SUSTAINABLE Concrete Bridge Design



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As with many states, California is faced with diminishing open space to improve congested transportation networks. Therefore, most of these improvements involve heavily-congested urban interchanges, where traffic disruption is not acceptable. Efforts are further hampered with construction cost increases in recent years that have largely outpaced inflation; thus delays in project delivery effectively diminish available budgets. All of this underscores the importance of delivering sustainable concrete bridges both cost-effectively and in an accelerated schedule. Bridge construction is often in the critical path of larger transportation improvement projects and is a significant portion of the overall project cost.

Completed low-profile precast concrete girder undercrossing on SR 22. Photo: Vinh Trinh, PBS&J.

When owner agencies and industry collaborate, the cost benefits of sustainable concrete bridge delivery are maximized, as demonstrated by the recently completed widening of the State Route 22 freeway in Southern California. Twenty-two bridges were widened, nine bridges were replaced, and three new bridges were added in an aggressive design-build schedule. These bridge improvements were part of an overall project to eliminate bottlenecks, reduce congestion, and improve safety on a 12-mile stretch of Route 22, located in Orange County, California, extending from Valley View Boulevard to its terminus at State Route 55. This project added a high-occupancy vehicle (HOV) lane, auxiliary lanes, shoulders along with ramp replacement, and interchange reconfiguration.

Formwork is placed around precast girders in the construction of a seismic-resistant integral connection with the columns. Photo: Jay Holombo, PBS&J.

The $670 million project was funded by the Orange County Transportation Authority (OCTA), and delivered using design-build, led by the Granite-Myers-Rados (GMR) joint venture. The GMR team hired PBS&J as the lead structural engineer in design and construction support. A collaborative environment facilitated by innovative project delivery methods was crucial in not only meeting the aggressive design-build schedule but also maximizing economy.

A significant challenge on the project was maintaining acceptable vertical clearance of the undercrossing and separation widening because widened bridge structures had to match the existing cross-slope and profile. Further, the widened structures had to match the structural seismic and gravity response characteristics of the existing cast-in-place box girder bridges that are both continuous longitudinally and monolithic with the substructure. And finally, disruptions to traffic had to be minimal during construction.

Agency-Industry Collaboration Maximizes Economic Benefits in California

To meet this challenge, the design-build team worked with OCTA and the California Department of Transportation (Caltrans) to select a system of precast, prestressed concrete bridge beams and stay-in-place (SIP) precast concrete deck panels with a composite concrete topping. Depending on the span range, bulb tees, California I-beams, and rectangular-shaped girders were utilized. The latter were used for shorter spans, where vertical clearance necessitated the use of bridge-specific girder depths, and exterior bridge beams to match the aesthetics of the existing cast-in-place bridges. Continuity for gravity and seismic loading was created with longitudinal reinforcement in the cast-in-place deck topping and bottom-flange continuity reinforcement mechanically coupled through the cap-beam making an integral connection with the columns. This system allowed the design-build team to expedite delivery economically while meeting the structural performance and aesthetic requirements.

One of the biggest challenges was widening the State Route 22/I-5 separation structure. This bridge spans 17 lanes of I-5 traffic on a curved alignment with a variable superelevation up to 6%, and on a 45-degree skew. The longest span is 170 ft, has an inside radius-of-curvature of 1300 ft and spans five lanes of mainline northbound I-5 traffic that had to remain open throughout the duration of the project. The design-build team elected to use curved precast, prestressed concrete tub girders to span over these lanes of traffic. These girders, measuring over 100 ft in length and weighing over 250 kips, were spliced with box girders cast on falsework using continuous post-tensioning. The contractor site-cast the curved tub girders using a cast-in-place concrete slab that was graded so the soffit would match deck contours including the variable super-elevation and camber. Vertical stems were used to simplify the interface with the cast-in-place sections. After casting, these girders were transported from the casting site, and lifted into place using a single crane. Although not necessarily new, the curved tub girder system allowed for an innovative structure that was economical, fit the aesthetic requirements of the site, and met the aggressive design-build schedule with minimum traffic interruptions. Savings amounted to approximately 10% of the overall bridge cost; however, this method had an added benefit of minimizing risk and providing a safer choice.

The challenges faced by agencies and industry, as more and more of our transportation improvements in California include highly congested urban interchanges, require innovative and cost-effective solutions to meet diminishing budgets. Construction materials and reduced cost escalation has largely outpaced inflation. To meet these challenges, agency-industry collaboration is essential in the delivery of sustainable concrete bridges, and the benefits of this collaboration have been demonstrated with successful delivery of the State Route 22 HOV widening.

Curved precast, prestressed concrete spliced girders span I-5 at the interchange with State Route 22. Photo: Rick Sharp, PBS&J.

Aerial view of State Route 22 passing over I-5 during construction. Photo: © James A. Gallego.