# The Tall Office Building:
## The Technology to Make It Possible

The Industrial Revolution that transformed Britain in the first half of the 19th Century had the same effect in the post-1850s United States. A powerful stimulus was the Civil War as the production of military weaponry, supplies and their far flung distribution became essential to the successful prosecution of the Union effort.

At war's end, the industrial capacity of the North had grown significantly and those who had created it were eager to apply what they knew to the peacetime effort of developing the nation. A spirit of innovation and endless possibilities found a ready market in the growing cities, where surging populations and increasing wealth and densities made solutions to building tall necessary.

No city benefitted more from these technological advances than Chicago. In the years immediately preceding the Civil War, it had become a commercial powerhouse due to its geographic position in the upper Midwest and the developing railroad infrastructure radiating from it that made it a logical transfer terminal for commodities heading in all directions. However, the poor bearing capacity of the soils bordering Lake Michigan made satisfying the increasing need for large buildings difficult using the traditional wood or masonry bearing wall construction methods. The Great Fire of 1871, which devastated a four square mile area in the center of the business district, created a further impetus for new solutions by wiping out virtually all the early buildings that were ill-suited to the burgeoning commercial needs. Although the concurrent growth of New York City was creating similar pressures on the built environment there, the close proximity of bedrock in Manhattan made larger buildings using conventional bearing wall construction still practical.

By the late 1870s, the economic Panic of 1873 was ending and the climate for prodigious growth in both places was improving. The pressures to increase the size of buildings in the center city were forcing architects and engineers to consider ways of building tall, if only to provide the raw space the surging city economies demanded. Architects in both regions were experimenting with the potential for load-bearing frames utilizing the increasingly available ferrous metals (cast iron, wrought iron and, newest of all, steel) that recent industrial advances were bringing to the market. Developments in mechanical and electrical systems were improving the environments that could be provided in new buildings. Occupant safety was improving through the development of fireproofing strategies to reduce the risk of fire. Perhaps the most significant development was the invention of a practical passenger elevator that made reaching the upper floors of a building a less strenuous experience.

In pre-Civil War New York, the construction industry early on embraced cast iron as a fire proof building material but a series of collapses after disastrous fires in Manhattan and the complete failure of cast iron fronted buildings in the Chicago firestorm of 1871 put an emphatic end to that concept. In mid 1870s New York, there was an interest in cage construction where a bolted iron frame supported floor loads but not masonry facades, which were built self supporting. These masonry assemblies were not bearing walls because they did not support floor loads. This allowed them to be thinner, but not as thin as the curtain walls that followed. These hybrid walls did resist lateral loads (wind) but there was a fatal flaw. Until they were in place, the cage framework behind them was vulnerable because cast iron had to be bolted and was therefore not a rigid assembly. As buildings rose in height on the typically narrow New York building sites, they became essentially top heavy - wind pushed them out of alignment and beyond their allowable stresses with catastrophic results. Although there are successful caged frame buildings still extant in New York, this structural direction was less popular in Chicago.

There was also a conservative attitude in the east, manifested by a tradition of European historicism in design that ironically, would triumph in the World Columbian Exposition of 1893 held in Chicago, that restrained the experimental impulse in New York, which was already a world class city and a very expensive place to build. While significant steps in the technological advances of the tall building were happening concurrently in both cities, Chicago, given its environment, had more foundation issues to deal with, less social tradition and a smaller inventory of significant existing buildings. The fire had cleared things out. Land was expensive downtown but plentiful beyond and business leaders wanted to show the nation that Chicago had arrived. Architects and engineers who had served in the engineering corps of the Union armies as young men were imbued with a problem solving, competitive spirit. This spurred them to ever more ambitious solutions to the technical problems of building tall on land that could not support the conventional big building.

The Chicago School of Architecture was the result. From the early 1880s until the end of the century, a steady stream of innovative designs from a group of Chicago architects and engineers would create ever taller, more complex buildings until the science of building tall was understood and commonplace enough to be repeated anywhere land values dictated the need. Architects William Le Baron Jenney, Burnham & Root, Holabird & Roche and Adler & Sullivan thrived in an environment where a prosperous economy and technical advances were encouraging creative solutions to the tall building.

Among the innovations:
The ferrous metal **skeleton frame** that could be built much taller than conventional wood frames or masonry bearing wall systems with a fraction of the material. Because it was riveted, the member connections could be rigid, which meant all types of loading could be accommodated with properly sized beams, columns and braces. While the smaller amount of material made it a cheaper approach, of most significance in Chicago was the lighter weight meant the low capacity soils could support 10 to 14 story buildings that had skeleton frames but only 4 to 6 stories of bearing wall structures.

William Le Baron Jenney is usually credited with designing the first full skeleton framed building with his 10 story Home Insurance Building in Chicago. Erected in 1884, it featured wrought iron columns, beams and girders to the 6th floor and steel beams and girders above, both of which were ductile and rigidly connected with rivets. Stone and brick masonry, still erected from grade as if it were weight bearing, was used as cladding and additional bracing for wind loads but the shallower wall thicknesses required with the metal frame doing the bearing work, left more room for larger windows to let in more daylight. In 1890, two additional stories were added, now framed entirely in steel. Unfortunately, this landmark building was demolished in 1931.

By the time Adler & Sullivan were planning the Guaranty Building (1894), steel had supplanted iron. Steel was lighter, stronger and more versatile, but the standard shapes we know today were still a few years away. Connections were made with rivets, which were more rigid than the bolted connections necessary for cast iron members, which meant they were better at resisting lateral (wind) loads. At the Guaranty, Adler devised a 15′ x 15′ bay system that utilized a patented assembly, the Gray's Column, which had been developed by his employee, John H. Gray. The Gray's Column featured a series of 4 paired, continuous back-to-back angles with the legs set at the perimeter and the cardinal points. Each pair was connected to its neighbors by bent steel plates set vertically at a couple feet on center. This assembly was very strong in compression and because of its shape, had superior lateral stiffness. It was remarkably lightweight and easy to detail for beam and lintel connections but it also required time-consuming prefabrication. At the Guaranty, each column spanned two floors with every other column starting at the midspan of its neighbor and rising one level beyond as a way of further enhancing wind bracing. Another enhancement Adler made to stiffen the frame was the use of secondary columns on the street elevations that occurred midspan between the primary columns. These secondary columns rose from a deeper girder at the third floor, offering an additional framework for mounting the pilaster terra cotta cladding between each window in the primary structural bay.

By the time of the Guaranty design, the exterior cladding could be a **curtain wall** that had no inherent structural role but was merely the barrier on the perimeter of the building to keep the weather out. This opened up the list of potential materials that could be used considerably but in the early days there was reluctance to wander too far from conventional masonry since building code officials were still not sure if the tall building was desirable or safe. In the earliest examples, known construction methodology dictated that brick and stone be used as a way of adding lateral stiffness to the metal frame and it was installed from the ground up. Architects quickly realized that the depth of the wall could be quite shallow when compared to bearing wall structures. Since electricity and mechanical systems were in their infancy, daylight and natural ventilation were still paramount so larger windows accomplished several things: more daylight, more outside air when the sashes were opened and less weight when compared to masonry. Terra cotta had become a popular facing material in the 1870s because of its easy moldability, its relatively light weight, its good fire protection characteristics and the fact that, in 1880s Chicago, where labor strife was a constant impediment to rapid construction, it was installed by a less contentious union than the bricklayers or the stone masons.

Chicago's Reliance Building was an 1890 design developed by John Wellborn Root of Burnham & Root Architects. Only the first phase of construction, the ground and second floors, were completed before Mr. Root died suddenly leaving the project moribund for a couple years. The upper 13 floors were finished in 1895 to Root's design by Charles Atwood, a Boston architect who Daniel Burnham had hired away from the east during the development of the 1893 World Columbian Exposition. Taking the curtain wall to its logical extreme, the steel frame was clad with ornamented white terra cotta and the entire spandrel space between columns and floors was enclosed with very large windows that gave the building a striking transparency. Both types of windows that became known as "Chicago Windows" were used: the three sash array with a fixed center unit and narrow double hung units to both sides, and the projecting bay where the fixed unit was on the face and the double hung operable units were on the angled sides. The Reliance Building still stands.

During the planning of the Guaranty, Louis Sullivan and his chief draftsman, George Grant Elmslie determined to cover the entire opaque surface of the street elevations in ornamented terra cotta. Sullivan established a hierarchy of implied structural elements to give the elevations a soaring character. Pilasters between each window were brought to the forefront, as Adler & Sullivan had done at the Wainwright Building in St. Louis, with no differentiation between the actual structural pilasters and those simply separating the windows. The space between the pilasters was filled with recessed spandrel panels at each floor and double hung windows, which were recessed even further. The terra cotta arrived on-site in repetitive units that were hung off the steel framework with steel cramps, hung lintels and clip angles. In a departure from earlier practice, the first units were placed at the fourth floor and the windows were set into the openings the terra cotta created instead of the more conventional arrangement where windows were set and the masonry cladding was laid up around them (as was done at the Wainwright Building).

**Floating Foundations** became the breakthrough solution to Chicago's poor bearing soils. Rather than building massive rubble masonry or concrete foundation walls that bore on bedrock, as was easily done in New York, solutions that spread the imposed structural load over a wider area provided equivalent stability.

John Wellborn Root of Burnham and Root devised what he called a floating raft system for both the 11 story Rookery Building (1887-88) and the eventually 15 story Reliance Building (1890) that placed a network of steel beams and rails in a grid that provided reinforcing to a very thick concrete slab poured around it. Other architects devised similar solutions using heavy timbers submerged in the Lake Michigan water table as the base layer for a similar thick concrete slab. Dankmar Adler, building within a few hundred yards of the Lake for the Auditorium Building in 1886, devised a hybrid of both of these approaches setting a bottom grid of timber beams that supported the floating foundation of networked steel rails in concrete.

At the Guaranty, Adler developed concrete spread footings with concrete encased steel rails supporting each column. Although we are located in proximity to one of the Great Lakes just as in Chicago, Buffalo's soils have better bearing capacity and bedrock is reached around 40 feet below grade in the downtown area.

Without **Elevators** there are no tall buildings. People cannot be expected to climb stairs beyond 4 or 5 levels to reach their offices or their apartments. Once a reliable elevator was demonstrated by Elisha Graves Otis at the 1854 New York Crystal Palace Exhibition (on the site of the current New York Public Library), this impediment to building tall was eliminated. It still took another 20 years before practical conveyance through hydraulics and finally, electricity, was perfected.

The first Equitable Life Building in New York (Gilman and Kendall Architects with George Post as Structural Engineer) included the first passenger elevators in the United States in 1870. Their run was 130 feet (7 stories) and this height plus a partial cast iron structural framework leads some to declare it the first "tall building" however, this distinction is usually bestowed on the 10 story Home Insurance Building in Chicago where the metal frame encompassed the full structure. By the 1880s, all tall buildings featured banks of elevators to afford easy access to the upper floors although true reliability and ease of operation in the early days remained somewhat elusive. Until the 1890s, the highest rents were still realized at the first two floors since they were most accessible without elevators.

The first generation elevators in the Guaranty Building were Sprague electric units powered off DC dynamos located in the basement. Within two years, the dynamos were replaced with an early alternating current installation by the Westinghouse Company that was tied into the nascent power grid from Niagara Falls. These were the first passenger elevators installed in the City of Buffalo. There were reliability issues with them however; in 1903, Standard Plunger Hydraulic units (combination roped, water hydraulic units) replaced the originals and functioned until they were replaced with Montgomery traction units in the mid-1950s.

Before people would accept living or working in tall buildings, the concept of **fireproofing** the structural elements was essential. Although iron and steel are non-combustible, prolonged exposure to fire leads to sudden cracking or deformation and catastrophic failure of the assembly. Since no fire apparatus could reach the upper floors from the surrounding streets, building occupants needed the assurance the structural framework could survive at least long enough to allow safe exiting. City governments needed to know the fire fighters sent to extinguish the fire could work for an extended period of time before fire exposure would cause collapse. Out of necessity, assemblies of masonry or plaster were devised that, when properly applied to particular specifications, could keep the encased iron or steel from reaching their failure temperatures for known periods of time. Terra cotta was particularly suited to this task since it was relatively lightweight and the air contained within the cored spaces of each unit added to the resistance of the assembly to temperature rise.

The Guaranty Building has terra cotta units wrapping the vertical and horizontal structure. Each column has a terra cotta surround. Floors are constructed using flat-arched terra cotta units set between the beams and girders. The terra cotta encases them and provides an insulating layer between floors that improves the fire resistance of the cinder concrete floor set above the terra cotta. At the exterior, there is significant space between the column and the encircling ornamented terra cotta at the ground floor but at the upper floors, terra cotta is packed tight to the steel. This was a common practice from that era that led to cladding failures; not because it compromised the value of the fireproofing layer but because the close proximity of the masonry allows for no thermal expansion of the steel as the seasons change. Frequently, the expanding metal cracked the closely set masonry, which then admitted water to rust the steel and cause even greater expansion. Over the decades, many late 19th and early 20th Century buildings with this detail have experienced significant cracking of the cladding material (brick, stone or terra cotta) that has required substantial re-cladding or repair campaigns to correct the problem. Although hairline cracks were encountered in the 2008 restoration, the Guaranty had remarkably few damaged terra cotta units, perhaps because of the fortunate location of the street elevations away from the prevailing winds and direct weather exposure.

**Electricity** was not available for the first generation of tall buildings, which meant occupancy after dark required artificial illumination from gaslight fixtures, which was always a very dim form of illumination. Practical daytime use depended on plentiful daylight through large windows and fairly shallow office bays no more than 20 feet from a window. This had a definite impact on the floor plan layout by encouraging shallow plan widths and the use of light wells to maximize potential exposure to daylight. Interior corridors usually featured borrowed light from the offices beyond through translucent panels in the corridor walls. At the Guaranty, these panels had Florentine Glass, which has a textured paisley shaped pattern.

By the time the Guaranty Building was being planned (1894), electricity was becoming available in the larger cities that had proximity to central electric power plants. Buffalo, with Niagara Falls close by, was one of the earliest and the Guaranty was an early subscriber. Nevertheless, when the building opened, the only available electrical source was direct current supplied through DC dynamos located in the basement. This source of electricity powered the first generation elevators, ventilation fans for the toilet rooms, one outlet and one single lamp light fixture per office and corridor and lobby lights in the public spaces. Once the alternating current power grid from Niagara Falls became available (circa 1898), the Guaranty owners made the change to this more reliable source of consistent electricity.

There were electric light fixtures in the building from the beginning. The wall sconces in the historic sections of the building today are replicas of the originals. Although they look like converted gas fixtures, they were always electric. The typical fixture featured a series of 8 watt carbon filament bulbs that produced impressive light to 19th Century eyes but are quite feeble to us today. Nevertheless, the reliable availability of artificial illumination was one of the features that made the Guaranty Building a desirable business address.

**Mechanical Systems** in the first generation of tall buildings continued the evolution of heating and ventilating systems that was already occurring in larger buildings from the 1850s forward. The development of central heating plants with boilers that distributed steam heat through pipes to radiators located around the perimeter of the building (usually in proximity to operable windows) was the most common heat distribution system at the end of the 19th Century but furnaces with ducts distributing heated air to grilles in the various rooms were also available. In the tall building, where every square foot wanted to be marketable to prospective tenants, steam heat was preferred since it required less space for the distribution system.

Ventilation was understood to be important to create a healthy interior environment but until electricity became widely available as a power source for circulating fans, it was difficult to achieve consistently. By the late 1880s, building codes were establishing a minimum air change standard of 30 cubic feet per minute per person. Engineers were developing recirculating air systems that took in building air through grilles in ventilation shafts, stairs and corridors and mixed it with conditioned air from the exterior but the predominant method of gaining fresh air remained operable windows.

The original mechanical heating system in the Guaranty Building had three coal-fired steam boilers located in the basement mechanical room that distributed steam heat to radiators located under all the windows. There were no temperature controls beyond valves at each radiator and the ability of building management to regulate the heat output from each boiler, singly or in series, depending on the season. Two dedicated ventilation shafts occurred on the south side of the western wing in the original U shaped floor plan and at the eastern end of the elevator shafts respectively – each in proximity to the rest room facilities located on the seventh floor. Both shafts had fan chambers in the attic (the 13th floor) that pulled air out of the interior and expelled it through the roof.

**Indoor plumbing** was essential in the tall building. Trips to public toilets located on the streetscape were impractical when the office was several floors above grade. Nevertheless, the concept of indoor plumbing as late as the opening of the Guaranty Building (1896) was new and a distinct amenity since most people not part of the wealthy class did not have indoor plumbing in their homes.

The Guaranty had deluxe accommodations for its time befitting Hascal Taylor's stated objective of it being "the finest building in the City". The Men's toilet room was located in the west wing of the seventh floor where 22 individual toilet stalls, 4 urinals and two lavatories were provided. There were also two private bath tub rooms, a barber shop, and a bootblack stand. The Women's Room was also on the seventh floor but, reflecting the make-up of the workforce in 1890s America, was much smaller. There were six toilet stalls and two lavatories. Both facilities were three steps up from the standard floor level, which allowed for a horizontal chase for drain-line distribution. Accessibility was not considered.

Another amenity offered to all office tenants was a lavatory in each of the approximately 240 offices available for rent. All lavatories throughout the building and the two bathtubs in the Men's Room had hot and cold water as did the restaurant space located on the Church Street side of the basement.