The Guthrie Theater

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Photo: Yoshio F.

The Guthrie Theater

Location:

- Minneapolis, MN
- Banks of the Mississippi River

Year Completed:

- 2006

Architect:

- Jean Nouvel

Purposes:

- To replace old Guthrie Theater built in 1963, which is currently being demolished

Construction Materials:

- Steel, concrete, and glass

Photo: Philippe Ruault

Program & Function

Floor Area: 285,000 sq. ft.

- Three Theaters
- Theater administration spaces
- Educational spaces
- Production program spaces
- Restaurant
- Bar

Photos: Yoshio F.

Uniqueness

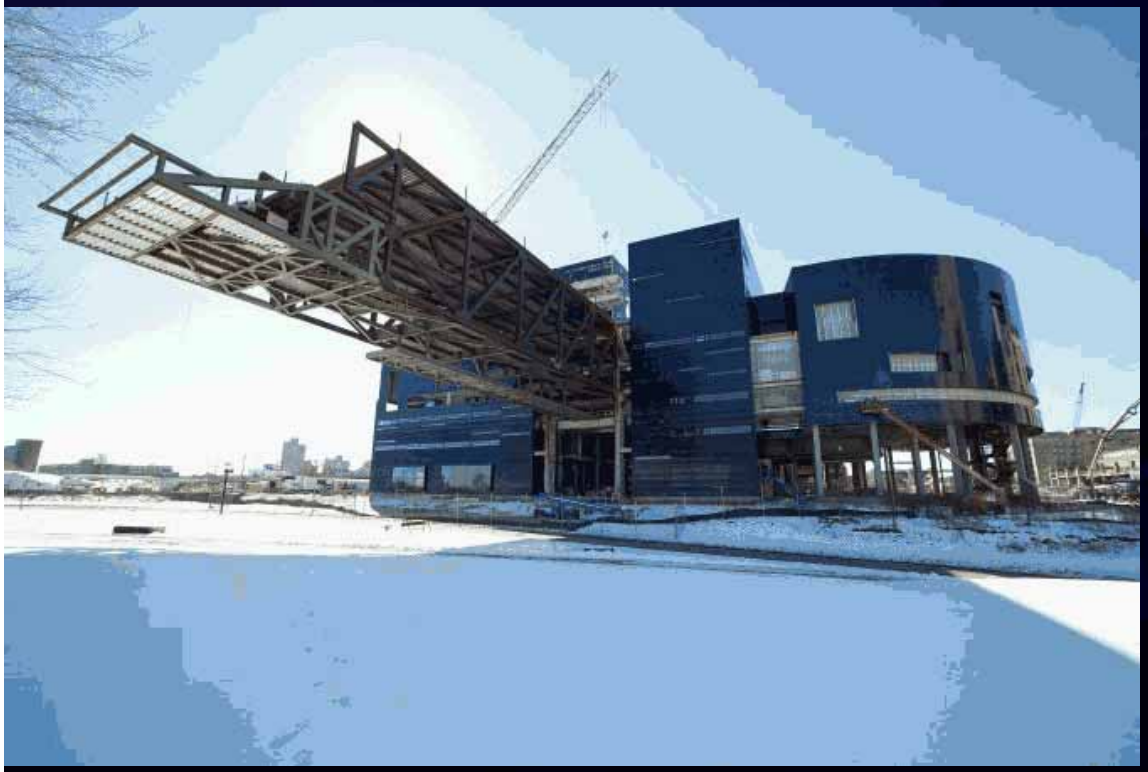
<u>The “Endless Bridge”</u>

- 178 foot Cantilever stretching toward the river
  - One of the longest occupiable cantilevered spaces in the world
  - 50 feet above the roadway
  - Canopy for first floor lobby
  - Balcony for second and third floors
  - Gives impressive views of the river, a waterfall, and Minneapolis

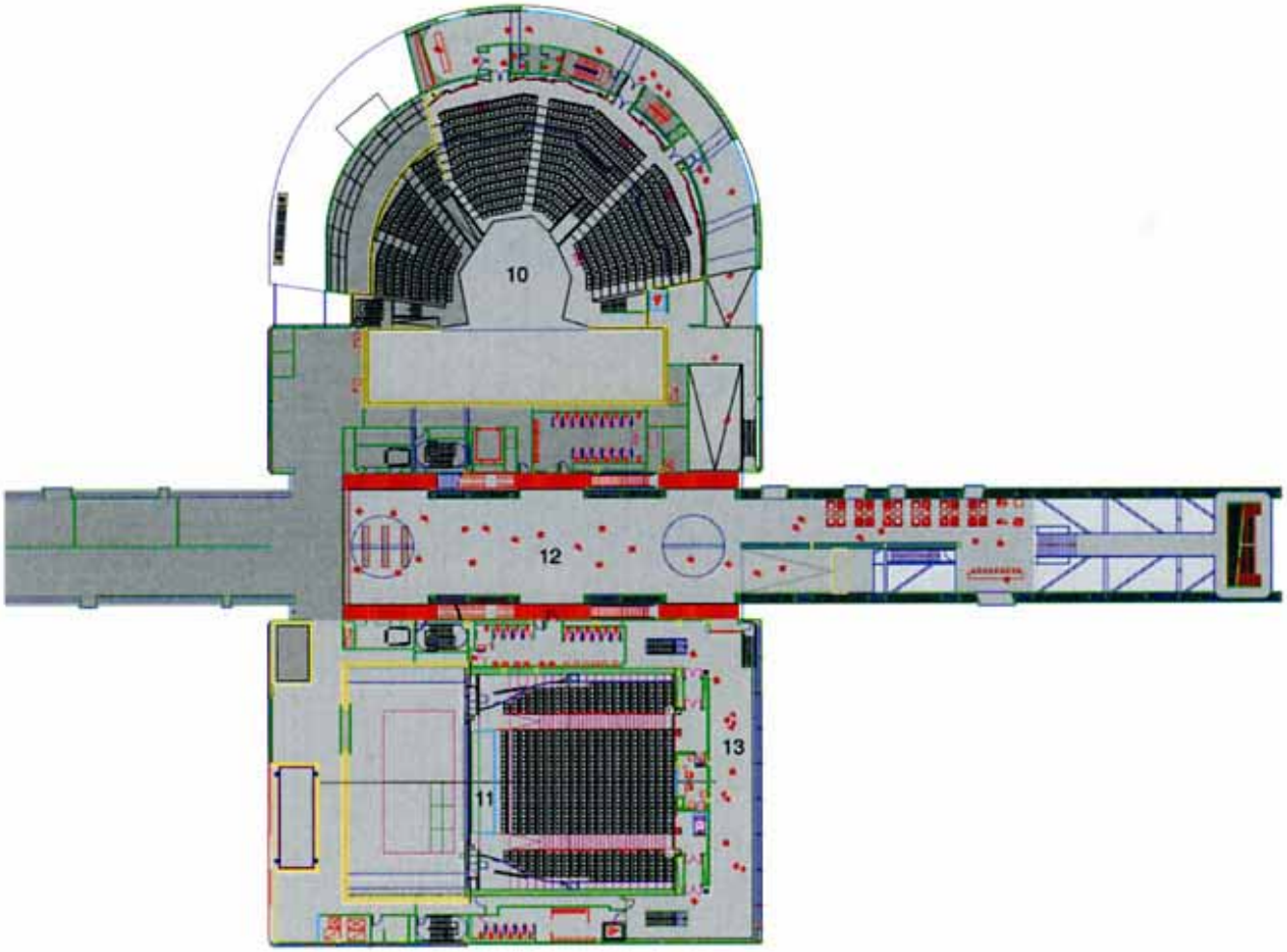
Photo: Yoshio F.

Photo: Michael Mingo

Construction Process

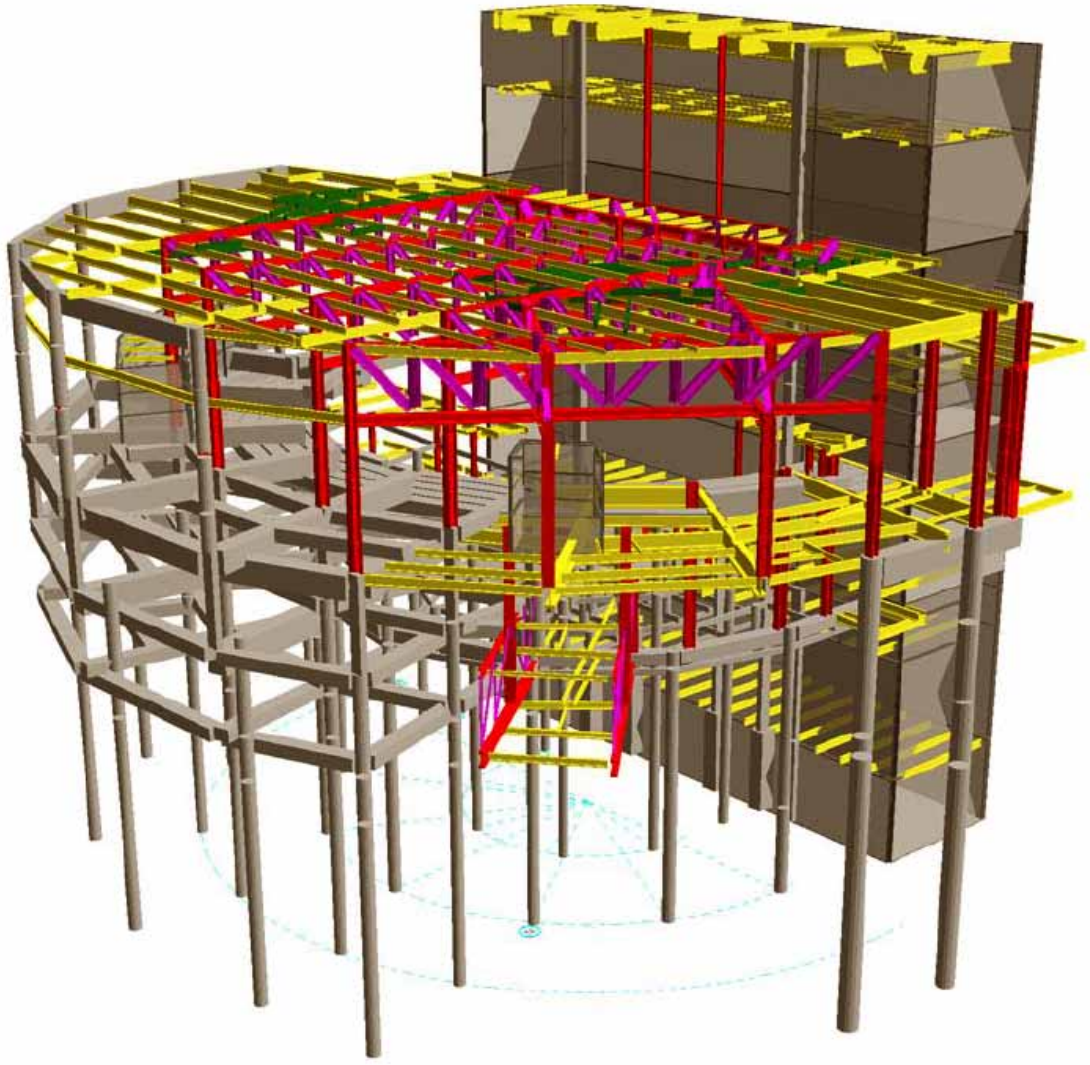


Guthrie Layout

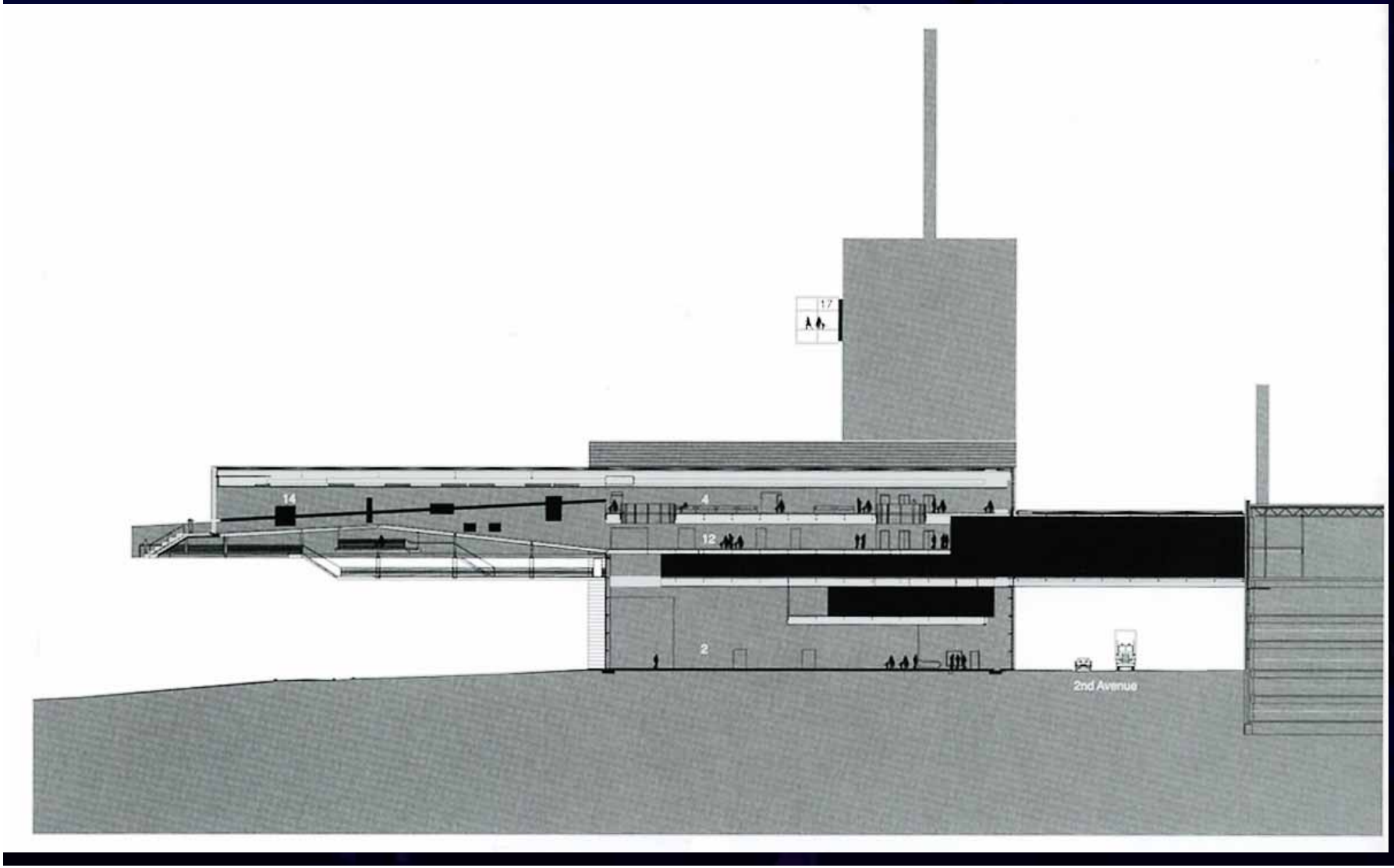


Theater Structure

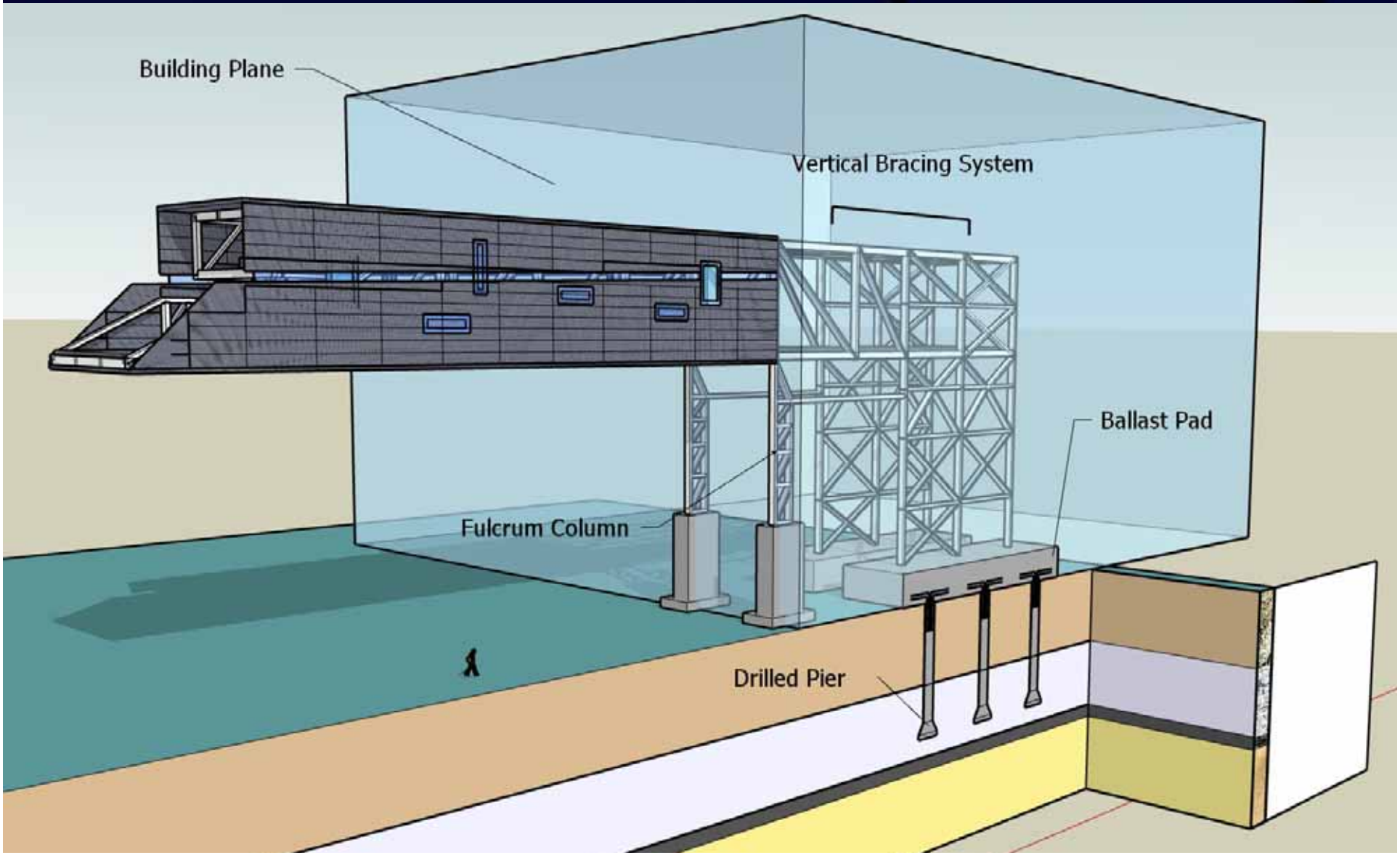
- Lateral stability is provided by the metal roof deck and braced frames located at the exterior walls



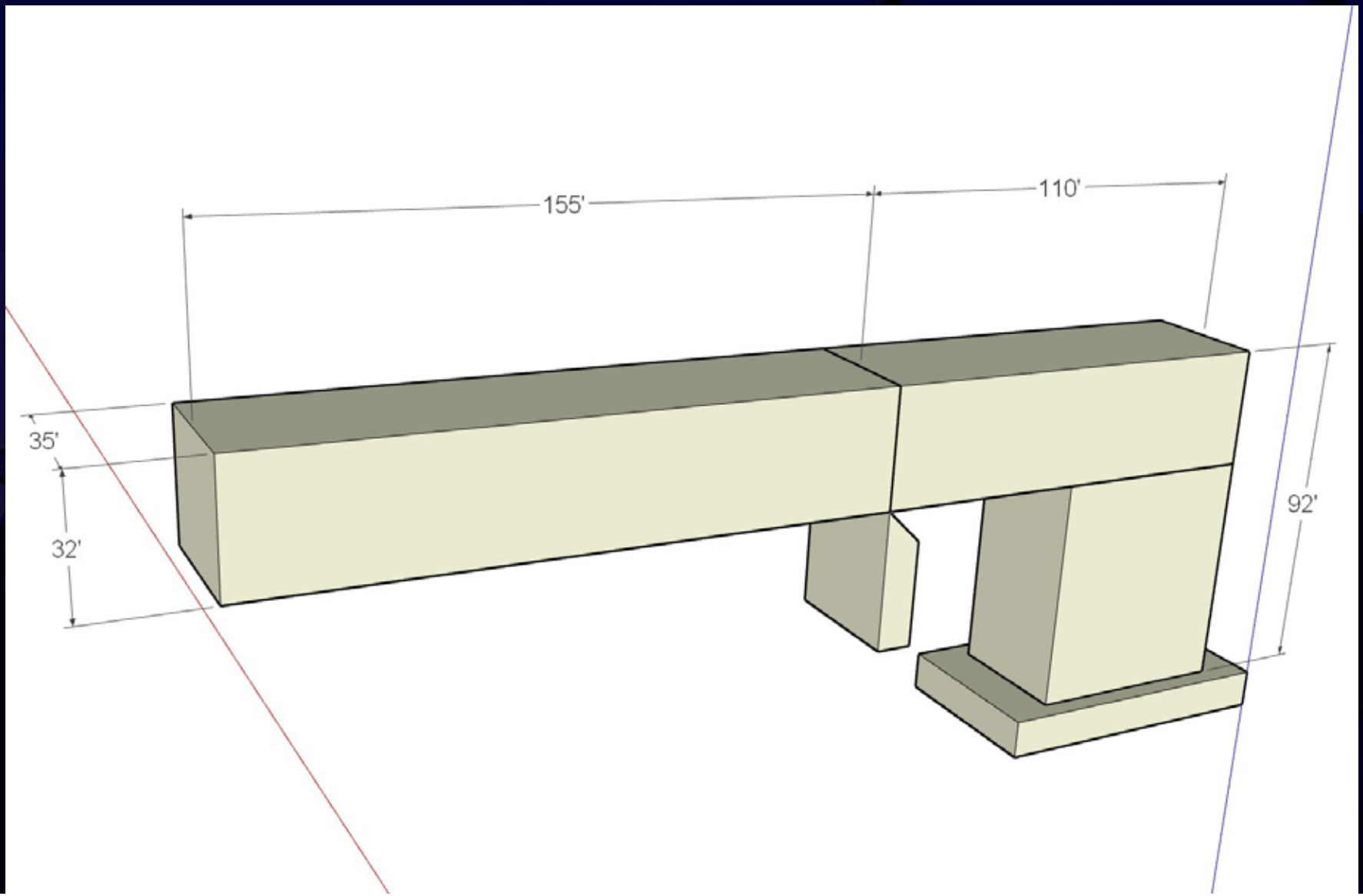
Cantilever Structure



Basic Structural Elements



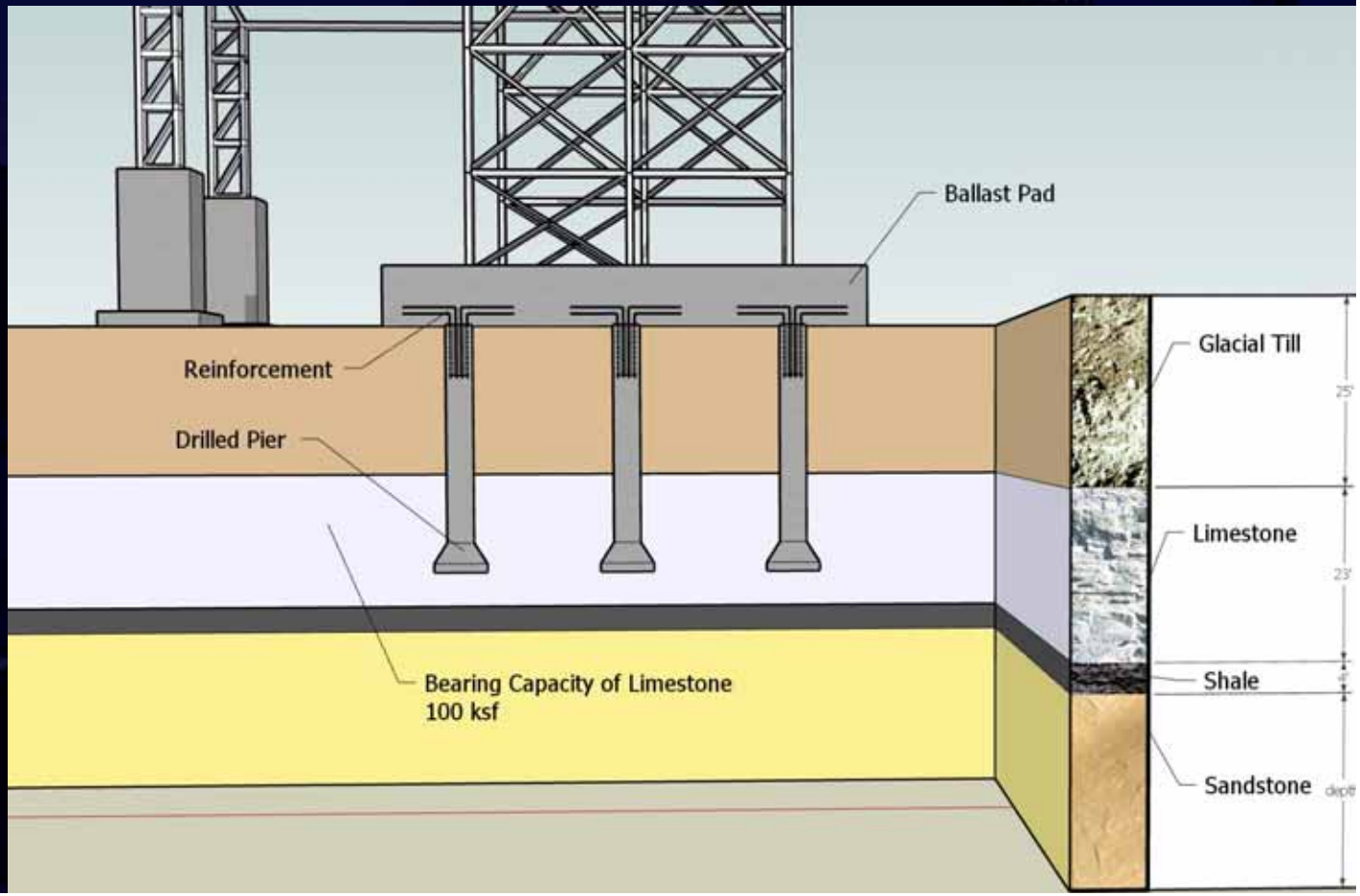
Cantilever Dimensions



Foundation

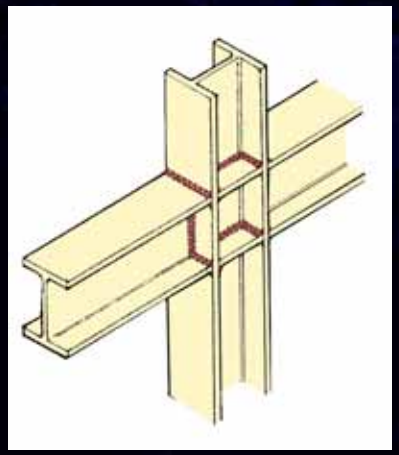
Use of deep pier foundation system that is anchored into limestone:

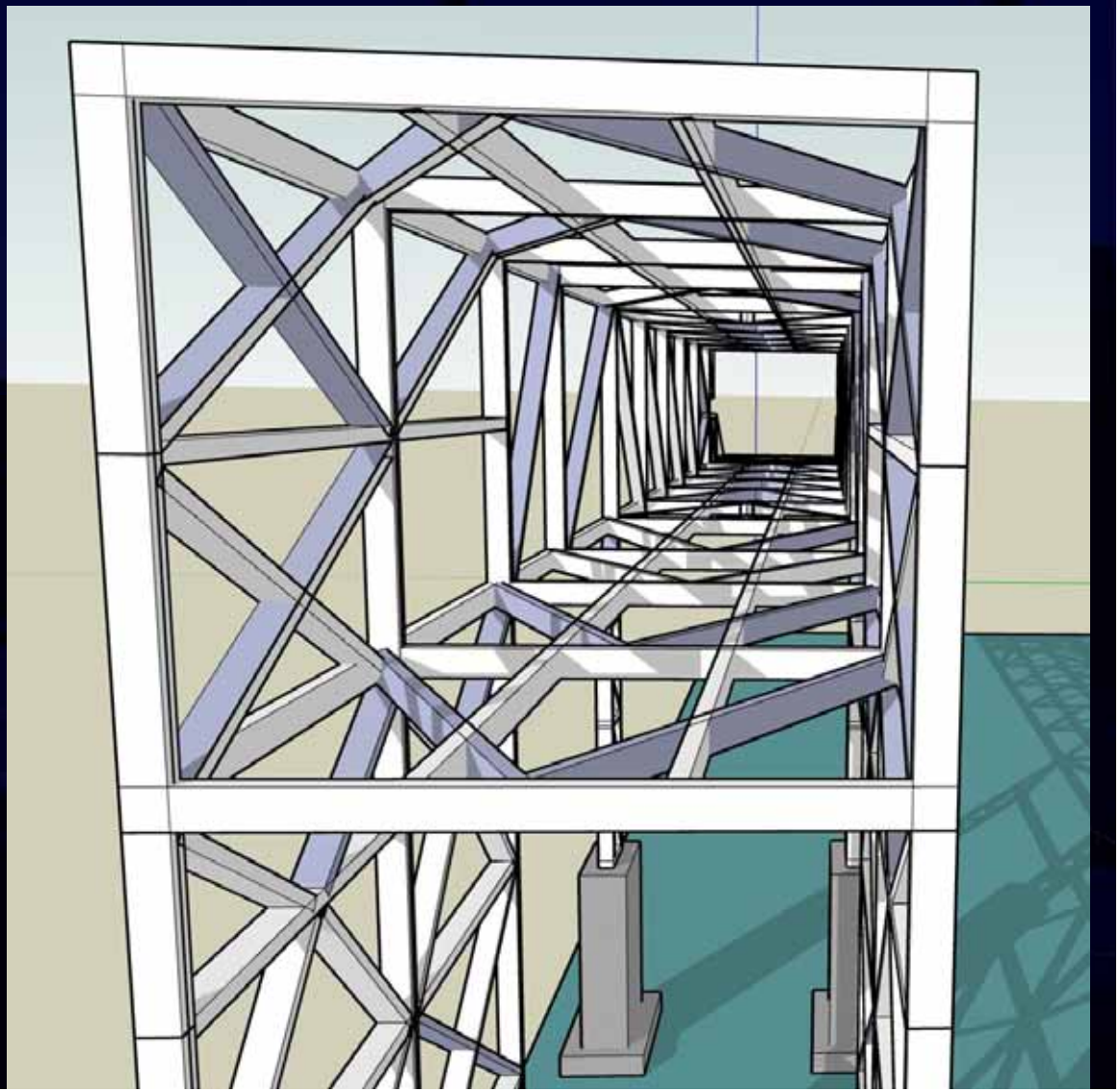
- Prevents overturning and sliding
- Reduces vibration from surrounding site



Structure

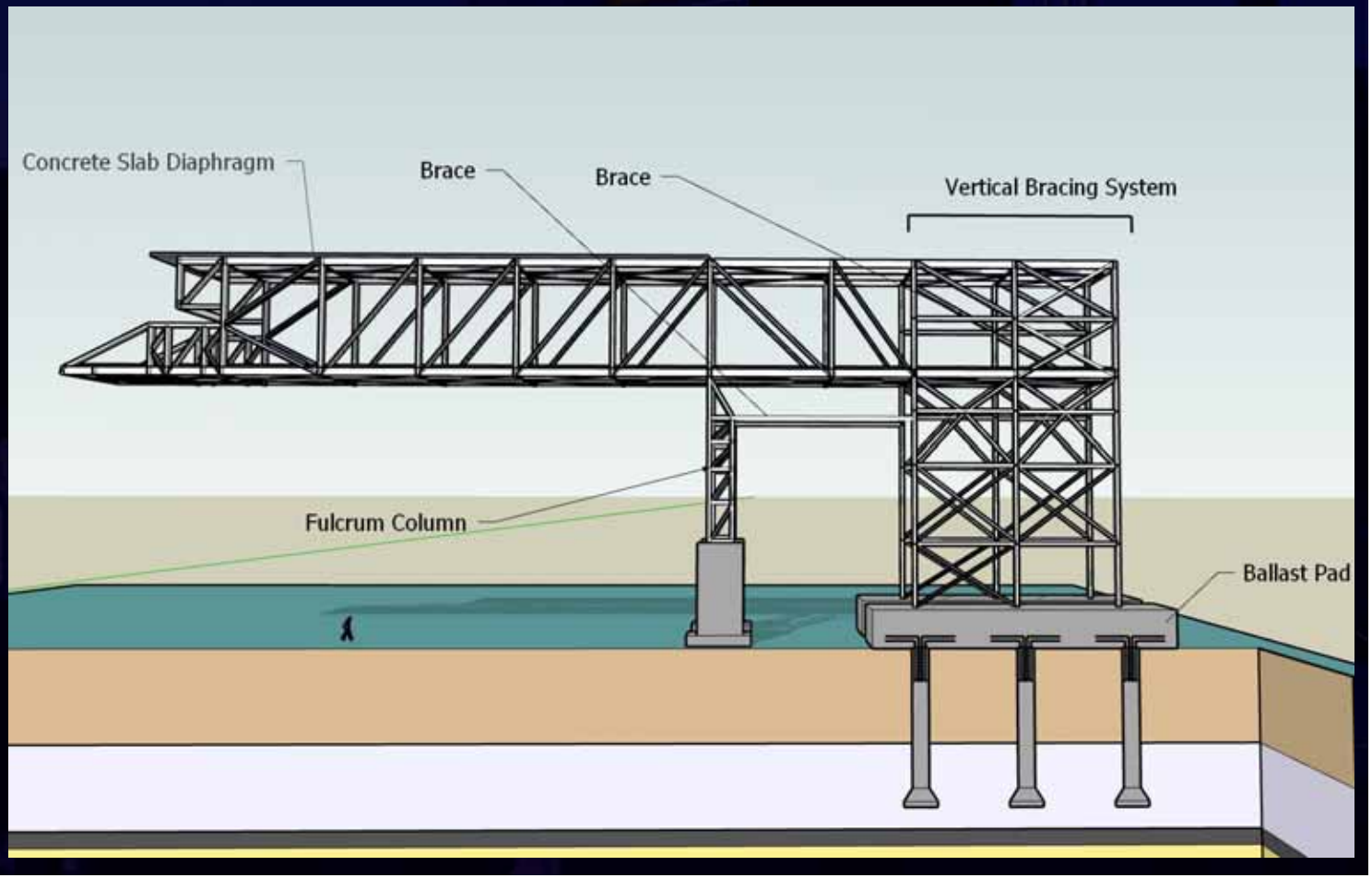
- Framed box truss
- Rigid connections





Lateral Resisting Mechanisms

- Vertical bracing restrains cantilever from overturning
- Prevents swaying



Lateral Resisting Mechanisms

- Lateral loads are transferred from concrete slab diaphragm to truss members to the vertical bracing system to the ground
- K-bracing on the top and bottom of the box truss provides stability
- Rigid joints used for connections
- Redundant system composed of diagonal bracing and rigid joints increases lateral stability

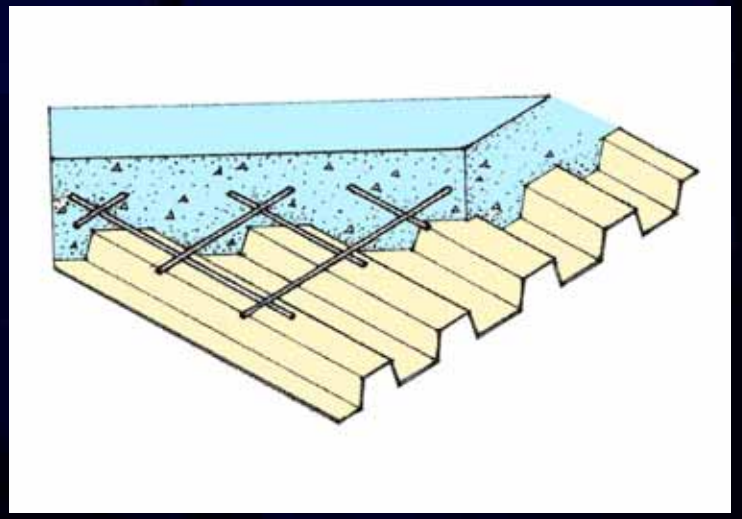


Photo: Yoshio F.

Dead Load

Total Weight of steel:

- 7502 linear feet of steel
- W14 x 730 members

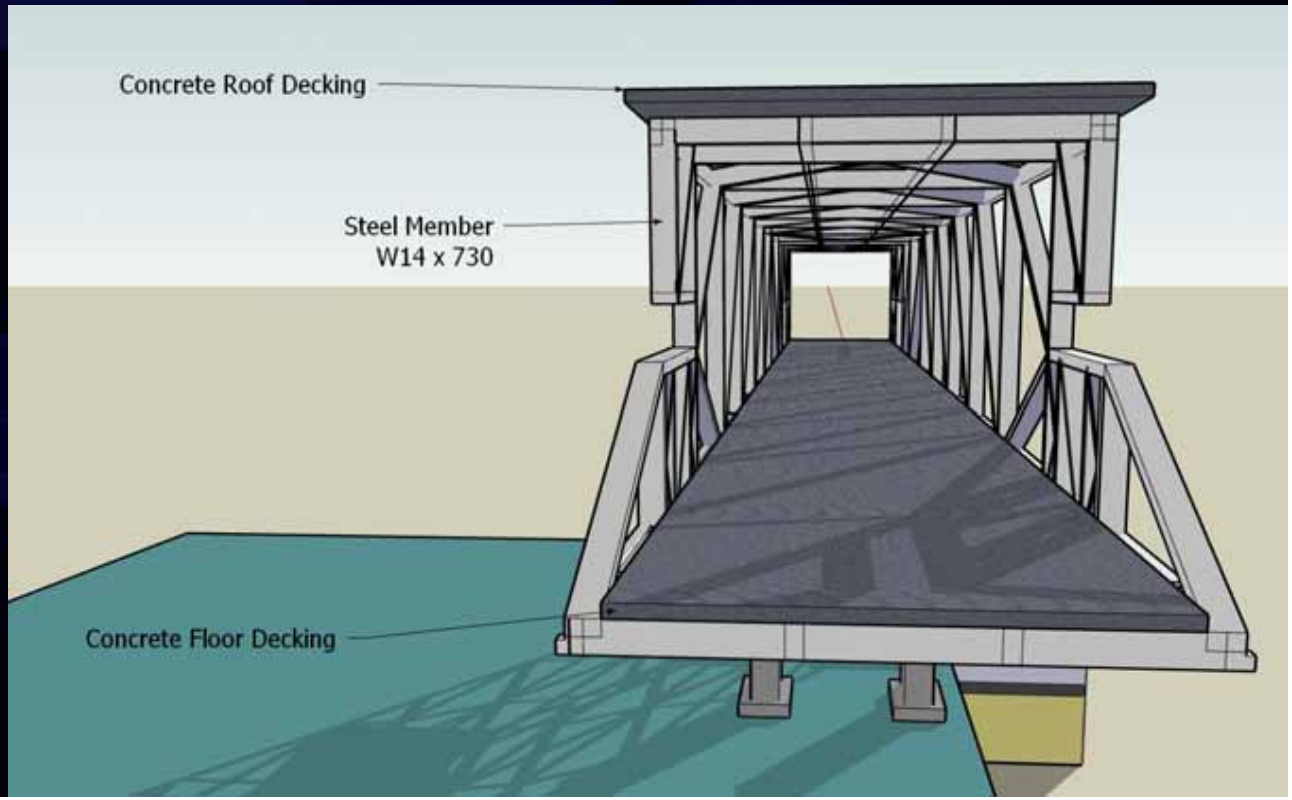
7501 ft x 730 lb/ft = **5,476,533 lbs**

Total Weight of Concrete:

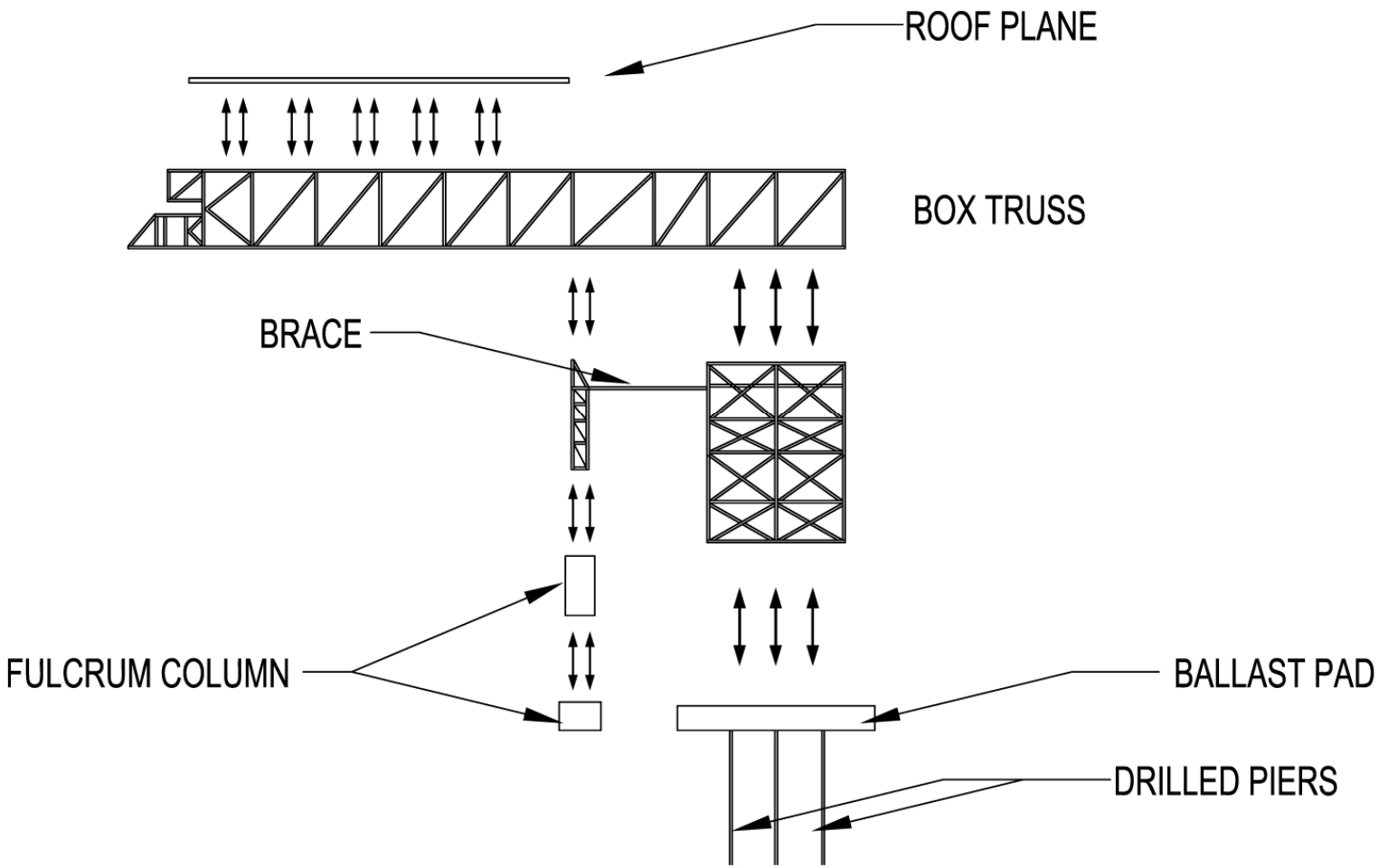
- 2.5 inches over 3 inch metal decking
- Concrete Density: 150 lb/ft^3
- Volume of Concrete: 28,350 ft^2 x 4in = 9451 ft^3
- Weight of Concrete: 9451 ft^3 x 150 lb/ft^3 = **1,417,650 lbs**

Combined Load:

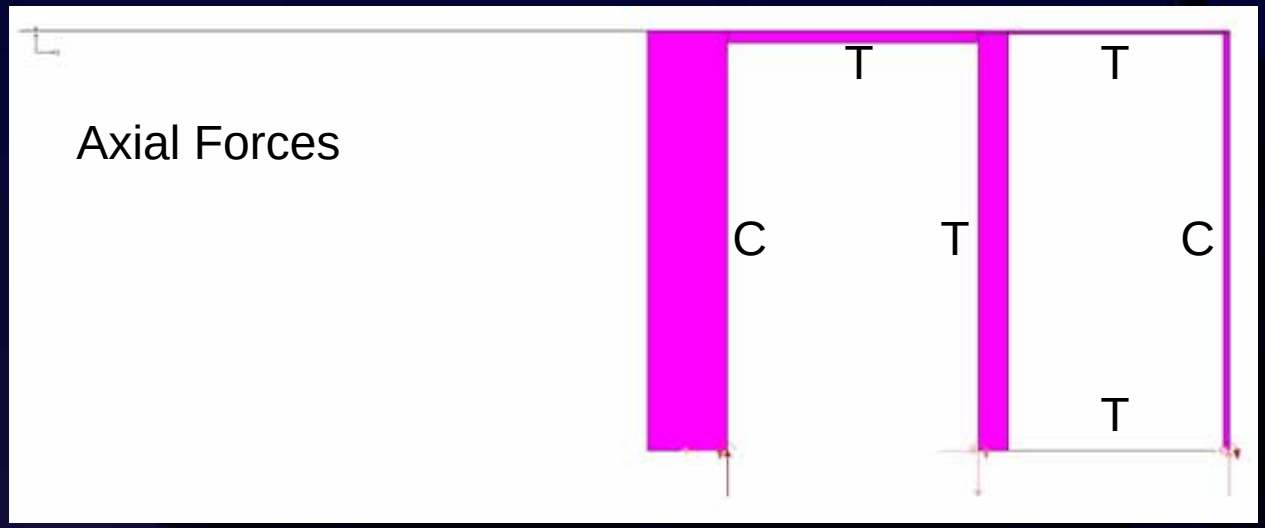
- 5,477 k + 1,418 k = **6,895 k**

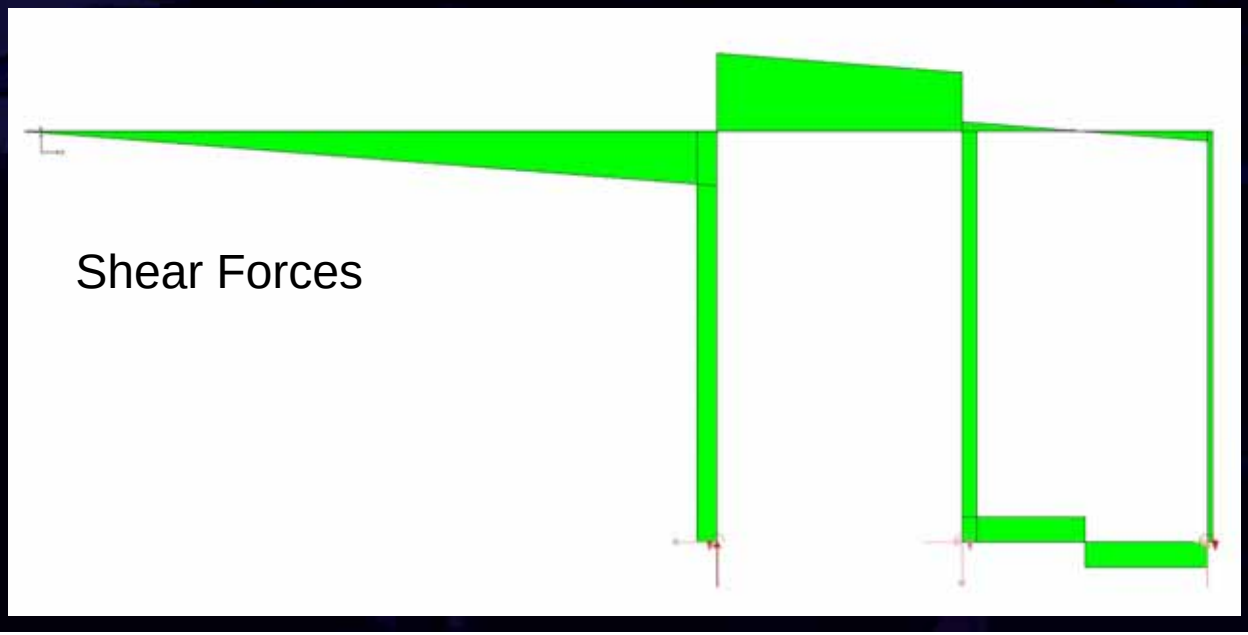


Load Tracing

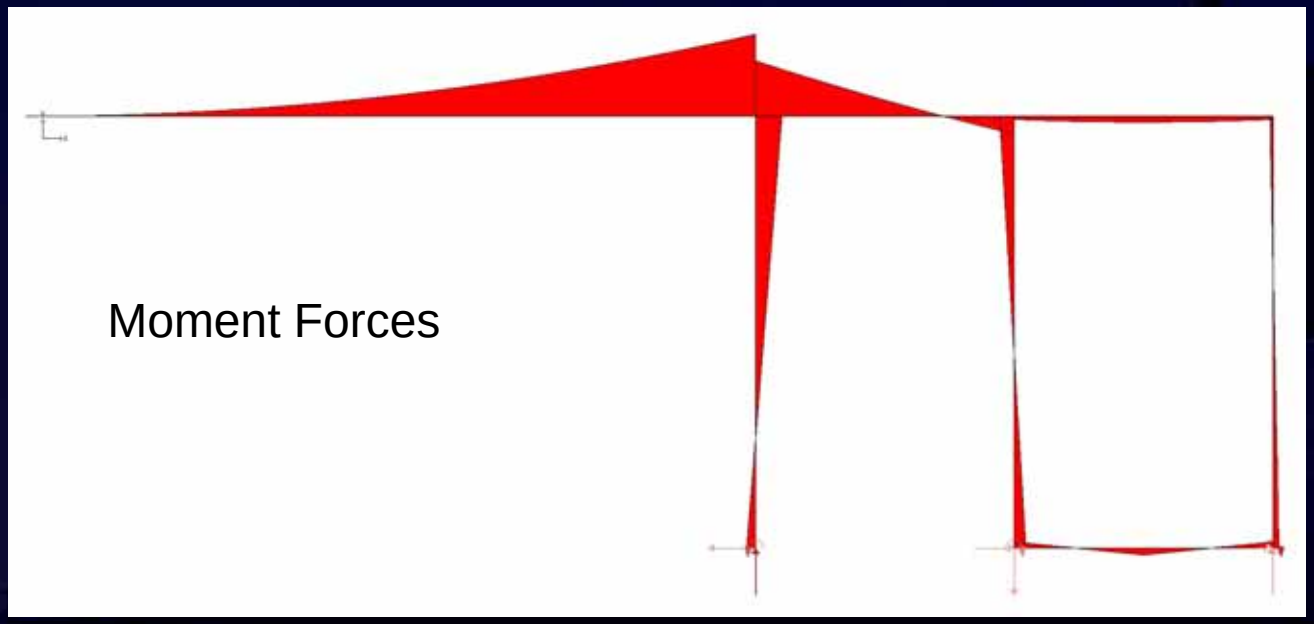


Simplified Analysis

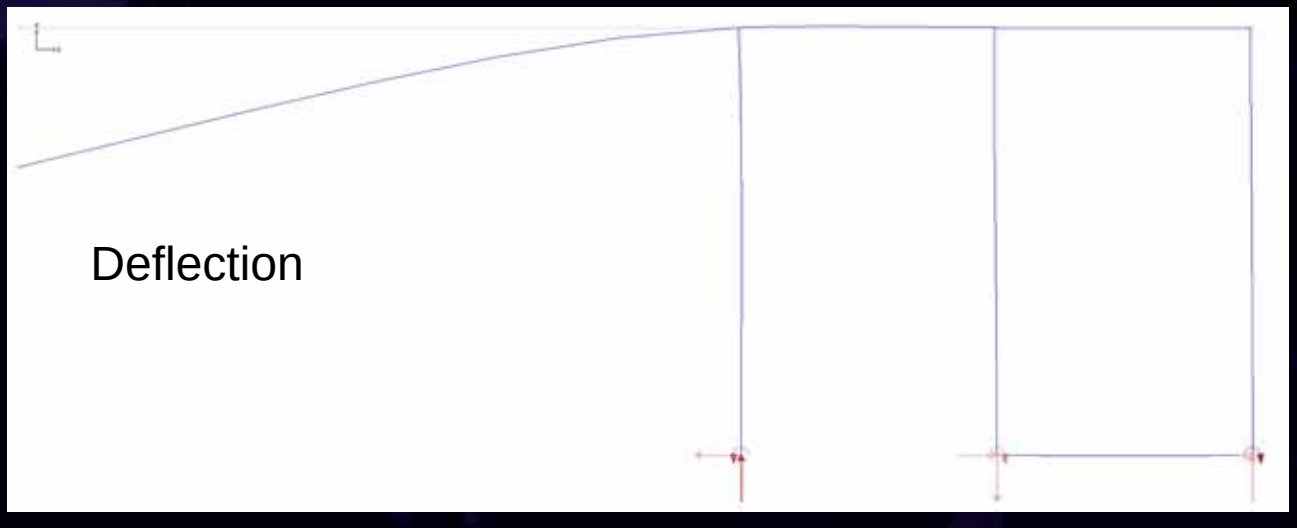




Simplified Analysis

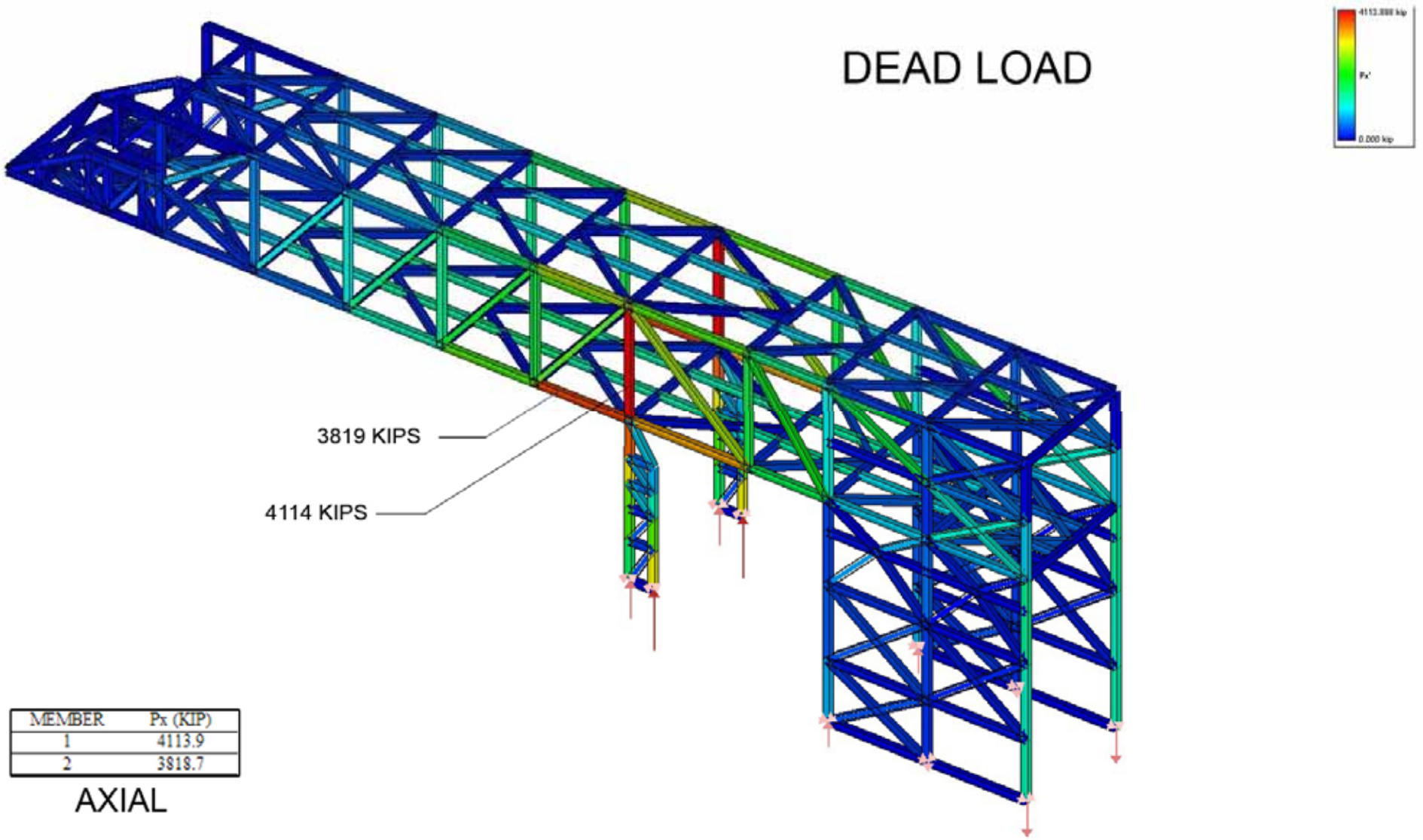


Moment Forces



Deflection

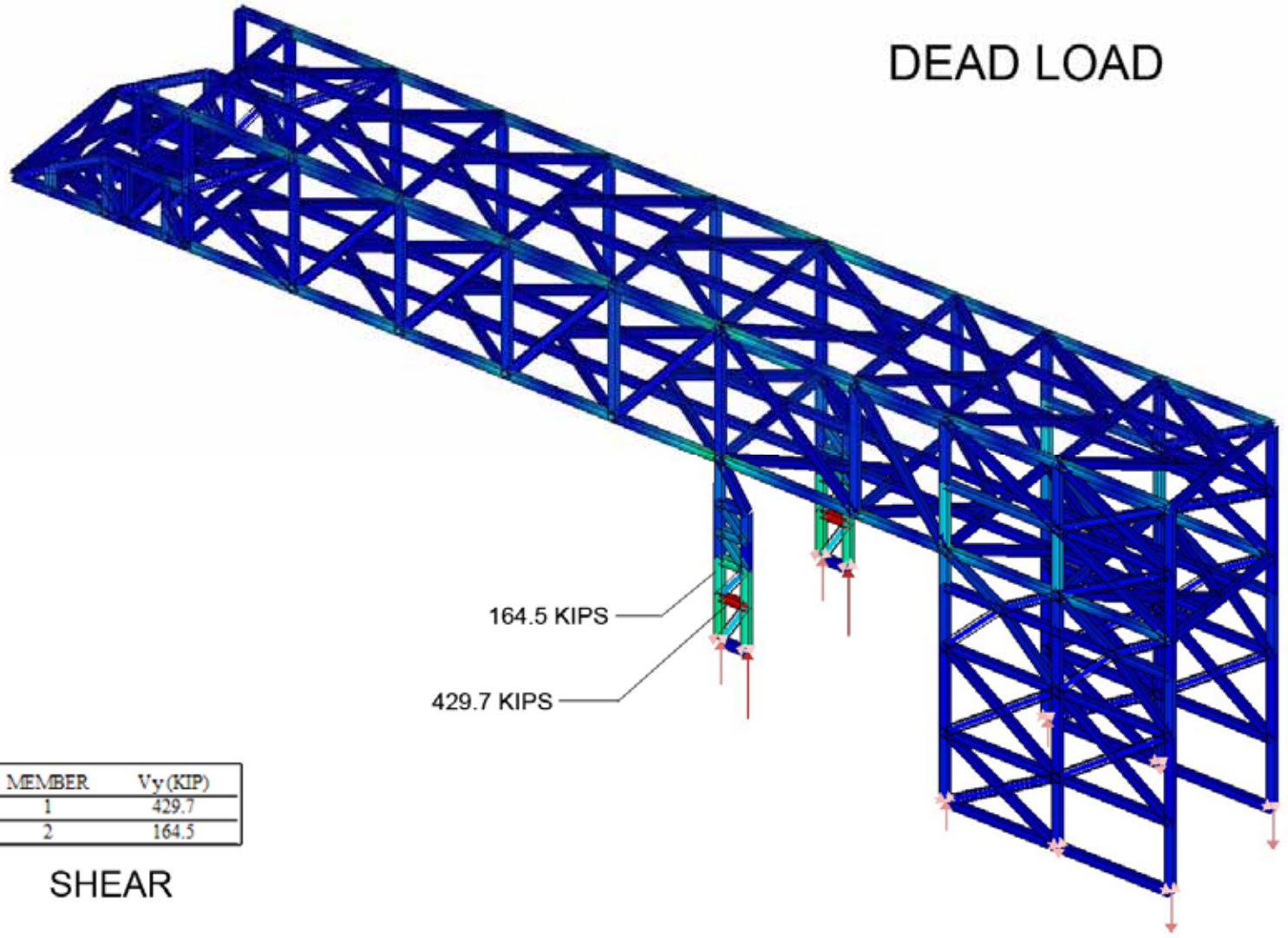
Multi-frame Analysis: Axial Forces



MEMBER	Px (KIP)
1	4113.9
2	3818.7

AXIAL

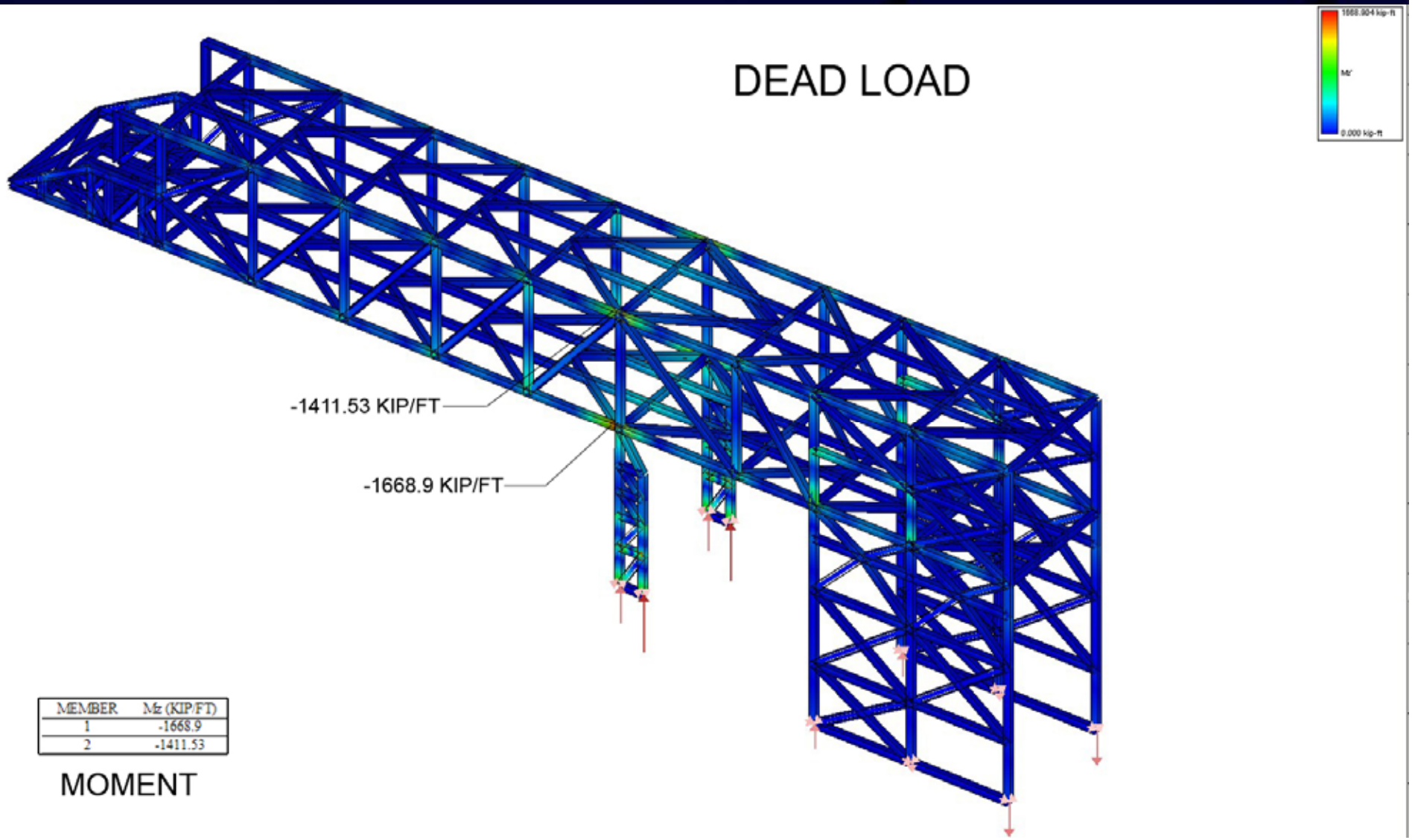
Multi-frame Analysis: Shear Forces



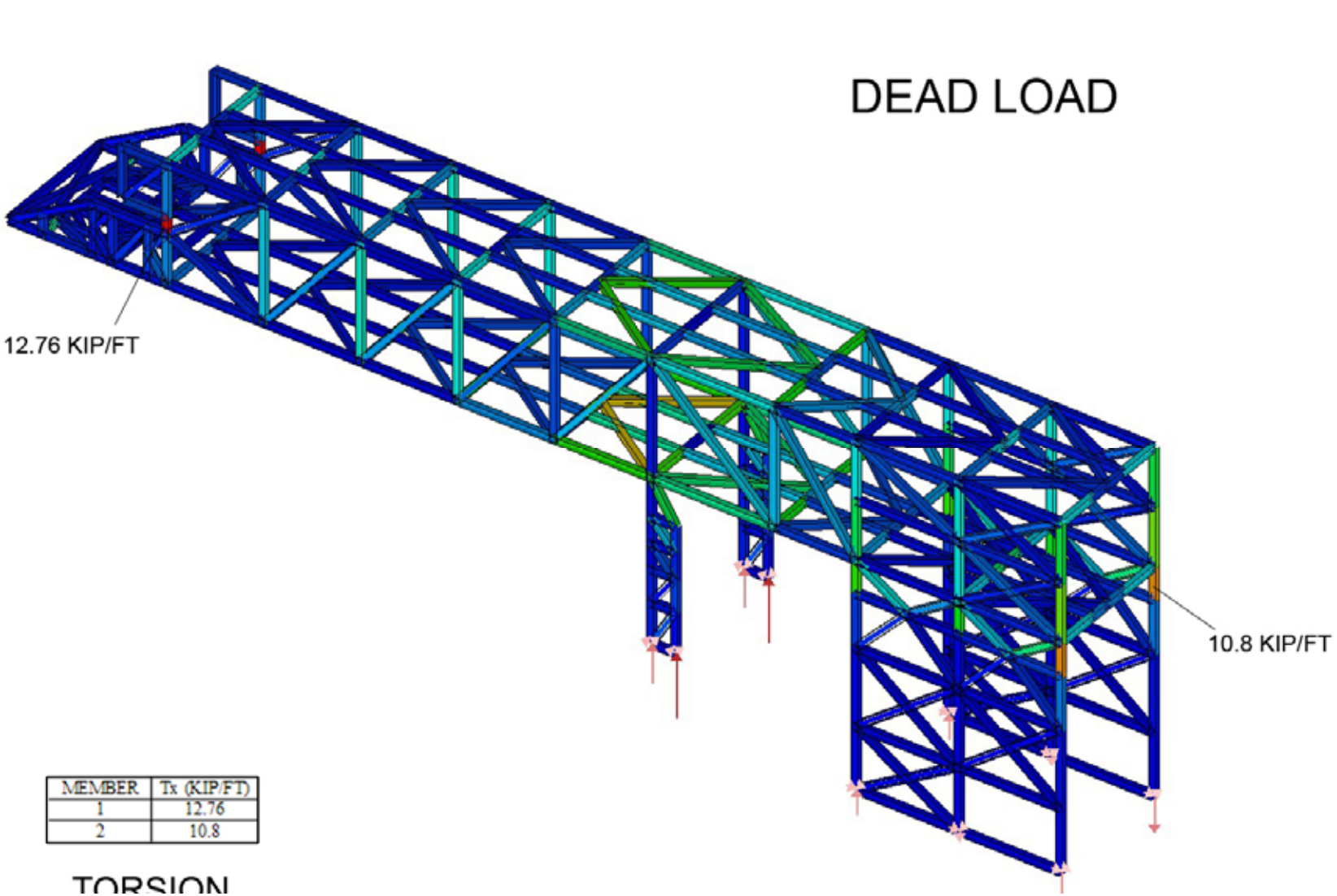
MEMBER	Vy (KIP)
1	429.7
2	164.5

SHEAR

Multi-frame Analysis: Moment Forces



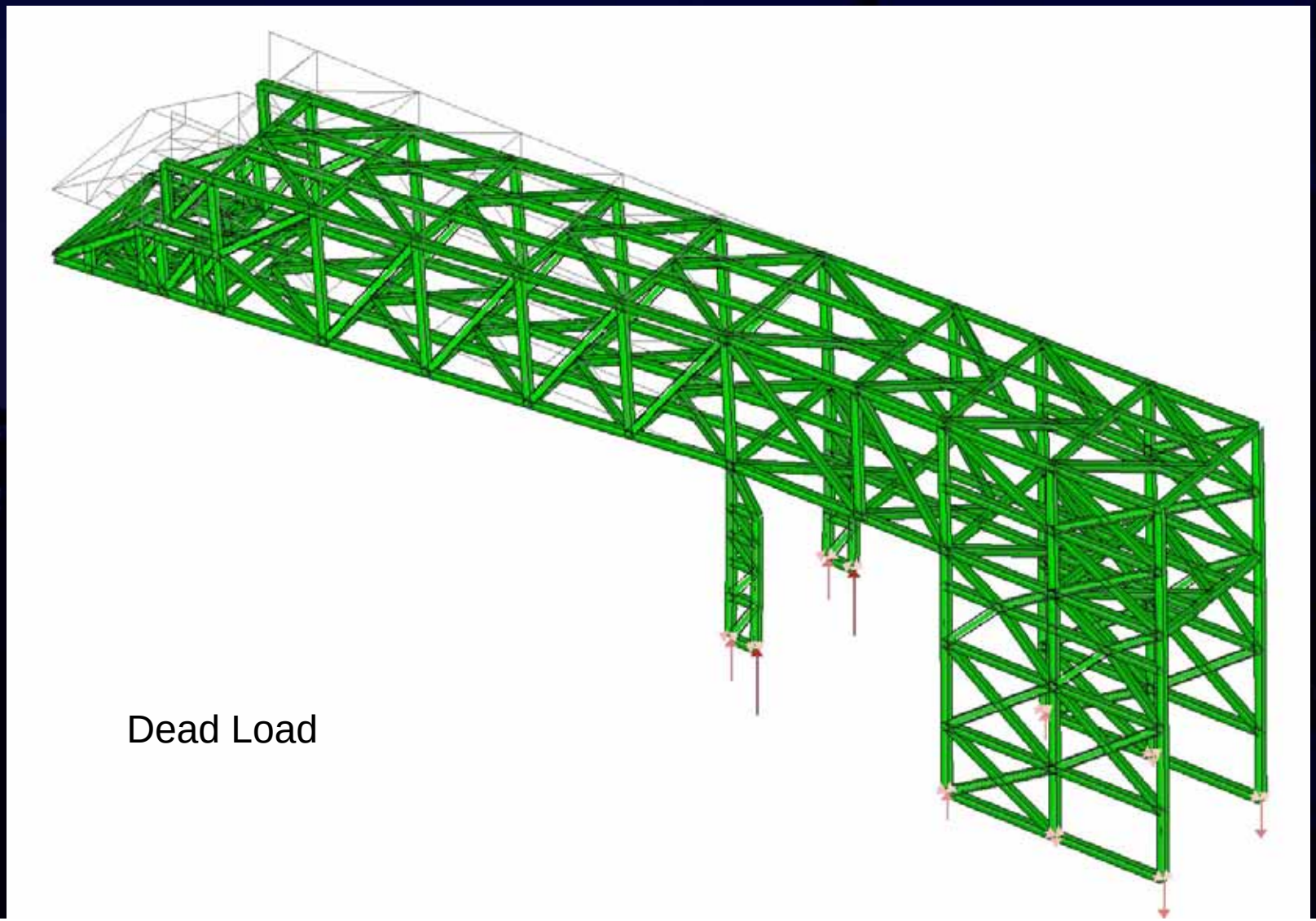
Multi-frame Analysis: Torsion Forces



MEMBER	Tx (KIP/FT)
1	12.76
2	10.8

TORSION

Multi-frame Analysis: Deflection



Dead Load

Lateral Load

Wind Load:

- Cantilever surface area: 4,826 ft
- Using Basic Wind Speed: 100 mph

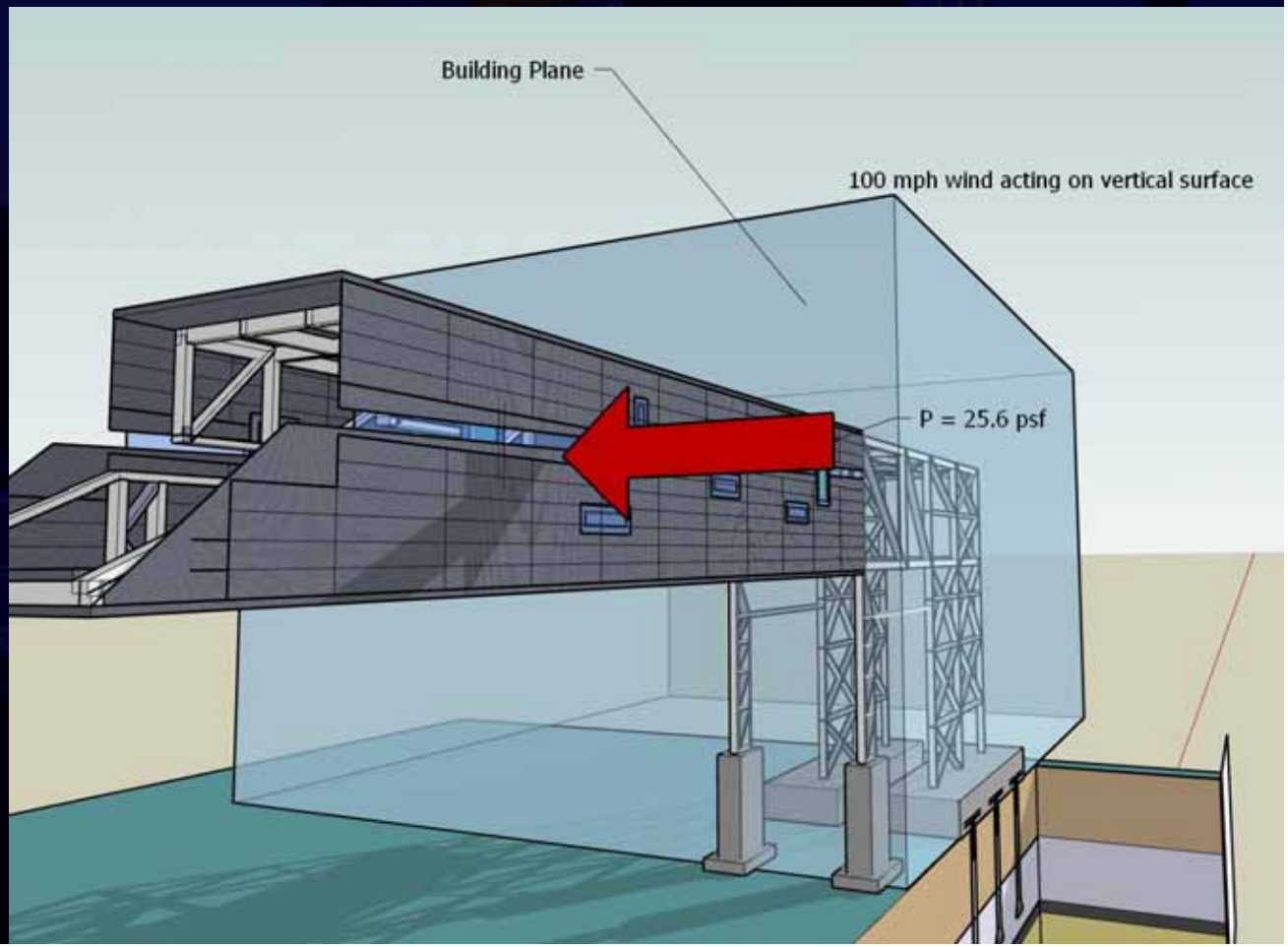
  $P_w = .00256 \times v^2$

  $= .00256 \times (100 \text{ mph})^2$

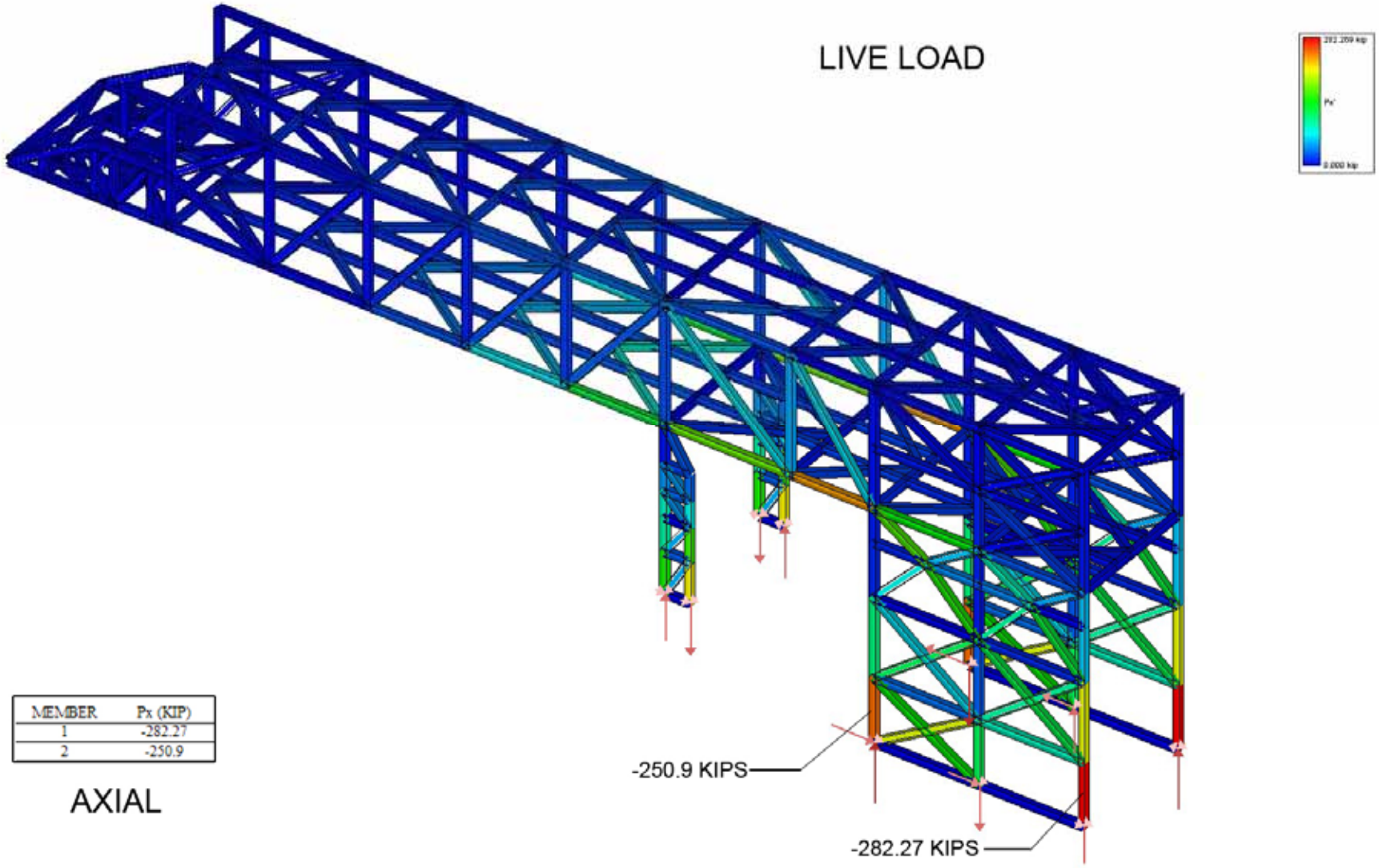
  $= 25.6 \text{ lb/ft}^2$
- Total force = 4,826 ft^2 x 25.6 lb/ft^2 = 123,545.6 lb
- Find Uniform Distributed Load:

  Total Length = (52 ft x 5) + (32 ft x 5) = 420 ft

  Uniform Dist. Load = 123,545.6 lb/ 420 ft = **294 lb/ft**



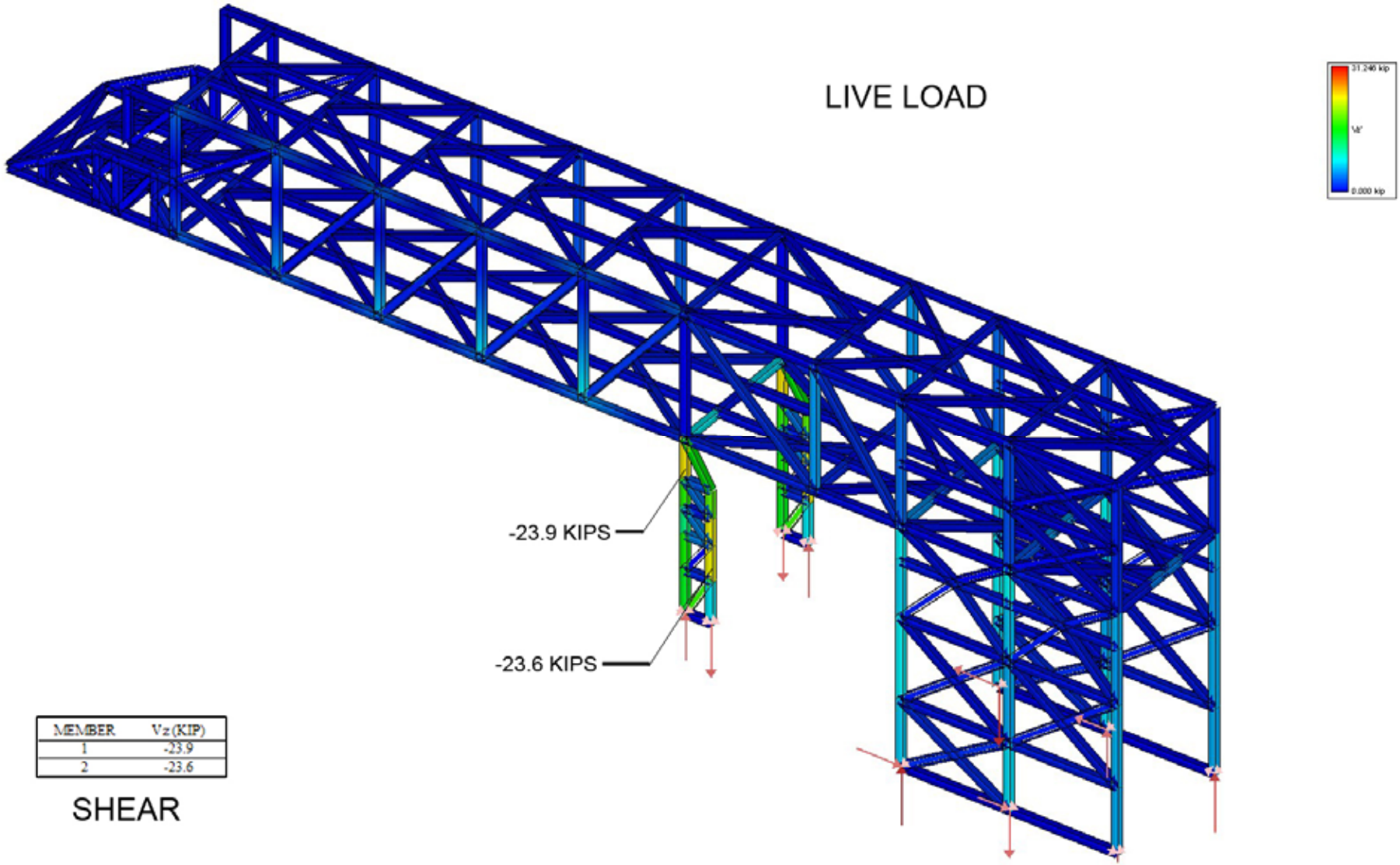
Multi-frame Analysis: Axial Forces



MEMBER	Px (KIP)
1	-282.27
2	-250.9

AXIAL

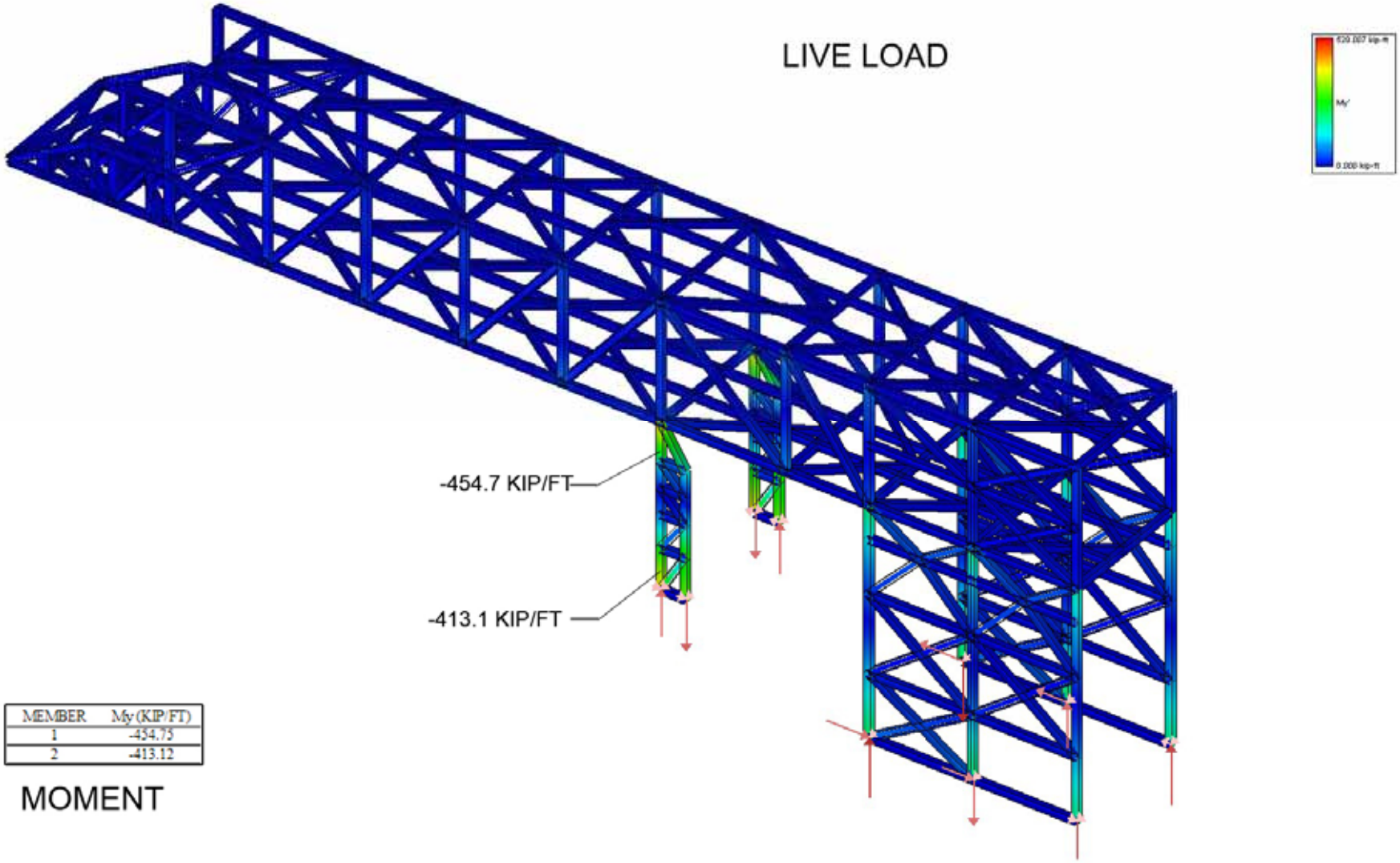
Multi-frame Analysis: Shear Forces



MEMBER	Vz(KIP)
1	-23.9
2	-23.6

SHEAR

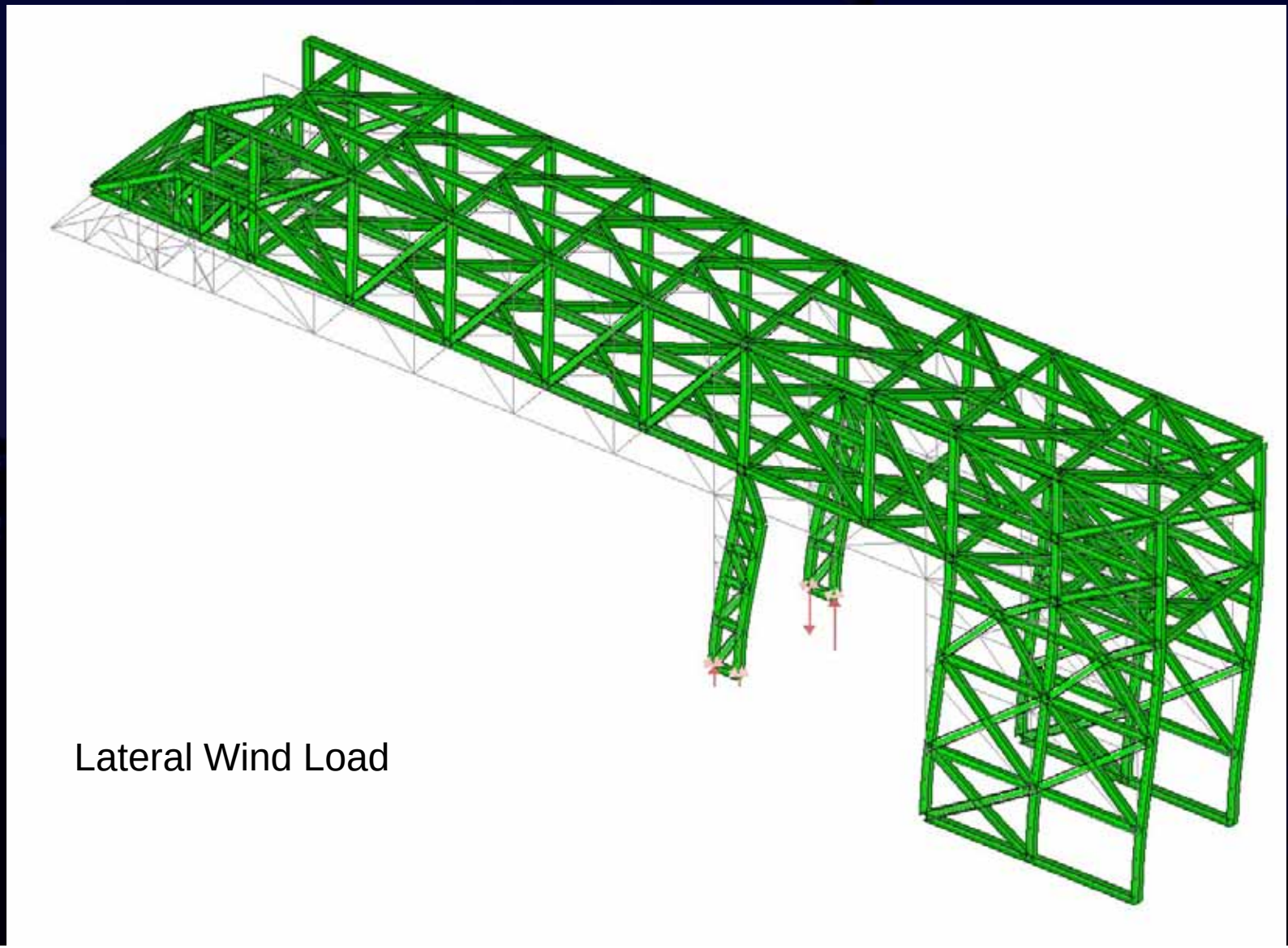
Multi-frame Analysis: Moment Forces



MEMBER	My (KIP/FT)
1	-454.75
2	-413.12

MOMENT

Multi-frame Analysis: Deflection



Lateral Wind Load

Conclusion

- Structural system: box truss is an appropriate selection because it has an occupiable space, uses material efficiently, and provides rigidity for long spans.
- Lateral resisting mechanism: Diagonal bracing, diaphragms, and horizontal and vertical braces transfer lateral forces efficiently and without infringing on the occupiable space.
- Foundation: Provides stability, balances overturning forces of cantilever, and transfers loads to the ground.

Lateral Wind Load

References

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MaCallum, Laura, “How the Guthrie Theater made it into a lean year’s bonding bill.” *Minnesota Public Radio* (June 12, 2003). http://news.minnesota.publicradio.org/features/2003/06/12_mccalluml_guthrie/ (accessed November 10, 2007).

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