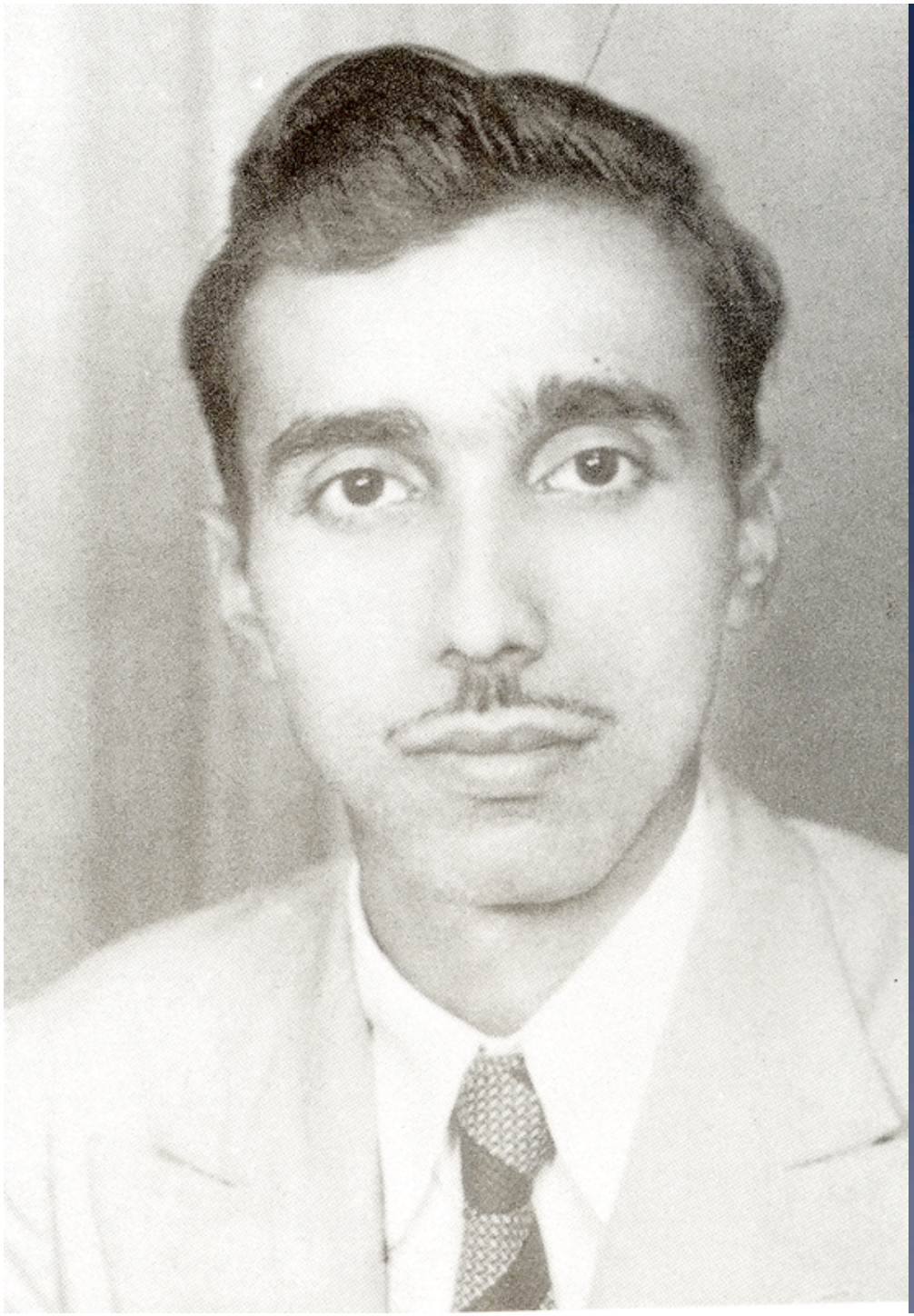
# Fazlur Kahn and the tall tube

Part One:

The vertical truss Eiffel never dreamed of



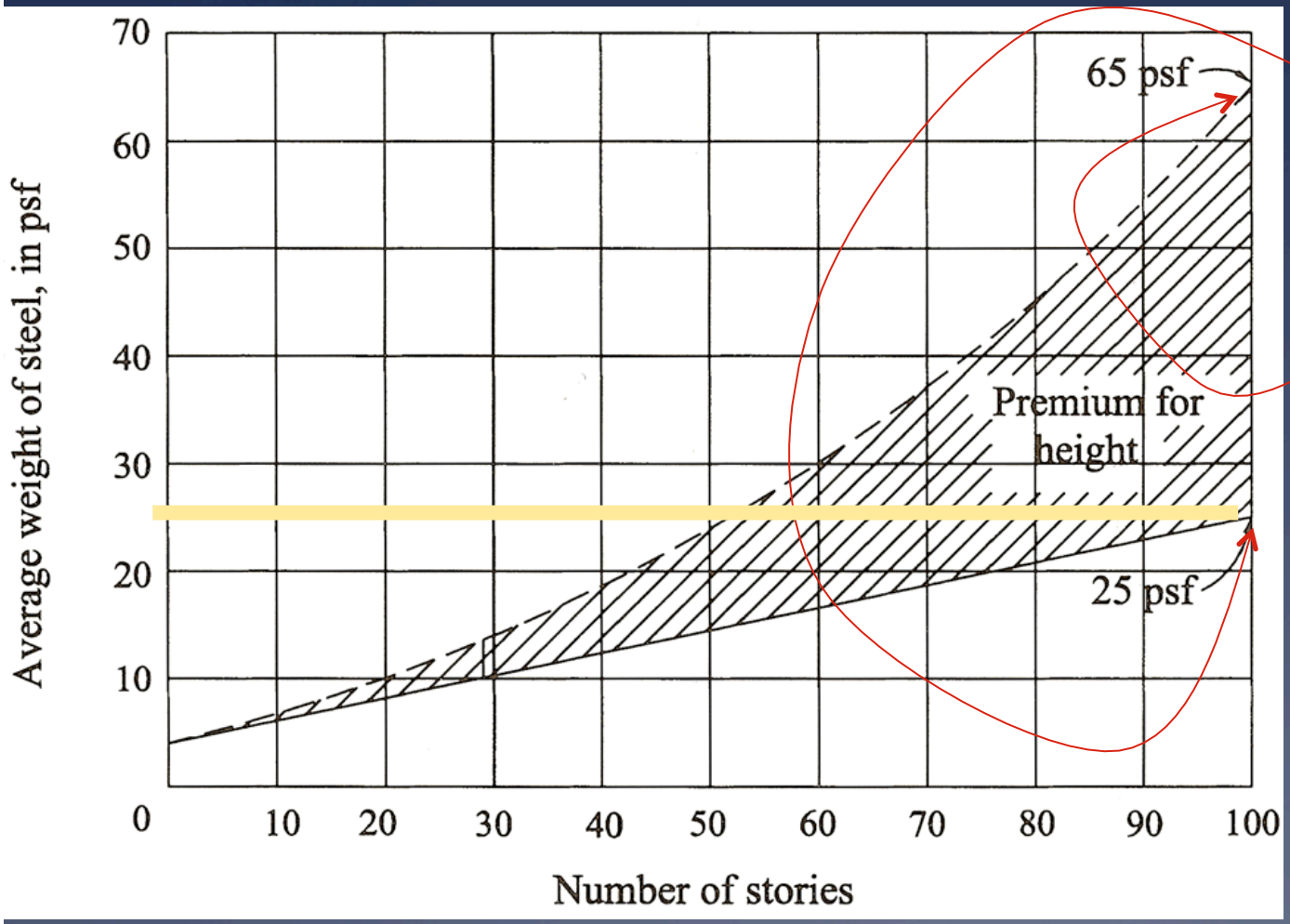
# Fazlur Kahn

* Born in Dhaka, Bangladesh
* Taught at University of Illinois
* Project engineer and partner, Skidmore Owings Merrill, SOM, Chicago

# Heavy Hitters

- Empire State, about 60 lbs of steel per s.f.
- Typical Chicago High Rise in 1960, 50 lbs of steel per s.f.

# The cost of wind...and seismic




- Gravity loads only require 25 pounds per s.f. of floor area for a 100 story building
- Depending on the design, lateral loads could add another 40 psf to stiffen the conventional steel frame

# 1965 Kahn's accidental discovery

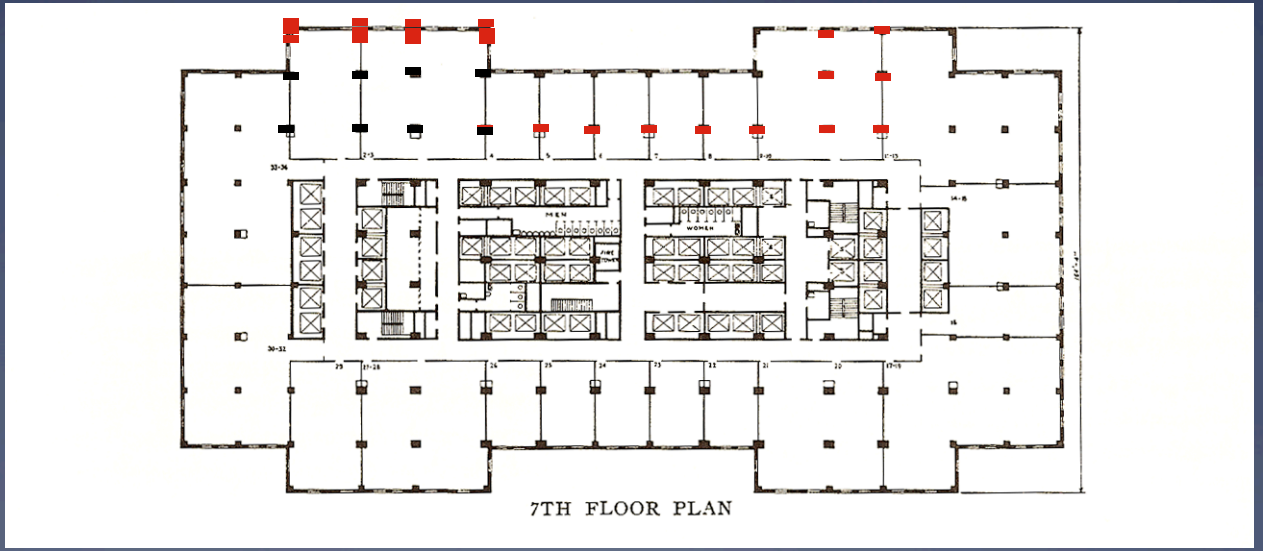
- Think of the wall of a high rise as a thin walled tube with punched holes as the exterior wall
- This led to framed-tube concept shown here in the concrete framed DeWitt-Chestnut Apartments 1965

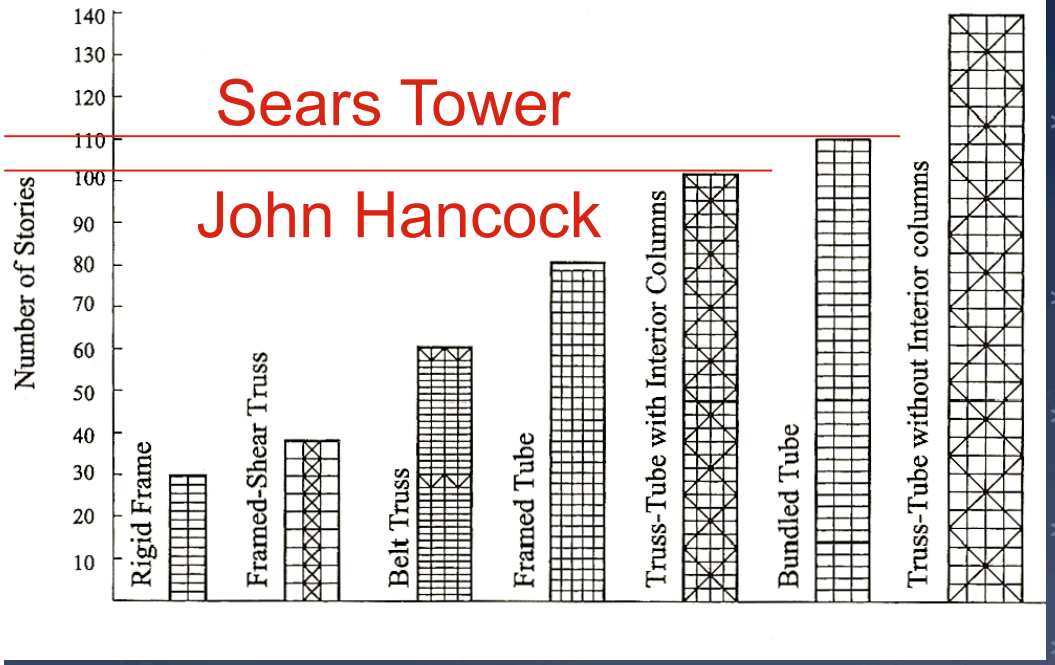
# Take out interior columns…the key to the efficiency of the tube

- Reverse intuitive but makes sense when you think about it.
  - Interior columns are sized to take gravity loads
  - Combining interior and exterior columns means exterior columns are "naturally" heavier….and now capable of taking the lateral load.
  - Brilliant, but not obvious

# Fewer columns=more load per column, heavier column resists wind

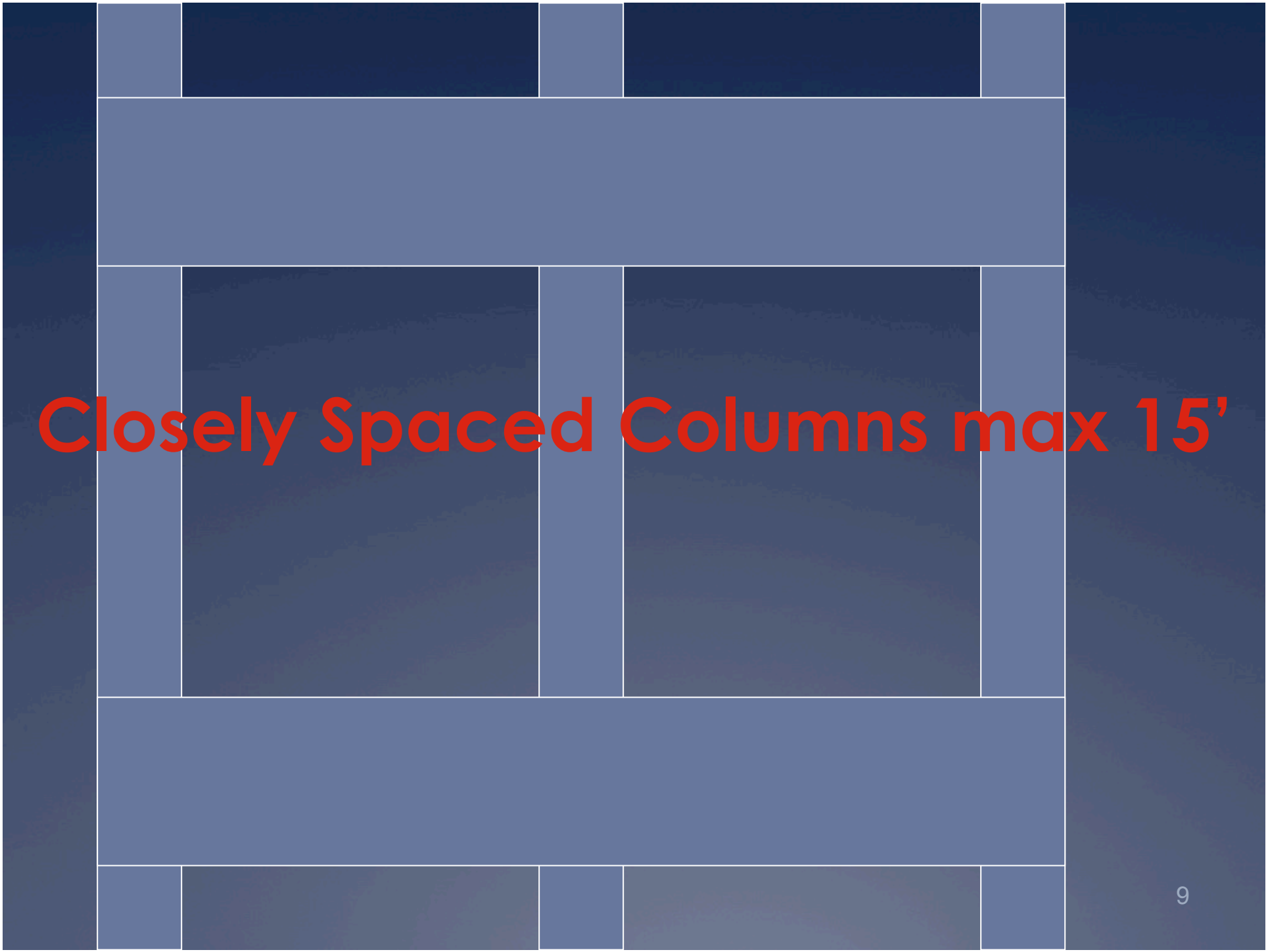
- Move interior columns to exterior to make columns naturally heavy enough to resist lateral loads



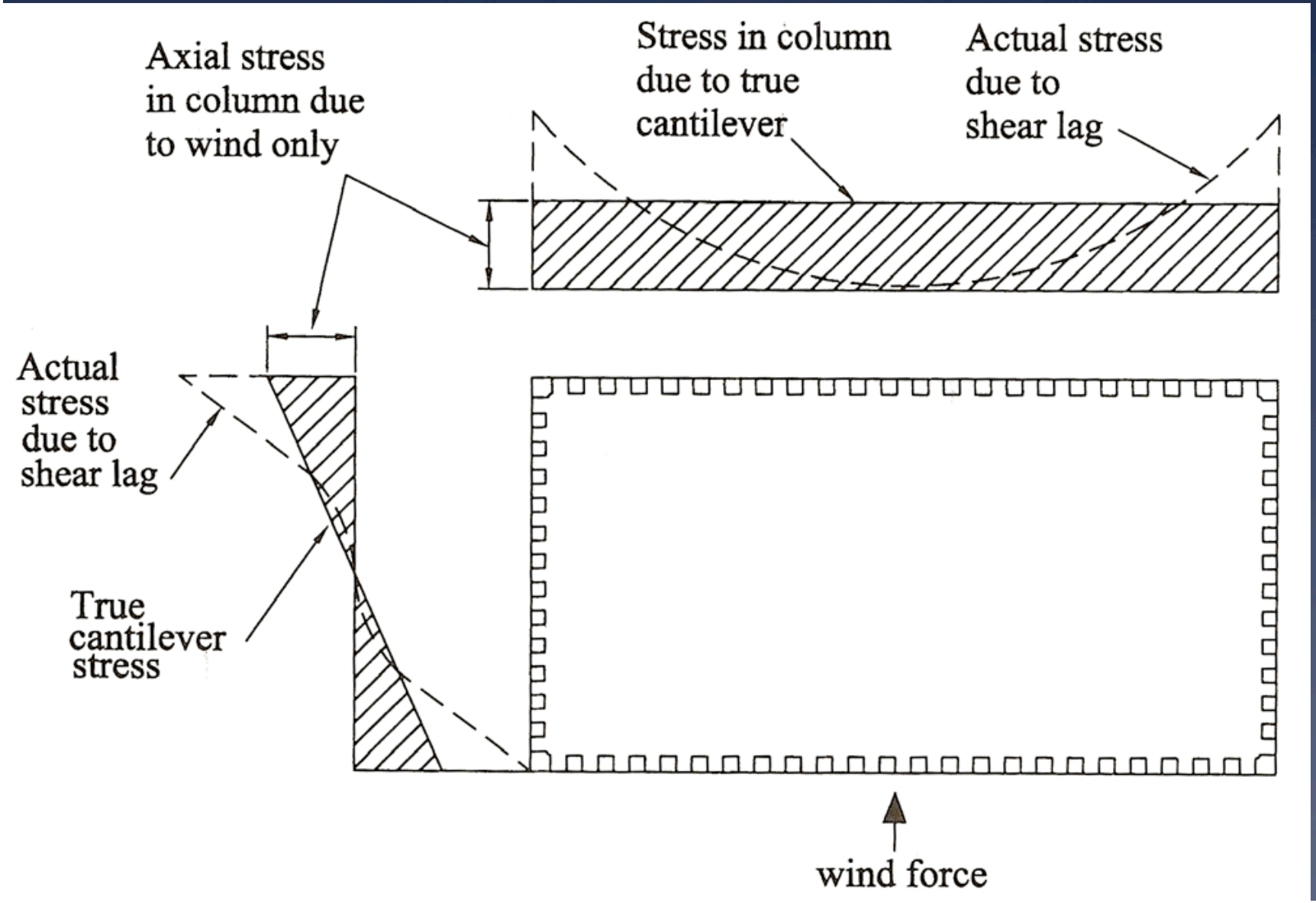


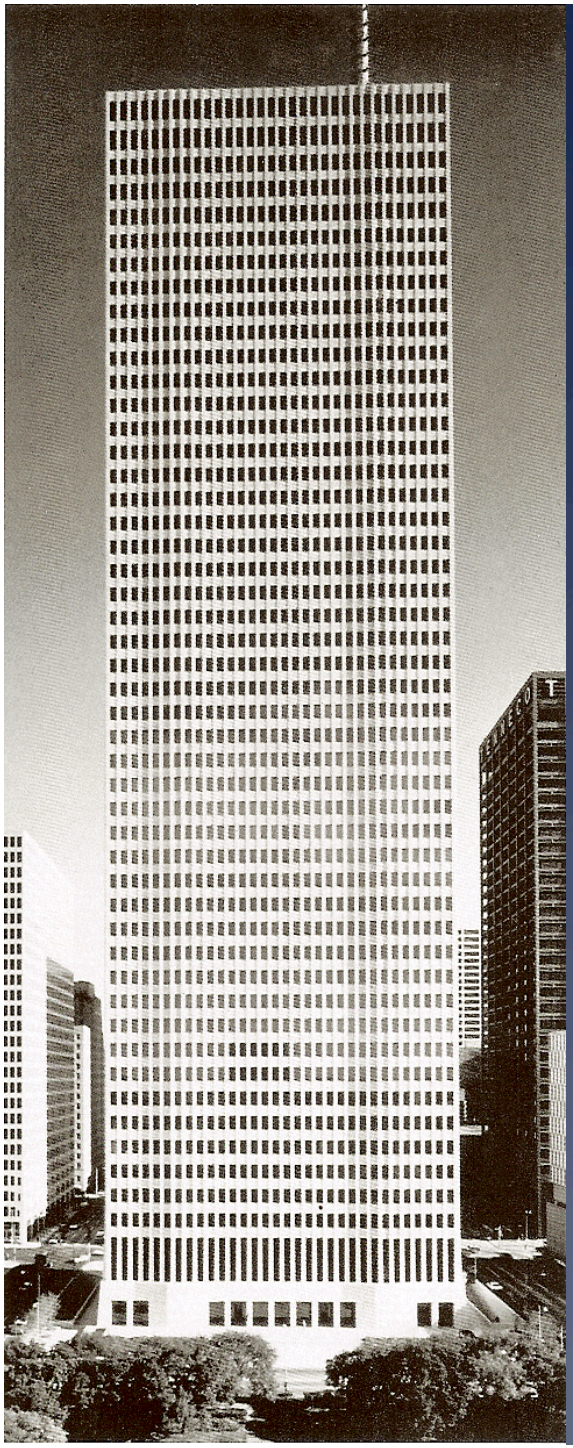

# Family capacity

- Kahn analyzed the capacity for various structural concepts and found the rigid frame began to pay a penalty above 30 floors
- Combining vertical trusses at the core could bring the rigid frame to 40 floors
- Adding belt trusses "stacked" rigid frames to reach 60 floors
- The whole exterior wall as a load bearing tube could reach 80 floors
- Trussing the exterior walls of a tube with some interior columns could reach over 100 floors
- Bundling Tubes could reach 110 floors
- A truss tube without interior columns could reach 140 floors


Closely Spaced Columns max 15’

# A unique tube behavior more force at the columns

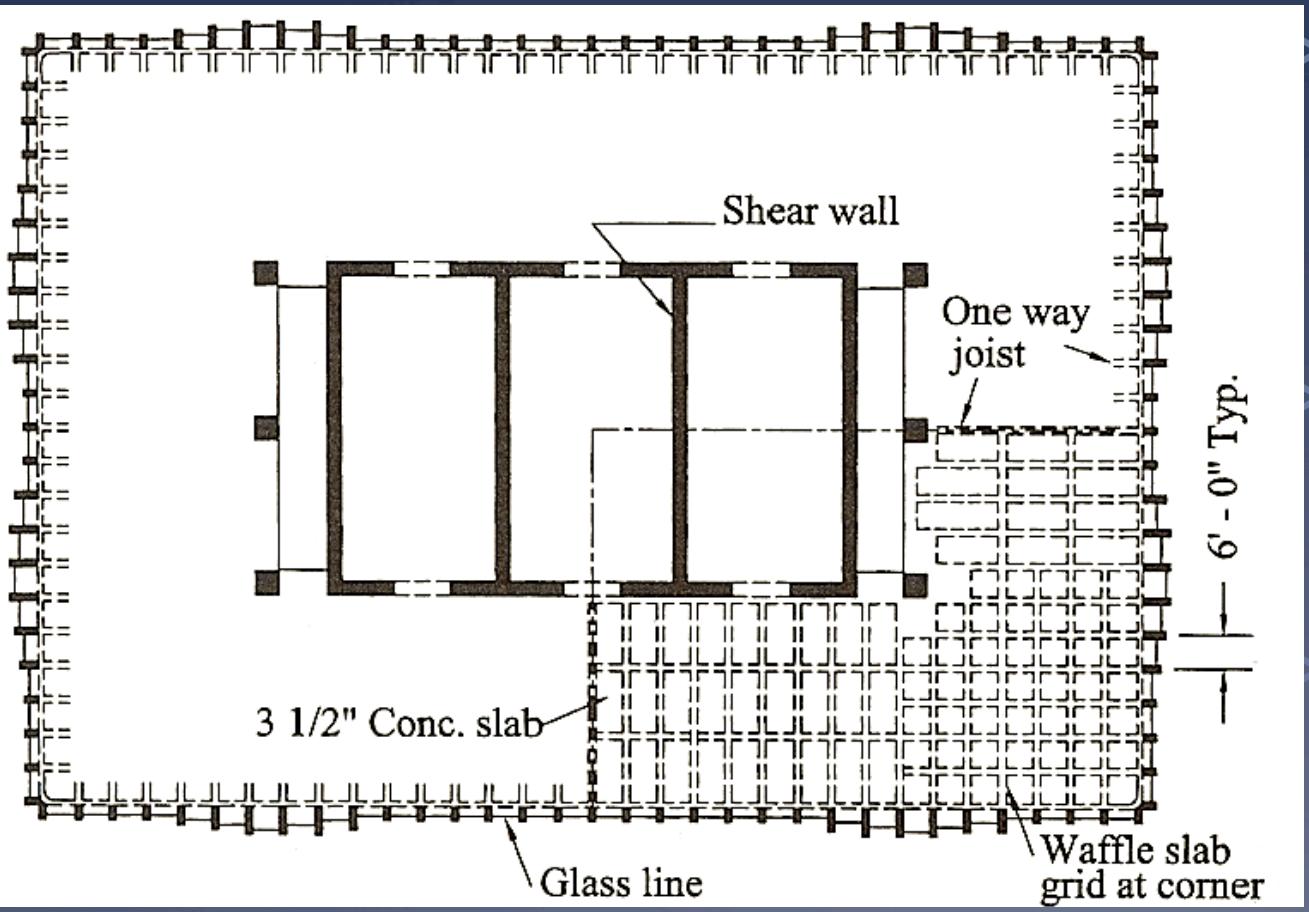




# One Shell Plaza 1971

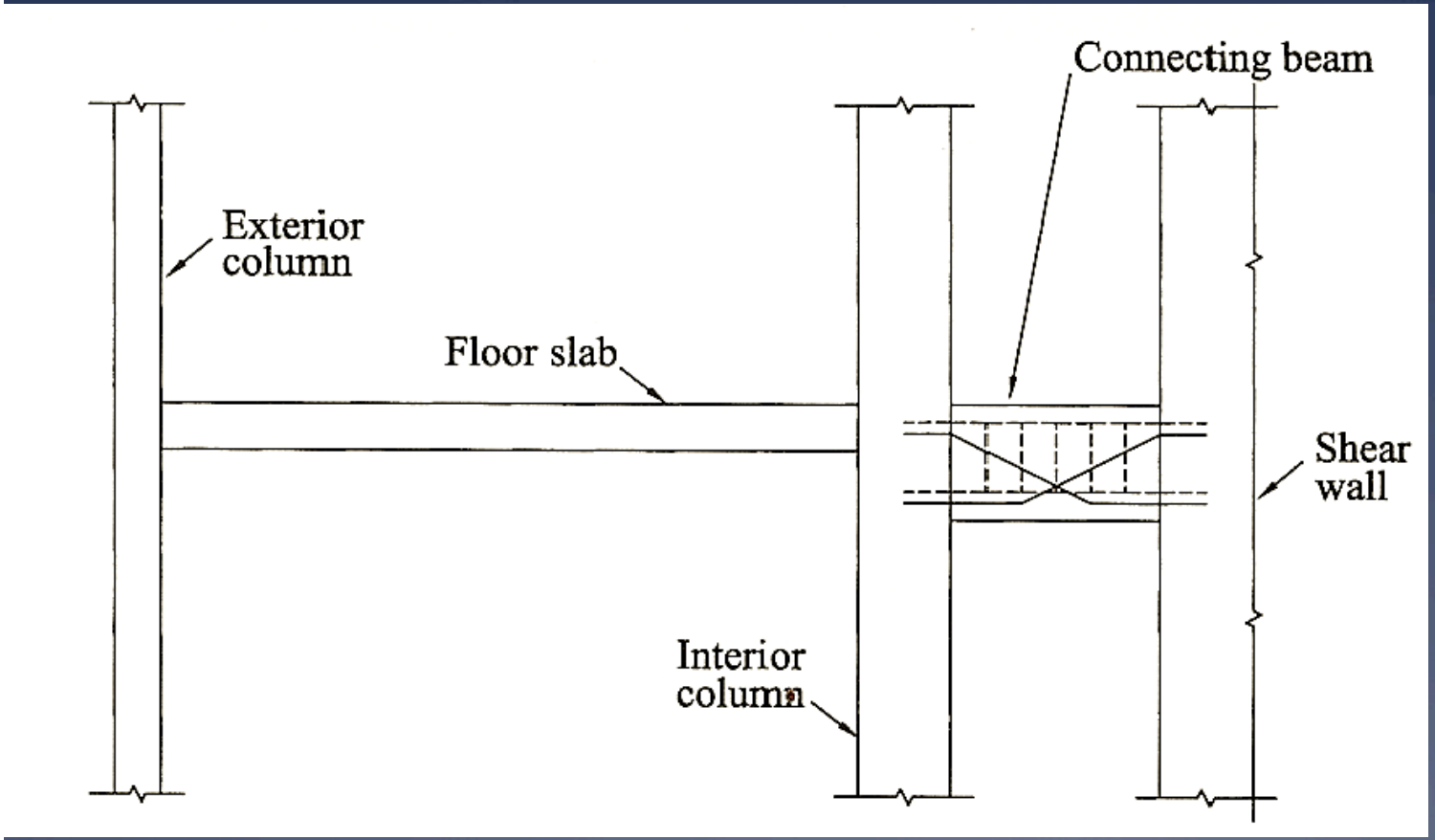
- Column dimensions vary from edge to center
- Glass follows face of column to make undulating facade

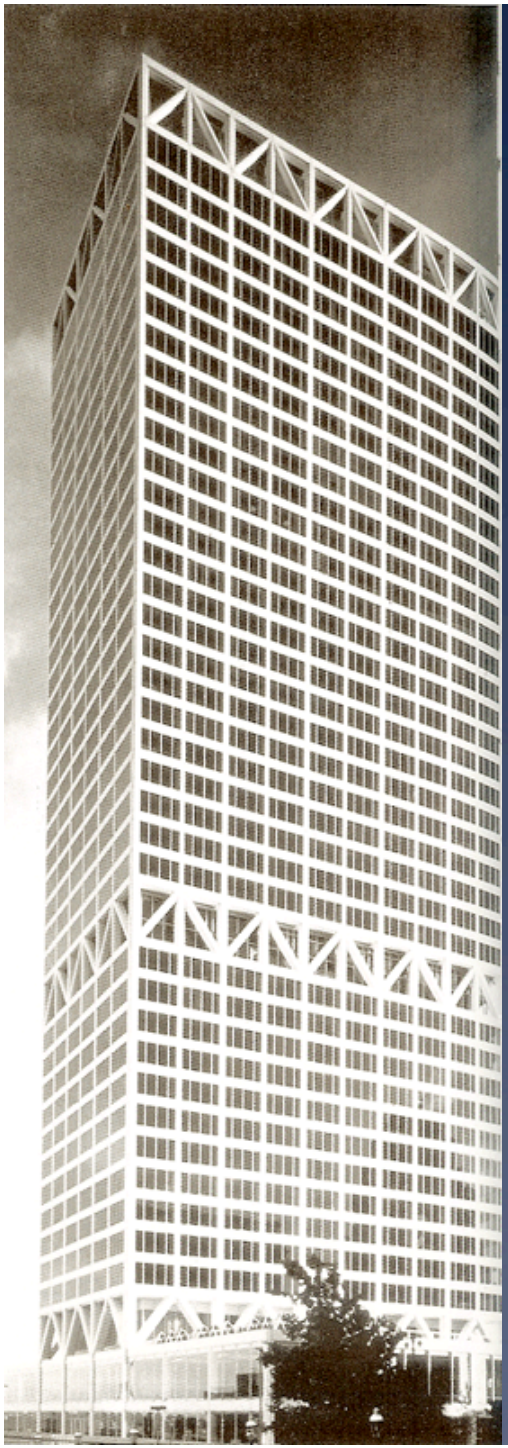
# Concrete Tube in Concrete Framed-Tube




- Shear core linked to tube through stiff floor
- Stronger corners with waffle slab
- Deeper columns at corners

# Floor transfers lateral to core



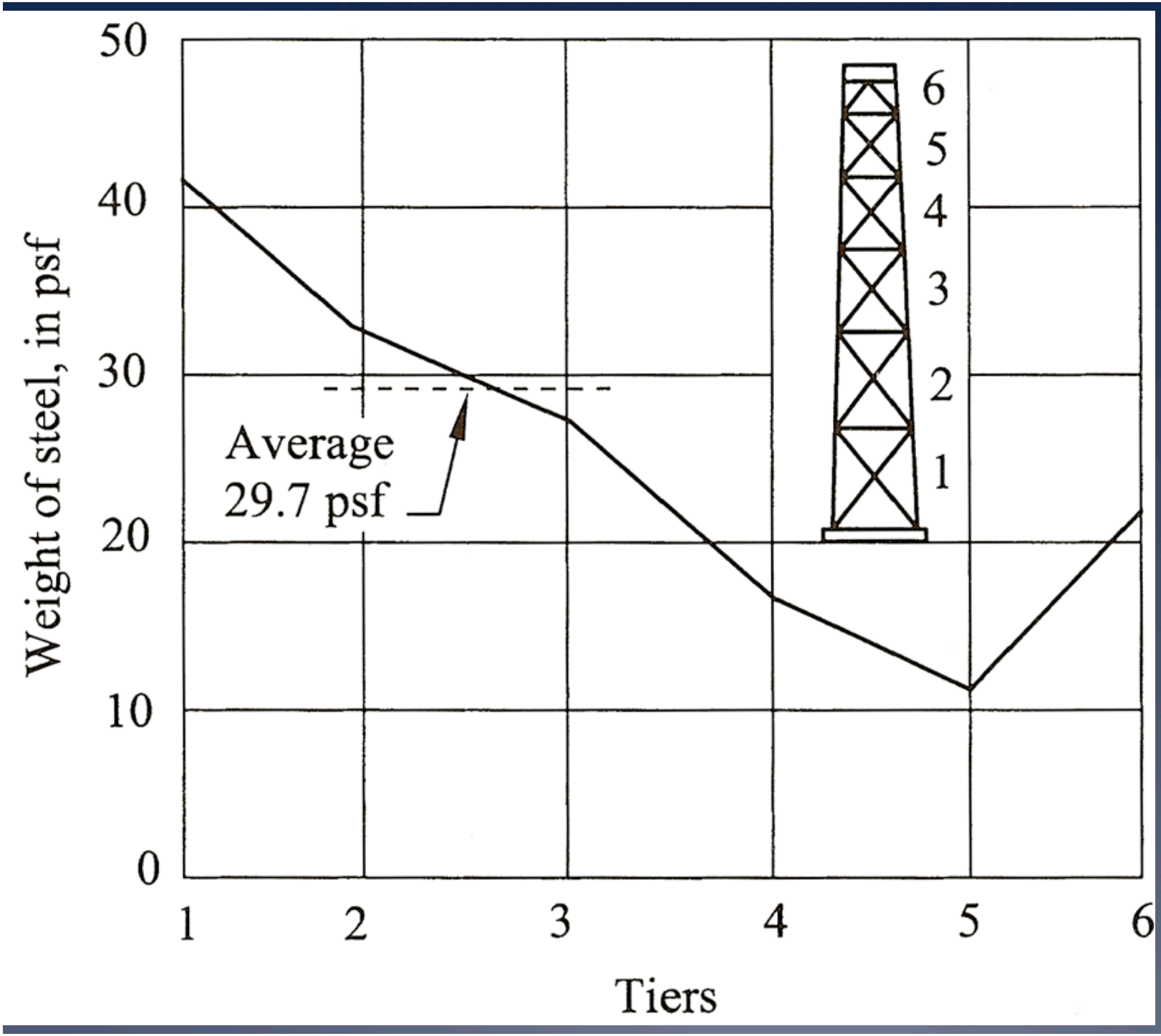


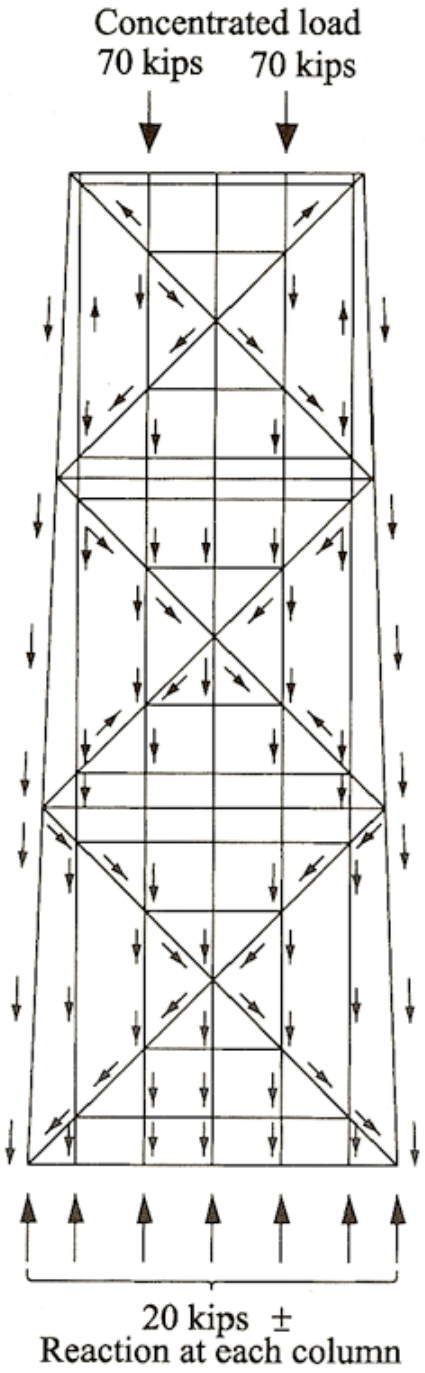
# 1973 First Wisconsin Center

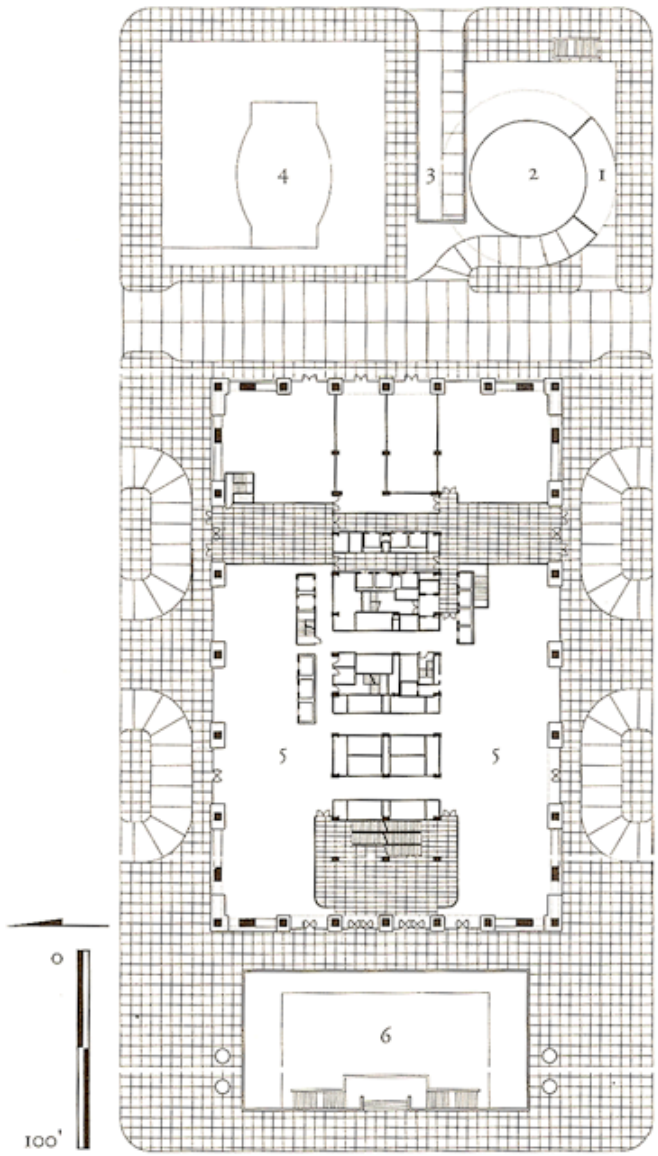
- Belt truss innovation to make building into two stacked rigid frames
  - To reduce  the shear lag
- Belt truss floors became mechanical unit spaces

# Radical in our midst: 1970 John Hancock

- 29.7 lbs of steel per s.f.
- 40% less
- 40% savings
- Twice the height - 100 floors (1,500 ft to antenna top)
- Frame drifts 2.5 ft. at max wind
- Frame cost the same as a 45 floor building


50
40
30
20
10
0
Weight of steel, in psf
Average
29.7 psf
6
5
4
3
2
1
1
2
3
4
5
6
Tiers


Concentrated load
70 kips
70 kips
20 kips ±
Reaction at each column

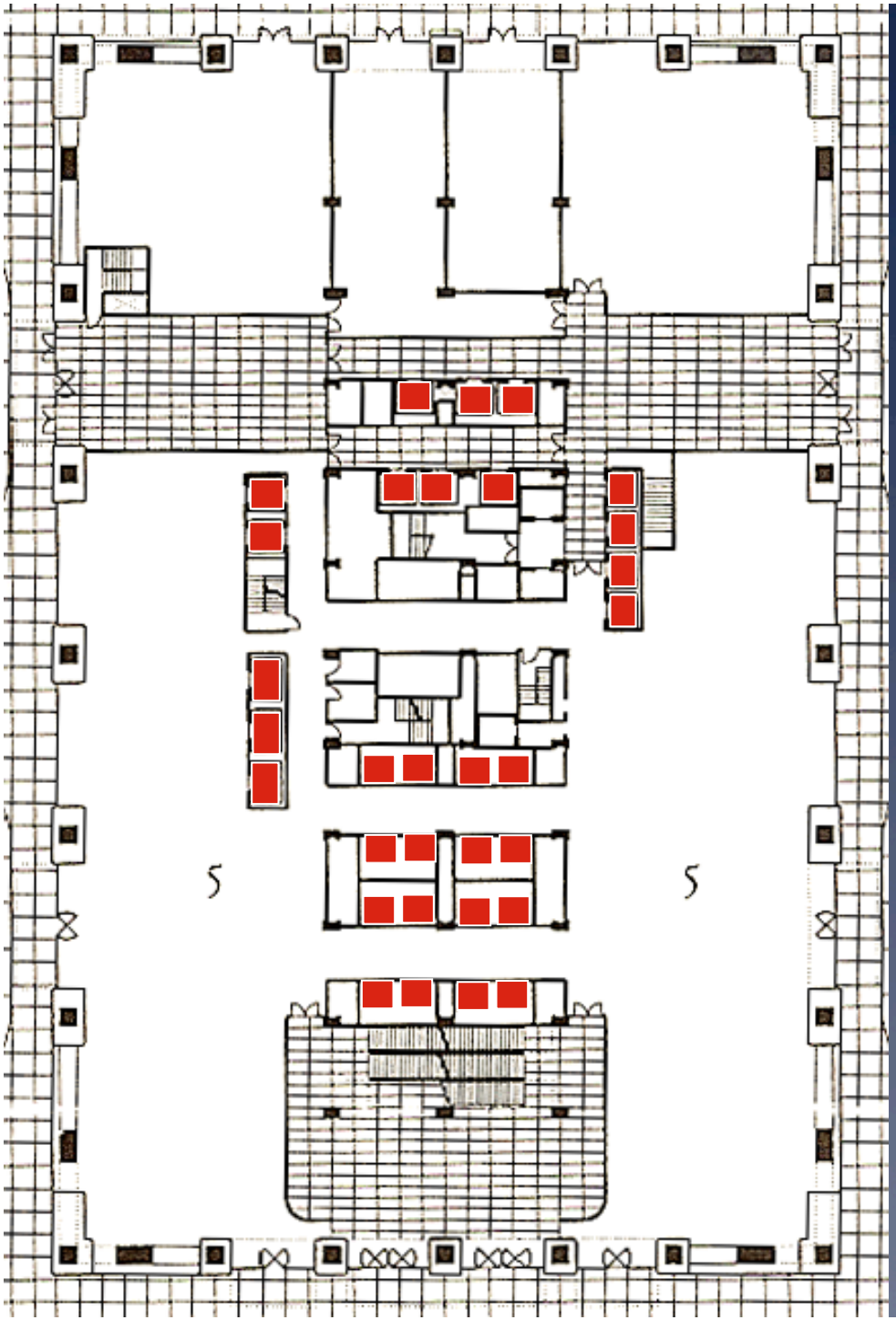



**Plan of center**

1. RAMP TO GARAGES
2. MECHANICAL
3. SERVICE RAMP
4. CLUB
5. LOBBY
6. COURT

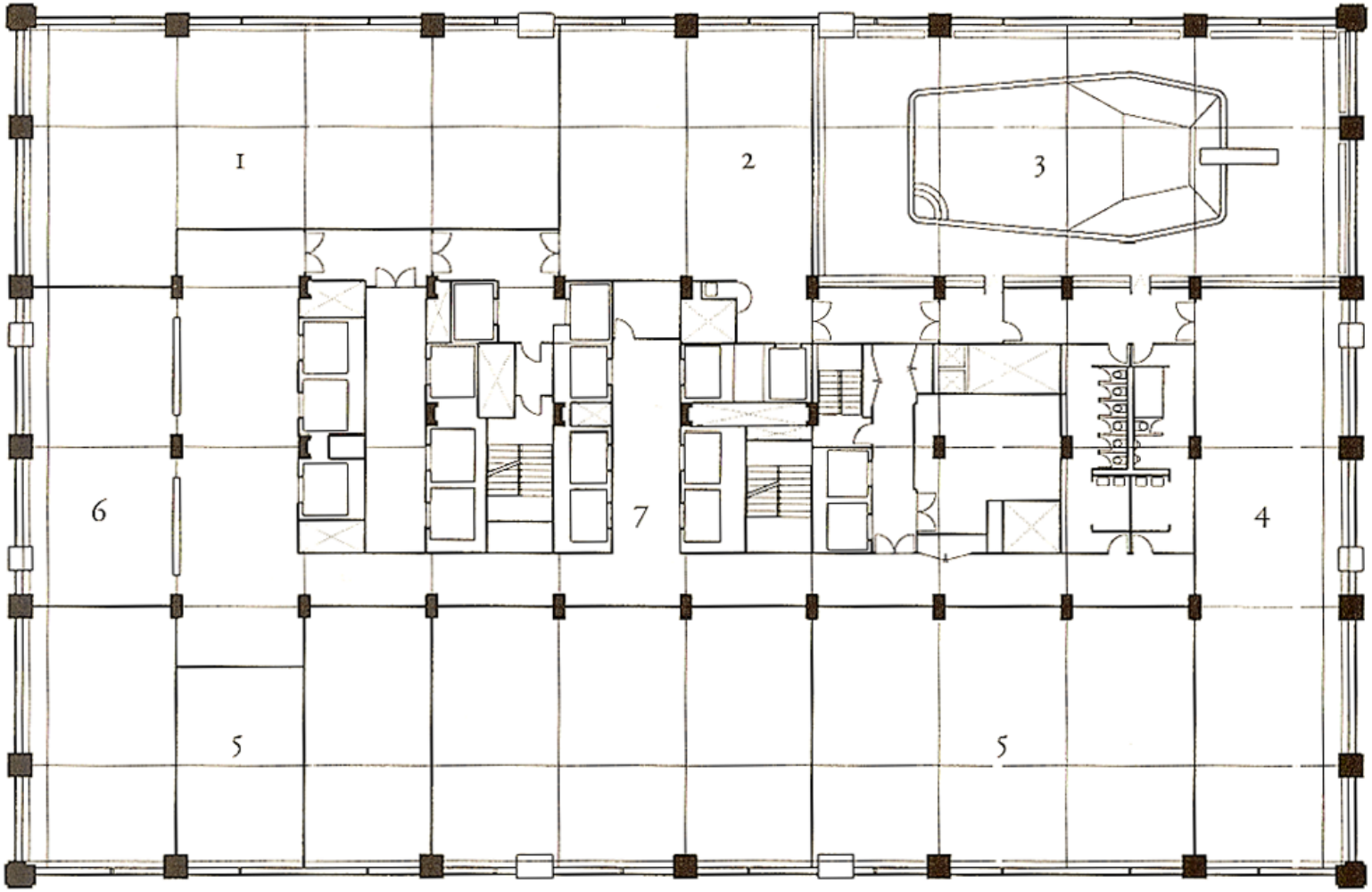
# Mixed Use for Market absorption

- Fl 1-5 commercial
- Fl 6-12 parking
- Fl 13-41 office
- Fl 44-92 apartments
- 93-102 observatory, restaurant, television transmitters
- 853,000 s.f.
- 4 year build



# Elevator racing

- Fastest is 1,800 feet per minute
- 50 cabs in 31 shafts
- 1 cab per 17,000 s.f. …luxury! Common to find 1 per 45,000 s.f. of office space

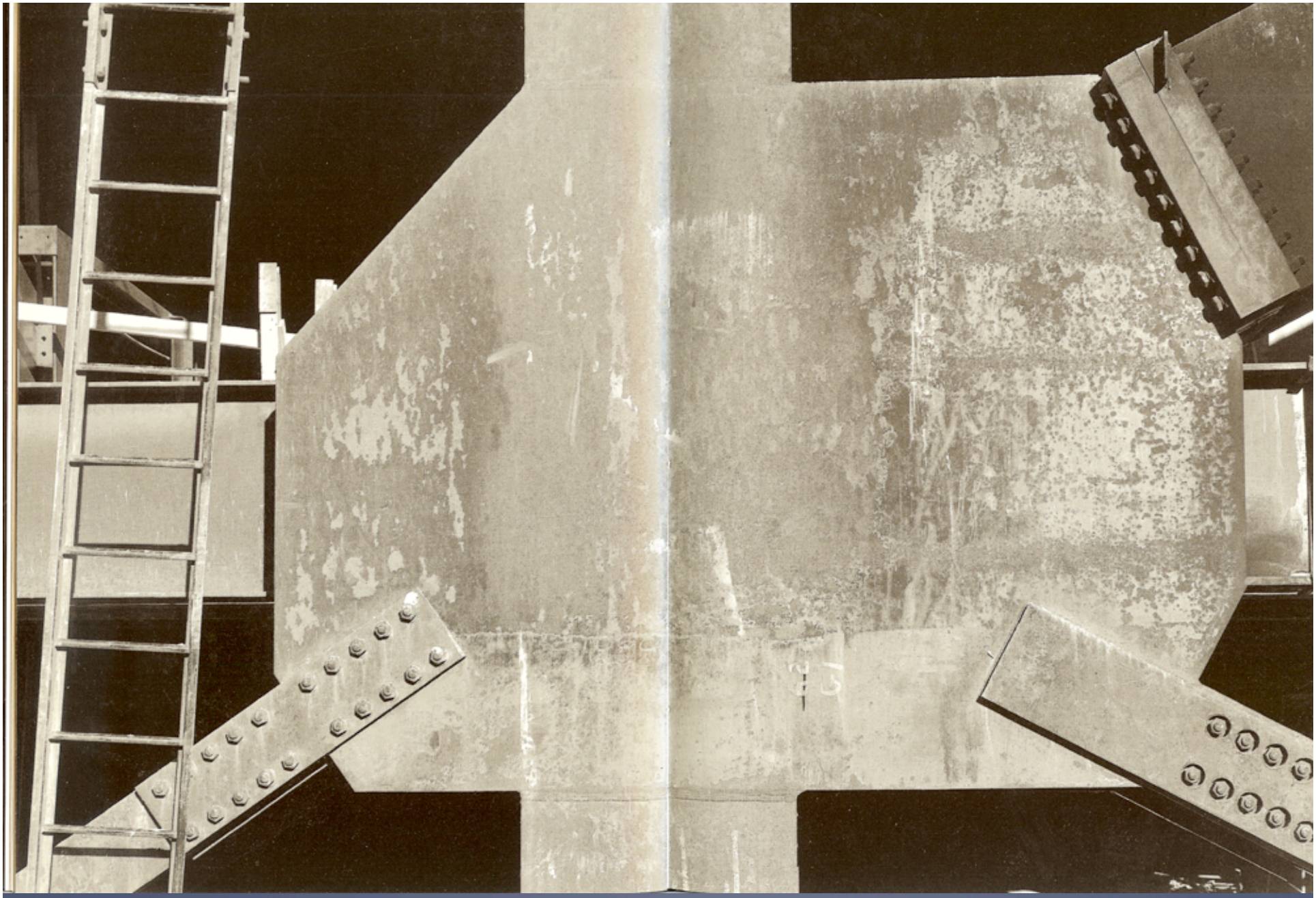



**Plan of 44th floor Sky Lobby**

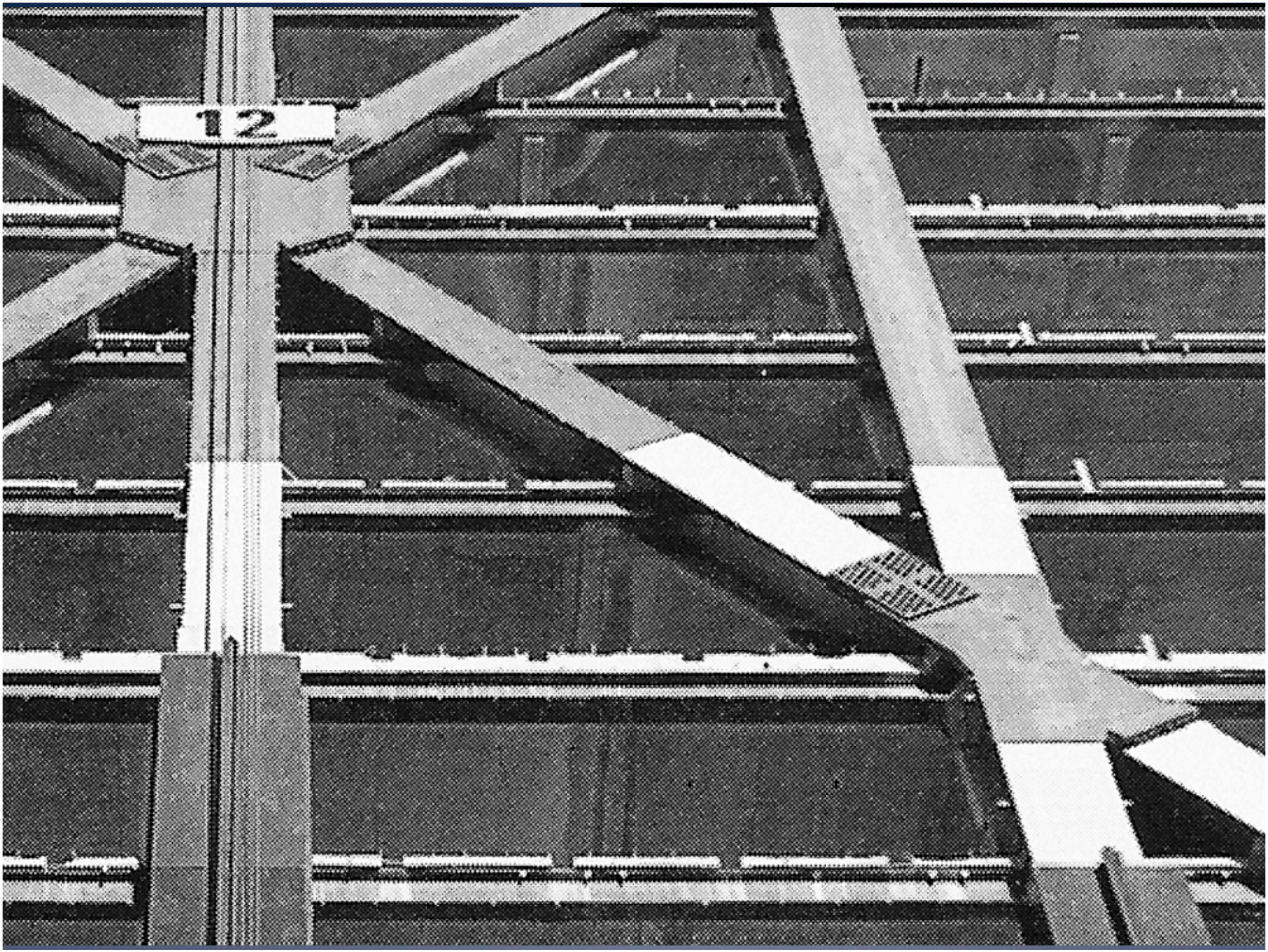
1. RESTAURANT
2. RECEIVING
3. POOL
4. HEALTH CLUB
5. SHOPS
6. LOBBY
7. SERVICE CORE

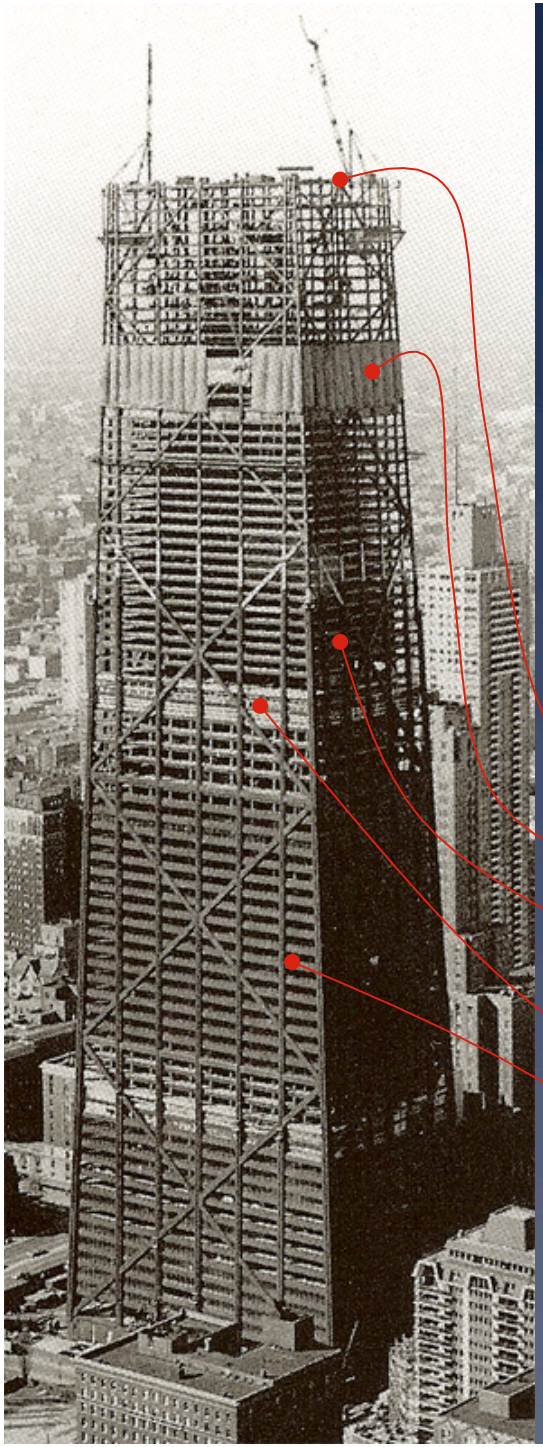
# No whitecaps in windstorms

# eight



# Cladding adds visual bulk


12

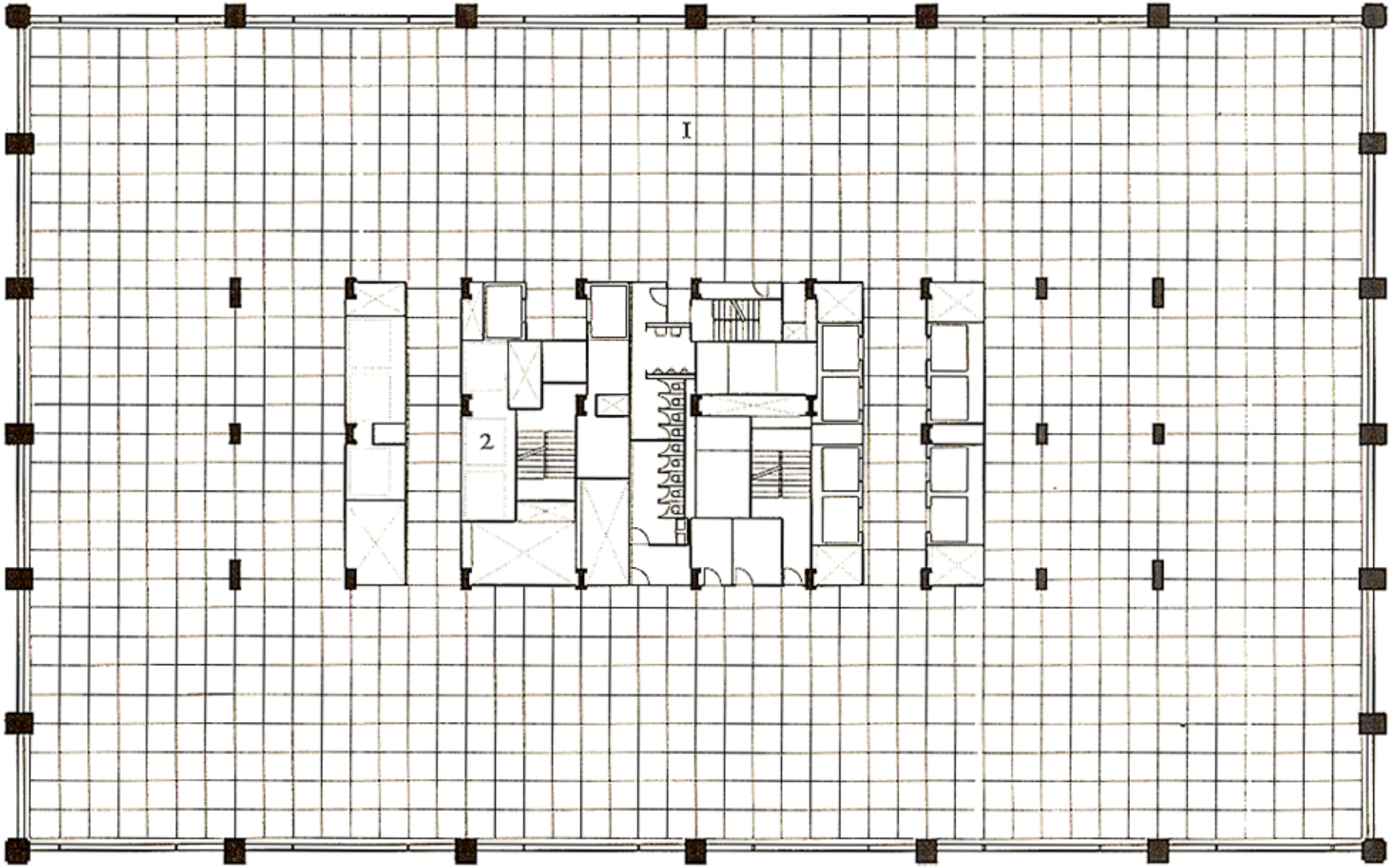


# Vertical Assembly line

- Unlike midrise or lowrise
- Multiple operations in progress simultaneously
  - Steel Assembly
  - Fireproofing
  - Exterior cladding
  - Interior slabs and partitions
  - Exterior glazing

# X marks the spot

# Braced for Market Rejection

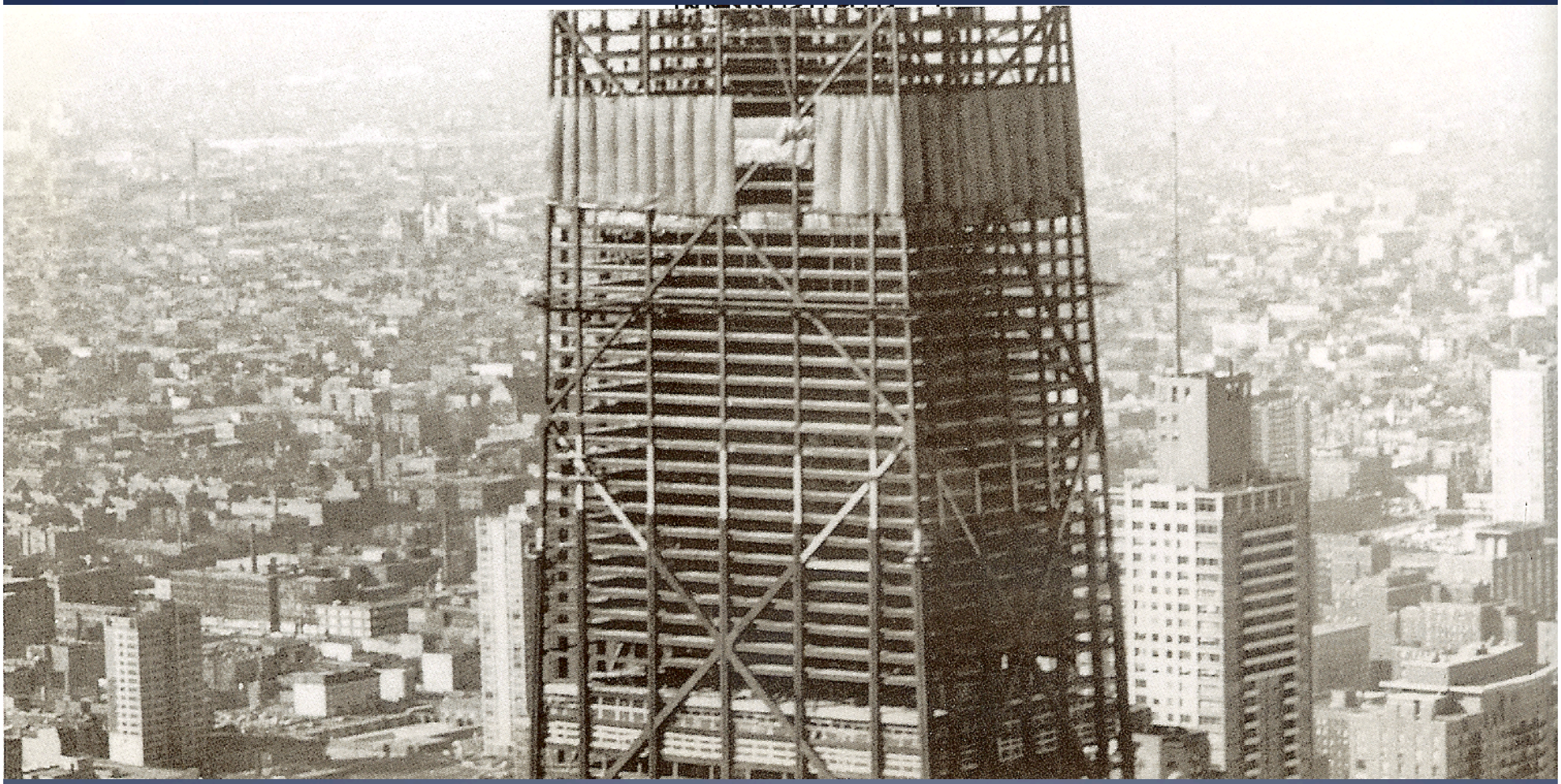



**Plan of typical office level, floors 26–33**

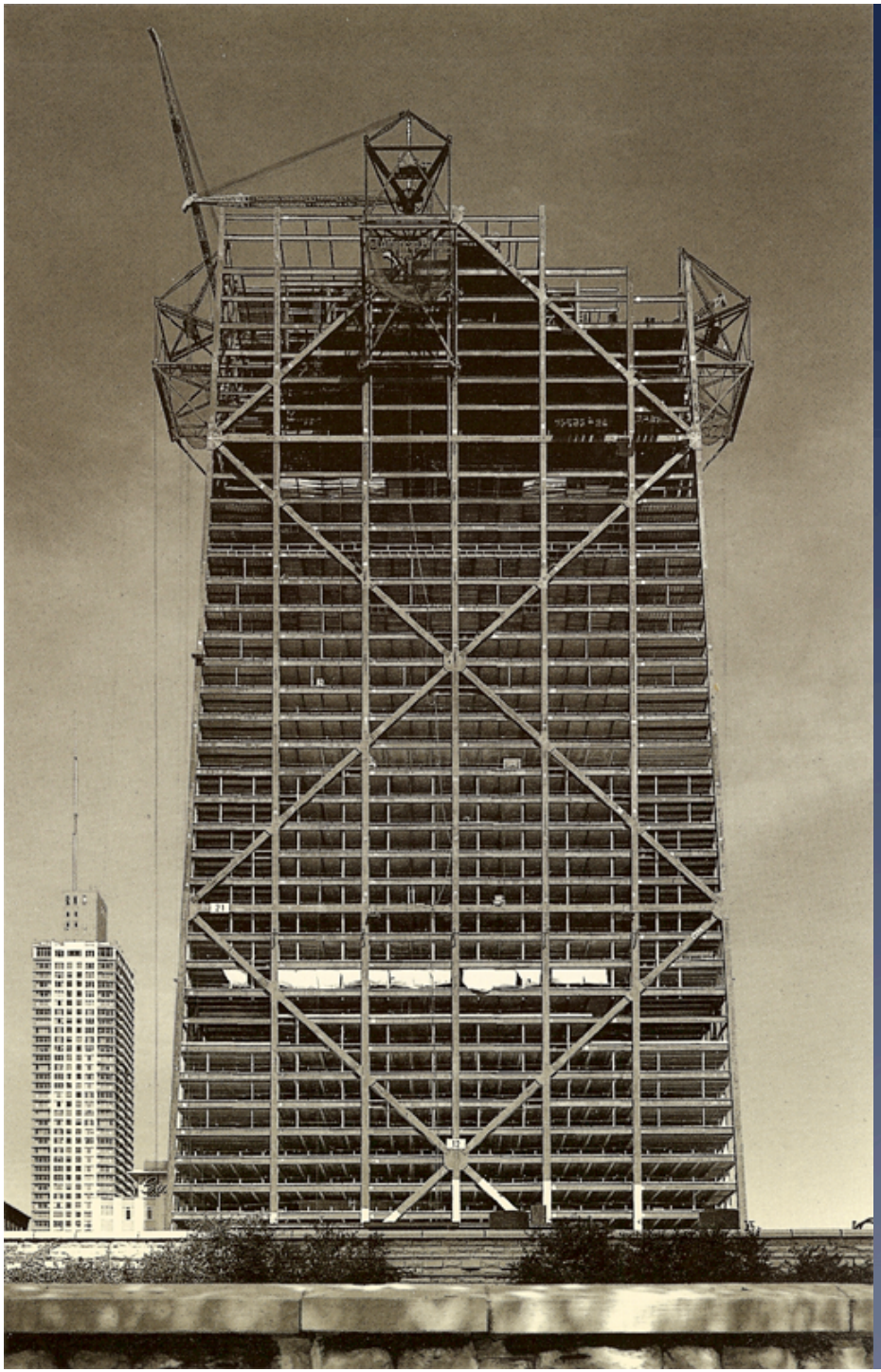
1. OPEN-PLAN OFFICE SPACE
2. SERVICE CORE

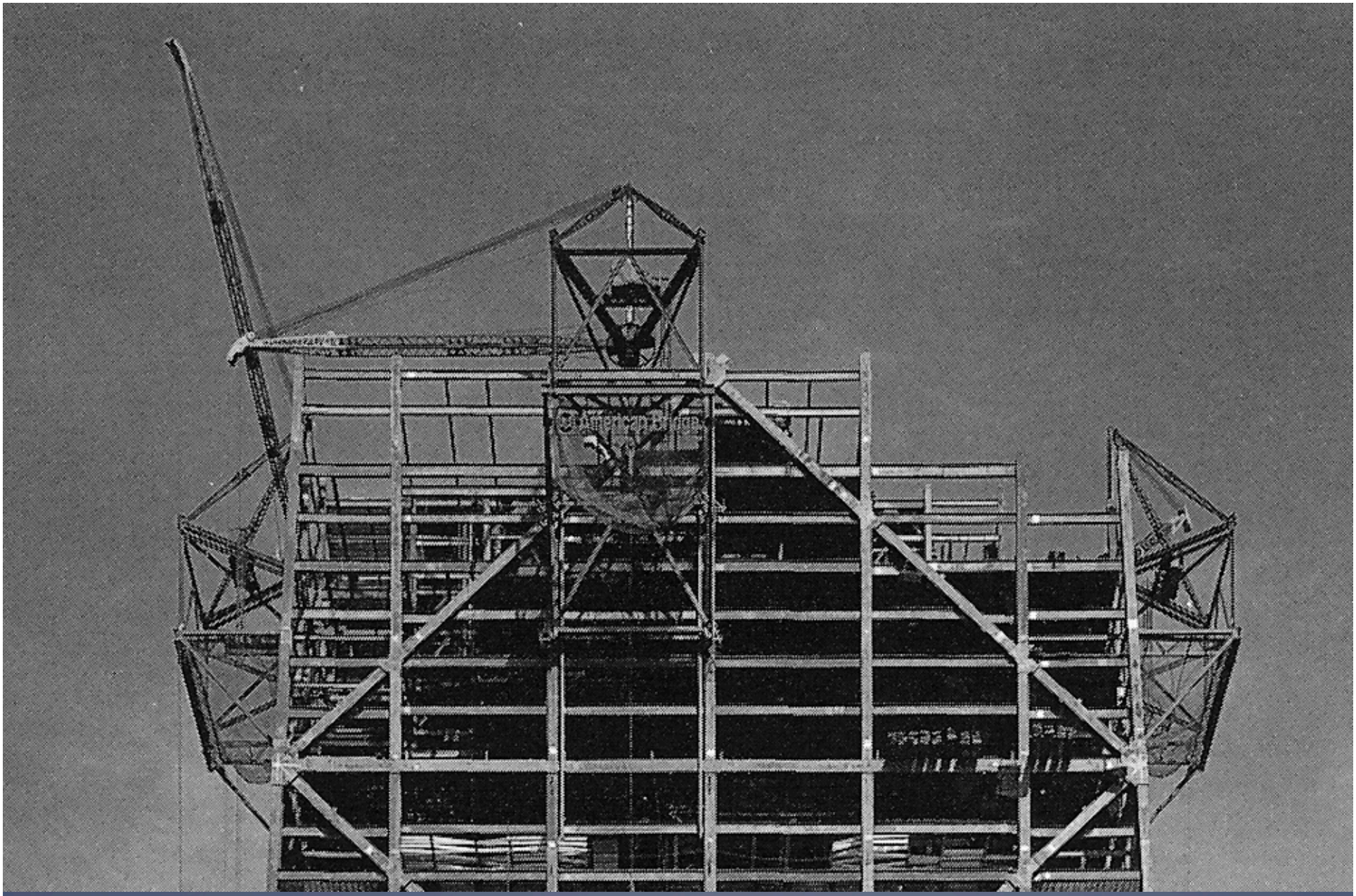
0 40'

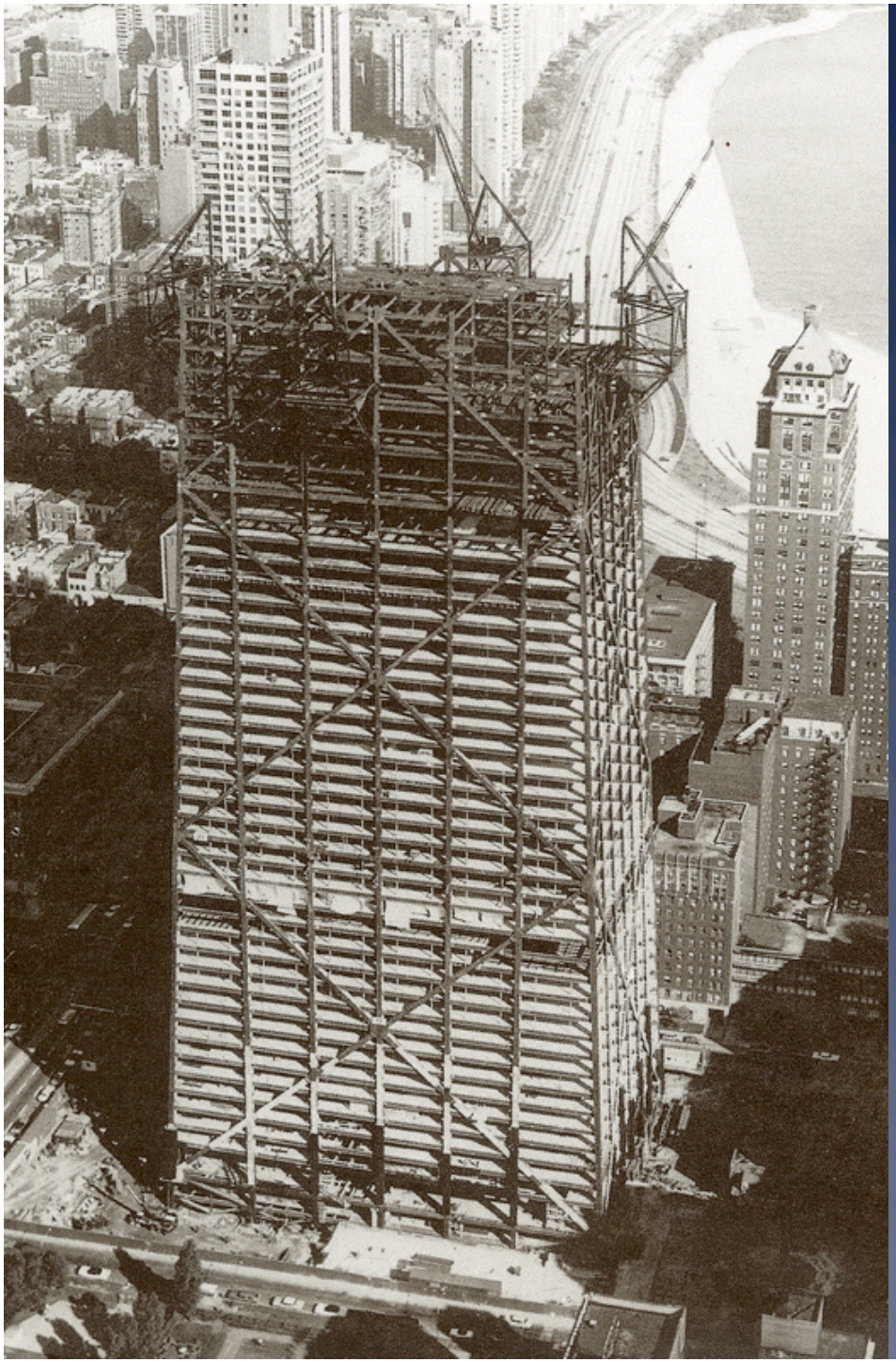
# Framing fireproofing cladding pouring



# Lifting contraption

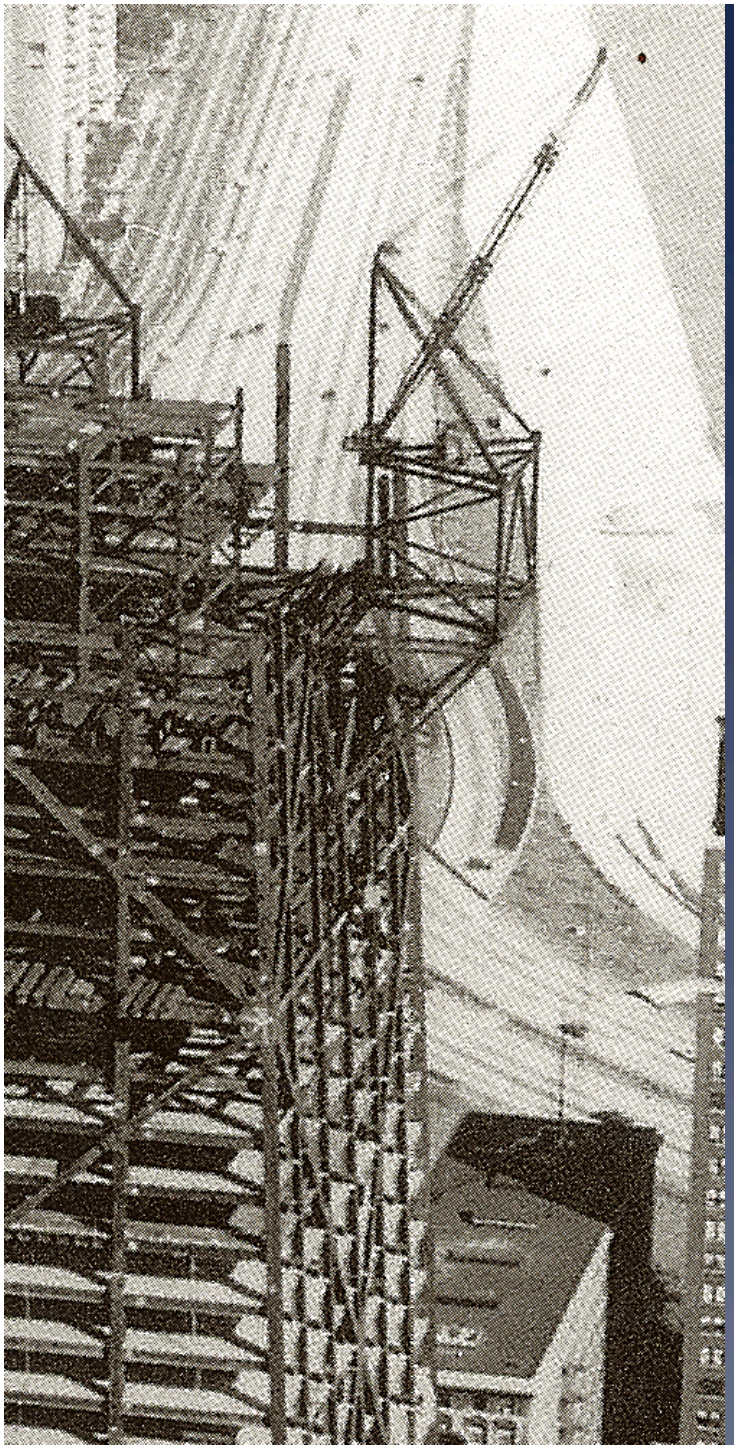




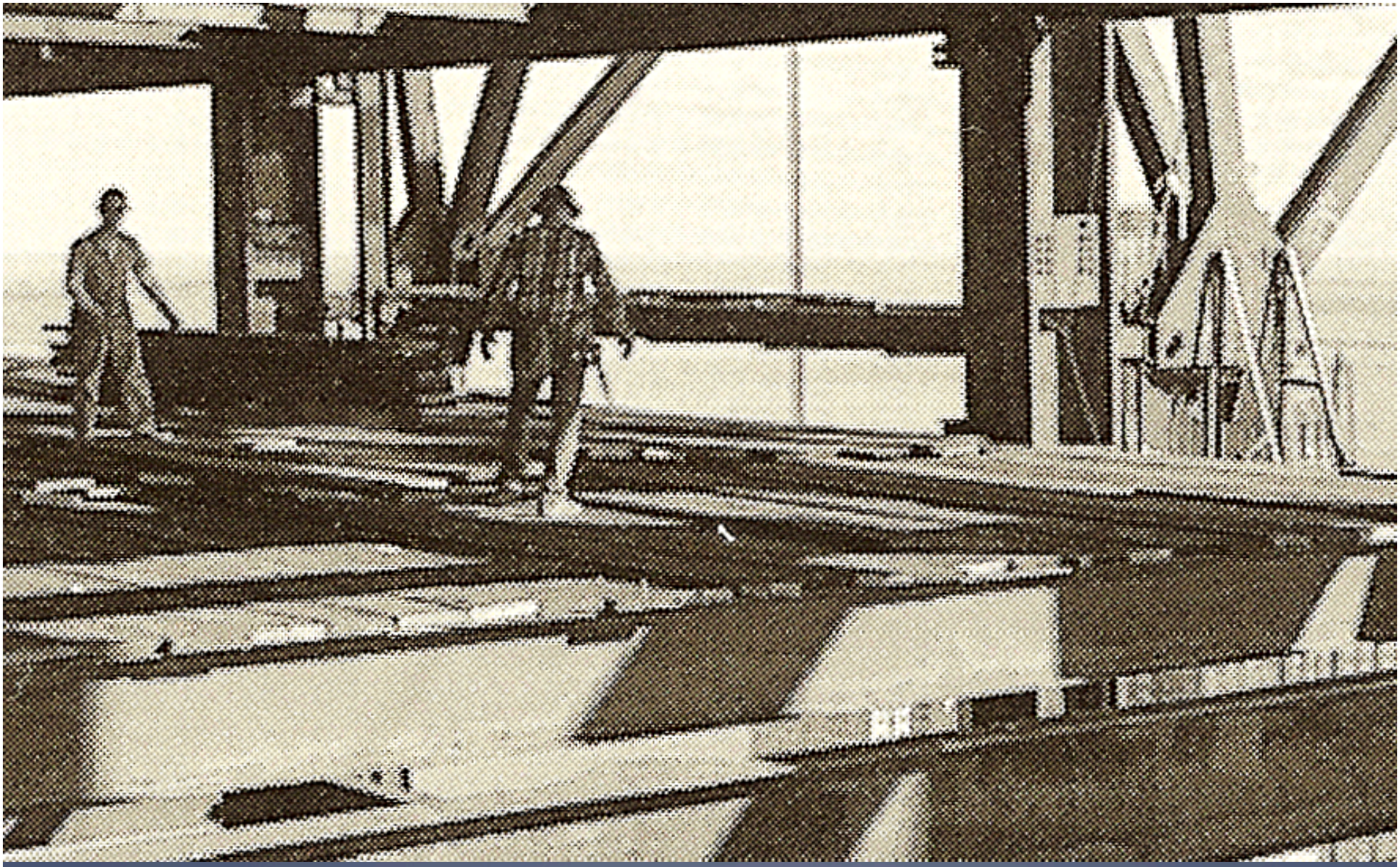


# 51 ft. of taper… No Setbacks

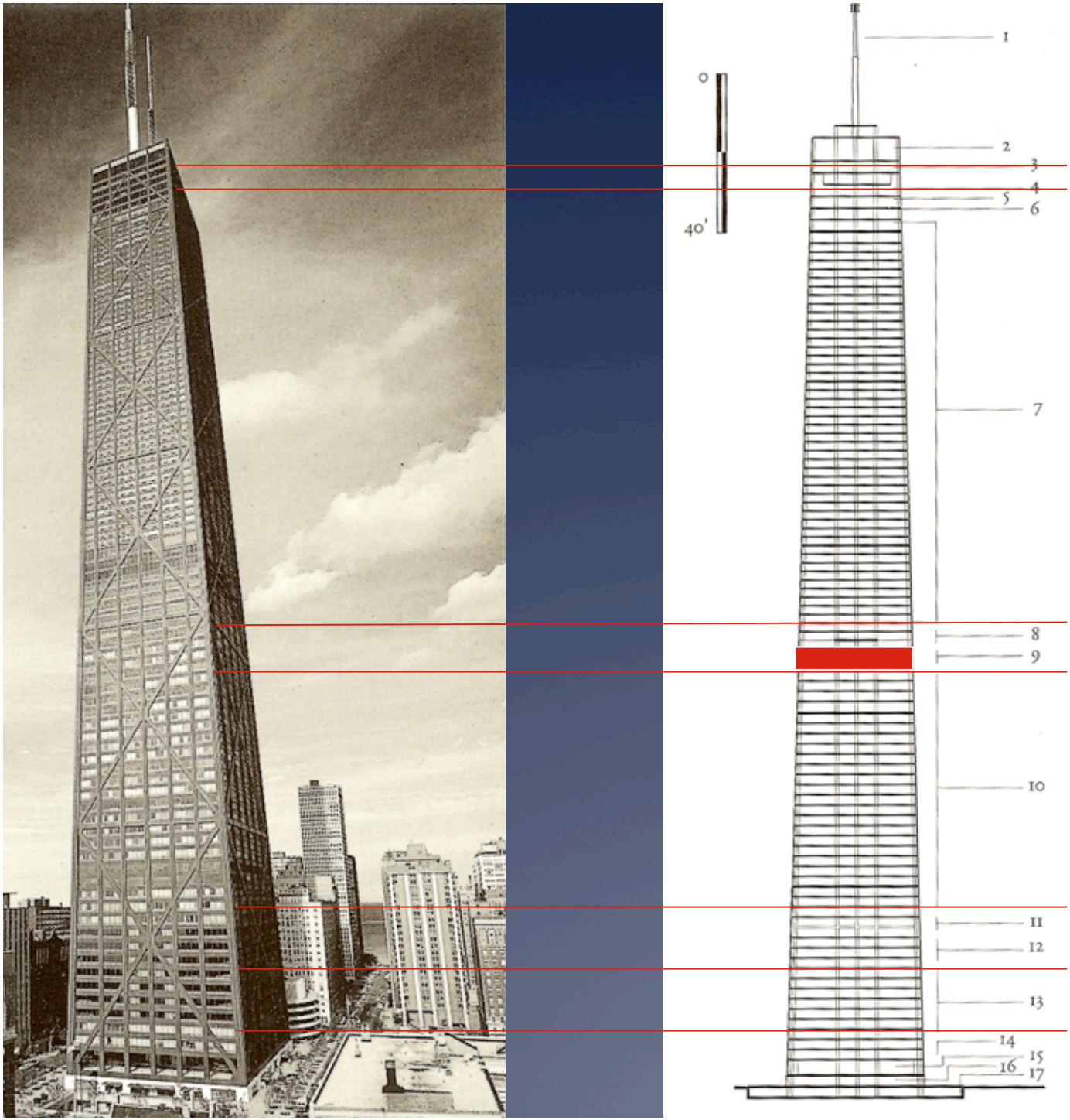
- Tapered tube gave steel assemblers extra challenge: reach out to lift up
- 104x62 at top
- 264x164 at bottom



# Reach out to lift up

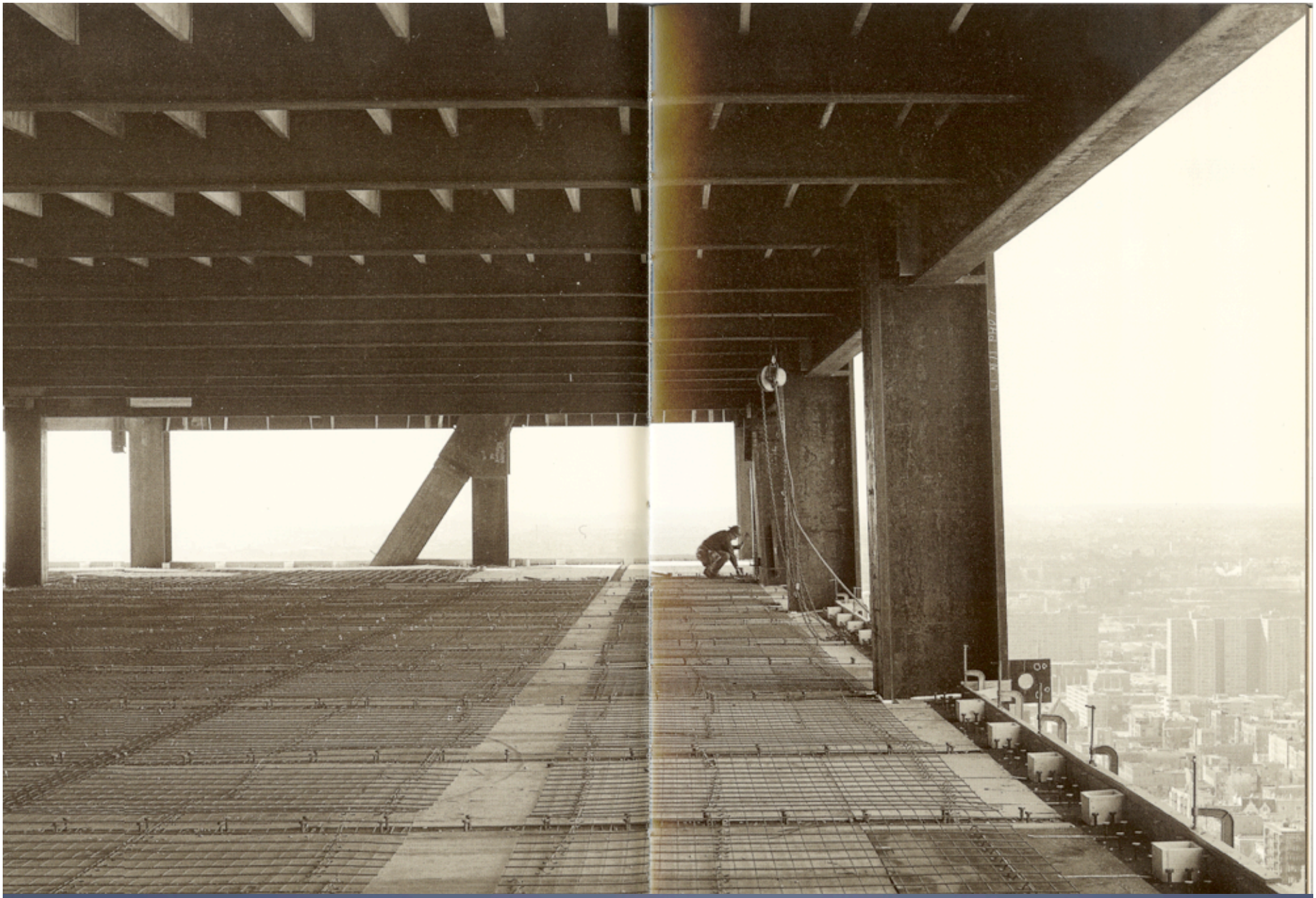


# Still planking after all these years



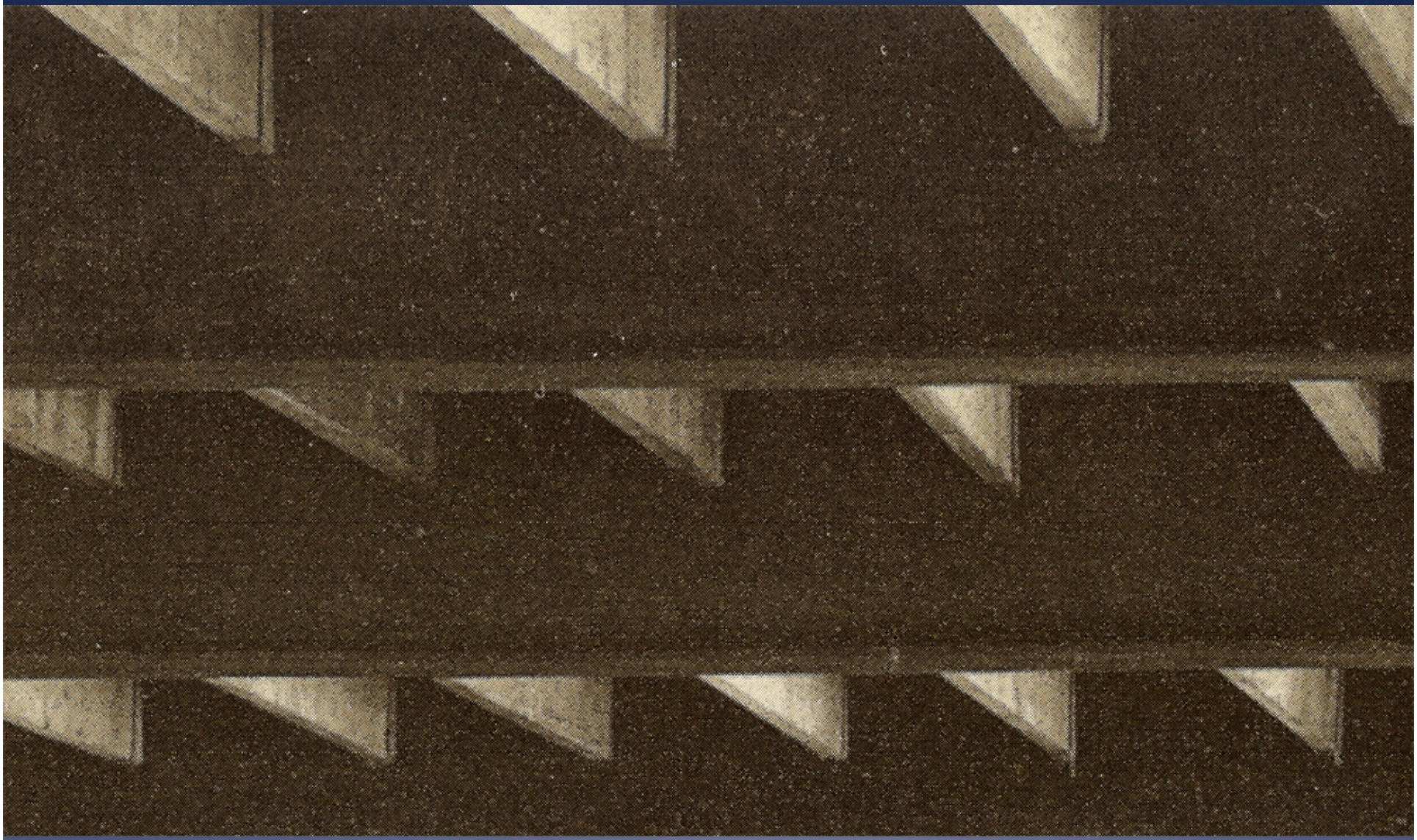

**Section**

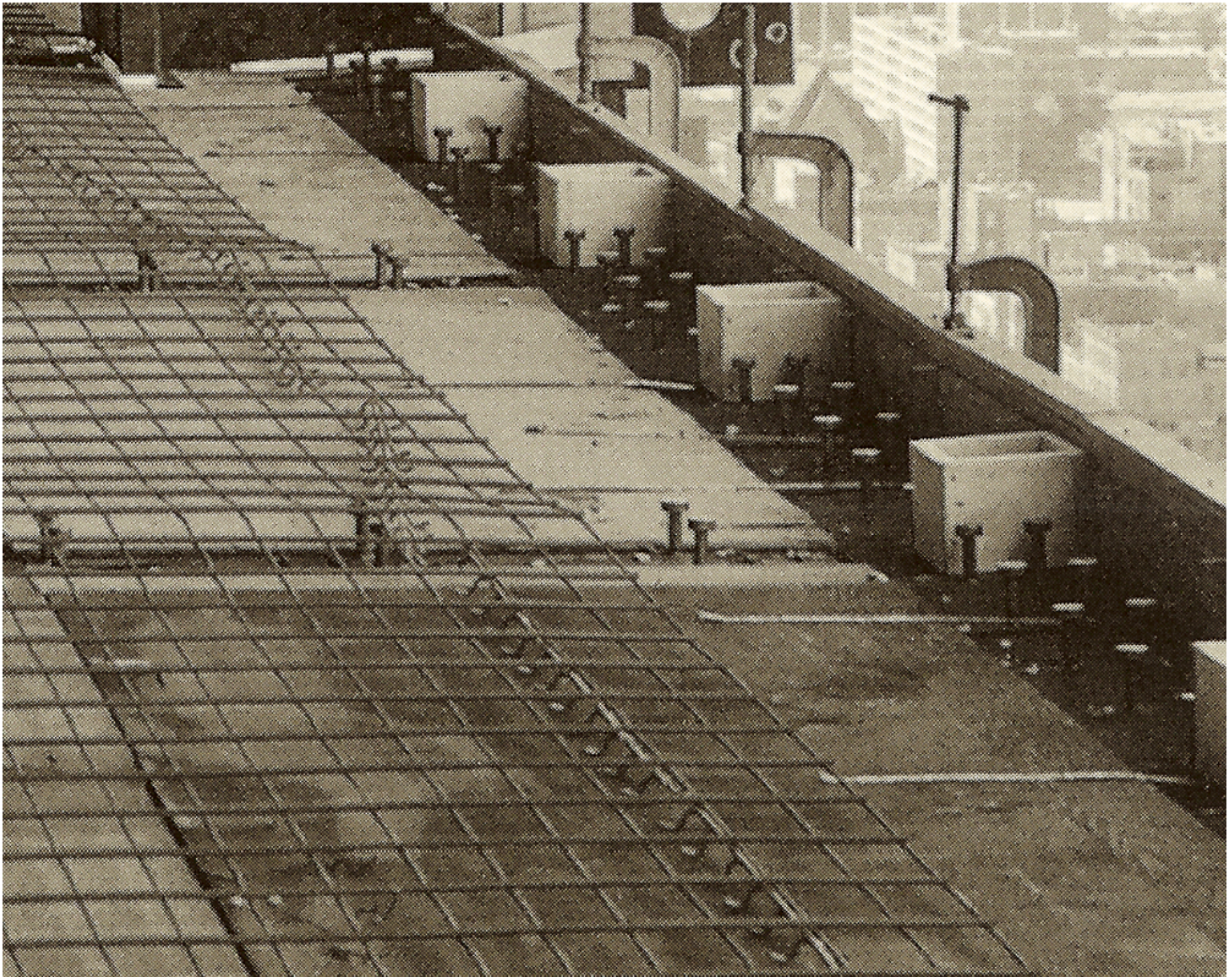
1. ANTENNAE
2. MECHANICAL
3. TELEVISION
4. RESTAURANT
5. OBSERVATORY
6. TELEVISION
7. APARTMENTS
8. SKY LOBBY
9. MECHANICAL
10. OFFICES
11. MECHANICAL/OFFICES
12. OFFICES
13. PARKING
14. COMMERCIAL
15. OFFICE LOBBIES
16. STREET LEVEL LOBBIES
17. BELOW GRADE SERVICE & COMMERCIAL CONCOURSE

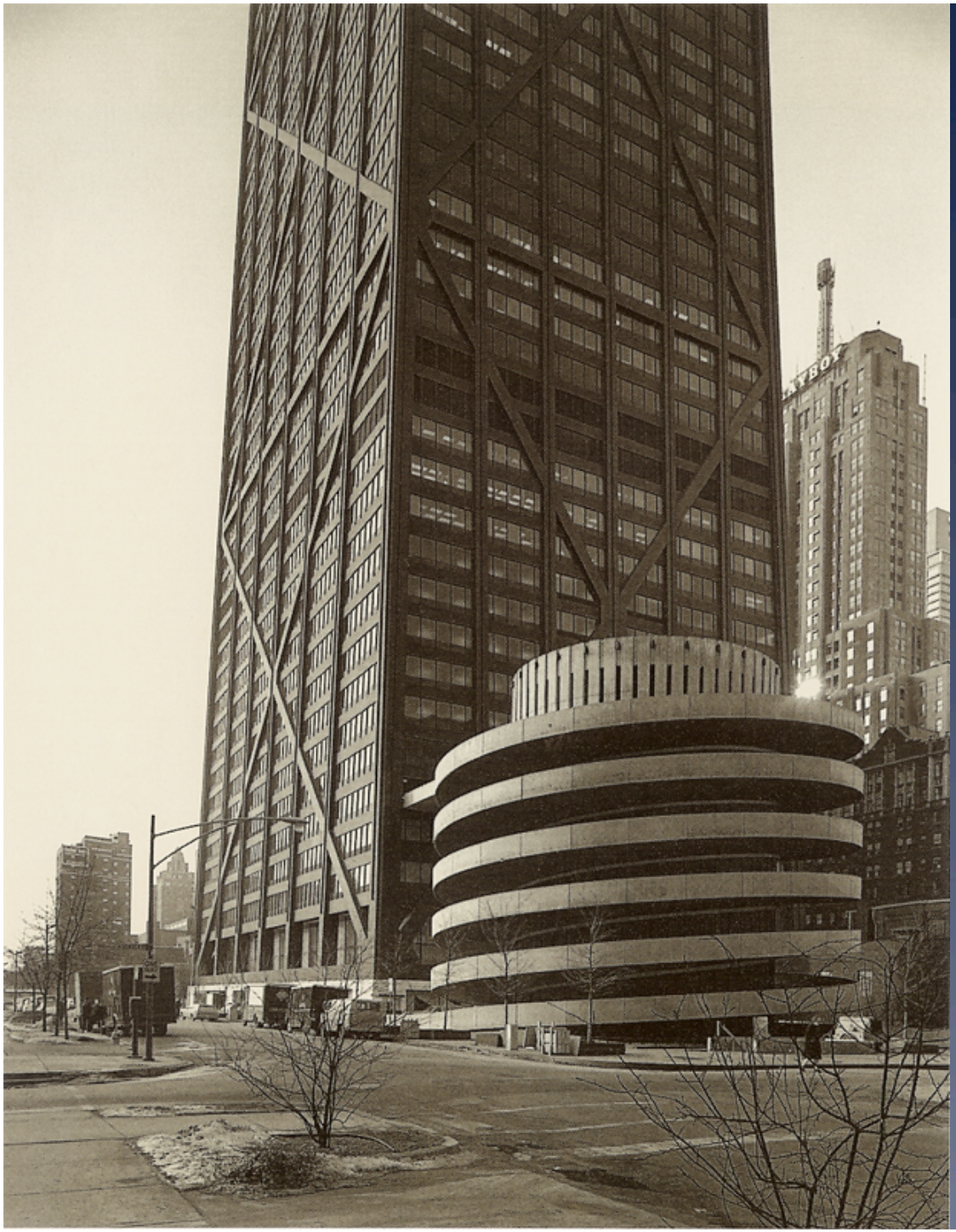


# 2x12's and plywood

# Joist hangars

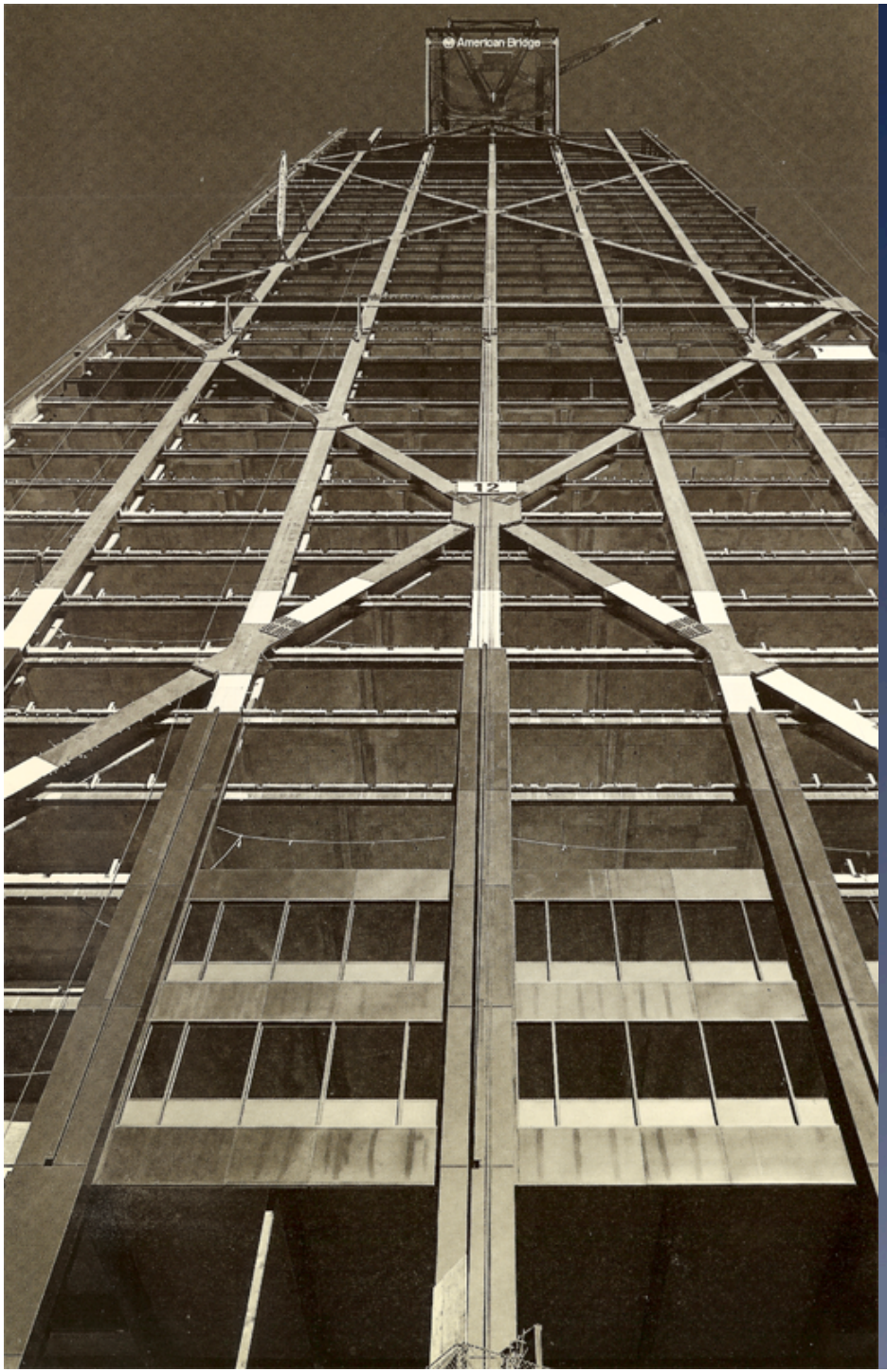






# Hi rise ramp

* Concrete double-helix brings cars up and down from the parking on floors 6-12



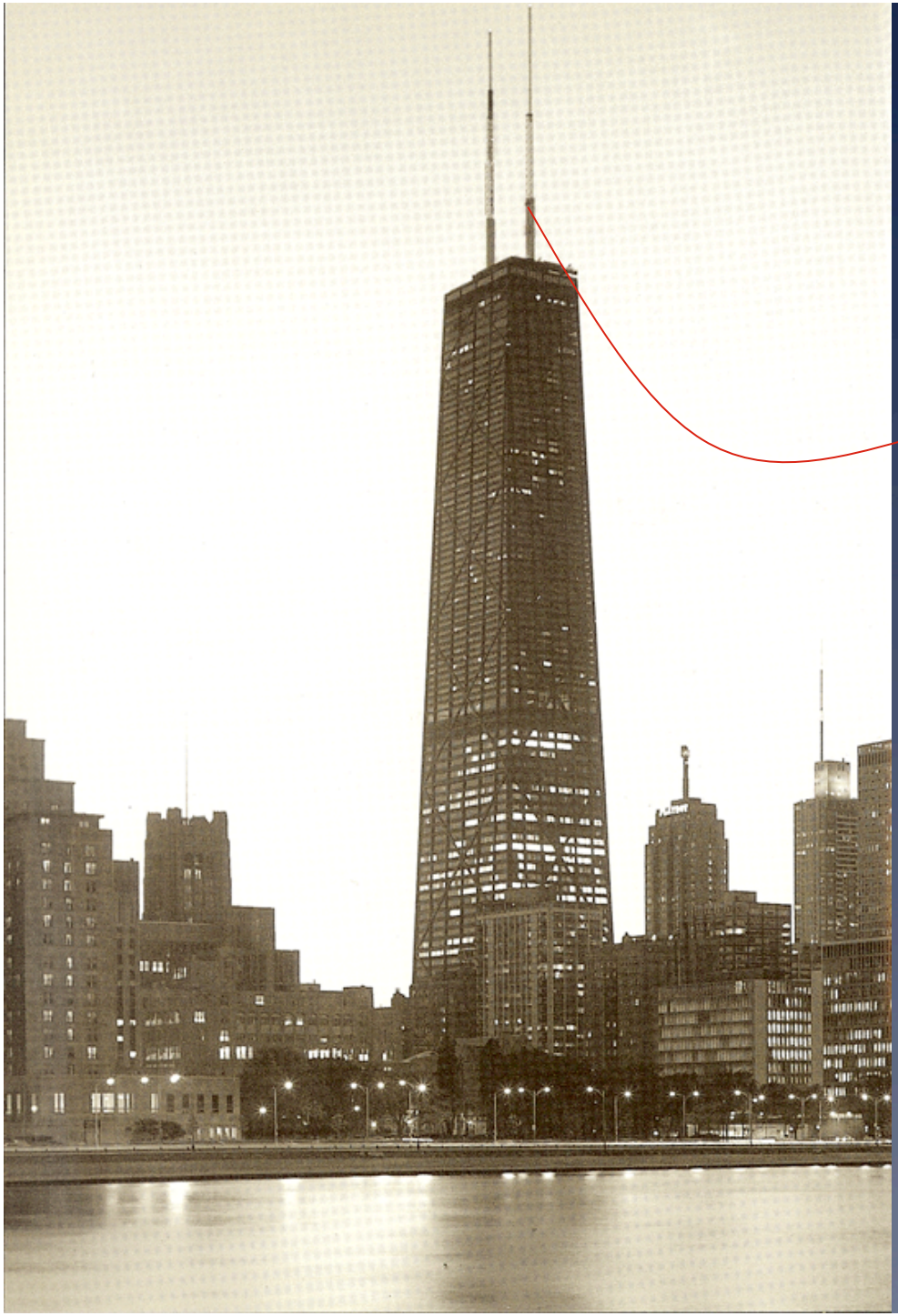

# American Bridge Company

* Set steel for Eads bridge 1860
* Set steel for John Hancock building in 1969

# Sky-City


# Where is the worlds 16th tallest building?

* Same problem as the Empire State Building, you don't know it's tall from the street



# Dad's mark on Chicago

* I R here (was)