PROJECT

Southwest Light Rail Transit Project: Excelsior Boulevard Bridge

by Eric Nelson, AECOM

Metro Transit is the primary public transportation provider in the Minneapolis–Saint Paul, Minn., area, and a division of the Metropolitan Council. It operates the region's public transit, including two light rail transit lines—the METRO Blue Line and METRO Green Line—which serve more than 23 million passengers per year. In late 2018, with projected additional growth in the area, the Metropolitan Council began overseeing construction on an extension of the METRO Green Line, known as the Southwest Light Rail Transit (SWLRT) Project. The SWLRT Project is Minnesota's largest public works project to date, and the extended Green Line will operate from downtown Minneapolis to the southwest suburb of Eden Prairie. The total alignment is approximately 14.5 miles long with 16 new stations and more than 3.5 miles of bridge structure.

One of the signature bridges on the project is the dual-track Light Rail Transit (LRT) Excelsior Boulevard Bridge, which crosses over both Excelsior Boulevard and the Bass Lake Spur railroad in Hopkins, Minn. The alignment crosses the four-lane Excelsior Boulevard and a relocated portion of the Bass Lake Spur at relatively sharp skews. Accommodating these site features, coupled with local business owners' desire for open views beneath the bridge, dictated the need for long spans. In the preliminary layout, the bridge was envisioned as a concrete box-girder structure with most of the spans cast in place on falsework, and the span over Excelsior Boulevard constructed segmentally in a progressive-cantilever manner. However, the final design of this five-span bridge (244, 360, 400, 360, and 244 ft) used cast-in-place concrete segmental balanced-cantilever construction with form travelers. This design was selected because the local contractors have limited familiarity with constructing long, cast-in-place concrete spans on falsework, and because many bridges in Minnesota have been succesfully constructed using segmental balanced-cantilever designs.

Design Details

The superstructure of the bridge is a variable-depth, single-cell trapezoidal box girder. The maximum depth is 20 ft at the main span piers and 18 ft at the side span piers. The minimum depth is 8 ft at midspan with the section height varying parabolically. The box-girder

Long spans (up to 400 ft) of the Southwest Light Rail Transit Excelsior Boulevard Bridge accommodate site constraints for both roadway and railroad crossings while also providing open views beneath the bridge in an urban environment. All Photos: AECOM.

profile

BRIDGE 27C10 OVER EXCELSIOR BOULEVARD FOR THE SOUTHWEST LIGHT RAIL TRANSIT PROJECT / HOPKINS, MINNESOTA

BRIDGE DESIGN ENGINEER: AECOM, Nashville, Tenn.

OTHER CONSULTANTS: Construction engineering services: Finley Engineering Group (now COWI), Tallahassee, Fla.; geotechnical engineer: American Engineering Testing, Saint Paul, Minn.

PRIME CONTRACTOR: Lunda Construction and C.S. McCrossan Joint Venture, Minneapolis, Minn.

CONCRETE SUPPLIER: Aggregate Industries, Egan, Minn.

Construction of both cantilevers at the first pier uses a form traveler at each end. A temporary support is visible at the pier, and the portion of the first span that was cast on falsework is visible in the background. The bridge is close to an active freight rail line, which, once relocated, will be within 15 ft of the new structure in some locations.

webs have a constant thickness of 1 ft 6 in. and are inclined on a constant slope, creating a varying bottom slab width. The bottom slab thickness also varies, with a maximum thickness of 3 ft at the piers and a minimum of 10 in. at midspan. The top slab is cantilevered approximately 8 ft 6 in. beyond the webs, with the distance between the webs at the top slab set to align with the distance between the centerlines of the two tracks on the structure. This configuration minimizes transverse bending effects in the box-girder section under LRT live loads.

The profile grade and horizontal alignment for the structure are controlled by the geometry of the eastbound track, which is offset 7 ft 0 in. from the centerline of the bridge. This track geometry places almost the entire structure in a vertical curve, with 5% grades at each end. The horizontal geometry of the track in this area consists of several spiral curves that transition to both left- and right-turning large-radius circular curves with radii varying from 4000 to 10,000 ft. To facilitate the layout and construction of the box-girder segments, a horizontal alignment along the centerline of the bridge consisting of a series of circular curves that closely mimic the spiral and circular curves of the track alignment was developed.

The box-girder segments are cast with a movable form traveler in a balanced-cantilever fashion with no more than one-half segment length out of balance at any time. The main span cantilever at piers 2 and 3 has 10 segments extending out on each side of the pier table, with all segments being 16 ft 9 in. in length. The maximum segment weight, including fresh concrete and reinforcement, is approximately 305 kip. The cantilevers at side piers 1 and 4 are composed of nine segments on each side of the piers, with an approximately 60-ft-long portion of the end spans at the abutments built on falsework. Closure segments vary in length from 5 ft 9 in. at the side spans to 13 ft 0 in. at the center span.

All post-tensioning tendons are internal to the concrete superstructure. A combination of cantilever and continuity tendons, all housed within plastic ducts and subsequently filled with prepackaged grout, are used longitudinally. Two top slab longitudinal cantilever tendons composed of eleven 0.6-in.-diameter strands are used for each cantilever segment cast. Eight continuity tendons in the center three spans and six continuity tendons in the end spans are provided

Continuity post-tensioning tendons, which are internal to the box-girder webs, are anchored on each side of the pier diaphragm. External tendon hardware for future post-tensioning is anchored in the middle of the diaphragm.

METROPOLITAN COUNCIL / SAINT PAUL, MINNESOTA, OWNER

POST-TENSIONING SUPPLIER: DYWIDAG-Systems International, USA Inc., Bolingbrook, Ill.

OTHER MATERIAL SUPPLIERS: Bearings: D.S. Brown, North Baltimore, Ohio; prepackaged grout: Euclid Chemical, Cleveland, Ohio; form travelers: NRS, Oslo, Norway; formwork: PERI Formwork Systems, Chicago, Ill.

BRIDGE DESCRIPTION: Five-span, 1608-ft-long, post-tensioned, cast-in-place concrete segmental box-girder bridge with spans of 244, 360, 400, 360, and 244 ft.

STRUCTURAL COMPONENTS: Single-cell cast-in-place concrete box-girder segments that vary in depth from 20 to 8 ft, cast-in-place concrete piers and abutments, and steel H-pile foundations.

A ballasted, temporary stability prop located under the fourth segment on the longer side of the cantilever is used to provide rotational stability for the box-girder span and resist uplift during balanced-cantilever construction. In the background of the photo, the portion of the span connecting to the abutment is being cast on falsework.

All reinforcement in the box-girder superstructure is epoxy coated for durability. Although deicing salts will not be used on the light rail structure, there is potential for chloride exposure given its proximity to adjacent roadways. The worker is installing a longitudinal post-tensioning duct in the last cantilever segment adjacent to a closure pour location.

within the webs that extend the full length of the spans along a parabolic profile. The tendons are composed of twenty-five and twenty-seven 0.6-in.-diameter strands. Bottom slab tendons are also provided; they use fifteen to nineteen 0.6-in.-diameter strands anchored within intermediate blisters in each of the spans. The relatively narrow width of the box section limited placement of anchorages in the pier diaphragms as well as the number of tendons that could be deviated in segment ribs. Therefore, external draped continuity tendons—which are common for this type of bridge—were not used, except to provide the needed anchorage and duct hardware for future post-tensioning as required by the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*. The top slab is transversely post-tensioned with three 4-strand tendons in plastic ducts for every 16-ft 9-in.-long segment.

The specified concrete compressive strength for the superstructure is 7500 psi, with minimum 4000-psi strength required before tensioning the post-tensioning tendons and advancing the form traveler.

Although deicing salts will not be used on the LRT structure itself, there is the potential for chloride exposure because of the proximity of the bridge to adjacent roadways. To minimize corrosion risk, epoxy-coated reinforcement is used in the superstructure. To mitigate stray current corrosion issues, galvanized steel stray-current collector cables were placed the full length of the bridge beneath each track plinth, bonded to all the post-tensioning anchors, and grounded at the abutments. The collector cables are kept electrically isolated and are not bonded to the epoxy-coated reinforcement in the segments.

Short Piers with Bearings

The substructure is composed of conventionally reinforced cast-in-place concrete piers founded on steel H-piles driven to bedrock. The piers are relatively short, ranging from approximately 8 ft tall at pier 1 to approximately 24 ft 6 in. tall at pier 3. For cast-in-place segmental bridges, tall, slender piers, such as twin-wall piers, are often cast integrally with the superstructure to provide strength and stiffness during cantilever construction; these piers are also longitudinally flexible to accommodate creep, shrinkage, and thermal effects without creating excessive loads on the foundation. However, on the Excelsior Boulevard Bridge, the piers were too short for such a solution. Therefore, to minimize foundation forces, the superstructure is supported with disc bearings that are free to move longitudinally at the piers and abutments except at pier 2, which has fixed longitudinal bearings. Two bearings are provided at each pier with vertical service limit state capacities of up to 5150 kip per bearing. One bearing per pier is multidirectional, and the other is unidirectional (guided) to restrain transverse displacements while allowing longitudinal displacements.

The disc bearing details electrically isolate the substructure from the superstructure so no special stray-current corrosion-

To reduce demands on the foundations, disc bearings free to move longitudinally are used to support the superstructure at all but one pier.

Balanced-cantilever construction with form travelers nears completion. The final closure pour of the 1608-ft-long, post-tensioned, cast-in-place concrete segmental box-girder bridge will be at this location in span 2 over Excelsior Boulevard, after the cantilever is completed.

control measures were needed for the piers and footings. Epoxy-coated reinforcement was used in the piers and abutments for enhanced atmospheric corrosion protection, and plain uncoated reinforcement was used in the pier footings. Architectural textures and other features were added to the concrete piers and abutments to achieve the overall visual quality requirements for the project. Additionally, after construction is complete, all visible elements of both the substructure and superstructure will receive a gray-colored finish coating.

Collision Resiliency

Based on the proximity of the Excelsior Boulevard Bridge to both the roadway of Excelsior Boulevard, which crosses under the bridge between piers 1 and 2, and the Bass Lake Spur, which runs parallel to and will cross under the bridge between piers 3 and 4 after it is relocated, all piers and both abutments are designed to resist 600-kip vehicle and train collision forces per the governing AASHTO and American Railway Engineering and Maintenance-of-Way Association design codes. Additionally, the foundations for the piers and abutments were evaluated for the addition of live-load surcharge from the adjacent railroad track, which in some locations is within 15 ft of the bridge structure.

Form Travelers and Props

Construction on the bridge began in fall 2019 with pile-driving operations. Construction of the superstructure is currently nearing completion. Four form travelers are being used, allowing two cantilevers to be constructed simultaneously. The original design envisioned that the final bridge closure pour would be completed in the center of span 3; however, after construction had commenced, the contractor opted to complete the longer cantilevers at piers 2 and 3 first, then the side-span cantilevers at piers 1 and 4, with the final closure pour to complete the bridge in span 2. The concrete superstructure was cast during approximately eight to nine months out of the year, with enclosures and heating elements used in the colder late-fall season. Construction was paused in the harshest winter months. Currently, all cantilevers and closure segments have been cast, except for cantilever 1, which was expected to be completed in late summer 2022.

With the superstructure being supported on piers with bearings, temporary supports were needed to allow cantilever construction; the contractor elected to provide stability using two types of temporary supports. The first type consisted of falsework bearing directly on the pier footing installed on both sides of the pier table, which provided rotational stiffness to complete cantilever construction for the first four segments on either side of the pier. The second type was a stability prop consisting of steel pipe columns bearing on a spread footing with added ballast to resist uplift. This prop and added ballast were installed beneath the fourth segment on the longer side of the cantilever to complete the remainder of the segments.

Construction of the Excelsior Boulevard Bridge, including all finishing and rail work, is expected to be completed in 2023, with revenue service on the entire SWLRT line expected in 2027. Once complete, the new LRT structure will be part of a system providing reliable public transportation for thousands of people every day in the Minneapolis–Saint Paul area.

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