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Reinventing Woolworth: Adaptive Reuse of a Historic Skyscraper

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This article presents a case study of structural and logistical issues involved in the adaptive reuse of an early 20th-century skyscraper, and outlines the case for achieving sustainability through such repurposing. Through skillful structural design, the redevelopment of the Woolworth Building serves as a case study of successfully repositioning an underutilized 1913 office tower to serve a new market – luxury residential. The Woolworth Building's historic context, existing structural systems, and scope of the residential conversion are described, while particular technical concerns are explained.

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Introduction

Downtown Manhattan's iconic 1913 Woolworth Building (see Figure 1) has seen multiple iterations of structural design and redesign over 17 years. These actions facilitated the conversion of a tower once tightly packed with office spaces for dentists and barbershops, into spacious luxury homes. The former "Cathedral of Commerce" will be home to some of the most luxurious in the city, including a six-story, US$110 million "Castle in the Sky" penthouse. Construction methods were designed around 100-year-old documents; modern structural systems interact with historic riveted framing and structural terracotta. This redevelopment project was governed by strict landmark preservation guidelines and provided opportunities to enhance the building's historical value through new construction.

History

The Woolworth Building, an innovative and elegant early skyscraper, endures today as an iconic form on the New York City skyline. Commissioned by F. W. Woolworth in 1910, the building was designed by architect Cass Gilbert in Neo-Gothic style. Gunvald Aus and Kort Berle engineered the structure. The finished building was an engineering and construction feat of its time: 241 meters tall, 57 floors, 91 million kilograms total weight, 6 hectares of floor area, 5,000 exterior windows, 21,772 metric tons of steel, 17 million bricks, and 6,804 metric tons of terracotta. The construction cost US$13.5 million at the time (almost US$325 million in 2015 dollars). It remained the tallest building in the world until 1930.

The building's terracotta façade started having problems immediately after completion, and was restored between 1977 and 1981 by the Ehrenkrantz Group, during which much of the ornate exterior terracotta cladding was replaced with concrete cast-stone panels, and Gothic ornaments were simplified or removed. More than 80% of the original terracotta still remains on the building. The Woolworth Company sold the building to the Witkoff Group in 1998, and Alchemy Properties purchased the top 30 floors in 2012.

> "The floor is framed within the depth of the terracotta flat tile arch. In this situation, not only the penetration location gets removed from the slab, but also the entire swath of area around the new framing, spanning from beam to beam, because the floor shape is an arch and would otherwise not support itself if only a segment were left intact."

CTBUH 2015
New York Conference

The Woolworth Building's renovation will be the focus of a conference technical tour led by Alchemy Properties on Wednesday, October 28.

Project Scope

Residential conversion

The fundamental objective of the project is to renovate and convert the upper 30-story "tower" portion to luxury condominium apartments, without disrupting ongoing office use of the lower 28 floors, which will continue to be occupied throughout the reconstruction (see Figure 2). The structure and proportions of the historic building lend themselves to an attractive, traditional apartment layout, yet a number of upgrades to building infrastructure and services, as well as the addition of new amenities are required. An abandoned basement swimming pool will be restored, in addition to the creation of a new wine cellar.

The building's 3.6-meter typical floor-to-floor heights are sufficient for residential layouts, so changes to floor elevations are not required. In fact, at some locations, the ceiling heights need to be reduced to achieve a more residential aspect ratio for the rooms.

New elevators

Early skyscrapers typically have an overabundance of elevators. At the time the Woolworth Building was designed, elevators were slower. The architecture therefore

Figure 1. The Woolworth Building, New York. © Marshall Gerometta

provided for 26 smaller cabs and shafts. While the elevators themselves have been upgraded over the past century, the new residential conversion requires larger and higher-speed systems to swiftly connect residences at the top of the building to street level and sub-cellar amenity areas. The original 1913 elevator cars were 2.8 square meters in area, and traveled 3 meters per second; the new residential elevators are 3.7 square meters and will travel up to 5 meters per second. Placement for the new, larger elevator shafts is designed within existing structural constraints. A massive boiler flue, which extends the full height of the building, is combined with an elevator shaft that is no longer used, providing the necessary space for the new shafts. At the ground floor, these elevators will be accessed through a new residential lobby that replaces an existing Park Place storefront. Cass Gilbert's ornate cruciform lobby remains to serve the building's office tenants.

MEP systems

Compared to office buildings, residential buildings demand many more slab penetrations spread out irregularly throughout the floor to accommodate individual MEP services for each private residence. At the Woolworth Building, the systems serving the residential portion must also be independent of those that serve the lower office levels. Risers will bring services from street level to the 29th floor through former elevator shafts that are no longer in use. Two new fire water tanks – one of which is a custom-built doughnut shape to be installed just below the top observation deck – will serve the residential tower from the highest floor in the pinnacle.

Depending on the sizes of MEP penetrations and their proximity to other openings, certain portions of the slab need to be reinforced. In buildings where the floor slab is a concrete and metal deck, openings can be simply framed from beneath the slab. However, as is typical of construction circa 1910, the floor is framed within the depth of the terracotta flat tile arch. In this situation, not only the penetration location gets removed from the slab, but also the entire swath of area around the new framing, spanning from beam to beam, because the floor shape is an arch and would otherwise not support itself if only a segment were left intact. The opening itself is then reformed by a patch of concrete and metal deck. While this does not affect the overall integrity of the building, it was a logistical issue that required planning in advance.

Stair replacement

Even larger portions of terracotta flat-tile arch had to be demolished in order to place a new set of egress stairs. While this work had been done previously, in 2007, as part of a renovation scheme to upgrade office space in the tower, the new residential use demanded that these stairwells be shifted south, away from the elevator, by approximately 1.2 meters to provide sufficient room for a common-area elevator lobby on floors with more than one apartment. The stairs themselves had to be demolished and rebuilt in the new position.

Truncation of existing elevators

Only three elevators serve the top-most office level at the 28th floor. Their shafts, which

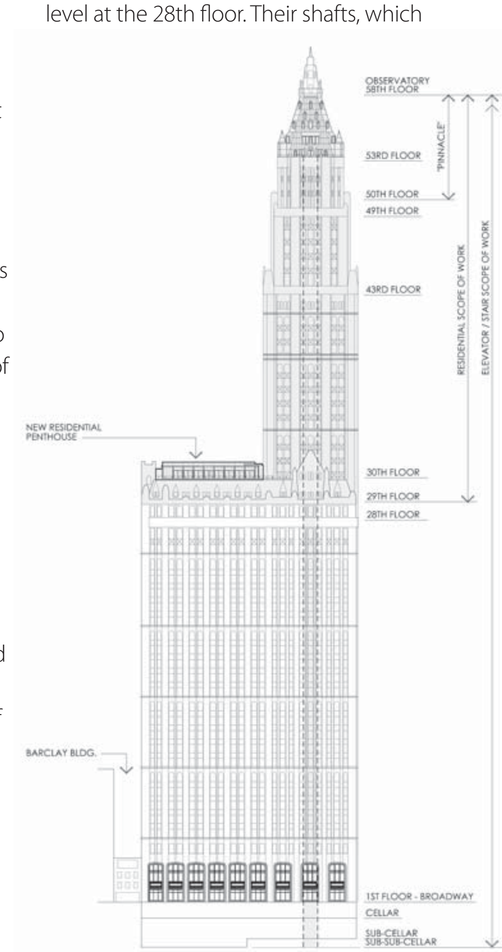

Figure 2. Scope of reconstruction work. © SLCE Architects

currently extend through the tower to the 49th floor, will be removed and the elevator machine room repositioned to the 30th floor. Since at least one elevator must remain in service at all times, this relocation will occur in phases. To minimize impact on existing building occupants, this work can only take place during off-hours (on nights and weekends). Additionally, to minimize the reinforcement of the existing framing in the operating shafts, the key girder separating the shafts was given increased capacity to support the elevator equipment loads by shortening the span with a new support hanger that continues up several floors, distributing the load between those girders as well.

Rooftop plant

The 29th floor, the lowest residential level, extends over the wings of the building and is enclosed by Woolworth's iconic green mansard roof. This floor will house not only terrace penthouse apartments, but also the building's new mechanical plant (i.e., cooling towers, generator, etc.), hidden behind the sloped roofs, as required by the Landmarks Preservation Commission. To accommodate these spaces, the existing framing and slab area of the roof and 30th floor are being removed. The new plant requires reinforcement of the floor, which is only accessible from above, because the space below is occupied and in active use by office tenants. The reinforcement consists of steel T-sections welded to the top of existing beams.

Modifications to the existing mechanical mezzanine level at the 48th floor require bracing of the exterior wall, as well as reinforcement of the floor framing, to support added pumps and new openings.

Converting the pinnacle

The six-story pinnacle will be converted to a single unique residence (see Figure 3). This involves removing a significant amount of floor area, adding an internal private dual-roped hydraulic elevator for that residence, replacing an existing spiral stair used to access the lantern with one that is code-compliant, and adding and enlarging windows and skylights within the landmarked pinnacle roof. Since a substantial portion of the floor diaphragm is being removed, the frame must be strengthened to support lateral loads at the top of the building.

Tourelles

The four iconic *tourelles* around the pinnacle will also be altered to provide air intake and exhaust for the tower. While only one of the *tourelles* has been used for this purpose since the building's construction (it provided the exhaust for the massive flue that ran the building's full height), all four will now house mechanical shafts in the redeveloped scheme.

Permanent rigging

In order to enable ongoing maintenance of the tower façade, a new permanent rigging system will be installed at setback levels to support a suspended scaffold. The setback at the 43rd floor, however, features a 1.5-meter ornamental vaulted overhang. In order for the scaffold to get close enough to the façade below, the suspension must therefore penetrate the masonry arches, and is anchored to cantilevered steel members installed above the overhang. This installation is not unlike drilling through a sidewalk vault, but it takes place at 167.6 meters above the street.

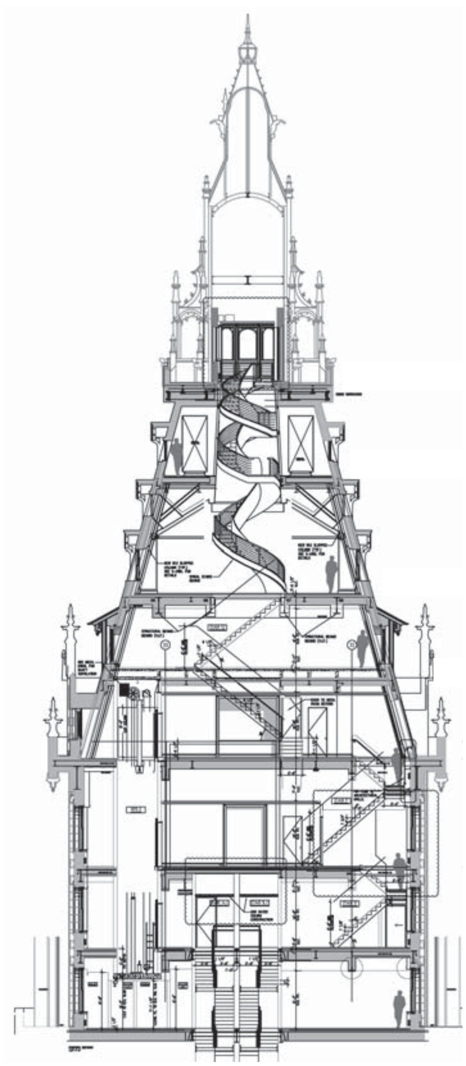

Figure 3. Section at pinnacle residence. © SLCE Architects

Existing Structural System

The Woolworth Building's foundation consists of 69 pneumatic caissons, ranging from 2 to 5.7 meters in diameter, that were driven down to bedrock 30.5 to 36.6 meters below grade to support the tower's mass. Closely spaced steel beams, in an assembly called a grillage, were installed atop each caisson to evenly distribute gravity loads. After the construction of the foundation piers was commenced, additional property was acquired and the building was redesigned. In order to utilize the piers already sunk or under construction, eight of the tower columns located near or beyond the face of the piers already built are carried partly by the existing piers, and partly by subsequently added adjacent piers. The columns are supported by heavy triple girders seated on both piers (Holtzman 1912). These girders carry the enormous concentrated loads of the tower columns. For example, one girder that supports a main tower column is 2.4 meters deep, 2 meters wide, 7 meters long, and weighs 59 metric tons. At its mid-span, it carries a concentrated point load of 4,264 metric tons.

Wind loads drove the steel frame design, which integrates diverse types of bracing: portal arch bracing, full-story diagonal bracing, and knee bracing (see Figures 4 and 5) (Holtzman 1913). The central tower functions structurally as a highly rigid vertical cantilever and stabilizes the entire building. Where the tower meets the building's flanking wings at the lower 28 floors, portal arches span each structural bay at every story in the tower's front and back elevations. The remainder of the building base is reinforced by concentric chevron bracing and K-shaped knee braces. Between the 28th and 42nd floors, the tower frame is reinforced by diagonal knee braces. Up to the 47th floor, additional perimeter columns connect to wall girders, and at the 47th to 50th floors, four interior columns join floor girders to resist lateral forces. At floors 50 and above (the pinnacle), inclined members of the pyramidal roof counteract the lateral forces of the wind (Wind Bracing 1912).

Very well-preserved structural drawings facilitated the new design for the converted tower, eliminating the need for extensive surveying.

Mass and Stiffness

Compared to other skyscraper conversions, the Woolworth Building has fewer performance issues when converted to residential use than similar-height office buildings that were built in the 1950s to the 1970s. These newer buildings frequently have movement and acceleration issues that need to be resolved by adding mass and stiffness before the buildings are comfortable for occupants. The structural technologies available during early 20th century when Woolworth was built, namely terracotta slabs and heavy built-up columns/girders, were massive enough to produce a building that is already very stiff. During the conversion, at any location where architecture demands demolition, modification or relocation of the existing structure, the removals are replaced with components of equal stiffness. This approach was required to assure no modification to the support conditions required by the terracotta façade.

Technical Concerns

Unlike new, ground-up high-rise developments, the constructability and logistics of this redevelopment scheme were additionally constrained by existing structural systems and the building's continued occupancy.

In skyscraper reconstruction, the options for delivery and installation of new structure are constrained by limited access at great heights, which also translates into added construction expenses associated with transportation of material. In a low-rise building, material can be pulled in through windows from the street using a boom lift or other elevated work platform. High-rises instead employ hoists and cranes. At the Woolworth Building's location, though, there is no adjoining space in which to erect a crane, and the building's shape and existing structure cannot support one on top. All material must therefore be delivered through the interior of the building and worked on from the inside. This entails a considerable coordination effort, especially since portions of the building remain in use.

Temporarily, during construction, one of the two new residential elevator shafts houses a hoist, which is laterally braced within the shaft. The new elevator pit supports its gravity load. All material arrives to the site through the future location of the residential lobby, and is lifted by the hoist to the working level and placed using a chain fall. Since access to upper floors is not available from the exterior of the building for delivery of material, structural members must be small enough to fit into the interior hoist shaft.

In certain locations, such as the sloped framing of the pinnacle's exterior wall, the required steel segments are longer than is transportable through the hoist shaft. In this event, shorter segments will be spliced together at the location of installation, on the 53rd floor. Splices will be bolted where

> "At the pinnacle's sloped exterior framing, the required steel segments are longer than is transportable through the hoist shaft. Instead, shorter segments will be spliced together at the installation location."

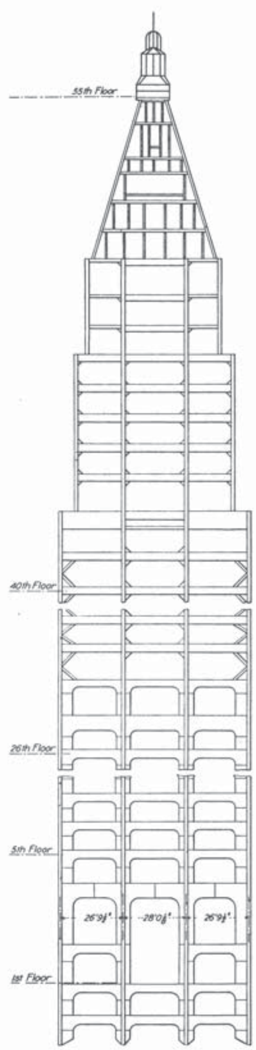

Figure 4. Overview of tower framing (1913). © Gunvald Aus

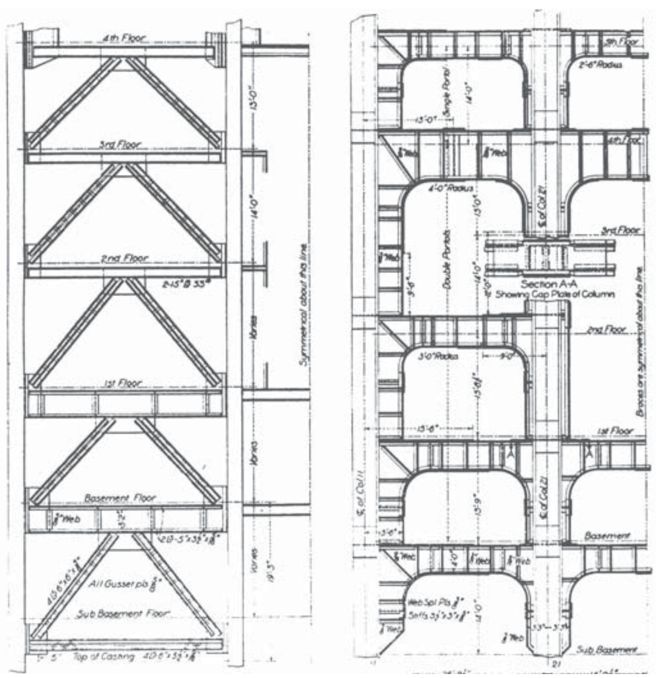

Figure 5. Detail of as-built bracing systems (1913). © Gunvald Aus

feasible, but predominantly, welding will be required, otherwise the composed member shape would be larger than the architecture allows. Other structural elements, like a new spiral stair that accesses the pinnacle's lantern, will be assembled and welded in place out of small, relatively light members.

The majority of such logistical peculiarities arise from the limitations of having several setbacks and a steeple roof. Skyscrapers that have a flat roof available for temporary and construction services would face fewer delivery, installation, and coordination challenges. Temporary derricks are frequently used to move materials to the top of the flat-roofed modern skyscrapers.

New elevators

The most prominent issues related to adaptive reuse of skyscrapers revolve around vertical transportation, i.e., elevators and egress. Additions and removals of these systems must be carefully coordinated. As in many buildings of this vintage, the Woolworth Building was over-elevatored by current standards; however, the existing elevators are all very small. Therefore, even though there are elevators which have been taken out of service, refitting an existing shaft was not a good option. Additionally, the shafts that could have been combined did not work efficiently with the residential layout.

Thus, an existing disused 4.9-meter-diameter boiler flue provided better access to the residential layout and allowed a larger cab size. Removal of the flue posed a challenge, because it was made of 13-millimeter riveted steel and, since it is surrounded by occupied spaces, it could only be demolished from within. The contractor was suspended within this duct and burned away the steel, which was then clipped to a lanyard and lowered down.

High-speed elevators require deeper pits. The locations of these pits had to be positioned among the enormous caissons, grillage, and transfer girders of the building's foundation. An operating parking garage below grade complicates this coordination further. Another impediment is an existing pneumatic safety system that had been installed for the original elevators, a hundred years ago. Novel for its time, this mechanism consisted of large air-tight silo-like chambers at the bottom of the elevator shafts, within which the air beneath a falling elevator cab gets compressed, thus cushioning the drop (Six Hundred-Foot Drop 1913). These "silos" had to be removed, to make space for the new elevator shafts. This demolition was difficult, because they are made of a cage of horizontal web I-beams spaced at 381 millimeters, which is densely packed with terracotta or concrete (see Figure 6).


Figure 6. Existing shaft reinforcement.

Once the plan space was cleared for the shafts, there were further complications involving the installation of the pits. One of the elevators had to extend to the lowest cellar level to serve the amenity/pool. The high-speed elevator required a 4.9-meter-deep pit, 2.4 meters of which was below the water table. Additionally, the pit needed to be supported on rock, so there would be no differential settlement. As installing a deep foundation to rock inside an existing, occupied building was deemed impractical, the alternative was to support the new pits back to the existing caissons. To complicate issues further, small pile caps had been added to support the "silo walls" and these had to be maintained in place. The final solution was to excavate down to just above the water table, minimally undermining the pile caps, and pour a1.2-meter deep structural "doughnut" around the pit, connecting into the existing caissons. This doughnut served to stabilize the pile caps while the excavation was extended down for the pit. Water infiltration was stabilized by extensive grout injection into the soil around the pit. The pit was then blind-side waterproofed, and the concrete elevator pit was poured within, hanging from the structural doughnut.

The 29th floor

The wings of the 29th floor presented many structural challenges. The basic architectural goal was to take a mechanical space with 1.8 meters of head room and turn it into exclusive penthouse residences (see Figure 7). In order to do this, the architect had to convince Landmarks that the new, higher penthouse could not be seen from the street. The resulting architecture has the higher occupied space set back from the existing mansard roof to leave the sight line from the street unchanged. This meant the existing roof had to be removed, while leaving the mansard in place to hide the new structure. Additionally, the new structure had to be supported without reinforcing anything from below and minimizing the rise in the floor elevation. Complicating this further was the addition of cooling towers and an emergency generator at the far end on one of the wings, coupled with the need to maintain access to an existing elevator machine room and egress stair, also at the far end of the wings.

The fact that the lower half of the building was to remain in active use by office tenants over the duration of reconstruction limited the options for structural reinforcement and required careful coordination of the construction process. Any reinforcement of the slab at the 29th floor – the lowest residential level – had to be applied at top of steel only using WTs (structural tees cut from wide-flange shapes), because the bottom of the steel is not accessible, as that floor remains in use.

In order to minimize the chance of flooding the occupied 28th floor, the existing roof and waterproofing is intended to remain in place as long as possible, and most of the reinforcement is sequenced to occur prior to the demolition of the existing roof. Once the reinforcement of the 29th-floor steel and the mansard bracing is complete, the new columns will be erected through localized penetrations, maintaining waterproofing, and the superstructure of the penthouse roof will then be erected above the existing roof. The permanent new waterproofing will then be installed in the new mechanical space, on the new penthouse roof, and the penthouse terrace. Only then will the existing roof structure and old waterproofing be removed.

Assuring the pinnacle's stability

Accommodating the structural changes required to create the pinnacle residence involved careful attention to the overall stability of the structure. Along with the usual localized structural analysis and reinforcement, the enlargement and addition of openings in the sloped roof were found to destabilize the pinnacle against lateral loads. The removal of half of the 54th floor destabilized columns and the roof, and the addition of a new water tank (fabricated in-place) and restructuring the spiral stair required significant reinforcement to account for the new load and the removal of the former load path. All of the required reinforcement is accompanied with detailed sequencing requirements to assure continuous structural stability.

At the pinnacle, existing posts are removed between the 55th and 57th floors to accommodate the installation of a new spiral staircase to the observation deck. The weight of a new doughnut-shaped, 56,781-liter, two-compartment stainless steel fire storage tank at the 57th floor must therefore be redistributed elsewhere. The supporting frame uses W8 braces to engage new sloped W12 corner columns that parallel the existing sloped exterior frame (see Figure 8).

Since more than half of the slab and floor framing at the 54th floor is removed to create a 7.9-meter-high open space known as the "Great Room," this level loses its diaphragm. Combined with the need to remove significant portions of the terracotta substructure of the sloped roof to increase the window openings, new chevron wind bracing is required at the new corner columns to maintain stiffness and lateral capacity. New HSS8 frames are installed around the perimeter at floors 54 and 55 to engage existing structure with the new bracing system.

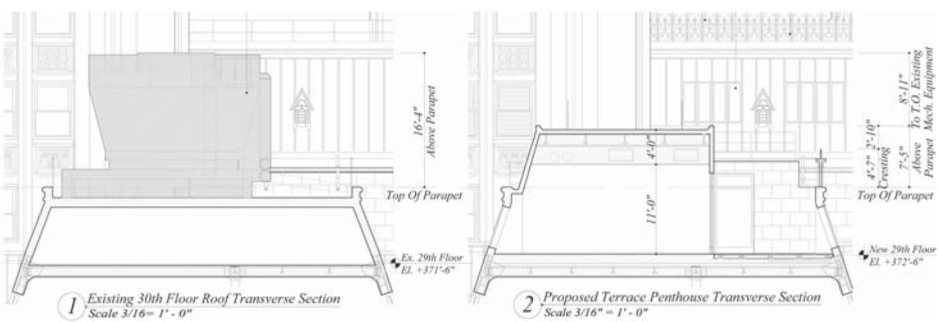

Figure 7. Residential conversion at 29th floor. © Thierry W. Despont

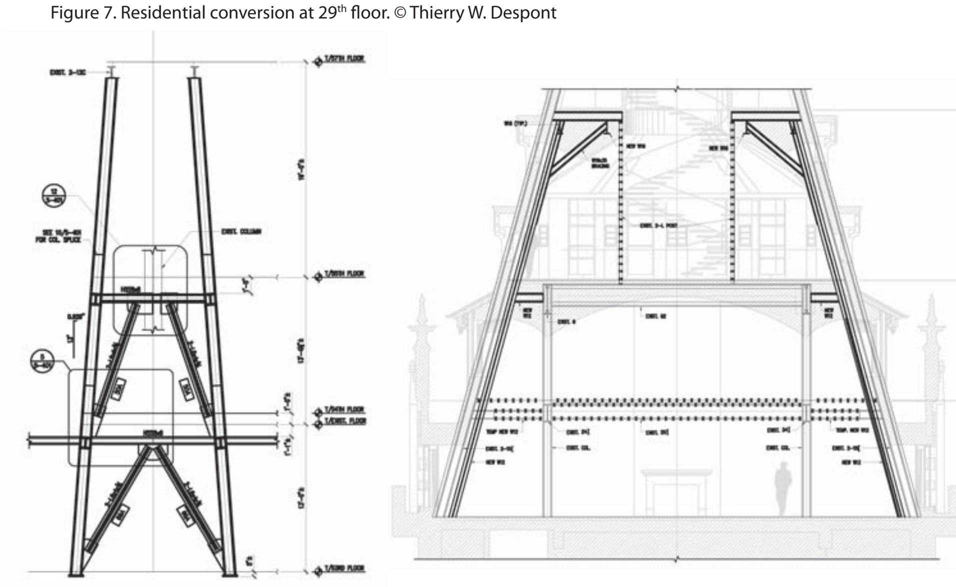

Figure 8. Pinnacle reinforcement.

Conclusion

Old structural systems and strict preservation regulations limited available adaptive reuse options. Concurrently, new technologies and building techniques supported redevelopment. These drawbacks and advantages were balanced within the design so as to achieve the proposed highest and best use.

The dense urban geographies, such as those which constrained the redevelopment of the Woolworth Building, are typical of settings where historical skyscrapers exist. Those buildings will face similar delivery and access challenges, as experienced at Woolworth. Beyond density, these locations may also be subject to historic district restrictions or land-use regulations such as view planes, setbacks, and bulk/envelope limitations, even if the building itself is not necessarily landmarked.

Portions of the renovation work had been accomplished as part of previous development plans, but there is more to be done. As of this writing, preconstruction work is proceeding on schedule and the developer projects occupancy in 2017. ■

Unless otherwise noted, all photography credits in this paper are to Gilsanz Murray Steficek LLP.

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