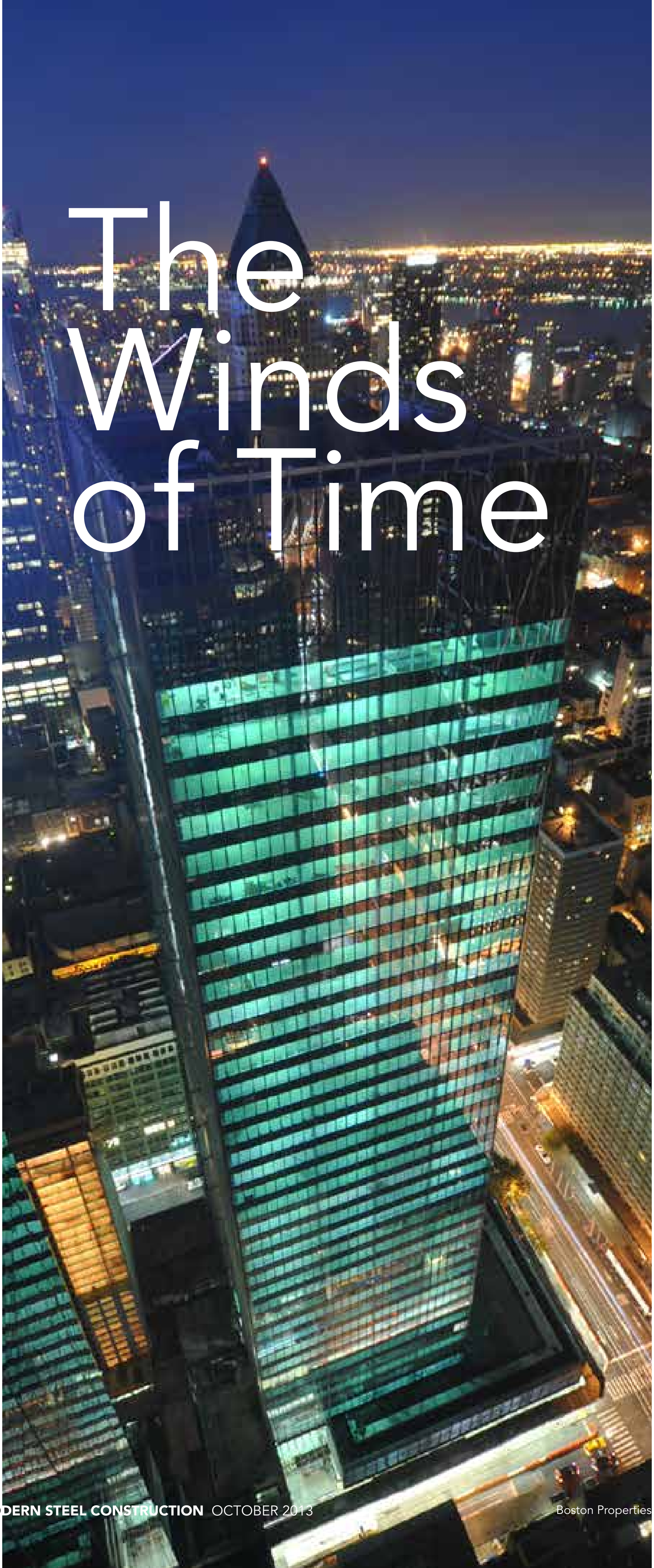
The Winds of Time



Boston Properties

Increased wind load requirements and the bad timing of the 2008 economic downturn couldn't keep a Manhattan skyscraper from topping out ahead of schedule.

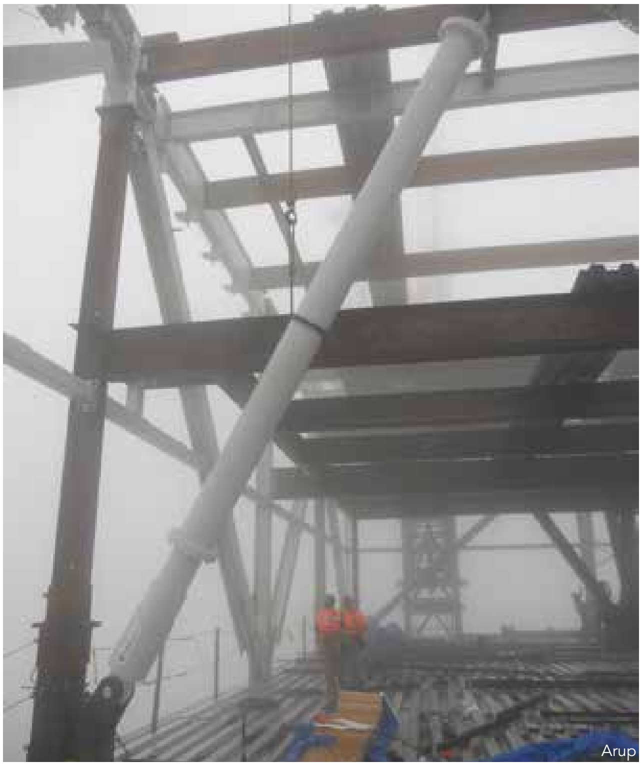
BY MATT JACKSON, S.E., P.E.

A SOON-TO-BE-OPEN New York skyscraper is doing its part to grow the nation's largest business district.

The sleek 40-story, 600-ft-tall 250 West 55th Street, which brings almost one million sq. ft of commercial space to Midtown Manhattan, is set back on a 50-ft-tall podium that, together with column-free interior spans, allows maximum light and views. The tower design maximizes efficiency not only in the programmatic layout and tight design of the core, but also in the use of new structural technologies.

As is typical for New York City office towers, the building has a steel frame with a steel braced core and composite floors. The floor structure is based on a 29-ft, 6-in. typical bay size, with spans from core to perimeter varying from 30 ft to 43 ft, and floor beams typically W18 to W21 in size. The slightly offset core was limited in width to 45 ft to optimize the office layouts for future tenants; to meet stiffness needs the core columns were plated jumbo W14 sections at the base of the core. To gain additional lateral stiffness, a "hat truss" formed by bracing the perimeter columns behind mechanical louvers was added at the top of the tower, and this was connected to the core with a series of outriggers. This system effectively joins the core columns to the perimeter columns and uses them to provide additional stiffness to resist wind loads.

◄ The building uses approximately 10,000 tons of steel in all, 9,000 tons of which were stored for several years while the project was on hold.



▲ Installing the viscous dampers.

➤ The building's floor structure is based on a 29-ft, 6-in. typical bay size, with spans from core to perimeter varying from 30 ft to 43 ft.

➤ A layout of the damper system.

Dynamic Damping

The framing design was initially based on ASCE 7 wind loads. Once the schematic design was completed, wind engineering firm RWDI carried out wind tunnel testing, and the initial results showed that the actual wind loads and base moments were lower than those predicted by ASCE 7 and the New York City Building Code; however, the accelerations were somewhat above typically acceptable ranges. The primary reasons for this were that 1) at lower levels there was significant shielding from other existing buildings, reducing the loads substantially, while 2) at higher levels the structure was also subject to some buffeting from wind interacting with surrounding tall buildings.

Based on these findings, two options for meeting the acceleration limits were considered: Increase the stiffness by approximately 20% or increase the damping. The design team determined that adding damping was the more efficient option and considered several damping methods, including conventional tuned mass dampers (TMD) and sloshing dampers, before finally settling on a system, from Taylor Devices, that effectively replaced some of the braces in the outrigger trusses at the top of the tower with viscous dampers. The specification for the dampers was quite different to those normally used for seismic applications in buildings, as the dampers are required to provide damping at very small displacements but also cycle constantly whenever there are high winds.

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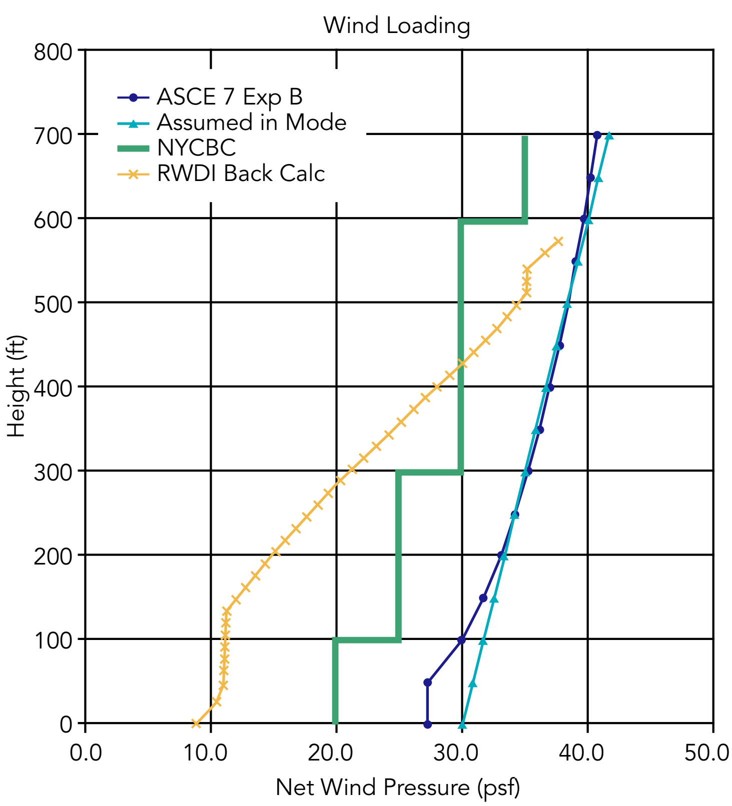
Much of the project's steel resided at fabricator Owen Steel's storage yard while construction was on hold.

The framing system of the building's basement.



A wind loading comparison for the building.

The corresponding comparison of the foundation loads.

Model	**Wind in X direction**				**Wind in Y direction**			
Load	Shear		Moment		Shear		Moment	
	(k)	%	(k–ft)	%	(k)	%	(k–ft)	%
ASCE 7	2,740	100%	826,567	100%	2,461	100%	742,396	100%
RWDI	1,733	63%	609,134	74%	1,376	56%	504,961	68%
NYC	2,092	76%	647,766	78%	1,879	76%	581,803	78%

Despite the high performance required of the seven dampers, their total cost was significantly less than that of a conventional TMD or sloshing damper. Also, because the final wind tunnel testing revealed that the actual loads were lower than expected—and because the damping system provided more than the required damping—it was possible to further optimize the steel package while still meeting acceleration criteria, leading to additional cost savings once the system was incorporated.

Designing a viscous damper system into a structure requires more effort on the part of the designer, as a conventional linear elastic analysis cannot be used, and the damped structural system must be analyzed as a whole with the entire structure rather than just analyzed as a separate bolt-on system. We used MSC-Nastran for the analysis and optimization of the damping system; however, as most of the steelwork is not governed by the damper forces, we were able to use conventional analysis processes for the vast majority of it.

Waiting Game

In addition to the challenges typical of a large construction project, the 2008 economic crisis also became a factor, hitting just after construction started; the week before the cranes were scheduled to mobilize in March 2009, Boston Properties made the decision to suspend construction until the market was more favorable, and the design and construction team quickly moved to put a plan in place to allow for an orderly demobilization and efficient restart. Foundation construction and steel fabrication was already under way at this time, so the team decided to complete the structure up to grade level to both stabilize the perimeter walls and allow the site to be more easily waterproofed and protected. Fabricator Owen Steel continued fabricating the remaining steel and set up a plan that would allow for storage and monitoring of the steel for an unknown duration and a quick restart when needed. The plan included finding a site large enough to store 9,000 tons of steel, which ended up being spread out over five acres, stacking the steel to avoid the collection of water and minimize corrosion and organizing the steel into the order in which the loads would be needed once construction restarted in the fall of 2011.

At that point, the team was concerned about the corrosion that had developed on the surfaces that had been prepared for slip-critical connections—in particular, those that had been blast cleaned to achieve a Class B surface. The *RCSC Specification* suggests that some corrosion for up to a year should be acceptable, but no further data was available to specify exactly what level of corrosion over what period of time would still perform in a satisfactory way.

We decided to test a sample of representative connections from the stored pieces and verify the coefficient of friction directly. The resulting tests showed that the stored steel exceeded the required 0.5 coefficient of friction. As such the steel required no further blast cleaning and could be trucked straight from the storage yard to the site in the order planned several years earlier.

Construction Reboot

When construction restarted, the steel erection progressed well ahead of schedule. This was in part due to the restart plans prepared at the time construction was halted, but also to the extensive 3D modeling that had been used for coordination; Revit was used from the beginning of schematic design. Although this process is more common now, it was somewhat unusual when the design started in 2007, requiring the team to find new ways to share models and coordinate in 3D. As is more widely understood now, this process required more information and detail at an earlier stage but also allowed for much tighter coordination of elements such as the core, which was critical to an efficient commercial development. Plus, the model made it easier to pick up on the project even after a substantial delay and changes to the job team during the delay.

The 3D work was carried through to the fabrication process, with the detailer's Tekla models reviewed and coordinated ahead of any piece drawings being prepared. These same models were also used for final architectural coordination. Once erection of the tower restarted, general contractor Turner Construction used the models as the basis of a detailed trade coordination process, with 3D models also being prepared by the mechanical and electrical contractors. This led to a significant reduction in both the number of RFIs during fabrication and the number of field hits requiring fixes.

The building topped out in June 2012 and achieved the first certificate of occupancy in May 2013, beating the original schedule by a significant margin. Fit-out for the first tenants is already underway, with occupancy planned for early next year. MSC

Owner/Developer
Boston Properties, New York

Structural Engineer
Arup, New York

Architect
Skidmore, Owings and Merrill, New York

General Contractor
Turner Construction, New York

Steel Team

Steel Fabricator
Owen Steel Company, Columbia, S.C. (AISC Member/ AISC Certified Fabricator)

Steel Erector
Cornell & Company, Inc., Woodbury, N.J. (AISC Member/ AISC Advanced Certified Steel Erector)