



Installation of a groin rib in the west cavern.

East Side Access: Manhattan Caverns

One of the largest transportation infrastructure endeavors ever undertaken in the United States, the megaproject will provide new Long Island Rail Road service to Manhattan's East Side with an eight-track expansion beneath Grand Central Terminal.

GRAND CENTRAL TERMINAL IS NOT wanting for superlatives. Host to more than 750,000 visitors and commuters each day, the station is the largest hub for train traffic in the world. Now, it can add one more accolade as the epicenter of the East Side Access (ESA) project, a more than \$10 billion endeavor that is the largest project ever undertaken by the Metropolitan Transportation Authority, not to mention one of the largest transportation megaprojects in the country. With congestion on the MTA's Long Island Rail Road (LIRR) lines common, especially during morning and evening rush hours, the project will add a new LIRR terminal within Grand Central Terminal (GCT), increasing rail capacity into Manhattan by nearly 50%. The project also promises to save LIRR travelers to Manhattan's East Side up to 40 minutes of commuting time a day, touting a "one-seat ride" connection into GCT from Long Island and Queens.

Starting with new tunnel connections from the Harold Interlocking section of Sunnyside Yard, the project will connect the LIRR Main Line and Port Washington Branch to the 63rd Street Tunnel under the East River. Hard-rock tunnel boring machines have tunneled deep under Midtown Manhattan from the 63rd Street tunnel's lower level at Second Avenue to a new LIRR concourse beneath the existing lower level of GCT. Below that, two new terminal caverns each have an upper and lower level, adding eight new tracks for incoming trains. To connect with GCT's lower level, a new passenger concourse within the footprint of the existing Madison Yard will

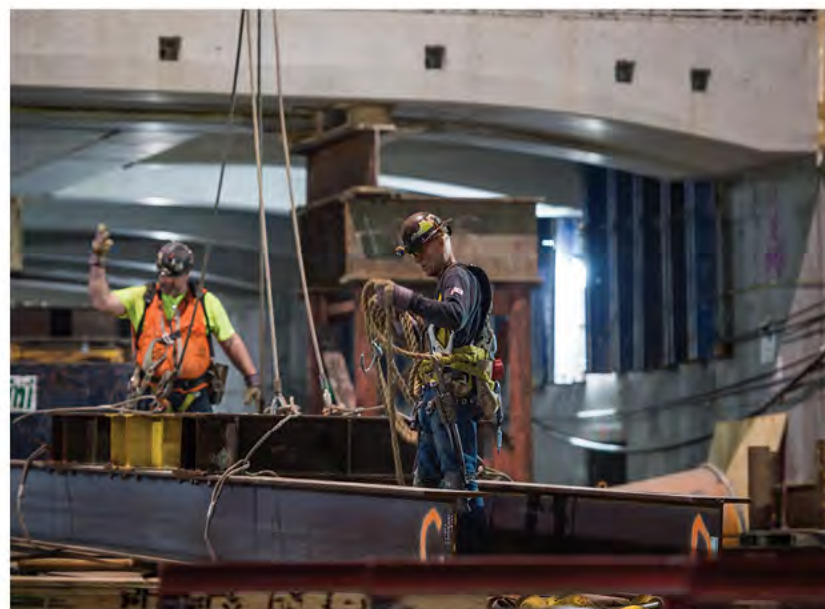
include escalator, elevator, and stair connections to GTC's dining concourse and the former arrivals waiting room, along with connections to 45th and 47th street cross-passages. When completed in 2022, the entire East Side Access project will serve an estimated 162,000 customers each day. The project's completion will also free up LIRR tracks into Penn Station, allowing trains from the MTA Metro-North Railroad's New Haven Line access to Penn Station through Queens. A Penn Station Access project will construct four new stations in the East Bronx, which will also significantly cut travel times to and from Manhattan.

With 150 prime construction contracts to date, the ESA project is a who's who of infrastructure experts. Roles traditionally held by an architect and structural and mechanical engineer are encompassed by the role of General Engineering Consultant, a tri-venture of Parsons Brinckerhoff (now named WSP USA), Parsons Corp., and STV. Overall construction management falls under the role of Program Management Consultant, held by AECOM; a Consultant Construction Management team, a joint venture of Jacobs and LiRo, provides additional construction management support.

Early in 2016, the MTA awarded the final major contract for the project's Manhattan Caverns to civil and building construction company Tutor Perini Corporation. The contract will transform two enormous 1,143-foot-long caverns carved out of solid rock into the new terminal station 100 feet beneath GCT. The work encompasses more than 12 miles of track work from Queens to Manhattan, as well as station platforms, elevators, escalators, and staircases to carry customers to and from the underground station, and all architectural finishes throughout the caverns—in renderings, these are depicted as stainless steel wall panels, modular metal ceilings, and stone flooring. When the project is complete, the caverns will hold 2,774 individual precast concrete elements including beams, deck panels, platform walls, and



The west cavern in January 2014.
Below A diagram of the new
LIRR terminal beneath Grand
Central Terminal.

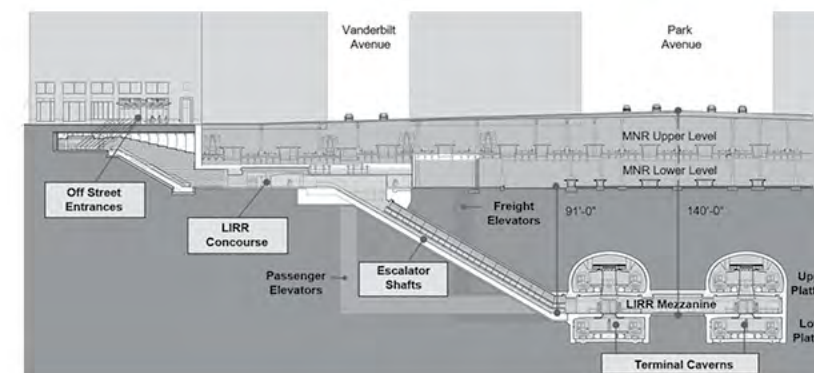


Top Groin rib installation in the west cavern.
Above Ironworkers hoist a steel truss used to support groin rib installation.

slabs installed by Tutor Perini. The new station's plenum, designed to contain and ventilate smoke if necessary, has been designed with post-tensioned precast wall panels in lieu of a traditional structural steel framing system, so the project's structural steel elements are largely used to construct elevator shafts, escalator trusses, and stairs.

"People say structural steel is good because it saves time; precast is the same way," explained Terrence Flynn, vice president of engineering for Tutor Perini's Civil Group on a tour of the site last spring. The precast concrete fabricator, Schuylerville, New York-based The Fort Miller Co., Inc., was able to homogenize the camber of many of the elements, ultimately relying on only eight molds to form the Manhattan caverns' precast members. Pieces are cast with special embeds to make crane picks safer. Fort Miller also invested a significant amount of effort to perfect the precast fiber mix, balancing a formula that would meet structural requirements while allowing for an exposed architectural finish in the completed LIRR mezzanines.

In addition to these design considerations, careful phasing was required to make work in the caverns as efficient as possible. From storage in Fort Miller's yard, precast elements were trucked and staged as needed at storage yards in Long Island City, then driven into the cavern on a designated rubber-tire route (along which train tracks will lie in the future) on the same flatbeds used for ground transportation to avoid double-handling of the ele-



"People say structural steel is good because it saves time; precast is the same way."

Terrence Flynn, Tutor Perini

ments. Maneuvering the flatbed trucks within the tunnels and caverns posed its own challenge and had to be carefully coordinated due to constraints including duct-bench clearances, shoring, elevator pits, and overhead cantilevers.

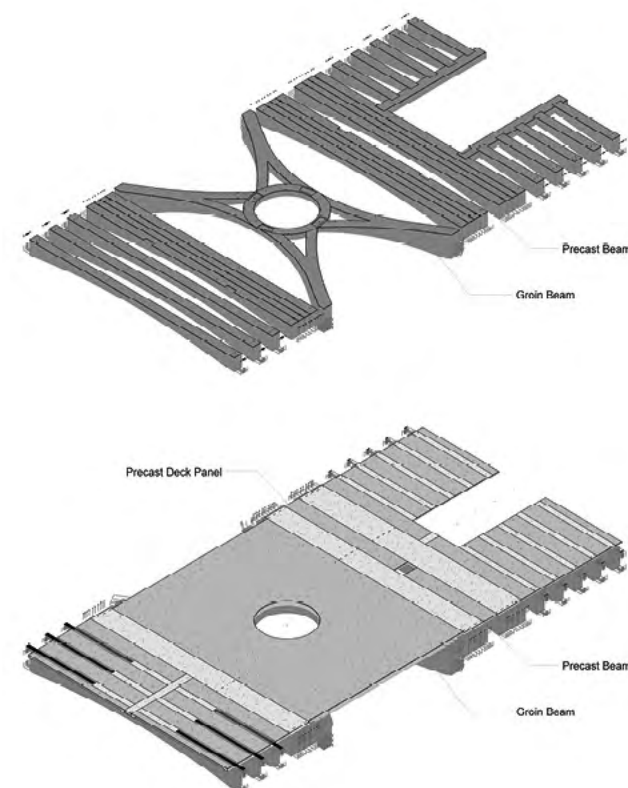
Within each cavern, a 400,000-pound telescopic Liebherr LTR1220 crawler crane is used to pick each precast piece from the flatbed and place it in its final location. (The crane itself was brought into the cavern in pieces on 10 flatbeds and assembled in place; it will be dismantled and driven out the same way.) The project teams developed a sequencing pattern to allow the crane to complete installation of both the upper- and mezzanine-level beams and deck panels from the lower track level.

The project's most noteworthy precast elements are quarter sections of four giant groin-rib assemblies within the east and west caverns, each weighing approximately 22 tons; the exterior precast elements for the assemblies weigh approximately 24 tons each, and each completed quadruple beam assembly, post-tensioned onsite, is approximately 60 tons total and measures 52 feet long, 7 feet wide, and 2½ feet deep. Nothing was left to chance due to the tight tolerances within the existing cavern, where new installation had to contend with the existing structure and reinforcing steel elements. The project team used a full-scale mockup to test the geometry of the groin rib assembly, and its constructability from fabrication through post-tensioning.

All photos and diagrams: Metropolitan Transportation Authority of the State of New York



The entire west cavern groin rib assembly takes shape.
Facing left Large precast members are trucked in on flatbeds one at a time.
Facing bottom One-quarter of the west cavern's massive groin-rib assembly waits to be hoisted into place.
Below Diagrams of the groin-rib assembly (top) and precast deck panel and beams above it (bottom).



With years of work ahead before the project alleviates Manhattan commutes for many LIRR customers, members of the public can take heart that some of the project's benefits have already been realized. The MTA has opened 50th Street Commons, a pocket park between Park and Madison Avenues, and a new entrance to Grand Central from within 245 Park Avenue, offering direct access to the terminal from points east of Lexington Avenue and north of 47th Street. And though out of sight for the hundreds of thousands of commuters, the caverns below their hurrying feet are transforming rapidly into the next chapter of Grand Central's importance to the growth and development of the city around it.

EAST SIDE ACCESS: MANHATTAN CAVERNS

Location: Grand Central Terminal, New York, NY
Owner: Metropolitan Transportation Authority Long Island Railroad, New York, NY
Architect, Structural Engineer and Mechanical Engineer: General Engineering Consultant (GEC), a tri-venture of Parsons Brinckerhoff (now WSP USA), Parsons Corp., and STV, New York, NY
Program Management Consultant: AECOM, New York, NY
Consultant Construction Management: Jacobs/LiRo Joint Venture, New York, NY
General Contractor: Tutor Perini Corporation, New Rochelle, NY
Structural Steel Erector: Tutor Perini Corporation, New Rochelle, NY
Terminal Structure Precast Concrete Fabricator: The Fort Miller Co., Inc., Schuylerville, NY
Terminal Structure Precast Concrete Erector: Tutor Perini Corporation, New Rochelle, NY