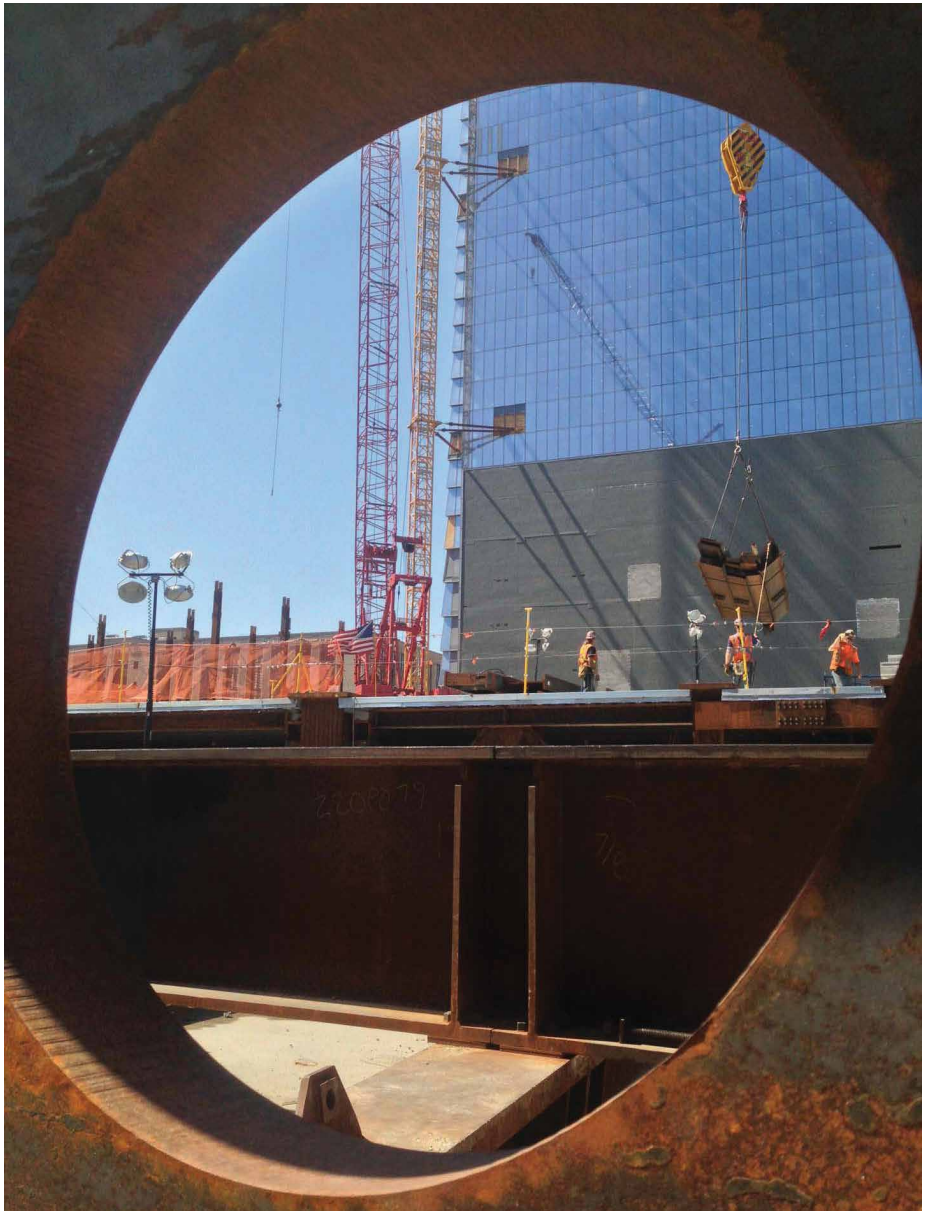


Hudson Yards East Platform

Structural gymnastics abound as a city on stilts is constructed on Manhattan's West Side, all while hundreds of trains come and go beneath.

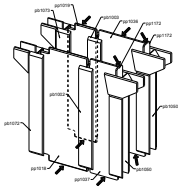
NEW YORK HAS NOT SEEN the likes of a real estate development project on a par with Hudson Yards since Rockefeller Center's fourteen buildings were constructed in the 1930s. A mixed-use real estate venture developed jointly by Related Companies and Oxford Properties, the site will include more than 17 million square feet of commercial and residential space, a cultural venue, 14 acres of open park space, a 750-seat public school, and a 200-room luxury hotel. Slated for completion in phases over the next several years, the new development is anticipated to draw more than 65,000 people daily. But almost none of them will be aware of one of the site's greatest feats: Nearly all of it sits atop two massive platforms that bridge 30 active Long Island Rail Road (LIRR) train tracks, three subsurface rail tunnels used by Amtrak, and a fourth passageway named the Gateway tunnel, which will help to double train capacity into New York City.

Of the two platforms, the structure over the Eastern Rail Yards does the most heavy lifting, supporting Hudson Yards' four massive skyscrapers and its main cultural, retail, and residential attractions. Those building foundations will extend through the platform and allow the new buildings to tower over it, totaling 11,340,000 gross square feet of new construction when completed. The Eastern Platform, and the structures overhead, are supported by a total of 288 caissons, ranging from 4 to 5 feet in diameter and 20 to 80 feet in depth, which are drilled to reach bedrock in strategic locations between existing railroad tracks. The platform over the Eastern Yard uses 25,000 tons of structural steel.

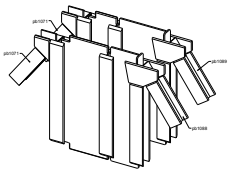
The undertaking has required a rolodex of the construction industry's experts—many of whom worked together at a similar scale and level of coordination on the World Trade Center redevelopment in Lower Manhattan. Thornton Tomasetti is the platform's structural engineer, and Langan Engineering & Environmental Services is its geotechnical and environmental engineer. Arup is the site's life safety systems engineer.

Building what is essentially a small city within a city, the team had to deal with a layer cake of complicated site conditions and constraints. "Thornton Tomasetti didn't have a blank slate to start with," says Jeff Brown, vice president of operations for Tutor Perini Civil Group, the general contractor for both Hudson Yards and the Gateway project. "They had a lot of restrictions on where to put the foundations."

Over seven million square feet of construction are now underway. Preliminary preparations on the Eastern Yard platform began at the end of 2013 and caisson drilling started in March 2014. Erection of the structural steel columns, beams, and trusses began in Fall 2014, and the Eastern Yard platform will be completed soon.



STEP #1



STEP #2

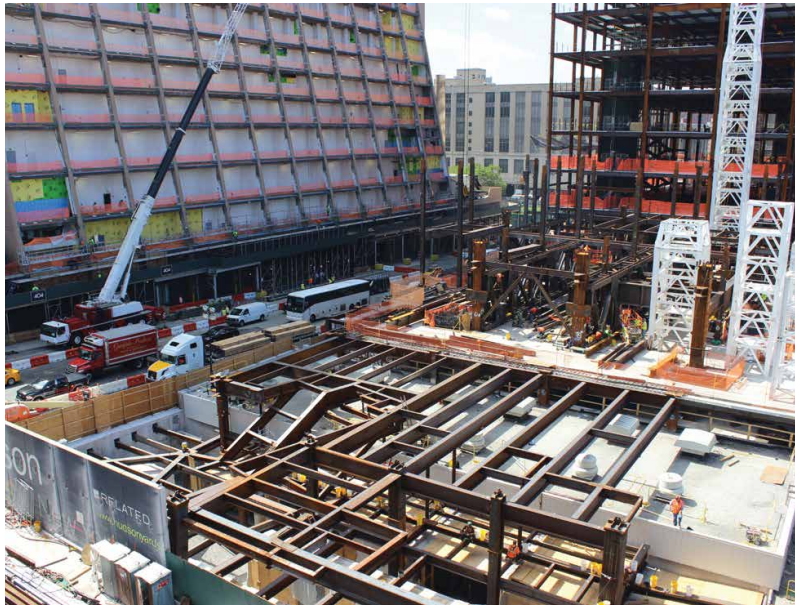
Opening page Local 40 ironworkers installing the truss of the retail structure platform.
This page from top The development of Hudson Yards will create more than 23,000 construction jobs. The Hudson Yards platforms will cover approximately three-quarters of the Eastern and Western rail yards. Diagrams of the platform's D10 node.
Facing page top Construction progress in August 2015.
Facing page bottom Installation of a precast concrete slab on structural steel grows the platform toward the west.

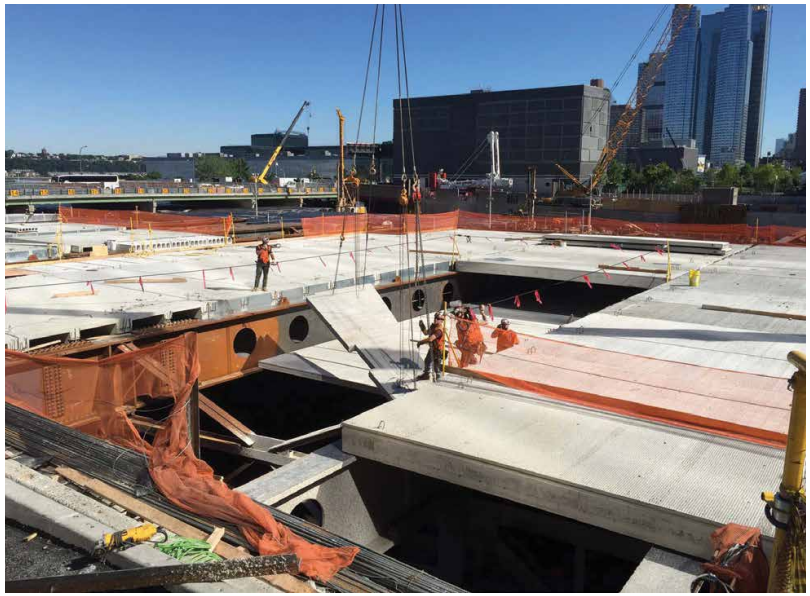
One of the project team's biggest feats was maintaining the operation of the railyards at all costs—throughout all of the project's construction, the LIRR and Amtrak trains remain operational. To accomplish this, the site was divided into segments: In areas where the train tracks are straight, the team could take four adjacent tracks out of service continuously, leaving drills or other equipment in place. In other areas that are required for switching trains between tracks, they could sometimes drill a caisson for only two hours each night due to train schedules. It could take days or weeks to achieve the 30- to 40-foot depth required for some holes. Because any emergency at all in the train system, like a switch failure, could shut down construction, the Tutor Perini team credits a good working relationship with LIRR for the smooth progression of caisson drilling.

A web of utilities below the tracks added even more complexity. "The utilities are more dense than the trains," says Brown. He estimates the hand-drawn, ca. 1987 site drawings that were available prior to the project were accurate, at best, to within 5 feet. Added on top of that were complications involving the organizational, and legal, separation of the site's operators.

Even before finalizing a contract to construct a platform, Tutor Perini's Civil Group convinced its client, Related, to pre-excavate the site in order to understand the true layout of utilities located there. Looking at a diagram of caisson locations marked by green dots, Brown notes "every one of these was hand excavated—there was something in every single one." The project's utility relocation budget alone is estimated at $12 million. Each time a new obstacle was discovered, Thornton Tomasetti altered structural designs for the frame of the platform to accommodate a new caisson location that avoided conflicts with both the existing tracks and the utilities below. This real-time design approach made another midstream change possible: Work was originally planned to begin at 11th Avenue and move east, toward 10th Avenue, but the plan was reversed to allow an early start on 10 Hudson Yards, which is now scheduled for completion this year.

Photos this page: Jennifer Kirchels; diagram: Tutor Perini Corporation; facing page from top: Jennifer Kirchels, Geoff Butler; opening page: Geoff Butler





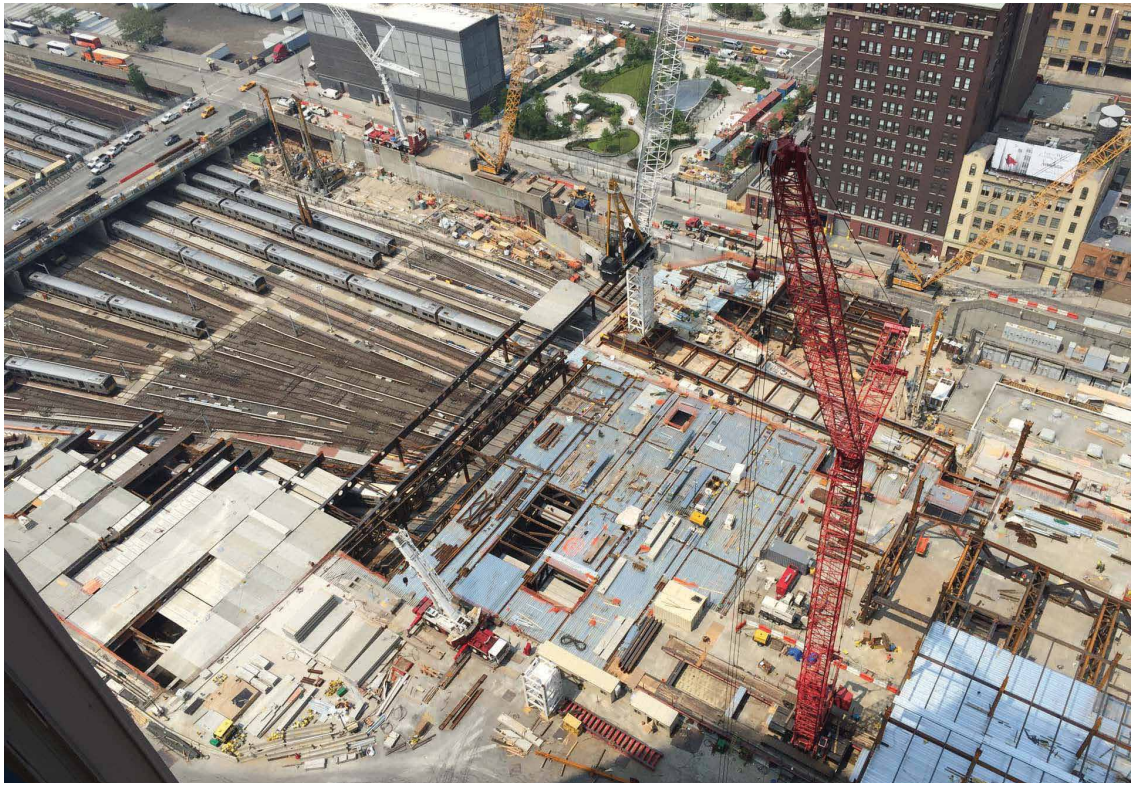
Taking into account the location of tracks, underground tunnels, and utilities, only 38 percent of the site may be used for structural support of the 10-acre platform. With so much weight bearing on fewer than 300 columns, in some cases columns are as large as 32x32 inches, built up of 4-inch layers of steel plate that satisfies ASTM A572-65 and ASTM A1066-65. While a typical 4-inch, A572 plate produced in the United States has a yield strength of 50 ksi, steel plate manufacturer Dillinger uses a fabrication process that allows them to produce the same 4-inch plate with a 65 ksi yield strength. The column structures vary in diameter from 1 foot to 5 feet, 6 inches, and are drilled into the bedrock beneath the railroad tracks at an average depth of 40 feet below the surface. Approximately 3,300 tons of solid steel cores, the largest of which was 30 by 30 inches square, were fabricated from the 4-inch-thick plate; the longest is 87 feet; the heaviest weighs a whopping 71 tons.

The platform's base structure clears the tracks by at least 17 feet, and ranges in thickness from less than 3 feet to up to 7 feet, depending on the architectural features of the planned plaza. For example, to meet city building requirements for resiliency, a truck-loading dock adjacent to 10th Avenue is fortified with W14x500 steel beams topped by 2-inch blast-resistant plate and an 8-inch concrete slab. In many areas, the platform houses a network of tubing carrying cooling liquids that will buffer the plaza's landscaping from the heat of the train yard below, which can reach up to 150 degrees.

On top of this, tall trusses support hung sections of a podium structure that connects 10 Hudson Yards and 30 Hudson Yards and will house a collection of shops and restaurants on multiple floors. Columns and other support structures for 30 Hudson Yards land between the rail lines below it, while trusses supporting the tower's south face span the tracks up to 115 feet. Here, site constraints came into play yet again: Because railroad operations required the use of a tower crane to erect the throat trusses, and the weight of the throat trusses exceeded the capacity of the Favco 1280 (the largest tower crane currently available), Thornton Tomasetti split the trusses into a pair of trusses, allowing them to be set one at a time by the Favco 1280, and then tied together to form a box truss.

From a design and fabrication standpoint, the area of the platform called the D10 Node also required detailed coordination, says Terry Flynn, vice president of engineering for Tutor Perini Civil Group. "It's a large steel box with trusses connecting to it, and a column below it," he describes. "Because of the node's complexity, structural steel fabricator Banker Steel Company created a presentation of their fabrication plan for the node as, simultaneously, Thornton Tomasetti developed the design in a Tekla model."

As a general contractor, Tutor Perini has found itself in the midst of an alphabet soup of agencies: LIRR, MTA, and Amtrak, as well as the City of NY, the DOB and the DOT. Basically, one could joke, every public entity that a contractor might have to deal with to make a project successful for its client. But, motivated by a sense of progress, not to mention the unprecedented revenue the plan should bring the city, the players involved have created a cohesive operational machine that is driving the project forward, relatively on schedule. As a result, the Hudson Yards development holds the promise of a new model for urban development, one in which buildings, public amenities, and utilities work together to create a cohesive community on the previously disparate landscape of Manhattan's West Side. □



Left Hudson Yards construction in September 2015.
Above Platform trusses set west of the throat platform support the plaza.

This page: Geoff Butler; facing: Tyson Reist

Of the two platforms, the structure over the Eastern Rail Yards does the most heavy lifting, supporting Hudson Yards' four massive skyscrapers and its main cultural, retail, and residential attractions.

HUDSON YARDS EAST PLATFORM

Location: **Hudson Yards, New York**
Developers: **Related Companies and Oxford Properties Group**, *New York, NY*
Structural Engineer: **Thornton Tomasetti**, *New York, NY*
Geotechnical and Environmental Engineer: **Langan Engineering & Environmental Services**
Life Safety Systems Engineer: **Arup**, *New York, NY*
General Contractor (Hudson Yards Eastern Platform and the Amtrak Gateway project): **Tutor Perini Corporation**, *New York, NY*
Structural Steel Fabricator: **Banker Steel Company**, *Lynchburg, VA*; (caisson cores) **Owen Steel**, *Columbia, SC*
Structural Steel Erector: **Tutor Perini Civil Group**, *New York, NY*