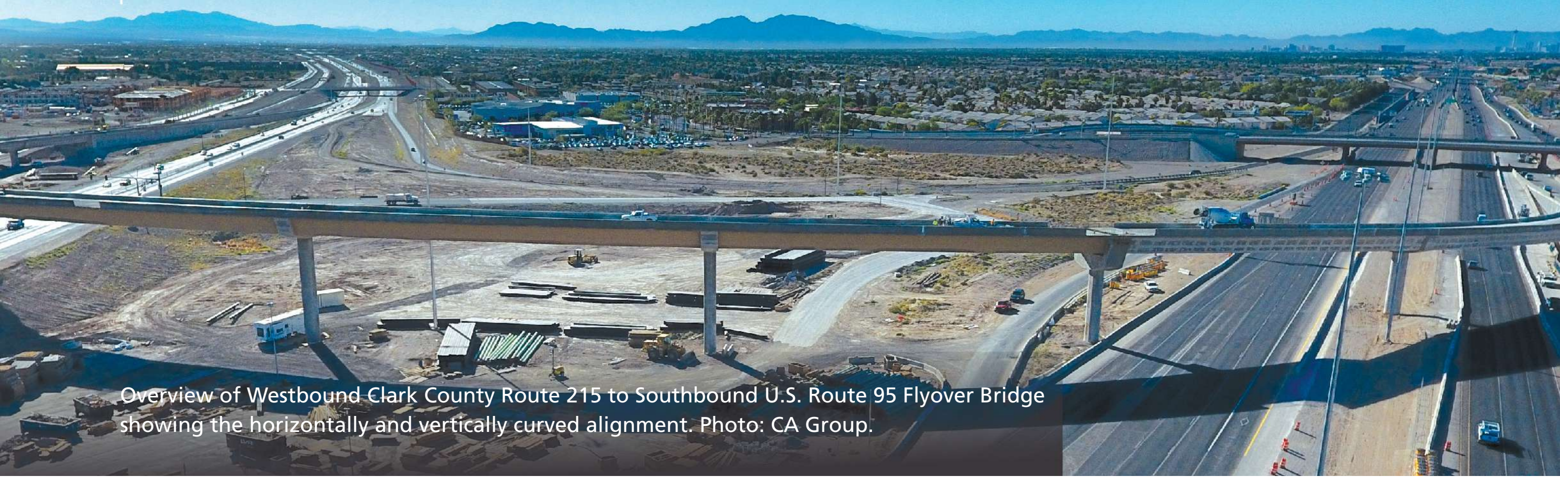
PROJECT

Centennial Bowl Interchange

Westbound Clark County Route 215 to Southbound U.S. Route 95 Flyover Bridge

by Michael Taylor, Nevada Department of Transportation



Overview of Westbound Clark County Route 215 to Southbound U.S. Route 95 Flyover Bridge showing the horizontally and vertically curved alignment. Photo: CA Group.

The U.S. Route 95 (U.S. 95) northwest corridor in Las Vegas is one of the fastest-growing areas in southern Nevada, and the U.S. 95/Clark County Route 215 (CC 215) Interchange serves as a critical link for regional commuters between the predominately residential areas in northwest Las Vegas and the large employment centers in the area. To meet the growth in the region, the Nevada Department of Transportation (NDOT) is currently upgrading the U.S. 95/CC 215 Centennial Bowl Interchange, the third busiest intersection in the state, from an at-grade intersection to a full system-to-system interchange.

In 2008, NDOT began design on the interchange, which was initially estimated to cost around $250 million. To work within funding constraints, the project was divided into three projects. In July 2017, the first phase of the interchange—a 2365-ft-long post-tensioned cast-in-place (CIP) concrete box girder carrying westbound CC 215 to southbound U.S. 95 (WS Flyover)—was completed.

Type Selection

Type selection and preliminary layout for the Centennial Bowl Interchange structures began in 2010. NDOT considered four different superstructure types for the interchange's 15 grade separations: CIP post-tensioned box girders; steel plate girders; precast concrete I-girders; and precast concrete U-girders. Structure types were evaluated based on cost, aesthetics, constructability, and durability. For the three large flyover structures, the selected structure type needed to accommodate spans longer than 200 ft, horizontally and vertically curved alignments (horizontal radii less than 850 ft), and superelevations of 6%. Historically, the CIP post-tensioned box girder is the most cost-efficient bridge type in Nevada, with typical costs under $150 per square foot of deck. At the time of type selection, steel plate girders and precast concrete girders cost $200 per square foot and $220 per square foot, respectively.

The geometric constraints of the interchange favored the CIP and plate girder solutions, with CIP ultimately selected based on cost, aesthetics, and durability. The use of CIP post-tensioned box girders for the interchange will result in an estimated 14% total project cost savings, lowering the cost for total structures by $30 million compared with steel plate girders.

Design

The WS Flyover is a fourth-level ramp, crossing over the major U.S. 95 and CC 215 roadways, six future interchange ramp movements, one existing local road, and a 36-in.-diameter high-pressure gas line. Due to these horizontal constraints, the layout of the flyover uses three frames with lengths of 858 ft, 862 ft, and 645 ft, for a total length of 2365 ft. The WS Flyover's alignment crosses the southbound lanes of U.S. 95 at a sharp skew, necessitating

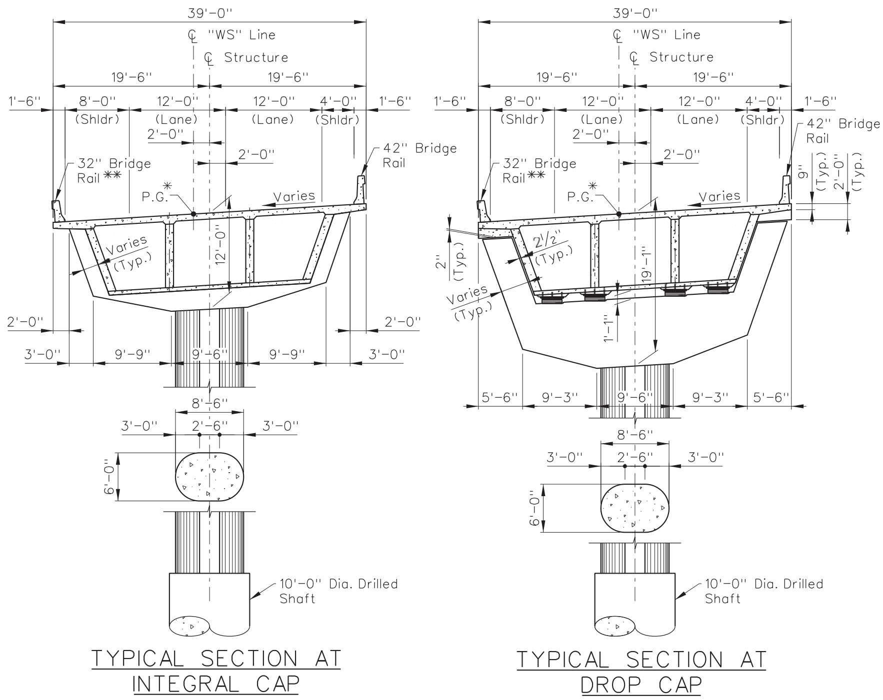
profile

CENTENNIAL BOWL INTERCHANGE (WESTBOUND CLARK COUNTY ROUTE 215 TO SOUTHBOUND U.S. ROUTE 95 FLYOVER BRIDGE) / LAS VEGAS, NEVADA

BRIDGE DESIGN ENGINEER: Nevada Department of Transportation, Carson City, Nev.

PRIME CONTRACTOR: Las Vegas Paving Corporation, Las Vegas, Nev.

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



Typical cross sections of three-cell concrete box girder and oblong column at integral and expansion piers. Figure: Nevada Department of Transportation.

a maximum span of 250 ft. The remaining 10 spans were configured to balance span lengths to maximize the efficiency of the superstructure cross section while working around the horizontal constraints imposed by the ramps and utilities.

Early in the design phase of the WS Flyover, NDOT performed Osterberg load testing on the large-diameter drilled shaft foundations. NDOT invested $600,000 in the load-testing program and realized a savings of $2.6 million in foundation costs for the WS Flyover by using the higher American Association of State Highway and Transportation Officials (AASHTO) resistance factors and higher soil capacities. Additional savings will be realized in future foundation construction phases.

The superstructure of the WS Flyover consists of a 39-ft-wide, three-cell CIP box girder, with 4-ft-wide overhangs and a 10 ft web spacing. The box-girder depth of 9.5 ft is dictated by a maximum bridge span of 250 ft, resulting in a span-to-depth ratio of 26.3.

The substructure consists of oblong-shaped single-column bents (6 ft by 8.5 ft) with integral pier caps. Per standard NDOT practice, drop-cap (or stepped-cap) expansion piers were used between frames instead of in-span hinges.

Durability considerations for the concrete included the use of 6.5-ksi high-performance concrete in the bridge deck. The project specifications mandated the use of a shrinkage-reducing admixture to limit deck shrinkage as well as the use of a three-aggregate blend in the deck concrete to reduce permeability.

The superstructure design resulted in a total post-tensioning force of 18,984 kips, achieved using twenty-seven 0.6-in.-diameter strands per tendon and four tendons per web for each of the four webs of the three-cell box. The tight 847-ft horizontal radius warranted additional design considerations. The girders were designed to resist lateral web bending due to post-tensioning and live loading, as well as global shear and torsion. Tendon confinement in the webs is provided by tie reinforcement proportioned to resist local web-bending effects, tendon deviation forces, and internal splitting forces due to the draped vertical tendon profiles.

All pier caps in the WS Flyover use post-tensioning to limit congestion of mild reinforcement, improve seismic joint performance, and increase the

Completed Westbound Clark County Route 215 to Southbound U.S. Route 95 Flyover Bridge. Photo: Nevada Department of Transportation.

NEVADA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: 2365-ft curved, cast-in-place post-tensioned concrete box girder on an 847-ft minimum horizontal radius (11 spans with a 250-ft maximum span)

STRUCTURAL COMPONENTS: 39-ft-wide by 9.5-ft-deep cast-in-place post-tensioned three-cell concrete box girder superstructure with 6.5-ksi, high-performance concrete deck; 10-ft-diameter drilled shaft foundations; 6-ft-by-8.5-ft oblong columns; post-tensioned integral and expansion pier caps

BRIDGE CONSTRUCTION COST: $10.1 million ($110/ft^2)

AWARD: Associated General Contractors/Nevada Contractors Association Nevada Civil Project of the Year, 2017

Falsework in place for frame 2. The maximum falsework height was 58 ft. Photo: Nevada Department of Transportation.

durability of the structure. The 3340-kip transverse post-tensioning force in each of the expansion pier caps is provided by nineteen 0.6-in.-diameter strands in each of the four tendons. Shear keys at the expansion caps restrain lateral movement of the superstructure and force composite behavior in the transverse direction between adjacent frames. These shear keys are designed to remain elastic under seismic loading, which is accomplished by permitting the supporting columns to fuse, and designing the shear keys for the associated column plastic hinging forces.

The transverse post-tensioning is a primary component of the seismic detailing, ensuring that the expansion pier caps have adequate capacity to resist lateral forces transferred through the shear keys. The 1932-kip post-tensioning in the integral pier caps is provided by 11 tendons with four 0.6-in.-diameter strands each running through the deck slab. The use of transverse post-tensioning in the integral caps was done primarily to promote durability of the bridge deck by limiting tensile stresses, but it has the added benefit of improving the joint shear performance by precompressing the joint region.

Falsework of frame 2 being lowered after completion. Photo: Nevada Department of Transportation.

Concrete box girder with reinforcement and post-tensioning ducts in place for soffit and webs. Photo: Nevada Department of Transportation.

Frame 3 tunnel bent over U.S. Route 95 with bracing. Photo: Nevada Department of Transportation.

Due to the size and complexity of the WS Flyover, seismic design was a key aspect of the design process. The flyover is the first bridge in Nevada to use the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*, 2nd edition, with 2012 Interims. In addition to these specifications, NDOT investigated the use of performance-based seismic design by evaluating the structure's performance at 500- and 1000-year-event seismic hazard levels. The performance criteria used to evaluate the columns are based on an essentially elastic response at the 500-year event, with light damage permitted at the 1000-year event. The 1000-year design response spectrum has the following site-adjusted spectral accelerations: peak ground acceleration of 0.235*g*, S_s = 0.59*g*, and S_1 = 0.33*g* (Site Class D). These values place the structure in Seismic Design Category C. The long frame length and variable column height due to the curved vertical profile result in a significant difference in stiffnesses between frames and adjacent columns. The use of isolation casings to lengthen three of the shorter columns provides a more uniform seismic response.

Construction

NDOT delivered the first phase of the Centennial Bowl Interchange via the design-bid-build delivery method in October 2015. The construction of the WS Flyover was completed in 375 working days, for a total cost of $110 per square foot.

Construction of long-frame CIP post-tensioned box girders in an urban setting poses several challenges. Due to the use of falsework, maintenance of traffic becomes an issue for construction. Careful planning during design, and coordination in construction, allowed the contractor to successfully manage traffic. For U.S. 95 traffic, adjacent collector/distributor roads served as detours for the erection and removal of falsework and during concrete placement. For daytime traffic, a minimum of three lanes in each direction was maintained. Due to the sharp skews of the WS Flyover alignment and U.S. 95, the contractor used a tunnel bent with a tiered-falsework system to maintain the minimum number of lanes.

Grouting of the longitudinal post-tensioning ducts proved to be another construction challenge, due to the vertical geometry, frame length, and the hot climate of southern Nevada. NDOT requires the use of prebagged thixotropic grout. Grouting pressures regularly exceeded 100 psi, with typical grouting durations of more than one hour for the long frames. The contractor used chilled water and took precautions to protect the grout bags from sun exposure. The grout material proved to be forgiving with respect to grouting times and temperature, maintaining its fluidity despite the long grouting durations and ambient temperatures greater than 100°F.

Conclusion

The WS Flyover, which opened to traffic in July 2017, demonstrates how CIP post-tensioned concrete bridges can provide an economical and resilient structure type for modern urban interchanges in Nevada. The CIP, post-tensioned concrete box girder structure type is well suited for the curved geometrics while maintaining a strong aesthetic appeal. Careful planning, coordination, and partnering through the construction phase successfully mitigated the typical risks associated with CIP construction. Use of high-performance deck concrete with a shrinkage-reducing admixture, as well as transverse post-tensioning at the pier caps, helps maximize the durability of the structure. With the second phase of the interchange preparing to advertise and the final phase beginning design, NDOT is confident in the choice of CIP post-tensioned box girders as the best solution for the Centennial Bowl Interchange.

Michael Taylor is a senior structures engineer with the Nevada Department of Transportation in Carson City, Nev.

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

For aesthetic as well as structural and economic reasons, box girders are an eminently suitable structural type for the flyover ramps of complex interchanges. All the lines of the superstructure—the tops of the parapets, the edges of the slabs, and the corners of the box girders—are parallel to each other and to the trajectories of the vehicles traveling across the bridge. The thin, single-shaft piers with hidden or minimal pier caps impose no cross lines or barriers to this visual flow. The pier shafts themselves are thin enough to keep the space of the interchange visually open and unencumbered, allowing drivers to see through to converging ramps and merge areas.

Although the use of cast-in-place concrete box girders can be problematic in locations where construction has to be done over existing roadways, this project successfully met the challenge. With a great deal of ingenuity, the team found methods to build the girders while still keeping traffic moving underneath. Hopefully, their experience will reassure others who are considering applying this structural type.

The slightly dropped pier caps at all of the intermediate piers add an intriguing rhythm to this structure. They punctuate the eye's progress along the curves, while at the same time creating some visual consistency with the dropped pier caps at the expansion joints. Coloring the box girder itself with a hue that contrasts with the colors of the slabs, parapets, piers, and pier caps makes obvious the visual ribbon of the girder. When viewed in the Las Vegas sunshine, the ramp is a memorable structure.

Progress photo of placement of falsework for frame 2. Photo: Nevada Department of Transportation.