

Yoyogi National Gymnasium



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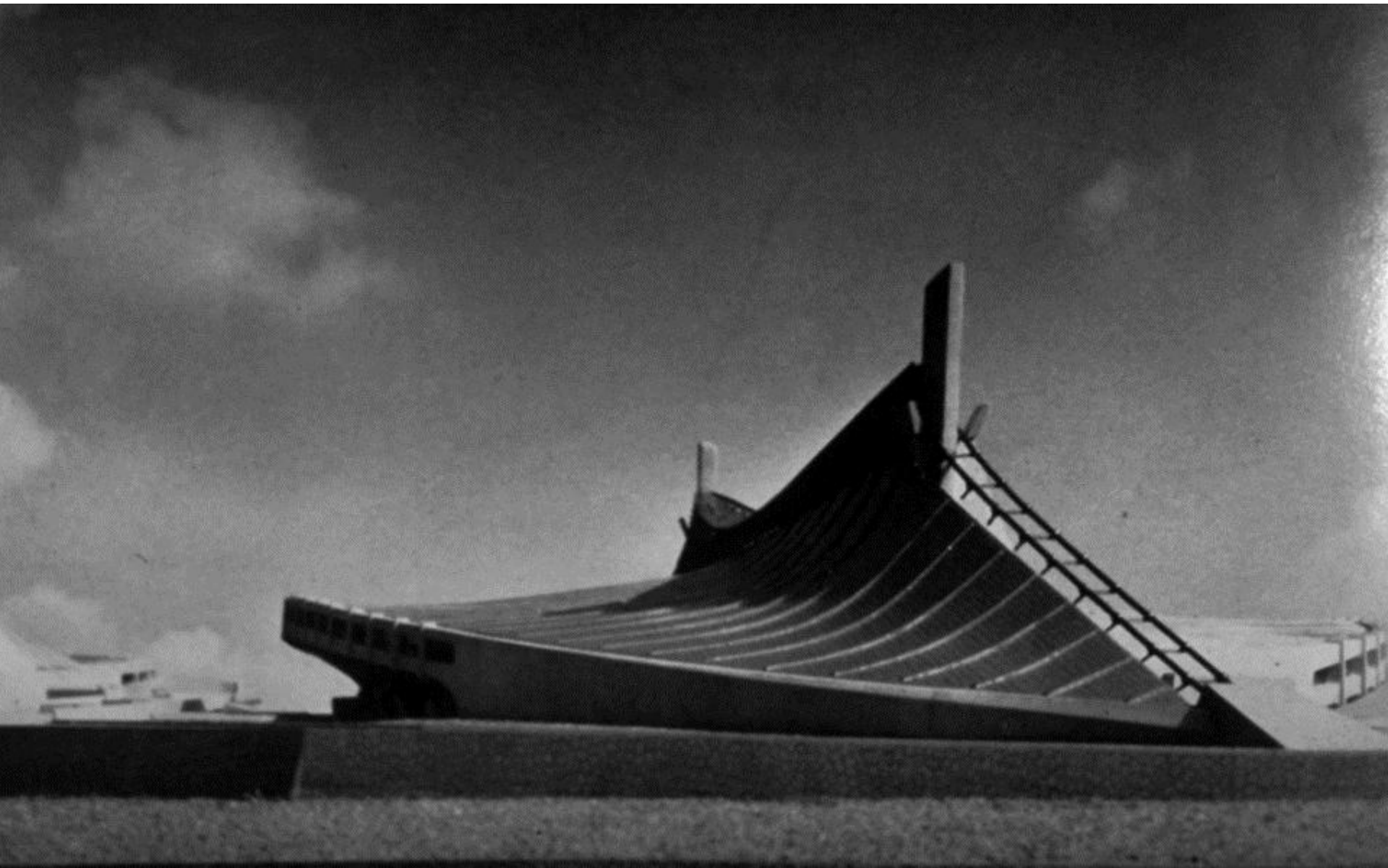
Kenzo Tange

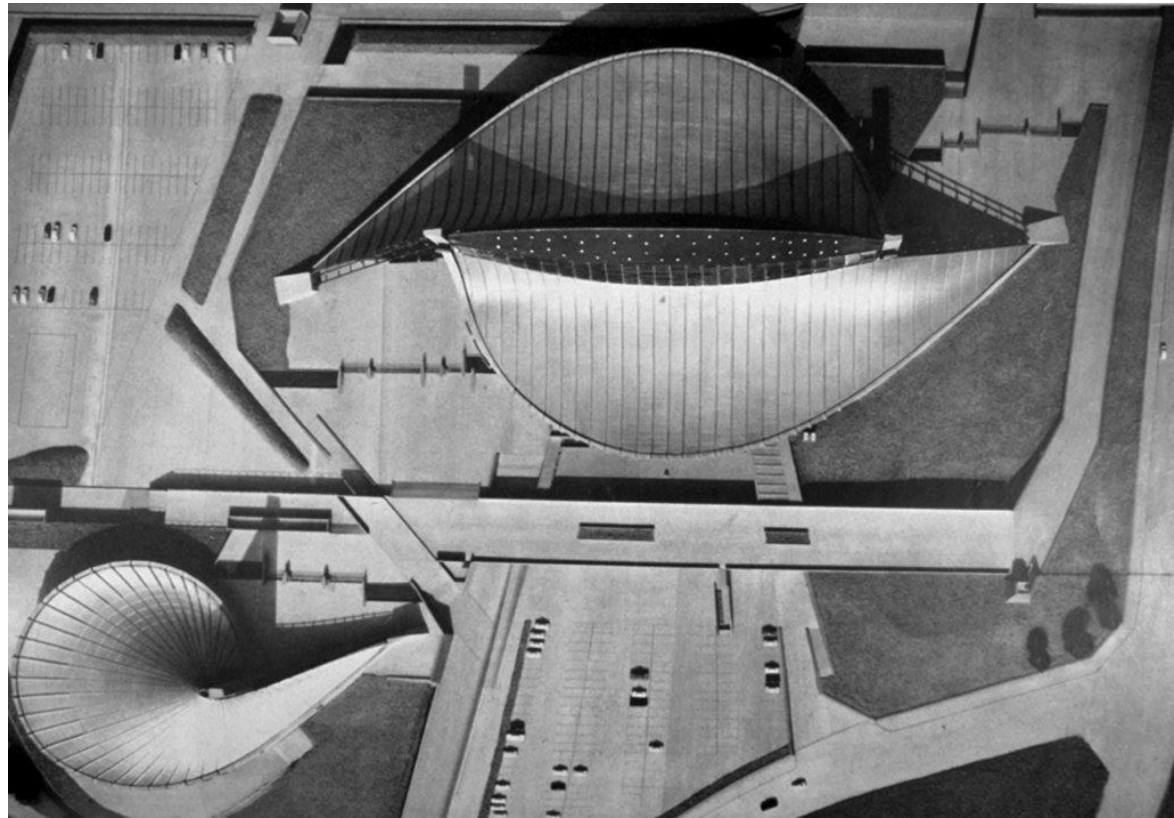
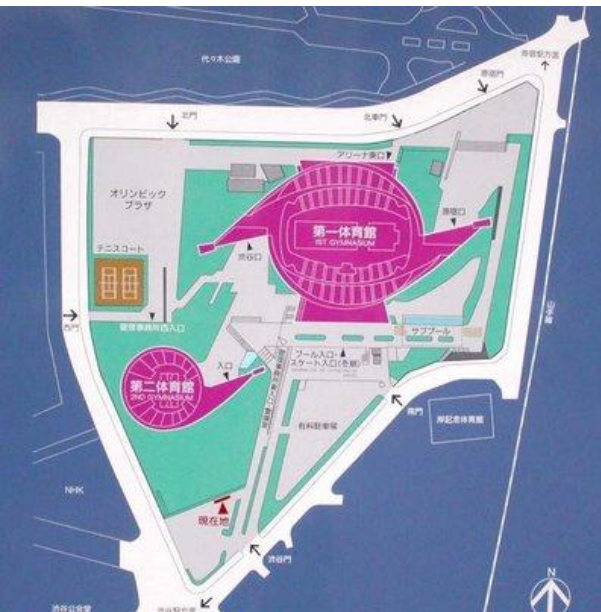
- **Kenzo Tange** (丹下 健三 *Tange Kenzō*², September 4, 1913 – March 22, 2005)
- 1987 Pritzker Prize for architecture
- Significant 20th century architect
- Member to Team X
- Leader in modernism, structuralism and metabolism movements



- site





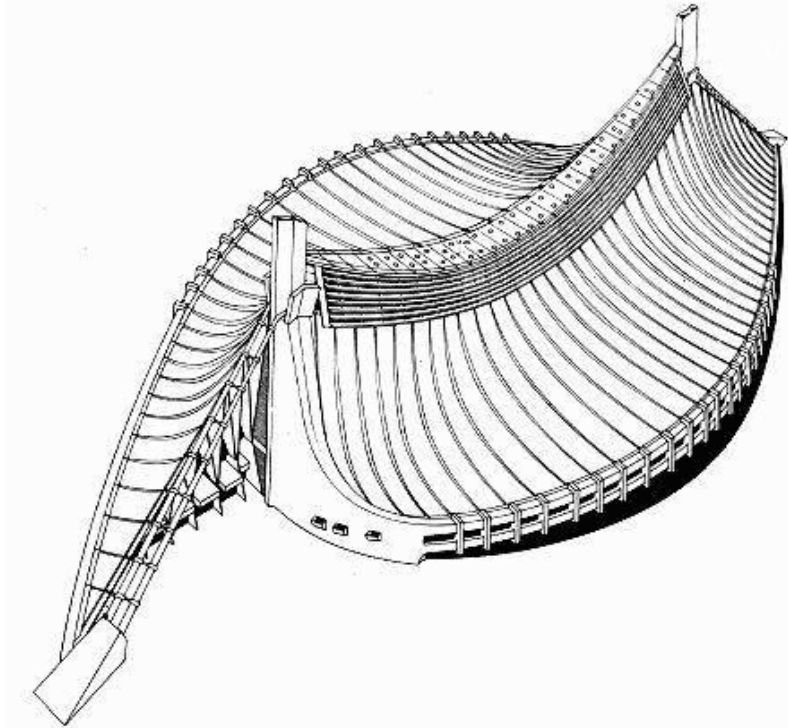


- Built 1964
- capacity 10,000 people
- Icon for Metabolism movement
- World's largest suspended roof for almost 50 years
- 2 swimming pools and 1 Basketball court

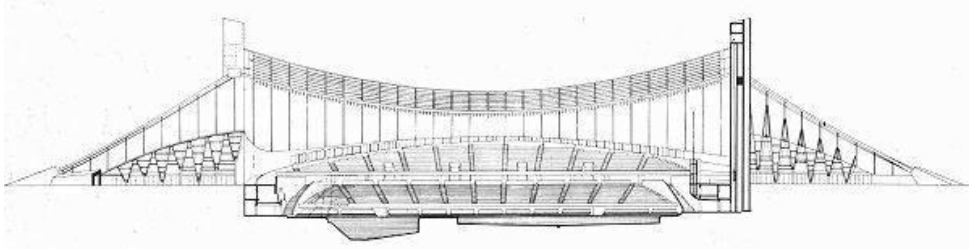


Description of the structural system

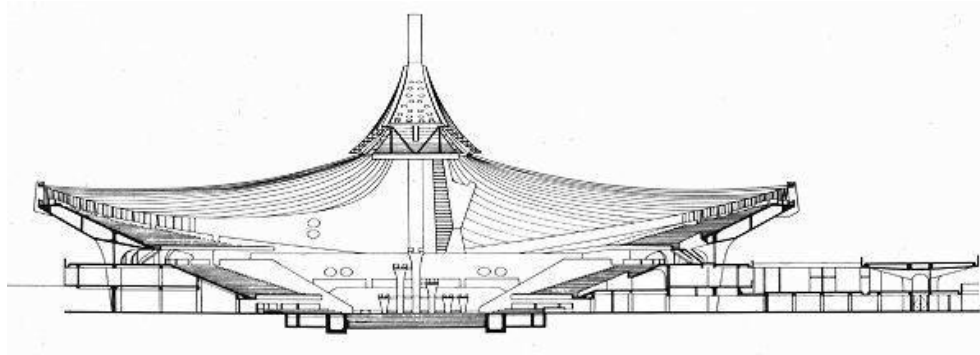
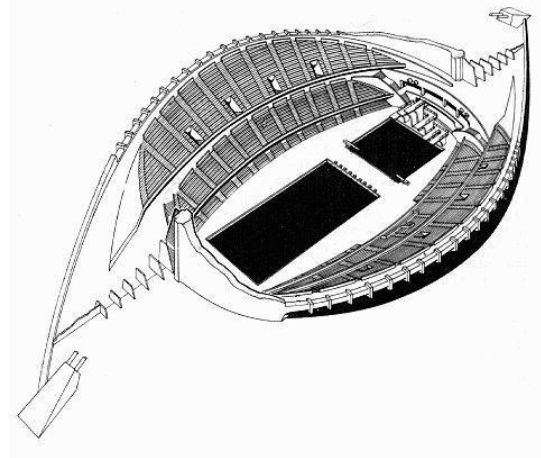
- A central structural spine from where the structure and roof originates is employed.
- Two large steel cables [13" in diameter] are supported between two structural towers in addition to being anchored into concrete supports on the ground.
- The suspended cables form a tensile tent-like roofing structure; a series of pre-stressed cables are suspended off of the two main cables that drape toward the concrete structure that creates the base of the gymnasium as well as providing the necessary structure for the seating within the stadium.



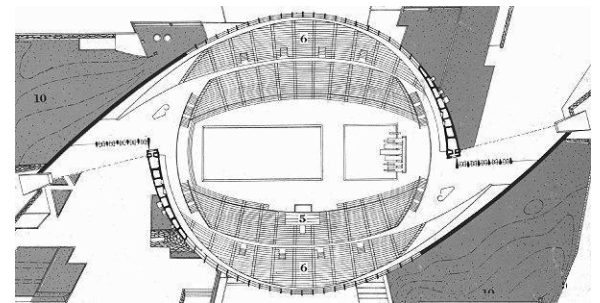
The reason we are interested in this building is that it was the largest suspended roof span in the world. It's dynamically suspended roof and rough materials form one of the most iconic building profiles in the world.



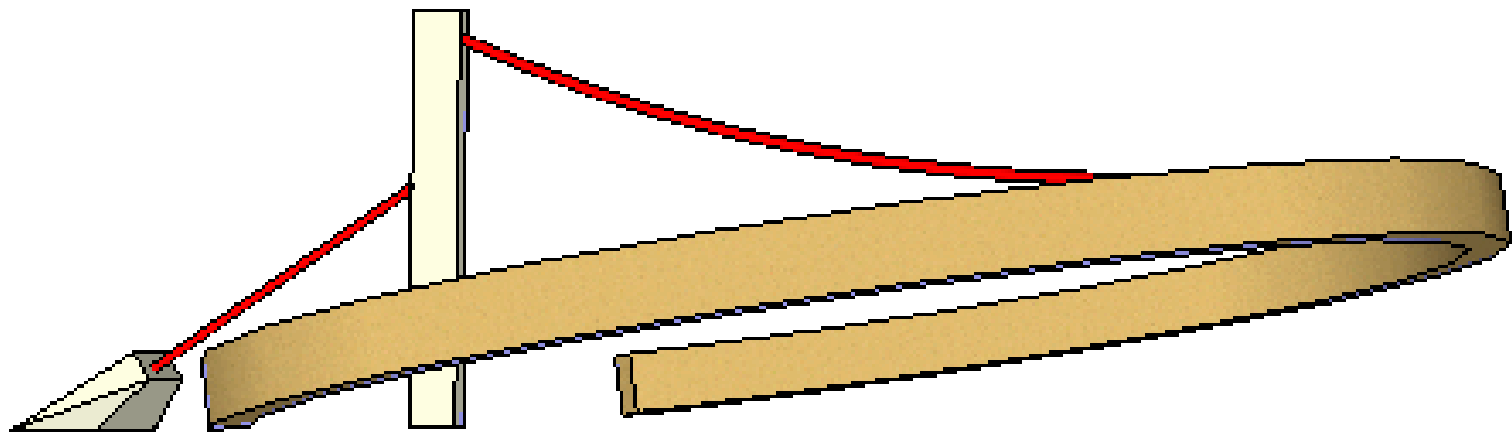
Section



Section

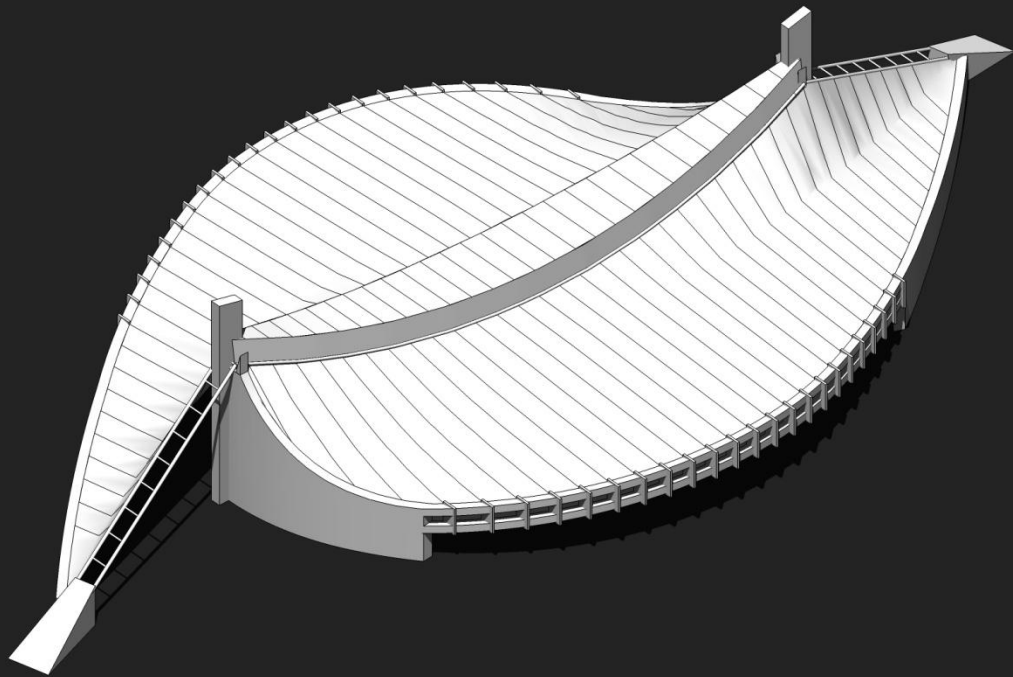


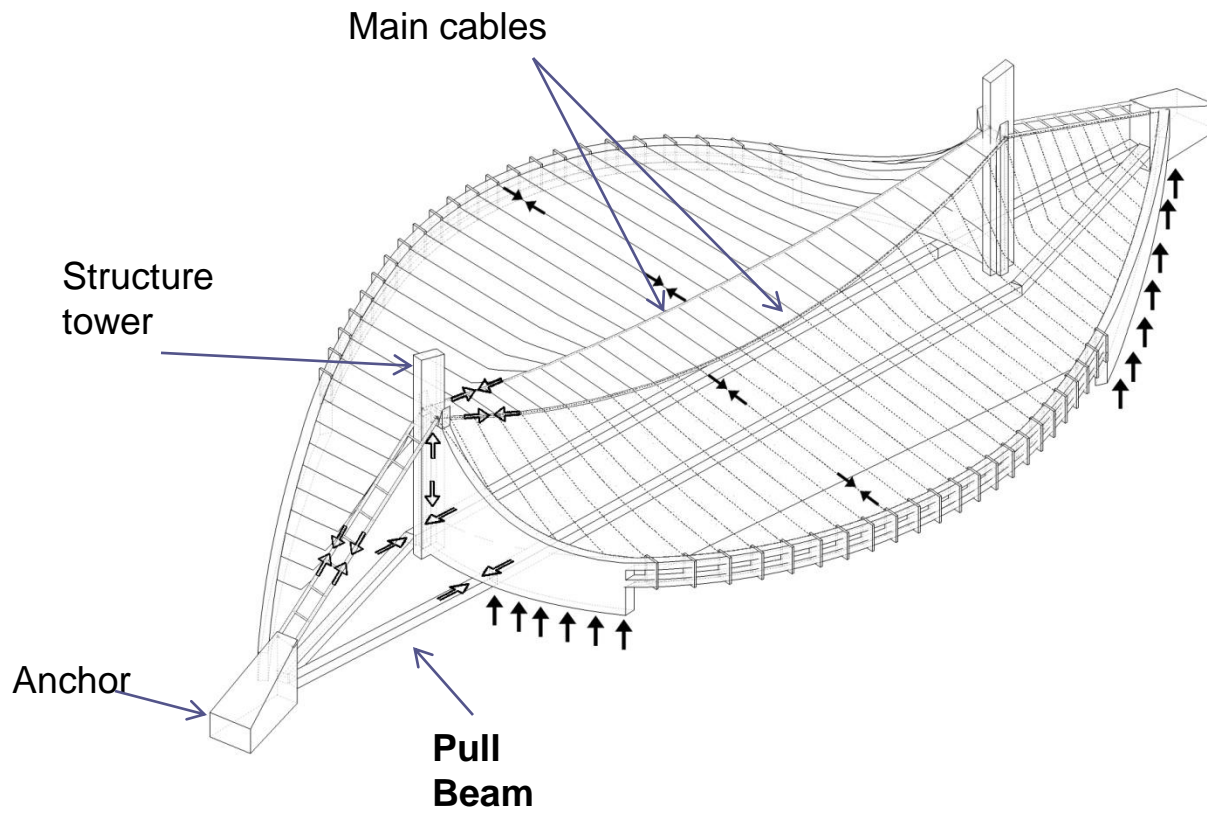
Plan



Connections







Roof Load

$$150 \text{ lb/ft}^2 \times (3.28 \text{ ft/m})^2 \times \text{kN}/224.81 \text{ lb} \times 0.875 \text{ m} \times 8.77 \text{ m} = 180.6 \text{ kN/m}$$

Snow Load

$$0.55 \text{ kN/m} \times 8.77 \text{ m} = 4.8235 \text{ kN/m}$$

Wind Load

$$0.6 \text{ kN/m} \times 8.77 = 5.262 \text{ kN/m}$$

LRFD

$$1.2DL + 1.6S + 0.8W$$

$$1.2(180 \text{ kN/m}) + 1.6(5.262 \text{ kN/m}) + 0.8(4.8235 \text{ kN/m}) = 408.278 \text{ kN/m}$$

H-20

Weights Of Building Materials, Agricultural Commodities, and Floor Loads For Buildings

The loads considered for a building are divided into two major categories; dead loads and live loads. Dead loads are associated with the building and do not change magnitude or location. It includes the weight of the building components, structural parts, and also any fixed equipment such as plumbing, electric, heating, ventilating, refrigeration, and sprinkler systems. Live loads change with time and include loads caused by people, animals, grain, potatoes, equipment, manure, etc.

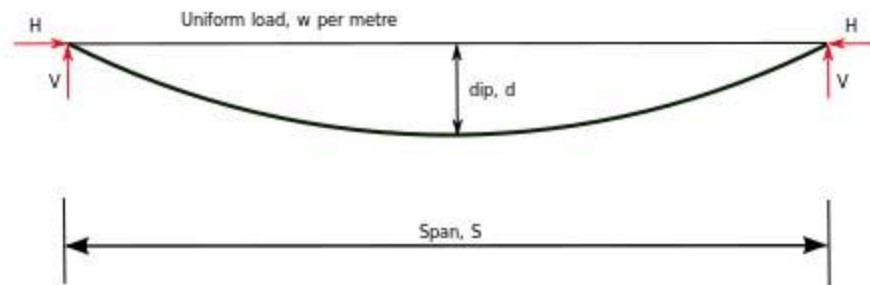
Table 1 and 2 list estimated weights of selected materials. Known values should be used when available.

Table 1. Weights of common building materials.

Building material	Unit weight
Aluminum ¹	171 pounds per cubic foot
Cast Iron ¹	450 pounds per cubic foot
Cement ²	94 pounds per cubic foot
Concrete ²	150 pounds per cubic foot
Crushed Stone ²	2,500 pounds per cubic yard
Gravel ²	2,700 pounds per cubic yard
Gypsum or plaster board ³	
3/8 inch	1.56 pounds per square foot
1/2 inch	2.08 pounds per square foot
5/8 inch	2.60 pounds per square foot
Insulation ³	
Mineral fiber (fiberglass)	2 pounds per cubic foot
Extruded polystyrene	1.8 pounds per cubic foot
Expanded polystyrene	1.5 pounds per cubic foot
Polyurethane	1.5 pounds per cubic foot
Vermiculite	40 pounds per cubic foot
Limestone	171 pounds per cubic foot
Lumber (@ 35 pounds per cubic foot, Douglas Fir) ⁴	
2X4	1.28 pounds per foot
2X6	2.00 pounds per foot
2X8	2.64 pounds per foot
2X10	3.37 pounds per foot
2X12	4.10 pounds per foot
4X4	2.98 pounds per foot
6X6	7.35 pounds per foot
6X8	10.03 pounds per foot

Transversely and uniformly loaded cable

For a cable spanning between two supports the simplifying assumption can be made that it forms a circular arc (of radius R).



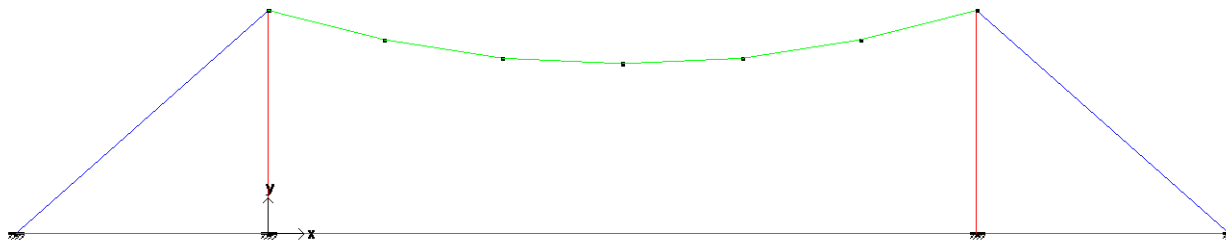
By **equilibrium**:

The horizontal and vertical reactions :

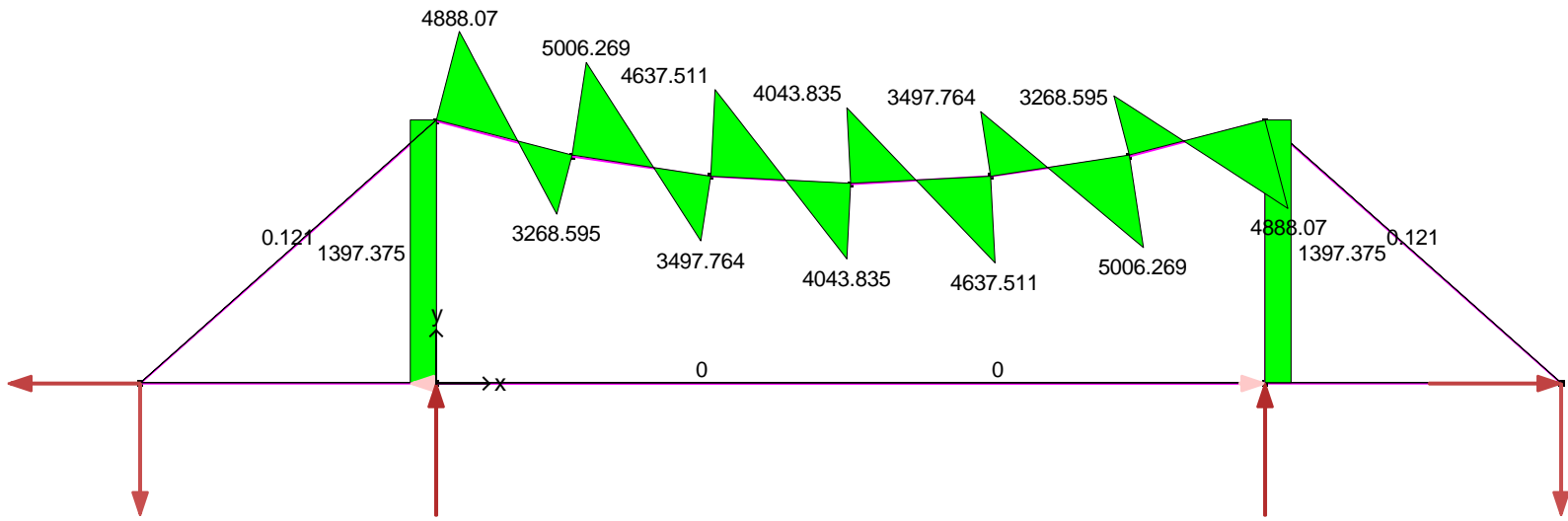
$$H = \frac{wS^2}{8d}$$

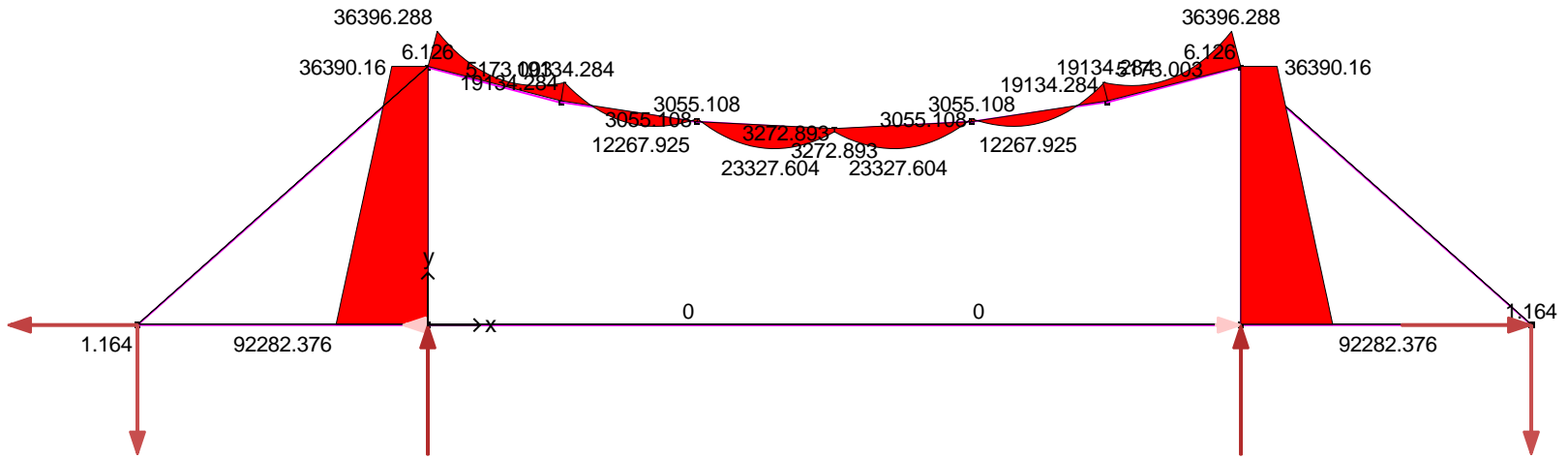
$$V = \frac{wS}{2}$$

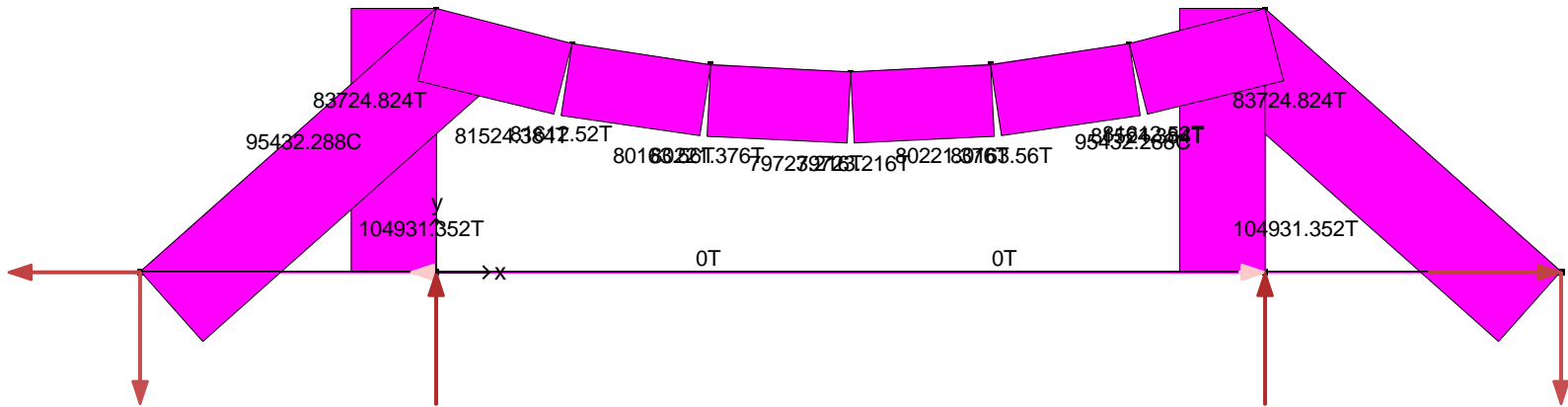
Multiframe



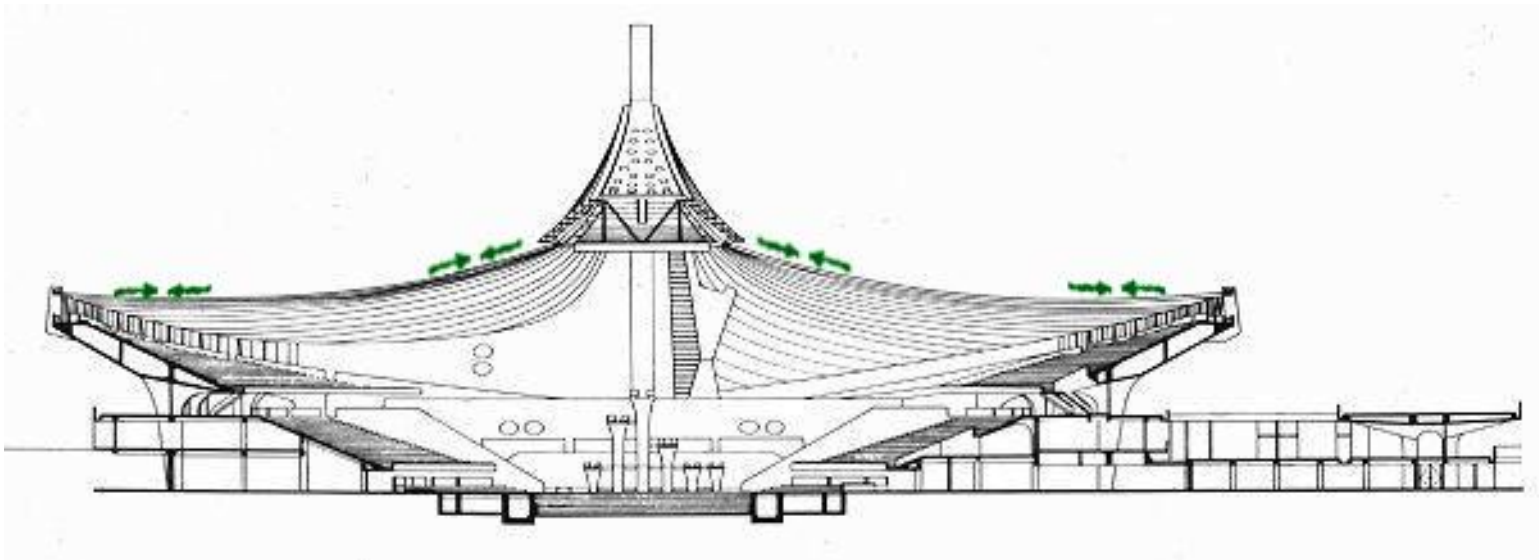
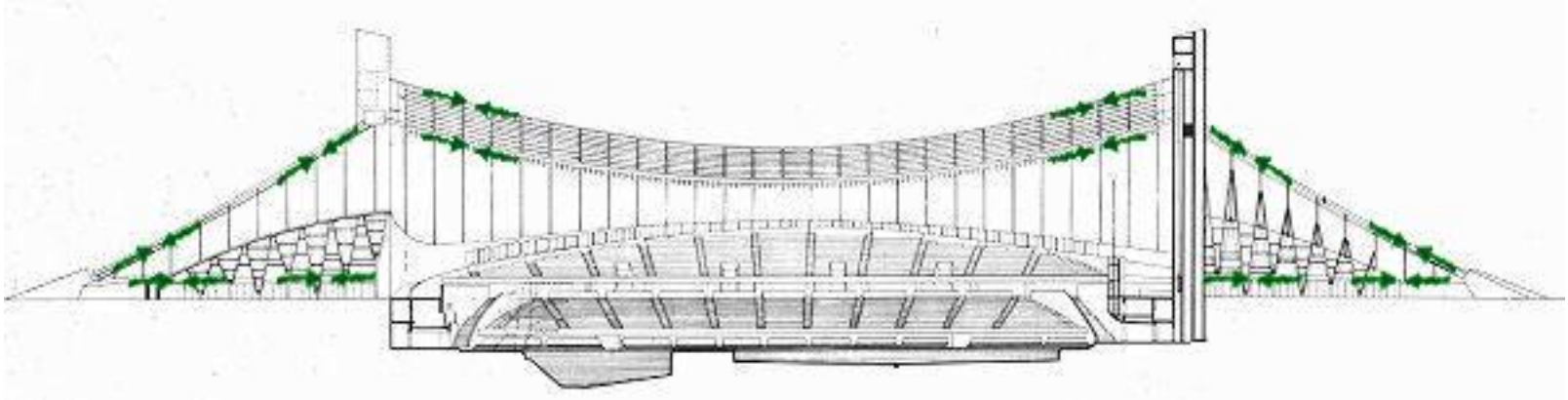
Sections	
■	300x300x19
■	60.5x4
■	912x302x18x34
■	48.6x3.2

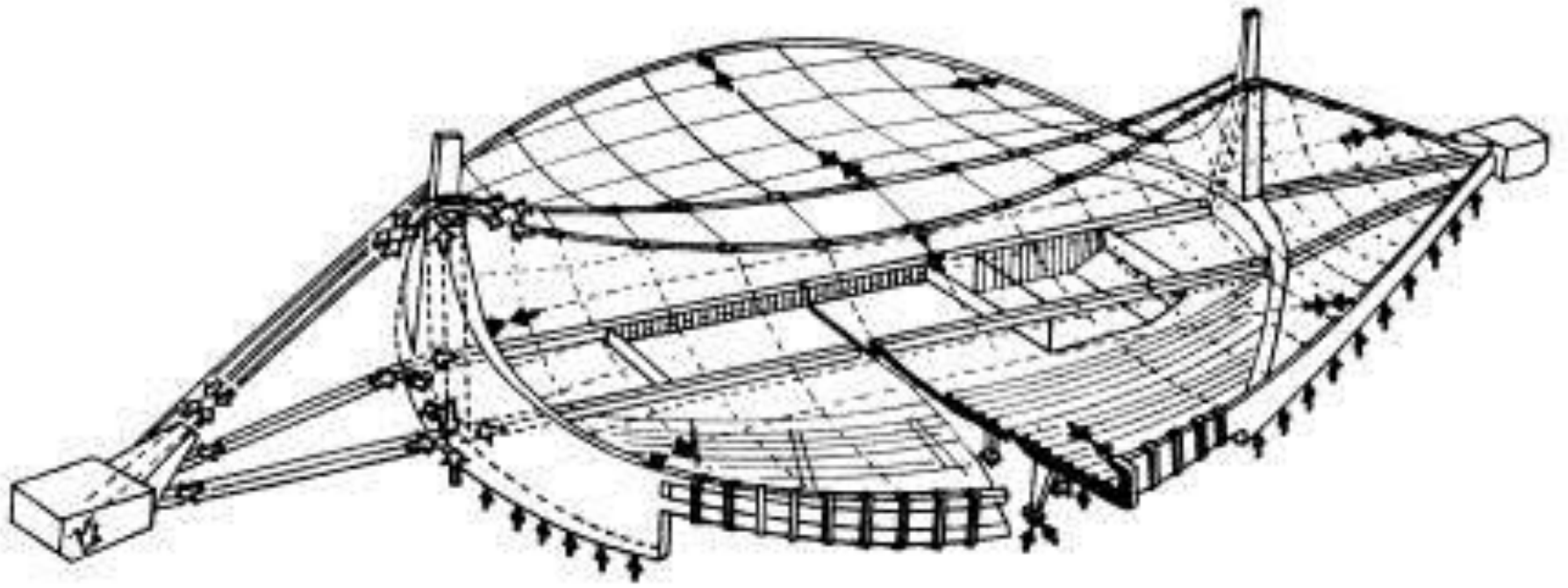


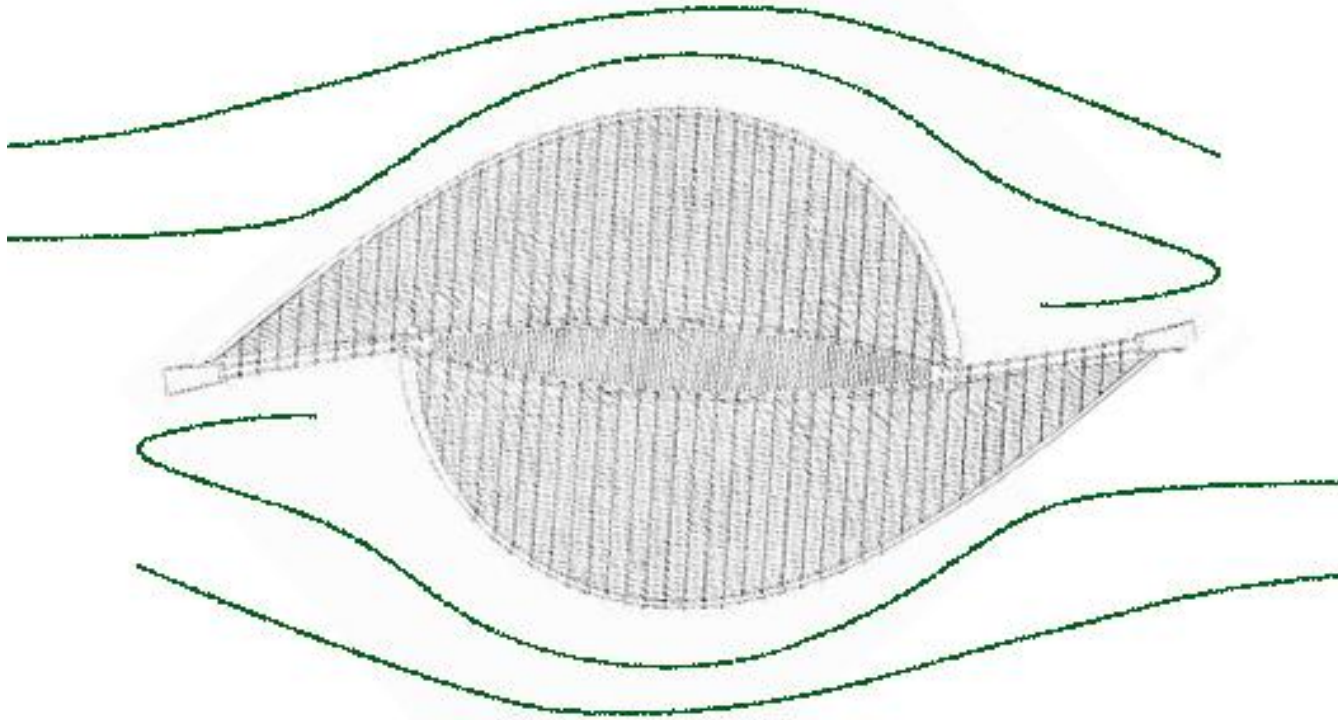




Response to lateral loading
-both wind and seismic



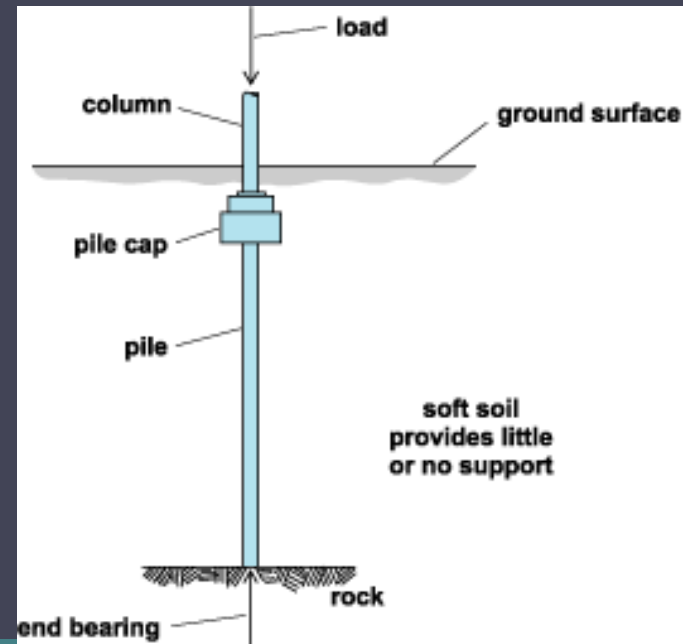




The **spindle** shape helps resist the lateral forces

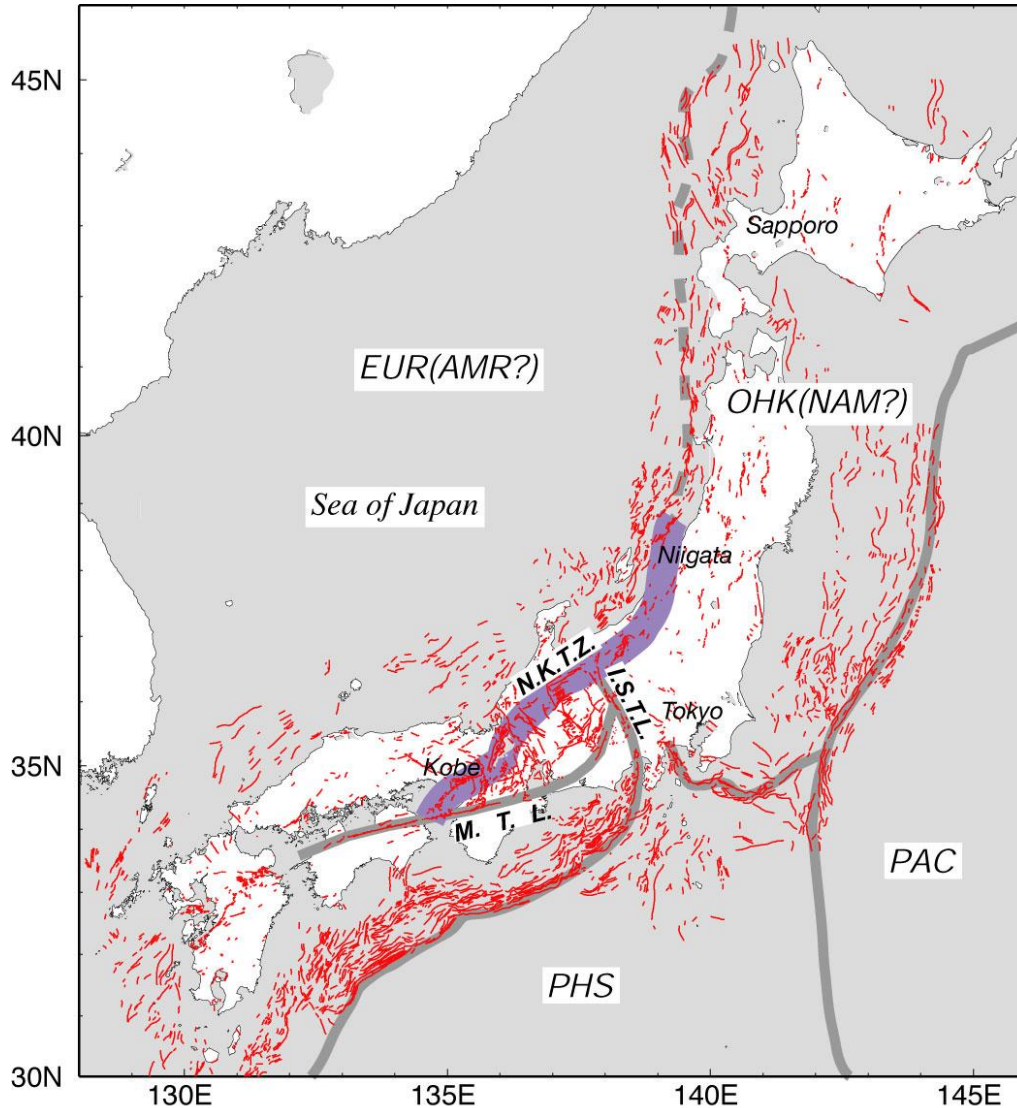
Foundation System

- Piles foundation system is used
- Piles are used to distribute loads by end bearing to the soil layer as deep as 20 feet which ensures the stability of the cap
- The resulting pressure is about 1.5Kpa per pile.



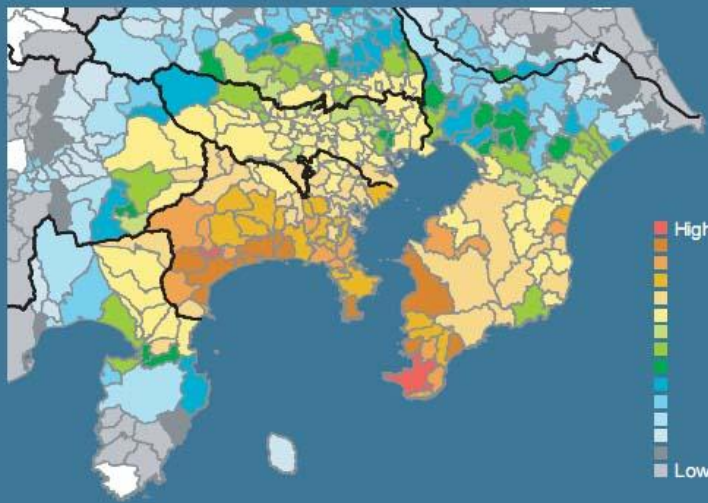
Typical foundation component

soil

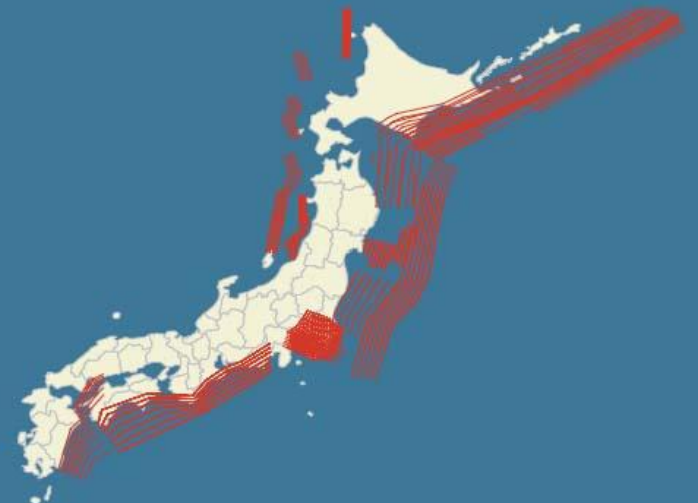


Tokyo is in close proximity to plate boundaries that define the Japan Trench, the Sagami Trough, and the Nankai Trough.

In reference to the ground, the greatest concern for builders is seismic activity.



Residential building damage in the Tokyo region from a repeat of the 1923 Great Kanto Earthquake



Major subduction zones in Japan

A repeat of the 1923 earthquake which was a 7.9 on the Richter scale is expected to \$80 billion in damages



Guang Yang
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Lei Shao

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