CITICORP CENTER

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INTRODUCTION

Location: 601 Lexington Avenue + 54th Street, New York NY 10022

Other Names: CitiCorp Center + CitiGroup Center + 601 Lexington (Current)

Architects: Hugh Stubbins,
William LeMessurier

Chief Structural Engineer: William LeMessurier

Years Built: 1974 - 1977

Year Opened: 1977

Cost: $195,000,000

GENERAL INFORMATION

- CitiCorp Center is the first skyscraper in the U.S to be built with a tuned mass damper
- The tower is the 6th highest building in NYC
- The building was built for commercial office
- Design for the building was drawn by William LeMessurier on his restaurant napkin
- The office lobby was renovated in 1997 and a new lobby was built in 2010
- The structure was being fixed secretly at night

THE ARCHITECT | HUGH STUBBINS

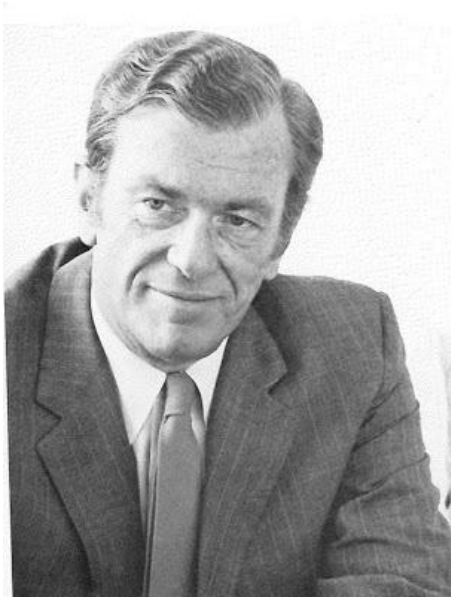
Born: January 11th, 1912 - July 5th 2006

Birthplace: Birmingham, Alabama

Education: Georgia Institute of Technology(Undergrad)
Harvard University (Masters)

Firm: Hugh Stubbins and Associates (won one of the 1st AIA Firm Awards)

Projects: CitiCorp Center, Boston's Federal Reserve Bank, Ronald Reagan Presidential Library, Landmark tower in Yokohama



Awards: Gold Medal (Tau Sigma Delta), Honor Award AIA 1979

THE STRUCTURAL ENGINEER | WILLIAM LEMESSURIER

Born: June 1926 - June 2007

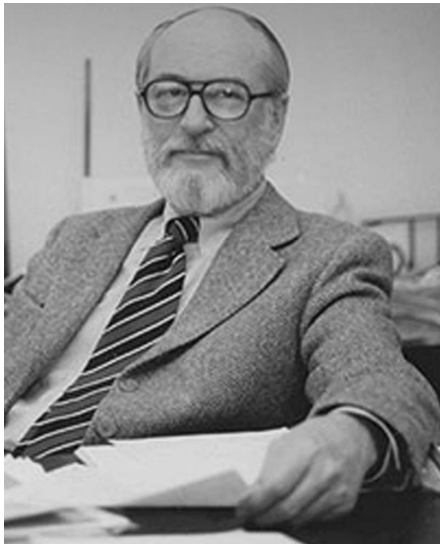
Birthplace: Pontiac, Michigan

Education: Harvard University(BA Mathematics), Harvard Graduate School of Design, MIT (Masters in Engineering)

Firm: LeMessurier Consultants

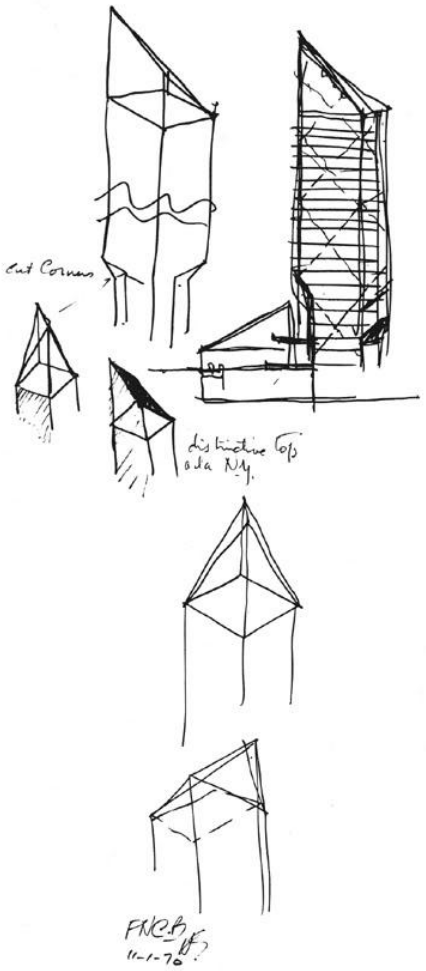
Projects: Mah - LeMessurier System, Staggered Truss System, Tuned Mass Damper, John Hancock Tower, First National Bank of Boston, CitiCorp Center, Yokohama Landmark Towers

Awards: Chi Epsilon as a chapter honor member



DESIGN CONCEPT

- Stubbins wanted to give the tower a light, bright, and easily cleaned curtain wall that has natural aluminum spandrels to make the building a recognizable and memorable corporate symbol to stand out against its neighbors
- The client of the tower wanted Stubbins to design a roof shape that was expressive and practical
- During the beginning stages of the design process Stubbins began to study the possibilities of a diagonally sliced pinnacle as a powerful mark against the sky.

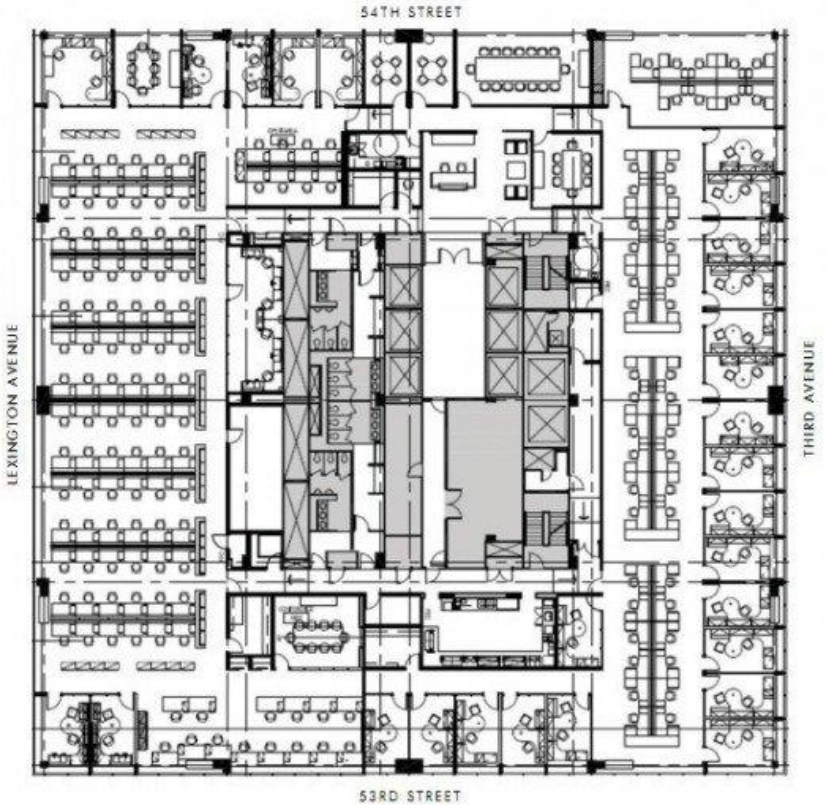


DESIGN CONCEPT CONT.

- The early scheme had two of them one larger going in opposite directions. At one point during the design process, the larger of the two areas of the roof was to contain over 100 terraced apartments. The city refused to grant a zoning variation
- Later on in the design, Stubbins proposed that the slanting surface serve as a solar collector but at the time was not practical
- The slanted crown is 160 feet tall.
- Part of his design was to preserve the Church. The base of the tower is cut away at the four corners and leaving the building to stand on it’s core that extends to the center of each side.
-

BUILDING LAYOUT

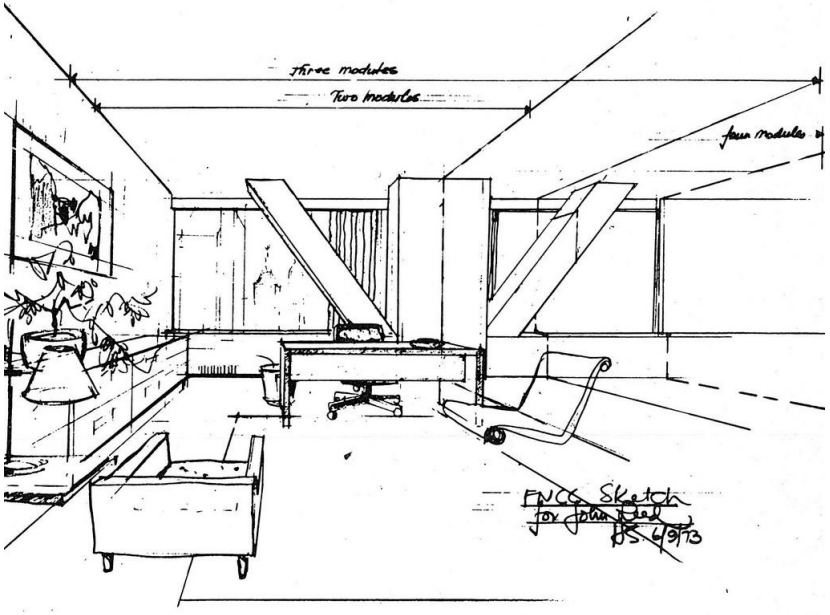
- There are 59 levels
- The central core of the building is an elongated octagonal shape that's independent from the columns
- There are four privately owned public spaces including a plaza, open air concourse, through block arcade, and covered pedestrian space
- The seven story atrium was the featured attraction



BUILDING LAYOUT CONT.

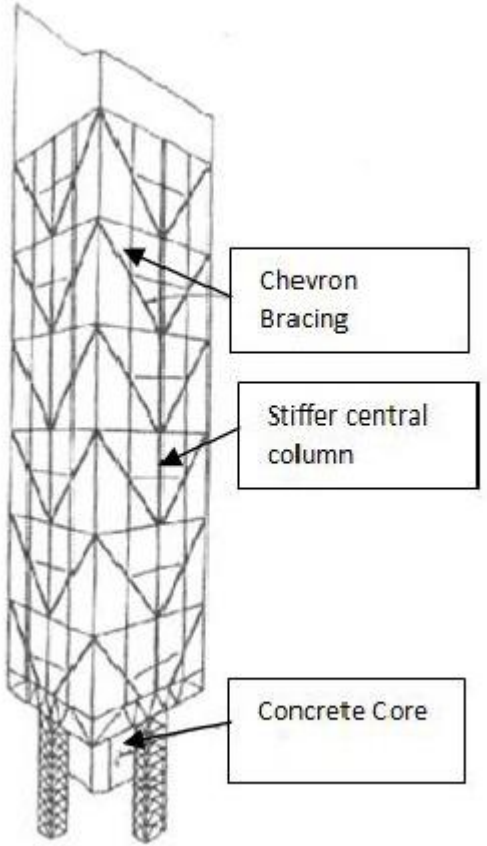
- There are a total of six access points from the surrounding streets, including two entrances to the through block arcade which is on either East 53rd or 54th Streets. Another entrance is on East 53rd Street. Another is on the southwest corner of East 54th Street and Third Avenue
- Due to zoning restrictions, the original creation of residential space on the top floors did not happen
- Having double decker elevator cars reduced vertical circulation core and opened up more space for offices
- The St. Peter’s Lutheran Church was the reason for overhanging corners.

ATRIUM VIEW + OFFICE



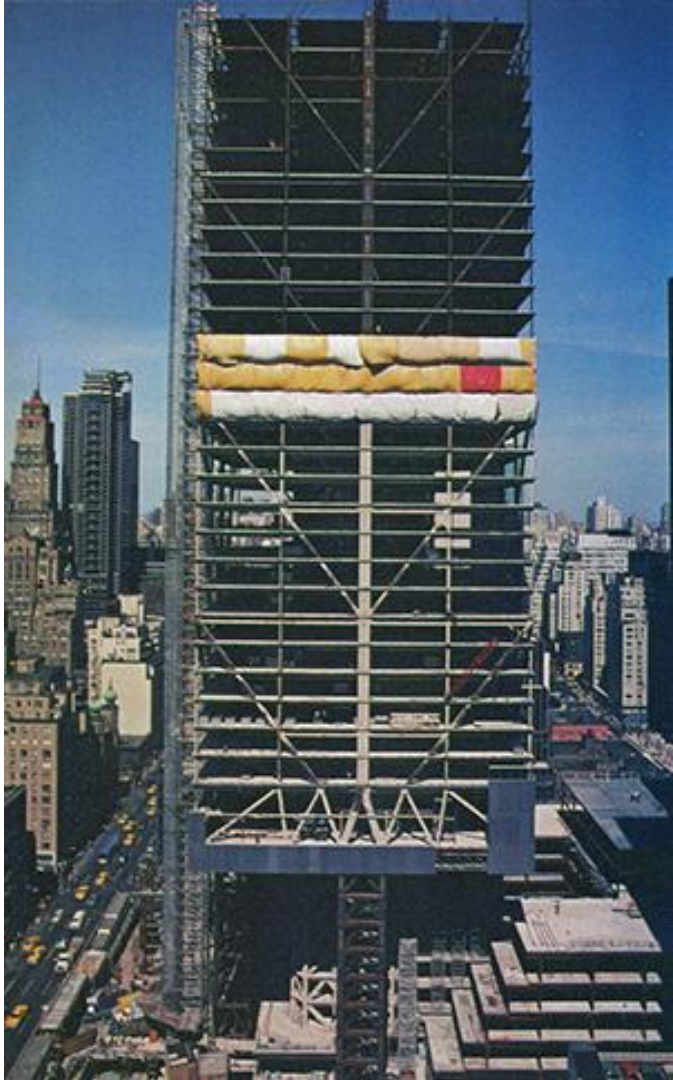
STRUCTURAL DESIGN

- The materials used for the structure were steel and concrete. The steel was used for the chevron cross bracing. The 400 ton ball on top of the building resist swaying of the building is made of concrete
- The exterior is double glazed curtain wall
- The main structure for the building was chevron cross bracing and four stilts and a central core
- The stilts are 114 foot tall that took up 9 stories of the building



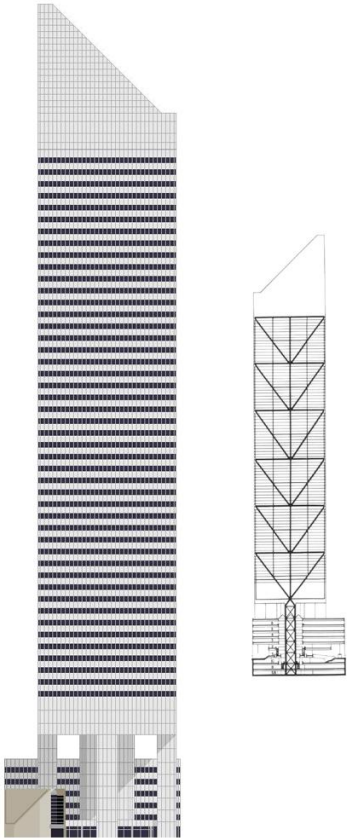
STRUCTURAL DESIGN CONT.

- Chevron bracing was used because of the stilts. It served as a skeleton for the building. It contained six rows of steel V's running vertically through the building
- The chevron bracing made the building very light and would cause the building to sway due to strong winds
- A 400 ton concrete ball at the top of the skyscraper was added to help with the lightness of the building



STRUCTURAL DESIGN CONT.

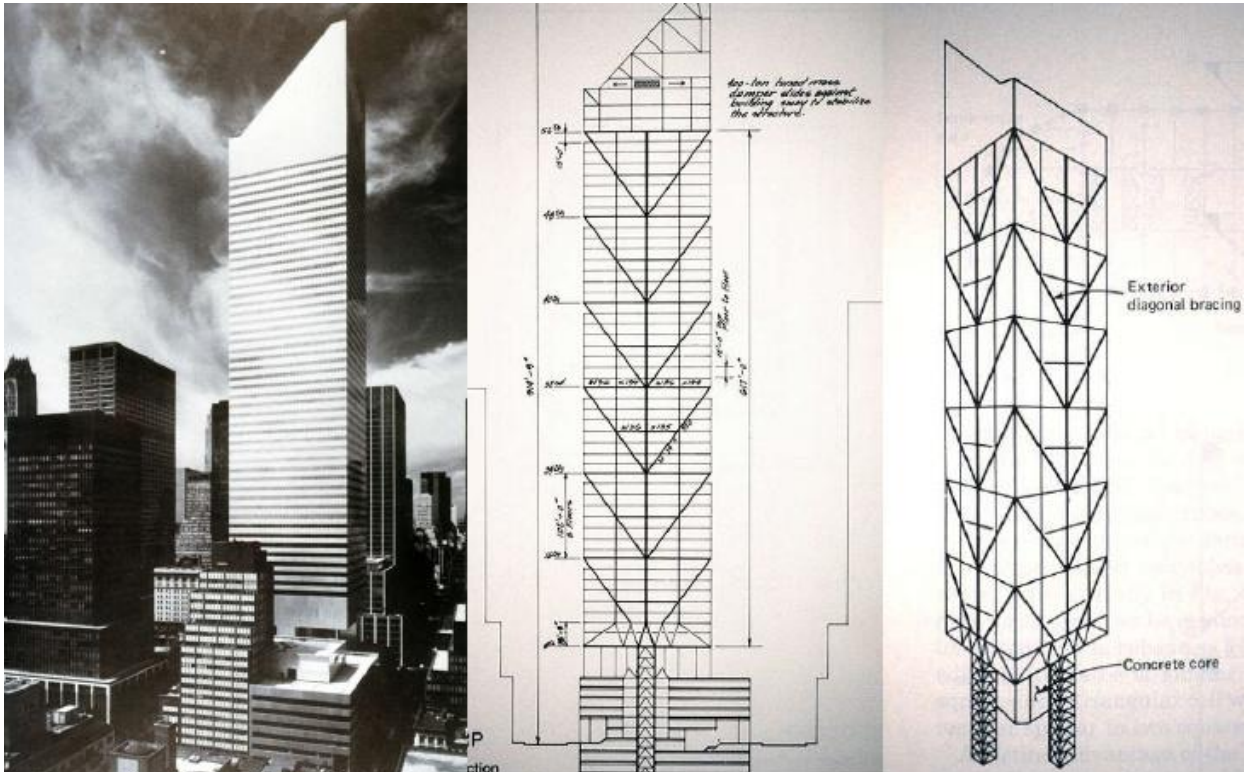
- The chevron bracing collects the massive floor loads to the center of each face which then transfers the load downward to the gigantic columns directly below
- The bracing also resist entire wind loads which prevents any torsion
- At the base of the tower, where the chevron braces end, is an entirely trussed transfer floor which helps the loads from the chevron braces transfer to the columns, as well as, transfer the wind shear
- The floor slab system includes beams, girders, and 6 inch floor slabs



STRUCTURAL DESIGN CONT.

- The slant of the roof was designed to make the building famous like The Chrysler Building
  - 45 degree angle
- Due to the structure of the stilts, it created a seven stories tall atrium
- The main core is for circulation and is made of steel and concrete
- The facade material is aluminum with reflective glass
- Tuned Mass Damper
  - To help with the stability of the building that’s computer driven
  - Uses two hydraulic pumps

STRUCTURE



STILTS + CORE

CORNER CANTILEVER

MATERIALS

- Structural steel members
  - W21 x 44 - 45 for horizontal floor plates
  - W14 x 550 for diagonal bracing
  - W8 x 24 - 31 - 48 for vertical columns
  - W12 x 40 - 58 - 85 for interior columns
    - The columns were reinforced with steel to protect against terrorist attack
- Concrete
  - Reinforced concrete throughout floor plates and columns
    - Steel reinforcement allows concrete spans and cantilever
- Aluminum
  - Exterior building cladding + light weight + cheaper than steel
- Glass
  - Mirror glass facade - emphasizes postmodern

BUILDING CONSTRUCTION

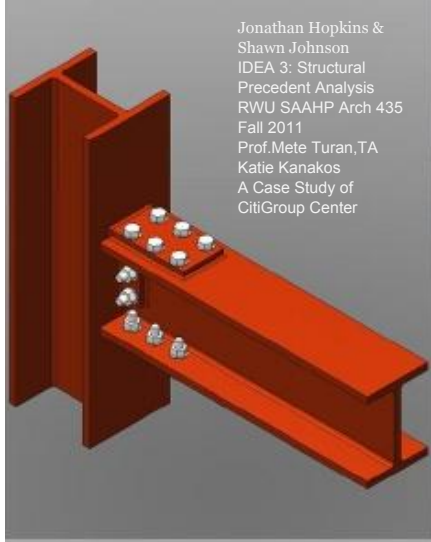
- 8 story modules
  - Each structural part independent
  - One full chevron bracing per module
- Each corner cantilever out 72 feet
- 4 columns located at the center of each side with a central core
- Loads are transferred from the 6 modules through the chevron bracing to each of the columns

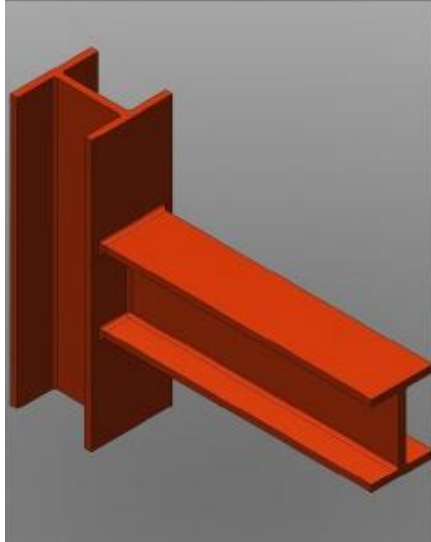
FOUNDATION + SOIL

- Deep bedrock in Manhattan. Downtown bedrock is approximately 40 feet below the surface.
- Constructing tall buildings in deep bedrocks, the building has to be anchored below surface to prevent cracks and uneven settling.
- Citicorp Center: has four 10 story pillars, that are aligned with the above columns.
- The columns were designed to create a load path through the building foundation.

POTENTIAL FAILURE

- A year after the tower's grand opening, a undergraduate student discovered a miscalculation in the structure that would cause the tower to collapse during a storm
- The cause of the failure was during construction all the connections were bolted without a weld
- There was a 1 in 16 chance every year for the building to fail, the structure took about three months to fix
- This failure was hidden from the public for almost 20 years
- The tower was considered capable of collapsing in a strong wind at one point. Emergency crews worked around the clock to reinforce the tower



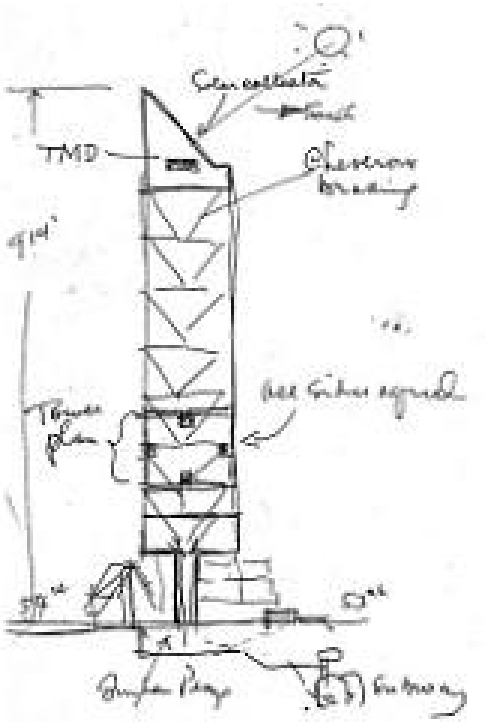


RESOLUTION

- It costed 8 million dollars in total to fix all the structural mistakes. CitiGroup covered 6 million of the total cost and LeMessurier's insurance covered 2 million
- Construction workers went in every night and took out the drywalls and welded over each and every bolted connection
- 6 weeks into the repair, a major storm was heading for New York but it never actually hit
- In order to correct the building's potential weakness in high winds, 2 inch thick steel plates were welded over each of the building's 200 bolted joints

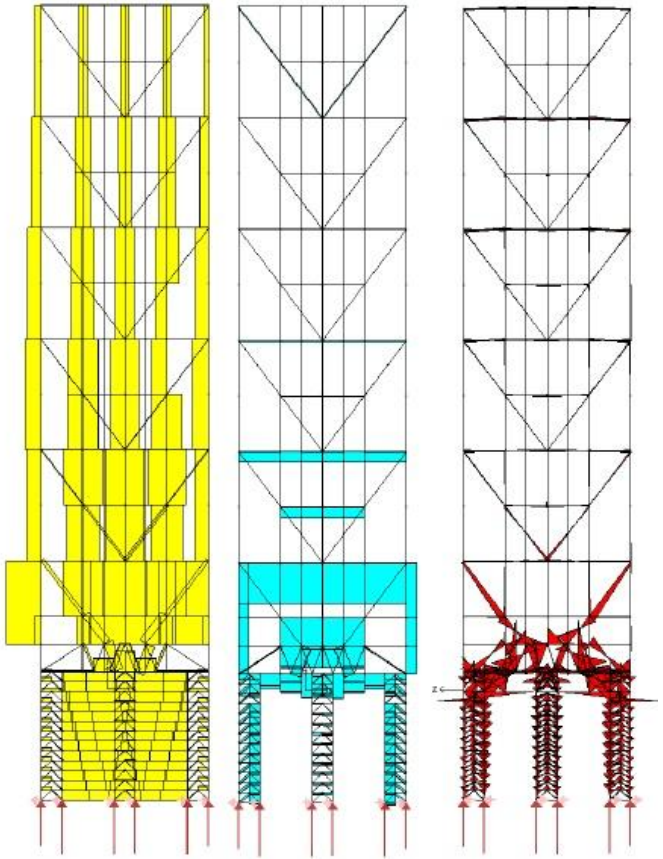
LOAD ANALYSIS

LeMessurier used a lot of steel for its structure for the CitiGroup Tower. The building balanced itself in its similarity in floor plans and the chevron style diagonal bracing. There were a total of six horizontal steel chevron bracing that took up eight stories in height each. Because of the stilts at the bottom floors, LeMessurier used a tuned mass damper to help with the wind loads to make the tower must stable. Steel was the perfect material for this design because it gave the lightness the architect wanted and the structural support it needs.



GRAVITY LOADS + RESISTANCE

- There's a 1000 K vertical load that is acting downward onto each of the 6 modules that are 8 stories in height
- The gravity load is acting onto the roof, then onto the diagonal bracing which then is transferred to the central column
- The chevron style diagonal bracing is transferring the load to the center of the columns and then to the ground, that frees up the load on the cantilevered corners



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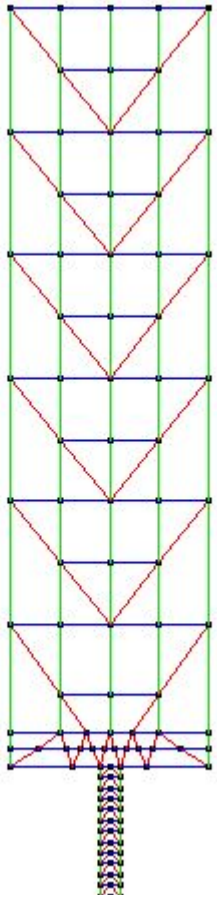
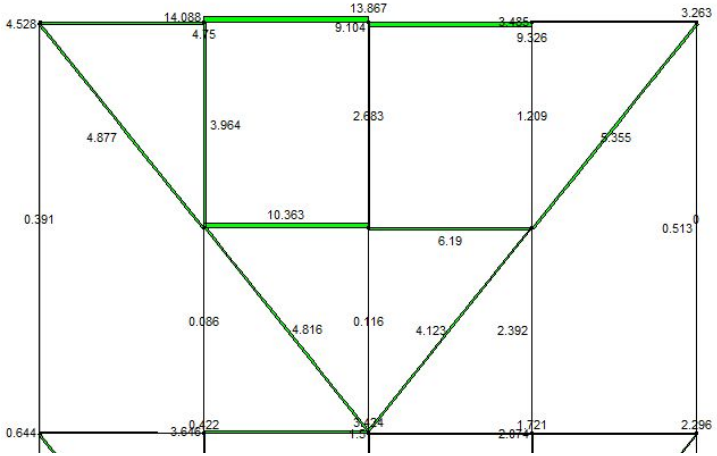
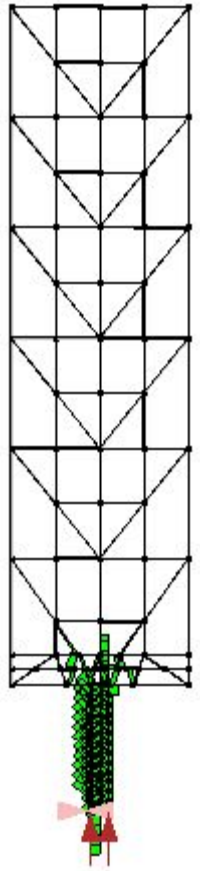
ELEVATION

- Black solid circles illustrates the connection of structural pieces which are rigid joints
- The floor slabs are shown in blue
- Chevron diagonal bracing is shown in red
- Columns are shown in green

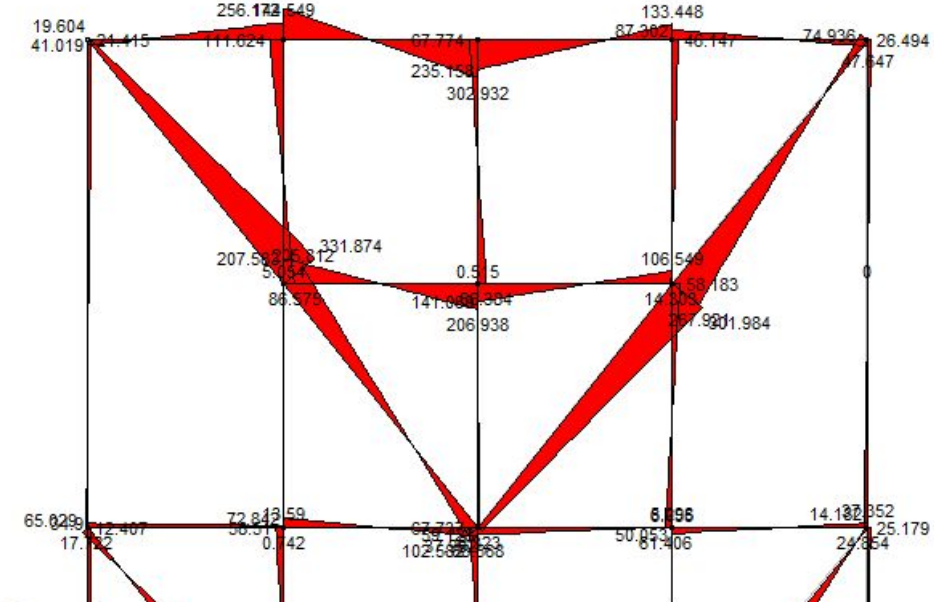


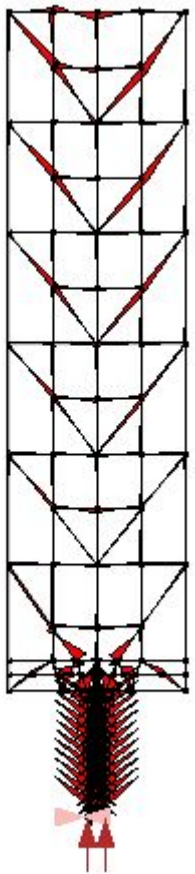
SHEAR DIAGRAMS



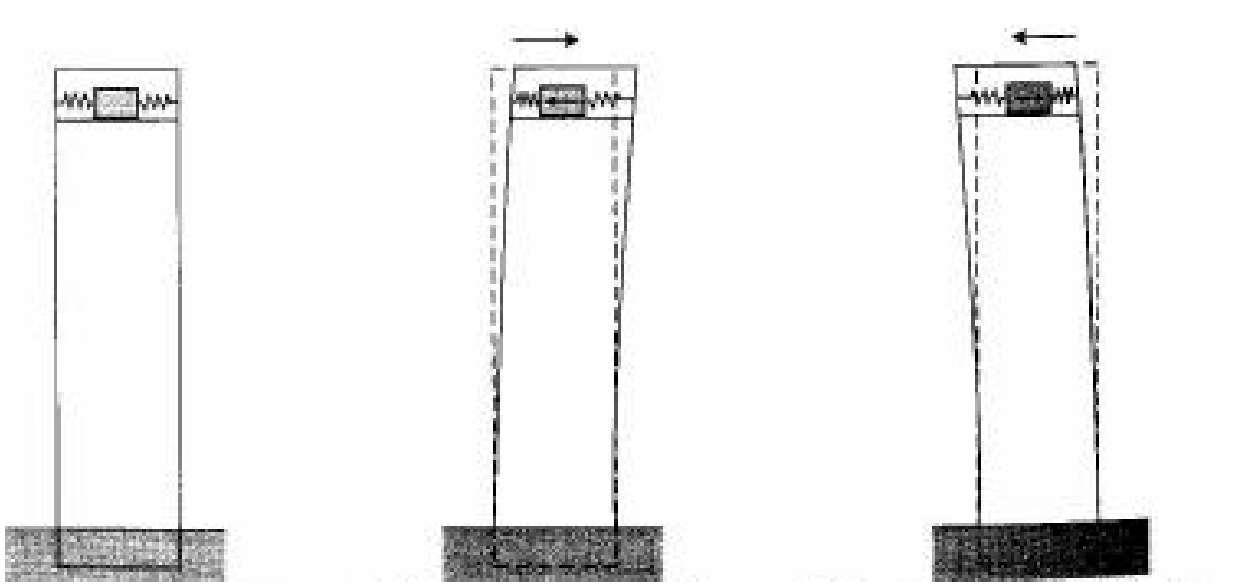


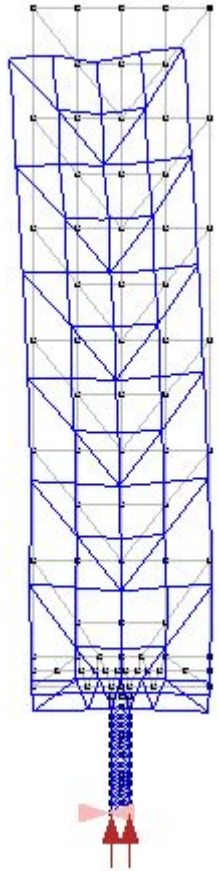
MOMENT DIAGRAMS





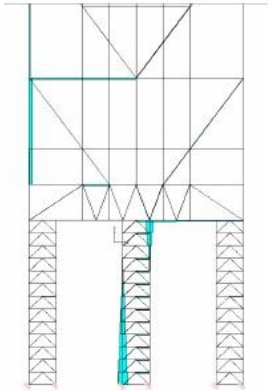
DEFLECTION

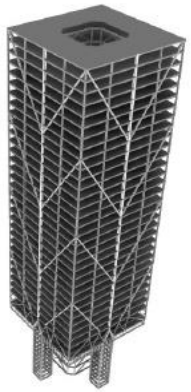


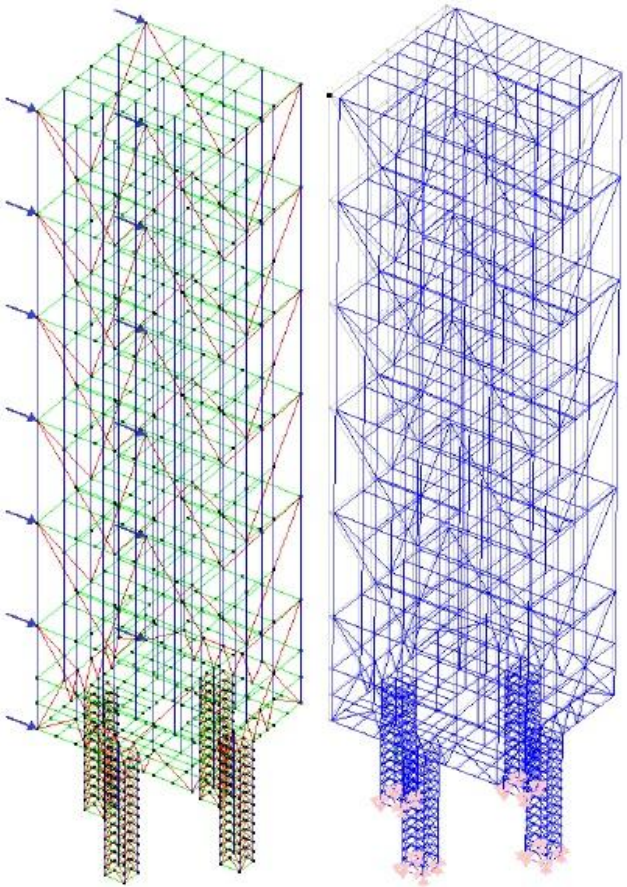


LATERAL LOADS + RESISTANCE

- Main lateral loads are wind loads
- The load is collected by the core and then transferred to the braced outer frames at the base of each tier.
- At the base, all the shear is then transferred to the core then to the ground.
- The wind load is mainly supported by columns and stilts that are normal to the wind







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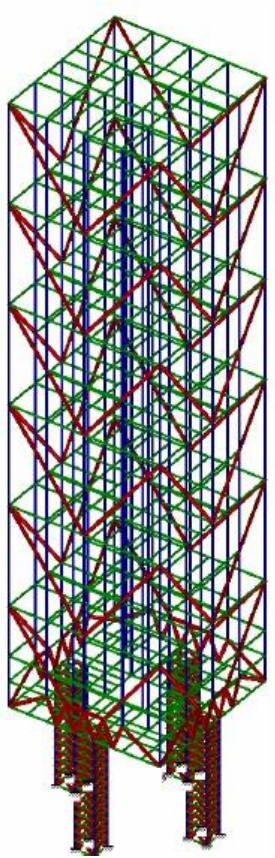
LOAD ANALYSIS SUMMARY

- Most of the gravity loads are carried by chevron diagonal bracing
- The tower is relatively light weight which can be effected by wind loads. Tuned mass damper is used to help that
- The central core takes about ¼ of the loads



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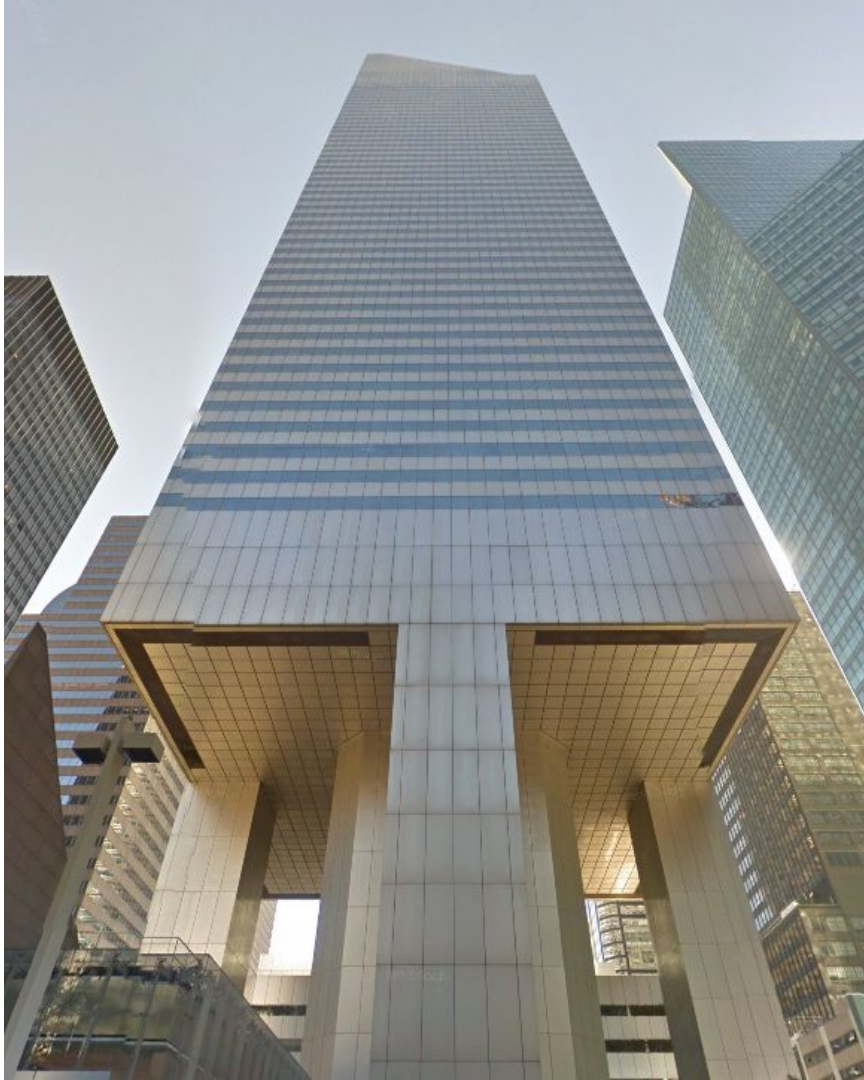
CONCLUSION

- Revolutionary design with first tuned mass damper and truss tube design ever used on a skyscraper
- Set precedent for future skyscraper designs
- It is one of New York City’s most recognizable buildings
- Despite potential failure, one of New York City’s most distinguished icons



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