56 LEONARD

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Villas in the sky.

The southwest corner formed by Leonard Street and Church Street in New York City is ground to the 56 Leonard project, a new and unique 57-story residential development comprising 480,000 square feet of gross area.

The current economic, cultural and social context of the real estate market in New York City requires serving a continuously changing and diverse group of buyers and investors from all over the world, which in turn has generated a very strong demand for excellence in analysis, design and construction of luxury residential buildings. In 56 Leonard, for instance, each floor gives the impression of being a singular, virtually independent structure carefully placed and balanced over yet another unique structural entity forming the floor below. The resulting sensation is that of a vertical community of uniquely "stacked" homes. In fact, the residents of 56 Leonard will each live in a bright, inimitable private home reaching the sky.

Herzog & de Meuron, the architects behind this project, have been known for forward-thinking concepts throughout their careers. In the case of 56 Leonard, these concepts take the form of an innovative stack of individual homes suggesting the new idea of a vertical neighborhood in which each owner can choose a unique residence, albeit in the sky. The vertical neighborhood is a new paradigm in which the penthouse is no longer the single story breaking from the typical floor plan mold. An innovation of this scope and relevance certainly presents an excellent answer to the desire for traditional home ownership in an urban setting that is as unique as its occupants, while reducing the footprint of a conventional horizontal community of homes. In other words, the design of 56 Leonard successfully combines the idea of old-fashioned home ownership with the present vernacular of luxury urban living. The blending of traditional, present and future needs demanded not only the incorporation of forward-thinking solutions but also a complete vision of sustainable and resilient design.

The new tower has a height of 825 feet from the street level and a width of about 78 feet, which results in a daring slenderness ratio slightly above 10. The building includes three mechanical floors located at the 32nd, 46th, and 56th floors, with outrigger and belt wall systems placed on the first two of those stories. The highest residential floor is the 55th level. The 56th mezzanine floor houses a liquid tuned damper to provide adequate structural damping for occupant comfort.

Foundation

The foundation of 56 Leonard consists of 1,500-ton, 24-inch diameter caissons socketed in bedrock, and 180-ton end-bearing H-piles. The lengths of caissons and piles range from 90 to 110 feet below the cellar level. Five-foot deep reinforced concrete caps structurally connect the caissons and piles. The caps serve as main supports for the vertical and lateral force-resisting systems.

The existing foundation walls on the north, east and south side of the site are a part of the new structure due to the adjacency of a Metropolitan Transportation Authority underground tunnel to the lot, as well as the column layout of the tower. The reuse of existing foundation walls not only contributed to the reduction of lateral support during the excavation process but also reduced the cost of construction.

Gravity System

The tower at 56 Leonard is a reinforced concrete building. The structure is composed of cast-in-place concrete flat-plate slabs supported by reinforced concrete columns and shear walls.

To accommodate the varying apartment layouts throughout the building, which represented the main architectural concept, practically all of the columns had to be relocated from floor to floor by using *walking columns*. The structural solution was to introduce one- or two-story walls able to transfer the load from one column location above to a different location below. The eccentricity associated with the transfer of vertical load resulted in additional lateral forces, applied at the top and bottom of the transfer walls. Then, rational load paths to the shear walls, present in each story, transferred all additional lateral forces.

The building also has a great number of cantilevered slabs. The thickness of the slab controlled short cantilevers whereas larger ones utilized beams. The largest of cantilevers, which are about 25 feet long, were solved by creating a reinforced concrete Vierendeel truss extending over two stories and engaging the vertical members between them. This structural solution did not have an impact on the architectural intent.

Lateral System

The combination of reinforced concrete shear walls and frame action between the flat plates and columns provided the lateral load-resisting system. The reinforced concrete core wall system is located at the center of the tower and acts as the main spine of the tower, providing not only support for gravitational loads but also resistance against wind and seismic forces.

The reinforced concrete core houses elevators and mechanical equipment, and is comprised of several walls connected to each other over access openings by reinforced concrete link beams. Wall thicknesses vary from 30 inches at lower levels to 12 inches at mid-height of the building.

Special enhancements to the lateral load-resisting system were provided to the main reinforced concrete core at the 32nd and 46th mechanical floors by connecting them to the perimeter columns using outriggers and belt walls in two orthogonal directions. The structural interaction between the core wall and perimeter columns induced by these special elements increased the overall building stiffness while significantly reducing lateral displacements.

The tower's height, limited space and large slenderness ratio imposed stringent demands on the overall strength and stiffness of the structure. Those demands were met economically by using high-strength concrete of up to 12,000 psi. The specified concrete compressive strength ranges from 12,000 psi at the base of the building to 7,000 psi at the top. In addition to the compressive strength, it was necessary to specify a larger modulus of elasticity of concrete than that set by applicable building codes. This requirement aimed to increase the lateral stiffness of the core walls without imposing the premium associated with higher concrete compressive strength or the thickening of the walls.

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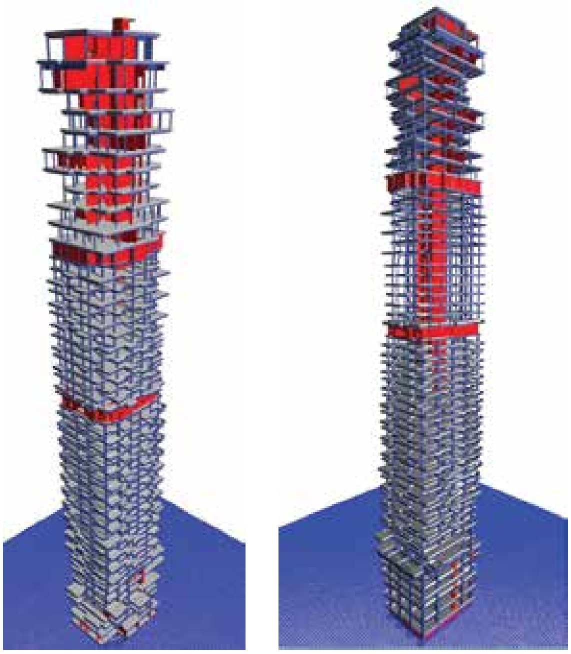
56 Leonard under construction.



3D structural model.

Codes and Standards

The primary design code for the project is the current *New York City Building Code*, including its amendments at the time of design. However, in consideration of the unique distribution of masses throughout the building, it was essential to perform a series of project-specific wind tunnel tests.

Rowan Williams Davies and Irvin Inc. (RWDI) wind tunnel facilities in Canada performed the tests at various stages of the design. The main objective was to ascertain the wind loading and wind-related response of the tower with respect to hurricane wind loads and human comfort criteria. High-Frequency Force Balance (HFFB) and aeroelastic tests, which are the prevalent methods for wind tunnel testing for tall buildings, were performed. These tests were able to provide design wind loads and main structural response in terms of acceleration.

An essential design requirement for 56 Leonard was the criteria regarding human comfort levels during high winds. Typically, the criteria for wind-induced motion have been established by experiments performed with different groups and ages of the population. The motion perceived by building occupants is a function of the peak acceleration at the top occupied floor. Since the desired performance is solely for occupant comfort and not governed by structural safety or integrity, there are no specific requirements in building codes. An exception to this is the acceptable acceleration suggested by the International Organization for Standardization (ISO). The corresponding acceleration of the structure is determined through wind tunnel testing of a solid model analyzed using the force balance method and by subjecting a flexible model to aeroelastic tests. Typically, various wind tests are carried out, each associated with wind events with periods of recurrence of 10 years, one year and one month. However, the most common performance criteria are given for wind events with a 10-year return period, for which acceptable accelerations guarantee human comfort in the range of 15 to 18 milli-g for residential buildings, and in the range of 20 to 25 milli-g for office buildings.

Liquid Sloshing Damper

The wind tunnel study performed for the 56 Leonard project resulted in the incorporation of a Liquid Sloshing Damper (LSD) aimed at reducing and controlling lateral displacements and accelerations. An LSD, measuring 32 by 36 feet in plan and reaching 10 feet high, was placed at the 56th mezzanine floor. This addition kept lateral accelerations due to the wind within accepted industry limits.

The LSD placed at the top provided additional benefits to the project. While it kept building movement at an acceptable level of human comfort under wind loads, it also reduced the weight of the building thereby minimizing the number of additional materials that the structural system would otherwise require.

The structural analysis and design for the 56 Leonard project used finite element modeling software that assisted the engineering effort aimed at achieving precision during the design process. The modeling reduced the need for an overly conservative structural solution, which is an important factor that tends to influence construction expenditures negatively by requiring larger quantities of materials, which in turn produce a greater environmental and financial impact.

Summary

The iconic project of 56 Leonard presented an interesting challenge to the design team who answered by providing a redundant and resilient structural system comprised of a main core of shear walls, perimeter columns, and reinforced concrete flat slabs. Additionally, outriggers and belt wall systems were provided at two elevations of the tower to meet the required lateral stiffness. Furthermore, a Liquid Sloshing Damper was installed at the top of the building to guarantee human comfort during high wind events.

Each of the engineering techniques and tools used throughout the structural analysis and design of 56 Leonard supports not only the original aesthetics and architectural intent, but also provides a cohesive amalgamation of advantages. In a holistic approach, these multi-level strategies elegantly link the demands of today's market with the traditional individualized character of home ownership, the protection of the environment for future generations, and the creation of a highly efficient and resilient structure. The complete yet detailed-oriented vision of the 56 Leonard design team produced a building that will be highly regarded in the long term, achieving consistency between the demands of current and new construction technologies and the social goal of meeting present and future sustainability mandates.▪

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Project Team

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Design Architect: Herzog & de Meuron
Architect: GHWA, Goldstein, Hill & West Architects