THE BENSON ROAD BRIDGE OVER I-405

Extending Precast Concrete Spans with Washington State's "Super Girders"

by Paul Guenther, Ben C. Gerwick Inc. and Hong Guan, CH2M HILL

The I-405 Renton, Wash., Stage 2 design-build project provides improvements to accommodate high occupancy vehicles and new freeway connections to local arterials of the city of Renton. As part of this project, the existing 1970s vintage Benson Road Bridge over I-405 was replaced with a new, wider, longer bridge that enabled widening of the freeway below. The project was part of the Washington State Department of Transportation's (WSDOT's) I-405 Corridor Improvements Program.

Superstructure Description

The replacement bridge provides for two traffic lanes, two bicycle lanes, and one sidewalk for a curb-to-curb width of 40 ft. The bridge consists of a three-span structure with spans of 132, 207, and 182 ft. The bridge was constructed with spliced precast, post-tensioned concrete girder technology. Span 1 used single segment precast girders and Spans 2 and 3 used two-segment precast girders.

Four girder lines were used, with the multi-segment spans erected on temporary falsework bents. The field-cast girder and pier closure placements were constructed monolithically with the bridge deck placement. The bridge was then post-tensioned, followed by placement of the abutment end diaphragms. The girders were then jacked up at the abutments to re-set the elastomeric bearings to relieve short-term deformations caused by post-tensioning. The final result was a highly efficient, cost-effective, durable, fully composite structure. The bridge construction was completed ahead of schedule and was opened to traffic in July, 2010.

Options Considered

The replacement for the existing Benson Road Bridge was conceptualized as a five-span curved steel plate girder bridge in the original request for proposal (RFP) documents. At 845 ft long, the RFP design represented a significant portion of the total project construction cost. The long lead time for the procurement of steel also posed a significant scheduling risk to the overall project.

During the proposal stage, the design-build team considered various alternatives. Most significant was changing the overcrossing alignment and the use of different structure types and materials. The final solution selected was a three-span alternative that would significantly shorten the overall bridge length to approximately 521 ft. The revised alignment also allowed the bridge structure to be

The Benson Road Bridge over I-405 in Renton, Wash., has spans of 132, 207, and 182 ft and at a 45-degree skew. All photos: CH2M HILL.

profile

BENSON ROAD BRIDGE / RENTON, WASHINGTON

BRIDGE DESIGN ENGINEER: CH2M HILL, Bellevue, Wash.

PRIME CONTRACTOR: I-405 Corridor Design Builders (a joint venture between CH2M HILL and Gary Merlino Construction Co.), Renton, Wash.

BRIDGE SPECIALITY CONTRACTOR: Mowat Construction Company, Woodinville, Wash.

PRECASTER: Concrete Technology Corporation, Tacoma, Wash., a PCI-certified producer

POST-TENSIONING CONTRACTOR: VSL, Wheat Ridge, Colo.

The final solution would significantly shorten the overall bridge length.

placed along a tangent alignment, thus making a precast concrete option more feasible. The revision required an additional off-ramp flyover bridge over Benson Road that was also a precast concrete structure. It was needed to accommodate the new roadway alignment, but the reduction in total deck area and the change from steel to precast concrete reduced the total bridge cost by over $700,000. The use of concrete in lieu of steel also reduced future maintenance requirements and was perceived as an advantage by the owner.

Design Constraints

Located in an urban environment, the project site is geometrically constrained. The owner's requirement to maintain all lanes of traffic on Benson Road and the I-405 freeway below during construction added additional constraints. To avoid excessively long spans, one of the center piers (Pier 3) needed to be located in the median of mainline I-405 and was thus constrained by the existing freeway on both sides. In order to limit the disruption to traffic, all construction work for Pier 3 had to be performed within a 20-ft-wide work zone centered within the median. Carefully designed shoring was needed with construction tolerances limited to a few inches. The orientation of the I-405 median relative to the new bridge alignment also dictated that the bridge would have to be placed on piers with 45-degree skews.

The uneven terrain at the project site also played an important role in the design. In order to accommodate a future on-ramp near the south end of the bridge, one of the two intermediate piers had to be designed significantly taller than the other pier. This resulted in a significant challenge to the seismic design of the bridge.

Although the project scope only involved widening existing I-405 to four lanes in each direction, the replacement bridge needed to accommodate a future widening adding a total of four more lanes. To meet this requirement, the longest span of the replacement bridge needed to be in excess of 200 ft.

Girder Selection

Conventional prestressed concrete girders were first considered due to their lower cost and the contractor's familiarity with them. Prior to 2008, the longest spans achieved with conventional precast, prestressed concrete girder sections available in Washington State was approximately 180 ft, well short of the required span. Post-tensioned, precast spliced-girders quickly emerged as feasible for several reasons. First, span lengths in excess of 200 ft were readily achievable. Secondly, spliced-girders provide the designer with greater latitude in selecting the number and location of piers, segment lengths, and splice locations—an important requirement for this project due to the extremely constrained site. Lastly, although the span lengths for spliced-girder bridges may be comparable to those of typical box girder bridges, construction methods are more conventional and falsework requirements are reduced.

Shortly after the start of preliminary design in late 2008, a new series of WSDOT precast girder sections became available. Called the WF100G/PTG, the 100 is the depth in inches (8 ft 4 in.) and the PTG indicates a post-tensioned girder section. Together with the WF83G and WF95G standards, these

Pier 2 nears completion of its column beam. Seismic isolation casings can be seen around the columns just above the ground.

Pier 3 shown during construction in the confined area in the median of I-405.

precast sections are commonly referred to as "super girders." In the case of WF100G girders, the span capability exceeds 200 ft. Although conventional pretensioned WF100G girders could achieve the span length required for the Benson Road Bridge, the design team eventually chose post-tensioned spliced girders in order to minimize transportation concerns.

The locations of the girder splices were selected so that shoring towers could be constructed with minimal impact to traffic on I-405. The first span consisted of a single segment, 125 ft long. The center span used two 100-ft-long segments. In the third span, the girders were splayed to accommodate the

SPLICED, POST-TENSIONED PRECAST GIRDER BRIDGE / WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A 521-ft-long, three-span, spliced, post-tensioned precast concrete girder bridge with spans of 132, 207, and 182 ft and a width of 40 ft inside curbs

STRUCTURAL COMPONENTS: 20 WSDOT WF100G/PTG precast concrete girder segments with composite cast-in-place concrete deck with full length post-tensioning and cast-in-place concrete substructure

BRIDGE CONSTRUCTION COST: $5.0 million ($200/ft^2)

AWARDS: 2010 American Society of Civil Engineers, Seattle Chapter, Project of the Year, Structures Category

The 8-ft 4-in.-deep girder is shown during production in the precast production building.

One of the longest girder segments at 125 ft is shown being transported to the site during nighttime erection to reduce impact to traffic.

deck flare at the northern end of the bridge. The longest segments were approximately 100 ft long and the shortest segments approximately 75 ft long. The closures between segments were 2 ft 0 in. long. Fabricating the two longer spans using two girder segments each provided for segment sizes that were more easily transported and erected. Each segment was pretensioned for handling, shipping, and erection.

Post-Tensioning

After the girder segments were erected and the concrete at the closures, diaphragms, and deck had been placed, post-tensioning was applied to the full length of the bridge to connect all segments into a continuous, fully composite structure. Post-tensioning after deck placement allowed the full composite section to be utilized for a portion of the dead load, thus maximizing the structural efficiency.

A total of four 19-strand post-tensioning tendons were used for each girder, stressed to a maximum of 3400 kips per girder at the time of jacking. The tendons were composed of 0.6-in.-diameter strands in 4-in.-diameter metal ducts. Post-tensioning was applied from one end, during which the girders lifted from their temporary supports on the shoring towers that were then removed. Then, the sidewalk and traffic barriers were installed. In addition to the enhanced structural efficiency of the resulting system, a fully composite, post-tensioned structure has the added benefit of being entirely in compression under service loads, thus eliminating flexural cracking in the deck and increasing the durability of the structure.

Considerations for Deep Girders

Although conventional pretensioned WF100G sections can span to 220 ft, the significant size and weight of the girders pose concerns for shipping and handling. At 205 ft long, the shipping weight of a single WF100G girder is approximately 250 kips. Special trucking equipment is required to haul these larger girders within legal load limits. Although the precast industry is usually equipped with these vehicles, it was decided to use shorter girder segments.

The WF100G girders are also almost 9 ft tall including the height of the protruding shear stirrups. When on the haul truck carriage, the top of the girder is over 15 ft above the roadway surface, approaching the vertical clearance limit of many bridges currently in service. An adequate haul route to the site must be assured.

To use these larger beams, crane access, reach, and maneuverability must be carefully evaluated for each site. The girder segment weight and length are both significant factors. The girders require a well-planned erection scheme. In the case of the Benson Road Bridge, a Sicklesteel 650-ton wheeled crane was used for girder erection—one of the largest wheeled cranes available in the United States.

Broader Applications

The precast concrete bridge industry is continuing to make advancements that result in more cost-efficient solutions. Advances reduce material quantities and speed construction, making better use of today's limited capital project dollars. The application of precast "super girders," combined with spliced construction techniques, is a prime example of these advancements. Once used primarily for larger and more exotic long-span bridges, this technology is quickly becoming more mainstream, with fabricators, construction contractors, and design engineers all becoming increasingly comfortable with their routine applications.

Effective use of precast concrete spliced super girders requires special design and construction considerations that may limit their use at some sites. However, with proper foresight and planning, these obstacles can be overcome at many sites, making this an effective solution for a wide range of bridge projects, from smaller grade separations and stream crossings to major bridges.

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A 125-ft-long segment is being erected in Span 1.

Epoxy-coated reinforcing steel was used to extend the life of the cast-in-place concrete deck.