Title: **A Statement in Steel: The New York Times Building**

Authors:
Thomas Scarangello, Managing Principal, Thornton Tomasetti
Kyle Krall, Vice President, Thornton Tomasetti
Jeffrey Callow, Senior Project Engineer, Thornton Tomasetti

Subjects:
Building Case Study
Structural Engineering

Keywords:
Outriggers
Steel
Structure

Publication Date: 2008

Original Publication: CTBUH 2008 8th World Congress, Dubai

A Statement in Steel: The New York Times Building

Thomas Z. Scarangello, P.E.[1]; Kyle E. Krall, P.E.[2] and Jeffrey A. Callow, P.E.[3]

[1]Managing Principal, Thornton Tomasetti Inc.
[2] Vice President & Principal, Thornton Tomasetti Inc.
[3] Senior Project Engineer, Thornton Tomasetti Inc.
51 Madison Avenue, New York, NY 10010 USA

KKrall
@ThorntonTomasetti.com

TScarangello
@ThortonTomasetti.com

Kyle E. Krall

Mr. Krall has more than 18 years of structural engineering experience in the design and renovation of commercial, sports, residential and mixed-use projects. He has extensive experience in the design of both steel and concrete structures and specializes in the design of long-span roof structures. As a project manager, he is responsible for all phases of structural design from schematic through project administration. His project experience includes The New York Times Building, the Nuova Sede della Regione Lombardia in Milan, Italy and The Residences at Ritz Carlton in Philadelphia.

Mr. Krall has received a number of awards for his projects and work and he has authored various articles. Mr. Krall received his B.A.E. degree from Pennsylvania State University and his M.S.C.E. Degree from Columbia University, where also lectures on architecture.

Thomas Z. Scarangello

Thomas Z. Scarangello, P.E., is a Managing Principal of Thornton Tomasetti, Inc., a 650-person engineering and design firm with 16 offices worldwide. He has more than 25 years of experience in structural engineering and is experienced in the application of state-of-the-art engineering technologies for building analysis, design and construction, including 3D modeling and interoperability. Mr. Scarangello has been instrumental in incorporating such technologies into the firm's design process. He has provided structural engineering services for a variety of building types, from long-span sports and entertainment arenas and stadiums to high-rise commercial and mixed-use buildings, in both steel and concrete. A registered professional engineer in 26 states, Mr. Scarangello has published numerous papers and artciles, , and served as an expert witness.

Mr. Scarangello received his bachelor's degree in civil engineering from Manhattan College in 1979 and his master's degree in civil engineering from Manhattan College in 1982. He also received a professional mechanic's degree through a Ph.D. program at Columbia University in 1987.

A Statement in Steel: The New York Times Building

Thomas Z. Scarangello, P.E.[1]; Kyle E. Krall, P.E.[2] and Jeffrey A. Callow, P.E.[3]

[1]Managing Principal, Thornton Tomasetti Inc.
[2] Vice President & Principal, Thornton Tomasetti Inc.
[3] Senior Project Engineer, Thornton Tomasetti Inc.
51 Madison Avenue, New York, NY 10010 USA

Abstract

The New York Times Building, currently under construction in New York City, is a study of balance and compromise. The vision of The New York Times to create a building ahead of the times was balanced by the goals of real estate developer Forest City Ratner to develop an economically efficient building to maximize their leasable space on the upper floors. The innovative European-style architectural design of architect Renzo Piano Building Workshop was blended with the understanding of local building code and practice by New York architect FXFowle Architects. One of the principal architectural features of the building, the expression of exterior steel, involved the compromise of aesthetic appearance, structural adequacy, and fabrication and erection practicality. The thermal movements of this exterior steel provided a great engineering challenge in attempting to balance the movements of interior and exterior steel to limit large differentials. The duality of each aspect of the building design from the ownership and design team partnerships to the overall balance between innovation and efficiency provided numerous engineering design challenges. This paper will outline some of these challenges, focusing on those driven by aesthetic, erection, and fabrication considerations of the exterior steel.

Keywords: Steel high-rise buildings; braced core with outriggers; exterior steel; design for thermal movements

Introduction

At the new headquarters building for The New York Times in New York City, expressed and exposed structural steel framing forms key elements of a complex and challenging architectural design. Framing configurations, member sizes and fabrication details reflect not just demands of strength, stiffness, cost and practicality, but also of architectural proportion, alignment and visual order, weather-tightness, fire protection, thermal control and special occupant needs. This interplay of architectural, structural, environmental, construction and user requirements posed some unusual structural design twists.

For this project, two user groups are involved: journalists and other New York Times newspaper staff in the lower half of the building, and general office tenants in the upper half. The New York Times Company wants a headquarters building that befits its position in the media industry, in the city, and in the world. The Times also has a long-term perspective; it has occupied its current building for a century. Its partner in creating this project, Forest City Ratner Companies, is a developer of office space familiar with local market needs and the financial requirements for a viable building operation. The design side has its own pairing: the Renzo Piano Building Workshop has created cutting-edge architecture in Europe and around the world, and FXFowle Architects has designed beautiful and innovative buildings in New York and many other cities.

Figure 1. The New York Times Building, looking east.

The resulting 52-story building design creates an impression of lightness. A light exterior tone is enhanced by a fine filigree screen of horizontal, closely-spaced, 1 $^5/_8$-inch diameter ceramic rods mounted outboard of the glazed weather envelope. The screen extends upward around rooftop equipment, with rods at gradually increased spacing to gently transition from building to sky. A 300-foot tapering mast on the roof completes the transition [Figure 1]. On the long east and west faces, perimeter columns are pulled several feet into the building space, and the north and south faces have cantilevers that extend a full bay beyond the end columns. The resulting overhangs contrast with the glazed steel storefront pulled inward at ground level to create an impression of office floors floating above the lobby. Large corner notches complete the tower composition, creating a cruciform building plan that shortens the apparent width of building faces and signals a change of façade treatment. The end façade screens extend slightly past the outer notch corners to soften the plane change. Screens are omitted on notch facades to create a sense of openness and transparency consistent with journalistic ideals. The notches also expose major structural framing to the weather and to public view, creating a dramatic shift of scale from thin screen wall tubes to one- and two-story high diagonals and X-braces. The structural engineering challenges of this exceptional building will be presented from inside out, much as the design itself was developed.

Structural Systems

Both steel and concrete framing systems were studied. Steel was selected based on the large, open office bays desired, future flexibility, local familiarity and construction cost and speed. The two user groups require different floor systems. The New York Times desired a raised floor to provide both wiring distribution and under floor air supply. The top of slab elevations are depressed 1 foot 4 inches below top of finished (raised) floor. In many locations, beams extend through the façade to connect to the exposed columns. For protruding beam stubs to properly cross spandrel panels, special 'cranked' or offset end details poke above the floor slab just inside the glass line (as a result of the large raised floor dimension). They fit below the raised floor and are coordinated with mechanical systems in that space. Core girders are depressed for a different reason: return air to fan rooms flows between filler beams that pass over them.

At the tenant spaces on floors 29 through 50, floors and core girders accommodate a 6-inch raised floor but are not depressed. Generous story heights allow for ducted air supply and return above suspended ceilings with 9 feet 7 inches minimum clear height. 10-foot clear height can be provided where coordinated with steel, and girder penetrations are included where necessary.

Vertical transportation is also affected by the dual users. Elevator layouts also affect the lateral load-resisting system. A central core 90 feet long and 65 feet wide was selected, as it provides continuous bays more than 45 feet deep along either side of the core, a practical distance for modern office plans, and 30 feet deep at each end. A braced-core lateral system was selected over perimeter braced or moment frame systems for perimeter transparency, construction simplicity and economy. Seismic forces are less than wind forces and stiffness is needed for occupant comfort. The braced core alone would be unacceptably flexible, so mid-height and rooftop mechanical floors are crossed by steel outrigger trusses that engage perimeter columns and improve lateral stiffness. A two-way grid of trusses engages every perimeter column, improving efficiency.

The core width accommodates four lines of passenger elevators, each with seven shafts. The lower half of the building has steel braced frames surrounding the core. To separate The New York Times and upper floor traffic, 12 passenger cabs are assigned to the lower, Times floors as a strip of three elevators. Above a mid-height mechanical room at floor 29, those elevators stop and the space is available for lease. If the north-south (or longitudinal) bracing lines were continued above, they would surround the newly available space, making it much less desirable. Instead, the two lower north-south brace lines stop at the mid-height mechanical room, and a single new brace line at the division between 4-cab and 3-cab elevator banks starts up from there. A single brace line is adequate because it is 90 feet long, used only at upper floors, and stiffened top and bottom by outrigger trusses. Because truss members would foul lower elevator shafts terminating at mid-height, this line does not have a direct mid-height outrigger. In-floor diagonals at outrigger upper and lower chord levels engage outriggers on other brace lines. Force couples from the diagonals restrain the bottom of this brace line and transfer its wind shear to lower brace lines.

Elevators also affect east-west bracing. With a broader wind face and a narrower core dimension, four lines of bracing were initially considered to meet wind drift and comfort requirements. However, service cabs with reverse facing doors would require crossing one of the four bracing lines, rendering it less effective. The solution, X-braced bays in the perimeter notches that work in tandem with the core, brought their own architectural and structural challenges [Figure 2].

Figure 2. Perimeter notch with exposed steel.

Exposed Bracing

One X-brace design challenge is fire resistance. Exposed perimeter bracing could be used as a design feature, but it would be vulnerable to fire. Conventional spray-on and mineral wool fire protection with cladding creates unacceptable bulk. Intumescent fire protection varies with thermal mass/exposed surface. A reasonable thickness of intumescent coating can provide an acceptable fire resistance rating on massive building columns, but not on smaller bracing rods. We avoid rod fire protection by designing twice. The perimeter bracing is ignored when checking building structural safety and stability under wind and seismic forces. A second design check, for occupant wind comfort only, includes the X-bracing enhancement to building stiffness. It reduces sway under design wind loads from height/350 to height/450. With the X-bracing, wind tunnel consultant Rowan, Williams, Davies and Irwin determined that the peak total acceleration at a top floor corner location during a 10- year non-hurricane windstorm (a storm with a 10% chance of happening in any year) is less than 25 milli-g (11% larger under hurricanes), an acceptable office condition.

A second X-brace challenge is pretensioning. In chevron or V-braced bays, one brace is in tension when the other is in compression, so both are stocky, sized for compression. X-bracing can be designed for single-diagonal tension-only conditions, assuming the other diagonal simply buckles out of the way if compressed. This is inefficient since only half the braces work at a time. If the braces could be pretensioned so that neither one goes slack or into compression, both would contribute to strength and stiffness. But how? Turnbuckles are architecturally unacceptable, and twisting a turnbuckle is ineffective to generate more than minimal tension as thread friction rapidly builds. European-style high-strength steel rods have thin, sleek sleeve nuts for length adjustment and a cone-shaped locknut for each end of the sleeve. The locknuts also work with a special hydraulic jack system to apply jacking loads with just 2% force deviation. For economy, tensioning should be a single step, not a prolonged 'piano tuning' process. But during construction, and even during wind or seismic load conditions, column shortening occurs. Chevron or V-braces are little affected since crossbeam flex accommodates the slight change in story height. However, X-braces experience compression as columns shorten, so pretensioning performed during construction must specifically compensate for this, based on a particular erection sequence. Forces will significantly exceed the target final pretensioning, but are still less than final pretensioning plus maximum wind force, so construction pretensioning does not control design of the bracing rods, fittings and connections.

The third design challenge is appearance of the X-braces and all exposed framing along the building notches. Beams, columns and bracing rods of uniform size would significantly increase steel tonnage, adding to project cost. The upper exposed columns would also act at much low stresses than upper interior columns, causing differential shortening that compromises floor levelness. Instead the sizes vary with building height at regular intervals. For example, exposed columns are built-up steel plate boxes with 30-by-30-inch outside dimensions and web plates slightly inset so flange tips 'read.' Flange thickness varies from 4 to 3.5, 3, 2.5 and 2 inches. X-bracing rod diameters closely follow the flange thickness on that floor, and beam flange thickness is ½ of the adjacent column flange thickness. The locations of size change suit both structural and architectural needs. Where beam or column properties must change between these steps, the thickness of web plates is varied since webs have no architectural impact.

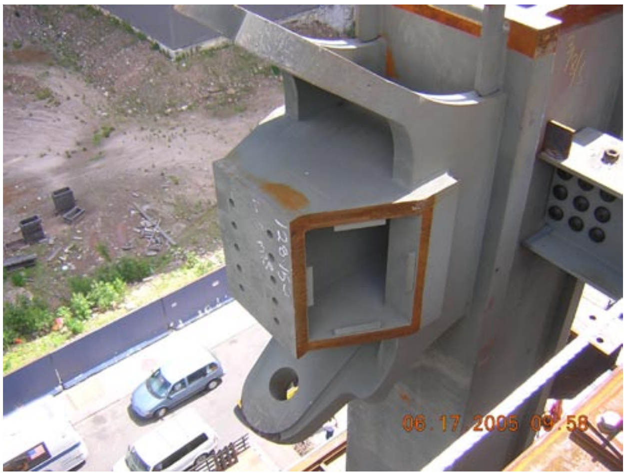

Figure 3. Plates at exposed knuckle connection.

Detailing also reflected input from the architect, structural engineer and contractor. Single-rod X-bracing would require large member sizes, and to allow crossing rods to clear they would have to be offset, inducing column torsion. Using pairs of rods can raise questions about load sharing, particularly during pretensioning, but the availability of highly accurate jacking systems resolved this concern. Rod pairs are used, with one pair in an X-brace oriented side-by-side to clear the other pair oriented over-and-under. Another major design question was the decision between uniform and alternating X-brace patterns. The architect chose a uniform pattern, with all over-and-under pairs running in the same direction. While rod bracing systems have standard details for sleeve nuts, forked ends and spade ends, the gusset plates to which they attach are project-specific. The architect and engineer tried a variety of shapes before deciding on gently curved gussets [Figure 3]. Reinforcing plates make up the necessary thickness to work with forks and spades, and to carry pin loads. The configuration was also reviewed for constructibility issues such as practical weld lengths and jacking access. Drawings and wooden mockup models were studied. While X-bracing rod lengths are adjustable, horizontal struts between the braced columns are not. The team developed a practical detail with adjustability that meets the architect's aesthetic requirements. Strut ends join fabricated knuckles on columns through field-bolted end plates with provisions for shims at gaps. The knuckles are then boxed in with field-welded closure plates [Figure 4].

Figure 4. Bolted connection at exposed compression shut.

Cantilever Bays

Appearance and constructibility also play key roles in the structural framing of the other notch faces, the cantilevered bays. Three framing lines extend out from the building, one on each side of the cantilevered bay and one down its center. The side framing lines support the cantilever through multiple load paths. A diagonal rod at each floor 'hangs' the outer tip of floor beam from the supporting column [Figure 5]. A continuous vertical member connects multiple beam tips together, available to act as a post or hanger and redistribute load in the event that one or more rods failed, as in a fire. And the tapered floor beams themselves are moment-connected to the supporting column with sufficient capacity to cantilever on its own, though with excessive deflection. The multiple load paths permit exposed steel to be used. The central framing line uses a different system, a 'ladder Vierendeel' with floor beams moment-connected to both the supporting column and to the cantilever tip vertical tie member. With both ends of the floor beam restrained against rotation, the beam has strength and stiffness to carry the floor loads.

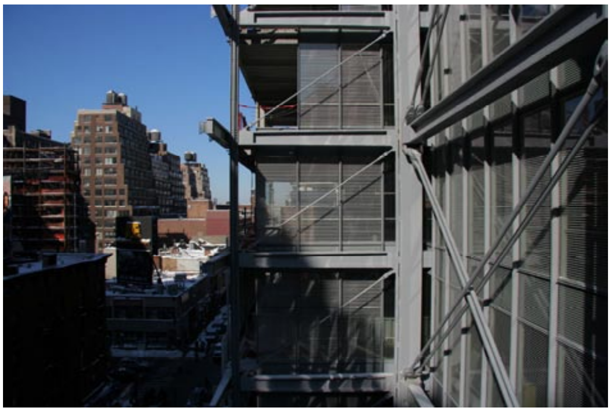

Figure 5. Exposed steel at cantilever bays.

While load paths for the completed cantilevered bays are straightforward, their construction is not. Shoring posts to grade would not be permitted due to other construction requirements. The solution was providing temporary sloping struts at the first cantilevered levels. They act in compression, putting the next floor beams above in tension. To permit later removal they incorporate jacks that can be relaxed. Although permanent framing would help to carry load as it was installed, the struts would still tend to accumulate large compressive forces, creating corresponding forces in main building framing. Sequential construction computer models were used to limit the forces going to framing, determine strut design forces, establish removal timing and validate removal methods. The temporary struts were removed when end bay framing reacheed the mid-height outrigger level.

Constructability

Designing for appearance and reviewing for constructibility are positive steps, but of course the goal of the architect and owner is a completed project of acceptable quality and cost. When assembling large, heavy, built-up and hot-rolled steel members, some dimensional variation in both shop fabrication and field erection is inevitable. Even a Swiss watch would have tolerance issues if it weighed thousands of tons! The owners approached this proactively well before construction, commissioning fabrication of a full-size joint in steel that includes some intentional fit-up deviations to illustrate the types and magnitudes of misalignments one could reasonably expect. This helped the architect and owner consider acceptable tolerances and appropriate remedial measures, and it alerted potential fabricators and erectors to the complexity of the work and the high standards that would apply.

Thermal Design

The mix of exposed and interior structure, and the beams that transition from inside to outside, required extra attention. Differential strain between inside and outside columns due to thermal changes can affect member and connection forces, floor levelness and local joint behavior. To study these effects we first established a design temperature differential of $+70^{\circ}$ F to -80° F based on historical daily maximums and minimums for New York City, modified by recommendations in the National Building Code of Canada (NBC) that reflect radiant heating and cooling effects. We then determined a floor slope criterion of less than span/300 between any two adjacent columns, following the NBC approach. For a 70° F temperature change, an unrestrained 650-foot tall steel column supporting the top office floor will grow about 3.5 inches, while a 30-foot span can accept only 1.2 inches of differential motion. The solution was to recognize that the exterior column is not unrestrained, and the first interior column is not stationary. Wind-resisting outrigger trusses are supplemented with 'thermal trusses' that link exposed and interior columns. By pushing down on an exterior ('hot') column and simultaneously pulling up on the adjacent interior ('cool') column, these trusses cut maximum growth of exposed columns in half and cut the differential between columns by a factor of three. Of course, the forces necessary to do this 'pushing and pulling' must also be considered in the design of members and connections.ASCE7 LRFD combinations apply. Combinations including thermal effects generally govern over those with wind load. The ends of beams connecting inner and outer columns could experience significant daily and seasonal rotations due to column temperature swings, potentially causing joint noises and 'sawing' of bolts. A moment connection at the outer connection provides sufficient strength to resist flexure induced by gravity plus thermal movements. A deep shear tab at the inner connection has slip-critical bolts. Our studies show this connection is unlikely to slip under the range of anticipated forces.

In the category of 'last but not least,' any project that mixes interior and exterior steel must address thermal bridge, condensation and weather-tightness issues. Determination of steel frame temperature gradients and appropriate measures for thermal performance and weather-tightness is not the responsibility of the structural engineer. However, members designed by the engineer are involved so an understanding of the issues is important. Beams penetrating the façade of The New York Times Building have their exposed stubs fireproofed, insulated and clad up to the intersection with the exterior column. Because thermal conductivity is much greater along the beam than across the insulation, a thermal gradient is established along the stub. In this way condensation on the beam is avoided. Stiffeners welded to the beam where it crosses the façade act as a collar to which the façade is sealed for weather-tightness.

Masts

The building culminates at the top with a 300-foot mast. The mast is a steel pipe that tapers from eight feet in diameter at the base to eight inches at the apex. The mast extends down to the 51st mechanical floor where it sits on a once-inch circular base plate. This base plate is bolted to a floor plate supported beneath by a grid of floor beams. The mast is also supported at the 52nd floor roof and a specified erection procedure was provided to ensure proper bearing at the base of the mast.

Both the slender shape of the mast and the higher wind pressures at that height of the building made it necessary to evaluate the mast for fatigue. The use of a chain impact damper was investigated to limit fatigue, but instead, specialized details were developed to address fatigue issues.

The effect of the mast on the actual building also had to be investigated. In-floor trusses were designed at the 51st and 52nd floor to distribute the base shear of the mast to the core braced frame. In addition, vertical trusses were used to transfer the weight of the mast to the building columns. Several small satellite dishes will be affixed to the mast and deflection had to be evaluated with respect to the allowable movements of the dishes and the serviceability criteria of the structure itself.

Conclusion

The New York Times Building design illustrates how architectural, environmental, structural, construction and user issues affect each other in cutting-edge architecture. Construction began in the fall 2004, with the first steel pieces erected in April 2005. The steel structure topped out in summer 2006 and the erection of the mast was completed in the fall. The New York Times occupied its floors in June 2007 amd the overall building is expected to be completed in fall 2007.