PROJECT

FAIRMOUNT LINE BRIDGES

Rehabilitating Boston's commuter rail line

by Aboud Alzaim, Malek Al-Khatib, and Daniel Deng, The Louis Berger Group Inc.

Commuter rail train (inset) passing over one of the new bridges. All photos: The Louis Berger Group Inc.

In 2010, the Massachusetts Bay Transportation Authority (MBTA) determined that two, century-old rail bridges over the Neponset River had reached the end of their fatigue service life. The bridges, which are on the Fairmount line, connect the Fairmount commuter line, connect the Fairmount and Readville stations in the Hyde Park neighborhood of Boston.

Both bridges were structurally deficient, with fatigue ratings below statutory limits, but replacing them posed several challenges. There had to be a minimum disruption of traffic, which required a phased construction plan. Work needed to be done quickly under tight constraints at the site, without fouling the adjacent track. The new structures were to require minimal future maintenance, with no fatigue concerns.

Given these constraints and economic considerations, the design engineer proposed a long-span, precast, prestressed concrete New England bulb-tee beam bridge. This type of bridge reduces material costs, future maintenance, and environmental impact, while also improving aesthetics in the surrounding area.

The bulb-tee beam optimizes the strength-to-weight ratio, maximizing the carrying capacity for live loads. At the same time, the wide top flange of the bulb-tee beam eliminated the need for formwork when

profile

FAIRMOUNT LINE BRIDGES / BOSTON, MASSACHUSETTS

BRIDGE DESIGN ENGINEER: The Louis Berger Group Inc., Morristown, N.J.

PRIME CONTRACTOR: S & R Construction Enterprises Inc., Newton, N.H.

GEOTECHNICAL ENGINEER: GEI Consultants Inc., Woburn, Mass.

PRECASTER: Northeast Prestressed Products LLC, Cressona, Penn.—a PCI-certified producer

OTHER MATERIAL SUPPLIERS: High load multi-rotational bridge disc bearings, The D. S. Brown Company, North Baltimore, Ohio

North approach view of the two main tracks looking north on bridge 2 over the Neponset River bridge.

Bridge Resiliency

To ensure the bridges' durability and ability to accommodate Cooper E-80 loads, high-performance concrete (HPC) was used to construct the bulb-tee beams, allowing the structure to resist higher loads with a more efficient cross section. The minimum specified 28-day concrete compressive strength was 10 ksi for the prestressed concrete bulb-tee beams, 6 ksi for the rock-socketed drilled shaft foundation, 5 ksi for the bridge deck, and 4.5 ksi for the walkway slab. Due to the weight of the concrete beams, the bridge is less prone to vibration-induced damage than a steel structure. These HPC beams in particular are anticipated to have an operational life span of 75 years.

The project was finished six months ahead of schedule, without any change orders, and is testament to the versatility of precast concrete.

constructing the bridge deck. Additionally, the concrete deck was built immediately after erection of the beams, which shortened the construction duration of the project. Using precast concrete beams with a ballasted deck also prevented construction debris from falling into the river, improving environmental sustainability and protecting recreational users of the river below.

History and Condition of Bridges

The two former bridges dated back to 1906. Bridge 1 was partially reconstructed in 1952 and again in 1974. The bridge was a 56-ft 8-in.-long, single-span steel structure carrying four tracks: two main line tracks and two spur tracks with one owned by the CSX Freight Line. This open deck-type bridge had open steel grates as walkways between the tracks and on cantilevers on both sides of its outer girders. The superstructure consisted of four pairs of steel girders, with each pair of girders supporting one track. The total width was 61 ft 9 in.

Bridge 2 carried two main line tracks. The bridge was an 89-ft 3-in.-long single span steel structure with a 30-degree skew. The out-to-out open deck width was 22 ft 10 in. and used timber planks as a walkway between the tracks. Its superstructure consisted of two pairs of steel riveted built-up girders supporting the main line tracks.

As an alternative to demolishing all the components of the old structures, the design engineer developed a hybrid design. For the main line tracks, two new bridge structures were selected to replace the existing bridges, while only the superstructure was replaced for the spur tracks of bridge 1.

Construction

Staged construction was planned around train operations and other concurrent

Elevation of one of the longest prestressed bulb-tee beams on bridge 2.

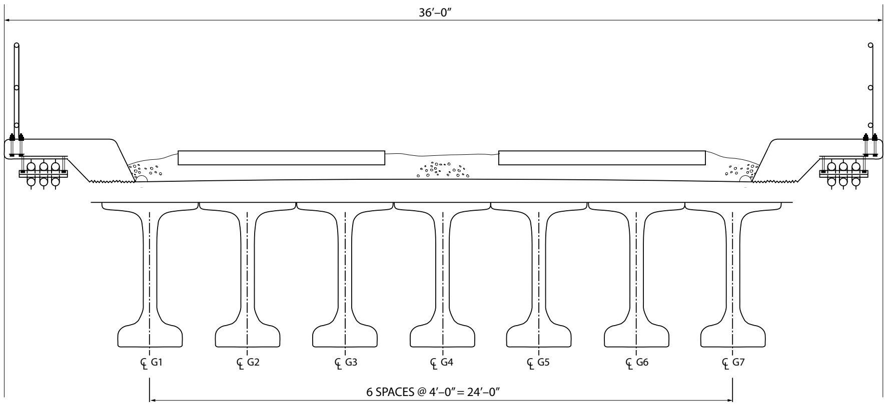
MASSACHUSETTS BAY TRANSPORTATION AUTHORITY, OWNER

PROJECT DESCRIPTION: Replacement of two existing steel railway bridges carrying two main line tracks with two new bridges using New England bulb-tee (NEBT) concrete beams

STRUCTURAL COMPONENTS: Bridge 1: a 71-ft-long, 37-ft-wide, single-span bridge with seven prestressed NEBT 1400 beams. Bridge 2: a 104-ft-long, 36-ft-wide, single-span bridge with seven prestressed NEBT 1800 beams. Both bridges have cast-in-place intermediate and end diaphragms, cast-in-place 10- to 12-in.-thick concrete deck, and 4-ft-wide cantilevered walkways on both sides with six 4-in.-diameter PVC conduits for signal and communication cables suspended from underneath. The substructure for each bridge consists of four, 3-ft-diameter drilled shafts with lengths, including 6-ft-deep rock sockets, ranging from 98 to 117 ft for bridge 1 and 50 to 78 ft for bridge 2.

BRIDGE CONSTRUCTION COST: $8.6 million

AWARDS: PCI 2013 Design Award for Best Non-Highway Bridge



Typical cross section of bridge 2. Drawing: MBTA.

Crane load transfer during beam erection.

Precast concrete beams for the Fairmont Bridge Replacement were transported to the site by truck.

construction projects along the Fairmount line. As a result, the bridges were built in two phases: the main line tracks were taken out of service one at a time, allowing the contractor to use the second track on weekends when passenger trains do not run. However, because both spur tracks were needed throughout the week, the spur track superstructure was replaced under accelerated construction techniques during one weekend shutdown.

Precast, prestressed concrete bulb-tee beam structures were determined to be the most economical for the main line bridges. A preliminary design was prepared to estimate the comparative costs of materials; based on this prototype, the cost of steel was estimated at $3,346,000 compared with $1,363,000 for concrete. Additionally, the maintenance cost for a steel bridge would be much higher than that for a concrete one, especially because the bridge is over the river with limited accessibility.

The new bridge abutments were designed as stub abutments supported on four, 3-ft 6-in.-diameter drilled shaft foundations. To minimize outage time, the new substructures were constructed behind the existing abutments. As a result, the span lengths of the new bridges increased to 71 and 104 ft for bridges 1 and 2, respectively.

The bulb-tee beams for bridge 2 have an overall span length of 110 ft, which according to the Precast/Prestressed Concrete Institute, is one of the longest spans for a bridge carrying Cooper E-80 train loads in New England. To achieve the long span, the bulb tees were spaced at 4 ft on center, using four beams connected laterally with concrete diaphragms to support each track during construction.

A 10- to 12-in.-thick, cast-in-place reinforced concrete deck was placed on the beams. Raised concrete walkways cantilevered beyond the exterior beam to contain the ballast and tracks. The new out-to-out concrete deck widths are 37 and 36 ft for bridges 1 and 2, respectively.

The beams were fabricated in Pennsylvania and transported to the sites. Two cranes located behind opposite abutments were used to lift each beam. One crane lifted the beam and moved it two-thirds of the way over the river. The second crane, on the opposite side, connected the sling on the far end in midair to transfer partial beam load to itself. A

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