

Approach Spans Steal the Show

Three cast-in-place approach structures take the spotlight by creating new public spaces

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Bridges where the vertical clearance below allows plenty of room for a standard precast concrete girder are usually pretty straightforward to design. The same is true for bridges of constant width that are straight or have gradual curvature: conventional girder layouts will do. Designers, fabricators, and contractors can apply familiar materials and techniques, and the structure will be stiff enough to control deflections.

However, if the profile of the bridge approaches the existing grade too closely, or if the bridge varies in width, or if it must accommodate a severe skew or curvature, a branching ramp, or critical drainage conditions, then conventional girder layouts become a challenge. Or, if there is a need to use the space under the bridge for civic purposes, which in turn requires an improved appearance of the underside, the dark, uninviting recesses and pigeon perches created by typical girder systems are not appropriate.

Where these circumstances occur, cast-in-place (CIP) concrete slab spans can address them all. This article describes three such bridges.

Belleair Beach Causeway Bridge Replacement, Largo, Fla.

The Belleair Beach Causeway Bridge was completed in 2009 to provide a 3350-ft-long high-level replacement for an aging bascule bridge crossing Belleair Bay and the Intracoastal Waterway. The 324-ft main span, with its spliced, haunched bulb-tee girders, is one innovative feature of this bridge. But this article concentrates on another feature:

the two 660-ft-long CIP post-tensioned concrete slab structures that are the east and west approaches for the bridge. (For details of the entire bridge, see the Summer 2010 issue of *ASPIRE*®.)

The approaches to the previous bascule bridge were across narrow causeways. On the east approach, Pinellas County had developed the north side of the causeway into a busy public boat ramp and the south side into “Dog Beach,” a popular area for exercising pets. Both were so popular that the county was looking for ways to expand them. That meant providing more space for parking and maneuvering boat trailers on the east causeway (**Fig. 1**). To provide still more space for activities, the county also wanted to enlarge an existing small park on the west causeway to create areas for exercising pets and for launching canoes and kayaks.

To get above the Intracoastal Waterway, the new bridge’s profile had to start rising well to the east and west of the existing parks. Supporting the approaches on embankments would have wiped out both facilities, as well as any possibility of expansion. Placing the approaches on structures was the obvious solution. However, with people under the approaches at all times, the underside surfaces of the bridges needed to be smooth, light colored, and without dark recesses, so that daylight would be reflected under the bridge and the area below the bridge would be easy to light at night.

How a Concrete Slab Addressed the Conditions

Selection of concrete slab structures for both approaches met the project goals (**Fig. 2**). The span lengths of the post-tensioned slab structures were

Figure 1. View of the Belleair Beach Causeway Bridge with the east approach structure in the foreground, showing Dog Beach and the new boat ramps. Photo: HDR Inc.



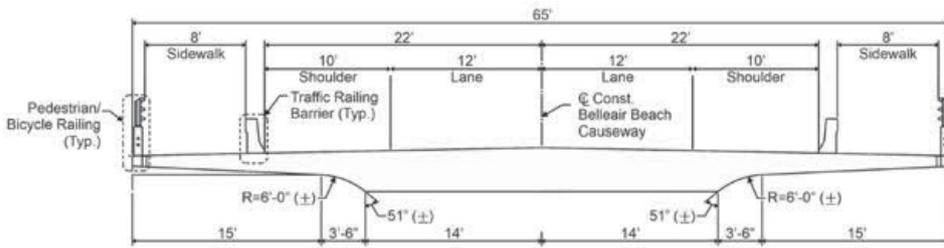


Figure 2. Typical cross section of post-tensioned concrete slab for the east and west approaches to the Belleair Beach Causeway Bridge. Figure: HDR Inc.

coordinated with the parking layout below the bridges to accommodate boat trailers. The 660-ft-long post-tensioned slab structures were divided into nine spans (eight spans at 75 ft and one end span at 60 ft at the abutments).

Integrating two different structural systems into one bridge requires some coordination so that the final result doesn't look like two different bridges mashed together. To that end, the same pier shape was used throughout the bridge: two closely spaced columns with an arched connection between them. On the approaches, the two columns support the concrete slabs; on the high-level spans, the two columns support a pier cap with cantilevered ends. At the two piers where the approaches join the high-level unit, the cantilevered pier cap ends support overlooks, which visually punctuate the junctions while obscuring the structural differences.

Construction and Design Challenges

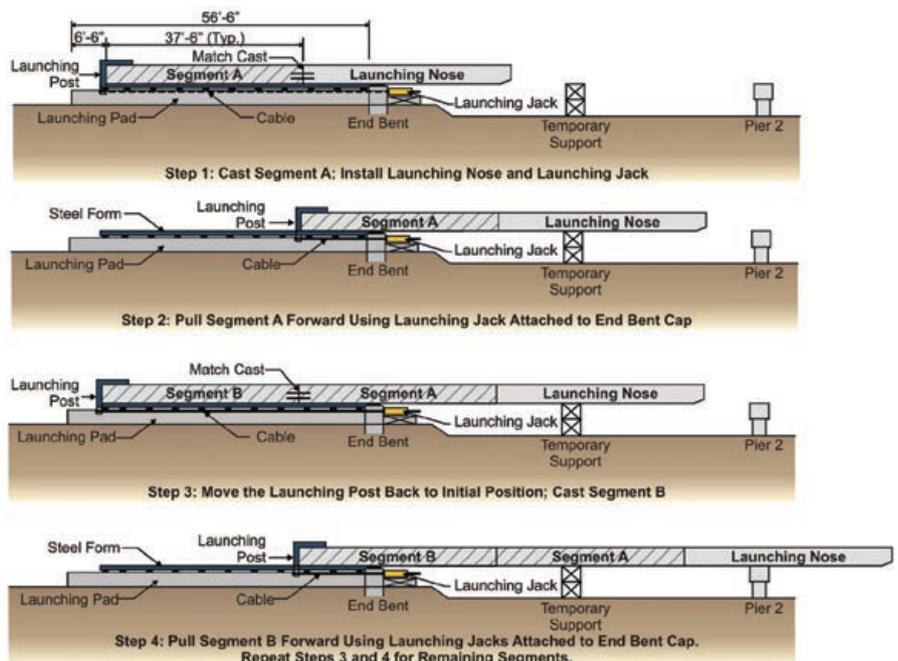
The CIP concrete slab structures for the east and west approaches were originally designed to be constructed on falsework. This technique would have required a wide construction area, creating a large environmental impact on the seagrass beds to the northeast of the bridge and interfering with the maintenance of traffic on the causeways. Also, it was questionable whether the poor soils of the causeways could support the falsework. To resolve these issues, the contractor decided to use incremental launching for the entire 660 ft of concrete superstructure on each approach (Fig. 3). The casting beds were supported on piles behind each abutment, which eliminated settlement issues. The launching system used strand cables to pull the slabs forward. The technique improved quality control, because all segments were cast at the same location, and accelerated construction, which averaged one 37.5-ft-long segment per week. Most important, the contractor pointed out, "Of course, incremental launching saves

time and money, but safety is the biggest benefit. Our workers were always on the ground, instead of 50 feet in the air."

Results

The Belleair Beach Causeway proved that incremental launching of concrete slabs can be a cost-effective method of accelerated bridge construction. Considered to be the largest single project awarded in Pinellas County Public Works Department's history, and managed by Pinellas County Public Works staff, the entire causeway was completed with just a 5.8% increase in construction time and a 0.06% increase in construction cost. The contractor estimated that the various savings resulting from adopting the incremental launching method of construction reduced costs by \$250,000. It was a truly successful project for both the county and the general public. The Belleair Causeway Bridge became the fourth bridge constructed with the incremental launching method in the United States and the first one using this method for post-tensioned concrete slabs.

Figure 3. Schematic showing the incremental launching sequence for the Belleair Beach Causeway Bridge post-tensioned concrete slab approach spans. Figure: HDR Inc.



In the years since the 2009 completion of the bridge, the eastside boat ramp and Dog Beach have become busier than ever, and the westside pet park and launching ramps have become equally popular.

U.S. Route 61 over the Mississippi River and Second Street, Hastings, Minn.

Hastings is a historic river port. The south approaches to the U.S. Route 61 (U.S. 61) bridge cross over the city's Second Street shopping district, with its 19th-century buildings, with minimal vertical clearance. The street also hosts antique car rallies and other events during the summer. U.S. 61 joins Hastings's street system just one block south of Second Street, leaving no possibility of raising the roadway to create additional clearance. The steel girders of the previous bridge had rendered the space below the bridge dark and uninviting, which discouraged the extension of shopping and community activities west of U.S. 61.

How a Concrete Slab Addressed the Conditions

Selection of a CIP concrete slab for the south approach maximized the vertical clearance under the structure. The slab structure also allowed the span length over Second Street to be increased so the piers could be located behind the



Figure 4. Parking area located under the south approach spans looking from Second Street toward the U.S. Route 61 bridge over the Mississippi River. Covers were later installed over the conduits mounted on the bridge. Photo: Dale Thomas.

line along the face of the buildings on each side of the street, so that the approach piers do not impinge on the width of the street and sidewalks. The slab span was also increased from the south building line on Second Street to the south abutment, enlarging the space under the bridge and making it more useful for civic activities. Finally, the spans from Second Street (Fig. 4) north to the river were optimized for parking under the bridge, better serving retail visitors to Second Street.

The smooth bottom soffit of the concrete slab replaces the utilitarian appearance of the typical multibeam and deck structure while eliminating the pigeon perches created by the girder flanges and exposed bracing of its predecessor. Instead, the slab provides a smooth and light-colored undersurface that reflects daylight into the space under the bridge, and which is uplighted at night to provide indirect lighting that illuminates activities under the bridge.

The south approach is 550 ft long with span lengths varying from 65 to 138 ft.

Figure 5 shows the typical cross section for this approach for northbound traffic, which is carried on a 52-ft-wide slab that includes a 12-ft-wide shared-use path. Southbound traffic is carried on a 39-ft-wide slab. Each slab has a typical thickness of 5 ft, which tapers to 3 ft 6 in. over Second Street to meet vertical clearance requirements. The transition between slab depths is accomplished by an aesthetically pleasing arched taper in the soffit. At its north end, the slab rests on the south pier of the main span that crosses the Mississippi River.

Construction and Design Challenges

The slab superstructure is post-tensioned in both the longitudinal and transverse directions to meet the owner's design requirement of 50-psi residual compressive concrete stress under service loads at the top of the structural slab. Post-tensioning was accomplished with longitudinal tendons, each containing thirty-one 0.6-in.-diameter strands, that run the full length of the slab structure. Transverse post-tensioning consists of tendons

containing four 0.6-in.-diameter strands that are regularly spaced along each span, with additional transverse post-tensioning concentrated at the abutment and pier locations. Time-dependent post-tensioned concrete analysis models were used for design, and a finite element model was used to evaluate the effects of shear lag at the support locations at each column and for the transverse design of the slabs.

The CIP slabs were constructed on traditional falsework. Concrete was placed full depth in longitudinal segments with volumes of up to 1200 yd³. Full-width shear keys were provided at each vertical construction joint. Special attention was given to the vertical reinforcing bars so they could serve multiple functions—post-tensioning duct support, robust “standee” support for the top layer of reinforcement that was more than 4 ft above the bottom layer, post-tensioning anchorage-zone reinforcement at end supports, and transverse reinforcement in pier regions (Fig. 6).

Results

Expansion of the under-bridge area created space for a plaza with benches and a natural stone mural on the south abutment wall (Fig. 7). This work depicts the history of Hastings in variously colored natural stones. Unusual for efforts of this type, the mural was the result of a collaboration between the design-build contractor,

Figure 6. Longitudinal post-tensioning ducts in the bottom of the slab, transverse post-tensioning ducts in the top of the slab, and other mild reinforcement for the south approach slab of the U.S. Route 61 bridge. Note the use of both stainless steel and epoxy-coated reinforcement in the slab. Photo: Jeffrey Cavallin.

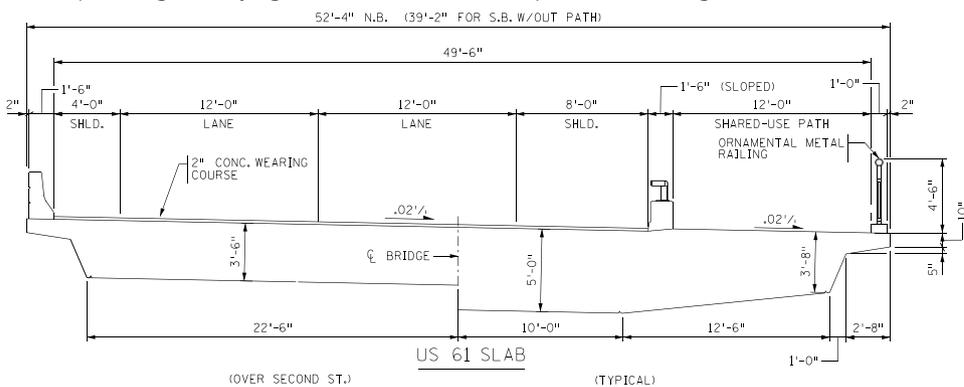


Figure 5. Typical cross section of the U.S. Route 61 south approach bridge carrying northbound traffic on the typical 5 ft depth (right) and the reduced depth over Second Street (left). Figure: Jeffrey Cavallin.





Figure 7. Civic plaza and mural at the south abutment of the U.S. Route 61 bridge. Lights illuminate the bottom soffit of the slab, which makes the whole plaza area bright and welcoming at night. A transition line is visible in the overhang, which is the taper for the reduced slab depth as the bridge crosses Second Street. Photo: Frederick Gottemoeller.

an artist retained by the contractor, and the Citizens Advisory Committee. The U.S. 61 Hastings bridge replacement project was very well received by both the community and the Minnesota Department of Transportation. At its dedication in the fall of 2013, Hastings mayor Paul Hicks said, “Our new bridge is a landmark that we look to with a sense of pride.” Among the first of the project’s many awards was the 2014 Midwest Best Project of the Year in the Highways/Bridges category of *Engineering News-Record*.

Grand Avenue Bridge, Glenwood Springs, Colo.

The Grand Avenue Bridge connects Interstate 70 (I-70) and U.S. Route 6 (U.S. 6) to downtown Glenwood Springs and points south. From north to south, the structure spans the parking lots for Glenwood Springs’ hot springs, I-70, the Colorado River, the Colorado mainline of the Union Pacific railroad, and finally Seventh Street, where it enters downtown. South of Seventh Street, the alignment is centered on the Grand Avenue street right-of-way (ROW), with barely 15 ft of horizontal clearance to the historic retail buildings on either side, and the bridge spans a plaza used informally for seating and community events.

As it crosses Seventh Street, Grand Avenue is about 20 ft above the street level. From there it slopes down to join the street system at Eighth Street. An alley crosses the alignment halfway between Seventh and Eighth Streets. The city wanted to establish the alley as a pedestrian connection through downtown, which required moving the south abutment of the bridge about 50 ft farther south to allow direct passage under the bridge (Fig. 8). At that

point, the vertical distance between the bridge roadway and the Grand Avenue sidewalks is just 11 ft. A typical girder structure would require a depth of 5 ft, leaving just 6 ft of headroom at the abutment.

How a Concrete Slab Addressed the Conditions

The Grand Avenue Bridge was designed and constructed as two units. Unit 1 of the bridge crosses the hot springs’ parking lots, I-70, the river, and the railroad tracks. This article focuses on the three-span (60, 77, and 60 ft) unit 2, which extends from the south abutment, where the vertical clearance is most limited. Selecting a CIP concrete slab with a depth of only 3 ft for unit 2 increased the headroom at the abutment from 6 ft to 8 ft. To create still more headroom at the sidewalks, the edges of the slab are tapered to 9 in., increasing the minimum headroom there to 10 ft (Fig. 9). Under the bridge, the pavement of the plaza was lowered 2 ft by adding a row of steps parallel to each edge of the bridge, so the minimum headroom throughout the

plaza is 10 ft. The tapered edge of the slab also makes it difficult to judge the full depth of the slab, so the bridge appears thinner than it really is. The underside of the slab includes 9-in.-deep recesses (coffers) in a rectangular pattern. They reduce the slab’s weight and create an attractive “ceiling” pattern for the space under the bridge.

Units 1 and 2 join at the pier on the railroad’s south ROW line, where the box girders from unit 1 are supported by three separate octagonal columns and the slab is supported on the dapped ends of the girders. To create visual continuity between units, all columns are octagonal, and all are faced with the same red/pink sandstone that is found on many of the town’s historic buildings.

Construction and Design Challenges

Because of public concern about the closure of Grand Avenue, the construction of unit 2 had to be completed within a 95-day window. With that in mind, the Colorado Department of Transportation (CDOT) brought the contractor onto the team at the beginning of design, using the construction manager/general contractor (CM/GC) method of project delivery. As a result, the design team could weigh each feature of unit 2 against schedule and budget (see the article in the Summer 2020 issue of *ASPIRE*).

The tapered overhangs, coffers, and integral columns produced a departure from typical slab behavior. The two longitudinal ribs between the columns are the primary load-carrying elements. The use of simple scaffolding-style falsework, combined with prefabricated

Figure 8. Cast-in-place concrete slab structure of the Grand Avenue Bridge at Seventh Street as it descends toward the south abutment. Photo: Davis Deaton.



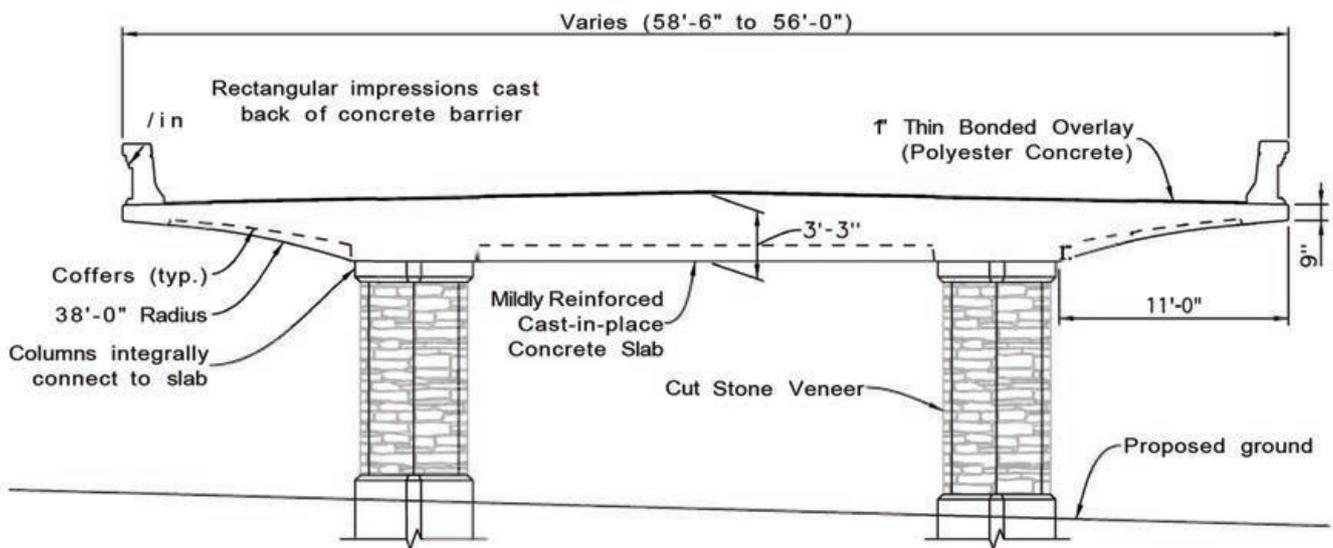


Figure 9. Typical cross section of unit 2 of the Grand Avenue Bridge. Figure: RS&H.

forms for the coffer and overhangs, accelerated construction. Rather than illuminating each coffer, widely spaced downlights simplified the conduit layout within the CIP slab (Fig. 10). Opting for a slab with mild reinforcement (no post-tensioning) also accelerated construction. The slab was cast in one continuous 15-hour placement of about 940 yd³. Unit 2 was finished 10 days ahead of schedule.

Results

The plaza underneath the Grand Avenue Bridge had always been noisy. However, 3 ft of solid concrete deadens a lot of sound. At the dedication ceremony in 2018, Colorado Governor John Hickenlooper made his remarks standing in the plaza under the bridge, with 18 wheelers traveling 10 ft above his head. Listeners could hear every word.

The finished bridge is a civic success story. The plaza underneath is playing a key role in helping adjacent restaurants struggling with reduced seating capacity in the wake of COVID-19 shutdowns. "The city is now allowing restaurants to use the plaza space for additional outdoor seating, which for some restaurants may completely offset the loss in indoor capacity," noted Roland Wagner, who served as the project manager for CDOT. "The bridge created this public space, and it's been rewarding to see its positive impact in a time of need."

Conclusion

All three of these concrete slab approach structures met very tight vertical clearance requirements while at the same time creating outstanding public spaces below the structures. The owners,

designers, and contractors of all three projects were willing to innovate and apply locally unfamiliar but proven techniques. While none of these examples confronted extreme skew, width variations, or other geometric complications, several of the coauthors have designed bridges using CIP concrete to efficiently address such requirements.

Where there is a tight schedule, or traffic must be maintained below the bridge, using CIP concrete might seem counterintuitive. But the incremental launching used at Belleair Beach proceeded quickly enough that the contractor termed it an example of accelerated bridge construction. The entire Grand Avenue slab was completed 10 days ahead of the allowed 95-day construction window. At the U.S. 61 and Grand Avenue structures, the contractors were able to use economical scaffolding-style falsework, and, at U.S. 61, to still maintain traffic on Second Avenue. At Belleair Beach, the limited footprint required for incremental launching allowed traffic on the causeways to be

maintained throughout construction. An additional advantage of CIP concrete is that it does not require the use of large cranes. That can be a decisive criterion where space is limited.

Whenever an unusual method of bridge construction is proposed, questions are always raised about whether there will be a "premium" cost compared to a more conventional structure. When considering bridges like the three described in this article, that question is, to some degree, irrelevant. No conventional structure could meet the requirements that these three bridge approaches had to meet. With that in mind, none of the designers attempted cost comparisons of alternative structural systems.

Even when looking at the construction contracts, it is difficult to determine what the approach structures themselves cost. To start with, all three are relatively small components of much larger projects. Also, the U.S. 61 structure was a design-build project and Grand Avenue was a CM/GC project, so separate cost figures were not available

Figure 10. Restaurant seating in the public area below the Grand Avenue Bridge. Photo: Davis Deaton.



— RAISING THE BAR

from the contractors. However, none of the contractors raised objections to the CIP concrete or complained that it imposed unbearable cost burdens. Indeed, the Belleair Beach contractor even cites his project as an example of cost-effective accelerated bridge construction! So, it does not make sense to assume that CIP concrete will impose an unnecessary or unreasonable cost premium on a project.

These three examples prove that CIP concrete slabs deserve consideration for bridges with tight vertical clearance restrictions or geometrical complications, or where the owner needs to provide for public uses in the areas below the structure, or even where there is a need to dampen noise intrusion below the bridge. 

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