Biloxi Interstate-110 Viaduct

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Presents the design and construction highlights of an elevated precast prestressed segmental structure built over moving traffic and restricted space in Biloxi, Mississippi. Balanced cantilever and span-by-span erection saved the owner $4.2 million.

An elevated precast prestressed concrete structure constructed within minimal clearance over U.S. 90 and within almost zero right-of-way limits in a congested business area solved a major traffic problem for the people of Biloxi, Mississippi.

The southern Gulf Coast city faced a dilemma that many other American cities face today: How to expand interstate systems in developed urban areas where highways must wrap around existing structures; minimize the impact to the environment when urban structures are built; maintain the integrity of established neighborhoods; utilize construction systems that do not interfere with day-to-day traffic flow; and, provide an aesthetically pleasing road and bridge system for a city.

Mississippi Highway Department officials never completed the interstate connector between Interstate-10, a vital east-west route in the southeastern United States, with U.S. 90. The U.S. highway follows the curve of the Gulf of Mexico. A few miles north, the interstate shoots straight across the southern United States. Part of the connector between the two highways had been built, but it stopped a mile (1.6 km) before reaching U.S. 90.

The missing link had never been constructed because it had to traverse an old neighborhood and then a flourishing business community that was immediately adjacent to the Gulf. The existing buildings made it almost impossible to acquire right-of-way land to build exit ramps. Additionally, Mississippi Highway Department officials did not want to disrupt the community or stop traffic on what is a major tourist route.

An elevated precast prestressed urban structure with exit and entrance ramps solved the problem for Biloxi (Figs. 1 and 2). The use of precast prestressed concrete and segmental technology proved to be the ideal solution for zero right-of-way construction. In fact, the connector's edges are within 10 ft (3.05 m) of private property lines. The structure also provided a much needed inland evacuation route for the hurricane prone area. The precast prestressed structure resulted in an aesthetic contribution to the community, and several projects—including bike paths, parks, playgrounds and tennis courts—are now being constructed under and around the structure.

Project Description

The I-110 Biloxi project was broken into two contracts that were approximately equal in size. The south half of the project was awarded in 1984 to Harbert International and included the exit ramps looping out over U.S. 90 and the Gulf of Mexico. The north half of the project was awarded to Dement Construction Company one year later in 1985.

Fig. 1. Panoramic view of Biloxi I-110 viaduct. The 5332 ft (1625 m) mainline urban structure provides four lanes of traffic. Five ramp structures totaling 4830 ft (1472 m) join the mainline facility.

The main structure is a four-lane elevated highway consisting of 5332 ft (1625 m) of mainline structure and 4830 ft (1472 m) of ramps, for a total precast prestressed concrete segmental bridge deck area of 616,600 sq ft (57344 m²). Two of the five ramps reach across U.S. 90, on 600 and 650 ft (183 and 198 m) radii curves. The superstructure depth is a constant 7 ft (2.13 m), even though the spans vary in length from 80 to 180 ft (24.4 to 54.9 m).

Three different construction techniques were used for the project. Conventional cast-in-place reinforced concrete box girders were used for the sharply curved portions over the Gulf of Mexico and one sharply curved entrance ramp at the far north end of the project.

The remainder of the project was constructed using precast concrete segmental box girder construction. For the majority of the project, the precast segments were erected using the span-by-span method. However, over U.S. 90 on the south end of the project, balanced cantilever construction was used because of longer spans and the need to minimize traffic disruption.

Two types of precast concrete segments were used. The Type I segments were 39 ft 8 in. (12.1 m) wide and typically carried two lanes of traffic while Type II segments were 28 ft 10 in. (8.79 m) wide and typically carried one lane of traffic.

Substructure construction consisted of cast-in-place reinforced concrete columns. Supports for the Type I segments consisted of two columns, each measuring 5 ft x 2 ft 6 in. (1.52 x 0.76 m), with a maximum height of 28 ft (8.53 m). These rested on a cast-in-place reinforced footing supported by either drilled shafts or prestressed concrete piling. For the Type II boxes, only one column was used at each foundation location.

Post-tensioning in the superstructure of the typical span-by-span portions featured external

Fig. 2. Aerial view of completed structure with four lanes of traffic and shoulders for a typical width of 81 ft 10 in. (24.9 m).

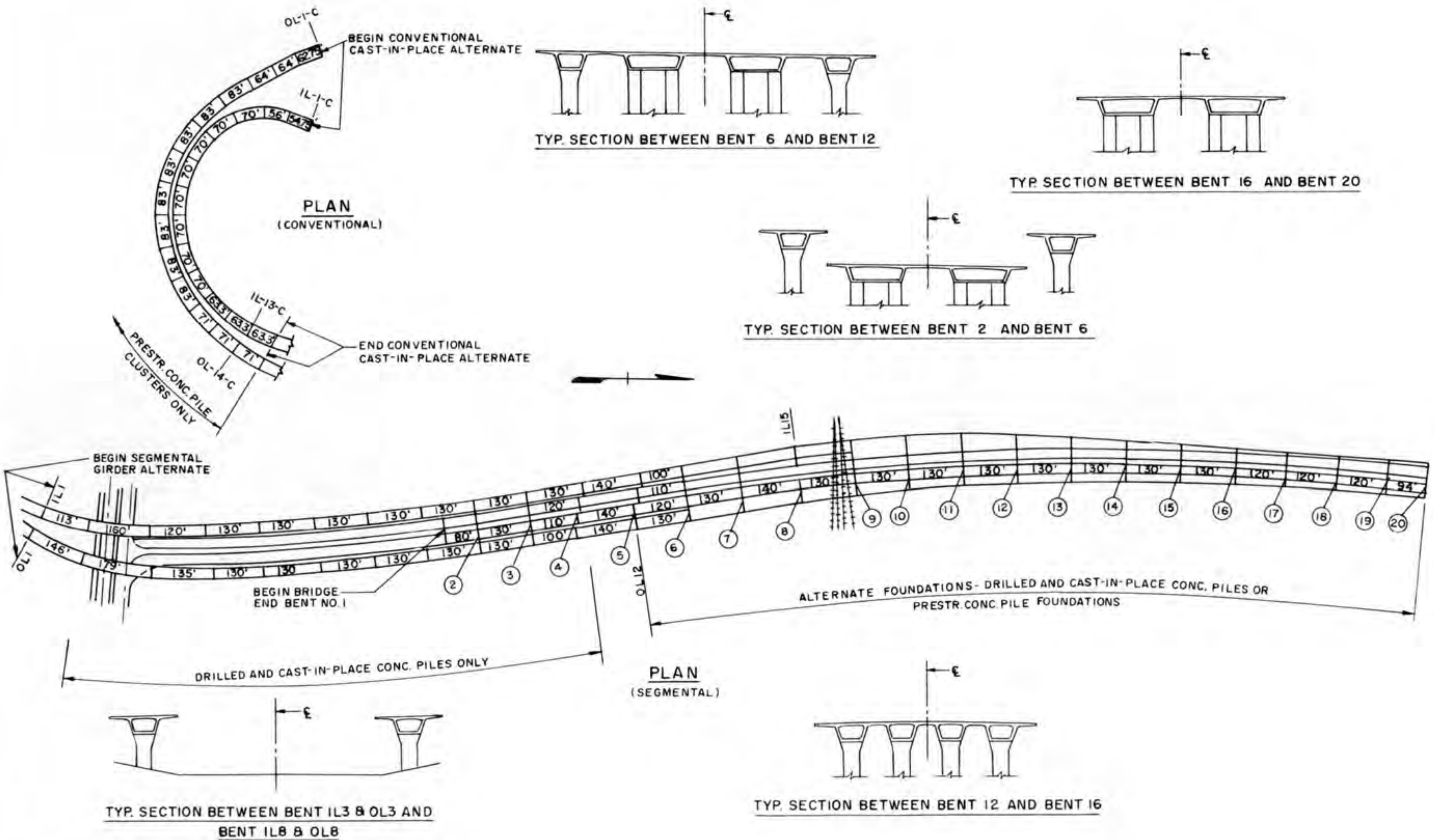

Fig. 3. Key plan I.

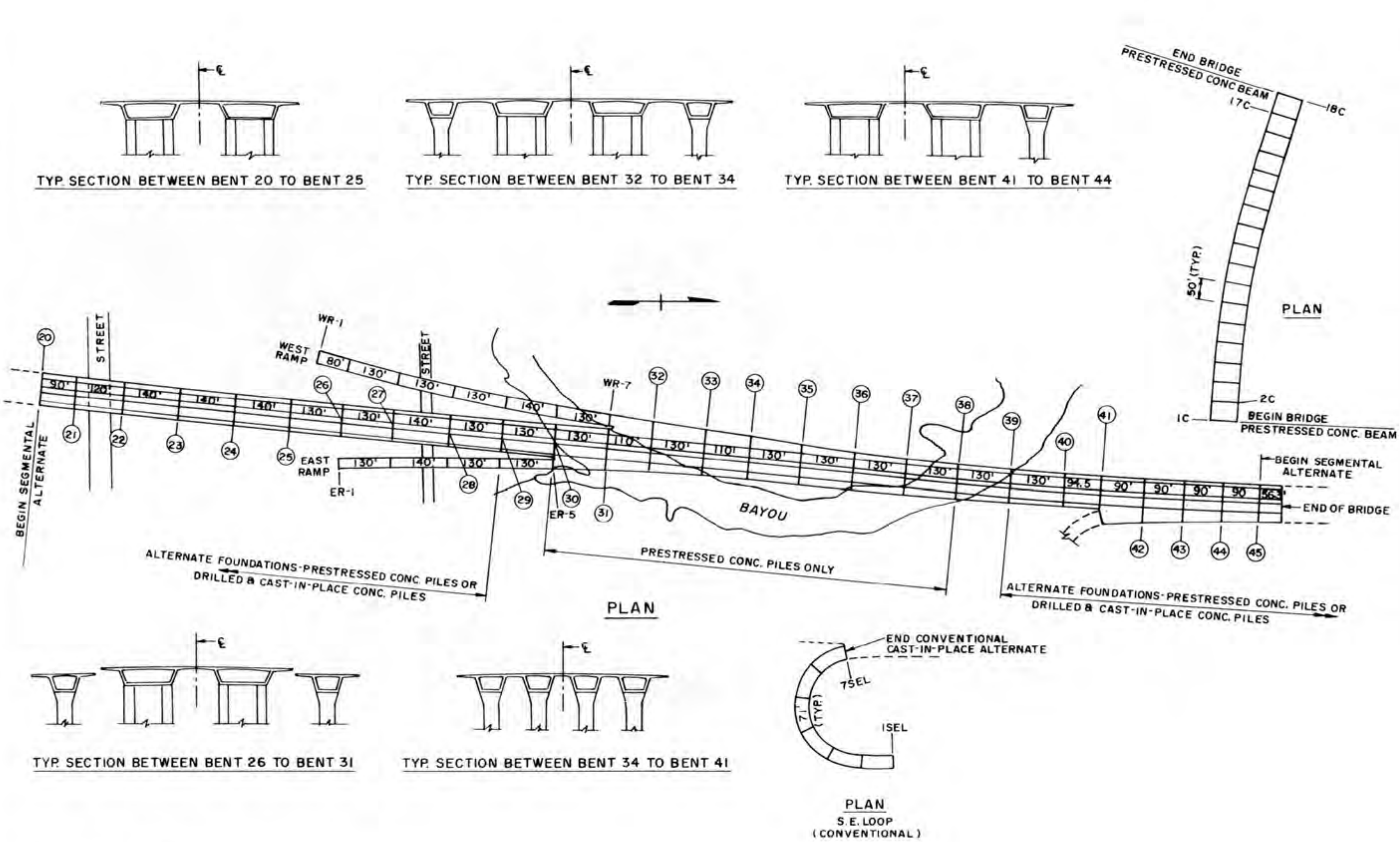

Fig. 4. Key plan II.

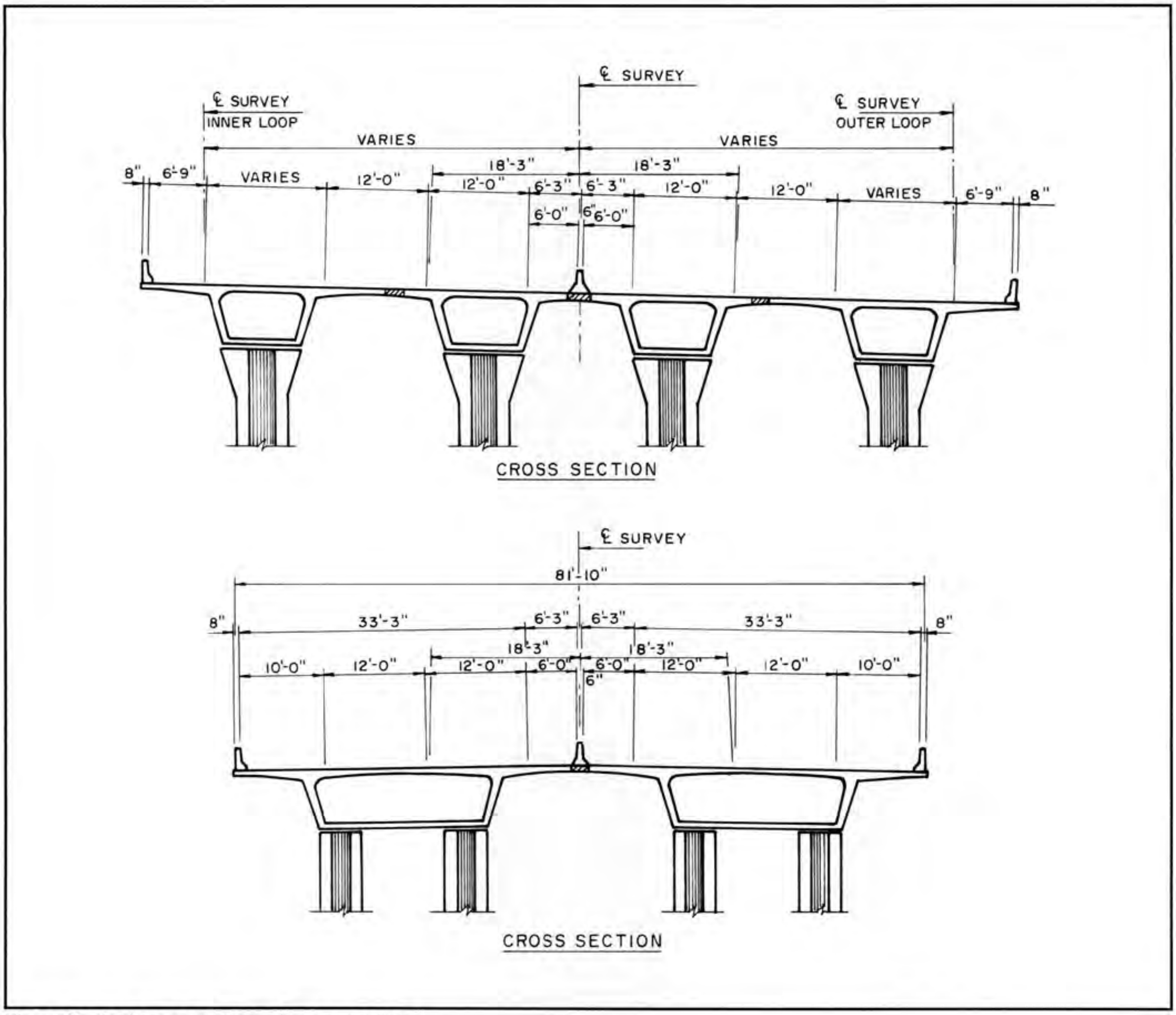

Fig. 5. Typical cross section of superstructure.

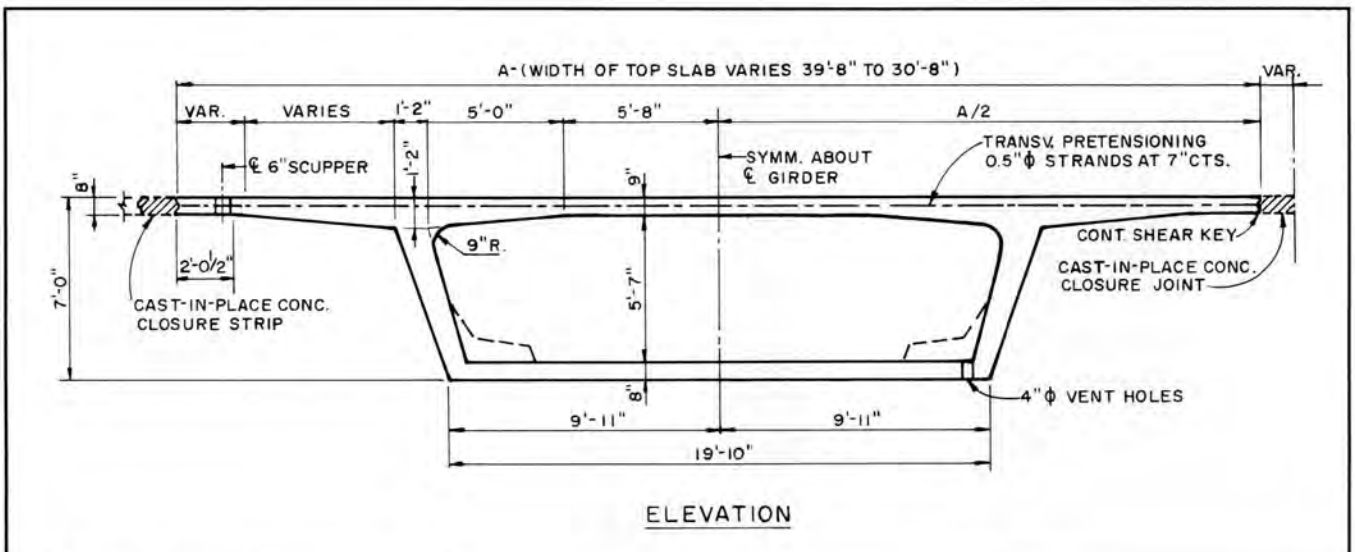

Fig. 6. Typical segment dimensions (Type I).

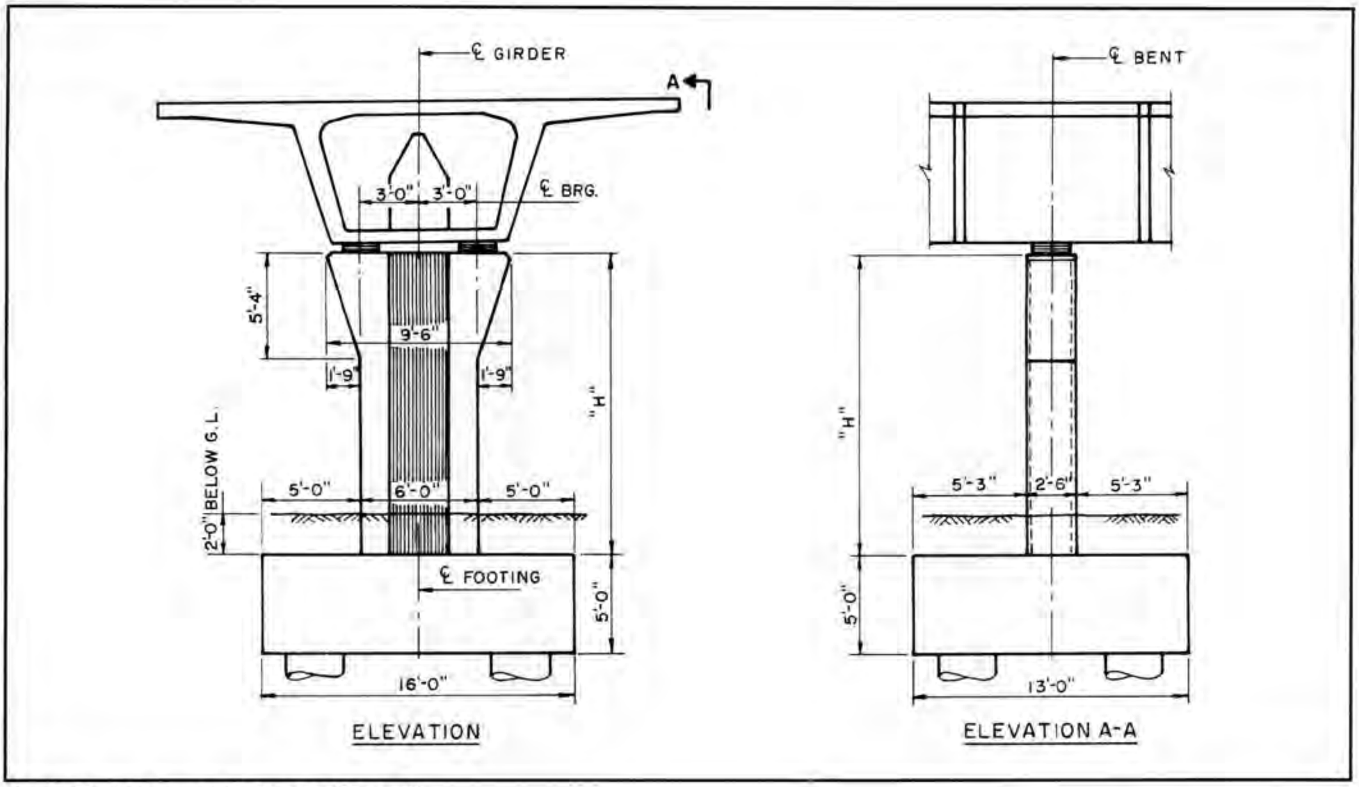

Fig. 7. Typical pier dimensions (Type II).

tendons. In this method, the tendons are anchored in concrete diaphragms at the piers and pass through the interior of the concrete box girder, connecting to the segments at several intermediate deviation points. Internal tendons in the top slab of the box girder were also used for the cantilever spans.

Key plans of the elevated structures, typical cross sections of the superstructure and segments, pier details and typical layouts of the post-tensioning steel are shown in Figs. 3 through 9.

Substructure Construction

Foundations for the I-110 Biloxi Bridge utilized both drilled shafts and prestressed piling. The 36 in. (914 mm) diameter drilled shafts were used primarily on the south end of the project, where damage to existing structures by pile driving equipment was a concern. The shafts were installed using the slurry method, and were 32 to 55 ft (9.75 to 16.8 m) deep.

The precast prestressed concrete piling was primarily 24 in. (610 mm) square. A total of 95,000 ft (28956 m) of piling was required in lengths from 35 to 95 ft (10.7 to 29.0 m). The piles were either driven to the required depth or first jetted partially and then driven to the required depth. The reinforced concrete footings were cast-in-place on top of the pilings. An architectural textured finish was cast into the pier faces to better blend into the urban environment.

Precasting Yard

At the same time that site preparation was progressing in Biloxi, construction of the precasting yard was underway 35 miles (56 km) to the west, at Gulf Coast Prestress Company. A new yard, located on approximately 7 acres (2.83 ha), was constructed for casting the segments on the Biloxi project.

Foundations for the segment casting machines were reinforced concrete supported by precast prestressed concrete piling. Reinforced concrete ramps were also constructed for the 60 ton (54 t) straddle crane used to handle the segments in the yard.

Eight casting machines were installed for use at the yard. Since the top slab of the segments was transversely pretensioned, a steel frame was constructed around each casting machine to hold the anchorage forces of the transverse prestressing while the segment was being cast.

In addition to the segment casting area, the yard also had a large segment storage area where the segments were stacked two segments high.

Typical Segment Casting Cycle

A typical segment casting cycle began early in the morning when steam curing of the previous segment was complete. The steam sheds were rolled back away from the casting machines and the after-cast survey was performed to determine the relative position of the wet cast segment and the match cast segment.

After the survey was complete, the form stripping began with removal of the interior core form. The straddle crane removed the segment cast 2 days earlier to the storage area, and the wet cast segment cast the previous day was moved out of the casting machine

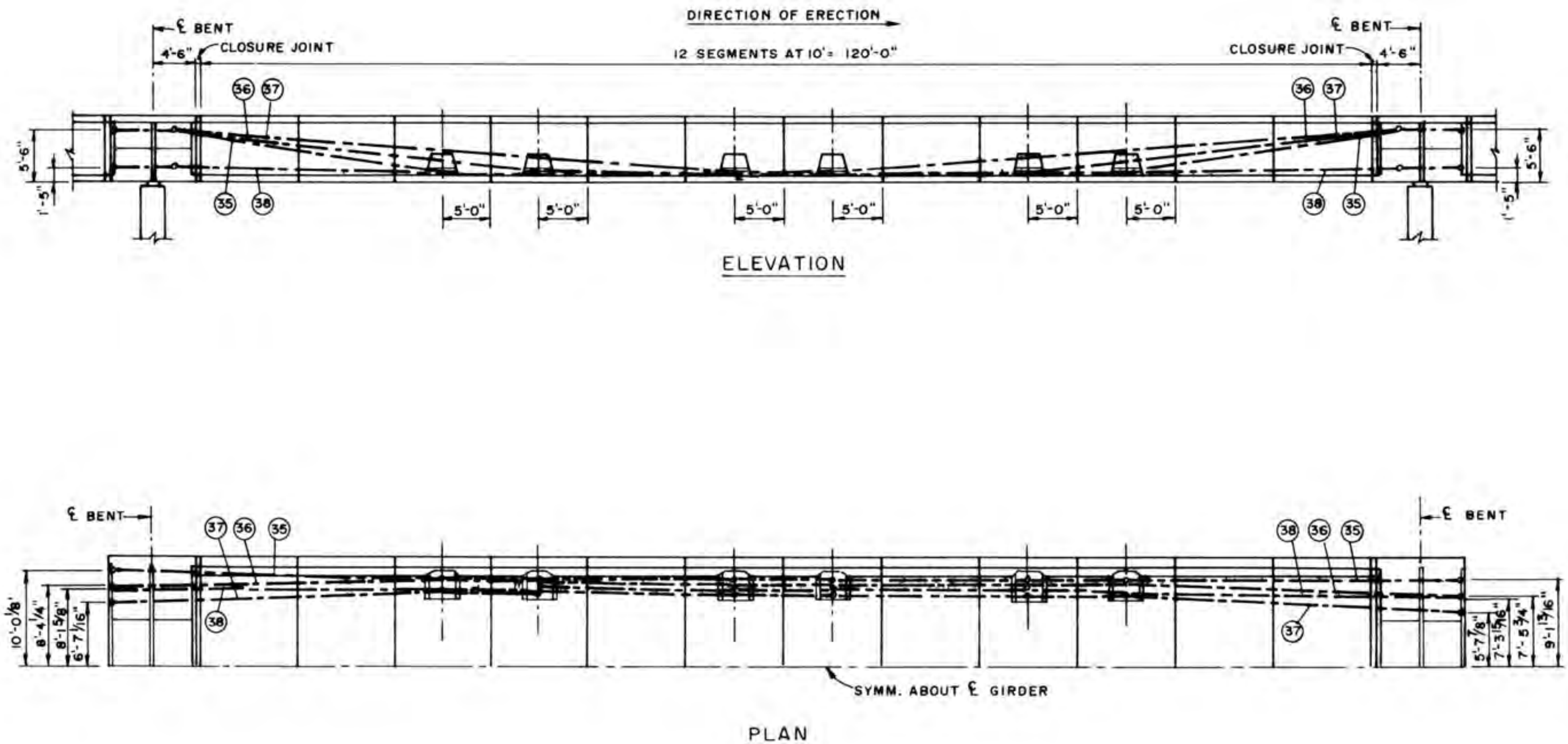

Fig. 8. Plan and elevation of typical span-by-span post-tensioning layout.

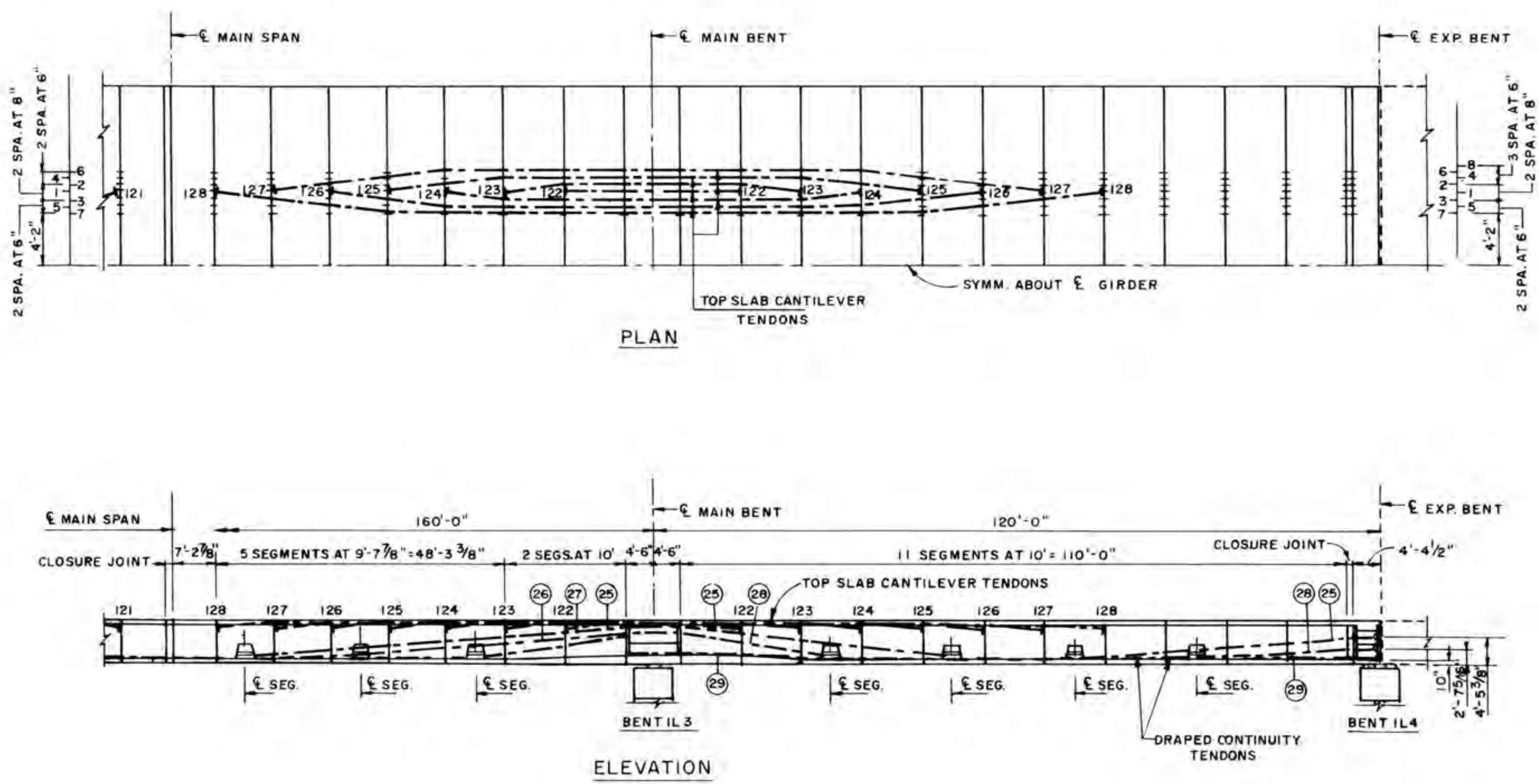

Fig. 9. Plan and elevation of typical post-tensioning layout for 160 ft (48.8 m) cantilever span over four-lane highway.

Fig. 10. Typical segment being cast. Steel frame surrounding the casting machine anchors the transverse pretensioning. The segment just to the left of the casting cell is in the match cast position, while the segment on the far left is awaiting transportation to the storage area.

Fig. 11. A lowboy truck carries segments from the casting yard to the project site 35 miles (56 km) away.

Fig. 12. The first set of cantilevers nears completion across U.S. 90.

and into the match cast position.

The segments were supported on their bottom soffits by a special soffit form placed on rollers. Three of these soffit forms were utilized for each casting machine in order to expedite stripping the forms from the segments and so that the crane would not have to move the previously cast segments immediately. Once a segment was removed to storage by the crane, the empty soffit was lifted up and placed back in the casting cell ready for the next segment to be cast.

The face of the match cast segment against which the current segment was to be cast was coated with a mixture of flax soap and talc to inhibit bonding between the fresh concrete and the previously cast segment. Location of the match cast segment was carefully surveyed and adjusted in relation to the casting cell formwork so that later, when the segments were rejoined during erection, they followed the proper geometry.

Reinforcing steel cages for the segments were prefabricated in rebar jigs in a separate operation, and then lifted into the casting cell in one piece. After reinserting the core form into the casting cell, transverse pretensioning strands were installed and stressed to the specified force.

For the Type I segments, concrete was first placed through a hole in the top of the core forms into the bottom slab of the segment. In the Type II segments, the narrower bottom slab allowed placement of the concrete in this area through the segment webs. After the bottom slab concrete had been placed, concrete was deposited and properly vibrated in each of the segment webs. Placing concrete in the top slab of each segment completed the concrete operations.

Each segment was then screeded between the match cast segment and the fixed bulkhead of the casting cell. Following hand finishing, the segments were given a tine surface finish which was later used for the as-cast riding surface. The enclosure shed was then rolled over the completed segment, which was steamed cured overnight.

After cylinder breaks confirmed that the concrete had reached the minimum required strength in the morning, the transverse pretensioning was destressed by cutting the ends of the strand. Final finishing of the segments took place later in the storage yard.

All 2164 segments required for the I-110 Biloxi project were cast using this procedure (Fig. 10). Normal rates of production for each casting machine were one segment per day for typical segments and two segments per week for pier and expansion joint segments.

A typical 10 ft (3.05 m) long Type I segment weighed 45 tons (41 t) while a typical Type II segment weighed 30 tons (27 t). Type I and Type II pier segments weighed approximately 50 tons (45 t) each. When ready for erection, the segments were transported to the project site using lowboy trailers (Fig. 11).

Cantilever Erection

The spans crossing U.S. 90 on the south end of the project were erected using a modified balanced cantilever procedure. On the south side of U.S. 90, the cantilevers utilized a falsework tower to stabilize the cantilever and reduce out of balance moments on the pier. For the cantilevers on the north side of U.S. 90, the trusses to be used later for span-by-span erection were utilized in the back spans to stabilize the cantilevers.

As each cantilever segment was being placed, epoxy was applied to one face of the segment to provide lubrication as the segments were drawn together and to seal out moisture from the cantilever tendon ducts passing through the top slab. Temporary post-tensioning was applied to each new cantilever segment using two 1¼ in. (32 mm) diameter post-tensioning bars on each side. This provided a tight fit between the two segments and eliminated excess epoxy between the segment joints. After the epoxy cured, longitudinal cantilever tendons anchoring at the top of each web were installed and stressed.

Fig. 13. Most of the bridge was erected by the span-by-span method of construction utilizing erection trusses supported by falsework at the piers.

Cantilever erection proceeded over U.S. 90 while maintaining traffic below (Figs. 12 and 17). A 2 ft (0.61 m) gap was left between the ends of the cantilevers built from opposite sides of U.S. 90. Strongback beams were used to properly align the ends of the cantilevers and a closure pour was made in the remaining gap. After the closure pour concrete had properly cured, continuity post-tensioning in the cantilever spans was stressed from inside the box girder.

Span-by-Span Erection

Most of the I-110 Biloxi structures were erected using the span-by-span method where the segments are temporarily supported on erection girders while being assembled (Fig. 13).

Two sets of erection girders were used by the contractor on this project. The first was a triangular truss 11 ft 3 in. (3.43 m) deep. Each of these trusses weighed 60 tons (54 t) and could erect spans up to 140 ft (42.7 m) long. The second set of erection girders was fabricated as a

Fig. 14. Segments are lifted by ground based crane onto the erection trusses.

Fig. 15. Post-tensioning of the main longitudinal tendons completes the span erection cycle and allows the erection trusses to be moved to the next span.

welded steel box girder section, 6 ft 6 in. (1.98 m) in depth. Each of these weighed 77 tons (70 t) and also was capable of erecting a 140 ft (42.7 m) span. The steel box girder erection equipment provided for greater vertical clearance from underneath, which was advantageous for erecting the bridge across an active railroad.

The erection girders were supported by steel falsework resting on the footings at each pier. Hydraulic jacks placed between the falsework and the erection girders provided for any vertical adjustments required.

The erection cycle began with the advancement of the erection trusses from the previously erected span. After being lowered onto roller supports at the piers, the erection trusses were pulled forward by either a crane with a drag line or by some other means of providing a nominal horizontal force.

All of the segments for a given span were typically delivered to the erection site prior to the start of erection for that span. A ground based crane would then lift each segment onto the erection girders where it was placed onto a three-point support (Fig. 14). Each of these support points had the capacity for adjustments in the longitudinal, transverse and vertical directions. Once all the typical segments were loaded onto the trusses, they were fitted together one at a time using hand winches and the adjustable supports.

Epoxy was not used in the segment joints on this part of the structure since all of the post-tensioning tendons were external to the concrete. Instead, a neoprene seal was installed in each segment joint to prevent water leakage.

At the same time that the segments were being aligned, other work crews installed ducts inside the box girder and threaded post-tensioning tendons through the ducts. A 6 in. (152 mm) closure joint was left between the typical segments and the pier segments at each end of each span to allow for adjustments during erection. Several temporary blocks were installed across these joints using a fast setting, high strength grout after the segments had all been aligned. This allowed a low initial post-tensioning force to be applied to the span, closing the segment joints tightly.

After forming the two closure joints, the concrete was placed and a tine finish was applied to the surface. Once the closure pour concrete had reached a minimum strength of 2500 psi (17.2 MPa) the next morning, stressing of the main longitudinal tendons for that span was begun (Fig. 15).

Following completion of the stressing operation, the erection girders could immediately be moved forward for erection of the next span. The erection cycle for one span typically took approximately 3½ days.

Fig. 16. A series of parallel box girders are later joined together using cast-in-place reinforced concrete closure strips to provide full deck width of ramp transition area.

Finishing Operations

The roadway for many portions of the I-110 Biloxi viaduct is made up of several parallel segmental box girders. In these areas, reinforced concrete longitudinal closure joints approximately 2 ft (0.61 m) wide were cast in between the girders to form the continuous roadway surface (Fig. 16). Barrier rails for the project were cast using a slipform technique. The addition of expansion joints, signs, stripping and a sprayed textured finish completed the structure.

The precast prestressed Biloxi Interstate-110 connector was dedicated and opened to traffic on February 19, 1988. During the past 2 years of operation, the viaduct structure has been performing with total satisfaction.

Figs. 18 through 20 show various views of the finished structure. The smooth clean lines and aesthetic quality of the precast concrete is plainly visible.

Fig. 17. Traffic continues to move during precast concrete segmental cantilever construction of the 180 ft (54.9 m) spans across U.S. 90.

Advantages of Using Precast Prestressed Concrete

The design, construction methods and materials selected for the Biloxi Interstate-110 structure made it possible to build the connector through the urban setting with minimal clearance over a major highway and in limited right-of-way for the greatest aesthetics, function and economy. The use of precast prestressed concrete in conjunction with a segmental design provided the following advantages:

Function

• The design of precast prestressed concrete with the balanced cantilever method of construction allowed a 180 ft (54.9 m) span on a 650 ft (198 m) radius and a 160 ft (48.8 m) span on a 600 ft (183 m) radius to be built over U.S. 90 while maintaining traffic and maintaining full vertical clearance needs during construction.

• The superior quality control achieved by precasting together with both longitudinal and transverse prestressing maximized the structure's durability. In addition, the longitudinal post-tensioning tendons are doubly protected by being encased inside the box girder, external to the concrete, as well as by being encased in grouted pipe.

• The same basic box girder cross section in precast prestressed concrete was used for both span-by-span and balanced cantilever construction, demonstrating even further the simplicity and versatility of precast prestressed concrete for outstanding function.


Fig. 18. A view from underneath the completed structure where four precast box girder superstructure sections are connected. The smooth, closed shape of the superstructure and the pleasing pier shapes insure compatibility with the parks, bike paths, playgrounds and tennis courts that the city is constructing under and around the bridge.

Economics

• Precast prestressed concrete provided an economical solution for the Biloxi Interstate-110 connector. The $40.2 million bid for the project was $4.2 million less than the lowest bids for the conventional cast-in-place alternates.

• The same superstructure box depth was used throughout the urban alignment but with different post-tensioning schemes to match the span length required. This enhanced economy while concurrently providing maximum aesthetics.

• Traffic rides on the as-cast concrete surface are another cost saving factor.

Environment

• Precast segmental construction enabled the structure to be erected through a densely populated area within severly restricted rights-of-way with little impact on the community. Only buildings and trees directly in the path of the roadway had to be moved. Otherwise, the park-like setting of the structure was not disturbed.

Aesthetics

• Because the structure had to travel through an already developed residential and business community, residents and tenants tended to be reluctant to accept a new highway structure. The aesthetically pleasing design of the structure, enhanced by clean girder lines, architectural treatment of the piers and a sprayed textured finish, made it an acceptable addition to the nearby residents and business people.

Rate of Construction

• Construction proceeded quickly. A maximum of 122 segments per month were produced at the casting yard using eight casting machines. The erection subcontractor was able to erect a maximum of 14 spans, or approximately 1600 linear ft (488 m) of bridge, per month.

Concluding Remarks

A major reason for the successful completion of the Biloxi project was due to the excellent cooperation between the owner, design engineer, contractor and precaster.

Precast prestressed concrete brought function, economy and aesthetics together for an outstanding structure solution through a difficult urban area. Building over moving traffic, on tight curves and through residential areas in almost zero right-of-way, saving $4.2 million to the owner over alternate designs, and giving the community a bridge that was pleasing for building parks around it are just some of the features which make the I-110 Biloxi project a success.

Fig. 19. A view across U.S. 90 of the completed precast prestressed structures. The pier shapes were designed to directly receive the bottom slab of the superstructure in a smooth transition for structural aesthetics.

Fig. 20. The completed structures at night. These precast concrete structures represent over 616,600 sq ft (57344 m²) of elevated interstate. The total project cost was $40.2 million. This precast concrete design saved $4.2 million over a cast-in-place concrete alternate.

Credits

Owner: Mississippi State Highway Department, Jackson, Mississippi.

Design Engineers:

• Roadway, Mississippi State Highway Department.

• Segmental Bridges, Figg and Muller Engineers, Inc., Tallahassee, Florida.

• Cast-in-Place Ramps, Michael Baker Engineers, Beaver, Pennsylvania.

Prime Contractor:

• Contract 1: Harbert International, Inc., Birmingham, Alabama.

• Contract 2: Dement Construction Company, Jackson, Tennessee.

Precasting Subcontractor: Contracts 1 and 2: Gulf Coast Prestress, Pass Christian, Mississippi.

Erection Subcontractor: Contracts 1 and 2: Lafayette Steel Erectors, Lafayette, Louisiana.