Precast, Prestressed Concrete I-Beams for the Red-Purple Modernization Program

by Emily Hereford and David Depp, Stantec Consulting, and Amelia Johnson, Walsh-Fluor Design-Build Team

With an average weekday ridership of 1.6 million and routes spanning the city of Chicago, Ill., and 35 surrounding suburbs, the Chicago Transit Authority (CTA) is the second-largest transportation system in the United States. The Red-Purple Modernization Program (RPM), which started in 2009 with a vision study, is the largest capital project in CTA's history. It is a multiphased program to improve the 90-year-old infrastructure of the CTA's Red and Purple transit lines along a 9.6-mile stretch of tracks from Belmont Avenue on the northside of Chicago to Linden Avenue in suburban Wilmette. The design-build team was awarded a $2.1 billion contract for phase 1 of the project in 2018 and received notice to proceed in early 2019.

Precast, prestressed concrete beams on the new structure adjacent to the existing, deteriorating steel structure. Photo: Walsh-Fluor Design-Build Team.

Project challenges have included the need to maintain rail operations during construction while following safe construction practices in a limited work area. CTA looked for a design-build team that would provide the best value while implementing innovative design development and construction methods, and the agency was willing to consider alternative technical concepts (ATCs) that would provide technical solutions equal to or better than the concepts set forth in the technical requirements of the request for proposal. The selected design-build team has used ATCs at several locations, most notably for the precast concrete segmental box girder for the Lawrence to Bryn Mawr Guideway (featured in a Project article in the Spring 2023 issue of *ASPIRE*®) and for the precast, prestressed concrete I-beams for the North Mainline Reconstruction between Belmont Station and Cornelia Avenue.

Preceded by the construction of a grade-separated bypass for the Brown line (whose route intersects with the Red and Purple line routes at Belmont Station), the North Mainline Reconstruction is modernizing and realigning

profile

CTA NORTH MAINLINE BRIDGE RECONSTRUCTION FROM BELMONT STATION TO CORNELIA AVENUE / CHICAGO, ILLINOIS

BRIDGE DESIGN ENGINEER: Stantec, Chicago, Ill.

PRIME CONSTRUCTION ENGINEER: Collins Engineers Inc., Chicago, Ill.

PRIME CONTRACTOR: Walsh-Fluor Design-Build Team (a joint venture), Chicago, Ill.

CONCRETE SUPPLIER: Ozinga Ready Mix, Chicago, Ill.

PRECASTERS: I-beams: County Materials Corporation, Janesville, Wis.—a PCI-certified producer; noise barriers: Utility Concrete Products, Morris, Ill.—a PCI-certified producer

Precast, prestressed concrete beams with deck formwork are adjacent to the historic Vautravers Building, which was relocated approximately 30 ft to eliminate a curve in the existing rail alignment. Photo: Stantec.

approximately 1.4 miles of mainline tracks from Belmont Station on the south to Cornelia Avenue on the north.

Design

In the Red-Purple bypass area, the total length of the mainline reconstruction segment is about 1400 ft. This segment carries four mainline tracks—two in each direction (north and south). It includes some track crossovers and a two-track turnout for the Brown line north of Belmont Station.

The existing track substructures consist of multicolumn riveted steel bents—typically with one column beneath each track—and are supported on relatively shallow spread footings. The existing open-deck track uses timber ties supported on two riveted steel girders per track, which span between the bents.

As part of the Chicago Transit Authority's Red-Purple Modernization Program, approximately 1.4 miles of mainline tracks from Belmont Station to Cornelia Avenue are being modernized and realigned. Figure: Walsh-Fluor Design-Build Team.

The CTA project documents designate "permissible area" limits for underground and overhead construction, based on right-of-way property ownership, existing and proposed utility locations, alleys and streets, and parking. Given these limitations, the design-build team has used the request-for-proposal base-case span layout for most spans; however, after CTA approved an ATC, a few spans have been refined or combined to make better use of the beams' capabilities and eliminate some substructures.

All new track structures in this segment use a concrete closed deck and a direct-fixation method to attach the track to raised concrete plinths, per the project requirements. The design team has minimized the use of transverse expansion joints in the deck, based on construction and maintenance considerations.

One of CTA's project goals is to improve noise mitigation for the new track structures, so the project requirements include concrete noise barriers extending 3.5 ft above the top of rail. The design-build team has used precast concrete noise panels at the outer edges of the new deck, with an architectural pattern on the exterior face. Thus, the precast concrete panels serve two purposes—they reduce the noise of the trains for the neighborhood, and their aesthetic design enhances the community.

The original RPM project documents required galvanized steel framing for the new track structures. However, during the prebid phase, the design-build team proposed an ATC to use 36-in.-deep precast, prestressed concrete I-beams for most of the framing in this segment. Advantages presented in the ATC included significant cost savings, shorter construction schedule, reduced future

CHICAGO TRANSIT AUTHORITY, OWNER

BRIDGE DESCRIPTION: 1400-ft-long, 22-span concrete deck bridge—17 spans framed with precast, prestressed concrete I-beams and five spans with steel beams—carrying four tracks of the Chicago Transit Authority's Red and Purple lines

STRUCTURAL COMPONENTS: One hundred sixty 36-in.-deep precast, prestressed concrete I-beams with span lengths of 41 to 77 ft, minimum 10-in.-thick cast-in-place concrete deck, 2800 ft of precast concrete noise panels, cast-in-place pier caps, columns, and drilled shafts or micropiles

BRIDGE CONSTRUCTION COST: $1.2 billion

Some of the 36-in.-deep precast, prestressed concrete beams were stored on site, where fixed bearings and fall protection were installed before erection. Photo: Walsh-Fluor Design-Build Team.


Precast, prestressed concrete beams after erection but before deck placement. The beams span up to 77 ft, with up to thirty-four 0.6-in.-diameter prestressing strands used for the longest spans. Photo: Walsh-Fluor Design-Build Team.

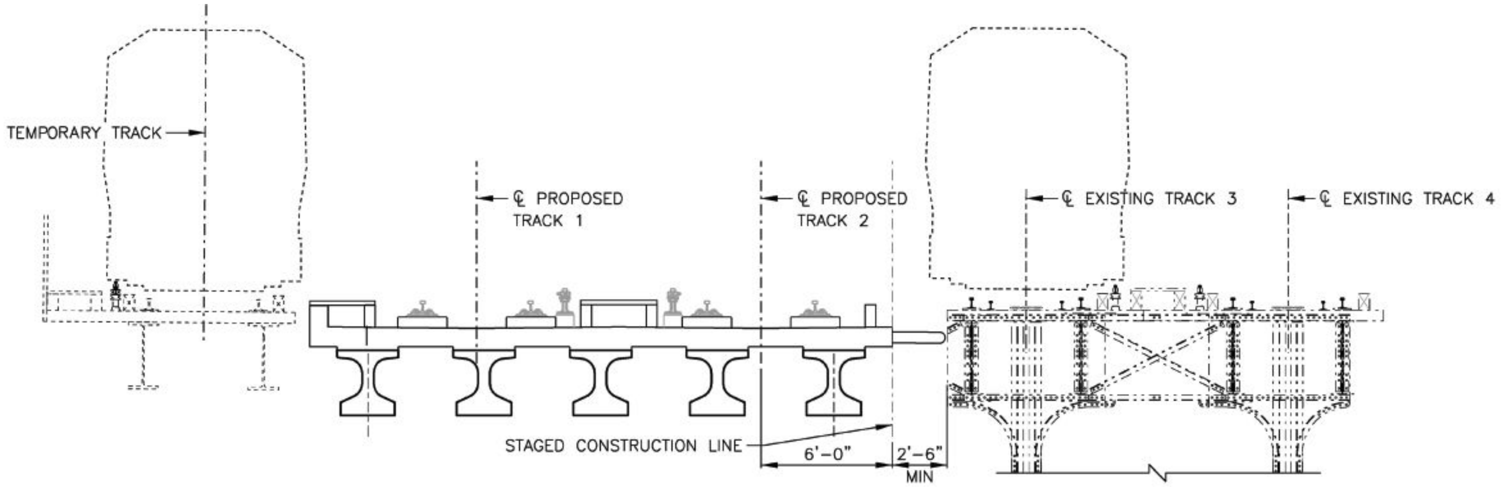
maintenance and inspection efforts, and reduced noise from train operation. When the CTA accepted the ATC for precast, prestressed concrete I-beams, the agency required that the design-build team address several issues, including auxiliary negative current return, stray-current control, and 100-year service life with corrosion resistance.

Precast, prestressed concrete I-beams are used for 17 of the 22 new concrete deck spans. Considerations, including vertical clearance over an electric power substation building and Clark Street as well as facilitating connections to existing framing, dictated the use of steel for the other five spans. Both precast, prestressed concrete and steel I-beams are used in four "hybrid" spans near the Brown line turnout to accommodate flared framing and staged construction. In the hybrid spans containing adjacent steel and precast, prestressed concrete beams, glass-fiber-reinforced polymer reinforcement is used instead of steel in the deck to address electrical grounding and stray current as well as considerations for the precast, prestressed concrete beams.


Erection of a precast, prestressed concrete I-beam. Most of the beams were erected at night to limit the project's impact on rail operations. Photo: Walsh-Fluor Design-Build Team.

The 36-in.-deep precast, prestressed concrete I-beams have a section commonly used by the Wisconsin Department of Transportation (WisDOT), with flange widths of 34 in. (top) and 30 in. (bottom) and web width of 6½ in. The design team chose this section because they determined that the WisDOT beams are slightly more efficient than a similar Illinois Department of Transportation section and the precaster had forms available for both options. The beam design uses a concrete strength of 8000 psi and a tensile stress limit of zero for the service dead-load and live-load case, per the American Railway Engineering and Maintenance-of-Way Association's requirements. The beam span lengths range from 41 to 77 ft, and up to thirty-four 0.6-in.-diameter prestressing strands are used for the longest spans. The beams act compositely with the 10-in.-thick cast-in-place concrete deck. The beams are not continuous over the piers, but the deck is continuous over most piers to eliminate expansion joints.

New substructures consist of concrete multicolumn bents. Typical bents allow the beams to bear on top of the concrete cap; however, a few bents use an inverted-tee cap design where vertical clearance is required for alleys or streets.



Cross section showing stage 2 construction for tracks 1 and 2 and accommodations for existing rail traffic. Figure: Stantec.

Per contractor preference, foundations are 4- or 5-ft-diameter reinforced concrete drilled shafts at locations where there is adequate construction clearance. Grouted steel micropiles are used at other locations where shaft construction is limited by vertical or horizontal constraints such as adjacent or overhead structure elements. Typical drilled shafts on this project have a belled end to bear on a hardpan soil layer about 65 ft below grade, and micropiles extend to solid bedrock about 85 ft below grade.

The design-build team developed a complex staging sequence for demolition and construction to keep two tracks operational during construction. The staging requires temporary alignment shifts at the north and south ends of the reconstruction segment. The staging is especially complicated in the very tight working area between Belmont Station and the Brown line turnout, and the structural framing layout in these spans was developed to accommodate the staging.

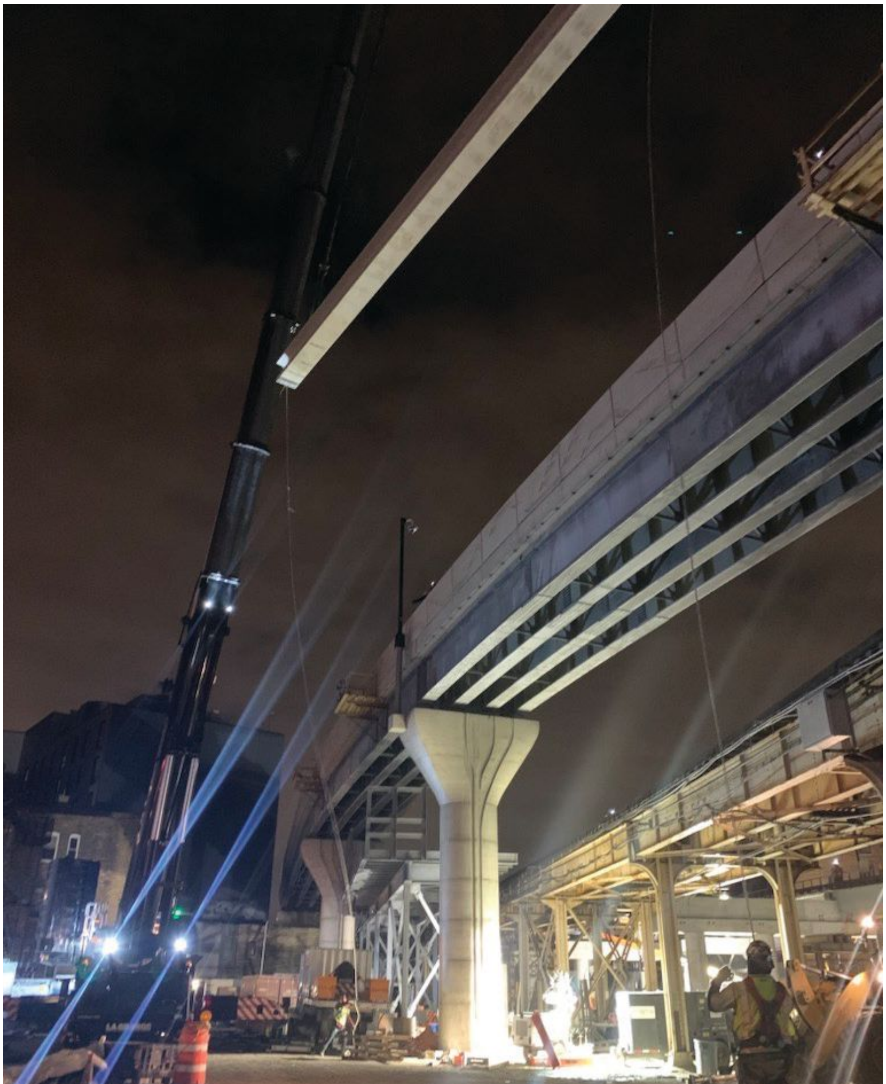
The placement of CTA structures next to properties throughout the transit system has posed multiple challenges for design and construction. When the original tracks used by the Red and Purple lines were constructed, they were routed around buildings where space was available. In the project area, the team needed to straighten a curve in the tracks to increase operating speed and reduce travel time. To accommodate this change, CTA acquired adjacent lots before issuing the notice to proceed. The historic Vautravers Building, a three-story building constructed in 1894, was adjacent to the tracks, and the project scope included relocating this building approximately 29 ft west of its current location. It was ultimately moved approximately 30 ft west and 4 ft south to align the building facade with other historic buildings on the street and accommodate right-of-way requirements.

Interdisciplinary coordination is a key part of this project, with the teams using a three-dimensional model to aid in coordination. Train operations require sophisticated electrical systems for traction power, signals, and communication, and the cables for these systems run below the deck and through raised footwalks on top of the concrete deck. Coordinating cable routing with the structural design was a significant challenge, and in many locations the cables pass through sleeved openings in the cast-in-place concrete deck and precast, prestressed concrete beams.

Construction

An RPM requirement is to maintain rail operations and minimize inconvenience for CTA customers. The mainline track

Erection of precast, prestressed concrete beams next to the Brown line flyover bridge occurred mainly at night. Photo: Walsh-Fluor Design-Build Team.



The north mainline construction for tracks 1 and 2 under the flyover structure. This view shows, from left, the temporary tracks; the precast, prestressed concrete beams that will carry tracks 1 and 2; tracks 3 and 4 on the existing structure; and the tracks on the flyover structure. Photo: Chicago Transit Authority.

structure carries four tracks and includes an at-grade crossing of the Brown line. The first stage of the project required construction of a curved steel girder flyover bridge to eliminate the at-grade crossing, as well as the construction of a temporary track structure to accommodate southbound Brown line travel from the Ravenswood structure to the mainline structure. This arrangement has allowed CTA to move into a two-track operation so that construction could begin on tracks 1 and 2 of the mainline structure during stage 2. Upon completion of tracks 1 and 2, train traffic will shift to them, and construction will begin on tracks 3 and 4 during stage 3. Train operations are scheduled to begin on tracks 1 and 2 in September 2023, and the overall project is scheduled for completion in 2025.

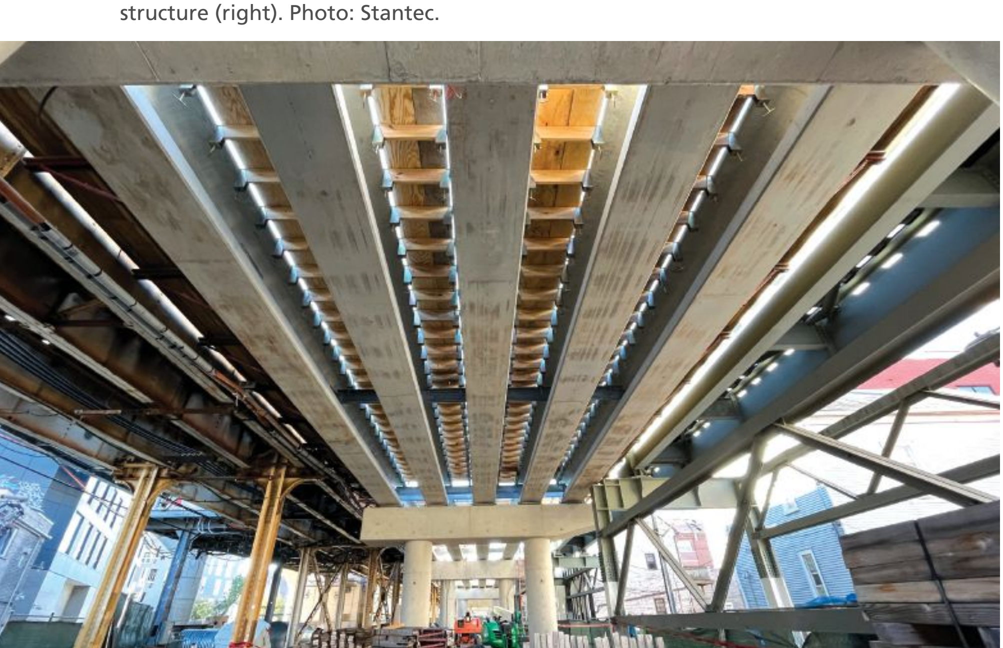
The eighty 36-in.-deep precast, prestressed concrete beams for stage 2 (the western half) were fabricated in May 2022, and delivery began in June 2022. Beam fabrication for the remaining eighty beams for stage 3 (the eastern half) will begin in late 2023.

Beam erection was also done in stages. The original intention was to install beams from north to south; however, due to other on-site circumstances, the beams were installed as the substructure was available. This modification to the original erection plan was easily accommodated because all precast, prestressed concrete materials were cast at the beginning of the erection.

Some precast, prestressed concrete beam installation challenges were due to the project's previous stage of construction, in which the flyover bridge for the northbound Brown line was built while the southbound Brown, Red, and Purple lines were actively running at deck elevation. To mitigate the project's impact on CTA riders, most of the beams were installed at night. The use of precast, prestressed concrete beams made it possible to install the beams over and then under the flyover and between the active tracks during the brief work windows between live trains.

Installation of the precast, prestressed concrete beams for stage 2 was completed by January 2023. The superstructure, trackwork, systems, and new track tie-ins are expected to be completed in late fall 2023, when the RPM will transition into the next phase.

Stage 2 construction between the existing steel structure (left) and the temporary steel structure (right). Photo: Stantec.



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