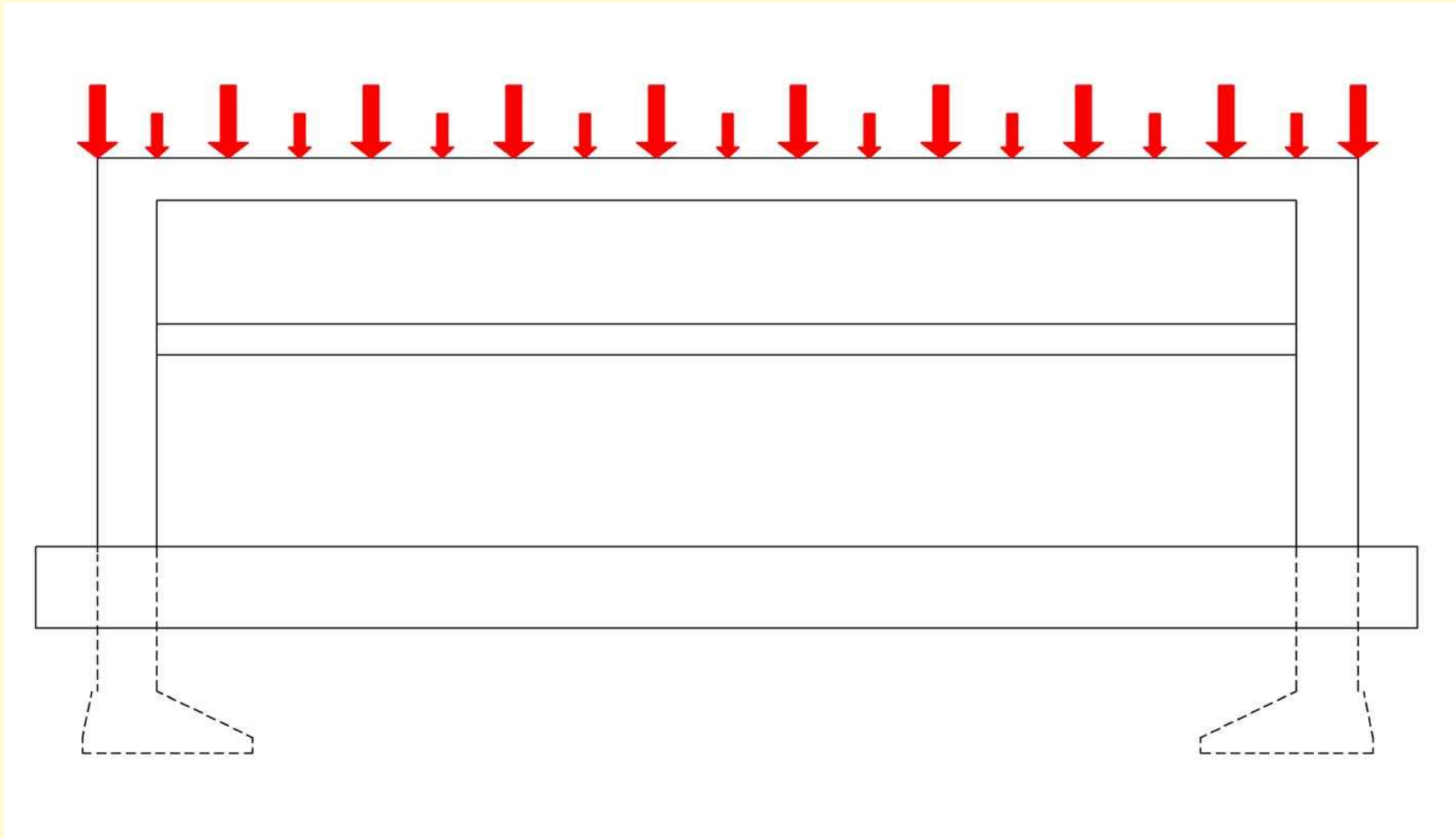


Load Diagrams



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Distributed load – weight of roof added

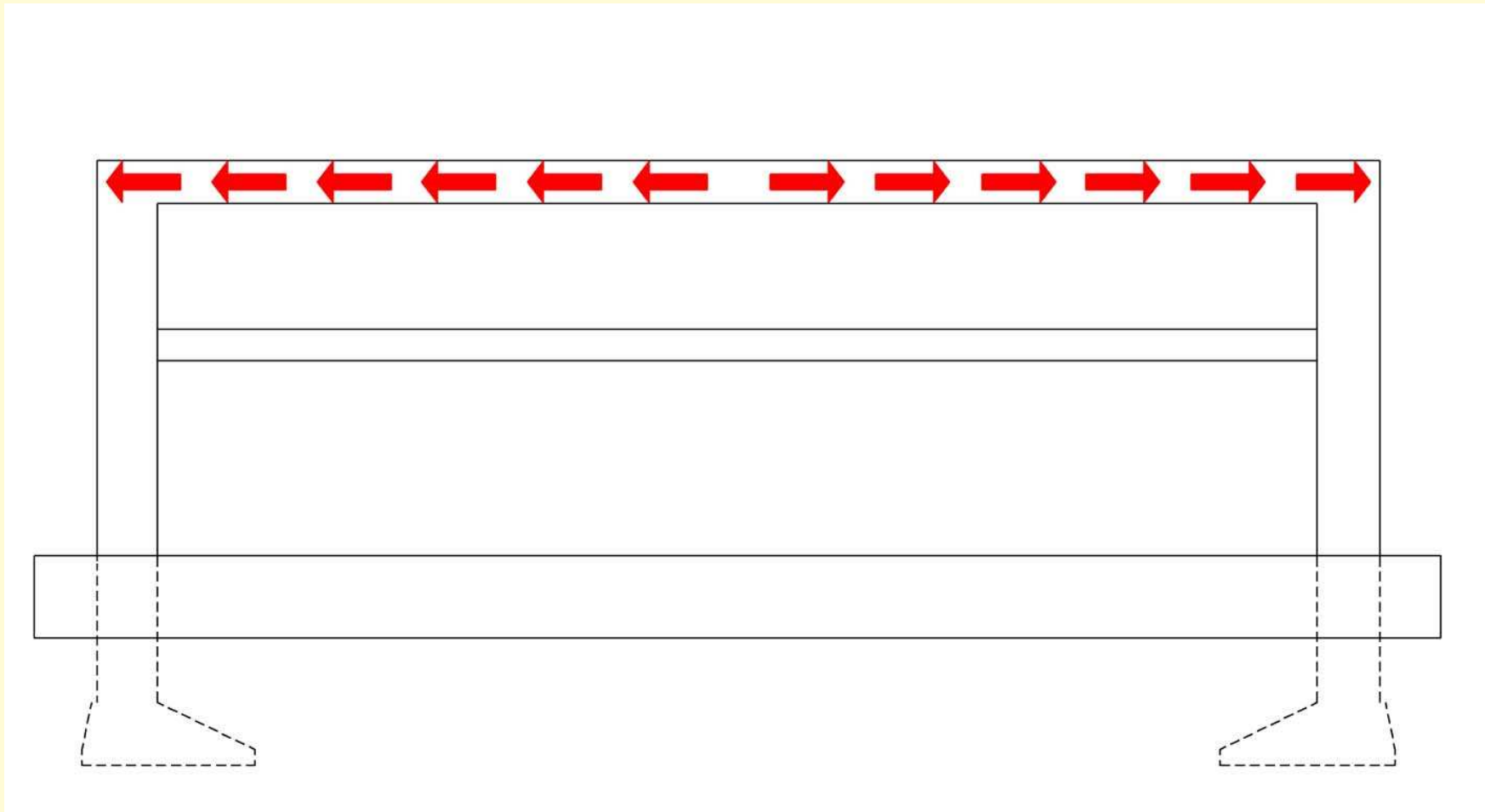


Load Diagrams



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Load transferred to columns

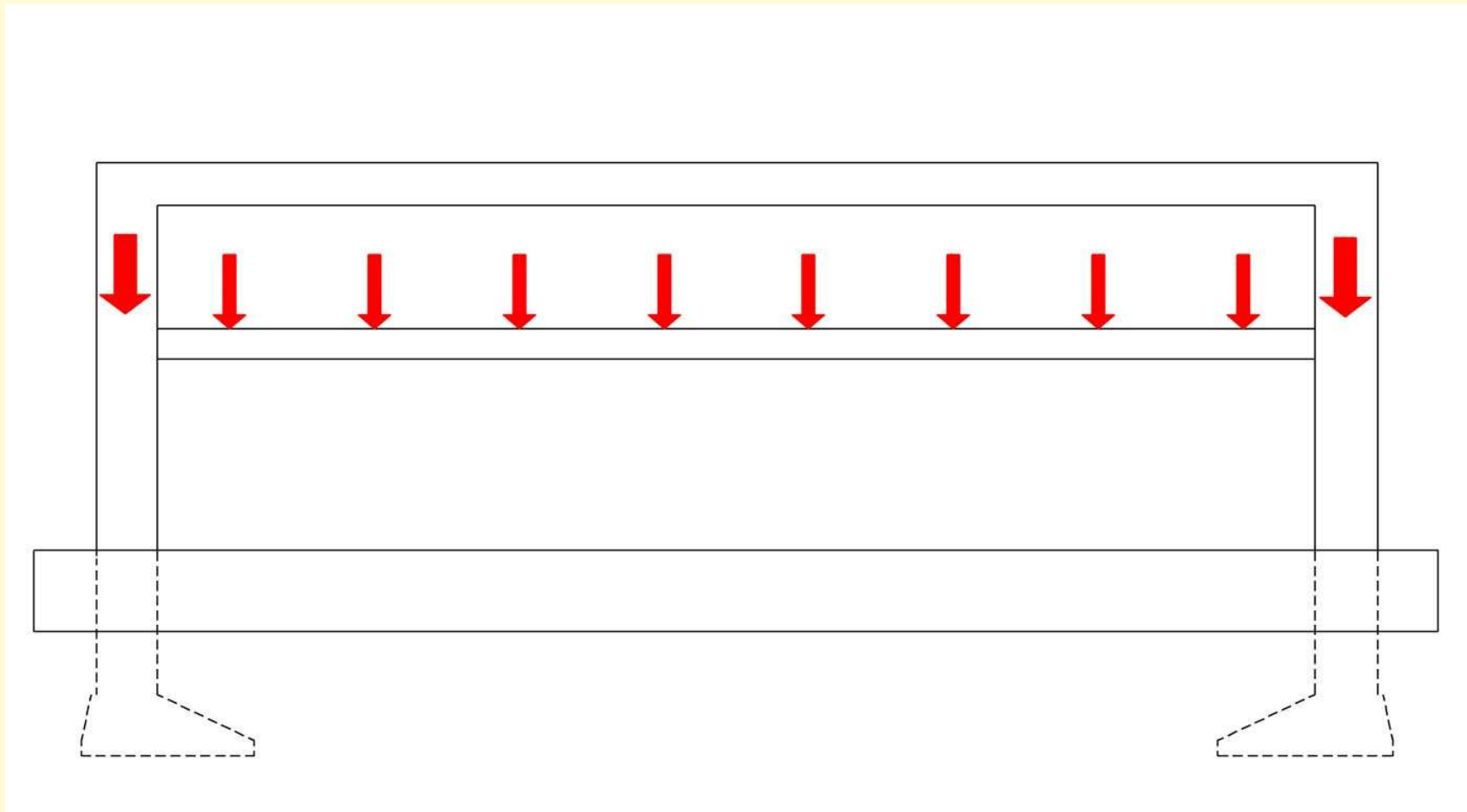


Load Diagrams



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Weight of central beam, plus floors above & below

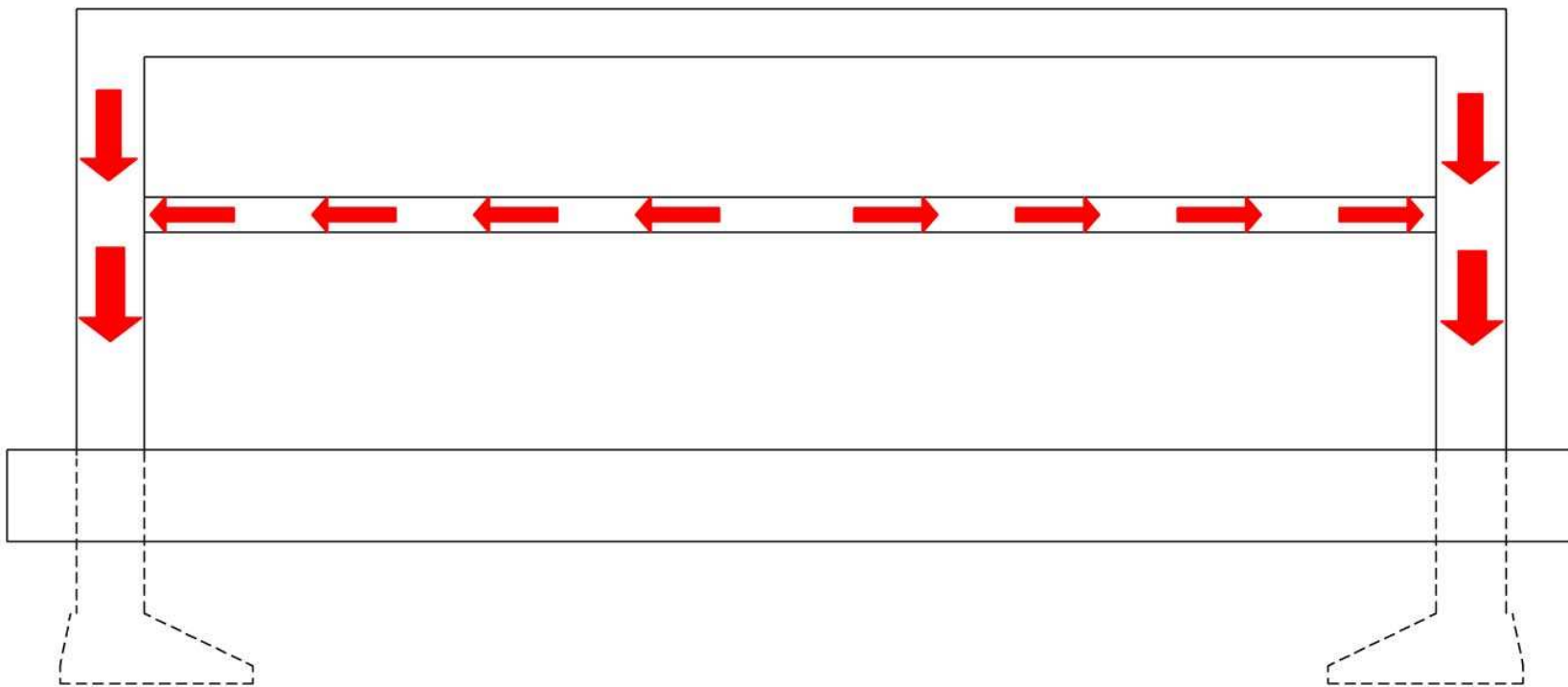


Load Diagrams



Art Museum in São Paulo, Brazil

Central beam weight transferred to columns

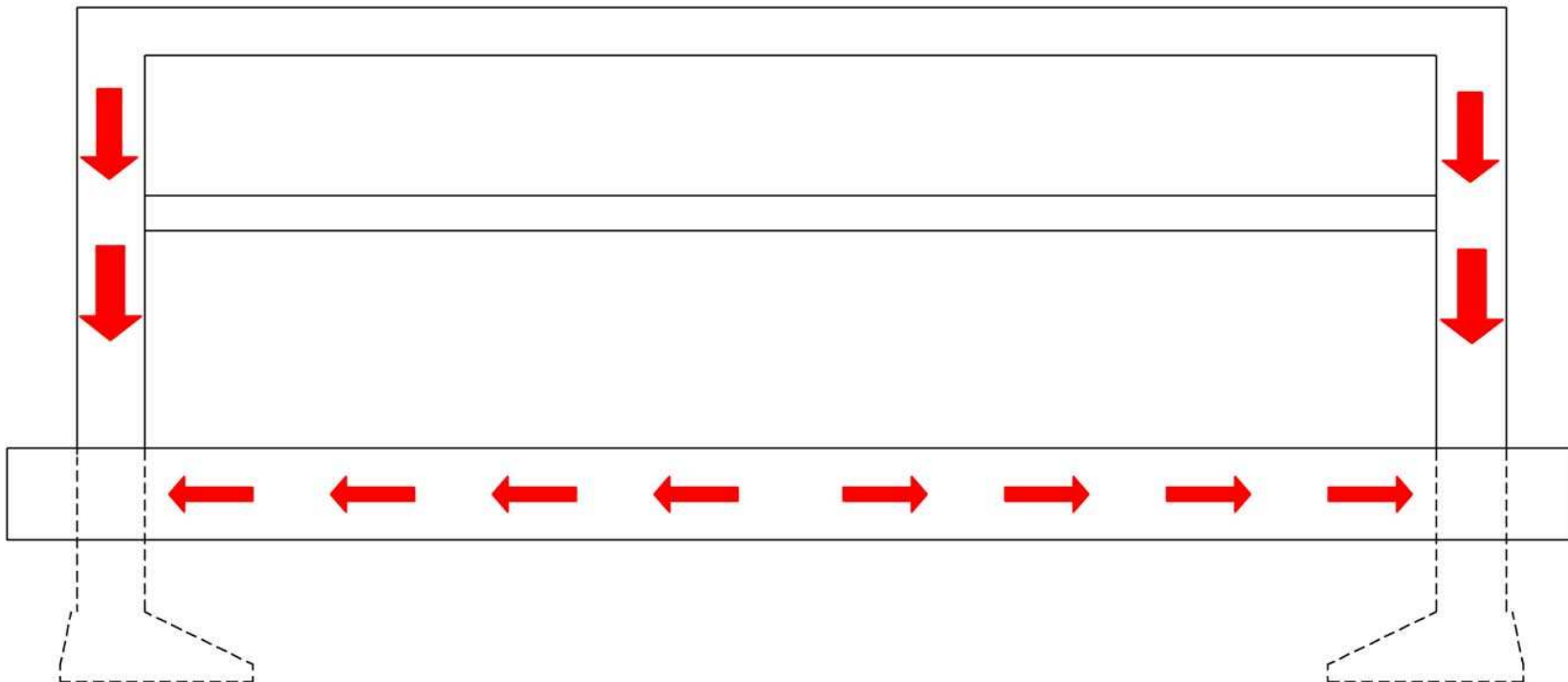


Load Diagrams



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Weight of ground floor added

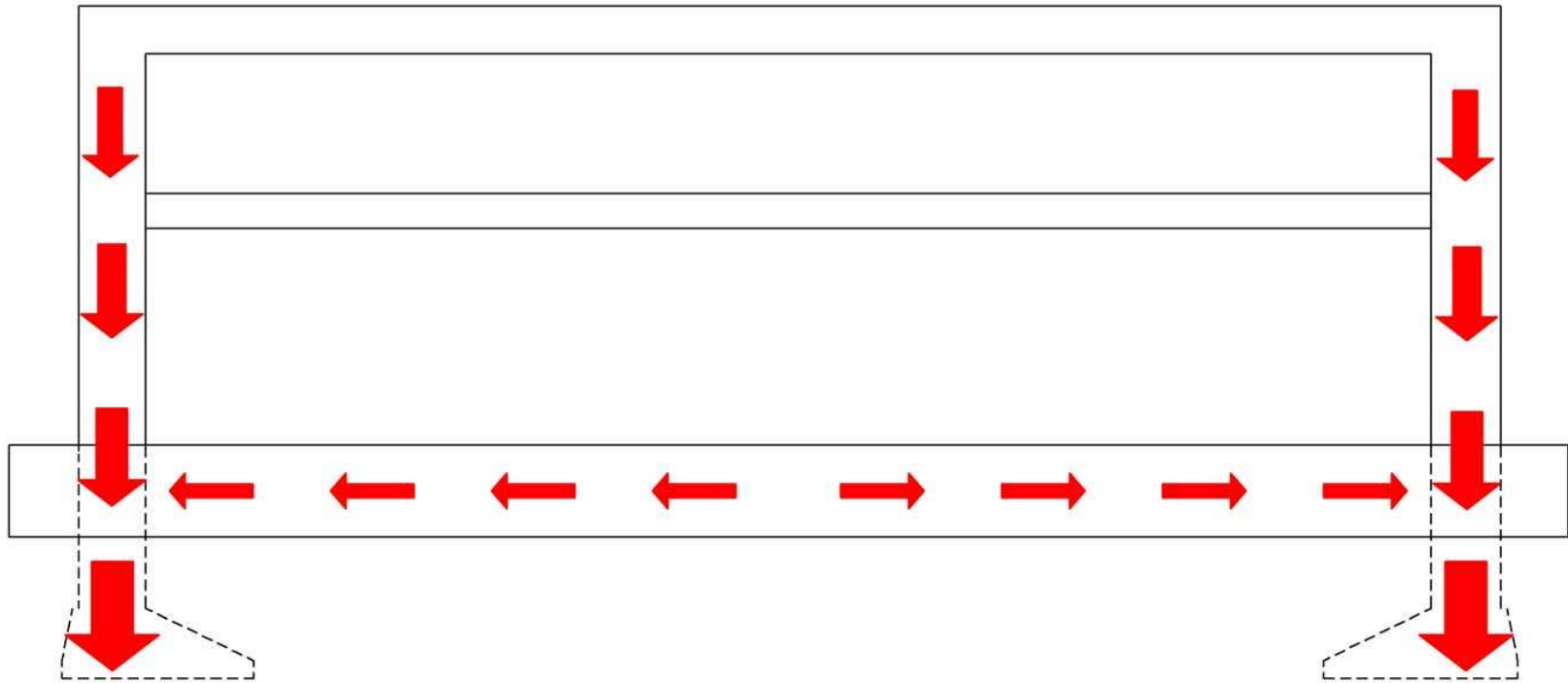


Load Diagrams



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Floor one weight transferred to columns

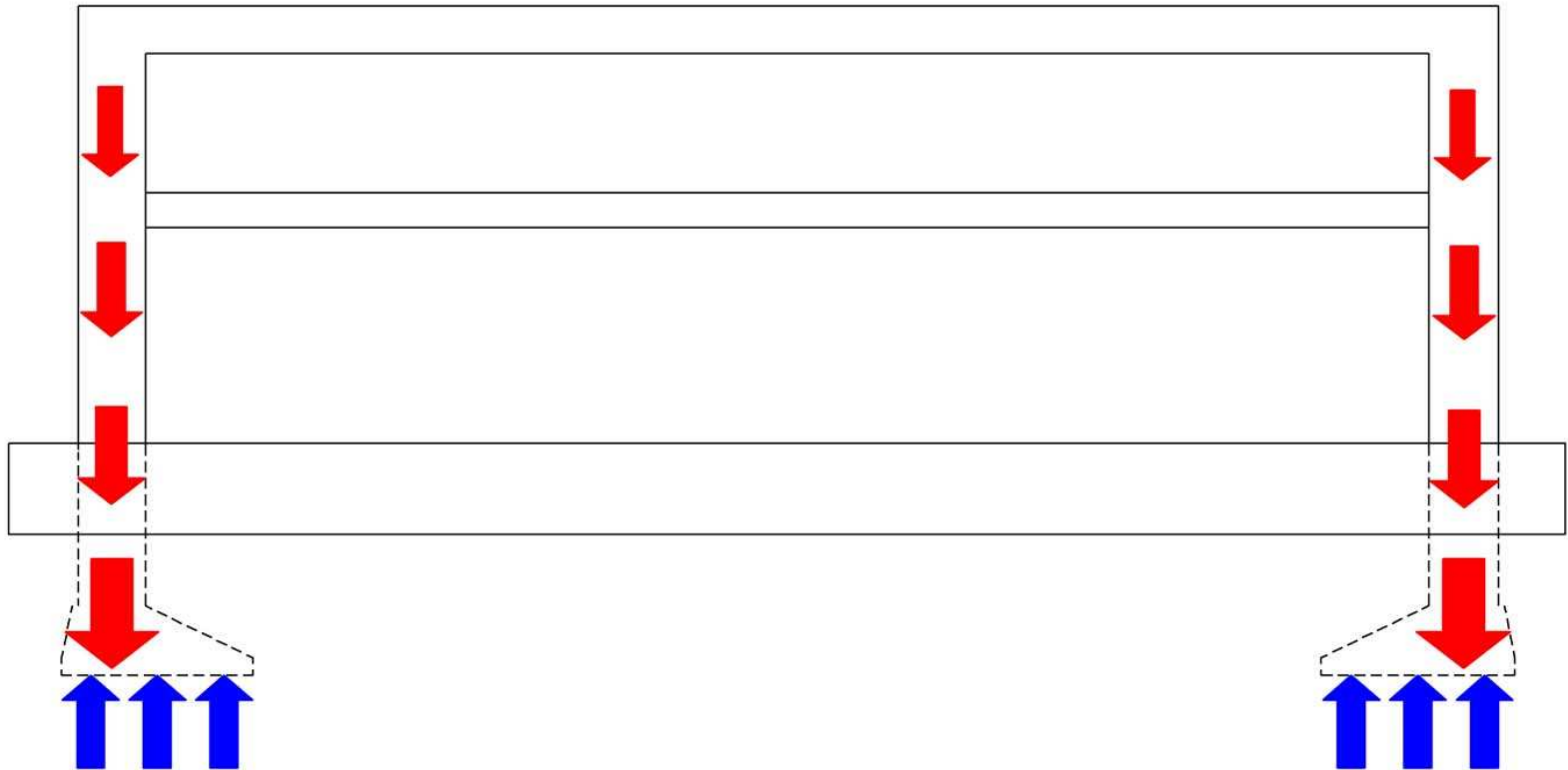


Load Diagrams



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Weight of columns, plus loads transferred to columns, transferred to footings, resisted by ground beneath



Load Diagrams



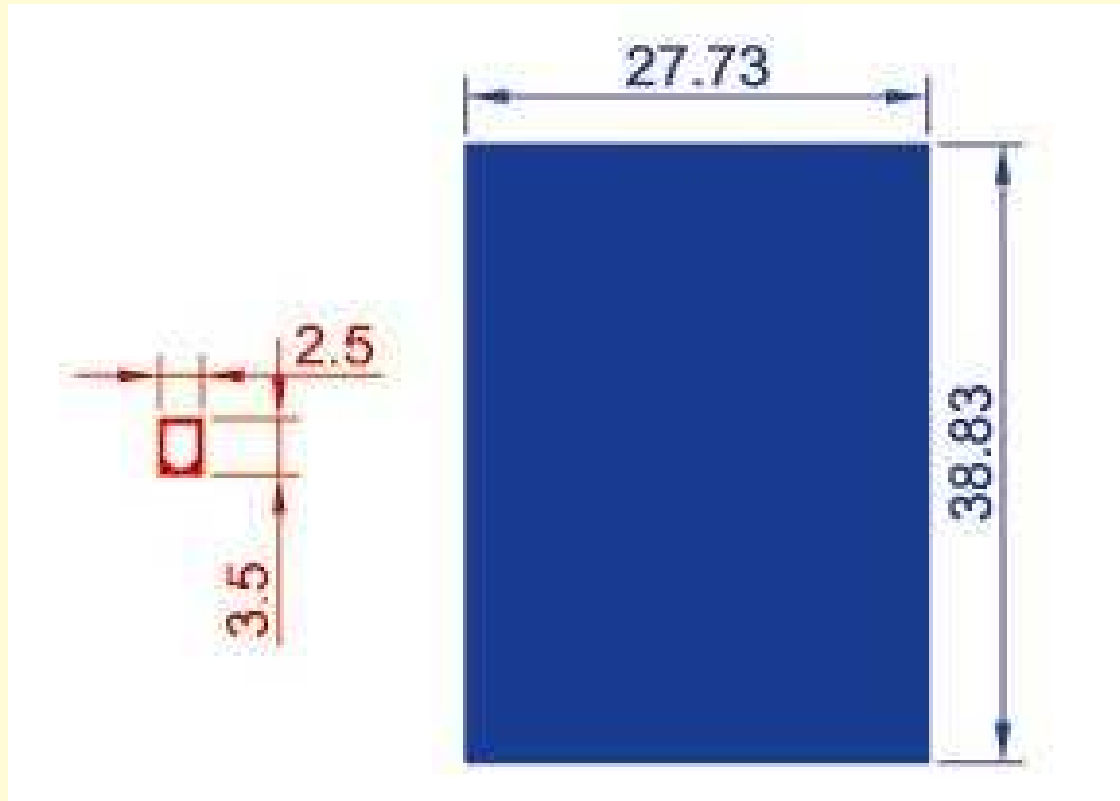
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- Estimated live load:
143.64 kN/m
- Estimated dead load (not including weight of beam):
150,202 kN/m
- Ratio of Height to Base of existing beam:
1.4:1
- Beam length:
71.5m

Beam Comparison



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This comparison shows the advantages of not only reinforced concrete but also post-tensioned concrete as well. This project would not have been possible without the use of post-tensioning. It is obvious that the size of the solid section makes it a ridiculous impossibility.

- Original beam:
Hollow section, post-tensioned

- New beam:
Solid Section, no steel reinforcing, and no tensioning
Calculated using 2000psi (13789.44 KN/m²) concrete

Beam Comparison



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- Charta. Lina Bo Bardi. Institute of Lina Bo and Pietro M. Bardi: Milan, Italy. Pgs. 9-12, 100-115; 1994.
- Figueiredo Ferraz e o MASP
Web Address:
http://www.figueiredoferraz.com.br/masp_t_p.htm
- Instituto Lina Bo Bardi
Web Address:
<http://www.institutobardi.com.br>
- Sásquia Hizuro Obota: Structures Professor at Fundação Armando Álvares Penteado in São Paulo, Brazil



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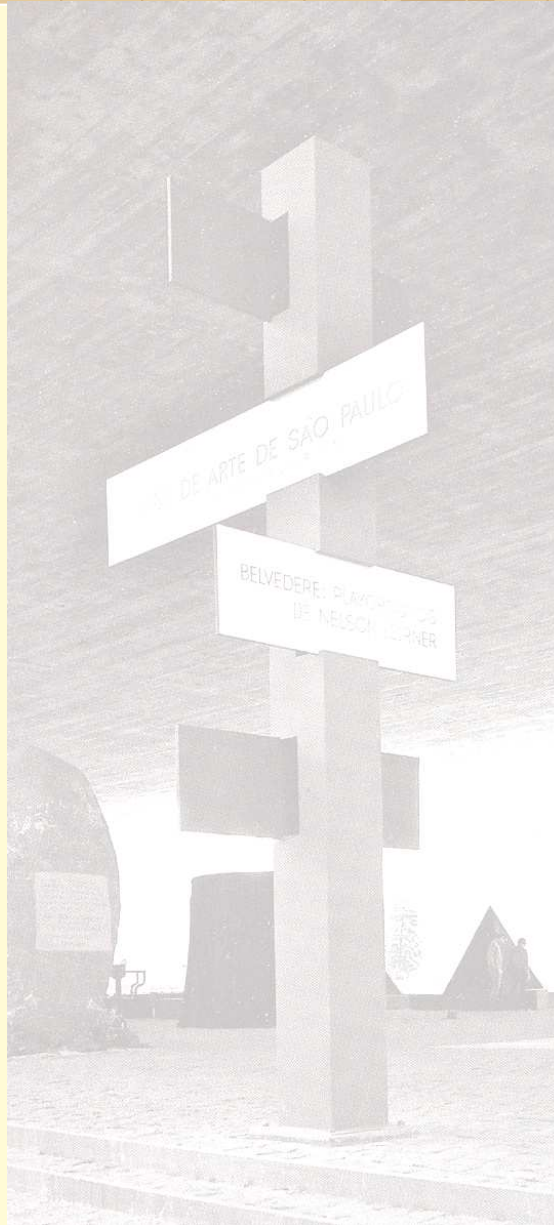
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