Pretensioned, precast concrete hollow-core units used for interchange bridge project in Honduras

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Located about 6 km (4 mi) southwest of San Pedro Sula, Honduras, the interchange bridge project proved challenging because of its sophisticated design. With its horizontal and vertical curves, this structure is an aesthetically pleasing infrastructure project. This paper describes the design of the prestressed, precast concrete hollow-core units used for the interchange bridge.

The interchange bridge was to be a four-span, one-way bridge with an overall length of 65 m (213 ft). Each span of the curve axis was 16 m (53 ft), and the deck width was 6.8 m (22 ft). The project requirements included a roadway with a 5.5-m-wide (18 ft) travel lane and two 0.65-m-wide (2.1 ft) shoulders on each side.

In 2005, the owner was commissioned to design the interchange project, which was constructed in 2006. **Figures 1** and **2** show views of the completed bridge. **Figures 3** through **6** are the site plan and elevation of the bridge, as well as distribution plans and the cross-section details of the hollow-core units.

The interchange bridge design had a horizontal curve with a radius of 50 m (163 ft) and a vertical curve with a radius

Editor's quick points

- This paper discusses the design of the precast, prestressed hollow-core concrete beams used in an interchange bridge in Honduras.
- The use of an all–precast concrete system in both substructures and superstructures may require the designer to compromise in order to provide an ideal solution to the geometry of a curved project.
- Tolerances were the most challenging aspect of this project.

Figure 1. The underside of the completed interchange bridge is shown from the south.

Figure 2. The topside view of the interchange bridge shows the precast concrete curb and the guard barriers.

of 20 m (656 ft). The slope of the deck on the horizontal curve was 3%, with the lower elevation on the inside of the curve, which provided a safe and smooth surface for vehicles using the interchange.

Superstructure design

Prestressed, precast concrete hollow-core deck system

The superstructure consisted of the beams and deck components. The interchange bridge had four spans ranging in length from 15 m to 17 m (49 ft to 57 ft). Shear keys were included along the entire length of the units, and 25-mm-diameter (1 in.) threaded steel reinforcing bars were placed at the bottom of the units, providing transverse post-tensioning at six locations along the hollow-core units. The top flange of the hollow-core unit was wider than the standard hollow-core unit and had special reinforcement with a curved shape. This special reinforcement allowed placement of both the deck topping and the small columns supporting the railing.

The hollow-core units had a 4% slope on the two middle spans and an 8% slope on both end spans. The cast-in-place, reinforced deck made the superstructure continuous for carrying dead and live loads. The deck topping had a thickness ranging from 0.10 mm to 0.16 mm (3.9 in. to 6.3 in.), which provided a continuous smooth surface that enabled the rod system to suit the required shape of the vertical curve.

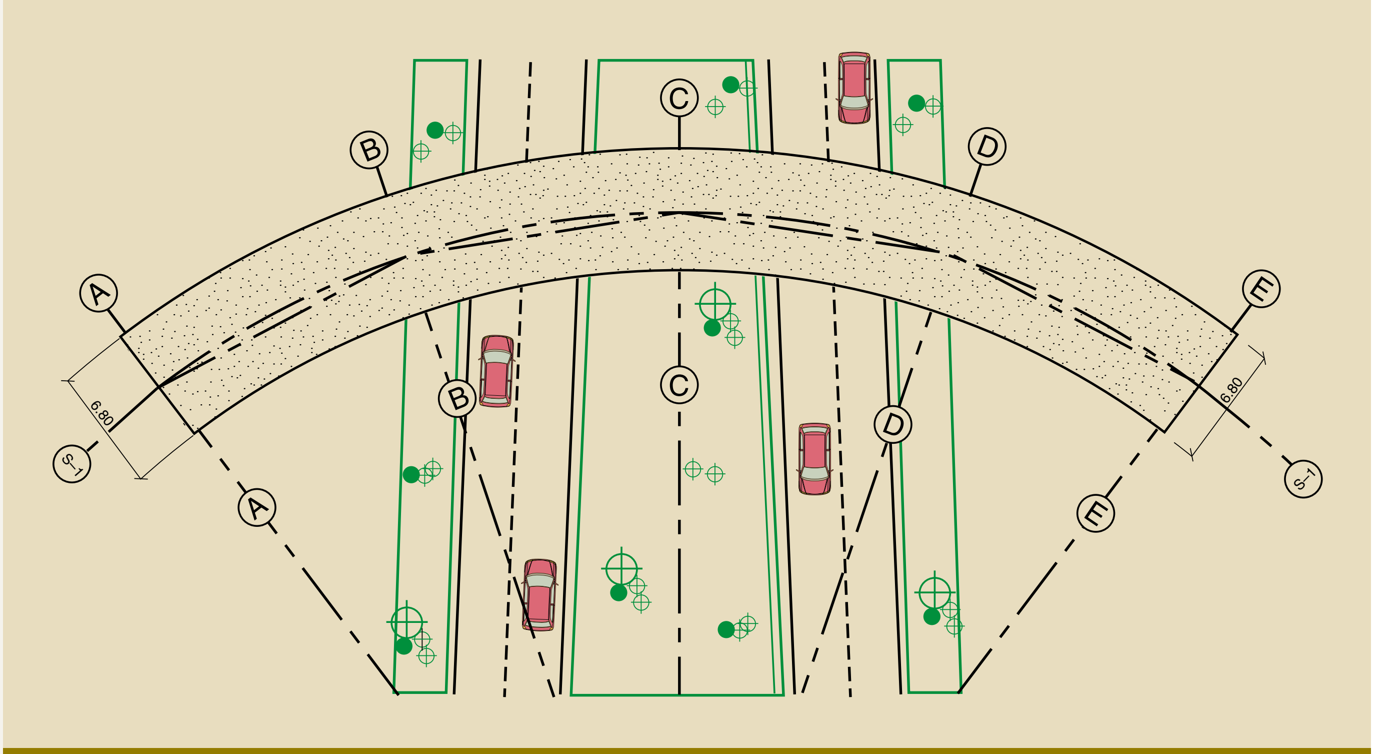

Figure 3. This figure shows the site plan of the interchange bridge project. Note: All measurements are in millimeters. 1 mm = 0.0394 in.

Prestressed, precast concrete hollow-core unit

Figures 7 and **8** show the details of the interior and exterior hollow-core units designed for this project. A total of 16 units were constructed, 8 of each type for the 4 spans. Each element consisted of a trapezoidal shape measuring 1.35 m wide × 0.70 m deep (4.4 ft × 2.3 ft). The length of the units varied from 14.9 m to 17.1 m (48.9 ft to 56.1 ft), which was necessary to satisfy the curve in the bridge. The top flanges of the eight exterior hollow-core units were attached to each edge of the deck pavement.

Inflated rubber hoses formed the hollow cores of the units. The hoses had safety valves to protect against overpressure caused by heat produced from steam curing. After concrete placement but before the curing, the hoses were deflated and pulled out of the hollow-core units. The compressive strength of the concrete was 55 MPa (8.0 ksi). Each hollow-core unit had twenty 13-mm-diameter (0.50 in.) prestressing strands. **Figures 9** and **10** show the fabrication of the units, which used long-line pretensioning technology.

Precast concrete curb and guard barriers

A total of 71 precast concrete components were used for the curb and the guard barriers on each side of the bridge. The top flange of the hollow-core units supported the curbs and the barriers. The barrier panels were parallelograms with a folded plate at the top. Each panel was about 1 m (3.3 ft) high and 0.1 m (3.9 in.) thick. The barrier panels were 2.9 m (9.6 ft) long on the outside of the curve and 2.5 m (8.3 ft) long on the inside of the curve. The 0.3-m-diameter (12 in.) columns of the barrier panels were 0.45 m (18 in.) high and were designed to resist lateral loads. They were made of cast-in-place concrete and were connected to the barriers and the curbs, which was a key feature to make the structure behave continuously. **Figures 11** and **12** show the concrete barrier panels that were placed on top of the columns and at the gap between the two columns at each radial axis. They provided an aesthetically pleasing structure and easier construction.

Substructure design

The substructure was designed with as many precast concrete elements as possible. **Figures 13** and **14** show the completed substructure cross section and elevation. It consisted of three types of precast and partial-precast concrete components. The substructural frame was composed of several piers, each made from two Y-shaped columns with a two-section footing and two beams. **Figure 15** shows the connections of the footings and beams to the columns. Both were rigidly connected to the columns.

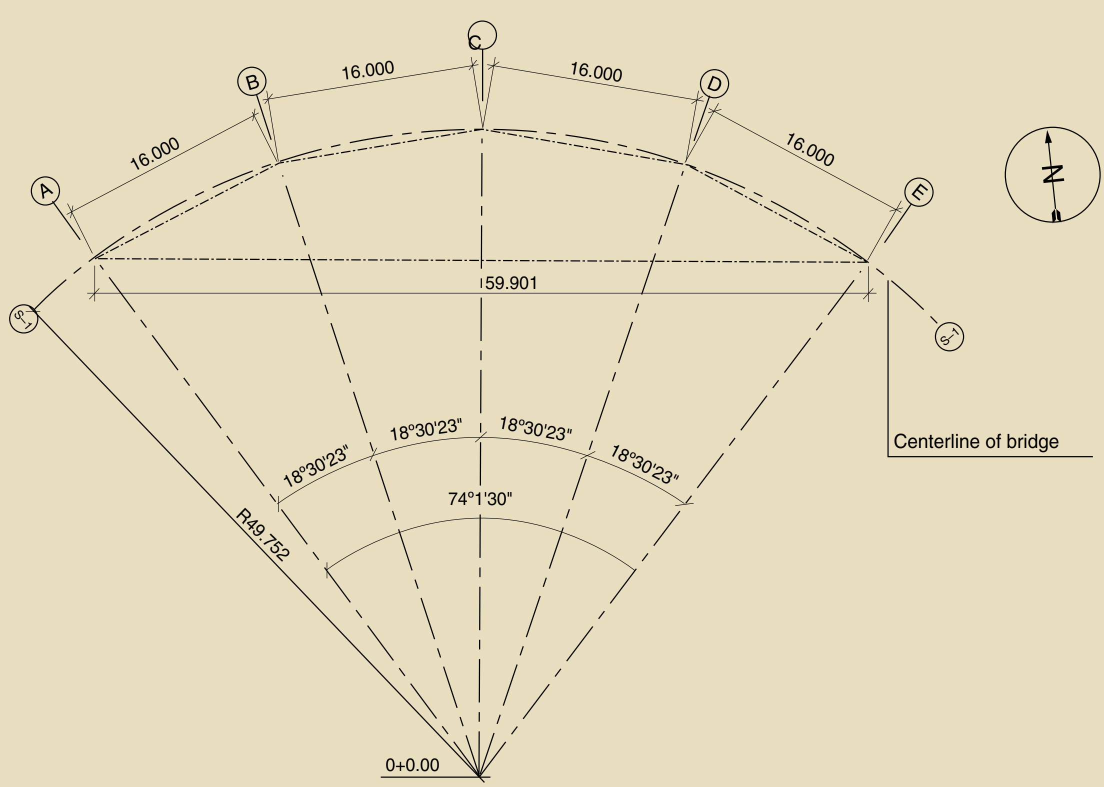

Figure 4. This is the axis distribution plan for the interchange bridge project. Note: Unless noted otherwise, all measurements are in millimeters. R = radius. 1° = 1 degree of arc; 1' = 1 minute of arc; 1" = 1 second of arc. 1 mm = 0.0394 in.

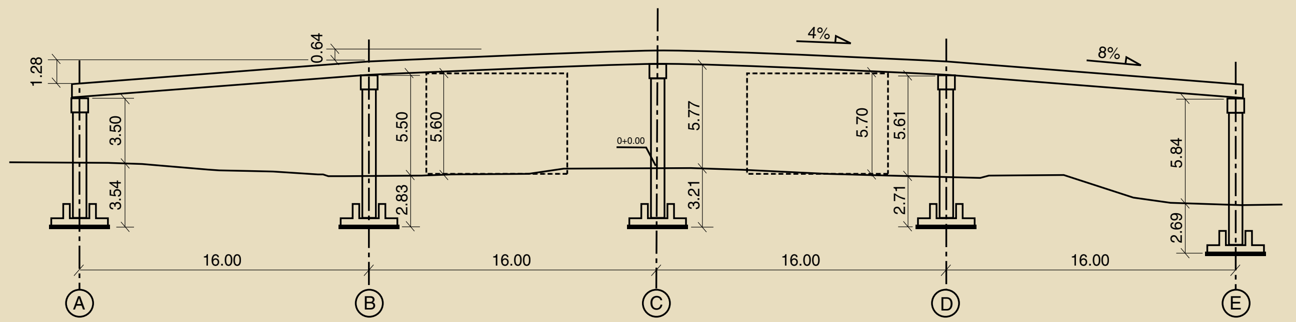

Figure 5. This diagram shows the elevation along the central axis of the interchange bridge. Note: All measurements are in millimeters. 1 mm = 0.0394 in.

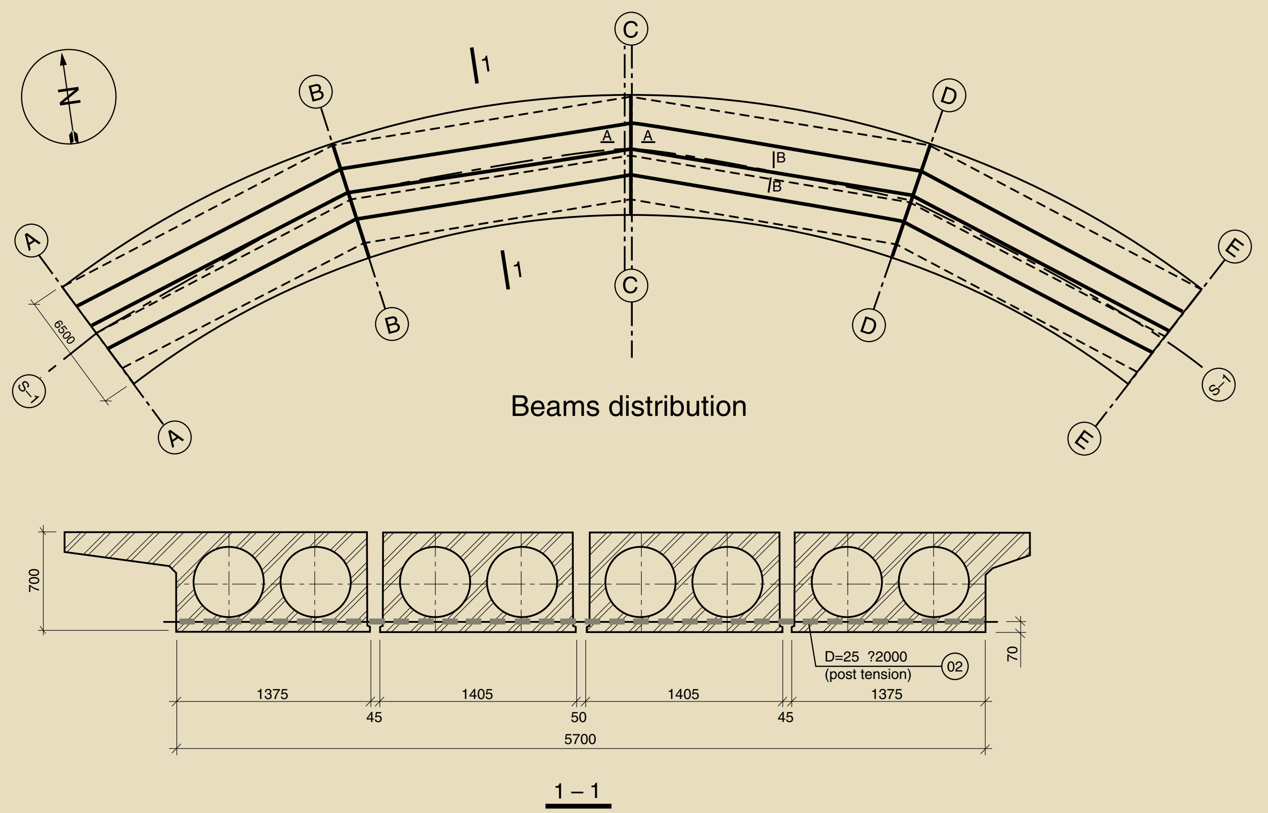

Figure 6. This diagram shows the hollow-core-unit layout and a typical cross section. Note: All measurements are in millimeters. 1 mm = 0.0394 in.

Partial-precast concrete footing

Each footing was divided into two sections to facilitate shipping, handling, and erecting. The precast concrete plant standardized the sections to reduce fabrication costs. **Figure 16** shows the details of the footings. Cast-in-place concrete provided a connection between the two precast concrete footing sections. This allowed the two sections to behave as a monolithic foundation.

Precast concrete columns

Figures 15 and **17** are the designs for the 10 precast concrete columns for the 5 abutment piers. Two of these Y-shaped columns, forming an inclined pier, supported each radial axis. The bases of the Y-shaped columns were square sections, and the stems were rectangular sections. To account for the different elevations of the deck and the footings, the Y-shaped column heights varied only in the base (Fig. 14), with lengths from 6.1 m to 8.1 m (20 ft to 27 ft). This design allowed the reuse of the steel formwork

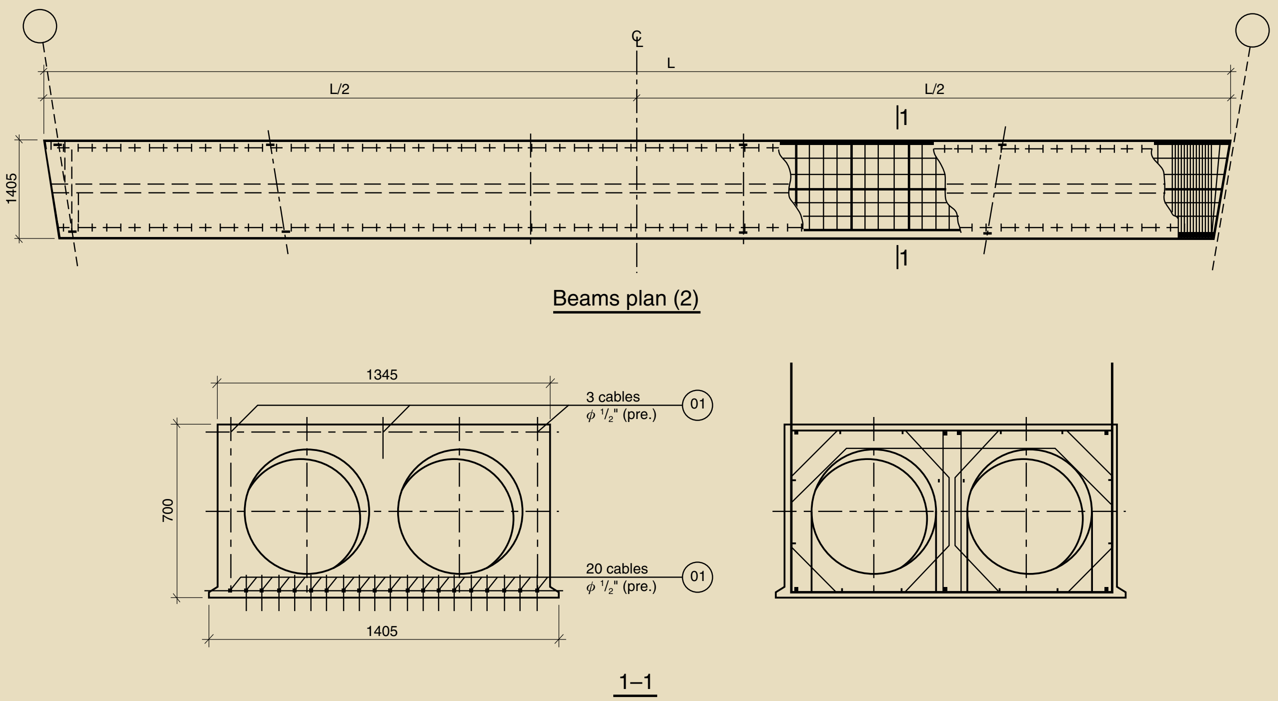

Figure 7. This is the trapezoidal hollow-core-unit design for interior units. Note: Unless noted otherwise, all measurements are in millimeters. ϕ = diameter; ℄ = centerline. 1" = 1 in.; 1 mm = 0.0394 in.

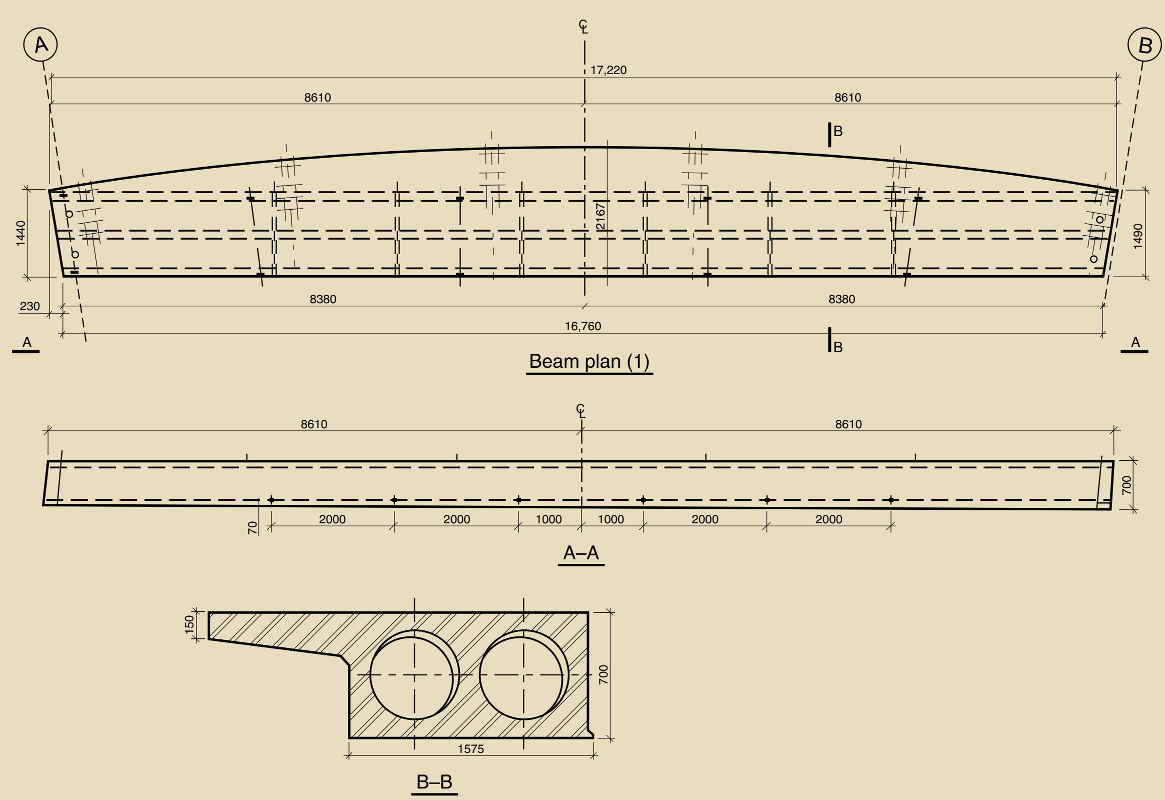

Figure 8. This is the trapezoidal hollow-core-unit design for exterior units. Note: Unless noted otherwise, all measurements are in millimeters. ℄ = centerline. 1 mm = 0.0394 in.

Figure 9. The reinforcing-steel cage for the hollow-core units is being transported from the fabrication site to the beds.

Figure 10. The hollow-core units are in the bed during prefabrication.

Figure 11. This photo shows the erection process of the precast concrete curb and guard barriers.

for the columns, which required adjustments to the length of the square section of the column base.

Precast concrete pier-cap box beams

The precast concrete box beams served as stay-in-place formwork for the placement of continuous, cast-in-place

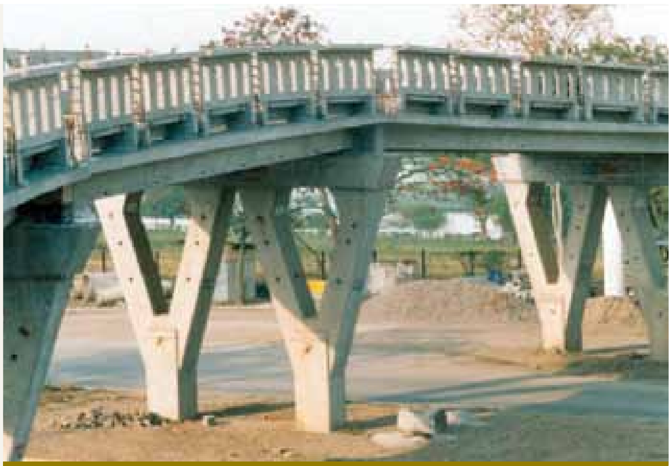

Figure 12. This photo shows the erected precast concrete curb and guard barriers for the interchange bridge.

Figure 13. This photo shows the Y-shaped columns in their final position.

Figure 14. This photo shows the cap box beams in their final positions on top of the Y-shaped columns.

concrete in the center of each box unit. A precast concrete plant fabricated and partially assembled the 7.8-m-long (26 ft), 0.9-m-wide (3 ft), 0.7-m-deep (2.3 ft) box beams, which were constructed using precast, prestressed concrete panels and reinforcing-steel cages. The precast concrete

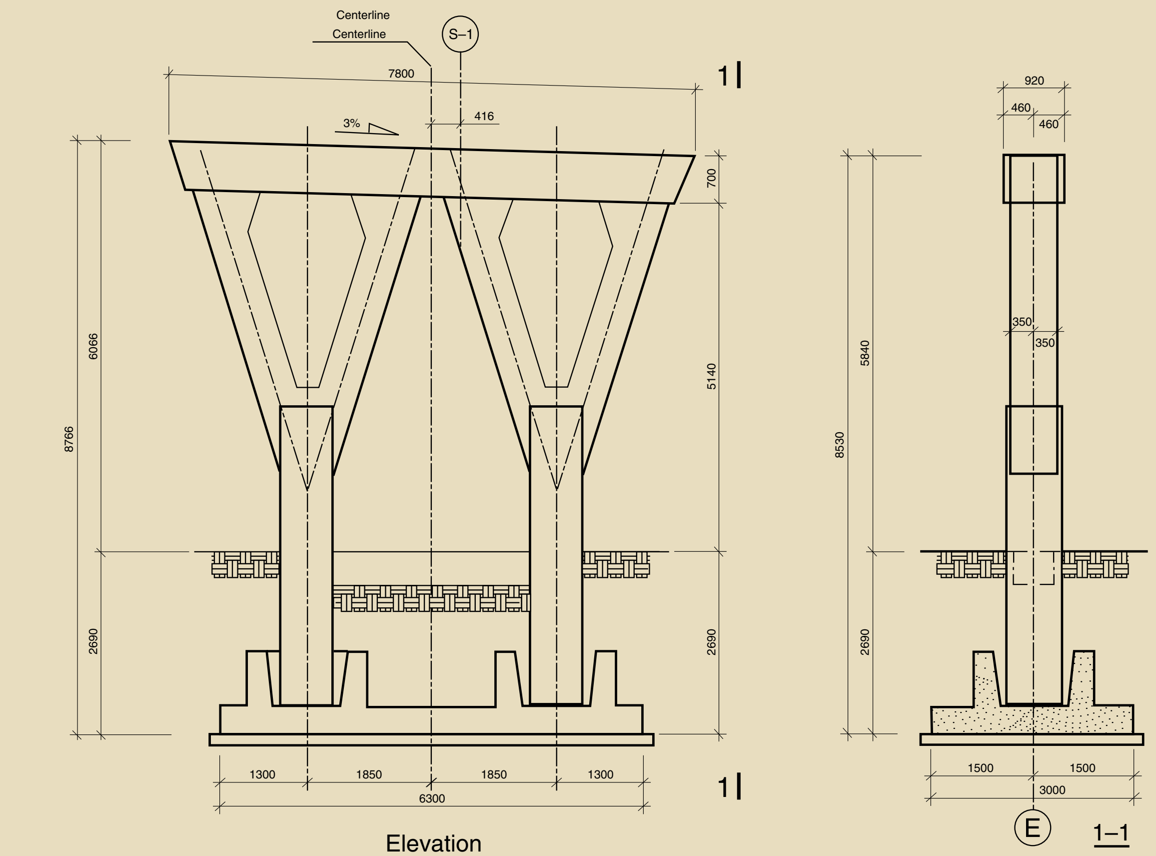

Figure 15. This elevation is for the Y-shaped columns and cap box beams. Note: All measurements are in millimeters. 1 mm = 0.0394 in.

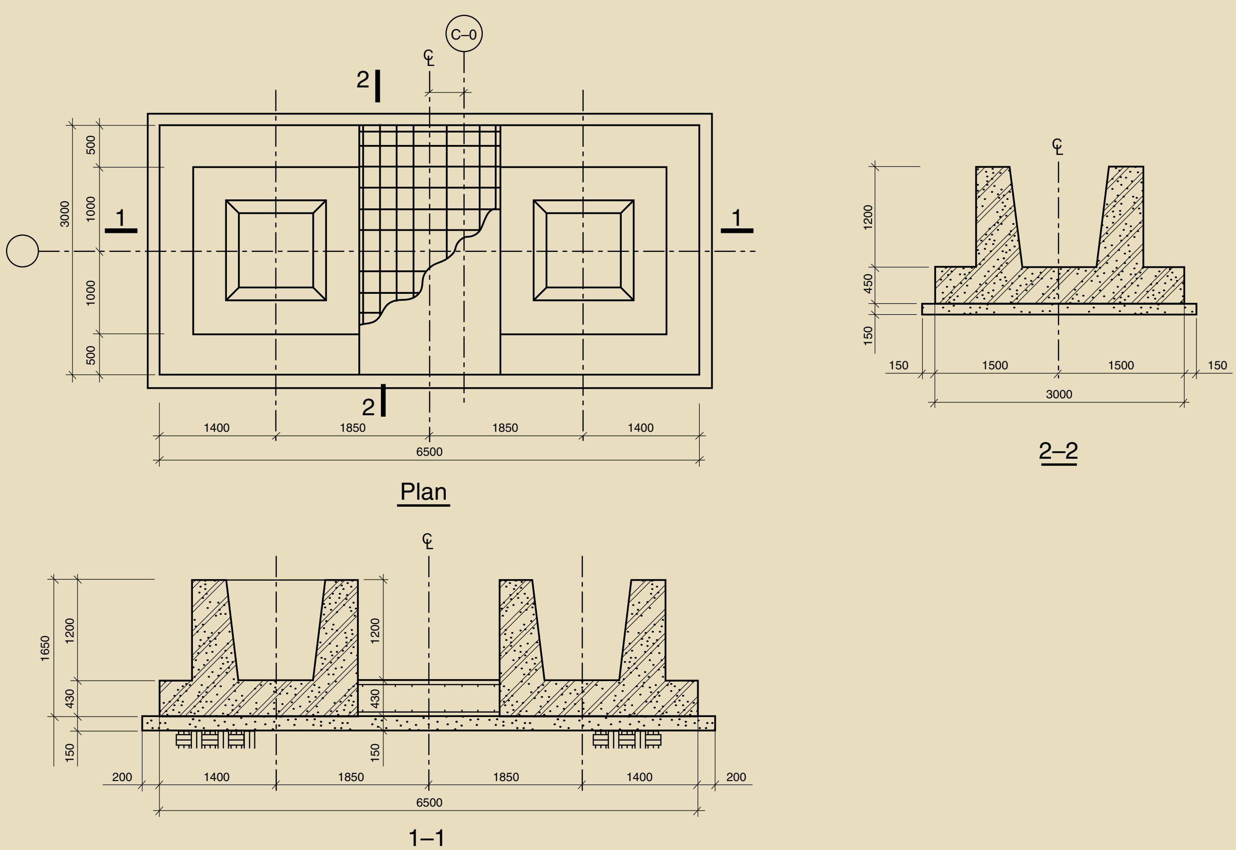

Figure 16. The design details of the precast concrete footings are in two sections. Note: All measurements are in millimeters. C_L = centerline. 1 mm = 0.0394 in.

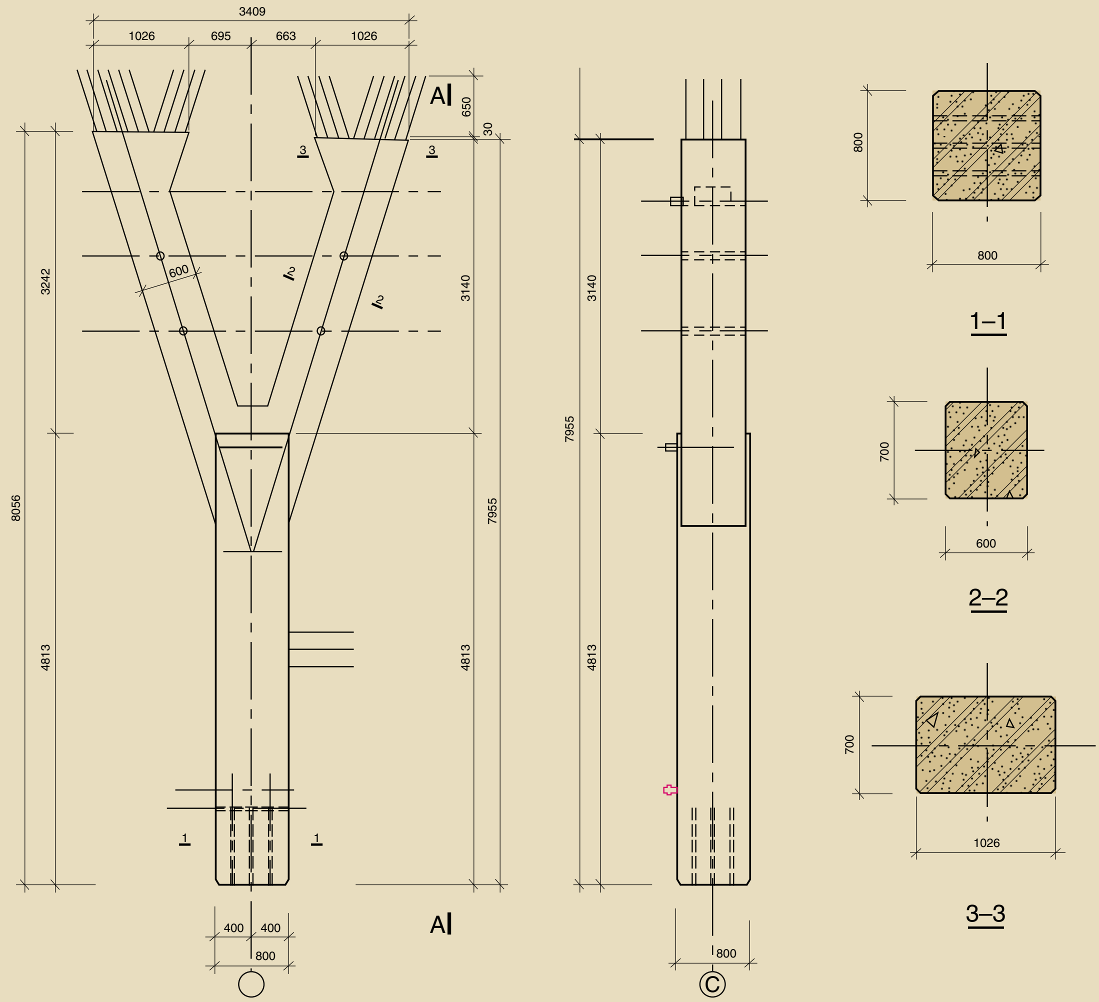

Figure 17. This shows the design details of the Y-shaped precast concrete columns. Note: All measurements are in millimeters. 1 mm = 0.0394 in.

box beams formed the pier caps, which enabled the substructure to behave monolithically. **Figure 18** details the box beam with the cast-in-place concrete located on the top of the pier-cap box beams, which had the dual purposes of making the form and addressing tolerance limitations. **Figure 19** illustrates the transverse post-tensioning of the hollow-core units. One row of six 50-mm-diameter (2 in.) ducts was included in the bottom of each hollow-core unit. Each unit had 25-mm-diameter (1 in.) Dywidag threadbare reinforcing steel to provide transverse post-tensioning in the deck at 24 locations. The superstructure, consisting of hollow-core units, was designed to fit the as-built position of the pier-cap box beams. The variance in slope of the top form was considered in the design. In addition, the construction schedule included the pier-cap box-beam tolerances, which were about ± 25 mm (± 1 in.) in both positions of the plan and slope. The tolerances of the cast-in-place concrete on the tops of the pier-cap box beams were about ± 10 mm (± 0.40 in.) both in the axis position and in the direction of the slope in order to suit the superstructure.

Lessons learned

The interchange bridge project had a deck area of 442 m^2 (4730 ft^2) and used a total of 131 precast, prestressed concrete components. The precast concrete composed about 80% of the total amount of concrete used. A variety of shapes and sizes were fabricated, including 16 hollow-core units and 10 Y-shaped columns.

It is possible to successfully construct structures using an all–precast concrete system. However, the use of an all–precast concrete system in both substructures and superstructures may require the designer to compromise in order to provide an ideal solution to the geometry of a curved project. The designer must focus on ease of fabrication, repetition, and ease of assembly to create a cost-effective solution using precast concrete.

Several concepts should be considered when designing a structure with an all–precast concrete system:

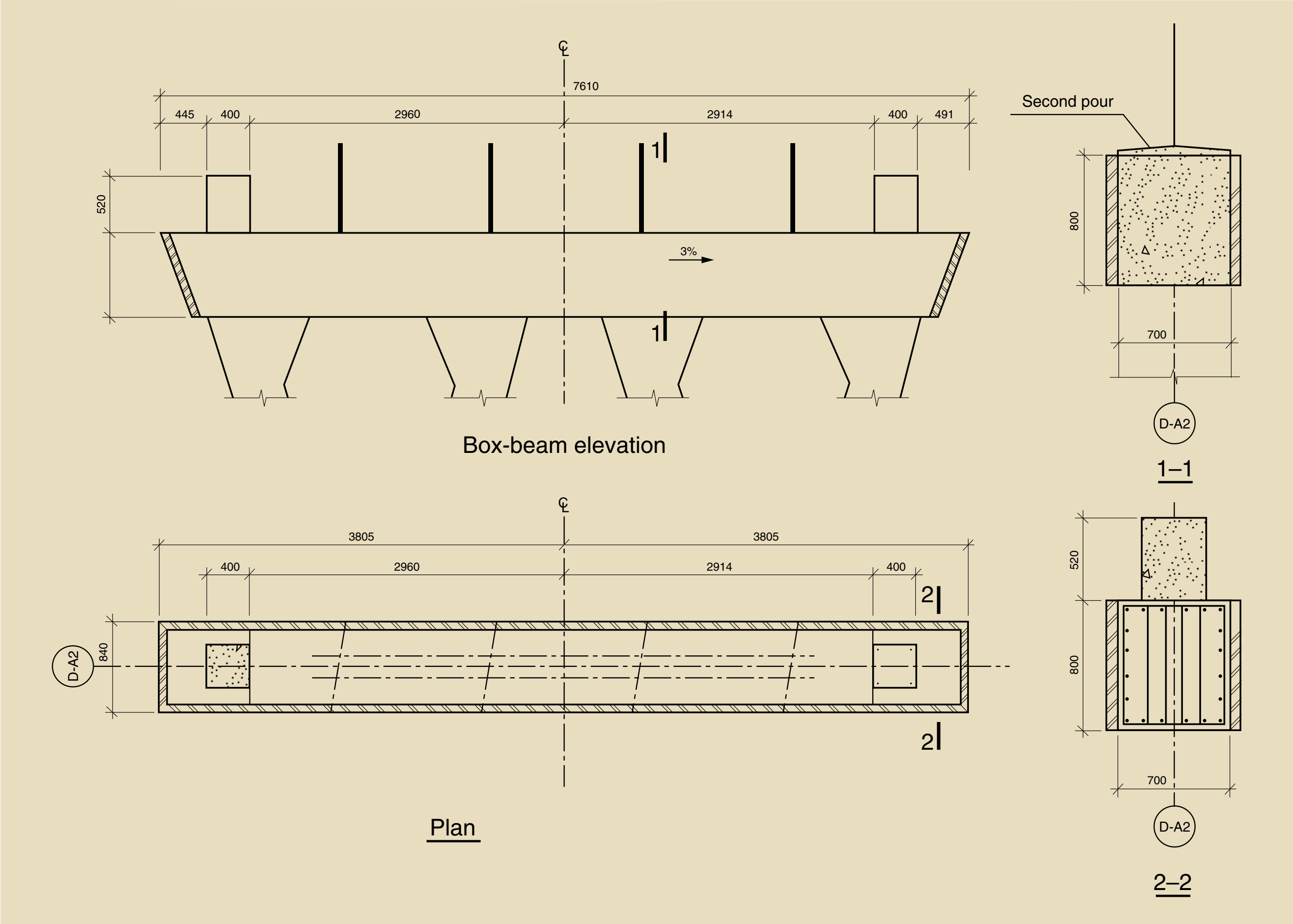

Figure 18. This shows the design details of the cap box beams. Note: All measurements are in millimeters. ℄ = centerline. 1 mm = 0.0394 in.

- Transportation of the precast concrete components must be considered in the design. Footings for the abutments were divided into two precast concrete elements to facilitate transportation and erection, which avoided the need for oversized-width permits.

- There is significant advantage in standardizing the size of the precast concrete components. Standardizing the two stems of the Y-shaped columns while altering the height of the base of those columns was the appropriate choice for the design to enable ease of construction.

- Configuration detailing is important for the assembly of the components. An effective solution to geometric tolerance problems was to use an additional layer of cast-in-place concrete on top of the box beams. As a result, the inherent risk of the tolerance for the superstructure was readjusted.

- Problems can arise when the transverse post-tensioning cable is pulled through the ducts. Construction for this project required each threadbare strand to pass through four hollow-core units. Two threadbare strands were difficult to pass through the ducts, which could be due to tight tolerances.

- Precast concrete structures require tight tolerances in both fabrication and erection because of the accuracy required in connecting the individual components during erection. The maximum tolerance for the 20 precast concrete barrier-panel components was 50 mm to 65 mm (2 in. to 2.6 in.) in six locations, which was in excess of the design tolerance, proving that tolerances were the most challenging aspect of this project.

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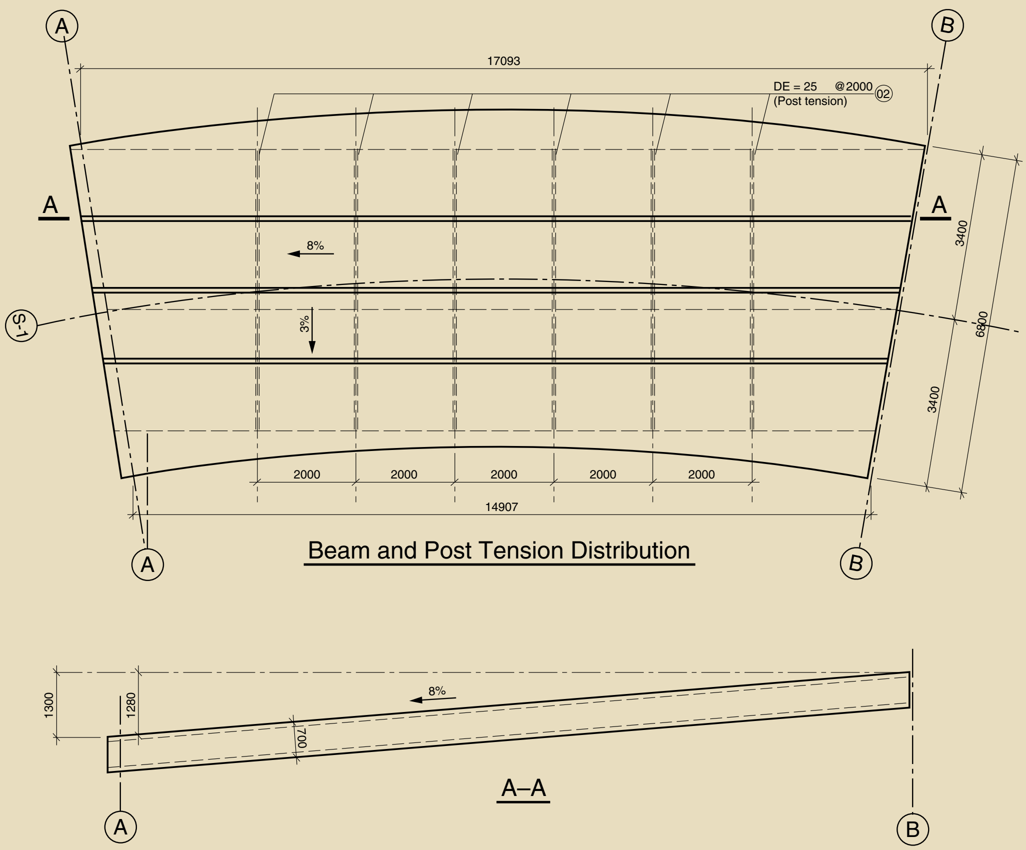

Figure 19. Transverse post-tensioning details are shown for six locations for each grouping of four hollow-core units. Note: All measurements are in millimeters. 1 mm = 0.0394 in.

About the authors

Li Zhenqiang is a senior engineer from the People's Republic of China in Beijing and chief engineer for Conhsa Payhsa Group in Honduras.

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Synopsis

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The interchange bridge is a four-span, one-way bridge with an overall length of 65 m (213 ft). Each span of the curve axis was 16 m (53 ft), and the deck width was 6.8 m (22.3 ft). The project requirements included a roadway with a 5.5-m-wide (18 ft) travel lane and two 0.65-m-wide (2.1 ft) shoulders on each side.

Keywords

Bridge, hollow-core, transportation, Y-shaped column.

Review policy

This paper was reviewed in accordance with the Precast/Prestressed Concrete Institute's peer-review process.

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