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San Francisco, California

INTERSTATE 15/U.S. ROUTE 95 HIGH-OCCUPANCY VEHICLE CONNECTOR BRIDGE

Las Vegas, Nevada

GILMAN DRIVE OVERCROSSING AT THE UNIVERSITY OF CALIFORNIA

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PROJECT

Flying Over Las Vegas

Interstate 15/U.S. Route 95 High-Occupancy Vehicle Connector Bridge

by Daniel Baker and Nick Eggen, HDR Engineering Inc.

Project Neon's signature bridge is the high-occupancy vehicle connector flyover in Las Vegas, Nev. All Photos: Kiewit Corporation.

For nearly 20 years, the Nevada Department of Transportation has been planning and preparing for the largest and most expensive public works project ever constructed in the state. In the fall of 2015, Project Neon was officially awarded under a design-build contract, and its design phase began shortly thereafter. An important component of Project Neon, the widening and reconstruction of 3.7 miles of Interstate 15 (I-15) between Sahara Avenue and the U.S. Route 95 (U.S. 95) interchange, is currently nearing completion. This stretch of interstate is currently the busiest portion of roadway in Nevada, serving over 300,000 vehicles per day.

Installation of the reinforcement cage for a 11-ft 6-in.-diameter drilled shaft, located in the median of U.S. Route 95. Shafts were more than 100 ft deep in several locations.

Geometry for the Project's Signature Bridge

Included in this $600 million project is the "signature" high-occupancy vehicle (HOV) connector bridge, an 18-span, 2600-ft-long flyover structure that directly connects the new HOV lanes between U.S. 95 and I-15 in the heart of Las Vegas. The bridge begins and ends on a tangent alignment and completes a greater than 90-degree left-hand turn on an 875 ft radius. The structure's entrance and exit are in the center medians of each arterial, all while crossing I-15, U.S. 95, Martin Luther King (MLK) Boulevard, and several other ramps. Superelevation varies drastically throughout the length of the structure. On the I-15 side, the bridge has a 3% right-down superelevation and quickly makes a full reversal to an 8% left-down superelevation, which is held constant throughout the main portion of the curve. Near U.S. 95, the superelevation transitions again, finishing in a 2% crown over the last several spans. While the bridge superelevation makes a full reversal and crown break, the profile rises from I-15 at a 5% grade before reaching a plateau at a 0.5% slope. Finally, the flyover drops from the sky at a 6% grade to tie back into U.S. 95.

profile

INTERSTATE 15/U.S. ROUTE 95 HIGH OCCUPANCY VEHICLE CONNECTOR BRIDGE / LAS VEGAS, NEVADA

BRIDGE DESIGN ENGINEER: HDR Engineering Inc., Coeur d'Alene, Idaho

PRIME CONTRACTOR: Kiewit, Omaha, Neb.

PRECASTERS: TPAC, Phoenix, Ariz. (girders) —a PCI-certified producer; Precast Management, Las Vegas, Nev. (precast deck panels)

POST-TENSIONING CONTRACTOR: DYWIDAG-Systems International, Long Beach, Calif.

DRILLED SHAFT SUPPLIER: Hayward Baker, Hanover, Md.

A hammerhead pier configuration was selected for pier locations where possible. Pier caps are 61 ft wide and 11 ft deep over the columns. The cast-in-place concrete caps are conventionally reinforced.

Considering the required bridge geometry, the search to find the most efficient bridge design possible for the structure began during the project pursuit phase. Designers recognized that optimizing individual elements could have a compounding effect that would lead to an overall more efficient system.

Pushing Boundaries to Find Superstructure Efficiencies

Finding the most efficient girder shape, concrete strength, frame layout, and girder spacing (and resulting number of girder lines) was paramount to achieving the most efficient structure possible. The bridge superstructure consists of six 3-span frames composed of California wide-flange (CAWF) precast concrete girders made continuous for live load. The girders are spaced at a remarkable 13 ft 7.5 in. The girders are arranged along chords of the 875-ft-radius horizontal curve between piers. Because of the curved edge of the bridge deck, there are variable deck overhangs. Spans range in length between 124 and 162 ft, for a total bridge length of 2606 ft. Two CAWF girder sizes, 66 in. and 84 in., are used on the bridge structure, and each type of girder uses high-strength (10 ksi), self-consolidating concrete. The overall depth of the superstructure varies with span and according to haunch requirements. In general, the depths are about 8 ft 6 in.

One of the two straddle bents on the project, which are critical aspects of the bridge layout. To keep span lengths reasonable so precast concrete girders could be used, straddle bents were required to span more than 100 feet over each mainline arterial.

The bridge is 62 ft wide with a 9.5-in.-thick deck. The deck is composed of a 4-in.-thick partial-depth precast concrete deck panel and a 5.5-in.-thick cast-in-place topping slab. Because of the climate in the Las Vegas area, standard plain reinforcing bars are used for the entire project; epoxy-coated reinforcing steel or other methods of corrosion protection are simply not needed.

Substructure Optimization

In addition to seeking an efficient superstructure design, designers were challenged to find the most economical substructure layout feasible given the geotechnical conditions of the site and surrounding geometric constraints. Efficiency came in the form of conventionally reinforced, single-column hammerhead piers. Column heights range between 13 ft 0 in. and 60 ft 5 in. throughout the length of the bridge. Most columns are rectangular in cross section and measure 7 ft by 10 ft, with 1 ft corner chamfers. However, two exceptions to this pier size were made where the bridge alignment crosses I-15 and U.S. 95 at extreme skews. In these locations, post-tensioned (PT) straddle bents were used to achieve reasonable superstructure span lengths given the chosen girder types. The PT straddle caps are 8 ft 6 in. wide by 11 ft 6 in. deep and include 12 PT ducts, each with thirty-one 0.6-in.-diameter strands, for a total initial post-tensioning force of 16,000 kip. These straddle bents, which span 106 ft 0 in. over I-15 and 104 ft 6 in. over U.S. 95, are supported by 8-ft-square columns, with 1 ft corner chamfers. Because of the large amounts of post-tensioning in the caps, tensioning was completed in stages to ensure that temporary concrete stresses remained within the limitations of American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*.

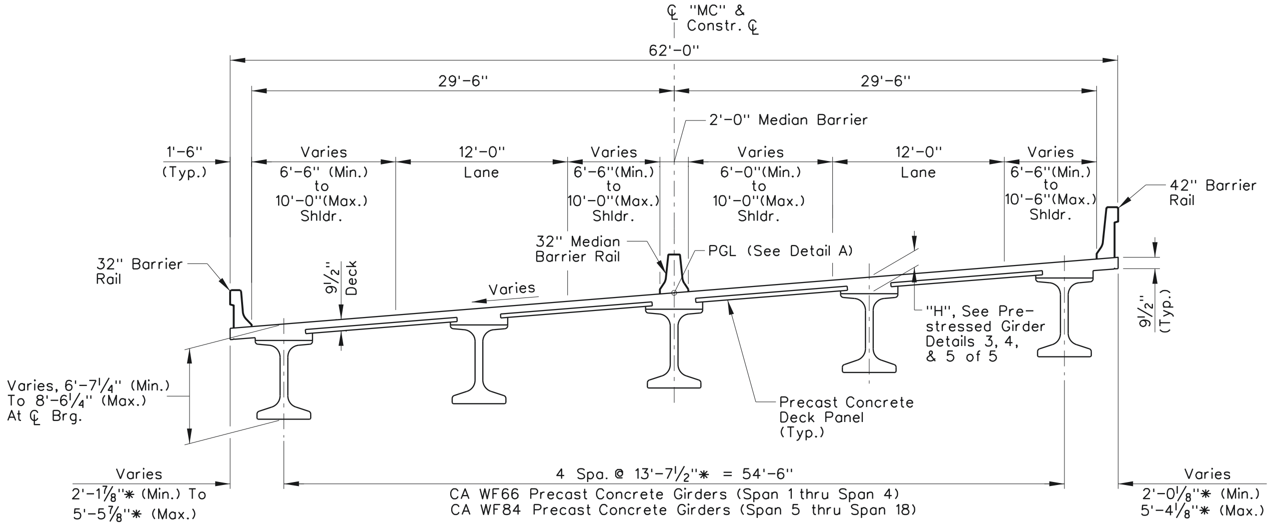
Drilled Shafts—What Lies Beneath

In the original concept, the foundation design included groups of small-diameter shafts with a typical cap

NEVADA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: An 18-span, 2600-ft-long curved flyover bridge that uses precast, prestressed concrete girders placed on chords, partial-depth precast concrete deck panels, post-tensioned straddle bents, and drilled-shaft foundations.

STRUCTURAL COMPONENTS: Ninety California wide-flange precast, prestressed concrete girders; 4-in.-thick partial-depth precast concrete deck panels composite with a 5.5-in.-thick cast-in-place concrete deck; conventionally reinforced single-column hammerhead piers; two post-tensioned concrete straddle bents; and 11.5-ft-diameter drilled shafts



TYPICAL SECTION

(Looking Ahead Station)

∗ Dimensions are measured normal to the ℄ Girder

All other dimensions are measured normal to the Construction ℄

A typical section of the HOV connector flyover bridge. Chorded precast concrete girders spaced at 13 ft 7½ in. highlight the efficiencies realized in the project design. Precast, prestressed partial-depth concrete deck panels contribute construction-related efficiency for the bridge superstructure.

footing supporting each column. This design was soon revised during the pursuit phase of the project to use a single, large-diameter drilled shaft for each column. The single, large-diameter drilled shaft was more economical than the shaft groups for this application. Additionally, in pinched areas where the flyover departs or ties in with I-15 and U.S. 95, the single-shaft configuration provided a clear geometric solution that would significantly reduce the structure's impact during construction on the adjacent roadway and the general public.

To support the typical 7 ft by 10 ft column and provide adequate reinforcement clearances between the column and the drilled-shaft reinforcement cages, drilled shafts were oversized by 1 ft 6 in., resulting in a diameter of 11 ft 6 in. Shaft lengths typically range between approximately 70 and 100 ft, with a few shafts in excess of 100 ft deep.

The design of the drilled shafts for the structure is controlled by axial demands. However, the single-shaft configuration provides a significant contribution to overall lateral flexibility of the bridge. The consequences of this flexibility for the design of the overall structure are both adverse (p-delta effects) and beneficial (a higher seismic period leads to lower accelerations). Even after consideration of the detrimental effects, the single-shaft configuration provided clear economic and geometric benefits to the bridge design. As these drilled shafts were constructed, their size and scale made quite an impression on observers.

The Final Puzzle Piece

The largest efficiency realized for the structure was the simplest—making the bridge shorter. This concept required the most "outside of the box" thinking on the project. The original HOV connector concept called for a total structure length of 4668 ft. To reduce the bridge length to 2600 ft would require a drastic change to the point where the flyover landed within U.S. 95. Because of a width restriction between existing bridges over MLK Boulevard, the HOV concept structure remained in a viaduct configuration until the U.S. 95 split was wide enough to land the HOV lanes in the center median. This original conceptual design resulted in a structure length extending for more than 2000 ft past MLK Boulevard.

The resolution of this issue was linked to the existing northwest ramp direct-connect bridge, an adjacent flyover bridge that landed on the west side of MLK Boulevard. This bridge was not originally scoped to be modified or replaced. However, the design team noticed that if the last frame of the existing bridge were realigned and reconstructed, it would create sufficient width to shift the U.S. 95 northbound structure far enough to the north so that the HOV connector flyover could touch down just to the west of MLK Boulevard. This innovation eliminated more than 2000 ft of bridge when compared to the base concept, resulting in roughly $20 million in savings. This concept was made possible by the alternative technical concept process within the design-build delivery model. Without this avenue for change, this type of innovation would not likely be realized or put into action.

Design Smart

Project Neon's HOV connector flyover bridge is a shining example of the benefits of using standard concrete bridge elements while also pushing the boundaries of what is possible for a precast concrete girder bridge. Often, the most economical design can be found by leveraging individual element efficiencies to create a compounding effect that significantly reduces the structure's costs for the client and general public. For more information on this project, see the Concrete Bridge Technology article in this issue of *ASPIRE*®.

Daniel Baker and Nick Eggen are bridge engineers for HDR Engineering Inc., in the Coeur d'Alene, Idaho, and Las Vegas, Nev., offices, respectively.

Stretching the Limits of Precast Concrete

by Daniel Baker and Nick Eggen, HDR Engineering Inc.

The Nevada Department of Transportation's $600 million design-build Project Neon includes a connector flyover bridge linking high-occupancy vehicle (HOV) lanes between Interstate 15 (I-15) and U.S. Route 95 (U.S. 95) in the heart of the Las Vegas, Nev., transportation corridor. The connector bridge's geometry involves a greater than 90-degree turn in 18 spans on an 875 ft horizontal radius, all while crossing multiple alignments at severe skews. That geometric complexity might seem to dictate the use of a steel plate girder superstructure. However, the design team refused to accept the status quo and chose precast, prestressed concrete girders for the superstructure.

Chorded, precast, prestressed concrete girders provided an economical solution for Project Neon's high-occupancy vehicle connector bridge in Las Vegas, Nev. The temporary lateral girder bracing visible in in the photo was removed when the structure was completed. All Photos and Figures: Kiewit Corporation.

Three girder shapes were analyzed during the design process: the Utah bulb tee, the Idaho Transportation Department's wide-flange girder, and the California wide-flange girder (CAWF). Each shape has distinctive attributes, but all three are similar in top-flange width (approximately 4 ft 0 in.), web thickness (6 to 6.5 in.), and bottom flange width (3 ft 2 in. to 3 ft 9 in.). All three shapes can also vary in depth by 6- or 8-in. increments. However, the larger bottom flange of the CAWF shape had a distinct advantage for this project because the larger flange lowers the centroid of the section and allows for more prestressing strand to be used for design.

For the connector bridge, large amounts of prestressing were coupled with the use of 10-ksi, high-strength girder concrete to maximize design efficiency. Additional layout efficiencies were captured by making the girders continuous for composite loading through the use of continuity diaphragms at the piers. The superstructure was arranged into six 3-span frames, which balanced the positive moments in the girders to the furthest extent possible while considering span arrangement requirements.

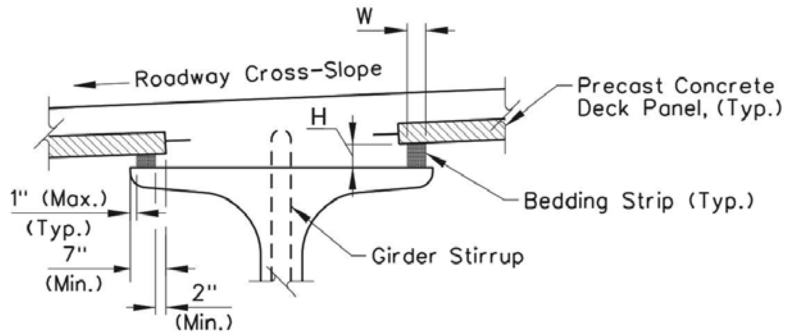
The girders are arranged along chords of the 875-ft-radius horizontal curve between piers. Pushing the span limits of a curved bridge with chorded girders turned out to be a significant limitation in itself. Deck overhangs varied and had to be kept within manageable boundaries, which essentially limited span lengths to approximately 150 ft. Greater span lengths within the curve would create either too small of an overhang or an extremely large overhang that would require extra measures, such as transverse post-tensioning. Precast concrete girders were well-suited for this span range. High-strength, self-consolidating concrete with a design compressive strength of 10 ksi was used for the precast concrete girders. Concrete strength at transfer was designed to be as low as possible to aid in the fabrication schedule.

After the basis for the superstructure's design (girder type, maximum span lengths, frame layout, and concrete strength) was established, it was time to determine the final major design parameter—girder spacing. The 62 ft 0 in. width of the deck lent itself well to a five-girder layout using steel plate girders. This layout would have an approximate girder spacing of 13 ft 9 in. with 3 ft 6 in. overhangs. Girder spacing of this magnitude is relatively routine when steel plate girders are used. However, the design team was using precast concrete girders, and the proposed spacing of 13 ft 9 in. seemed improbable. This girder spacing was beyond that used in any of the design team's previous precast concrete girder projects.

At this point, the design team evaluated all feasible efficiency modifications. In the end, their calculations seemed to support the proposed spacing. Still skeptical, the design team searched for all possible reasons why the spacing would not work. Aside from the standard girder design calculations, engineers investigated other design issues such as deck span, girder top-flange lateral bending, and girder deflection requirements. Surprisingly, every design check came back favorable. After more analysis and optimization, designers landed on a girder spacing of 13 ft 7½ in. The design team took a deep breath and moved forward with design.

To maximize construction efficiency and reduce the amount of traditional deck formwork to be placed and stripped 60 ft in the air, stay-in-place partial-depth precast concrete deck panels were used for the deck design. Panel dimensions were standardized at 11 ft by 8 ft by 4 in. Each standard panel contains twenty-one $\frac{3}{8}$-in.-diameter strands. Panels are

Installation of a California wide-flange (CAWF) girder at a straddle-bent location, with the neon lights of Las Vegas shining in the background. Compared with similar girder cross sections, the larger bottom flange of the CAWF shape allowed for more prestressing strands to be used.



A detail of the typical support condition of the 4-in.-thick precast, prestressed concrete deck panels.

normal to the centerline of the girders, and, because of the chorded girders and the curve of the alignment, the panels needed to have a skewed end at most pier locations. This was accommodated through the use of a special skewed-panel (trapezoidal) design.

While the design of the precast concrete deck panels was simple and straightforward, the design and practical accommodation for girder haunches (or buildups) and temporary deck panel support were far from ordinary. Along with typical precast concrete girder haunch considerations, the unique aspects of the bridge, such as the large and drastically varying superelevation and the effect of chorded girder geometry, had to be evaluated. Ultimately, the design heights of camber strips ranged from a minimum of 1 in. to a maximum of 11.5 in.

Deck panel support consisted of polystyrene camber strips placed at the edges of the girder top flanges. These strips are considered temporary—edges of panels become rigidly supported once the deck and haunch have cured. Design of the polystyrene supports was limited to a maximum height-to-width ratio of 2.0; therefore, with a maximum design height of 11.5 in., the maximum actual width was approximately 6 in. To ensure that this extreme haunch height could be accommodated without loss of panel stability, full-scale testing of a sample panel and camber strip assembly was performed before the final design was completed. Furthermore, during construction, panels were connected at intermittent locations along the girder for additional temporary stability. Additional panel stability was achieved by using tie wire to connect the panel-lifting loops (at four locations on each panel) to the projecting shear stirrups in the girders.

The underlying theme for the design of the HOV connector flyover bridge can be summarized in two themes: "push boundaries" and "design smart." The design efficiencies realized on this bridge resulted in enough savings to add an additional bridge replacement to the project. This outcome offers clear benefits to the owner and general public. In times where infrastructure funding is tight and often difficult to secure, finding real and practical design efficiencies should be high on every engineer's to-do list. (For additional information on this project, see the Project article in this issue of *ASPIRE*®.)

Daniel Baker and Nick Eggen are bridge engineers for HDR Engineering Inc., in the Coeur d'Alene, Idaho, and Las Vegas, Nev., offices, respectively.

Partial-depth precast, prestressed concrete deck panels were used in the deck. The 4-in.-thick panels eliminated the need to strip deck formwork 60 ft in the air and accelerated bridge construction.