Case Study of
John Hancock Center
Structural Design

Michael Maddox
Paige Pickens
Victor Badillo
Lesley McCoy
Thomas Ham
Sepeedeh R-Panah

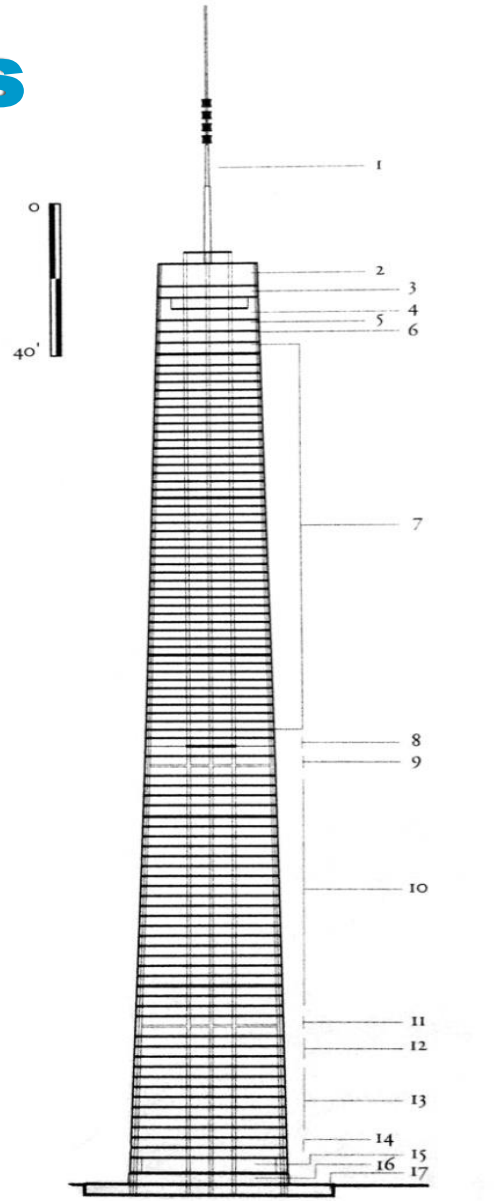
ARCH-631 | Dr. Anne Nichols .....Fall 2013

Introduction and Facts

- Client: Jerry Wolman
  the John Hancock Mutual Life Insurance Company underwrote the project
- Location: **Chicago**, Illinois
- Project Year: **1969**
- Project Area: 2.8-million-square-feet
- Height: 1,127 feet
- Project Cost: $95 million
- Lead Architect: Bruce J. Graham, Skidmore, Owings & Merrill (SOM)
- Structural Engineer: **Fazlur R. Khan**, SOM
- Primary Contractor: Tishman Construction

Program Requirements

- 100 Story **multi-use** tower
- 1,000,000 sq. feet of **residential** space
- 800,000 sq. feet of parking and **commercial** space



Section

1. ANTENNAE
2. MECHANICAL
3. TELEVISION
4. RESTAURANT
5. OBSERVATORY
6. TELEVISION
7. APARTMENTS
8. SKY LOBBY
9. MECHANICAL
10. OFFICES
11. MECHANICAL/OFFICES
12. OFFICES
13. PARKING
14. COMMERCIAL
15. OFFICE LOBBIES
16. STREET LEVEL LOBBIES
17. BELOW GRADE SERVICE & COMMERCIAL CONCOURSE

Project Challenges

- **Large** floor areas needed for Parking levels and offices
- **Small** floor areas needed for Residential space
- Designing for wind loads
- Cost
- Sway and vibration

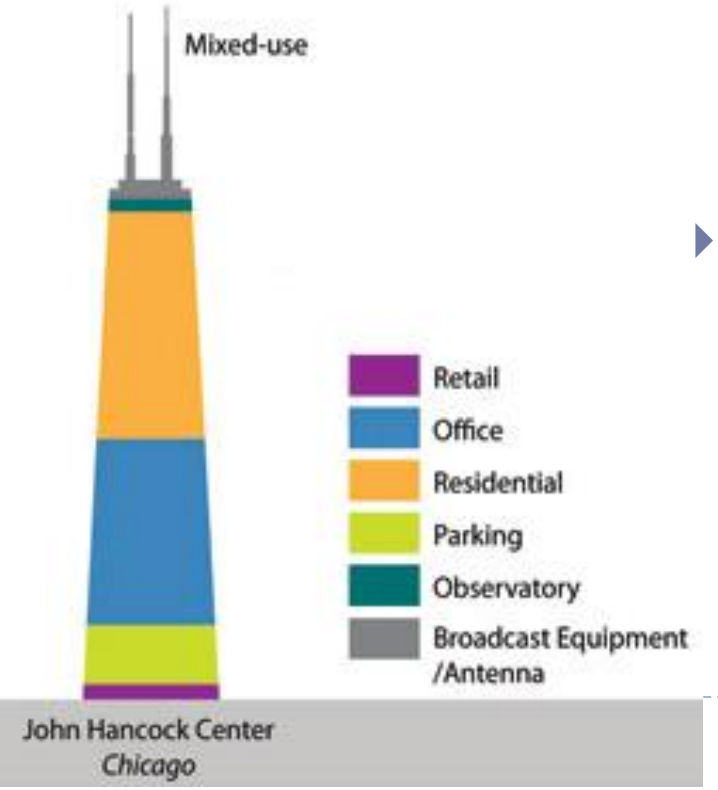
Importance of Building

- The structural design marked an evolution in the design of structural systems for skyscrapers
- The John Hancock Center was the first "trussed tube" structure utilizing exoskeletal members

Design Concept

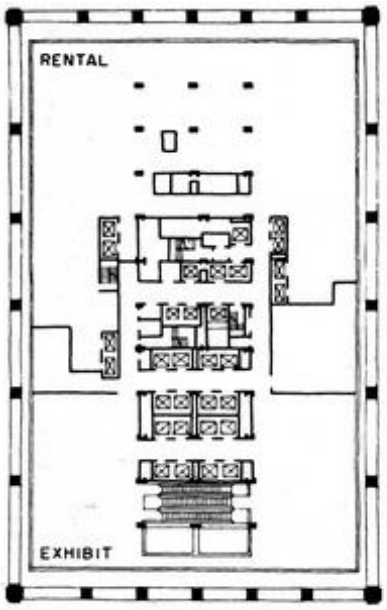
- 100 stories above the ground
- 343.7 meter / 1128 feet tall
- 2,799,973 sq ft Floor area
- 896,980 square feet of office space
- 171,771 square feet of retail space.
- 49 floors are dedicated to 700 residential condominiums.

Design Concept

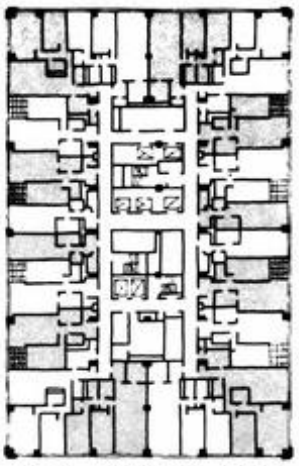


- A true architectural aesthetic form must express the nature of itself
  - Two separate towers; A 70 story office building and a separate 45 story residential building.
  - One of the few mixed use high rises
- Gently Tapered and inward sloped façade
  - Increased visual verticality of the building; adding perceived height
  - Optimum floor plan size
  - Reduced wind loads

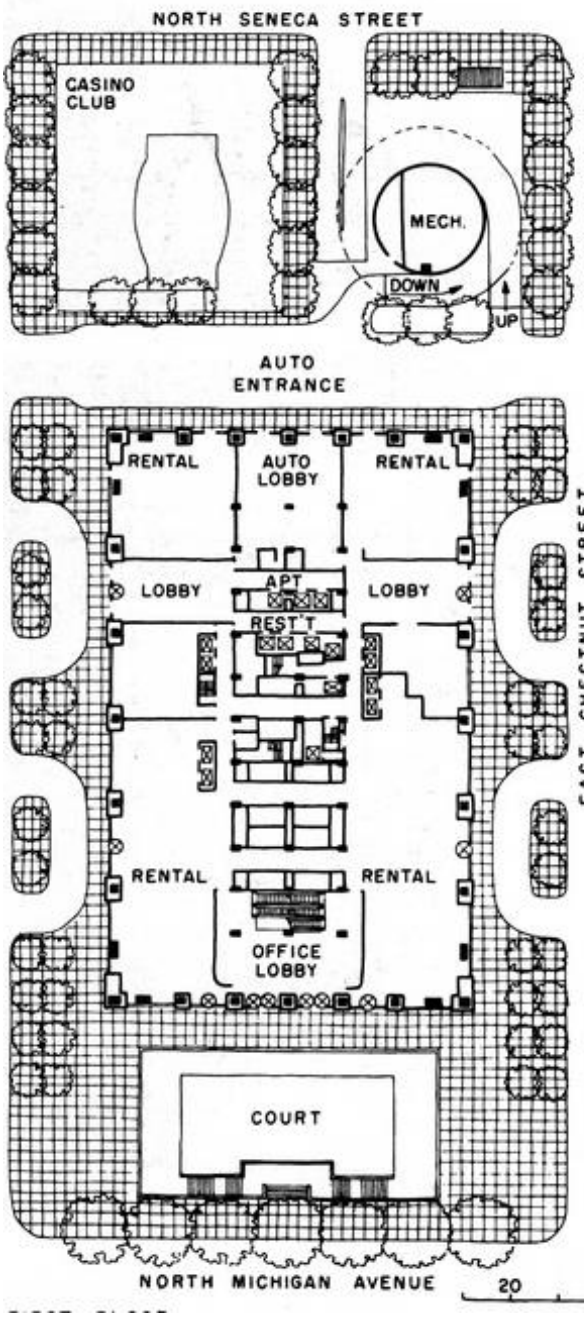
Diagonals & Interior

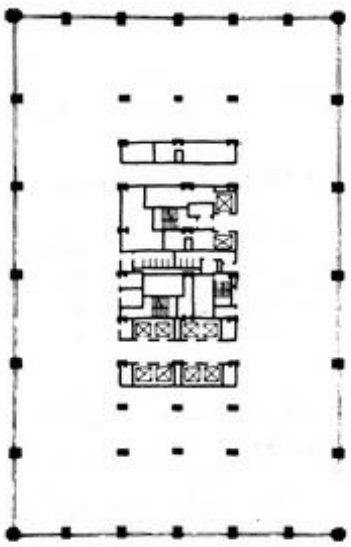


SECOND FLOOR

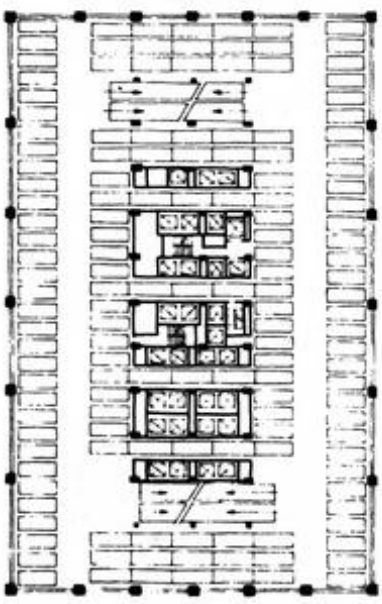


TYPICAL APARTMENT FLOOR





TYPICAL OFFICE FLOOR



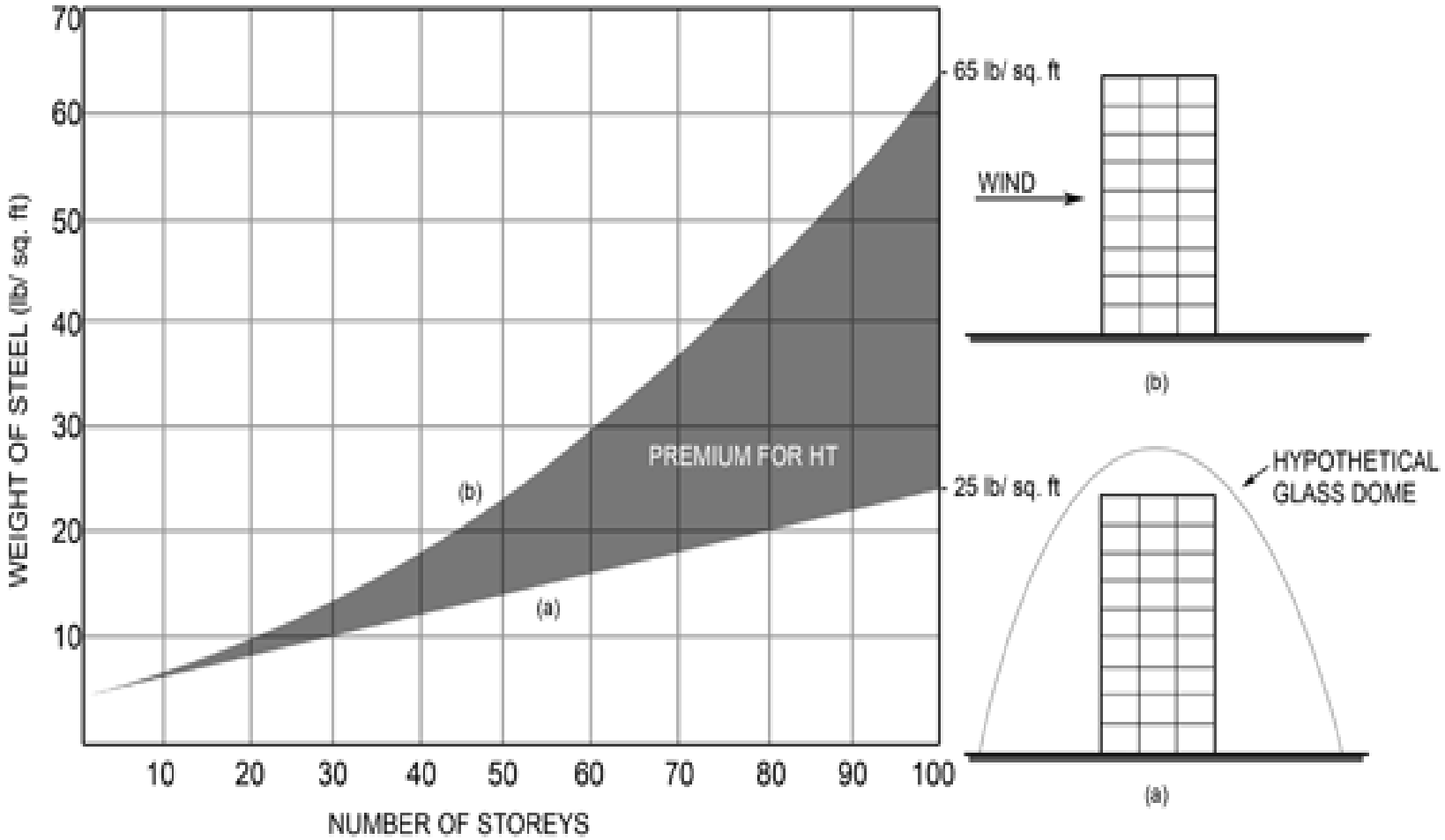
TYPICAL PARKING FLOOR

Innovations and Interesting Facts

- One of the **few** mixed use high-rises for the time
- Tapered shape the efficiency in
  - floor plans,
  - floor heights,
  - and steel usage ($15 mil)

- Provision of at least **12" higher interior** spaces by avoiding the conventional usage of concrete slab ceilings
- The very first use of the trussed tube system with concern to height premium and shear lag concepts

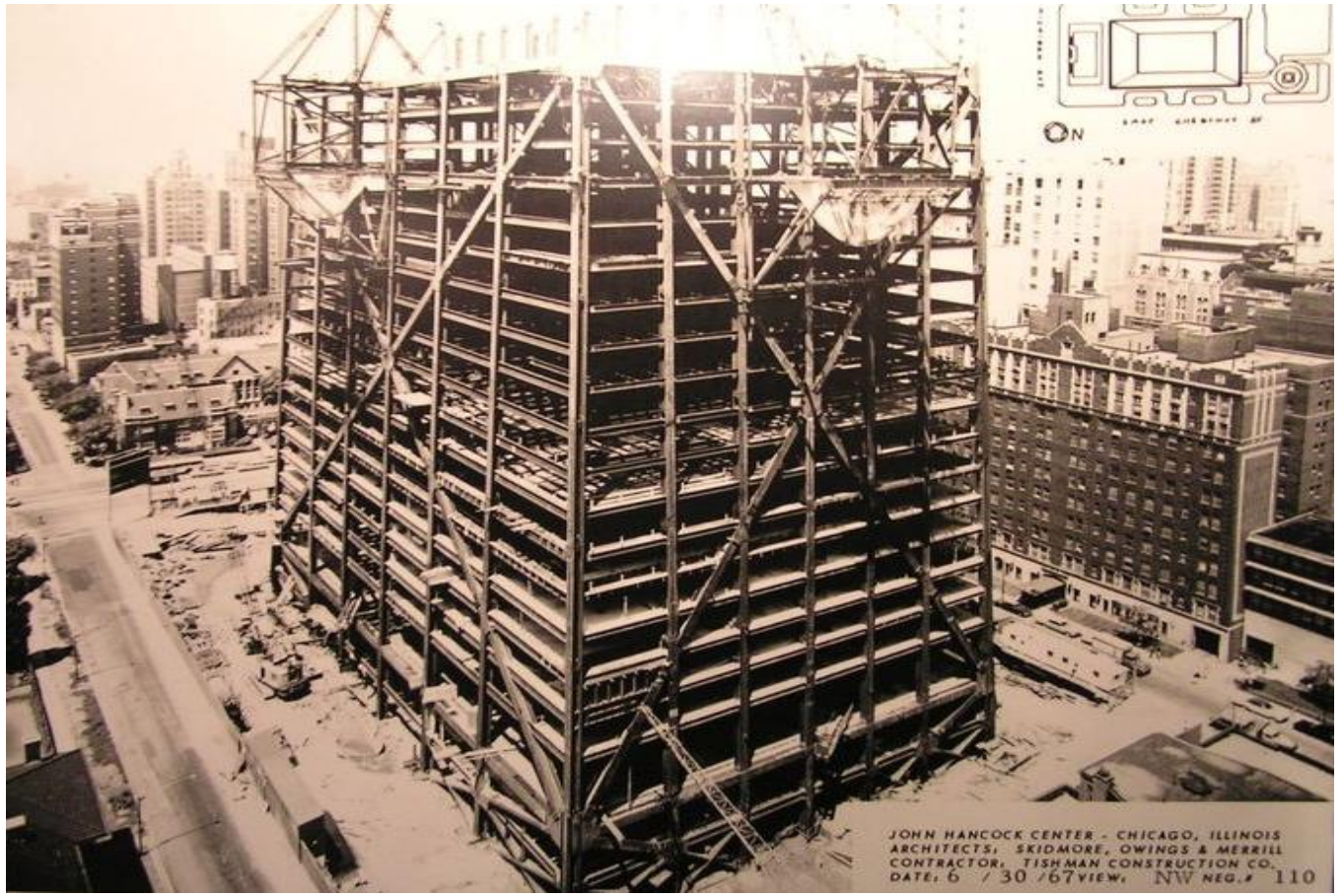
Structural Height Premium



Precedents

Plaza at DeWitt
Location: Chicago
Architect: SOM
Engineer: SOM
Start of Construction: **1963**
Completion: 1965
Height: 373ft
Number of Floors: 43
Material: Concrete

Tall Buildings

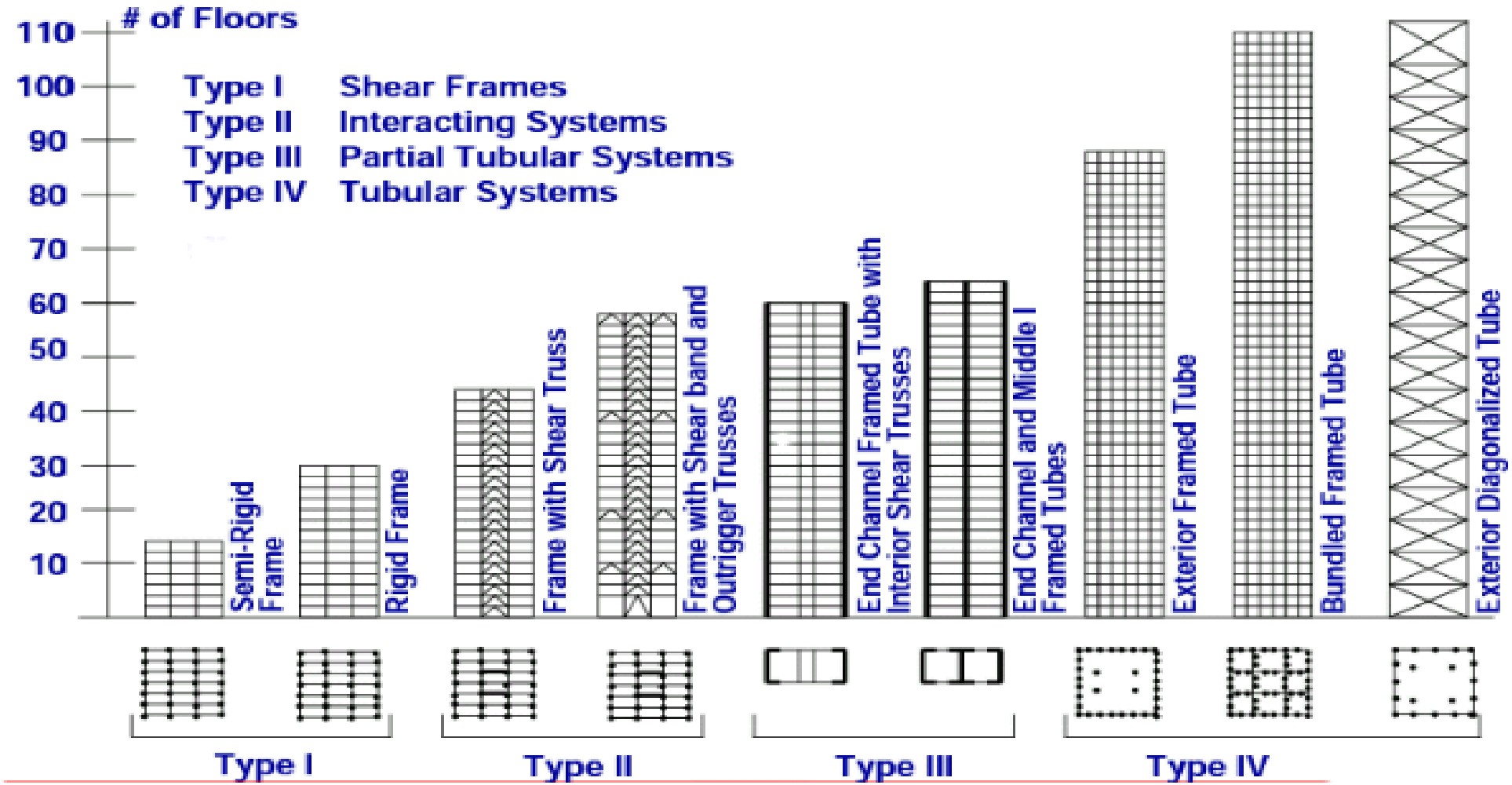


- "Harmony between structure and architectural form is the key to success of expression" (Ali, 990).
- Architecture as Structural art and express their structure with clarity.
- "The John Hancock Center design is surely rooted in constructional reality" (Sev, 19)

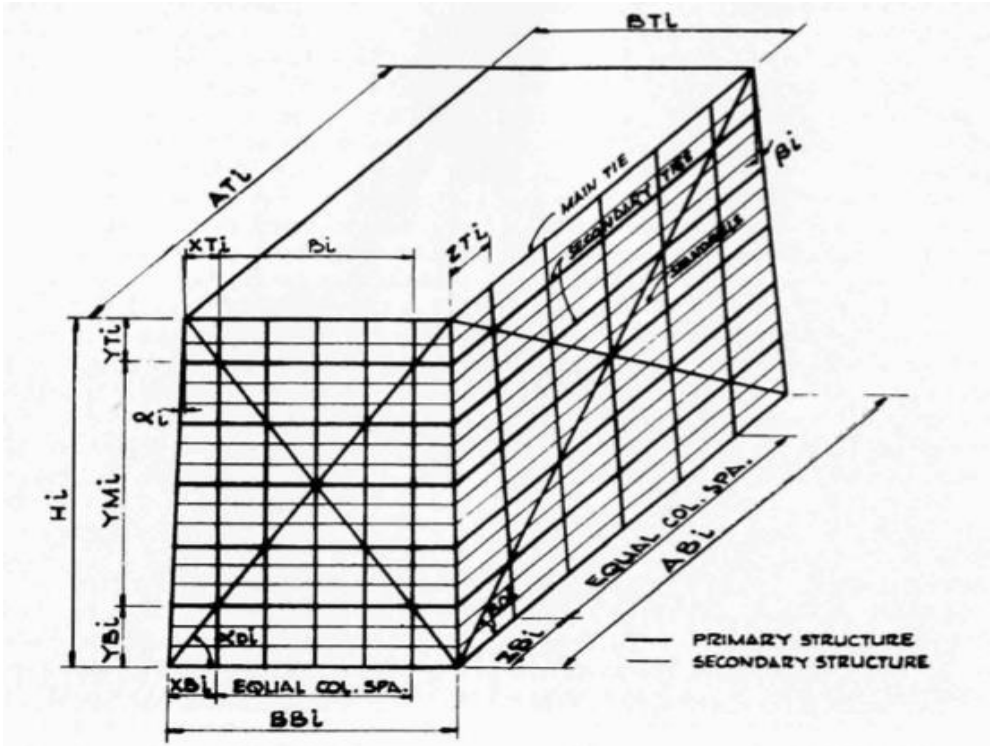
Innovation of the Tubes

- Creator of the tubed structure 1963. Father of tubular designs for high rises
- Defined as: "a three dimensional space structure composed of three, four or possibly more frames, braced frames, or shear walls, joined at or near their edges to form a vertical tube-like structural system capable of resisting lateral forces in any direction by cantilevering from the foundation" (Evolution of Skyscrapers)

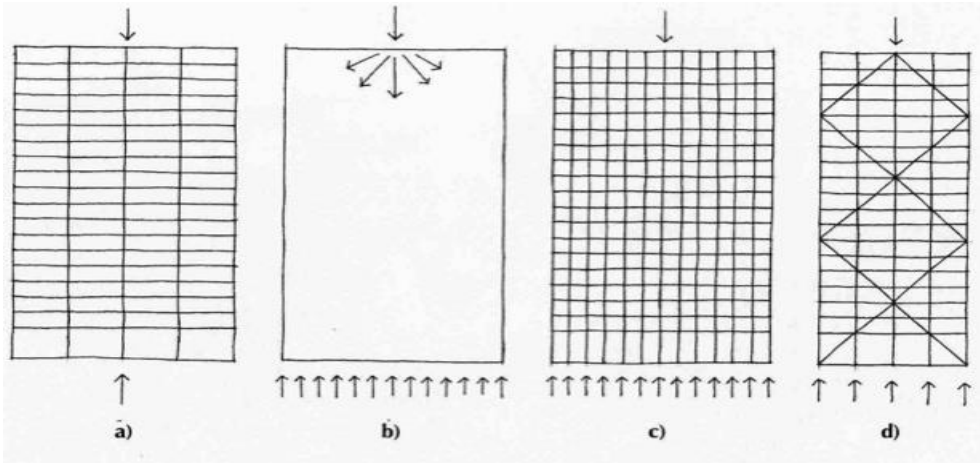
Evolution of Structural Systems



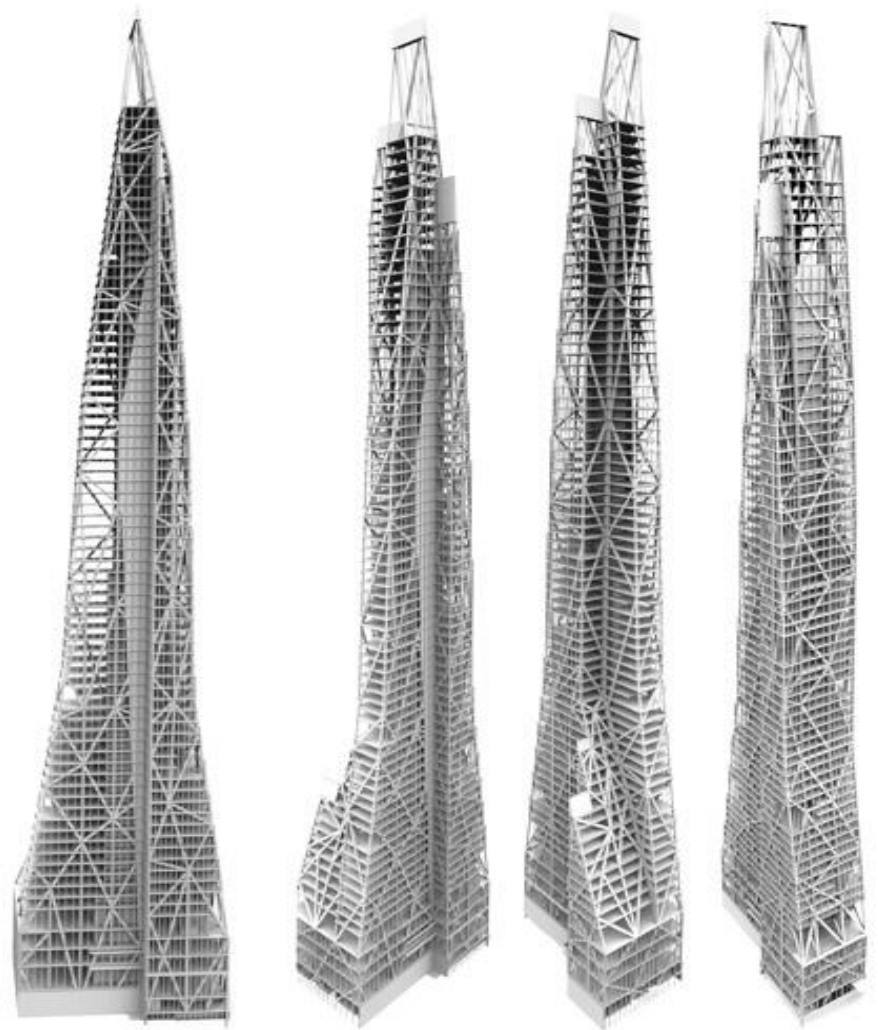
Tubed Structures



- **Advantages of Trussed Tube form:**



Advancement



Foundation

- **Composite** Foundation System comprised of

  - Basement **Concrete Slab**
  - **Compacted** Soil
  - Gridded **two way** Concrete Slab
  - 239 **Caissons**

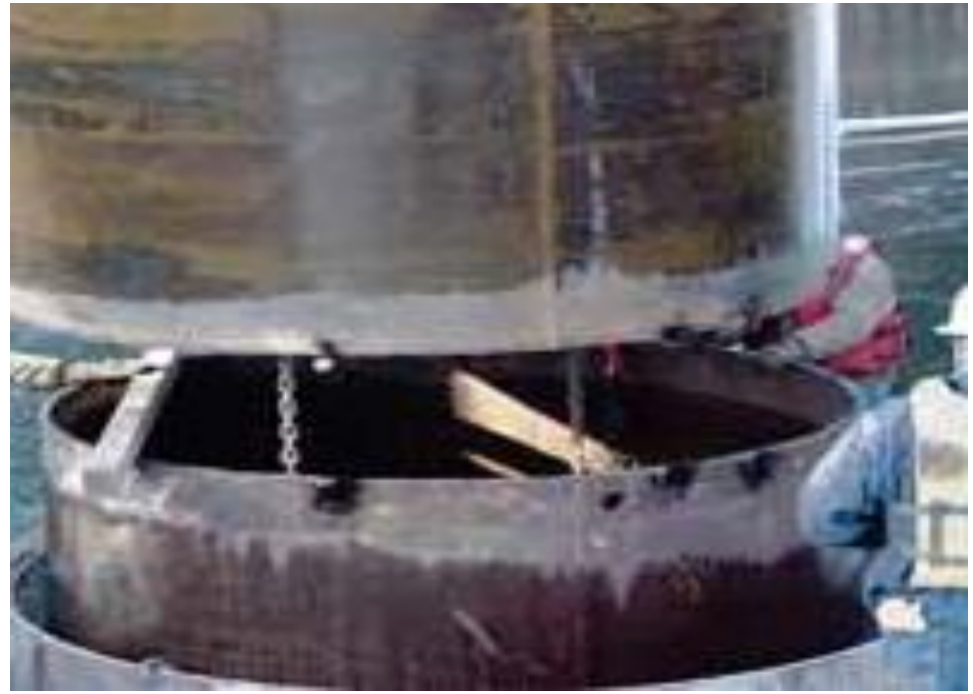
Soil Conditions

- **Clay** soils (former lake-bed) with low bearing capacity
- Bedrock **120 -190 feet** below grade with much, much greater bearing capacity

Caisson Construction Issues

- **Steel tubes** used to retain soil and water as **caisson holes** excavated
- As concrete was poured, the tubes were removed for **re-use**
- Some concrete was pulled up with the steel, leaving voids that was filled with water or soil
- Settling during construction caused all caissons to be **tested** and 26 received **corrective** work


JOHN HANCOCK CENTER - CHICAGO, ILLINOIS
ARCHITECTS: SKIDMORE, OWINGS & MERRILL
CONTRACTOR: FISHMAN CONSTRUCTION CO.
DATE: 8/17/66 VIEW: NE NEG.# 46F
CAISSON D-11



Lateral Loads

Wind load:

- Consulted with meteorologists and researched data from the U.S. Weather Bureau
- Factor of **1.25 above** the municipal Chicago building code of that time.
- The building's tapered form helps **reduce surface**/wind loads

Seismic Load:

- **low risk** seismic zone
- Khan later concluded system would be **too rigid** and **not sufficiently ductile** for use in high seismic zones

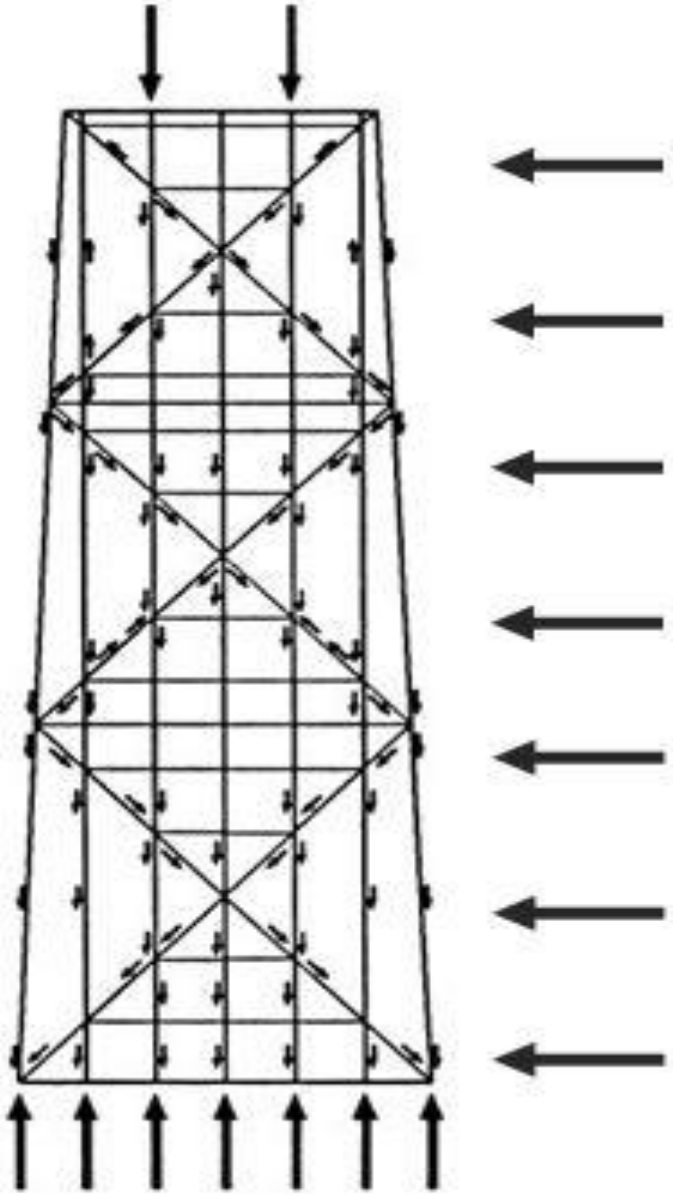
Load Resistance

Trussed tube system handles the **lateral loads** on the **exterior** of the building

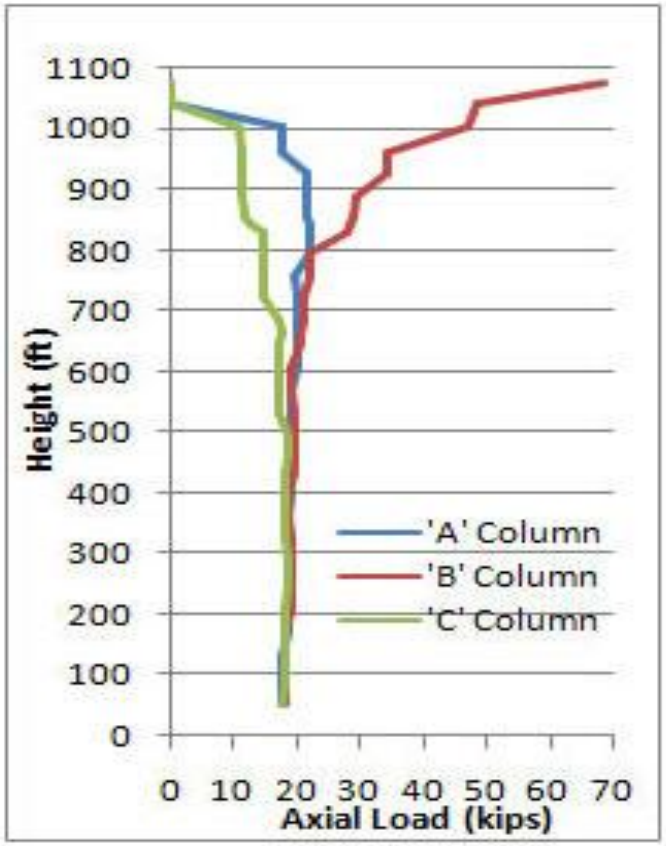
Efficient because the diagonal bracing **redistributes** lateral loads **evenly** to the **exterior columns**

Without the cross-bracing, the columns would act more independently and there would be significant difference in the loads that they carry

Figure shows how forces are redistributed at the column, diagonal and spandrel intersections



Load Resistance



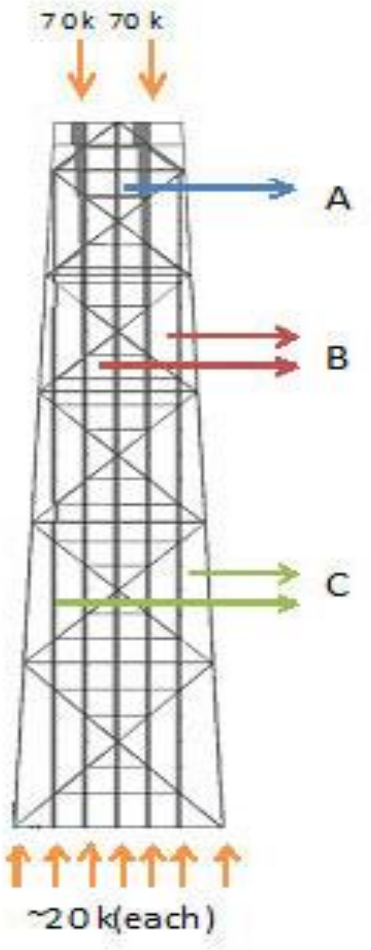
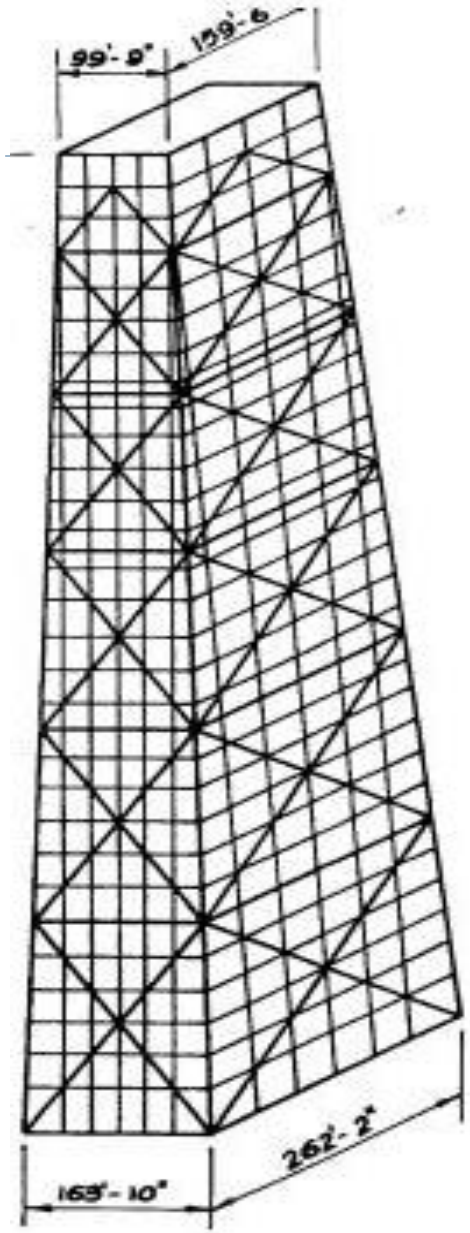


Figure illustrates how a hypothetical load is **redistributed** as it goes down the structure where ultimately **each column** ends up carrying a **similar load**

Lateral loads and vertical loads are **integrated by** the diagonal **cross-bracing**

Spandrel beams are also helpful in redistributing **lateral** and **gravity** loads to the columns



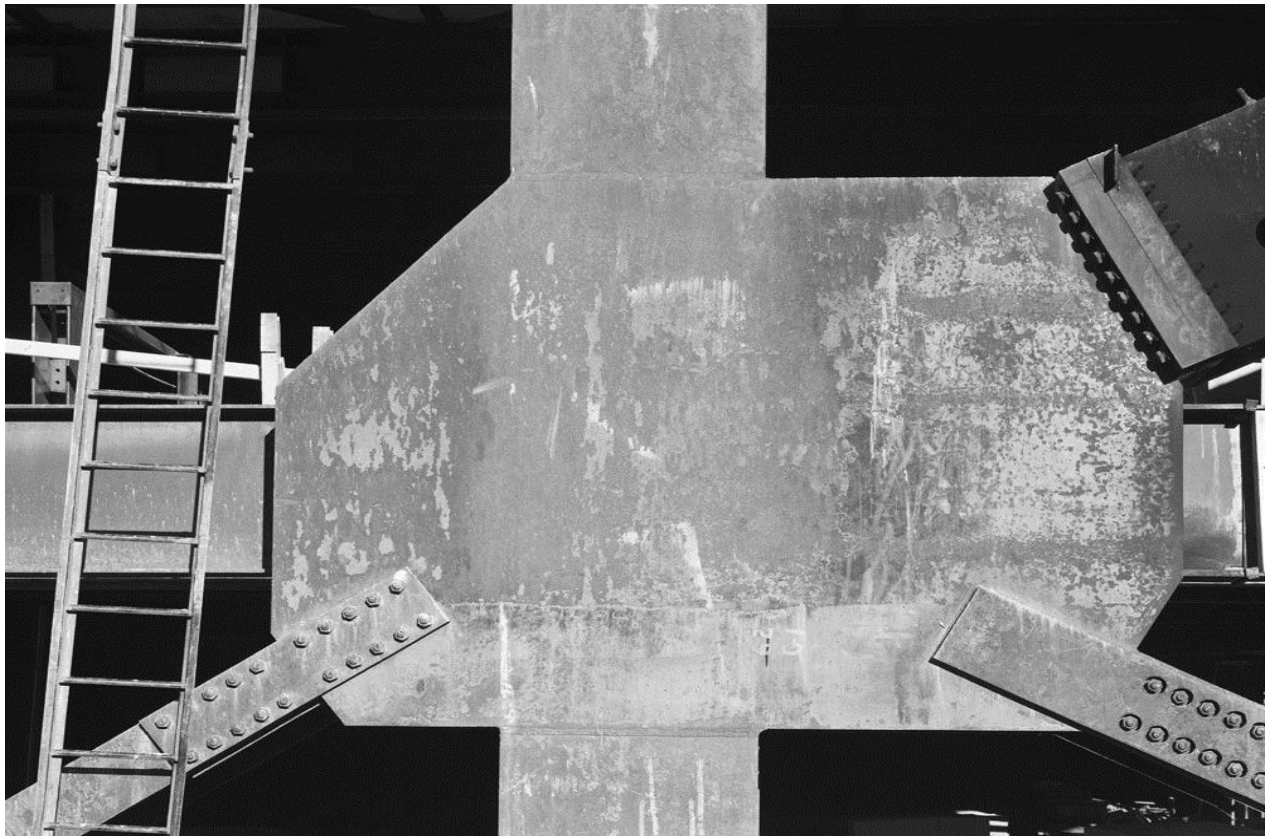
Load resistance

Vortex shedding frequencies wouldn't be able to come together to produce an effective amount of **dynamic force**

Connection Details

Heavy **gusset plates** tie the diagonal bracing, columns, and spandrel beams together

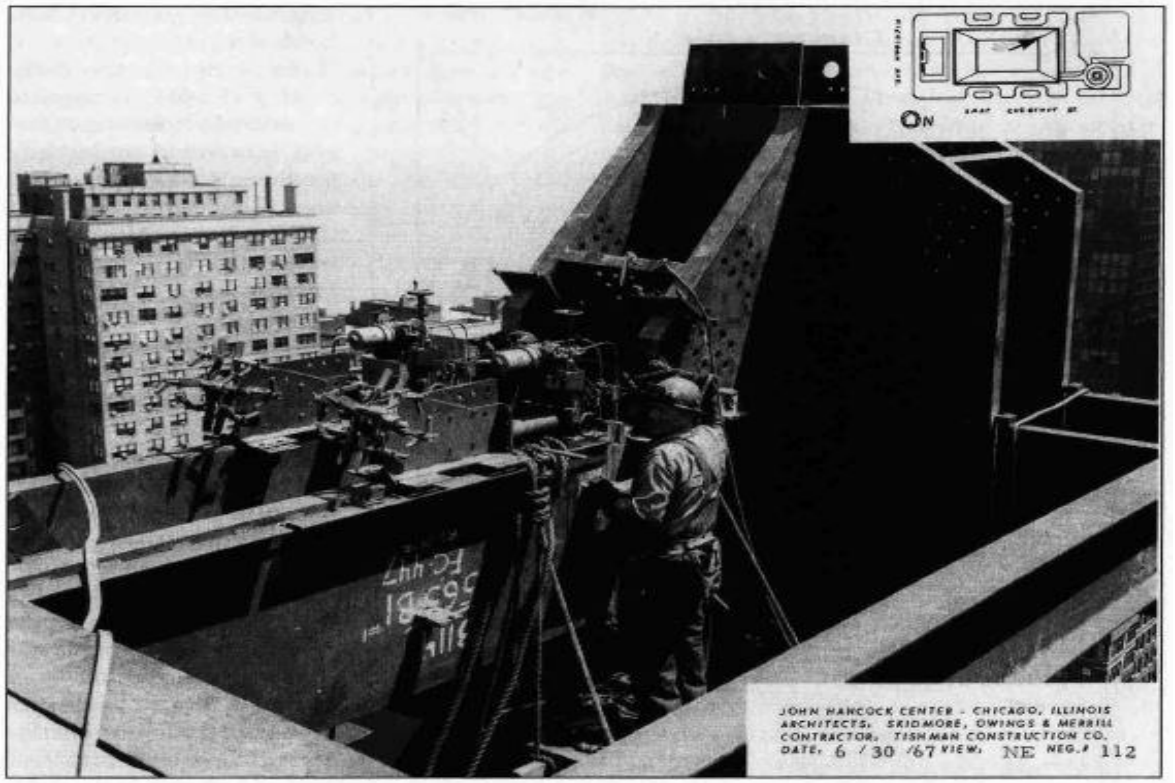
Members are **ASTM A36 steel** and gusset plates are **ASTM A441**



Connection Details

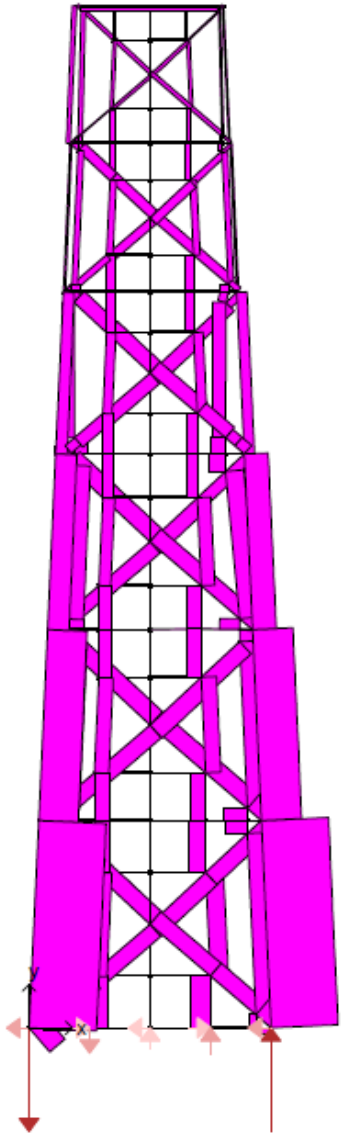
Avoided field welding by **prefabricating** the joint assemblies

Bolted the wide flange members in place

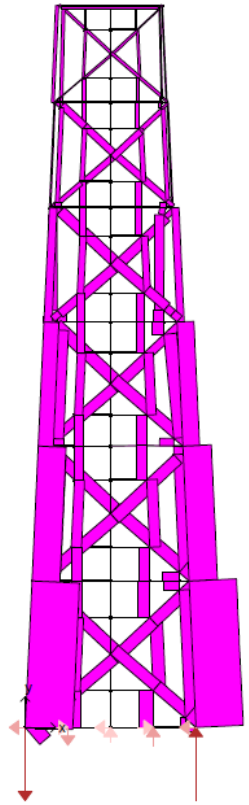


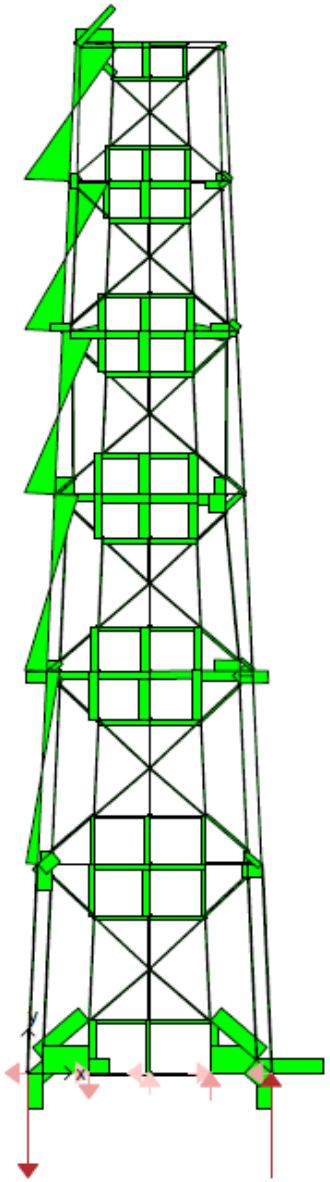
This construction photo reveals the scale of the prefabricated main joints. (Courtesy of Skidmore, Owings & Merrill LLP.)

Axial Stress Diagram

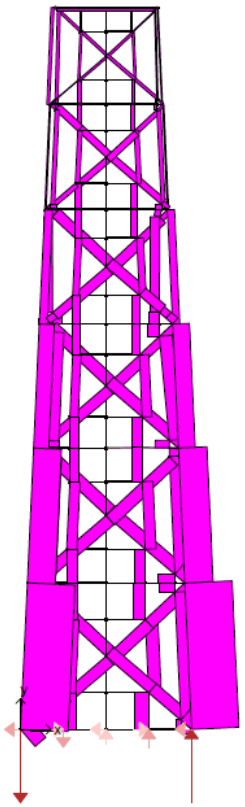


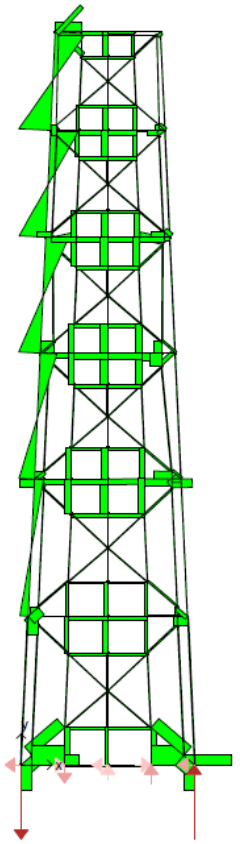
Shear Stress Diagram

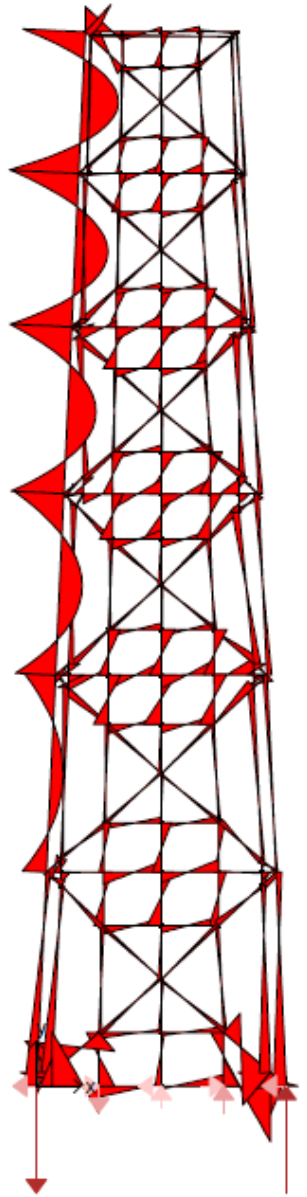




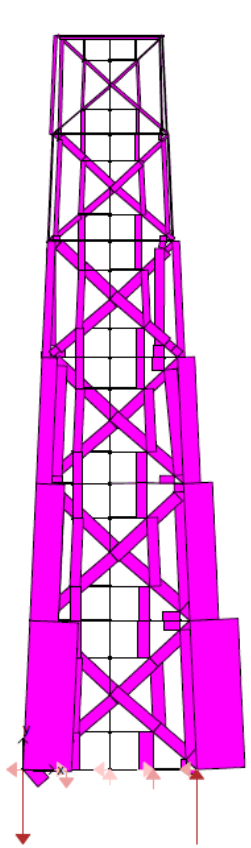
Moment Diagram

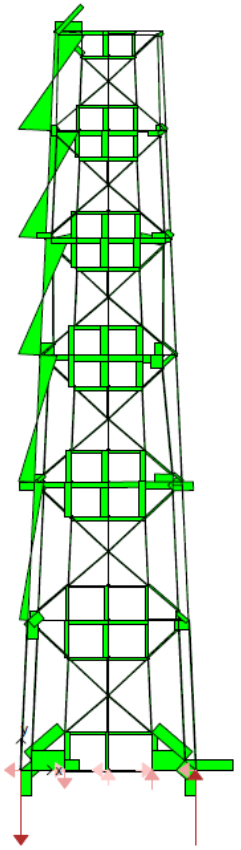


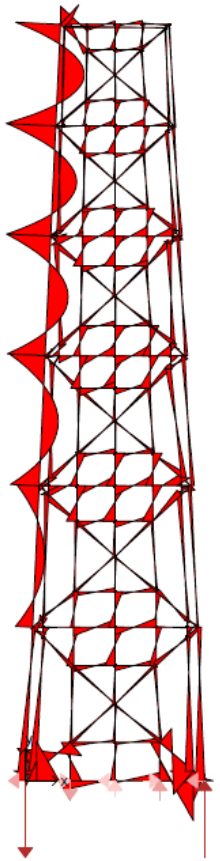


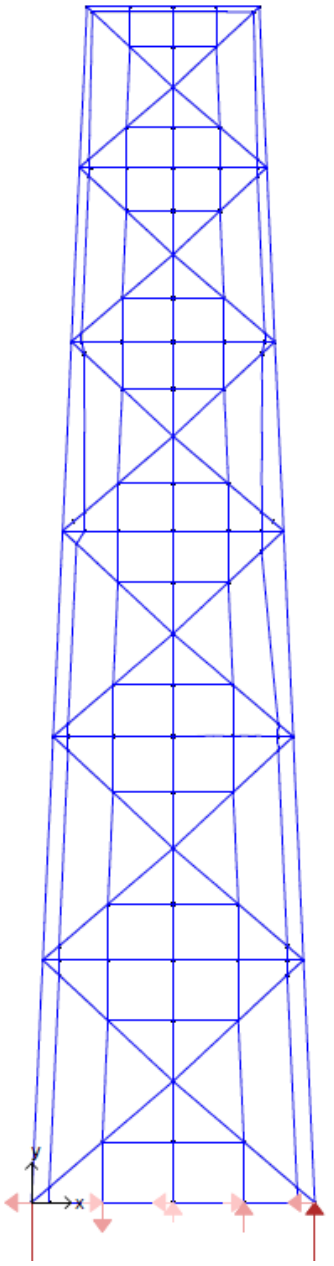


Deflection Diagram









Design Wind Pressure

- Initially set **20% past** the Chicago Building Code recommendation
- Later raised to **25%** due to disputes with the independent consultant
- Building members **analyzed** when wind loads twice the size of the Chicago building code recommendation were applied to the structure
- Checked the Gravity Loads at the same time to make sure the members would not yield or buckle

Movement And Vibration

- **No standards** for movement and vibration criteria in reference to wind load in **1965**
- Few studies had been done by 1965 on **movement** or **vibration**
- Khan **tested eight subjects** to see how they were affected by differing levels of motion
- Used 2 **accelerometers** to move the floor and found at which point the subjects could **feel** the **motion**
- Khan's **research** gave the owner and designers **confidence** in the future performance of the building

Conclusions

- "A building's natural strength should be expressed"
- The integration of structure and form made the John Hancock center an efficient and successfully building

Reference

1. Weingardt, Richard (2005) Engineering Legened ASCE Publication pg. 76
2. Sev, Aysin. Conuncil on Tall Buildings and Urban Habitat (2007): 27-31. Web.
3. Khan, Falzur. "The Trussed Tube John Hancock Center." Civil Engineering Practice 19.2 (2004): 7-28. Web.
4. Kahn, Yasmin Sabina. "The Trussed Tube: John Hancock Center."
5. Engineering Architecture the Vision of Fazlur R. Kahn.
6. New York: W. W. Norton & Company, 2004. 105-129. Print.
7. Foundation Analysis and Design Note Set 24.1 Pg. 4
8. Reflections on the Hancock Concept. Hal Iyengar. CTBUH Journal Issue 1, 2000. P51
9. Journal Title: Civil engineering practice, Volume: 19, Issue: 2, MonthNear: 2004, Pages: 7-28, Article Author: Khan, Article Title: The trussed tube John Hancock center
10. "SAN FRANCISCO | Transbay Transit Center Redevelopment Plan - SkyscraperPage Forum." *SkyscraperPage Forum RSS*. N.p., n.d. Web. 25 Nov. 2013. <http://forum.skyscraperpage.com/showthread.php?t=136300&page=5>.
11. Skidmore, Owings & Merrill. *John Hancock Center Exterior* . 1969. ARTstor Slide Gallery, University of California, San Diego, Chicago, Illinois. *ARTstor*. Web. 24 Nov. 2013.

11. ….

12. Fazlur Khan (1929-1982): Reflections on his life and works; Mufti, Aftab A;Bakht, Baidar; Canadian Journal of Civil Engineering;Apr 2002; 29, 2; ProQues; pg. 238

13. Ali, Mir M.. "The Tower of Strength." Art of the skyscraper: the genius of Fazlur Khan. New York: Rizzoli, 2001. 106-121. Print.

14. Bora, V.A.. John Hancock Center. 2011. John Hancock Center, Chicago, Illinois. City Profile. Web. 24 Nov. 2013.

15. Hursley, Timothy . The John Hancock Center. N.d. Skidmore, Owings & Merrill LLP, Chicago, Illinois . Plataforma Arquitectura. Web. 24 Nov. 2013.

16. K&S PhotoGraphics. Fazlur Khan and Bruce Graham with a model of the John Hancock Center. N.d. Skidmore, Owings & Merrill LLP, Chicago, Illinois. Lehigh University Fazlur R. Khan Distinguished Lecture Series. Web. 13 Nov. 1924.

17. Stoller, Ezra. The John Hancock Center. New York: Princeton Architectural Press, 2000. Print.

18. http://www.archdaily.com/333251/ detail photo

19. http://khan.princeton.edu/khanHancock.html