PROJECT

Grand Avenue Bridge
Glenwood Springs, Colorado

by Clint Krajnik, RS&H Inc.

Overhangs with tapered coffers illuminated by architectural lighting. All Photos and Figures: RS&H Inc.

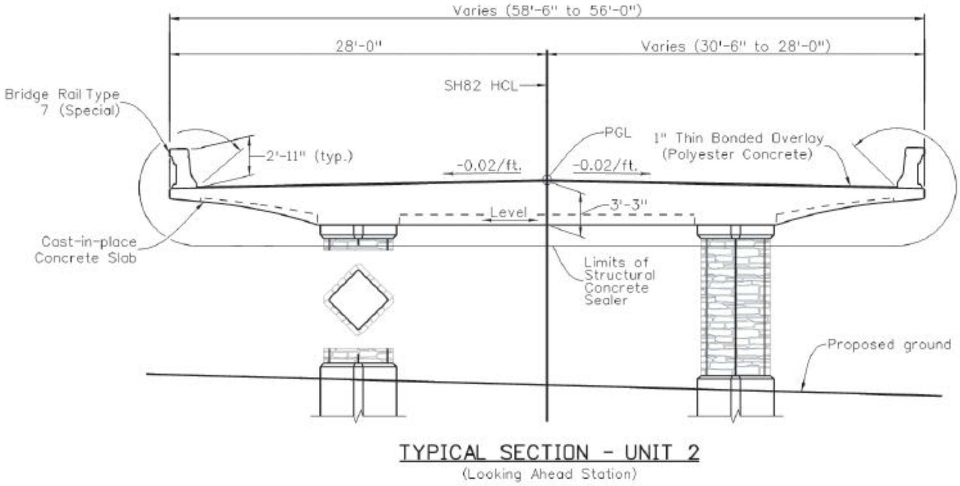
A half century after its construction in 1953, the nine-span steel plate girder Grand Avenue Bridge in Glenwood Springs, Colo., was functionally obsolete, with travel lanes just over 9 ft wide. The Colorado Department of Transportation (CDOT) decided the structure had to be replaced and sought a durable, aesthetically pleasing design for the new viaduct.

Aesthetic and Functional Concrete Design

The new viaduct has two units. Unit 1 of the new viaduct carries Grand Avenue (State Highway 82) over Interstate 70, the Colorado River, and the Union Pacific Railroad on a curved steel superstructure. Unit 2, known as the downtown unit, is an architecturally enhanced cast-in-place concrete slab bridge that descends into the city's historic central business district, serving as the aesthetic focal point of the project.

For the 197-ft-long downtown unit, which has three spans (60, 77, and 60 ft) and includes the spans over 7th Street and a planned pedestrian plaza, the project team selected a 3-ft-thick cast-in-place concrete slab bridge. This design provides a thin structure to improve overhead clearance for the plaza below and opened possibilities for creative concrete forming of the slab soffit to enhance the user experience. A concrete slab superstructure was also preferred for its sound-deadening attributes, which would mitigate noise from traffic on the bridge reaching the plaza area beneath it. As another noise-abatement measure, a solid parapet was chosen for the bridge rail.

Typical section of the cast-in-place conventionally reinforced concrete slab bridge. Coffer recesses on the bottom of the slab were up to 9 in. deep.



Cast-in-Place Concrete for an Accelerated Schedule?

Aesthetic opportunities aside, the decision to use cast-in-place concrete at first seemed counterintuitive. The construction schedule for the last two spans of unit 1 and the entire downtown unit was limited to a 95-day window during which Grand Avenue would be closed as the bridge was replaced. This tight timeline might seem to rule out cast-in-place concrete, which is not considered a speedy

profile

GRAND AVENUE BRIDGE / GLENWOOD SPRINGS, COLORADO

BRIDGE DESIGN ENGINEER: RS&H Inc., Denver, Colo.

PRIME CONSULTANT: Jacobs Engineering, Denver, Colo.

OTHER CONSULTANTS: Bridgescape LLC, Columbia, Md.

PRIME CONTRACTOR: Granite/RLW Joint Venture, Glenwood Springs, Colo.

Epoxy-coated reinforcement was used in the slab. The reinforcement projecting into the slab from an integral column is visible.

Shading on the tapered overhangs produces a visually thin superstructure. The stone finish on the columns matches the color of the mountains in the area.

construction method. However, cast-in-place concrete construction does not require the use of large cranes, and that was an advantage on this project where construction equipment had to fit between adjacent downtown buildings. Also, because 7th Street was permitted to be closed during construction, the contractor was able to use economical scaffolding-style falsework to construct the unit.

To help accommodate the accelerated closure schedule, several of the bridge's spread-footing and drilled-caisson foundations were strategically located under or outside of the existing bridge footprint, allowing their installation prior to the closure. The slab for the downtown unit was cast in one continuous concrete placement of roughly 940 yd^3. A single shift crew worked 15 hours and placed 65 to 70 yd^3 of concrete per hour to construct the slab. During the closure, the contractor increased the crew size to work in shifts 24 hours per day, 7 days per week to increase production rates. CDOT provided an incentive for the contractor to finish early and a disincentive for finishing late. According to Roland Wagner, CDOT's project manager, "The public was supportive of a shorter-duration full closure instead of the long-term hassle of a phased approach, so we went with the full closure and did what we could to minimize impacts." Construction on the downtown unit started in August 2017, and the structure was open to traffic 10 days ahead of schedule in November 2017. The project was completed in June 2018.

Post-tensioning of the slab bridge was considered to achieve an even thinner structure, providing additional overhead clearance while gaining the serviceability

The longitudinal ribs between coffers define the primary load paths through the structure.

COLORADO DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Unit 2: Three-span, 197-ft-long, cast-in-place conventionally reinforced concrete slab bridge with epoxy-coated reinforcement

STRUCTURAL COMPONENTS: Unit 2: Cast-in-place concrete coffered slab with varying-thickness overhangs supported on cast-in-place concrete columns, spread footings, and drilled shafts

BRIDGE CONSTRUCTION COST: \$2.8 million (\$255/ft^2 of bridge deck) for Unit 2

AWARD: 2018 Rocky Mountain Chapter ACI Excellence in Concrete Award, Infrastructure Category

Scaffolding-style falsework was used for construction of the new bridge in close proximity to existing buildings. This style of falsework was also a factor that made the cast-in-place concrete slab economical. The use of simple scaffolding and large crews helped accelerate construction.

benefits of prestressed concrete. However, the extra steps of tendon installation, tensioning, grouting, and installing concrete cover caps would have increased the duration of the Grand Avenue closure, which was already pushing the boundary of public acceptance.

Aesthetic Innovations

Given the planned pedestrian plaza area under the bridge, Frederick Gottemoeller, the project's bridge architect, suggested two key improvements over a typical slab bridge. First, typical blunt slab edges were replaced by graceful, 10-ft-wide tapered and arched overhangs. "The taper allows more natural light to enter the space under the bridge, and the arched profile complements the historic character of Glenwood Springs," Gottemoeller said. "The taper also makes it impossible for an observer to judge how thick the slab actually is. It looks like it is only as thick as its edge. That allows the downtown unit to fit better with the delicate 19th-century architecture only a few feet away."

Further paying homage to the traditional aesthetic, a coffered bottom soffit was proposed. The "coffers" consist of large, 9-in-deep rectangular recesses in both the flat middle portion of the slab and within the tapered overhangs. "The coffers are effective at imposing a pedestrian scale to what would otherwise be a wide, smooth expanse of concrete," Gottemoeller noted. A pattern of rectangular impressions was added to the back of the concrete barrier to complement the coffers. Another aesthetic enhancement was the elimination of pier drop caps throughout the bridge. Instead, the structure has integral pier caps that reduce the visual mass at the piers and allow unobstructed views from under the bridge toward the city's historic architecture, the Colorado River, and the beautiful mountain scenery. The nearly 60-ft-wide bridge used only two widely spaced columns per pier, which further opened the pedestrian plaza. The square columns of the piers were rotated 45 degrees relative to the bridge, producing a "diamond" orientation to enhance the aesthetics of the plaza. Additionally, a rose-colored, ashlar-pattern cut-stone veneer was applied between the formed concrete capitals and pedestals of the columns, abutment, and wingwalls.

Atypical Slab Bridge Behavior

Concrete slab bridges with mild reinforcement are among the easiest structure types to design. Equations for live load distribution can be combined with a simple beam-model analysis and force effects are easily calculated. Typically, the structural capacity is also easy to calculate using the 1-ft-wide strip assumption of a solid section. However, the architectural enhancements on the Grand Avenue Bridge project complicated the slab's behavior.

"Because of the ribs created by the deep coffers, the presence of wide tapering overhangs, and the discretely spaced columns that frame into the superstructure, we knew early on that this wasn't going to be a typical slab design," said Jack Garrison, RS&H's structural design engineer for the downtown unit. To capture the true behavior, the bridge was analyzed using a three-dimensional plate model in LARSA 4D software. "We used varying shell thicknesses to model the changes in section depth at the coffers and through the tapered overhang, with the discrete columns modeled as beam elements," Garrison said.

With the refined analysis approach, Garrison learned that force effects from both dead and live loads funneled quickly to the two main longitudinal ribs that lined up with the columns, thus minimizing the force effects in the integral cap between columns. "The results showed us where the reinforcing steel was really needed, and the longitudinal ribs, especially near the columns, required the most concentrated reinforcement, while the integral pier caps required only a nominal amount of steel," he explained.

Durability Mitigation

Durability of the reinforced concrete structure was enhanced by using epoxy-coated reinforcement and a polyester concrete overlay, both of which are proven mitigation measures against the corrosive magnesium chloride used on Colorado's roads during the winter. In lieu of a colored concrete coating, exposed concrete surfaces were left in their raw natural state, a preference shared by both the architect and the local stakeholder groups, to create a more authentic aesthetic within the historic downtown setting. The contractor used enhanced procedures, forming techniques, and systems to achieve the best quality natural concrete finish. For protection, a flat-finish clear silane concrete sealer was applied to all exposed concrete surfaces.

Conclusion

In November 2017, after the contractor finished construction 10 days early, more than 3000 people attended a bridge walk-on and opening ceremony just before the structure was opened to traffic. "The public response was overwhelmingly positive," said Wagner. "The downtown unit is now a popular gathering spot for the historic downtown area, with movie nights under the bridge and live concerts also using the new venue."

Clint Krajnik is the Denver Bridge Group leader with RS&H Inc. in Denver, Colo.