Record Span Spliced Bulb-Tee Girders Used in Highland View Bridge

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At 250 ft (76.2 m), the main span of Highland View Bridge — a 2600 ft (793 m) long precast, prestressed concrete structure on U.S. 98 over the Gulf Intracoastal Waterway in Florida — is the longest concrete girder span ever constructed in the United States. This record span was achieved with the use of continuous precast post-tensioned concrete bulb-tee girders combined with a spliced drop-in girder. This article discusses the competitive bidding, design considerations, production and construction operations, and erected cost of the bridge. With this experience, it is expected that even longer span precast, prestressed concrete bridges will be constructed in the near future.

The Highland View Bridge is a 2600 ft (793 m) long precast, prestressed concrete bridge on U.S. 98 crossing the Gulf Intracoastal Waterway near Port Saint Joe in Gulf County, Florida (see Fig. 1).

The bridge consists of a south approach having 11 spans of 89 ft (27.1 m), a 642 ft (196 m) central span section and a north approach also with 11 spans of 89 ft (27.1 m). The approach spans are constructed with conventional AASHTO Type IV I-beams.

This article will concern itself with the central three-span section and especially the 250 ft (76.2 m) main span, which currently is the longest concrete girder span in the United States. In particular, the design challenge and solution are discussed together with the economics, construction method, production and erection highlights of the project.

The central three-span structure (see Fig. 2) has spans of 196 - 250 - 196 ft (59.7 - 76.2 - 59.7 m) for a total length of 642 ft (196 m). The 250 ft (76.2 m) main span is achieved by splicing, with cast-in-place concrete, a 141 ft 8 in. (43.2 m) drop-in girder to the cantilevered haunched sections at the inflection points of the span (see Figs. 3 and 4). Post-tensioning is used to provide the final load-carrying capability of the structure.

The principal girder type is a continuous segmental post-tensioned precast concrete bulb-tee girder. Altogether,

Fig. 1. Aerial view of Highland View Bridge showing record-setting main span.

Fig. 2. Partial view of Highland View Bridge showing 250 ft (76.2 m) main span in foreground.

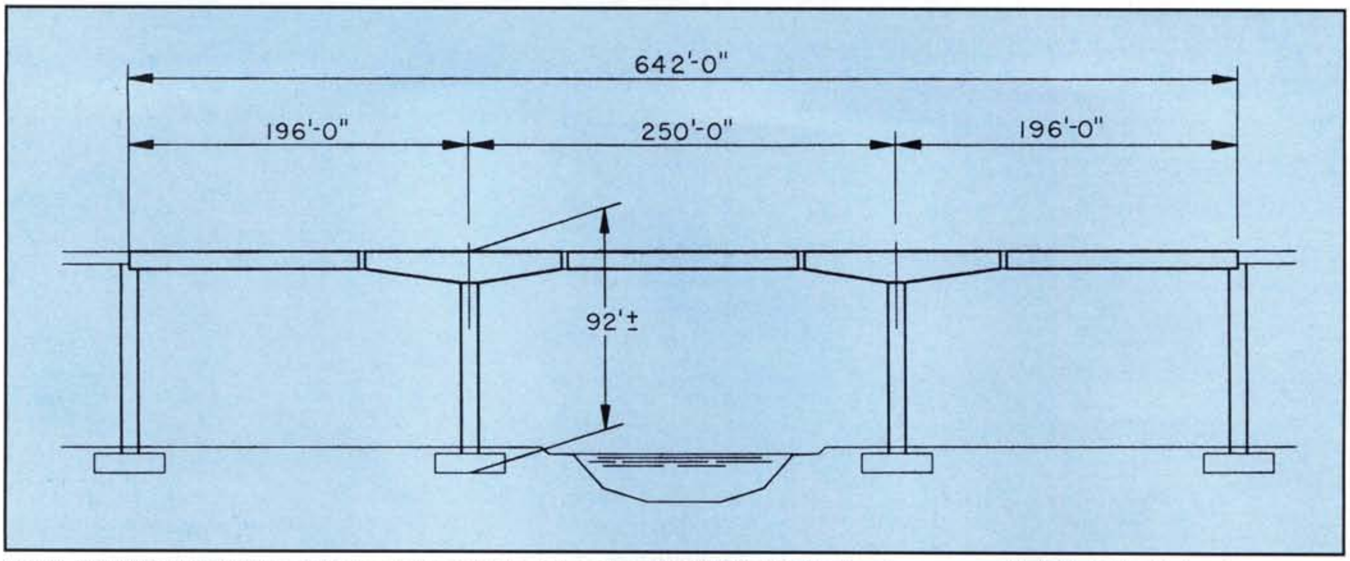

Fig. 3. Simplified elevation of three-span central section showing 250 ft (76.2 m) main span and total height of structure.

25 precast, prestressed concrete bulb-tee girders are used in the structure.

Table 1 provides the particulars and principal dimensions of the three-span central structure. Table 2 gives the number and describes the type of bulb-tee girder. Table 3 indicates the specified compressive strength of the concrete and the major characteristics of the mild reinforcing steel and the prestressing steel. Fig. 5 shows a half-section of the deck width at the piers and closure joint.

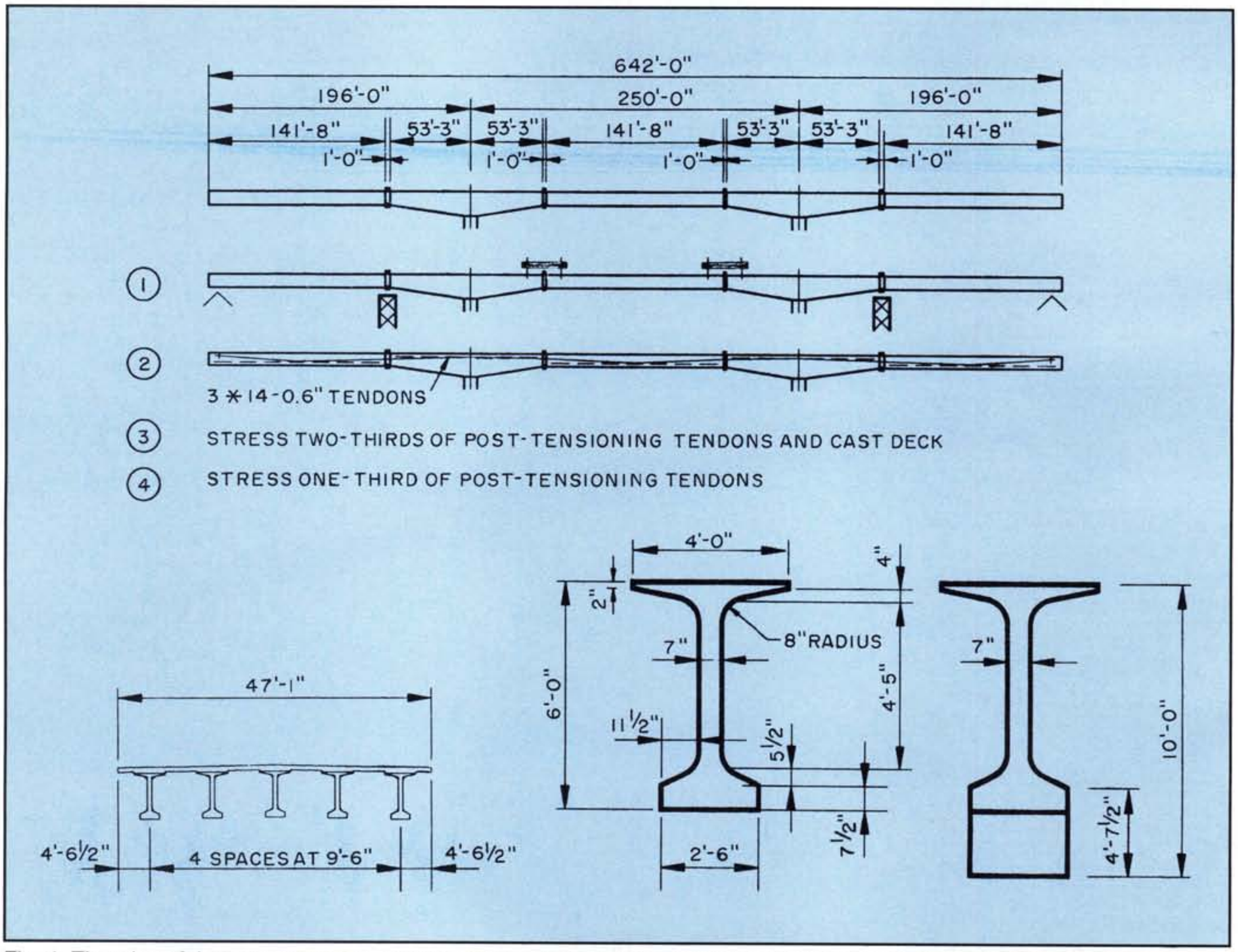

Fig. 4. Elevation of three-span section, erection steps, deck section and cross-sectional dimensions of bulb-tee girders.

Table 1. Particulars and principal dimensions of three-span bridge.

Bridge length:	642 ft
Deck width:	47 ft 1 in.
Deck area:	30,250 sq ft
Three spans:	196 - 250 - 196 ft
Girder type:	Continuous segmental post-tensioned precast concrete bulb-tee girder
Number of girder lines:	Five
Girder spacing:	9 ft 6 in.
Vertical clearance:	75 ft 10 in.

Note: 1 ft = 0.3048 m; 1 in. = 25.4 mm; 1 sq ft = 0.093 m².

Table 2. Number and type of precast prestressed concrete girders.

Type of girder	Number
Pier section girders, 106 ft 6 in. long	10
End span section girder, 141 ft 8 in. long and a depth of 6 ft	10
Midspan section girders, 141 ft 8 in. long and a depth of 6 ft	5
Total number of precast concrete girders	25

Note: 1 ft = 0.305 m; 1 in. = 25.4 mm.

Table 3. Characteristics of materials.

Material	Characteristic
Concrete	6500 psi compressive strength at 28 days
Reinforcing steel (mild)	Grade 60
Post-tensioning steel	Strand, 0.6 in. diameter, 270 ksi Bars, 1¼ in. diameter, 150 ksi
Pretensioning steel	Strand, ½ in. diameter, 270 ksi

Note: 1 in. = 25.4 mm; 1 psi = 0.006895 MPa; 1 ksi = 6.895 MPa.

Table 4. Erected costs of spliced bulb-tee girders based on bid tabs for Highland View Bridge.

• 6 ft deep bulb-tee girders $140 per ft (erected)	2124 ft	$297,360
• Haunched girders, $426 per ft (erected)	1068 ft	$454,968
• Post-tensioning, $1.37 per lb	99,560 lbs	$136,397
Total girders erected		$888,725
Cost of girders erected per sq ft of deck area: 888,725/(642 x 47.08) = $29.50 per sq ft		
Comparable cost of structural steel: Lump sum bids • Low = $ 873,000 • High = $ 1,862,000		

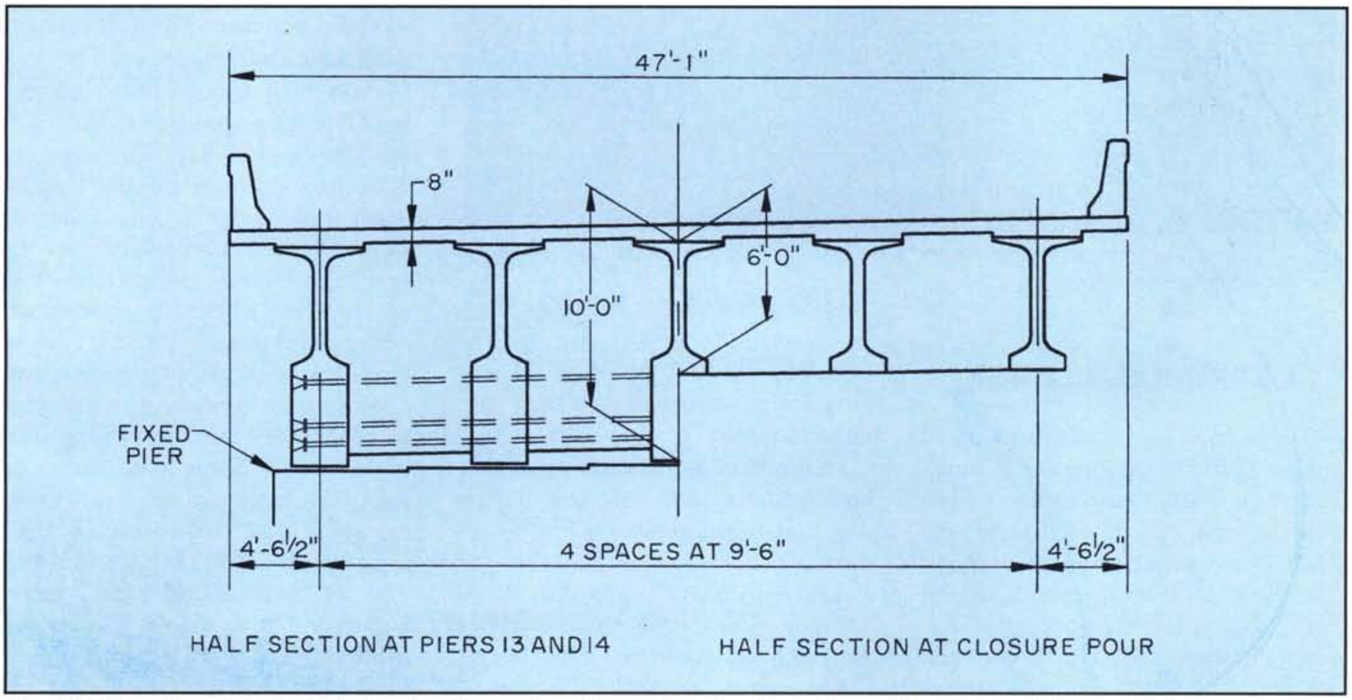

Fig. 5. Half-section of deck width showing the configuration and major dimensions at the piers and closure joint.

Fig. 6. Closeup view of octagonal columns showing tapering pier cap.

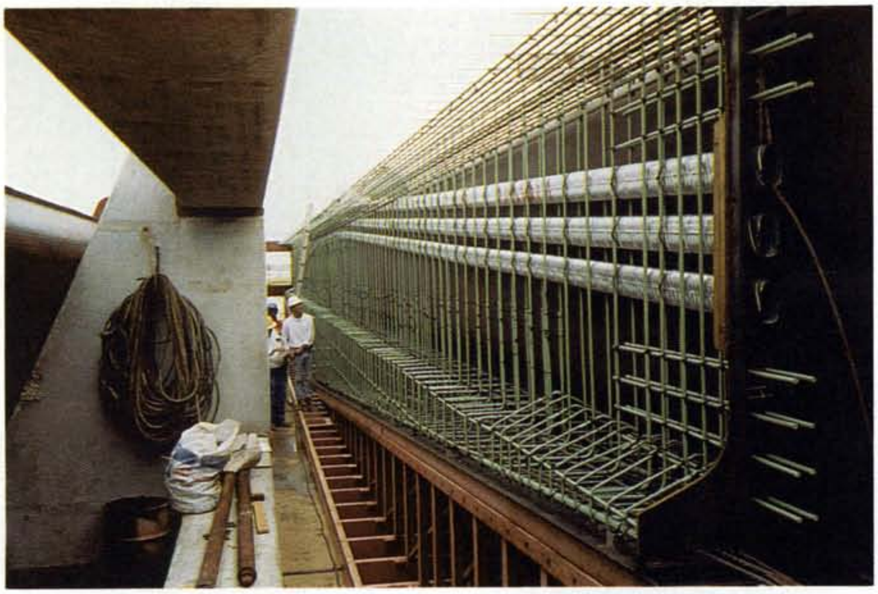

Fig. 7. Forms, post-tensioning ducts and mild steel reinforcement used in casting haunched girder section.

DESIGN CHALLENGE

The request for proposals prepared by the Florida Department of Transportation (FDOT) called for a main span of only 200 ft (61 m) over the Gulf Coast Intracoastal Waterway. This is the main span required to provide a shipping channel of 150 ft (45.7 m) minimum width between fenders. The fender systems are required to protect the main span piers from possible ship collisions. These piers are also designed for a large ship impact loading.

Preliminary studies indicated that both fender systems and ship impact resistant footings would not be required if the span length were increased from 200 to 250 ft (61 to 76 m). This would place the two channel piers on land where they could not be impacted by ships. Using this modification, the cost of fender systems ($200,000 to $250,000) and the additional cost for making special footings capable of withstanding a 1200 kip (5338 kN) ship impact force could be saved. Thus, the savings would more than offset the additional cost required to provide the greater span length.

It could also be shown during the preliminary design phase that the cost of a 250 ft (76.2 m) span in precast, prestressed concrete would compare favorably with the cost of a steel structure. Despite the fact that a concrete bulb-tee girder span of 250 ft (76.2 m) had not been constructed before in the United States, the FDOT decided to commission both a steel plate girder and concrete girder design to determine the economy of the concrete design by competitive bidding. Although the bids were close, the concrete span was the low bid (see Table 4). As contractors become more familiar with this method of construction, it is expected that the cost of concrete bridges in the 250 ft (76.2 m) span range will decrease.

DESCRIPTION OF STRUCTURE

The main span substructure consists of four reinforced concrete pier columns, traditionally constructed on concrete footings 29 x 35 x 7 ft (8.83 x 10.67 x 2.13 m). Because of poor bearing soils, 24 in. (610 mm) square prestressed concrete piles are used to strengthen the foundation. The 75 ft (22.9 m) high piers are of the hammerhead type. An effort was made to give the pier cap a slender appearance by offsetting and tapering the variable depth section, and blending it into the face of the octagonal column (see Fig. 6). Pot bearings are used to transfer the superstructure loads to the substructure.

The superstructure is 642 ft (196 m) long. It is made in five precast concrete sections connected by four cast-in-place splices. Temporary steel brackets transfer the loads across the joint. The lengths of the five sections are 141 ft 8 in., 106 ft 6 in., 141 ft 8 in., 106 ft 6 in. and 141 ft 8 in. (43.2, 32.5, 43.2, 32.5 and 43.2 m). Together with four 1 ft (0.305 m) splices, they make up the 642 ft (196 m) length of the central section (see Fig. 4 and Table 2).

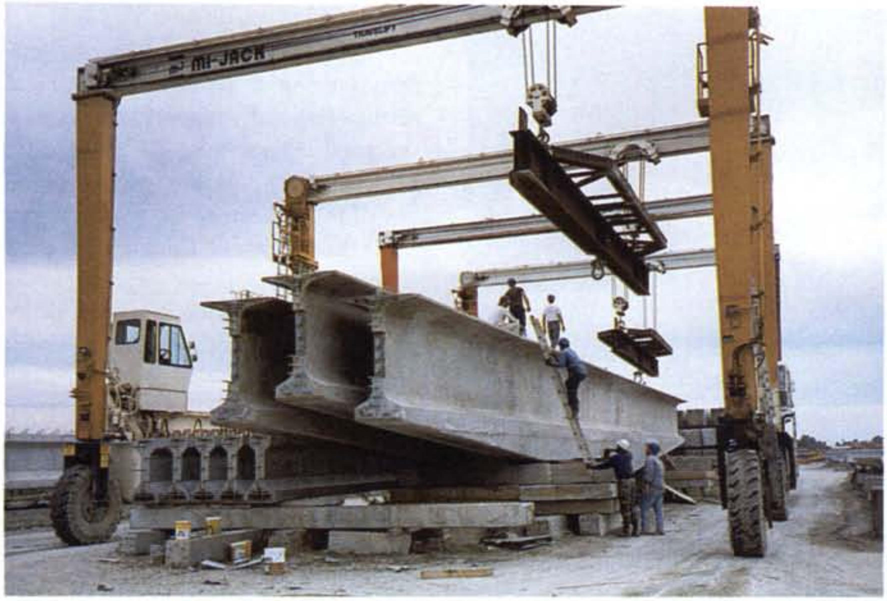

Fig. 8. Special lifting equipment was used to handle the heavy haunched girder sections.


Fig. 9. After arrival at the bridge site, a haunched girder section is lowered by crane for temporary storage.

The 141 ft 8 in. (43.2 m) long girders have a Florida bulb-tee standard section. This is a 6 ft (1.83 m) deep girder specially developed by the FDOT for use in conjunction with post-tensioning.* The 106 ft 6 in. (32.5 m) haunched sections vary in depth from 6 to 10 ft (1.83 to 3.05 m). Details are given in Fig. 5 and Table 2.

The depth variation of the haunched girder sections is obtained by extending the side forms of the standard girder downward by 4 ft (1.22 m) and combining these modified side forms with a special wooden soffit (see Fig. 7). Thus, the 642 ft (195.7 m) bridge is obtained by splicing three standard components to two non-standard components. The non-standard components are fairly economical to produce.

All the girders are pretensioned with ½ in. (13 mm) diameter strand for handling and transportation. The 141 ft 8 in. (43.2 m) long girders have 24 strands in the bottom flange. The 106 ft 6 in. (32.5 m) long haunched girders have 26 strands in the top flange and six strands in the bottom flange.

CONSTRUCTION METHOD

The two haunched girder sections are erected at the channel piers in such a way that the middle of the girder is supported by the pier and the land side-end is supported on temporary falsework (see Fig. 4).

As the haunched girders are erected, temporary bracing is installed. In the next step, the 141 ft (43 m) long girders are installed in the end spans. These girders are also supported on a pier and the temporary falsework.

After attaching the end span girders to the supports and the installation of wind bracing, the 141 ft (43 m) long drop-in girders of the main span are placed. These girders are supported by the haunched girders cantilevering over the main span piers, thus eliminating the need for falsework in the water.

The temporary connections consist of steel brackets attached to the drop-in girders with prestressing bars. The drop-in girders are also provided with temporary wind bracing which remains in place until permanent concrete cross girders are made.

It is important to realize that erection of the 25 precast concrete elements which make up the bridge occurs in one continuous operation. Heavy erection equipment is, therefore, needed for only a short period of time.

Cross girders are located at the four piers and at the longitudinal splices. The four reinforced concrete cross girders at the splices are made first. Upon completion of the splices, the longitudinal post-tensioning tendons are placed. After a few tendons are stressed, the entire structure is both longitudinally and transversely connected. Cross girders at the piers are made and transversely post-tensioned with 1¼ in. (32 mm) prestressing bars.

Each girder is designed with three 642 ft (196 m) long tendons which pass through the girders from one end of the structure to the other. Each tendon has 14 strands with a diameter of 0.6 in. (15 mm) and is stressed to a

* For more information on the development and application of Florida's bulb-tee girders, see the article by Antonio M. Garcia, "Florida's Long Span Bridges: New Forms, New Horizons," published in the July-August 1993 PCI JOURNAL, pp. 34-49.

Fig. 10. Installation of haunched girder sections over piers.

Fig. 11. Erection of end spans over piers.

Fig. 12. Completion of span adjacent to main span.

force of 599 kips (2664 kN).

The stressing and grouting of tendons, casting of the deck and removal of the temporary supports occurs in a specified sequence:

- After curing of the cast-in-place splices/diaphragms to 6000 psi (41 MPa), stress Tendon 1 in each girder.
- Next, stress Tendon 2 in each girder and grout all tendons that have been stressed so far.
- After curing of the grout, cast the deck.
- After curing of the deck [2500 psi (17 MPa) minimum required], remove temporary bracing and supports.
- After curing of the deck to 5000 psi (34 MPa), stress and grout Tendon 3.
- Erect girders in adjacent spans and complete the structure.

STRUCTURAL ANALYSIS

The design of this type of structure requires that all construction steps be carefully analyzed and properly monitored. The analysis starts at initial application of the pretensioning strand in the stressing bed, through handling and transportation, erection on and removal of temporary supports, phased post-tensioning, casting of the deck and, finally, accounting for prestress losses and moment redistribution.

The effect of moment redistribution is that compressive stresses in the top fiber of the girders are transferred to the deck as the creep process in the girder develops. This means that during the service life of the bridge, the deck will be composite for both dead and live loads.

PRODUCTION AND ERECTION HIGHLIGHTS

The precast concrete components [AASHTO Type IV beams, 24 in. (610 mm) square prestressed piles, Florida bulb-tee girders and haunched girder sections] were manufactured by Gulf Coast Pre-Stress, Inc., at its plant in Pass Christian, Mississippi. The precast concrete components were produced routinely with existing equipment except that for the haunched girder sections, special forms had to

Fig. 13. Aerial view of completed Highland View Bridge.

be made (see Fig. 7). Also, a high capacity crane was needed to handle and lift the heavy bulb-tee girders and haunched girder sections (see Fig. 8).

The precast concrete components were manufactured during a 10-month period, December 1991 to October 1992. They were shipped by barge along the Gulf of Mexico coastline to the bridge site following a staggered time schedule — piles first, then I-beams, and lastly haunched girder sections and bulb-tee girders. Each sea voyage took about 3 days. At the bridge site, the precast components were transferred from the barge with cranes and then temporarily stored (see Fig. 9).

After the piles were driven, the concrete piers were cast in place in the latter part of 1992.

The superstructure was erected rapidly over a three-month period in early 1993. The erection steps have been described earlier in the paper. First, the haunched girder sections were installed over the piers using temporary wind bracing and ground supported scaffolding. Next, the bulb-tee girders were installed in the end spans. Last, the drop-in girders were placed and spliced with cast-in-place concrete. Figs. 10 through 12 show progressive views of the erection process of the segments.

The bridge was substantially completed by June 1993. The official ribbon-cutting and opening ceremony took place on July 20. Regular traffic commenced on July 25. Fig. 13 shows an aerial view of the bridge as the structure neared completion.

COST

Detailed cost data on the bridge cannot be provided because the structure was bid as part of a larger project. An examination of the bid tabulations yielded a cost for the erected girders of \$889,725, or \$29.50 per sq ft of bridge deck (see Table 4 for cost breakdown). This figure is slightly lower than the structural steel bid.

CONCLUDING REMARKS

The successful completion of this record 250 ft (76.2 m) main span has shown that precast, prestressed concrete bridges can compete economically in this span range with structural steel bridges. The bids and erected structure costs of the concrete alternate compared favorably with the cost of a similar structure designed with steel plate girders. As contractors become more familiar with the construction technique, it is expected that the cost of the concrete design will decrease. Also, the simple addition of an alternate design to the bid documents in concrete and steel will reduce the low bid price.

The FDOT, which pioneered the development of the post-tensioned bulb-tee girder, is using these girders in many of its new bridges. When combined with a spliced drop-in girder, spans can be greatly extended. Because precast and prestressed concrete bridges have had an excellent track record with regard to durability and low maintenance costs, this method of construction is being advocated by the FDOT.

With the completion of the Highland View Bridge, it is anticipated that bridges with even longer spans will be constructed.

Studies indicate that this design concept will also work well for bridges with a main span of 310 ft (94.5 m). Thus, the future looks bright for precast, prestressed concrete bridges in this span range.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Gulf Coast Pre-Stress Inc., for permission to publish the photographs and also for supplying the production and transportation details of the precast concrete operations.

Credits

Owner: Florida Department of Transportation, District 3, Chipley, Florida.

Design Consultant: Janssen & Spaans Engineering, Inc., Indianapolis, Indiana.

General Contractor: L&A Contracting, Inc., Port Saint Joe, Gulf County, Florida.

Precast Concrete Manufacturer: Gulf Coast Pre-Stress Inc., Pass Christian, Mississippi.