Ticket to **Success**

Sankar Chakraborty, P.E, Madan Naik, P.E., Ira Hooper, P.E. and Nazih S. Makary, P.E.

A new steel-framed parking facility for buses in New York CIty demonstrates the advantages of Design-Build.

The new 100th Street Bus Depot in New York City is designed and constructed to be a modern and environmentally friendly bus depot for servicing and parking an assigned fleet of public transportation buses. The facility is located on the east side of Manhattan bounded on the north by 100th street, on the south by 99th street, on the east by Lexington Avenue and on the west by Park Avenue. The large building foot print area of approximately 80,000 sq. ft. covers the entire city block. The owner of the facility, the New York City Transit (NYCT), is an agency of the Metropolitan Transportation Authority (MTA). Due to a large surge in public bus ridership and the need to maintain and service its bus fleet, the NYCT decided to retain the services of a design-build team to fast track the design and construction of its new bus depot.

The project team consists of the MTA NYCT as the owner and the design-build team of Perini Corporation of New York City as the construction contractor, with STV Incorporated, also of New York City, providing engineering design services including architectural, geotechnical and environmental services.

The Capital Program Management (CPM) division along with the Department of Buses (DOB) of NYCT established the preliminary project scope of work, specifications and design criteria. After the job was awarded, Perini and STV conducted several meetings with CPM and the facility end-user DOB and identified the critical issues of design and construction. Those issues were addressed during the early design process in order to avoid any possible delay and future problems during construction. In order to remain in character with the adjacent buildings, an innovative architectural design by STV utilized a mix of exterior brick and glass façade sensitive to the neighboring environment.

The building has four floors and a roof, each extending to the property lines without setbacks, a partial mezzanine and a partial basement. The bus depot was designed to accommodate parking and maintenance of approximately 133 articulated buses. The administrative offices of the bus depot are located on the mezzanine level between the first and the second floors. The Lexington Avenue subway line runs north-south underground adjacent to the bus depot. An existing underground substation borders the present site on the 99th street close to Lexington Avenue.

A typical connection at the top chord of a typical long-span (100’) truss.

FOUNDATIONS

The design and construction of the foundation systems were part of the major challenges on this project. From the very beginning of scope development, the NYCT engineers were aware that the foundation system of the building adjacent to the existing underground subway tunnel and substation structures had to be designed and constructed so that the building foundation load will not damage these structures.

All foundations bear on hard rock, so spread footings or circular reinforced concrete piers were used. A comprehensive study of the existing Lexington Avenue subway tunnel showed that the new spread footings impart negligible loads to the 20′ thick rock dome over the tunnel and to the rock at the tunnel wall. Adjacent to the underground substation, 8″ diameter mini-piles have been drilled into the rock to transfer their loads below the existing structure.

The partial basement that houses fuel oil tanks and boilers is 200′ long, 75′ wide and approximately 22′ deep. The hard rock that occurs 5′ below the surface required removal by controlled blasting to protect existing buildings, subway structures, gas lines and sewer. An extensive pre-construction survey to determine acceptable blasting vibration parameters was performed for all the adjacent structures. Seismographs were positioned at key locations and monitored continuously during the blasting period to ensure that acceptable vibration parameters were not exceeded.

THE FLOOR SYSTEM

The building was designed with wide column spacing and high stories to meet the space requirements of the bus traffic maneuvering and maintenance areas. The building is approximately 198′ wide in the N-S direction and approximately 400′ long in the E-W direction, separated into two parts by an expansion joint. In the main parking areas of the building, the columns were spaced approximately 75 to 100′ in the E-W direction and approximately 36 to 58′ in the N-S direction. At the ramp areas the columns are spaced approximately 18 to 26′ in the E-W direction and 15 to 36′ in the N-S direction.

The first and the second floors of the bus depot are for maintenance of the buses. The first floor was designed as slab-on-grade except the area over the partial basement. The area over the partial basement is a reinforced concrete elevated slab supported on concrete beams, girders and basement walls. The third and the fourth floor of the depot are used for bus parking. The second, third, and fourth floors including the mezzanine floor are designed as normal weight reinforced concrete composite slab supported on steel beams and girders. These floor slabs, except the mezzanine floor, consist of $6^1/_2$″ normal weight reinforced concrete over 1-$^1/_2$″ metal deck spanning between the floor beams. The mezzanine floor is made up of $2^1/_2$″ normal weight concrete over $1^1/_2$″ metal deck. The roof of the bus depot consists of $1^1/_2$″metal deck supporting the architectural roofing. The roof deck is supported by steel joists framing to

A typical built-up girder with a web penetration for mechanical systems. Spray-applied fire protection material is already in place.

girders. W24 and W30 sections were used for beams on the maintenance and the parking floors. W36 girders along with deep built-up plate girders were used to support these beams. Beams and plate girders were cambered for deflection control. The built up plate girders span from approximately 75 to 100′. Vertical web stiffeners were provided for some of the heavily loaded plate girders. A story high deep truss spanning about 100′-0″ was used to support the second and the mezzanine floors with large framing areas. The floor beams on the second and mezzanine floors frame into the top and bottom chord of the truss, respectively. Heavy W30 sections were used for the truss chords. W14s were used for the vertical and diagonal members of the truss.

To accommodate the installation of the mechanical ducts, openings were provided at suitable locations in the web of the floor girders. Wherever required, duct penetration openings were reinforced with plates around the opening. Access ramps for the parking floors were provided from the first to the fourth floors. The width of the ramps is approximately 22′. The ramp slabs were designed as $6\frac{1}{2}$″ normal weight reinforced concrete over $1\frac{1}{2}$″ composite metal deck spanning between the ramp beams. The ramp beams frame into ramp girders spaced along the column line. W24 and W30 sections were used for long span ramp beams, while W16s were provided for short spans. W24s and W30s were used for ramp floor girders. All concrete reinforcing bars were epoxy coated.

LATERAL LOAD RESISTING SYSTEM

Due to the unique requirements of the column-free open spaces for bus parking and maintenance areas, the selection of an economical and efficient lateral system with huge floor plates was another challenge to the project team. After careful study of different alternatives and required space planning, the design team selected a combined system of bracing and moment resisting frames for the lateral load resisting system of the bus depot. Chevron bracing systems were provided along the perimeter and the ramps at selected bays while moment resisting systems were used for the selected interior frames. The framed floor slabs and the roof were designed as rigid diaphragms to transfer loads to the lateral load resisting system. Wind analyses were done to meet New York State and New York City Building Codes, and a seismic analysis was performed as per New York City Building Code. The high stress levels of the lateral load bearing columns due to seismic/wind and gravity load necessitated the use of heavy W14 sections with and without cover plates at lower levels. Base plates of some of the heavily loaded columns required stiffener plates. Shear lugs under the base plates were used for some of these columns resisting high lateral loads to transfer the base shear to the foundations.

STEEL CONNECTIONS

Connections for the bus depot used shear tabs for beams framing to plate girders, shop-bolted/field-bolted double angles for beams framing to beam and for beams framing to columns. Shop-welded angles or end plates were used at beams with axial loads. For moment-connected beams framing to columns, connections were primarily top and bottom moment plates shop-welded to the column and field-bolted to the beam flanges. Where large w-shapes with high end-moments occurred, beams were field-welded to the column in lieu of the top and bottom axial plates. The effect of moment connections on the W14 column sections was checked for local stress concentration. Column flange stiffener plates and columns web shear reinforcements were provided as needed.

The project used $\frac{7}{8}$″ A325 and $1\frac{1}{8}$″ A490 bolts. Slip critical bolts were used at moment connections, plate girder to column connections, horizontal and vertical bracing, beams with axial loads and at truss connections. Bearing bolts were used at the remainder of the connection types.

Truss connections were designed field bolted for the truss to be "knocked down." Truss joints used gusset plates shop welded to W-shape truss chords, field bolted to W-shape truss verticals. W-shape truss diagonal members were field-bolted to gusset plates with flange plates that were shop-welded to the gusset plate. One and one-eighth inch A490 bolts were used throughout the truss. Vertical bracing used concepts similar to the truss. Brace connections were made through shop welded gusset plates to the beam flange to resist the horizontal component of the forces and field bolted to the column and brace to resist the vertical and axial forces.

STEEL ERECTION

The inclusion of a large, deep basement area in the middle of the depot site had a big impact on both the design and the construction of the structural steel. In order to maintain the fast-track schedule for the project, it was necessary to begin steel erection prior to closing off the top of the basement. This, in effect created two separate work areas inaccessible to each other, one east and one west. The erection was performed by a Manitowoc M250 lattice-boom crawler crane on the west side and a Manitowoc 888 on the east side. These cranes sat inside the building footprint and worked their way from the south side of the project out to the northeast and northwest corners respectively. When the cranes reached the corners, they were disassembled and smaller cranes were brought in to finish the small amount of remaining work. This method of erection, similar to painting a floor and working your way from the far corner back to the door, was necessitated by the nearness of the narrow surrounding residential streets and by contract prohibition against extended street closings.

The large steel elements of the enormous truss assembly (approx. 19' deep, 100' long, 85,000 lbs.) and several large deep plate girders (max. 100' long, 90,000 lbs.) posed many challenges for erection. The open excavation adjacent to the cranes and the weight of the members precluded the use of either crane individually to set the steel without tipping over. Instead, both cranes working together were required. This was a very complex and precise undertaking. Both cranes were operated in perfect unison, since there could be a possibility of overstressing one of the cranes, resulting in catastrophic failure.

Prior to each pick, a professional engineer and a master rigger developed a detailed plan of operations. The plan accounted for the weight of the members being lifted, the lifting capacity of the cranes, the lifting radiuses needed by the specific site parameters and the soil capacity under the cranes. In this case, two cranes with different lifting capacities further complicated the matters, requiring the pick points for the members to be asymmetrical. When erecting the plate girders, the girders were lifted off the delivery trucks by the largest capacity crane (M250), which then had just enough capacity and reach to lower them down into the open basement excavation. The plate girders were then moved and dragged into position by both cranes. Once properly positioned, the two cranes then lifted the girders into place. The most challenging steel element erected on the job was the truss. It arrived on the site in pieces that were lowered into the basement area for assembly. With the help of one of the cranes, the truss was put together laying down flat. Both cranes then tipped the truss up vertically and lifted it slowly and carefully into place. Because of this careful pre-engineering and healthy respect for the inherent hazards, the steel erection for the project was completed safely and successfully.

The construction of the 100th street bus depot offered many opportunities for the project team to witness and participate in the unique procurement process of design-build, state-of-the-art design and construction practices, associated field engineering problems and their solutions. In the design-build of this innovative structure, the owner MTA New York City Transit, the designer STV and the builder Perini Corporation all worked in unison as a team dedicating themselves to the common cause and contributing their strength and skills to reach the established goal.

Sankar Chakraborty, P.E., is a Principal Transit Management Analyst (Line Equipment, Shops and Yards program) and Madan Naik, P.E., is the Chief Civil/Structural Engineer with the Department of Capital Program Management, New York City Transit Authority, New York, NY. Before joining NYCTA, Sankar Chakraborty was with Thornton-Tomasetti Engineers, New York, NY.

Ira Hooper, P.E., is a Vice President and Nazih S. Makary, P.E., is a Project Engineer with STV Incorporated, New York, NY.

A typical column moment connection assembly for the lateral force resisting system.

OWNER
MTA New York City Transit, New York City

STRUCTURAL ENGINEER
STV Incorporated, New York City

STEEL DETAILER
Tri Penn Steel Detailers, Sinking Spring, PA (NISD member)
CMT Detailers Incorporated, Farmingdale, NY

DESIGN-BUILD TEAM CONTRACTOR
Perini Corporation, Hawthorne, NY

SOFTWARE
RAM Structural System, STAAD III