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The Elevator, the Iron Skeleton Frame, and the Early Skyscrapers: Part 2

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Abstract

In Part One, I documented the evolution of the use of the elevator and the iron frame to build ever-taller buildings that would eventually be called "skyscrapers," to offset the ever-increasing cost of Manhattan real estate. By the start of the Great Depression of the 1870s in 1873, New York architects had erected two ten-storied skyscrapers. In Part Two I document the major events, designers, and buildings in New York, Chicago, and other American cities that eventually culminated in the ability to erect 20 story skyscrapers by 1890.

Keywords: Skyscraper, Iron Framing, Terra Cotta Fireproofing, Peter B. Wight, Masonry Curtain Wall, George B. Post, New York Produce Exchange, Home Insurance Building, William Le Baron Jenney, The Rookery, Burnham and Root, Leroy Buffington, The Cloudscrpaer, Diagonal Bracing, Bradford Gilbert, New York World Building, Masonic Temple.

5.1. Chicago Loses Its Fire Insurance After the 1874 Fire

Much has been written about the effect that the Chicago fire of October 8-10, 1871, had on the city's architecture. My research has found that while the fire had a major impact on Chicago's overall urban structure (i.e., the relocation of the entire wholesale district for example), the city's architecture and construction practices did not experience any major revisions. (If you are interested, you can read my findings and conclusions on my Instagram site: "thearchprofessorinchicago.") The changes that have been credited to the fire in the past actually were the result of a second fire that occurred on July 14, 1874. The insurance companies that had paid out millions of dollars on "Great Fire" claims and had also loaned substantial sums for the rebuilding, suddenly found defaults on these loans increasing at an alarming rate as the financial panic of September 1873 grew into the "Great Depression of the 1870s." These companies now found themselves in possession of large amounts of real estate, primarily in Chicago's business district.

While the 1871 fire had destroyed the business district and the Near Northside, the same conditions that contributed to the scale of its destruction still existed in the South Division, the larger portion of which had been left untouched by the fire and therefore, was to where the burned out retail businesses had relocated to resume business. (Ericsson, 1942) It was only a matter of time until the inevitable fire in this area occurred. On July 14, 1874, it started in a two-story frame building at 449 S. Clark St. at 4.30 P.M. and raged with an intensity reminiscent of the "Great Fire" for eleven hours, destroying forty-seven acres bounded by Van Buren, Michigan, Polk, and Clark containing some 800 buildings. (Moses and Kirkland, 1895). The next morning, twenty-five more buildings were destroyed by another fire at Sangamon and Milwaukee. Fortunately, especially for the insurance companies, neither fire had spread into the rebuilt Business District, where these companies were now in possession of a significant amount of the defaulted properties. The 1874 fire, therefore, had convinced the insurance companies that nothing really had changed in Chicago since the 1871 fire. (Wallin, 1966).

The National Board of Underwriters met on the night after the fire, July 15, 1874, to discuss what action to take. The consensus action was an unveiled threat to Common Council that demanded immediate improvements in the fire department and other various improvements pertaining to fire safety, or else face the possibility of the cancellation of all existing fire insurance policies within the city's limits. The Council simply ignored the warning and with no response forthcoming, the National Board had no alternative but to formally request on October 1, that its members cancel all current fire insurance policies within Chicago, with the result that by November 1 the entire city was left without any fire insurance protection. The Board also issued further demands for better regulation of construction, including the prohibition of wood balloon frame buildings, the demolition of all wooden cupolas and awnings, and the prohibition of the use of cast iron columns. As we saw in the design of Hunt's *New York Tribune* Building, by 1873 Bogardus' iron frame was no longer considered to be fireproof and the 1874 fire had finally confirmed the suspicions previously raised over the behavior of unprotected cast iron columns when subjected to the heat of a fire. The insurance companies were now making every possible effort to procure the substitution of cast iron columns with timber posts that had proven they

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could survive such a holocaust. (Wight, 1876).

5.2. Peter B. Wight Invents Terra Cotta Fireproofing and Saves the Iron Frame

The demand to stop the use of cast iron columns and substitute them with heavy timber columns was a direct threat to Chicagoan Nathaniel S. Bouton's Union Foundry Work's structural iron business, pressuring him to take an active role in the development of a fireproofing system for iron framing. Bouton turned to Peter B. Wight, a New York architect who had moved to Chicago after the 1871 fire, a national expert in building fire issues for assistance in developing a technique of fireproofing cast iron columns in order to save his business. Wight and his partner William Drake wasted little time in beginning to experiment with timber as an insulating material for cast iron columns. Wight's use of wood to protect iron should not come as a complete surprise, for as has already been shown, many critics had begun to champion solid timbers as a total replacement for iron construction, that was only reinforced by wood's lower cost. In the latter part of August 1874, he attempted one of the earliest recorded tests of the ability of hard, slow burning oak to protect cast iron, by exposing three different types of columns to a controlled fire. *(American Architect and Building News*, 1877). His column (Fig. 20) employed a cast iron column with a cruciform section with an outside diameter of 10." This was encased by four pieces of oak that were attached to the column by recessed plates and screws. Wrought iron battens covered the joints between the pieces of wood. Plaster of Paris was poured in from the top of the assembly to fill all of the gaps between the metal and the wood. The other two columns that were to be tested were not protected; one had the same cruciform section while the other was a 9" diameter hollow cylindrical iron section. The test procedures did not maintain an intense heat for a long enough period of time, however, so the test results proved somewhat inconclusive. Nevertheless, Drake and Wight (I believe that although Wight was the expert on such issues, the two partners listed their names alphabetically in the patent application) were granted a patent (#154,852) for this assembly on September 8, 1874. Symbolically on October 8, 1874 (the third anniversary of the 1871 fire but more importantly, *only a week after the insurance companies began to cancel insurance policies*), Wight ran a successful test at Bouton's Foundry. After a one-and-a half hour exposure to an intense fire, the wood-encased column survived with only a slight charring of its surface while the other two columns had completely failed. (*American Architect and Building News*, 1876; Wight, 1897).

5.3. Sanford Loring Invents Porous Terra Cotta

Three weeks after Wight's successful test while Chicago was still without insurance protection, Chicago architect Sanford Loring was issued a patent (#156,361) for "Porous Penetrable Tiles for Plastering" on October 27, 1874,

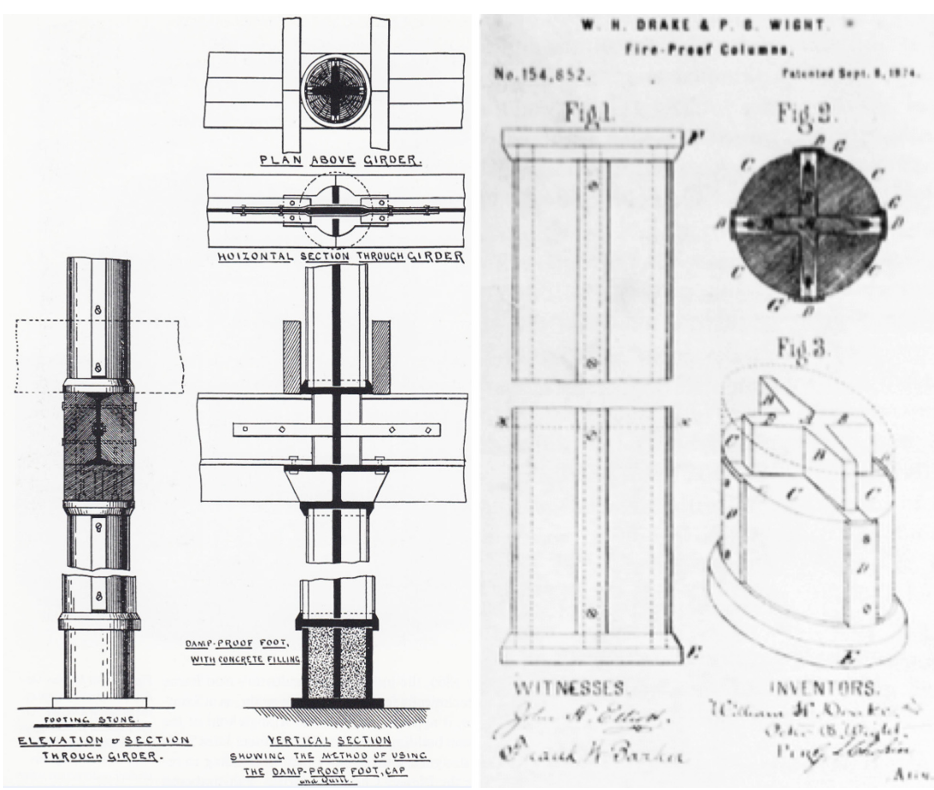


Figure 20. William H. Drake and Peter B. Wight, Patented Wood Encasing Fireproofing System for Iron Columns, Chicago, 1874.(*Wight, Brickbuilder*, August 1897, Landau, *P.B. Wight*)

(Landau, 1981). In his patented “porous terra cotta” process, Loring mixed sawdust or other pulverized organic material into the clay that burned away during firing. This resulted in the formation of air pockets relatively evenly dispersed throughout the material that not only gave the material an insulative quality, but also reduced the weight of the finished piece. The collaboration between Loring and Wight in the development of terra cotta fireproofing systems began to publicly emerge at this point. This was first documented at the 1874 A.I.A. convention, held only days after Wight's successful test of his wood-encased iron column. Wight, then president of Chicago's A.I.A. Chapter, delivered one of the convention's papers in which he not only happily reported the success of the Drake and Wight wood-encased column, but also discussed Loring's system of porous terra cotta tiles. The key to the future work of Loring and Wight in developing terra cotta fireproofing systems for iron structures was that the furnace that had been built around the three columns in which the necessary fire was maintained so as to conduct the test on October 8, was constructed in part with Loring's new porous terra cotta tiles. In his paper, Wight noted that the tiles, even though subjected both to the extreme heat of the fire as well as the cold water used to extinguish the blaze, had remained completely intact. (Wight, 1876). Porous terra cotta's insulative properties meant that a hollow air space was no longer needed to separate an incombustible covering from the material it was protecting, such as iron. This proved to be a distinct advantage over hardwood and made it the logical choice to replace the wood in Wight’s system with Loring’s porous terra cotta (Fig. 21). Therefore, while the wood-encased column led the way in principle, it was never actually used in a building. Wight's first terra cotta-encased columns were incorporated late in 1875 in the six-story Chicago Club Building at 12 E. Monroe Street. (Wight, 1892 and 1897). The depression of 1873-9 would slow the adoption of Wight’s invention, but would also give him the time to fully develop it so that it would be ready to use when construction picked up in New York and Chicago during the latter half of 1879.

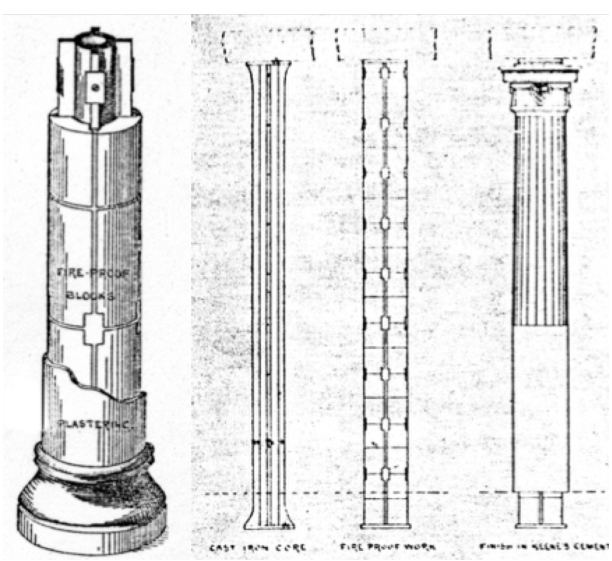


Figure 21. Peter B. Wight, Terra Cotta Fireproofed Iron Columns, Chicago, 1878. This was similar to the columns used in the Chicago Club House and the Mitchell Building, both built in 1875-76.(Wight, *Brickbuilder*, August 1897; *Inland Architect*, July 1892.)

As I have shown over the course of this paper, James Bogardus and Daniel Badger had developed the iron skeleton frame in New York during the 1850s. New Yorker Elisha Otis and Bostonian Otis Tufts had begun the development of the elevator during the latter half of the 1850s. New Yorker Henry Hyde had been the first to recognize how the elevator could increase the real estate value of a multistoried office building, i.e., skyscraper. George Post had used the iron frame in New York to support the interior of the Equitable Building as well as the taller Western Union Building. The problem of New York’s iron frame that kept it from gaining universal acceptance was iron's inherent lack of any resistance to the heat of a fire. *The solution to this problem, and not the origin of the skyscraper or of iron skeletal framing is Chicago's true claim to architectural fame.* The essence of the Chicago skeletal-framed skyscraper that evolved during the second half of the 1880s (i.e., “Chicago construction”) was that the iron frame supported its exterior masonry envelope, especially the fireproof covering of the column completely on the iron frame, thereby relieving the masonry from any load-bearing function.

As Wight’s column was the first successful example of a fireproof covering being mechanically attached to an iron column, it is appropriate to note that the Chicago iron skeleton frame had been developed in July 1874 by Peter B. Wight. Therefore, Chicago's fireproofed iron frame was developed not in response to the 1871 fire, as usually stated, but instead as a direct response to the threat to discontinue the use of iron columns and the reality of the cancellation of all fire insurance policies throughout the city in October 1874, by the National Board of Underwriters that was a direct result of the second fire on July 14, 1874. (Larson, 1983). Wight’s application of a thin surface of Sanford Loring’s porous terra cotta to the iron skeleton frame had reduced the function of masonry in a building from load-bearing to that of only fireproofing that resulted in a lightweight structural system that could finally overcome the limits of Chicago’s weak soil that would unleash the skyscraper to grow beyond the traditional height limit of ten stories, once the economy rebounded following the Great Depression of 1873-79.

6.1. George Post Designs the First Iron-Framed Exterior: The New York Produce Exchange

Wight’s system of terra cotta fireproofing for iron framing quick gained acceptance and was employed in the interiors of ten-storied skyscrapers in New York, Chicago, and other American cities after the economy had begun to recover in 1879. One of the best these designed in New York during the early 1880s was the United Bank Building (Fig. 22) at the northeast corner of Broadway and Wall Streets designed by Peabody & Stearns of Boston. The challenge now facing American architects was how to reintroduce iron into the exterior of buildings, even though Bogardus had initially proposed back in 1847 that iron framing be used as the exterior in his cast iron fronts. The problem was that the building codes, as a response the urban holocausts in Chicago and Boston, now required solid masonry exteriors as they were known to be fireproof. In 1880, George Post got around this restriction by using iron skeleton framing in the exterior walls of the lightcourt, that was not at the lot line of the building, and therefore, not legally considered as an exterior wall, in the New York Produce Exchange (Fig. 23). for a site adjacent to the Bowling Green at 2 Broadway. (Landau, 1998).

Faced with a program that required a very large (32,000 sq. ft.), skylighted trading room in addition to the requirement to provide 300 private offices for the brokers as well as for rental income, Post arrived at a solution not unlike his design for the Equitable Building. He placed the four

Figure 23. George B. Post, Produce Exchange, New York, 1880.(*Chicago and New York: Architectural Interactions*, Chicago: Art Institute of Chicago, 1984.)

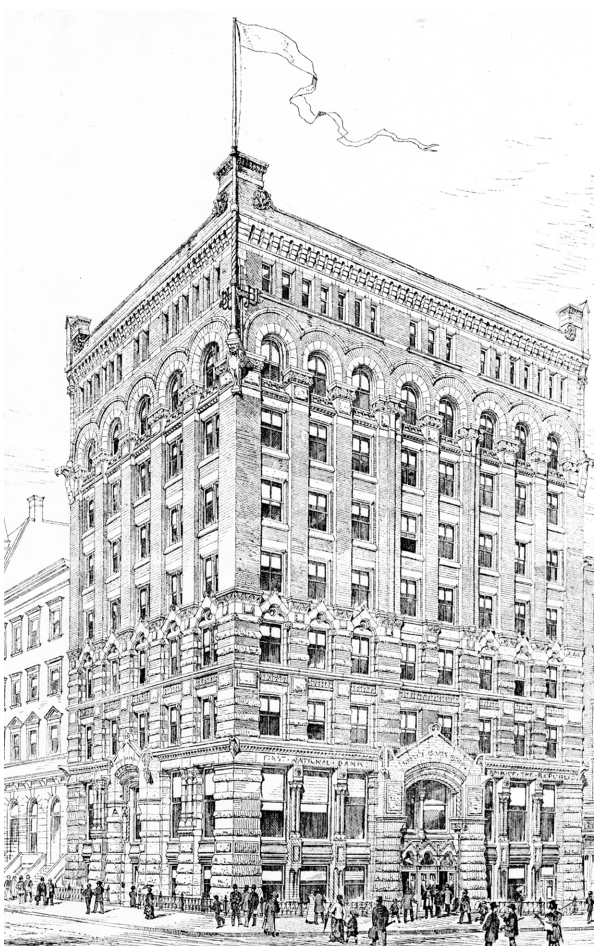


Figure 22. Peabody and Stearns, United Bank Building, New York, 1880.(American Architect, April 23, 1881.)

floors of office space above the trading room (Fig. 24), and lined the perimeter of the large site with the cellular offices (the lower two floors contained larger offices that were single-loaded while the offices in the upper two floors were smaller and, therefore, could be double-loaded), thus creating an exterior lightwell in the center (Fig. 25) that not only lit and ventilated the inner tier of offices, but also allowed the placement of a skylight over the center of the trading floor to illuminate it as well.

Using a similar detail to what is thought he had used in the exterior walls of the Equitable Building's lightcourt, he designed the four stories of exterior walls ringing the lightcourt as an iron skeleton frame that supported its exterior brick curtain walls (Fig. 26). He expressed the iron structure in the design of these elevations by articulating the rectilinear framework of columns and beams by covering the columns with a cast iron panel (Fig. 27), a detail

Figure 24. Post, Produce Exchange, Interior of Trading Room.(Stern, Robert A.M. *New York*: 1880. *New York*: Monacelli Press, 1999.)

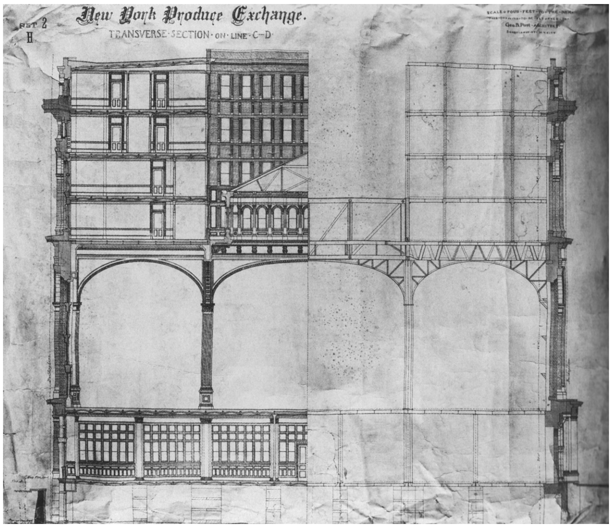


Figure 25. Post, Produce Exchange. Transverse section. (Landau, Sarah B. George B. *Post*, *Architect*. New York: Monacelli Press, 1998.)

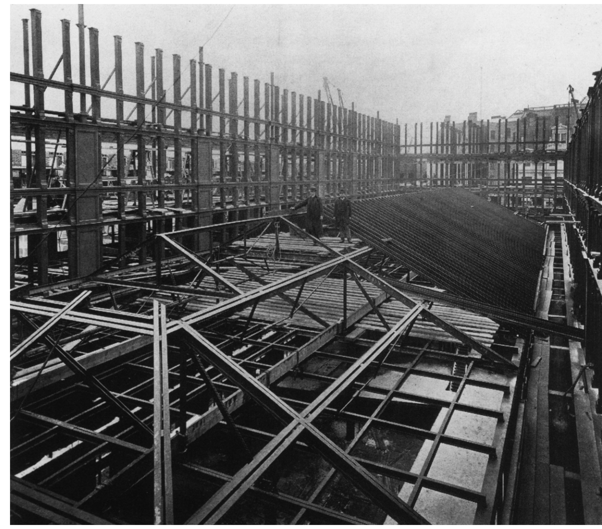


Figure 26. Post, Produce Exchange, Photo of Construction showing the iron skeleton framing in the lightcourt walls. (Landau and Condit, New York.)

similar to how Bogardus had protected the iron columns in the Tatham Bros. shot tower of 1856. (Landau, 1981 and 1998). By simply infilling the rectangular voids either with double-hung windows or with a brick panel, he had created one of the earliest, if not the first, truly modern curtain-walled exterior elevations based solely on the expression of its construction and structure: gone were the romantic arches of an earlier era. While James Bogardus can be credited as the inventor of the American iron skeleton frame, George Post deserves the credit as being the first post-Civil War American architect who continued to push the technological envelope in the design of his buildings and led the development of the American iron frame and the skyscraper during the 1870s and into the 1880s.

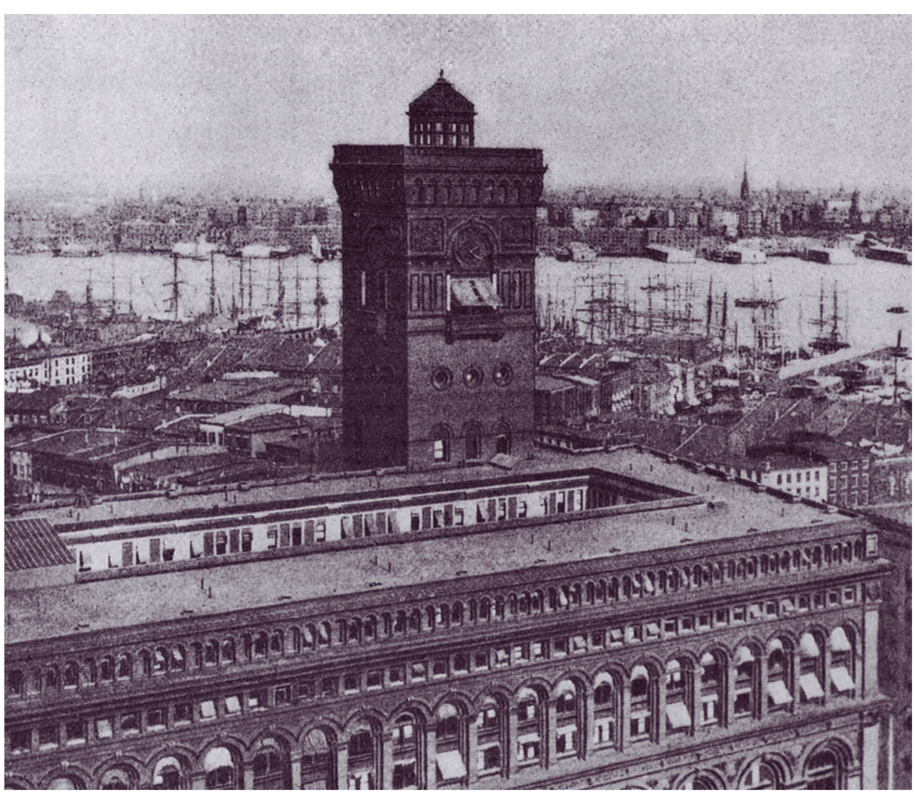


Figure 27. Post, Produce Exchange. Photo showing lightcourt's exterior walls.(Siry, Joseph M. *The Chicago Auditorium Building*. Chicago: University of Chicago Press, 2002.)

6.2. W.W. Boyington's Iron Columns in the 303' High Chicago Board of Trade

Wight's system of fireproofing allowed Chicago to build a bevy of 10-storied skyscrapers between 1881 and 1885. The best, or least the largest example of Wight's system used in this period was W.W. Boyington's 303' tower of the Chicago Board of Trade (Fig. 28), the first structure in Chicago to surpass the 175' height of his famous pre-fire Water Tower. (*Real Estate and Building Journal,* 1884; Randall, 1999). The upper portion of the 32' square plan tower was supported by four 90' high, 12-sectioned Phoenix wrought iron columns (Fig. 29), that were 3 feet, 3 inches in diameter, and fireproofed with Wight's patented terra-cotta casings. (Wight, 1892). The columns were fabricated in 1883 by Bouton's Union Foundry, in conjunction with George Pullman's Palace Car Works, proving the wisdom of Bouton's earlier contract with Wight after the 1874 fire to invent a system to fireproof iron columns. In late 1884 Boyington's tower reached its final height, besting the national record of the spire of New York's St. Patrick's cathedral (281') by some twenty-two feet. The tower's topmost height was increased at the end of 1885 to 322' with the addition of the nineteen-foot high "corona" of twenty electric arc lamps fabricated by Elmer A. Sperry, Chicago's electric light entrepreneur. Chicago could now claim to have the tallest building in the U.S., that was second in the U.S. only to the recently completed Washington Monument that was then the tallest structure in the world. (In December 1890, New York would reclaim the tallest building record with the completion of George Post's 309' high *New York World* or Pulitzer Building.)

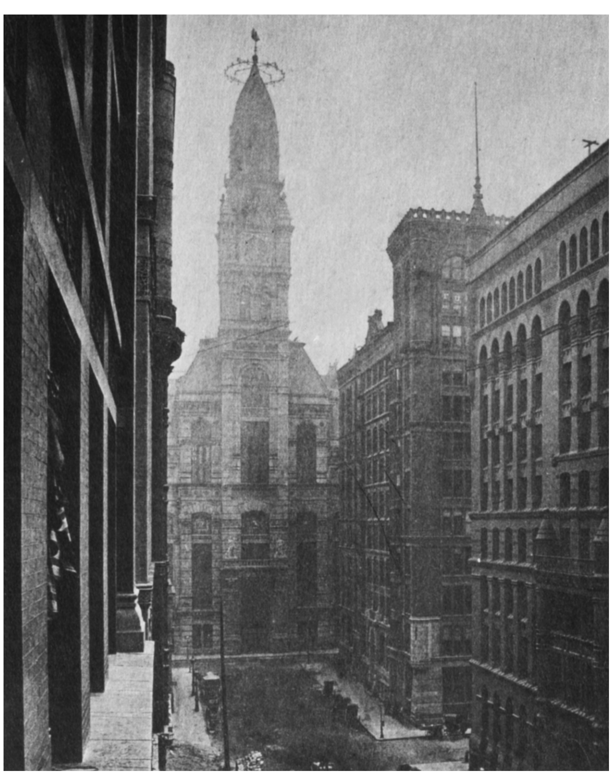


Figure 28. W.W. Boyington, Chicago Board of Trade, Chicago, 1882. The Tower sports the Sperry Corona. (Mayer, Harold M. and Richard C. Wade. *Chicago: Growth of a Metropolis*, Chicago: University of Chicago Press, 1969.)

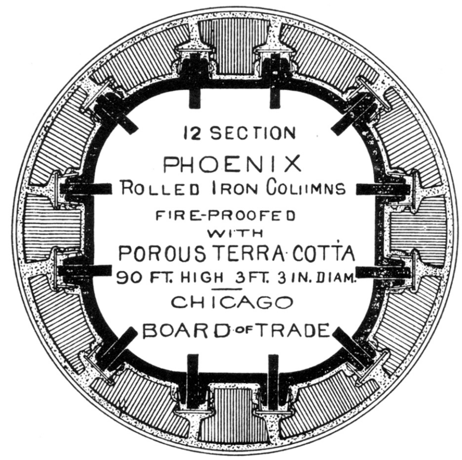


Figure 29. Peter B. Wight, Fireproofed Wrought Iron Phoenix Columns in the Chicago Board of Trade Tower, 1883.(*Brickbuilder*, August 1897.)

6.3. Frederick Baumann Publishes the Concept of the Tall Iron Frame

Besides the known advantages that the use of iron columns in the exterior of a building imparted to a tall building, i.e., larger windows (better daylighting) and a reduction in the loss of rental floor area due to smaller structural dimensions, it was imperative that Chicago's builders develop a way to reintroduce iron columns into their building exteriors if they wanted to erect skyscrapers taller than ten floors because the city's soil bearing capacity was limited to 3000 psf. (New York City did not have this limitation.) Taller buildings using bearing walls on the exterior weighed more than this and simply would settle a greater dimension than was acceptable (the most notorious example of this was the 17-story tower in the Auditorium, that eventually would settle almost 30.")

Frederick Baumann, an architect who had emigrated from Germany in 1850 and had established a reputation as Chicago's leading theoretician on building construction with his development of the uniformly-stressed pad foundation in 1873, appears to have been one of the earliest Americans to apply the concept of Bogardus' independent iron frame to the construction of tall buildings, since it had fallen out of favor following the Civil War, in an article, "Improved Construction of High Buildings," published in the March 15, 1884, issue of *Sanitary News*.

The design is to erect on foundations a firm and rigid skeleton, or hull, of iron, and cover it at once with a proper roof... The practicability of erecting buildings on Chicago soil, twelve and more stories high, then becomes a fact. Light, the great desideratum in all city buildings, *is secured, even on the lowest-the most valuable-floors, whereas, otherwise, the necessarily broad piers would be a hinderance. The piers may not only be made narrow, but shallow-twenty-seven inches at the most, thus, again making a saving of light.. The iron uprights are to be provided with a series of projecting brackets for the purpose of anchoring and supporting the parts forming the exterior enclosure. These supporting brackets will be so arranged as to permit an independent removal of any part of the exterior lining, which may have been damaged by fire or otherwise. The iron-floor girders are securely fastened to the outer posts at both ends. This imparts firmness to the structure;*

He later stated that he had already publicly presented his scheme at an earlier lecture, so the first public discussion of his ideas would have necessarily preceded the article by, being conservative, at least two weeks to account for writing, editing and printing. This, then pushes the date of Baumann's revelation conservatively back to at least March 1, 1884, if not even earlier. (Baumann, 1884).

6.4. Cobb and Frost Detail Exterior Iron Columns in the Chicago Opera House Block

As the erection of the iron columns in the Board of Trade was being completed in August 1884, construction began on the ten-story Chicago Opera House Block (Fig. 30) at the southwest corner of Washington and Clark Streets, designed by Henry Ives Cobb and Charles Sumner Frost. The program called for a 2500 seat auditorium, that Cobb & Frost located in the interior of the site, running north to south. Access to the lobby was provided by the theater's famous illuminated canopy on Washington Street. It was the lower two floors of the skyscraper that aroused the interest of the local building community.

They had lined the two street fronts with stores on the first two floors that were then topped with eight stories of offices. To better serve the stores on the ground floor by creating windows as large as possible, they used iron columns and beams in the exterior of the two street fronts (Fig. 31) to support the upper eight floors of loadbearing masonry. Curiously, the iron structure in these two floors appears to have been completely exposed, with no apparent means of fireproofing visible. Even though the iron columns had a spindly appearance in relation to the thickness of the masonry piers above them, the Opera House Block marked the post-fire return of the use of iron skeleton framing in the exterior of Chicago's multistory buildings. (*Inland Architect*, 1884).

Cobb and Frost had met in the Boston office of Peabody & Stearns, the designers of the United Bank Building (Fig. 22) in New York. Cobb had moved to Chicago in early 1882, convincing not only Frost, but also George A. Fuller, another Peabody & Stearns associate to move to Chicago to supervise the construction of their anticipated designs. Prior to his move to Chicago, Fuller had been in charge of Peabody & Stearns' New York office, where

Figure 30. Cobb and Frost, Chicago Opera House Block, Chicago, 1884.(Condit, Carl W. *The Chicago School of Architecture: A History of Commercial and Public Building in the Chicago Area, 1875-1925*, Chicago: University of Chicago Press, 1964.)

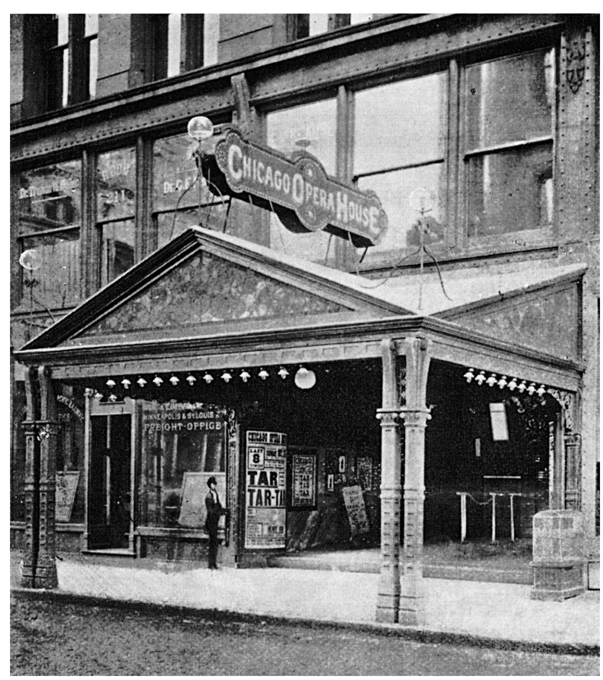


Figure 31. Cobb and Frost, Chicago Opera House Block, Detail of exposed iron framing in the first two floors. (Siry, *Auditorium.*)

one of his last projects had been the United Bank Building. Fuller paired his New York experience with a Chicago contractor, C. E. Clark to form Clark & Fuller, who as we will see, would become the city's leading construction firm. (Van Zanten, 1984; Wolner, 2011).

6.5 William Le Baron Jenney and the Home Insurance Building

Following Cobb & Frost's use of exterior iron framing in the lower two floors of the Opera House Block, Chicago architect William Le Baron Jenney incorporated iron columns in portions of the two street fronts of the Home Insurance Building (Fig. 32) at the northeast corner of La Salle and Adams. Although he received the commission in March 1884, his personal notes show that he did not consider the use of exterior iron columns until April 17, over a month after the publication of Baumann's article on the possible use of skeleton framing. As the building's number of floors increased while he was designing, he became concerned about the size of the masonry piers in relation to the need for daylighting and decided to embed iron columns within the piers that would support the floor beams to keep the piers' cross sections within reason. (Larson-*JSAH*, 1987). Constrained by the building code's requirement for masonry exteriors, he did not employ Baumann's idea of placing the exterior masonry on each floor of the iron skeleton frame but embedded the iron columns (that supported the iron floor beams) *within* the masonry piers. Note that he did not use iron spandrel beams at each floor that, at least, could have made the iron armature in the exterior into a skeleton frame (Fig. 33).

Jenney had earlier published an article in 1883, in which he revealed his understanding of the subject just before he received the Home commission: "Educated

Figure 32. William Le Baron Jenney, Home Insurance Building, Chicago, 1884.(J.W. Taylor, IChi-00989; Chicago Historical Society.)

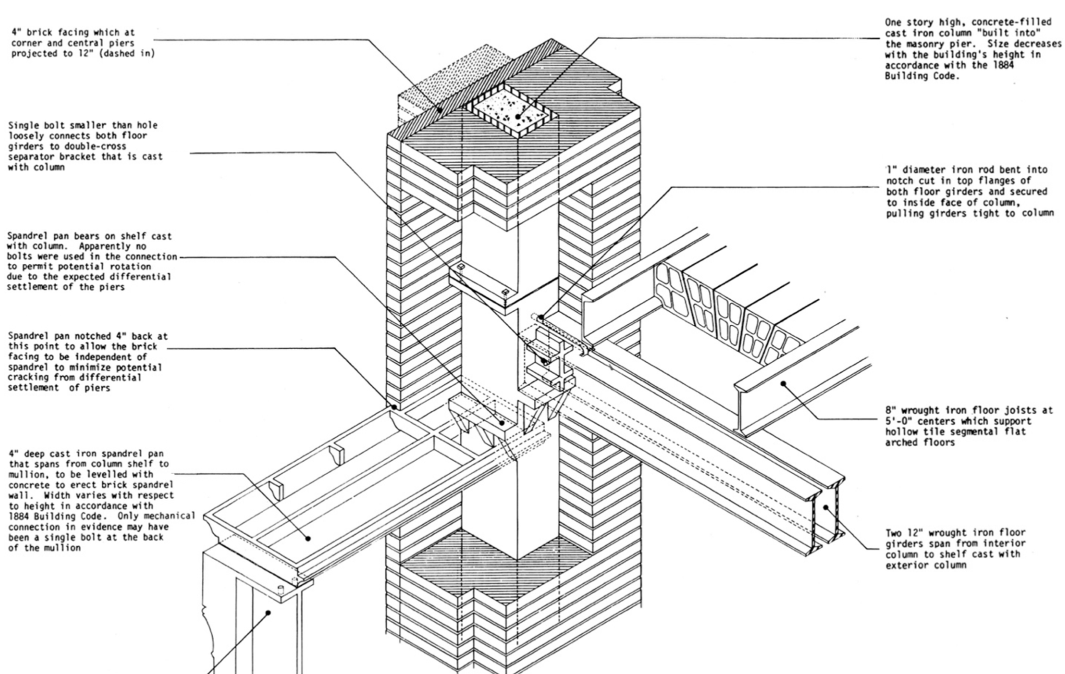


Figure 33. Jenney, Home Insurance Building. Reconstruction of the structural detailing of the exterior piers.(Drawing by Deborah Cohen and Maxwell Merriman.)

architects in Europe... have been working with and writing on the *combination of stone, brick and iron*, in the street elevations of buildings." (Jenney, 1883) In other words, he did not mention the concept of an iron frame supporting its exterior masonry curtain wall but spoke instead of the structural combination of brick and iron. This combination clearly reflected his French training and familiarity with French theorist Viollet-le-Duc's early ideas about the use of iron and masonry. To Jenney's credit as a pioneer in iron construction, he had first experimented with this technique in 1879 in the First Leiter Building (Fig. 34), a small five-story loft building at the northwest corner of Monroe and Wells. In order to make the load-bearing masonry piers in the Wells Street façade with the same dimensions as those in the non-loadbearing Monroe Street façade, he had placed iron sections on the inside face of only the piers in the Wells elevation to support the timber floor girders. (Larson-Art Institute, 1987).

Five years later he used a similar detail in the two exterior street facades of the Home Insurance Building. The building's interior structure was the by-then standard iron frame protected with Wight's terra cotta casings. Also standard were the two masonry bearing party walls (Fig. 35) on its north and east that ran the entire height of the building and provided much of the building's lateral stability. In fact, even the first two stories in the street fronts also were loadbearing rock-faced granite piers, battered in thickness from 4'-0" at the base to 2'-10" at the third floor. The only detail in which Jenney had departed from standard Chicago construction of the early 1880s

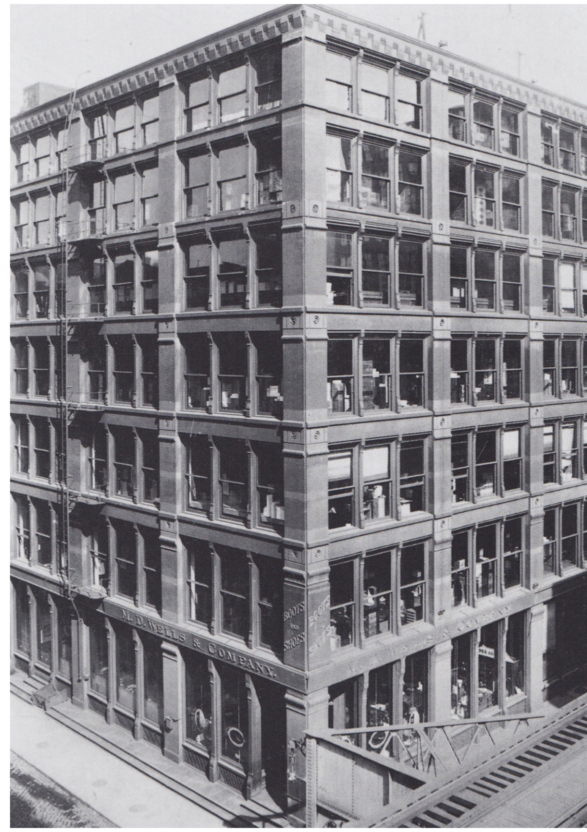


Figure 34. Jenney, First Leiter Building, Chicago, 1879. The two upper floors were added in 1888.(Zukowski, John (ed.), Chicago Architecture, 1872-1922: Birth of a Metropolis, The Art Institute of Chicago, Chicago, USA. 1987.)

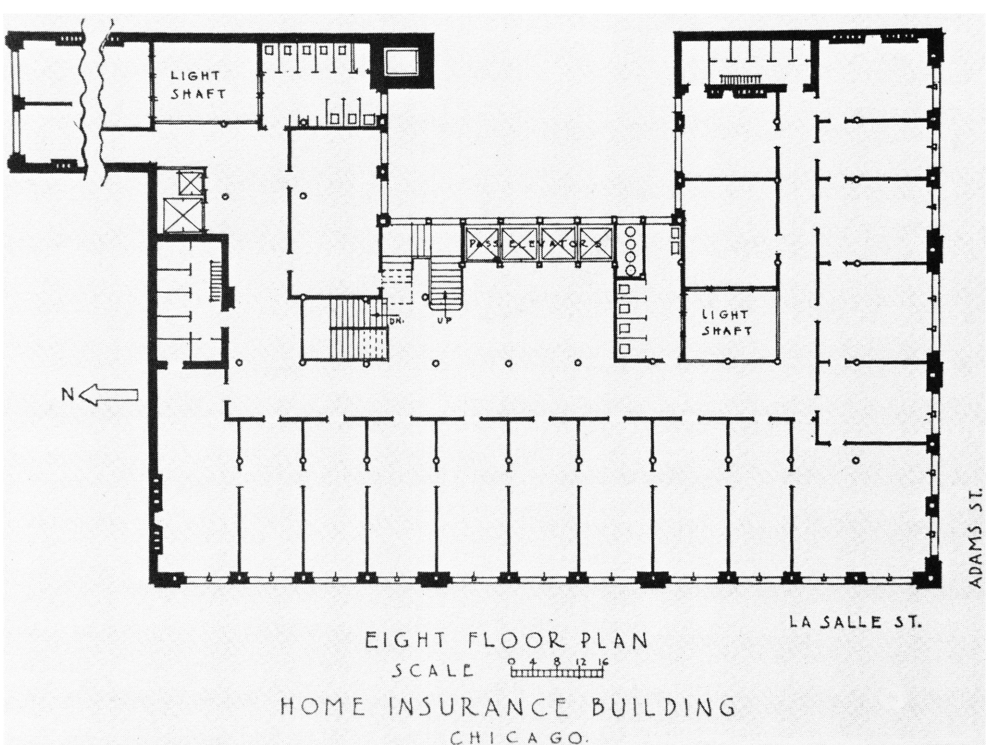


Figure 35. Jenney, Home Insurance Building. Typical floor plan.(Tallmadge, Theodore E., *The Origin of the Skyscraper-The Report of the Field Committee*, Chicago, 1934.)

was his insertion of a rectangular, concrete-filled cast iron section (Fig. 36) within the exterior masonry piers in only the upper eight stories of the two street fronts. (Larson-*JSAH*, 1987).

The iron sections were story-high, hollow cast-iron sections that supported the floor beams. These sections were set on the top of the granite piers at the third floor and were bolted one on top of another, helping to support the upper seven floors and roof. These sections were cast with shelf brackets to support two 12-inch deep wrought iron floor beams (Fig. 37). These beams were loosely bolted to the column by a single bolt that passed through the beam webs and connected them to a spacing bracket that was also cast with the column. As tolerance was needed for erection, the holes were larger than the bolt, leaving the connection with a considerable amount of play. Therefore, Jenney had incorporated a clamp that was a one-inch diameter wrought iron rod that was bent at one end and placed into a notch cut into the top flange of both beams. The rod on the other end was threaded, allowing it to be connected to the column by a nut placed inside the column, thereby pulling the beams tight to the column face, after which the iron column was filled with concrete. The concrete-filled iron column was then surrounded with masonry that at times exceeded twelve inches in thickness, creating a solid cross section in the building's exterior piers. Rather than describing this technique as wrapping or enclosing the iron column with a masonry skin, Jenney stated that he embedded the iron column *within* the masonry pier: "a square iron column was *built into* each of the piers in the street fronts" (Jenney, 1885).

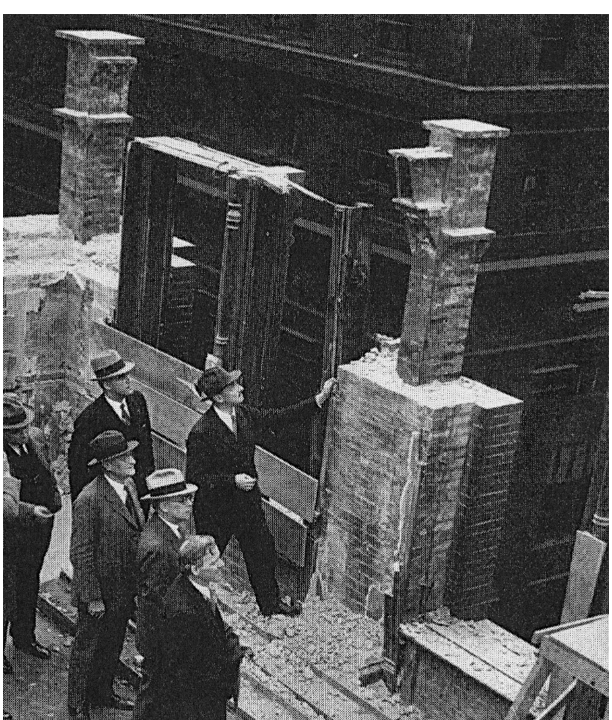


Figure 36. Jenney, Demolition of the Home Insurance Building, 1931.(Tallmadge, *The Origin of the Skyscraper*, 1934.)

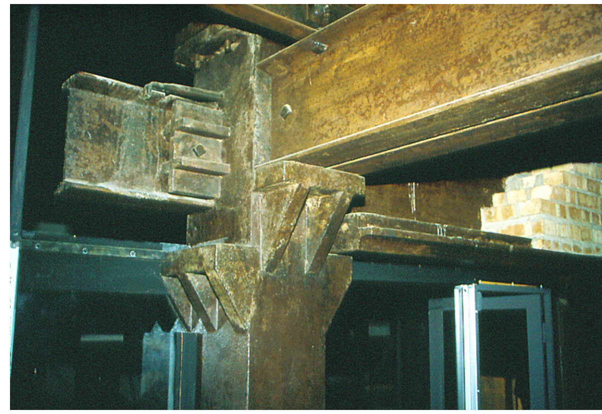


Figure 37. Jenney, Home Insurance Building. Surviving fragment of the iron structure in the Museum of Science and Industry. Note the stub spandrel beam (at the left of the column) that the Field Committee chose to include in the fragment left for history. As this beam was located in only three of the eight floors that were skeleton-framed, the committee attempted to mislead future historians about the true nature of Jenney's structure.(Author image.)

Unlike a skeleton frame, however, Jenney did not insert an iron spandrel beam at each floor that should have spanned between the columns that would have not only connected them into a rigid framework but also supported the windows and the masonry spandrels at each floor. Instead, to support the windows and masonry spandrels between the piers, Jenney detailed four-inch deep, hollow cast-iron lintel pans, that were also filled with concrete like the columns. Note that these were not one, continuous iron member that spanned between the piers but comprised of two halves that each spanned only the distance between a column's shelf bracket and the intermediate cast iron mullion. The iron pans were not mechanically connected to either of their vertical iron supports, but simply rested on their horizontal surfaces, relying on the masonry in the spandrel and piers to hold them in place.

The lack of a mechanical connection between the iron columns and lintel pans was his technique to impart some flexibility at the pier/spandrel connection to accommodate expected differential settlement of the piers, because at this time, it was still conventional construction practice to make the foundations for both the columns and intermediate mullions the same size, independent of the load they carried. This resulted in the heavier-loaded piers settling at a greater rate than the smaller mullions, transferring more and more load to the mullions, and often resulted in cracking around them. Jenney's flexible column/lintel joint was augmented by his notching the front of the iron pan back four inches from the face of the pier that allowed the pier's exterior face brick to continue past the lintel so that it would not be supported by the lintel pans.

This detail minimized the potential of the face brick to crack if the spandrel rotated, but it also meant that the pier's eight stories of brick facing was self-supporting from the granite piers and was not supported at each floor on the iron column. Jenney also did not connect the intermediate iron window mullions into a continuous line of support to the foundation. In fact, the mullions were not even mechanically connected to each other. Each mullion simply sat on the concrete filling of the lintel pan below it, and once again, was held in place by the surrounding masonry.

The easiest way to avoid the anticipated differential settlement between the piers and the intermediate mullions was to transfer the mullion loads over to the main piers, thereby the mullions would never reach the ground. If this was done not with a single transfer beam at the lowest floor, but with a series of transfer beams as Jenney had detailed (Fig. 38), the loads in the mullions would be uniform, and therefore the mullions' cross-section would not have to increase as the piers did, keeping the windows as large as possible. Jenney, therefore, placed iron transfer beams to carry the mullions' loads to the piers immediately above the cast iron lintel pans at the fourth floor (four 7-inch I-beams), sixth floor (three 15-inch I-beams), ninth floor (two 12-inch I-beams), and roof (two 15-inch I-beams). (Larson-*JSAH*, 1987). These transfer beams also nominally laterally tied the iron columns in the piers together (especially at the roof), thereby creating what one might optimistically call a "skeleton frame." However, if it was Jenney's intention to actually create a rigid iron skeleton frame in the street fronts, these beams should have been introduced at every floor to not only carry the spandrels' masonry, but also to laterally brace the iron columns at each floor to minimize their buckling length since the iron lintel pans were not bolted to the columns and, therefore, any bracing provided by them was negligible at best. As constructed, the iron columns in floors 6-8 stood laterally unbraced for three stories (Fig. 39). Consequently, without the masonry and the concrete filling, the iron armature in the exterior would not only have been structurally unstable, but also have been very difficult, if not impossible, to erect it two or three floors ahead of the stiffening masonry of the piers and spandrels as some reports claim. (Tallmadge, 1934). From the evidence I have presented (for a more detailed analysis of the building's structure, please see my 1987 *JSAH* article), therefore, we can conclude that the loosely-bolted, eight-story framework of masonry-stiffened cast iron columns and lintel pans conceived and used by Jenney was not entirely self-sufficient nor independent of the masonry, i.e., it was not an iron skeleton frame. The Home Insurance Building was simply just one of a handful of skyscrapers that were under construction in Chicago during 1884. Therefore, if one adopts the definition of a skyscraper that is a tall building constructed solely with a metal skeleton frame, one needs to ascertain what was the first such tall building

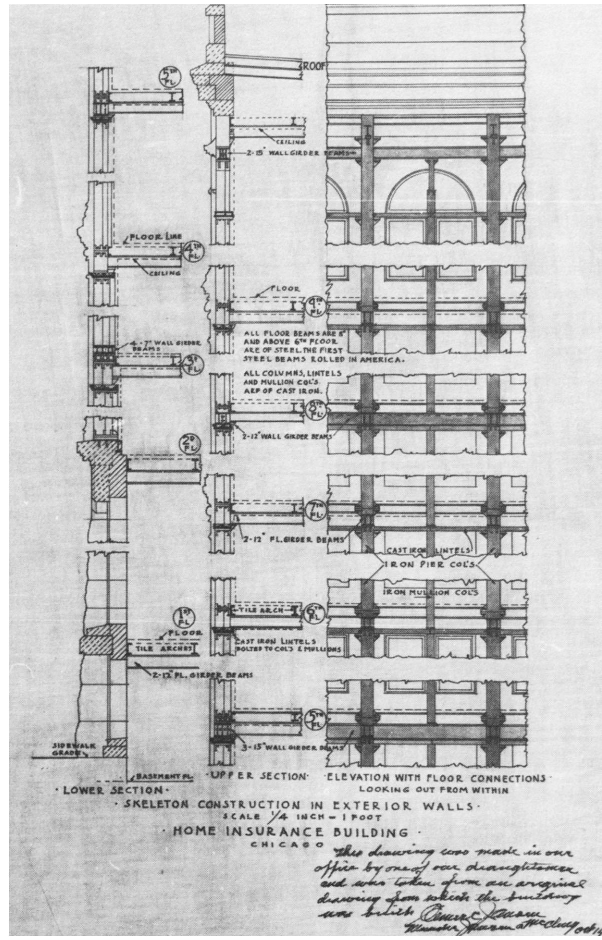


Figure 38. Jenney, Home Insurance Building. Section and elevation of structural iron members in the exterior, showing the location of the transfer beams at Floors 4, 6, 9, and roof. It is more important, however, to understand that there were no spandrel beams in Floors 5, 7, 8, and 10.(Jensen & Halstead, Ltd., Chicago.)

erected, for it was not the Home Insurance Building.

Jenney's structure in the Home Insurance Building did not generate much attention or acclaim in the U.S., or for that matter, even in Chicago, during its construction nor immediately following its completion, and most likely was viewed by Chicago's architects and builders as an eccentric curiosity because I am not aware of any Chicago architect whomever employed Jenney's details in any building in Chicago. Even during its construction during the latter half of 1884, Jenney himself modestly spoke of S.S. Beman's Pullman Building as the highpoint of Chicago's architecture. (*Inland Architect*, July 1884). In fact, as the iron columns began to be erected in August 1884, Inland Architect stated that the commission for the Union League Club, and not the Home Insurance Building, was "the greatest compliment Mr. Jenney has yet received professionally." (*Inland Architect*, August 1884). If Jenney's use of iron in the Home Insurance Building had been considered to have been of a revolutionary nature, surely

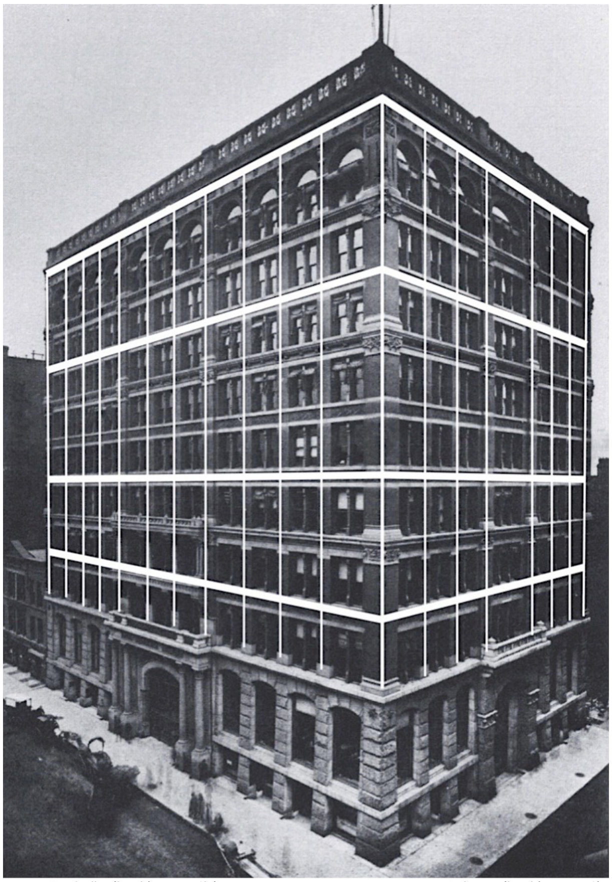


Figure 39. Jenney, Home Insurance Building. The exterior iron structure overlayed the building's elevations, showing the lack of spandrel beams in Floors 5, 7, 8, and 10. (Drawing by David Burwinkel.)

it would have been quoted in any of the obituaries for Daniel Badger, who died in November 1884 and was referred to as "the first person in this country to use iron on a large scale for building purposes." (*American Architect*, 1884). Not surprisingly, following Jenney's description of its structural system at the 1885 A.I.A. convention in October, the Home Insurance Building and the potential of its "unique" structural system were not discussed for the next two and a half years in American trade magazines or conference proceedings. (As we will learn in a few paragraphs further down, the threat of a patent granted in 1888 for iron framing to build skyscrapers would send lawyers scurrying in search of "prior art.")

6.6 John Wellborn Root and the Rookery's Lightcourt

All it takes to understand why Jenney's structure in the exterior of the Home Insurance Building cannot be considered to be skeleton framing is to compare it with the iron skeleton frame George Post had detailed two years earlier in the exterior walls of the lightcourt in the New York Produce Exchange (Fig. 26). In 1885 John Wellborn Root (who not so coincidentally, was brought from New York to Chicago after the 1871 fire to be a draftsman by Peter B. Wight) was confronted with a similar program and scale of building to that of Post's with the commission to design the 12-story Rookery (Fig. 40), for the southeast corner of La Salle and Adams, immediately across Adams Street from the Home Insurance Building. Root's design began in the middle of May 1885, only weeks after the doors of the Home Insurance Building were opened to the public. One would have thought that if Jenney's details were revolutionary that Root would have been quick to employ them in the Rookery's design. Instead, he chose to emulate Post's details from the Produce Exchange.

Daniel Burnham's preliminary plan studies would have revealed a startling fact: unlike all of Burnham & Root's prior skyscrapers, the site for the Rookery's 167' depth would free them from their conventional scheme of the thin slab of a double-loaded corridor (Fig. 41). Undoubtedly, Burnham would have examined a similar scheme for the Rookery's site, discovering that the extra depth would permit a more radical departure from their typical skyscraper floor plan. The site could be most efficiently used (net rentable floor area) if he lined all four street fronts with a thin slab of a double-loaded corridor, thereby, in effect, creating a double-loaded doughnut plan with a totally concealed exterior lightcourt in the center (Fig. 42), similar to Post's Produce Exchange. The double-loaded corridors, however, required that the skylight over

Figure 40. Burnham and Root, The Rookery, Chicago, 1885.(Zukowski, *Chicago: Growth of a Metropolis.*)

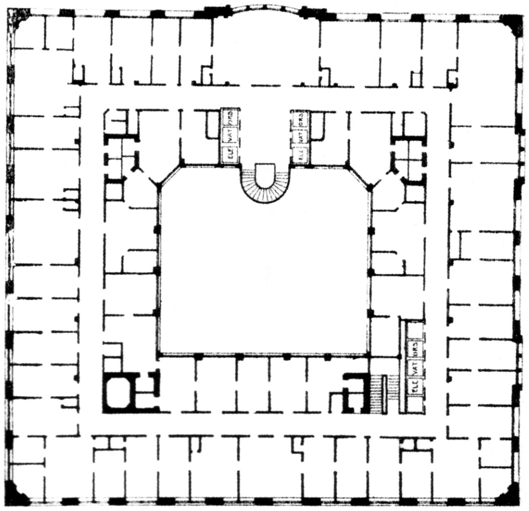


Figure 41. Burnham and Root, The Rookery. Typical floor plan.(Schaffer, Kristin, *Daniel H. Burnham: Visionary Architect and Planner, Rizzoli*, New York, USA, 2003.)

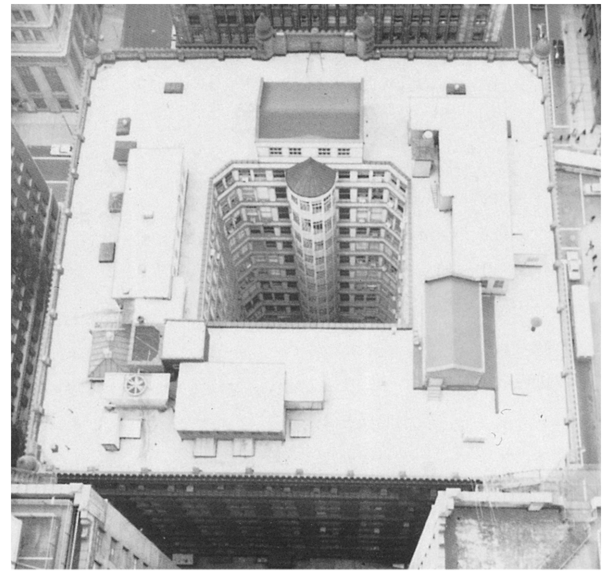


Figure 42. Burnham and Root, The Rookery. Rooftop view, showing the oriel stair tower within the lightcourt. (Pridmore, Jay with the Chicago Architectural Foundation, *The Rookery*, Pomegranate, San Francisco, USA, 2003.)

the atrium, that in single-loaded schemes was located at the roof that resulted in a tall, spacious atrium, be brought down to the second floor, so that the inner tier of offices above would have exterior exposure to fresh air and daylight. In the Rookery, therefore, Root was forced to pull the skylight all the way down from the roof to the point where it hovered, somewhat menacingly, over the 62' by 71' atrium at the relatively low level of the third floor (Fig. 43). Although denied the opportunity to add another of his designs to Chicago's growing collection of tall, light-filled atria (the Grannis Block and the Chicago, Burlington, & Quincy Railroad Headquarters, as well as Boyington's Grand Pacific Hotel and the Royal Insurance Building), Root would take advantage of the lower location of the Rookery's skylight to actually allow people to penetrate up and through it, blurring the boundary between what was inside and what was outside.

Given the same design parameters that George Post had synthesized in his design for the Produce Exchange, i.e., the design of the exterior walls in the lightcourt that were

Figure 43. Burnham and Root, The Rookery. Atrium.(Pridmore, *The Rookery.*)

not subject to the building code's requirement for masonry walls because they were not located at the perimeter of the lot, and heavy masonry walls around the perimeter of the building that provided the necessary lateral bracing against wind loads, Root took the opportunity to experiment with the structure of the lightcourt walls, and as Post had done four years earlier, would detail these four walls as the first use in an exterior wall of a Chicago skyscraper of an independent iron frame that supported a uniformly-dimensioned glass and masonry curtain wall at every floor (Fig. 44), a great improvement over Jenney's anachronistic system of iron-reinforced masonry piers used across the street in the Home Insurance Building.

Root cantilevered a line of 7-inch channel sections and 12-inch I-sections off the face of the columns (at each floor, in contrast to Jenney's detailing) to support the interior wall of hollow tile and the exterior brick veneer. (Hoffman, 1973). In order to reflect as much light as possible down into the lightcourt and into the inner ring offices, Root used an English cream-colored glazed enameled brick. However, opposed to how Post had designed the elevation of the Produce Exchange's lightcourt in which he had equally articulated both the horizontal and vertical lines that resulted in a rectangular grid, Root completed his essay on modern, iron skeleton construction by subtly detailing the brick spandrel at each floor level as a continuous, unbroken horizontal layer around the court, interrupting the vertical line of the columns. As the masonry was no longer supporting its own weight continuously to the ground, Root had expressed this new reality by making the vertical masonry covering of the iron columns subordinate to the horizontal bands. The lines of the floors were accented with bands of gold-leafed, brown glazed terra cotta at the top and bottom of each spandrel that flowed continuously through, breaking the vertical continuity of the column's masonry surface. The columns, although also faced with the brick, were, thereby, appropriately subordinated to the spandrels by being inserted between the spandrels' trim, with each column panel being capped with a matching terra cotta capital. The resulting horizontal composition of alternating layers of white brick and ribbon windows was a straightforward expression of the wall's construction. A modern architectural expression had finally appeared in public. (Le Corbusier would name this detail some forty years later as the "free façade" in his "Five Points of a New Architecture.")

Figure 44. Burnham and Root, The Rookery. Exterior Lightcourt.(Author image.)

Coming through the aperture of the Rookery's elevator lobby, Root enticed you to come up, through the skylight and into the lightcourt itself, in order to view this new architectural language. One was presented by Root's unconscious prophesy of what a skyscraper's exterior in the immediate future would look like: thin, lightweight, rectilinear, light-colored and clean, and somewhat released from the tyranny of gravity: free from having to be vertically connected to the ground. The contrast between the exterior's elevations and those of the atrium was not only startling, but it was also profound. The chrysalis of the skyscraper had emerged within the pro-tective confines of its protective masonry cocoon, for Bogardus' iron skeleton frame of the shot towers had finally reappeared in the exterior of a tall building. The lightcourt in the Rookery could be described as taking a department store with a skeletal structure and enclosing its multistory atrium with Bogardus's technique of supporting brick panels at every floor, that he had first used thirty years earlier in the McCollough Shot Tower (Fig. 7). (*Inland Architect*, June 1886). In fact, Root had even inserted such a form within the lightcourt that housed his by now characteristic cantilevered oriel stair tower (Fig. 45). Root had not only changed construction history with the Rookery, he had also devised an appropriate monu-ment to the history of the iron skeleton frame for later generations to appreciate the radical differences between the two structural systems. It would take a few more years before this non-romantic elevational expression would make its first appearance on the public exterior of a building (one only had to wait five years for it to appear on Burnham & Root's Reliance Building), yet one cannot dispute that Root's atrium walls

Figure 45. Burnham and Root, The Rookery. Exterior lightcourt.(Zukowski, *Chicago: Growth of a Metropolis*.)

Figure 46. Holabird and Roche, Tacoma Building, Chicago, 1888.(Merwood-Salisbury, Joanna. Chicago 1890, University of Chicago, Chicago, 2009.)

was its first showcase.

6.7. Holabird & Roche Turn the Rookery Inside Out: The Tacoma Building

Sooner or later, some Chicago architect would be the first to put Root's Rookery lightcourt's iron frame and curtainwall on the outside of a building. The first to have done so in Chicago appears to have been the young firm of William Holabird and Martin Roche in early 1888, in their design of the 13-story Tacoma Building (Fig. 46), for the northeast corner La Salle and Madison. Just who deserves the credit for initially suggesting that the Rookery's lightwell's detailing be used on the exterior of the Tacoma Building is not recorded. I tend favor the building's contractor, George Fuller, who, not so coincidentally, had been the contractor of the Rookery as well as the Chicago Opera House Block. Others credit Sanford Loring of Chicago Terra Cotta, while we also cannot ignore the creativity of the architects themselves. (Bruegmann, 1997). While both partners had cut their professional teeth in Jenney's office prior to the design and construction of the Home Insurance Building, what they designed for the Tacoma Building bore little resemblance to Jenney's detailing. While I noted that the construction of the Home Insurance Building generated little professional interest among Chicago's construction community, the Tacoma's inventive structure and construction would provoke great interest among the townspeople and the professional press.

Robert Bruegmann's research has documented that the plan to wrap the corner site with a double-loaded corridor scheme, creating a lightcourt in the northeast corner of the site, was first proposed by William E. Hale, the elevator manufacturer on March 8, 1888. The architects, along with Fuller and their consulting engineers, Charles G. Wade and Corydon T. Purdy, examined both a traditional masonry load bearing exterior and a much thinner, Rookery-like iron frame and curtain wall exterior, calculating that the much thinner curtain wall would generate $4500 a year more in rent that would quickly offset its $10,000 higher construction cost. The owner, meanwhile, added another floor to the already large project, making it 13 stories tall, a height that demanded extra caution with regards to the building's ability to resist the increased wind loads. The architects were very conservative about the overall structure of the building, resorting to four interior bearing walls (Fig. 47) to gain the necessary rigidity in response to the expected wind loads. So while the *Chicago Inter-Ocean* could describe the exterior of the Tacoma Building as an "iron framework," this technique was limited to only the exterior curtain wall, for the architects had simply turned the Rookery inside out: they moved the heavy masonry

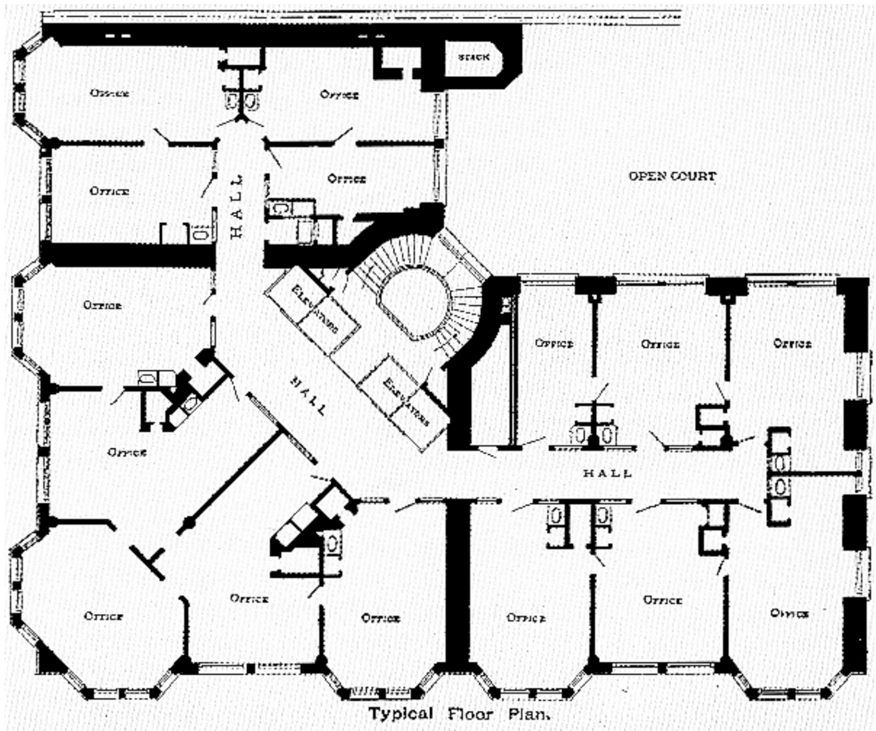


Figure 47. Holabird and Roche, Tacoma Building. Typical floor plan.(WikiArquitectura.)

bearing walls that also stiffened the building against wind loads from the exterior to the interior. Nevertheless, for the first time, the language of the iron frame was to be seen on the streets of Chicago (for the construction of the Rookery's lightcourt had been hidden from the public by its massive masonry exterior), and the *Inter-Ocean* immediately had appreciated the revolutionary nature of the Tacoma's exterior cladding: "its skeleton as it were - fireproofing tile will be used with such completeness that not a vestige of iron will be seen anywhere. A new order of architecture is evidently here, and coming to stay - iron and fireproofing." (*Inter-Ocean*, September 1888).

The Tacoma Building was not just "a new order of architecture," but it was also revolutionary in its construction process. So much so that a company of policemen had to be assigned to the construction site for crowd control, as people were flocking to the site to see for themselves what rumor had called "floating brick." (Wallin, 1966). Holabird & Roche had detailed the exterior structure (Fig. 48) that supported the curtain wall using a wrought iron spandrel beam and a cast iron lintel that spanned between cast iron columns. (Freitag, 1904; Leslie, 2012.) The spandrel beam not only supported the interior lining of hollow tile but was also connected to the cast iron lintel that supported the face brick and a middle lining of hollow tile that more than likely was still required by Building Commissioner W. J. Edbrooke for fireproofing purposes. The cast iron lintel was cantilevered off the exterior face of the columns that allowed the curtain wall to be erected in front of the columns, meaning that the spandrels would

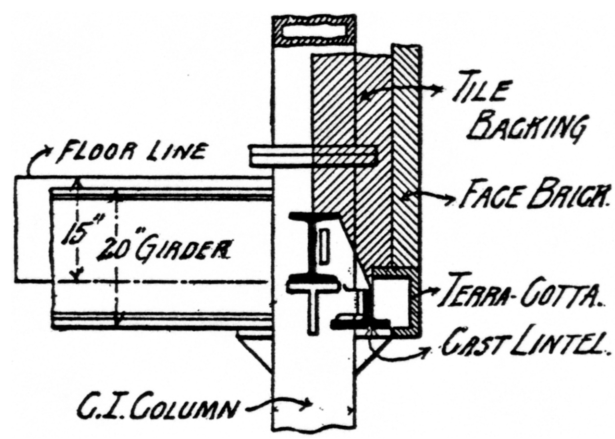


Figure 48. Holabird and Roche, Tacoma Building. Wall section at a typical exterior spandrel.(Freitag, Joseph K. Architectural Engineering: *With Especial Reference to High Building Construction, Including Many Examples of Prominent Office Buildings (2nd ed.)*, Wiley and Sons, New York, USA, 1904.)

read as unbroken horizontal layers, not unlike Root's detailing in the Rookery lightcourt. When one studies this detail, it is quite obvious that the heavy load of the facebrick is not inline with the centroid of the lintel, meaning that the lintel would be subjected to a significant amount of torsional rotation. By tying the wrought iron spandrel beam to the cast iron lintel, as shown in the wall section, the spandrel beam added its torsional stiffness to the entire assembly, as well as laterally braced the cast iron columns.

But it was the "floating brick" that grabbed people's attention that was the result of Fuller's realization that as the masonry curtain wall was no longer a continuous brick wall from the ground up, but a series of brick partitions that were constructed at each floor on the iron frame, it would be faster, and therefore, less expensive, if instead of having his bricklaying crew start the brick exterior at the ground and proceed upwards, he had three separate teams that would start laying brick at three different floors at the same time. The result of this decision was that crews two and three were laying brick on two of the upper floors that had no contact with the ground, hence, to eyes that had become accustomed to seeing brick walls from the ground up, the brick in the upper floors did, indeed, appeared to "float." (Wallin, 1966)

The final design of the elevations consisted of a ground floor of stores (Fig. 49) with unusually large plate glass windows, made possible by the exterior iron frame. In essence, it was an anti-base: gone was the traditional solidity of a massive masonry wall or a stone colonnade, and replaced by the transparent veil of the enclosing glass planes, above which the upper floors appeared to magically float. Holabird & Roche went to great extremes to pull most of the building's columns inside of the glass to reinforce the openness of the base. The only masonry purposely exposed on the ground floor were the three corner piers and those at either side of both entrances. Never before in a Chicago building had the base of a building been made so open, which had to have been quite apparent in the evening, especially during the dark winter months when the interior lights were on more than they were not.

7.1. Gustave Eiffel's Iron-Framed Spine in the Statue of Liberty

The Tacoma Building was the first, but only the first in a number of subsequent experiments in which architects and builders attempted to use the iron frame in a building's exterior for the advantages we've discussed. These designs still required, however, that the lateral stability provided by the heavy masonry exterior walls be moved somewhere into the interior of a building. The final step in the evolution of the iron skeleton-framed skyscraper was to eliminate all masonry walls, something that required either one of two structural solutions that had been used throughout the history of construction to stiffen both timber and iron buildings against the lateral loads of the wind: rigid or portal connections between the beams and columns, or diagonal bracing. While builders had used diagonal bracing to stiffen iron towers for decades, the diagonals typically created obstacles to navigate within buildings. While Henri-Jules Borie had avoided this inconvenience some twenty years earlier by using portal frames to brace his proposed eleven-story iron-framed *Aérodômes* (Fig. 12-14), the French during the summer of 1885 would also export directly to the U.S. a perfect model of the use of diagonal bracing to stiffen an iron tower that would show American architects how to solve the problem.

As American architects were timidly experimenting in 1885 with the iron frame as a potential structural system for the skyscraper, the French were exporting the Statue of Liberty in wooden crates aboard the French frigate *Isère* directly to New York. The Statue of Liberty had been the brainchild of two Frenchmen, liberal republican

Figure 49. Holabird and Roche, Tacoma Building. Note the large plate glass windows in the second floor. (http: connectingthewindycity.com)

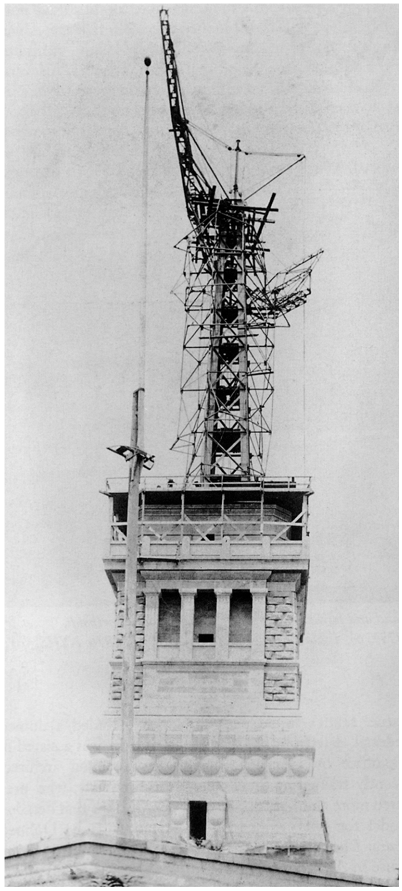


Figure 50. Gustave Eiffel and Richard Morris Hunt. Construction of Statue of Liberty, Summer of 1886.(Stern, *New York* 1880, 1999.)

Édouard-René Lefebvre de Laboulaye and sculptor Frédéric-Auguste Bartholdi, in June 1871, following the end of the Franco-Prussian War and the defeat of the Paris Commune, to be a gift from the French people to the people of the U.S. to mark the centennial of the signing of the Declaration of Independence, but it took another four years for the project to be formally approved. Bartholdi started construction in November 1875, but it was obvious to all involved that the project could not be completed in time to arrive on July 4, 1876.

With such a large structure, the sculptor had needed the experience of an engineer and immediately approached Viollet-le-Duc, who had been the engineer for the 35' high statue of Vercingétorix in Alise-Sainte-Reine. This statue's relatively small size had still permitted it to be constructed in loadbearing masonry, not unlike the masonry bearing walls still being used in American skyscrapers at the time. (Loyrette, 1985). For Bartholdi's statue Viollet-le-Duc had planned to still rely on mass to resist the forces from the wind. Instead of a traditional masonry structure, however, he had proposed that the statue's exterior be made with copper plates that would be supported from a core in the interior comprised of an iron framework that contained a "system of interior compartments... filled with sand." In the case of an accident, he believed that a masonry structure would more than likely require some demolition, whereas, with the sand-filled coffers a valve could be opened to remove the sand in order to make the appropriate repairs and then simply be refilled. However, his ideas were for naught as he died on September 17, 1879, leaving Bartholdi in search of an engineer who had the necessary knowledge and experience. Thus, we encounter the design of Gustave Eiffel. (Trachtenburg, 1977; Sunderland, 2003).

Eiffel replaced Viollet-le-Duc's mass with geometric stiffness by simply inserting an iron pylon, similar to those that he was designing at the time for the Garrabit Bridge in France, into the inside of the hollow sculpture. The 92' tall central spine or pylon (Fig. 51) upon which the copper skin of the statue would be hung consisted of four columns made of riveted (laminated) wrought iron plates. These were connected with diagonal bracing that gave the pylon its stiffness against the wind. A secondary system of wrought iron braces would be built from the pylon that roughly estimated the actual shape of the copper sculpture. (Loyrette, 1985).

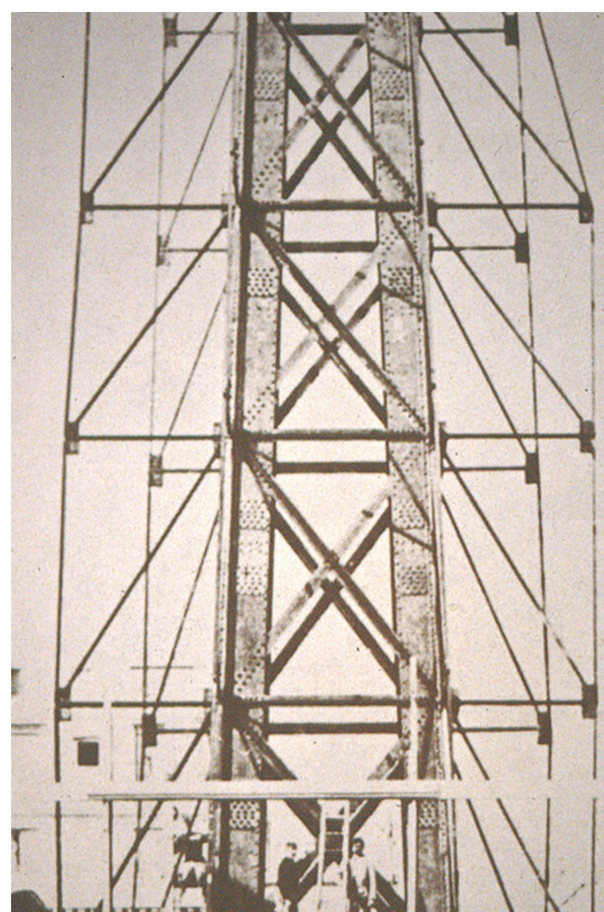
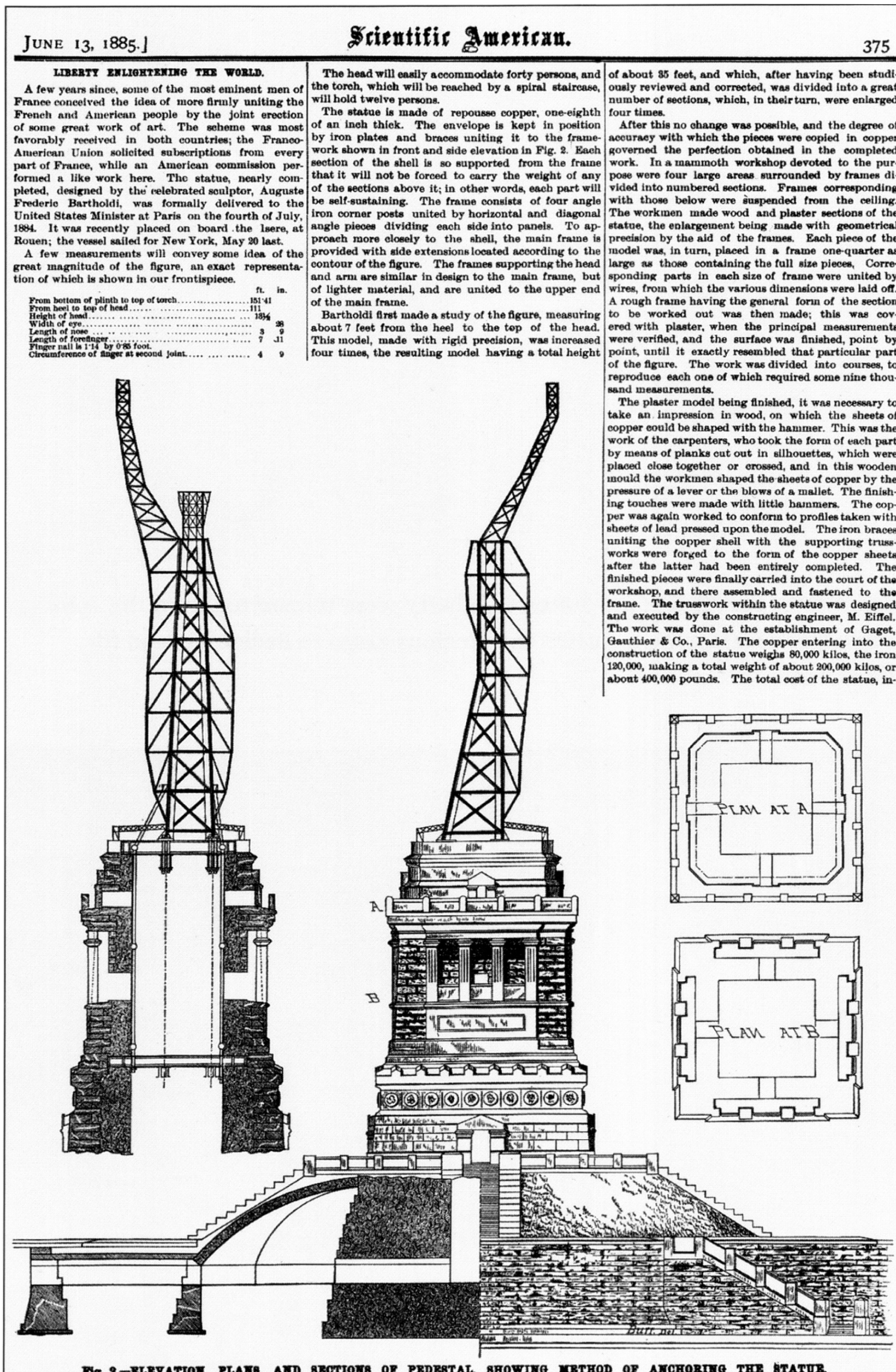


Figure 51. Gustave Eiffel, Iron Structure of the Statue of Liberty, 1880.(Trachtenberg, Marvin, *The Statue of Liberty*, Penguin Books, New York, USA, 1977.)

On the eve of the statue's arrival in New York harbor, the American Press had flooded the country with images and articles on it (Fig. 52). Eiffel's structure arrived in the U.S. on June 17, 1885, but its erection had to wait until the pedestal, designed by Richard Morris Hunt was completed. Erection of Eiffel's iron tower in all its naked glory (Fig. 50) finally began in April 1886, affording any interested American architect or engineer to study its details during the summer of 1886. (Harvie, 2004).


JUNE 13, 1885.] Scientific American. 375

LIBERTY ENLIGHTENING THE WORLD.

A few years since, some of the most eminent men of France conceived the idea of more firmly uniting the French and American people by the joint erection of some great work of art. The scheme was most favorably received in both countries; the Franco-American Union solicited subscriptions from every part of France, while an American commission performed a like work here. The statue, nearly completed, designed by the celebrated sculptor, Auguste Frederic Bartholdi, was formally delivered to the United States Minister at Paris on the fourth of July, 1884. It was recently placed on board the Isere, at Rouen; the vessel sailed for New York, May 20 last.

A few measurements will convey some idea of the great magnitude of the figure, an exact representation of which is shown in our frontispiece.

	ft.	in.
From bottom of plinth to top of torch	151·41	
From heel to top of head	111	
Height of head	13½	
Width of eye		28
Length of nose	3	9
Length of forefinger	7	11
Finger nail is 1·14 by 0·85 foot.		
Circumference of finger at second joint	4	9

The head will easily accommodate forty persons, and the torch, which will be reached by a spiral staircase, will hold twelve persons.

The statue is made of repousse copper, one-eighth of an inch thick. The envelope is kept in position by iron plates and braces uniting it to the framework shown in front and side elevation in Fig. 2. Each section of the shell is so supported from the frame that it will not be forced to carry the weight of any of the sections above it; in other words, each part will be self-sustaining. The frame consists of four angle iron corner posts united by horizontal and diagonal angle pieces dividing each side into panels. To approach more closely to the shell, the main frame is provided with side extensions located according to the contour of the figure. The frames supporting the head and arm are similar in design to the main frame, but of lighter material, and are united to the upper end of the main frame.

Bartholdi first made a study of the figure, measuring about 7 feet from the heel to the top of the head. This model, made with rigid precision, was increased four times, the resulting model having a total height of about 35 feet, and which, after having been studiously reviewed and corrected, was divided into a great number of sections, which, in their turn, were enlarged four times.

After this no change was possible, and the degree of accuracy with which the pieces were copied in copper governed the perfection obtained in the completed work. In a mammoth workshop devoted to the purpose were four large areas surrounded by frames divided into numbered sections. Frames corresponding with those below were suspended from the ceiling. The workmen made wood and plaster sections of the statue, the enlargement being made with geometrical precision by the aid of the frames. Each piece of the model was, in turn, placed in a frame one-quarter as large as those containing the full size pieces. Corresponding parts in each size of frame were united by wires, from which the various dimensions were laid off. A rough frame having the general form of the section to be worked out was then made; this was covered with plaster, when the principal measurements were verified, and the surface was finished, point by point, until it exactly resembled that particular part of the figure. The work was divided into courses, to reproduce each one of which required some nine thousand measurements.

The plaster model being finished, it was necessary to take an impression in wood, on which the sheets of copper could be shaped with the hammer. This was the work of the carpenters, who took the form of each part by means of planks cut out in silhouettes, which were placed close together or crossed, and in this wooden mould the workmen shaped the sheets of copper by the pressure of a lever or the blows of a mallet. The finishing touches were made with little hammers. The copper was again worked to conform to profiles taken with sheets of lead pressed upon the model. The iron braces uniting the copper shell with the supporting trussworks were forged to the form of the copper sheets after the latter had been entirely completed. The finished pieces were finally carried into the court of the workshop, and there assembled and fastened to the frame. The trusswork within the statue was designed and executed by the constructing engineer, M. Eiffel. The work was done at the establishment of Gaget, Gauthier & Co., Paris. The copper entering into the construction of the statue weighs 80,000 kilos, the iron 120,000, making a total weight of about 200,000 kilos, or about 400,000 pounds. The total cost of the statue, in-

Fig. 2.—ELEVATION, PLANS, AND SECTIONS OF PEDESTAL, SHOWING METHOD OF ANCHORING THE STATUE.

Figure 52. *Scientific American*, June 13, 1885.(Sutherland, Cara A., *The Statue of Liberty*, Barnes & Noble Books, New York, USA, 2003.)

7.2. Leroy Buffington Patents the Iron Skeleton-Framed Skyscraper

One such architect appears to have been Minneapolis architect Leroy S. Buffington, who shocked the entire profession in March 1888 when he published a fully-detailed proposal to build a 28-story, 350' high "Cloud-scraper" (Fig. 53) in the March issue of *Northwestern Architect*. At this moment, the 12-story Washington Building at 258' was the tallest building in New York, the Maller Building stood at twelve stories in Chicago, and St. Paul was just starting construction of the 13-story Pioneer Press designed by Chicago architect S.S. Beman. By 1886 Minneapolis/St. Paul's economy had grown sufficiently to support the erection of skyscrapers and following the complete halt in investment/construction in Chicago following the Haymarket Square debacle of May 4, 1886, had offered Chicago's architects an outlet for their talents.

Buffington had become the Twin Cities' leading architect during the first half of the 1880s. By 1885, his office staff had grown to over 30, and was responsible for buildings from New Hampshire to Wyoming, and from Kentucky to Canada. In addition to major buildings in the Twin Cities area in which he had worked with Peter B. Wight as the fireproofing contractor, he had also designed the state Capitols for North Dakota and West Virginia, as well as the Minnesota State Capitol in St. Paul. The real measure of his professional reputation in the Midwest at the time of his patent, however, was that he was voted as the Vice-President of the Western Architectural Association at its 1888 convention held in Chicago that November, only four months after the first publication of his "Cloudscraper."

Buffington's Cloudscraper contained more than twice the number of floors in any existing skyscraper! He was able to design such a tall building because he had developed a system of iron framing (Fig. 54) that enabled the erection of buildings to almost unlimited heights, for which he was granted a patent two months later on May 22, 1888. News of the patent and the rendering of the Cloudscraper had to have greeted Chicago's architectural community like a cold shower when it was first published in the July 1888 issue of *Inland Architect*. Buffington had finally succeeded in giving physical form to James Bogardus' claim in 1856 that with the iron skeleton frame, it was possible "to erect

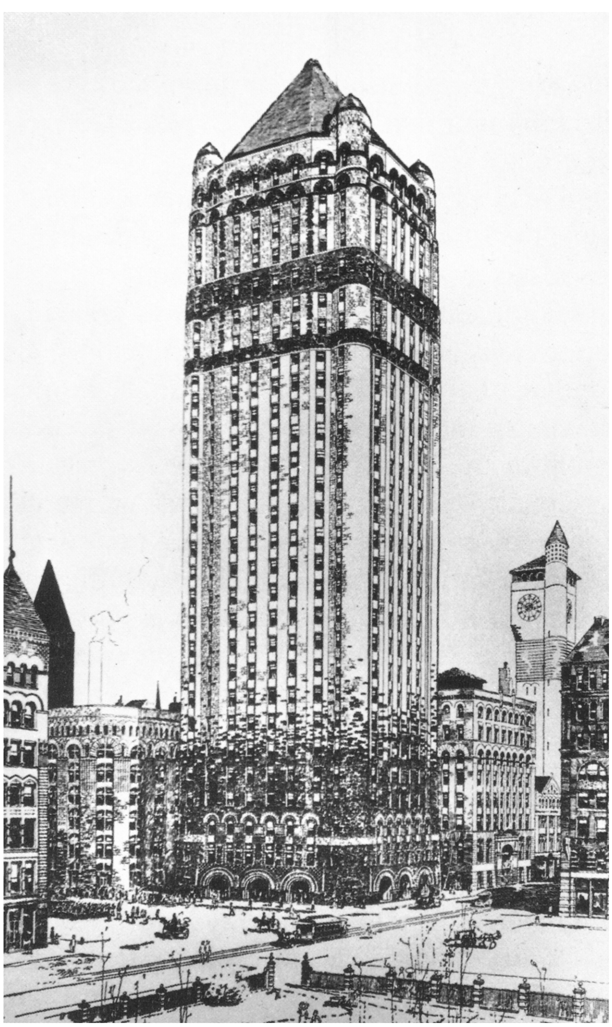


Figure 53. Leroy S. Buffington, Propsed 28-story "Cloudscraper," Minneapolis, 1888.(*Inland Architect*, 11, July 1888.)

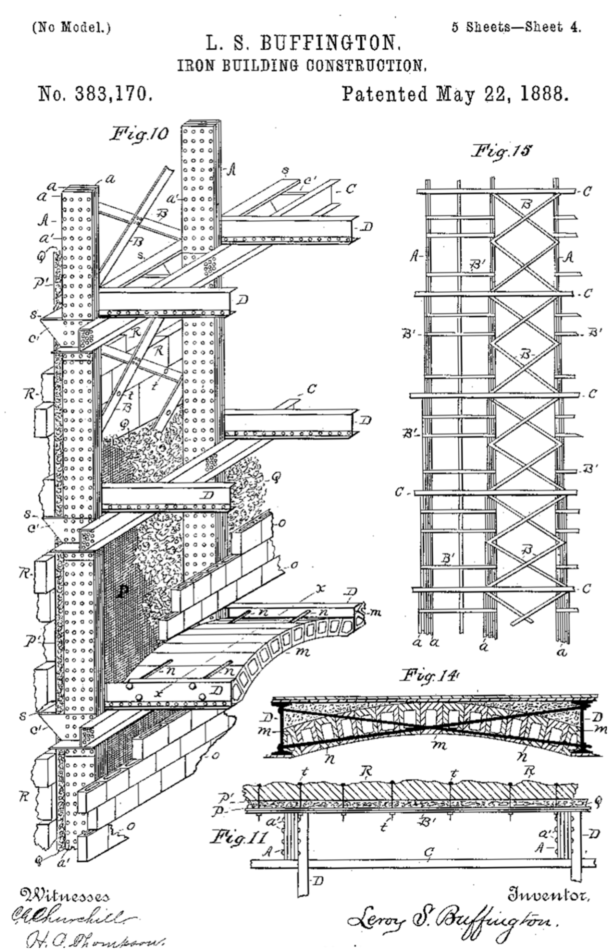


Figure 54. Leroy S. Buffington, Patent for Iron Building Construction, May 22,1888.(*Art Bulletin*, 26, March 1944.)

a tower or building *many times the height of any other edifice* in the world.” (Bogardus, 1856).

Buffington's patent bore an uncanny resemblance to the iron structure that had been designed for the Statue of Liberty and erected in New York harbor only two years prior to the granting of his patent. (If you are interested in a detailed study of the influence that Eiffel’s work, including his Tower for the 1889 Fair had had on Buffington, please see: Larson, 1987.) Buffington's patented system incorporated continuous columns that were built-up by riveting together plates of wrought iron that overlapped the joints of adjacent plates, quite similar to Eiffel’s columns in the Statue of Liberty. These would be assembled into a rigid rectilinear grid by iron C-section spandrel beams that were riveted to the columns via iron angles. This created a rigid connection, and thereby, imparted a stiffness to the frame that would replace that role formerly provided by the exterior masonry wall. Wrought iron floor girders sat on these spandrels and were also riveted to the face of the columns. Similar to Root's detailing in the Rookery’s lightcourt, Buffington detailed an iron lintel at each floor at the exterior face of each column, providing a ledge upon which the building's lightweight exterior enclosure of masonry and windows could be constructed. (Upjohn, 1935). With the exception of the solid section, built-up columns, that had never been used in an American building by 1888, Buffington's system had simply utilized the best contemporary details in use. The one significant improvement he had made in construction technology was his use of diagonal bracing for the first time in an iron-framed skyscraper to increase the frame's resistance to windloads. He had specified double-diagonal bracing per each floor, in the form of thin iron plates that were riveted to the columns and to each other where they crossed, also similar to Eiffel’s detailing in the Statue of Liberty. Buffington's use of double-diagonal bracing also reflected Eiffel's detailing of the double-diagonal bracing in his system of demountable bridges for railroads for spans less than 45 m. (Loyrette, 1985).

7.3. Bradford Gilbert and the Tower Building

Although Buffington's Cloudscaper had challenged those who had built earlier skyscrapers, who was the first to actually build a skyscraper that was solely skeleton framed in iron? It appears that honor probably belongs to New York architect Bradford Gilbert and his Tower Building (Fig. 55) in New York. In early 1888, Gilbert was asked to design an 11-story building for a 21.5’ wide interior lot at 50 Broadway, that ran through the entire block to New Street. To build such a tall structure on such a narrow footprint not only meant that it would be more susceptible to wind loads, but also if load-bearing masonry was used for the structure, the building code required the lower walls to be 36" thick, on both sides. Gilbert had no real alternative but to propose a building with an iron skeleton frame, but as this type of structure was not in compliance with the city’s building code, Gilbert's design

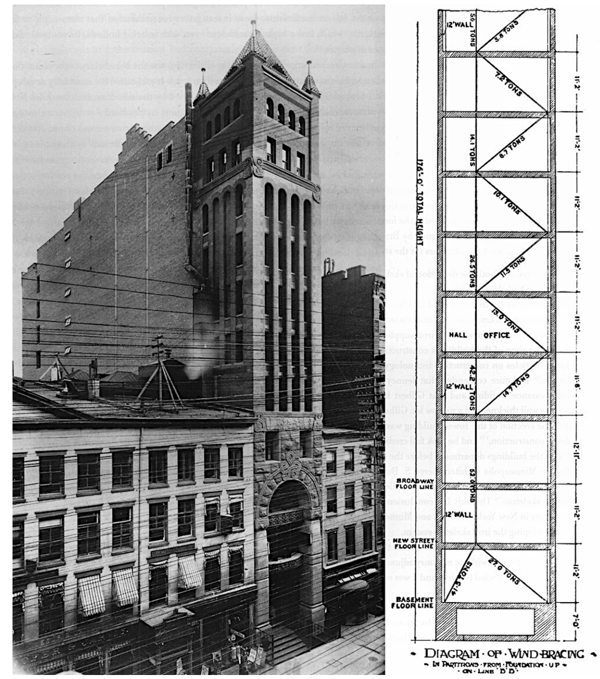


Figure 55. Bradford Gilbert, Tower Building, 1888; Diagram of diagonal bracing. (Landau and Condit, *New York*)

had to go through a number of reviews before being granted a building permit on April 17, 1888. (Landau and Condit, 1996; Stern, 1988). This occurred after Buffington's system had been reported in the March *Northwestern Architect*, but before the first publication of his Cloudscaper in July.

In each plane of columns, Gilbert had placed a pair of iron angles that alternated directions between floors in a Warren truss configuration. While some critics question the effectiveness of Gilbert's bracing, no one disputes the fact that he was the first architect/engineer to use it in an all iron skeletal-framed building, for which he was awarded the Gold Medal at the 1893 Chicago World's Fair “for a new type of American architecture.” (Landau and Condit, 1996). But trying to erect a larger footprint to a greater height would be a substantial challenge, one that demanded of its builders the ultimate level of respect for the nature of this challenge. Only a fool would try to “do everything at once” in constructing a 12-story building with an untested structural system. And so, the iron frame would slowly, and carefully, shed its heavy, rigid, masonry bearing walls, one at a time, as it grew taller and taller.

7.4. Fulfillment: The *New York World* Building and the Masonic Temple

The free publicity generated by Buffington’s patent and 28-story “Cloudscaper” during the spring of 1888 would not have escaped the eyes of one of New York City’s great “promoters” and newspaper publisher, Joseph B. Pulitzer, the owner of the *New York World*, who was also ultimately responsible for the successful campaign to save the Statue of Liberty with his campaign to fund the construction of the pedestal for the Statue of Liberty. He had decided to generate free publicity for his paper by erecting a new building at the northeast corner of Park Row and Frankfort Street, that would be taller than those of the competing New York newspapers along Newspaper Row across the street from City Hall. During the fall of 1888 he held a design competition that was supervised by Richard M. Hunt that George Post won with a design (Fig. 56) that would ultimately top off at 309.' The *World* Building can be understood as having been designed by Pulitzer and refined by Post. Pulitzer wanted the record height and also wanted to top the building with a domed cupola. Post designed a 14-story extruded body, upon which was placed a six-story cupola that was topped with a gilded dome that was inspired by Michelangelo's dome of St. Peter's. (Stern, 1999). Post was not limited by New York's underlying soil substructure, as were Chicago's architects, so he erected the first skyscraper to beat the 300' height target (and the 303' tower of the Chicago Board of Trade) employing conventional New York exterior bearing wall construction. The walls tapered from 88" at the ground to 24" at the top. (Chicago's Monadnock Block bearing walls are only 72" thick. It is curious that at 216' high, it has the reputation as having been the tallest bearing wall building ever built, although when compared to the 309' height of the World Building, it seems to be more accurate to state that the Monadnock is the tallest surviving bearing wall building.)

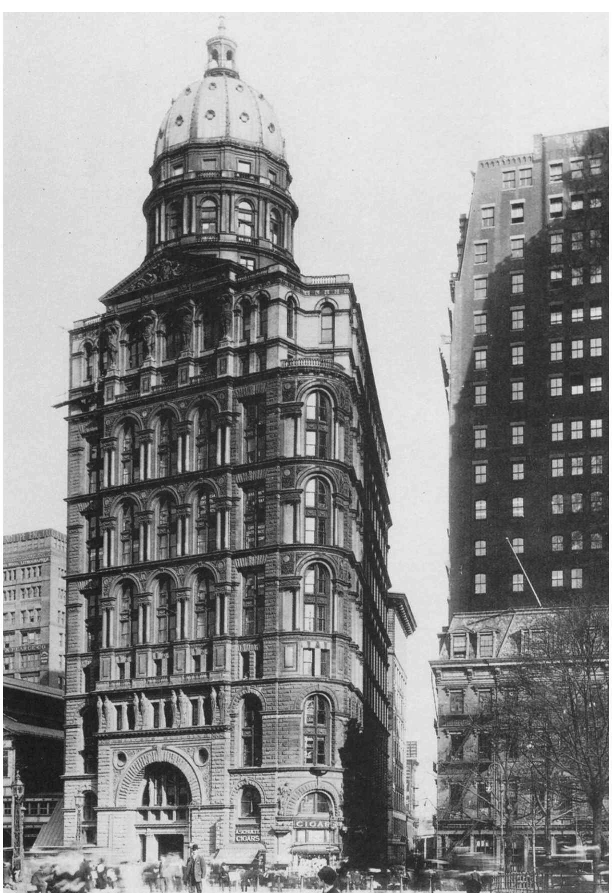


Figure 56. George B. Post, *New York World* Building, New York, 1889-90.(Landau, Sarah B. (1998) *George B. Post, Architect*, Monacelli Press, New York, USA.)

Figure 57. Burnham and Root, Masonic Temple, Chicago, 1890.(Hoffmann, Donald, The Architecture of John Wellborn Root. Johns Hopkins University Press, Baltimore, MD, USA, 1973.)

New York and Chicago at this moment were engaged in a mano a mano competition to win the 1892 World's Fair, and Chicago could not simply stand by and let Pulitzer's project go unchallenged. Chicago's Masonic Order picked up Pullitzer's gauntlet and commissioned Burnham & Root to design a 20-story skyscraper, the Masonic Temple (Fig. 57). The difference between the New York and Chicago skyscraper at this time is quite apparent in the two vastly different structures employed by the country's leading skyscraper designers in the design of these first two buildings to exceed 300.' We have already noted that the 238' tower in the recently completed Auditorium would eventually settle almost 30." This amount of settlement was totally unacceptable, and potentially unstable, leaving Burnham & Root no choice but to design an all iron-framed skyscraper, braced with two lines of continuous diagonal bracing (Fig. 58) that were located on either side of the elevator bank. (Scientific American, October 1891). The iron skeleton was enclosed with a nonloadbearing

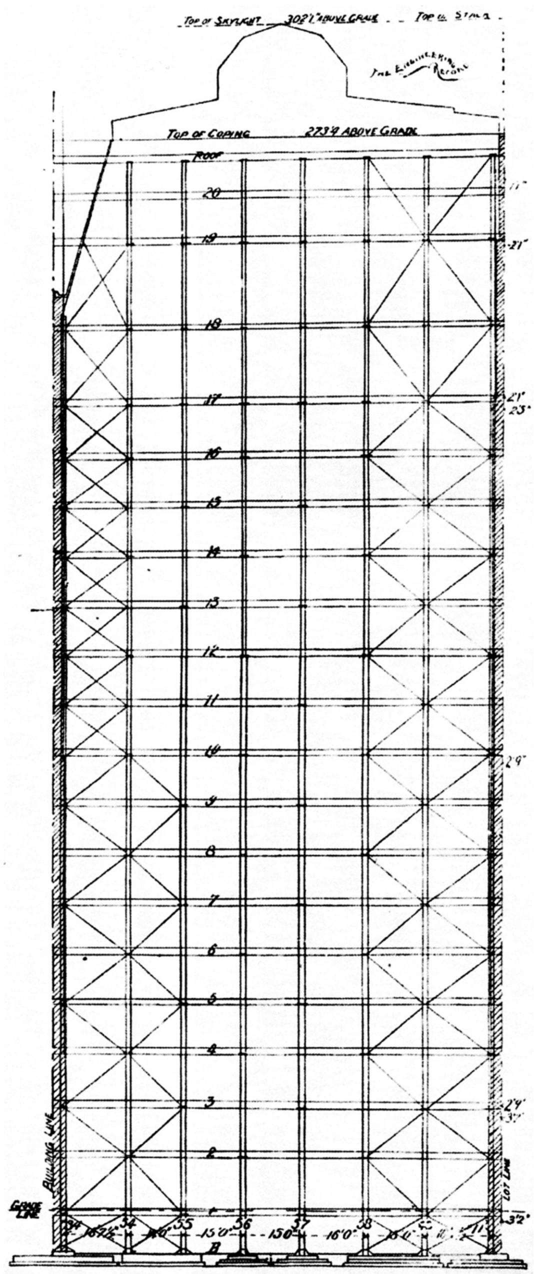


Figure 58. Burnham and Root, Masonic Temple. Cross section showing the configuration of the diagonal bracing. Note the total height at the top of the building reads: 302' 1."(*Engineering Record*, January 21, 1893.)

masonry and glass curtain wall and serviced by thirteen elevators, the culmination of the efforts by architects, engineers, and contractors over the past four decades to build such a structure. It was sufficiently completed to be dedicated in May 1892, leaving almost a year for the building to be finished and all the glitches worked out before May 1, 1893, the opening day of the World's Columbian Exposition.

7.5. The Legal Battle over Buffington's Patent

Six months after the Masonic Temple was dedicated, and six months before the Fair opened its doors, Buffington filed his first patent infringement suit on Dec. 10. 1892. No one in Chicago seemed to have wanted to "open the can of worms" by an outright challenge to the granting of or the validity of Buffington's patent for over four years. In fact, it took over a year from when Buffington was granted the patent for anyone to put two-pus-two together vis-à-vis the potential threat that Buffington's patent represented. Curiously, the *Inter-Ocean* reported in an article dated July 7, 1889, describing the new (Second) Leiter Department store designed by Jenney and being erected on South State St., in which Jenney's iron frame was like "the system of construction first used in this extensive way by Mr. Jenney in the Home Insurance Building, and which has since become so popular for commercial and office buildings." (*Inter-Ocean*, July 1889). This was the first published mention of the use of structural iron in the Home Insurance Building since its completion in May 1885 that I have discovered. Over four years had passed without any interest or mention of Jenney's experiment with iron columns. Was this a couched attempt to negate Buffington's patent?

Following his patent in May 1888, Buffington seems to have been too busy with his practice to have given the patent a second thought, until 1892. On November 12, 1892, Buffington formed a company, "Buffington's Iron Building Company," with his brother, A.L. Buffington and E. H. Steele. While the company's literature stated that it was ready to manufacture the structural parts for a building using Buffington's system, in reality the three had formed the company in order to collect a 5% royalty for the use of his patent, and to finance a series of legal challenges based on patent infringement. It took the Buffingtons less than a month to file their first patent infringement suit on against William E. Eustis who had constructed an iron and masonry building in Minneapolis. (Upjohn, 1935).

The *New York Tribune* may have best identified Buffington's intentions: "Mr. Buffington is on the warpath... It is plain that [he] has taken a large contract, but in his survey of the future he is courting damages amounting to hundreds of millions." I believe that this fact scared the pants off of architects and owners alike, and forced them to scurry through prior patents and published articles in search of "Prior Art," legal proof that others had used or invented the idea of an iron skeletal-framed skyscraper before Buffington had applied for his patent in November 1887. If found, this would negate his patent and put a halt to his litigation, and most important, prevent their having to pay 5% of their existing and future buildings' total construction costs to Buffington. Chicago's architects thought they had discovered such a precedent in the Home Insurance Building and began the big lie that Buffington had simply copied Jenney's design. All one has to do to prove this to be a fabrication is to compare Jenney's details (Fig. 33) with those of Buffington's (Fig. 54) or for that matter, Eiffel's details in the Statue of Liberty. The historiography of the reputation of the Home Insurance Building versus Buffington's "Cloudscraper" are beyond the scope of this paper, but I have endeavored in this paper to present a factual chronology of the events as well as an accurate documentation of the structural details central to the evolution of the iron skeleton-framed skyscraper to allow the reader to come to her/his own conclusion.

Conclusion

The invention of the elevator allowed building owners in New York City to erect buildings, eventually known as skyscrapers with more floors than the traditional limit of 5-6 floors that increased the rentable potential of a site to offset the rising cost of Manhattan real estate. The use of iron framing in the interiors of these buildings, originally developed by New Yorkers James Bogardus and Daniel Badger and perfected by George Post, reduced the floor space dedicated to structural walls, further increasing the profitability of such buildings.

Chicago enters this story following its second fire of 1874 that caused the insurance companies to seek a mode of construction for these tall buildings better than unprotected iron columns and beams. Chicagoan Peter B. Wight invented a system of fireproofing iron members with a fireproof casing, thereby saving the iron frame from being outlawed by the insurance companies. The iron frame employed in a tall building's exterior wall was critical in Chicago buildings taller than 10 stories because the city's underlying geology did not have the bearing capacity to support such buildings and, therefore, resulted in unacceptable amounts of settlement in such buildings. Through an incremental process, Chicago's and New York's architects and engineers carefully replaced the stability formerly gained with masonry bearing walls with the use of braced iron framing in a building's exterior walls, By 1890, Burnham & Root were able to build the 20-story Masonic Temple without the use of any bearing walls.

References

American Architect and Building News. (1876). "Fireproof Columns." I (Jan. 22, 1876), pp. 29-30.

American Architect and Building News. (1877). "A New Method of Fire-Proof Construction." March 17, 1877, p. 88.

American Architect and Building News. (1884). November 29, 1884, p. 254.

Baumann, Frederick. (1884). "Improved Construction of High Buildings." *Sanitary News*, March 15, 1884, p. 123.

Bogardus, James. (1856). *Cast Iron Buildings: Their Construction and Advantages*. New York, USA.

Bruegmann, Robert. (1997). *The Architects and the City: Holabird & Roche of Chicago*, *1880-1918*. University of Chicago Press, Chicago, USA.

Chicago Inter-Ocean. (July 1889). July 7, 1889, July 7, 1889, p. 16.

Chicago Inter-Ocean. (September 1888). "The Latest." September 30, 1888, p. 10.

Ericsson, Henry L. (1942). *Sixty Years a Builder: The Autobiography of Henry Ericsson*. A. Kroch, Chicago, USA.

Freitag, Joseph K. (1904). Architectural Engineering: With Especial Reference to High Building Construction, Including Many Examples of Prominent Office Buildings (2nd ed.). Wiley and Sons, New York, USA.

Harvie, David I. (2004). *Eiffel: The Genius Who Reinvented Himself*. Sutton, Stroud, UK.

Hoffmann, Donald. (1973). *The Architecture of John Wellborn Root*. Johns Hopkins University Press, Baltimore, MD, USA.

Inland Architect. (August 1884). "Architectural and Building News." p. 12.

Inland Architect. (July 1884). "The Chicago Builders and Traders' Exchange." p. 80.

Inland Architect. (September 1884). p. 28.

*Inland Arc*hitect. (June 1886). "Architectural Iron Contracts." June 1886, p. 84.

Jenney, William Le Baron. (1883). "Improved Construction." *Real Estate and Building Journal*, May 5, 1883, p. 198.

Jenney, William Le Baron. (1885). "The Construction of a Heavy, Fireproof Building on Compressible Soil." *Inland Architect*, December 1885, p. 100.

Landau, Sarah B. (1981). *P.B.Wight: Architect*, *Contractor*, *and Critic: 1835-1925*. The Art Institute of Chicago, Chicago, USA.

Landau, Sarah B. (1998). *George B. Post*, *Architect*. Monacelli Press, New York, USA.

Landau, Sarah B., and Carl Condit. (1996). *The Rise of the New York Skyscraper*, *1865-1913*. Yale University Press, New Haven, CT, USA.

Larson, Gerald R. (1983). "Earth, Wind, and Fire: Part-II," *Inland Architect*, January 1983, pp. 31-37 (note 6).

Larson, Gerald R. (1987). "The Iron Skeleton Frame: Interactions Between Europe and the U.S.," Zukowski, John (ed.), *Chicago Architecture*, *1872-1922: Birth of a Metropolis*. The Art Institute of Chicago, Chicago, USA.

Larson, Gerald R. (JSAH-1987). "Toward a Better Understanding of the Evolution of the Iron Skeleton Frame in Chicago." *Journal of the Society of Architectural Historians*, March 1987, pp. 39-48.

Leslie, Thomas. (2012). *Chicago Skyscrapers: 1871-1934*. University of Illinois, Urbana, IL, USA.

Loyrette, Henri. (1985). *Gustave Eiffel*. Rizzoli, New York, USA.

Moses, John, and Joseph Kirkland, eds. (1895). *The History of Chicago*, *Illinois*-vol.1. Munsell, Chicago, USA.

Randall, Frank A. (1999). *History of the Development of Building Construction in Chicago* (2nd ed.). University of Illinois Press, Urbana, IL, USA.

Real Estate and Building Journal. (1884). August 12, 1884, p. 364.

Scientific American Building Edition. (1891). "The Masonic Temple, Chicago." October 1, 1891, p.12.

Stern, Robert A.M. (1880). *New York.* Monacelli Press, New York, USA.

Sunderland, Cara A. (2003). *The Statue of Liberty.* Barnes

and Noble, New York, USA.
Tallmadge, Theodore E. (1934). *The Origin of the Skyscraper-The Report of the Field Committee*. Chicago, USA.
Trachtenburg, Marvin. (1977). *The Statue of Liberty*. Penguin, New York, USA.
Upjohn, E.M. (1935). “Buffington and the Skyscraper.” *The Art Bulletin*, V.17, 1935.
Van Zanten, David. (1984). “The Nineteenth Century,” *Chicago and New York: Architectural Interactions*. Art Institute of Chicago, Chicago, USA.
Wallin, Chad. (1966). *The Builder's Story*. Chicago, USA.
Wight, Peter B. (1876). “The Fire Question-Part III,” *The American Architect and Building News*, July 1, 1876, p. 209.
Wight, Peter B. (1892). “Recent Fireproof Building in Chicago-Part 2.” *The Inland Architect and News_Record*, 19, 2, March 1892, p. 22.
Wight, Peter B. (1892). “Recent Fireproof Building in Chicago-Part 3.” *The Inland Architect and News Record*, 19, 3, April 1892, pp. 33-34; -Part 6, July 1892, p. 71.
Wight, Peter B. (1897). “Details of Fire-proof Construction with Burned Clay-Part 2.” *The Brickbuilder*, (Sept. 1897), p. 54.
Wolner, Edward W. (2011). *Henry Ives Cobb's Chicago*. University of Chicago Press, Chicago, USA. 2011.