



REVITALIZATION OF THE HANCOCK OBSERVATORY

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In early 2013, Thornton Tomasetti (TT) partnered with colleagues at Montparnasse 56 (M56), who had recently purchased the 94th-floor observatory in Chicago's iconic John Hancock Tower, with a plan to modernize and revitalize the experience for its visitors. The M56 plan involved gutting and modernizing the interior space and installing a unique attraction that would add an adventure element experience for guests. The concept of "tilting" patrons outside the footprint of the tower was pitched by M56 as a way to provide a one-of-a-kind thrill, taking full advantage of the Hancock Tower's height and spectacular views of Chicago.

Key Challenges

Designing and constructing a fixed-tilted exterior curtain wall is no easy task, so taking that concept to the next level and developing an operable exterior wall with the ability to safely hold observatory patrons was a complex challenge. A steel-framed operable wall skeleton was developed to provide a robust and durable system that would be capable of operation 7 days a week. A steel frame provides excellent fatigue resistance and element ductility, as well as a clear load path. Integrated into the steel frame were structural glass components.

The powered actuation system was also a direct part of the structure's load path, so full-scale static load proof testing was done on the actuators to ensure their published load carrying capabilities. Ergonomics and patron experience required evaluation to test the concepts of thrill and comfort. For this challenge, TT fabricated a full-scale mockup of a single bay of the Tilt. This mockup was utilized by surveying the experiences of both a random sampling of TT and M56 staff to evaluate the comfort of the geometry, vertical hand railing, tilt angle, tilt speed, and tilt motion profiles.

HANCOCK'S
TILT



Hancock's tilt.

The final and very important challenge of maintaining the integrity of the world-famous architecture was also addressed by designing the Tilt structure's geometry to mimic the existing exterior wall expression.

Mechanism and Components

The Tilt system is a mechanized steel and glass structure that is comprised of three main components:

- 3-Dimensional Steel L-Frame
- Rigid Steel Platform at the Base
- Overhead Actuation System

The 3-D steel frame structure of the Tilt is 27 feet wide and 7 feet tall and can hold eight patrons at a time, one in each module. The geometry of this frame fits in one complete bay of the Hancock Tower and can rotate 30 degrees outward from the face of the tower's exterior. A 30-degree angle was determined to be a point where the majority of patrons would have their center of gravity outside the exterior

face of the tower while maintaining a reasonable clear height for patron modules, as this height is controlled by rotational clearance of the L-frame and the existing structure of the building. Rotational joints are located at three points along the base of the L-frame and are comprised of PTFE spherical bearings with custom machined AISI 4140 quenched and tempered hollow sleeve bolts, each containing an internal ASTM A320 L7 high-strength bolt for redundancy. These three locations serve as the rotational frame's anchorage to the rigid steel platform at the base. W8 and W6 wide-flange beam members,



PTFE rotational joints and redundant pins.

which were posted down to the existing W18 floor beams, comprise this rigid base platform.

Hydraulic actuators, with 4-inch diameter bores and 2.5-inch diameter rods, are located at three locations overhead and are aligned in plan with the three lower L-Frame points of rotation. These actuators are capable of resisting forces over 40,000 pounds and are digitally controlled with the ability to be programmed for different motion profiles and push-pull speeds. A hydraulic pumping system was installed in the mechanical space of the tower core area, which serves to power the Tilt actuation system. Overhead end-stops comprised of steel plates and rubber buffers were mounted to the underside of the existing spandrel beam to prevent over rotation of the L-frame. These stops are engaged by steel armatures, which are welded to the top of the L-frame, contacting them if the frame were to rotate beyond 30 degrees.

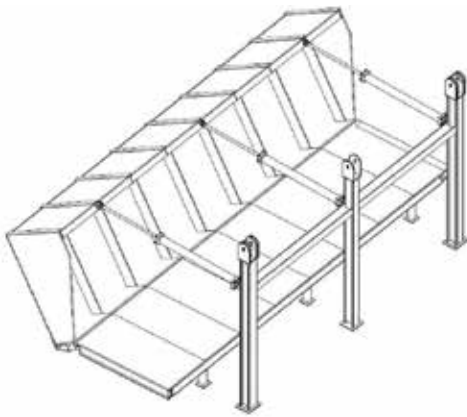
With the cyclical nature of the Tilt mechanism, a detailed fatigue analysis was conducted utilizing both AISC design approaches and ASME fatigue design approaches like those developed by Shigley. Special detailing and testing requirements for welded connections and their base metals were also developed to be in accordance with AISC's fracture critical detailing requirements and AWS D1.1 requirements for "cyclically loaded structures."

Wind Tunnel Testing Program

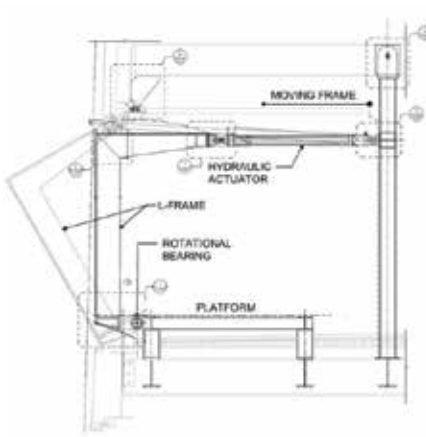
At a height of 1030 feet above grade, actual wind loads for the design of Tilt would be much greater than those required by the Chicago



Tilt mockup.



Tilt system.



Tilt in use.

Building Code and are greatly influenced by the surrounding tall building topography. The Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario was engaged to address this issue and conduct a High-Frequency Pressure Integration test (HFPI) at a scale of 1:200 of the top of the Hancock Tower, with the Tilt both open and closed. These loads were then utilized for the design of the Tilt structural steel frame, actuation system, and structural glass elements. Wind climate data was also utilized to better understand daily and weekly operational wind speeds, and corresponding wind pressures, that the Tilt would experience regularly.

Structural Glass

The glass elements of the Tilt are assemblies of $\frac{3}{8}$ -inch thick fully-tempered glass panels with DuPont SentryGlas laminate inner layers. The front elements are comprised of three glass panels and two laminate inner layers, and the side and overhead elements are comprised of two glass panels and one laminate inner layer. The design of these assemblies was based on the results of the wind tunnel test wind pressures, and considering the glass panel assembly as a "Glass Walkway" in accordance with ASTM E2751-11. All panels are continuously supported along their edges and were analyzed in both SJ MEPLA and ABAQUS to evaluate their performance. The finite element analyses indicated that only two $\frac{3}{8}$ -inch thick glass panels with a single SentryGlas inner layer were required for the front main elements; however, the third layer was kept at these locations as a redundant layer for added safety.

Inspection and Maintenance Program

As the Tilt is a machine in addition to being a structure, a required regular Quarterly Inspection Program was developed for the steel

connections and implemented by M56. Each quarter, component and member connections are inspected and maintained, as required, to ensure that the Tilt's condition is in general conformance with the original design intent. All inspections conducted by M56 are performed in conformance with AISC, AWS, and ASTM requirements for cyclically loaded structures.

The Tilt Experience

The Tilt system is an understandable, robust, and regularly maintained structural steel and glass mechanism that has been offering Chicagoans, and its visitors, a safe but unique and exhilarating experience in the much loved John Hancock Tower.■



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Christian DeFazio, P.E., LEED AP, is a Senior Project Engineer with Thornton Tomasetti and served as the Project Manager of Tilt through construction. He can be reached at CDeFazio@ThorntonTomasetti.com.

Project Team

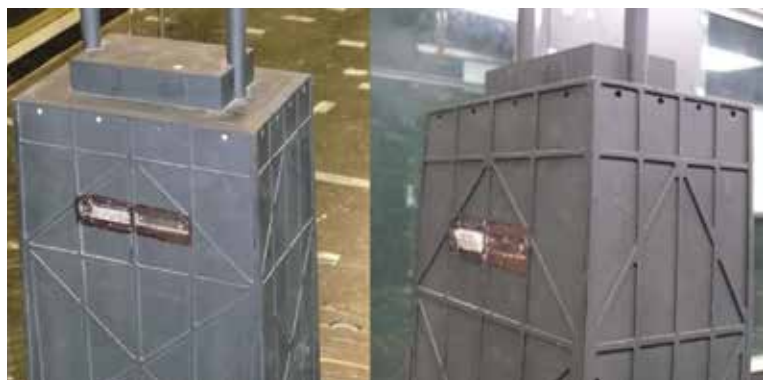
Owner: Montparnasse 56 USA

Structural Engineer: Thornton Tomasetti

Contractor: Cupples



Actuation system and overhead end-stops.



BLWTL HFPI test model.