Dauphin Island Bridge

Presents the major design/construction highlights of the Dauphin Island Bridge—a 17,814-ft (5430 m) long prestressed concrete structure located near Mobile, Alabama. The bridge, which utilized precast concrete in many innovative ways, was built using four distinct construction techniques and was completed on schedule within 2 years at a total bid price of \$43 per sq ft (\$463 per m²).

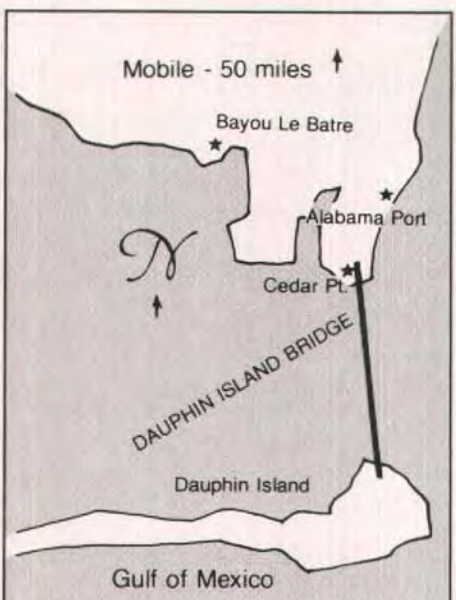

Fig. 1. Location of Dauphin Island Bridge. The original structure was destroyed by a hurricane in September 1979.

A combination of several construction techniques was used advantageously to build the superstructure of the new 17,814-ft (5430 m) long Dauphin Island Bridge. The structure links Dauphin Island in the Gulf of Mexico to Cedar Point about 50 miles (80 km) south of Mobile, Alabama (see map, Fig. 1).

The various construction methods included:

1. Precast segmental balanced cantilever erection.
2. Precast segmental span-by-span erection.
3. Precast girder/deck monolithic span construction.
4. Standard precast girders with cast-in-place deck construction.

This article focuses primarily on the precast segmental aspects of the project.

The bridge combines 13,924 ft (4240 m) of precast prestressed concrete full-deck trestle spans with high-level precast segmental concrete bridge spans. The segmental portion is composed of 26 118-ft (36

Fig. 2. Panoramic view of Dauphin Island Bridge showing the high-level central and approach spans. Entire structure was built within 2 years.

m) approach spans (using 160 uniform depth box girder segments) and a three-span 822-ft (250 m) unit (employing 92 variable depth segments). Construction of the approaches was by the span-by-span method on temporary trusses and of the main span and two side spans by the balanced cantilever method.

A panoramic view of the completed bridge is shown in Fig. 2.

The following major features were incorporated into the structure:

- The 400-ft (122 m) main navigational span is of variable depth and one of the longest precast segmental bridge spans in the world.
- The 822-ft (250 m) main span unit is epoxy jointed. Traffic rides on the as-cast surfaces in both main and approach spans.
- External post-tensioning tendons inside the box girder segments were used for the high-level approaches without using epoxy in the match-cast joints.
- In the approach spans, up to 90 ft (27 m) high precast hollow box piers were match-cast and post-tensioned vertically.
- Multiple shear keys were used for all the precast segments.

The original Dauphin Island Bridge was built in 1955 and was destroyed by Hurricane Frederick in September 1979. As a result, residents of the island were physically cut off from the mainland, depriving them of regular supplies and emergency health services. Ferry service from the mainland to the island was established as a temporary solution, but despite this service there was an urgent need to build a replacement bridge.

Therefore, on October 10, 1979 the consulting firm of Figg and Muller Engineers, Inc. was commissioned to design a new bridge, with a limited time to prepare a design for the entire structure in segmental concrete which could be constructed within 2 years.

Simultaneously, the Alabama Highway

Fig. 3. Dauphin Island Bridge in service. The center span is 400 ft (122 m) with a vertical clearance of 85 ft (26 m) to allow small ships and sea craft to pass. The two side spans are 211 ft (64.4 m).

Department Bridge Bureau was to prepare alternate designs.

Finished drawings and specifications were completed in December 1979. A prebid conference was held the following month and bids were received in February 1980. The main contract was awarded to Brown and Root, Inc., for $32 million.

The contract included the 822-ft (251 m) main segmental unit with a 400-ft (120 m) center span, which has an 85-ft (26 m) vertical clearance over the Gulf Intracoastal Waterway. This feature allows small ships to pass under the main span safely. To protect the bridge piers from possible collisions with errant ships, suitable bulkheads were built adjacent to the piers (see Fig. 3).

Because the bridge is located in an ecologically sensitive area, special care was taken during construction to work within strict environmental restraints.

In planning the bridge, the engineers raised its elevation 23 ft (7 m) and designed the structure for winds up to 200 miles per hour (330 km/hr), thereby increasing its resistance to potential hurricanes. The entire design and construction process for the Dauphin Island Bridge was engineered to meet the needs of the emergency situation caused by the 1979 hurricane.

The main span of the bridge was erected as a balanced cantilever made up of various depth precast single-cell box segments. For the approach spans, the span-by-span erection method, used so successfully on the Florida Keys bridges, was employed.

Figs. 3 and 4 show various views of the completed bridge. Fig. 5 is a cutaway section of the bridge at the start of the 400-ft (120 m) main span. Shown on the diagram are some of the major features of the construction method.

Fig. 4. Bird's eye view of bridge. The overall span is 17,814 ft (5430 m).

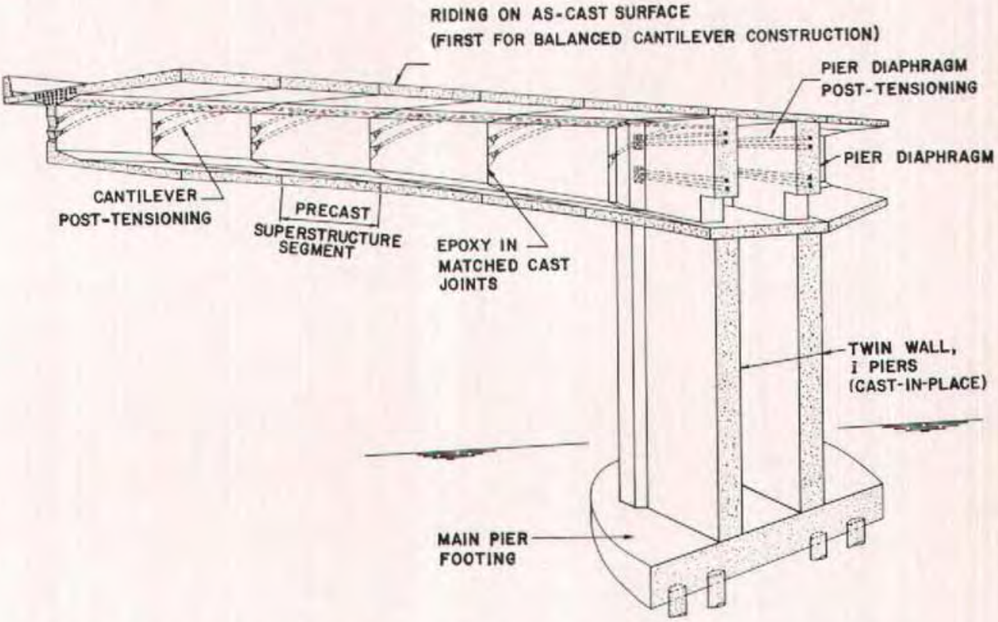

Fig. 5. Cutaway section of bridge at start of 400-ft (122 m) main span, showing major features of construction method.

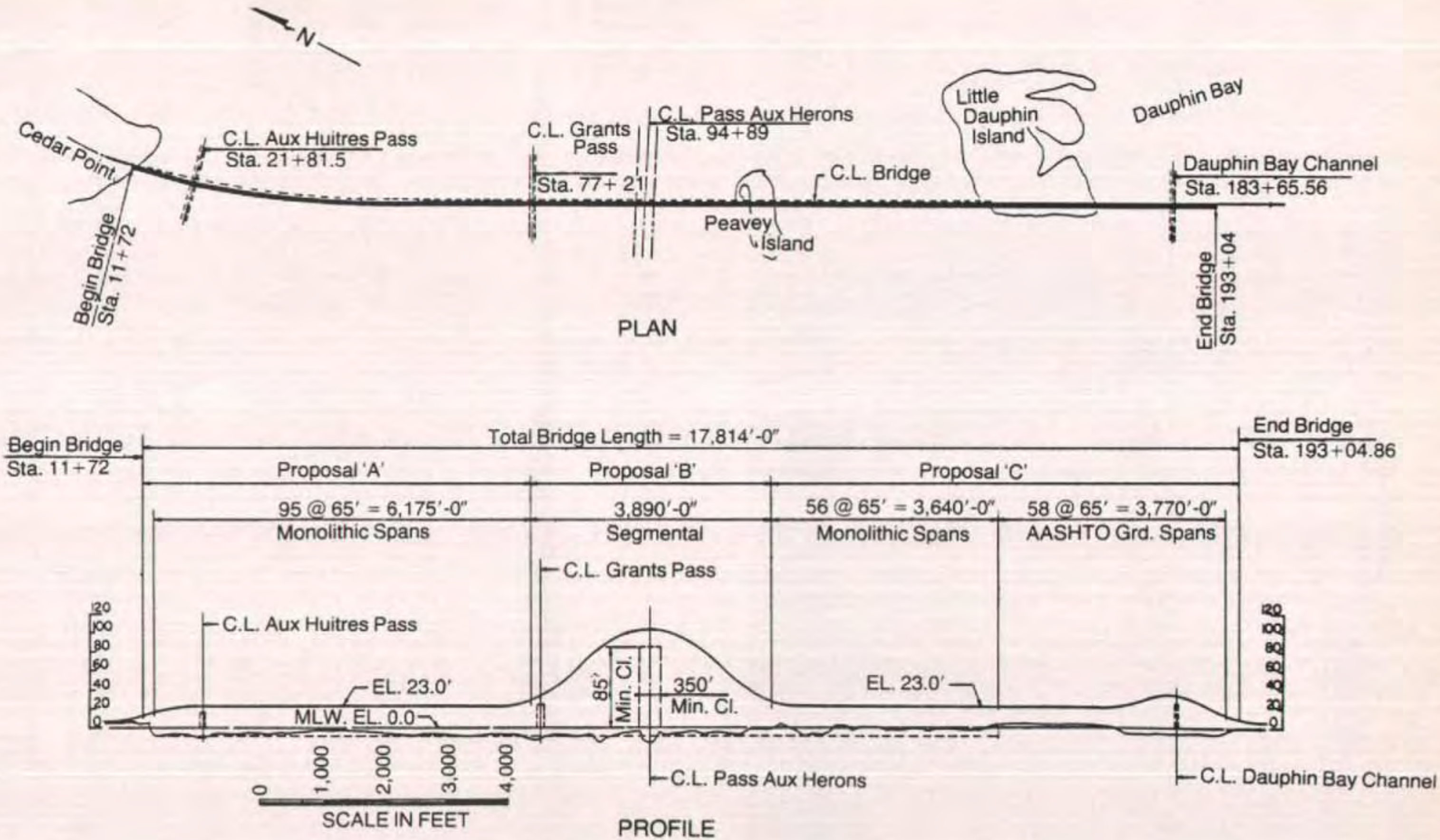

Fig. 6. Plan and profile of Dauphin Island Bridge. (Note: 1 ft = 0.305 m; 1 in. = 25.4 mm.)

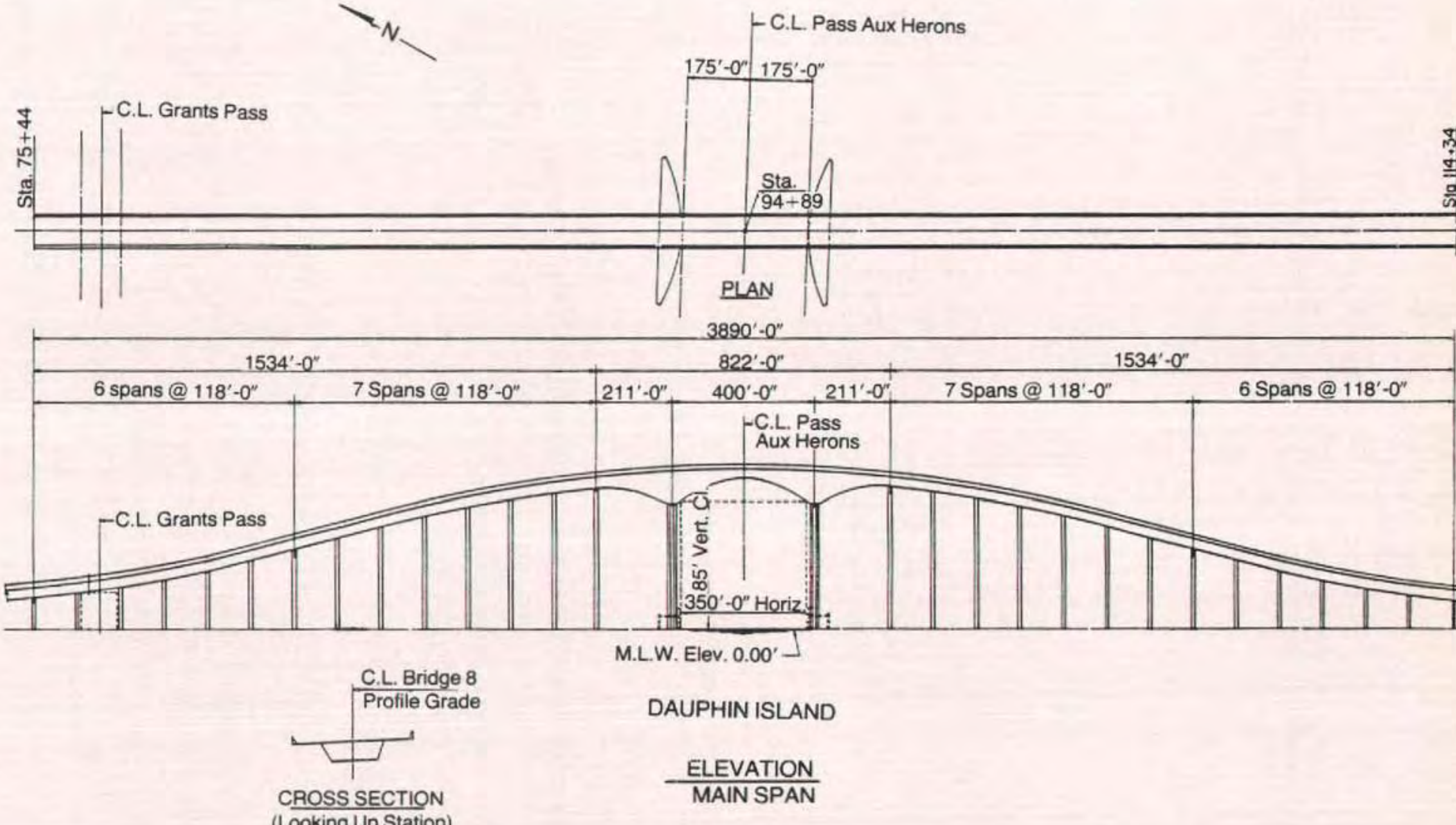

Fig. 7. Plan and elevation of main span of Dauphin Island Bridge. (Note: 1 ft = 0.305 m; 1 in. = 25.4 mm.)

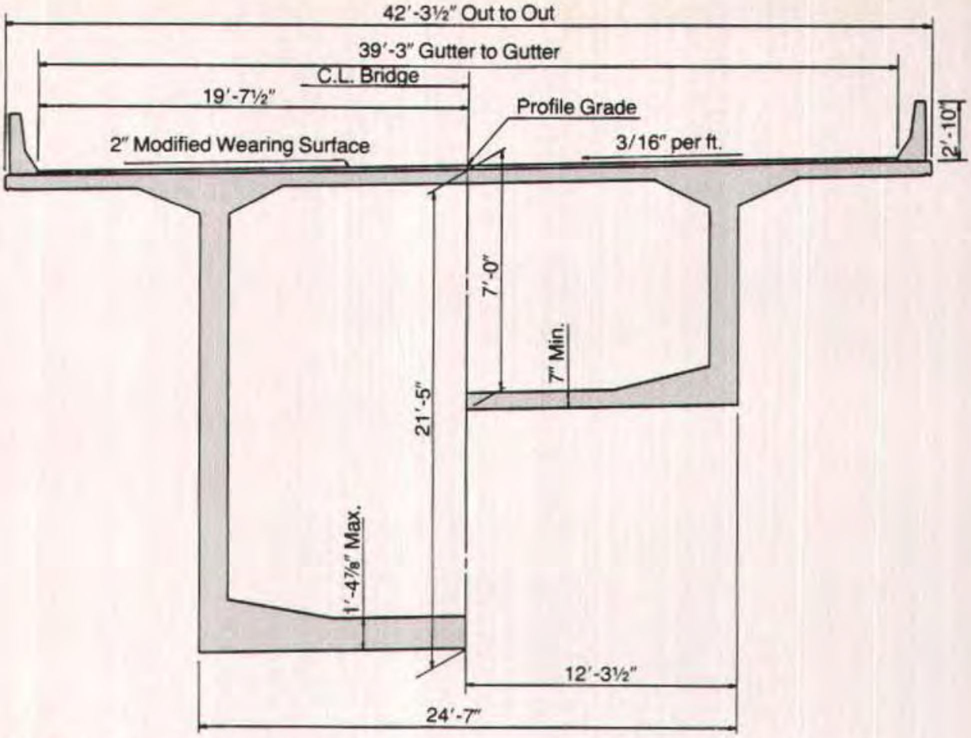

Fig. 8. Half section of variable depth box segments for 400-ft (122 m) main span of Dauphin Island Bridge. (Note: 1 ft = 0.305 m; 1 in. = 25.4 mm.)

Number and Size of Precast Segmental Components.

Approach Spans (Superstructure)

156 typical segments, 42 ft 3½ in. wide, 18 ft long, 7 ft deep, weighing 63 tons each.

4 expansion joint segments, 42 ft 3½ in. wide, 9 ft 6 in. long, 7 ft deep, weighing 65 tons each.

24 pier segments, 42 ft 3½ in. wide, 9 ft 6 in. long, 7 ft deep, weighing 65 tons each.

Approach Spans (Substructure)

174 box pier segments, 16 ft x 8 ft, 9 ft high.

Cantilever Center Spans (Superstructure)

92 variable depth segments, 10 ft 3½ in. long, 42 ft 3½ in. wide, 21 ft 5 in. high to 7 ft; maximum segment weight: 150 tons.

Note: 1 ft = 0.305 m; 1 in. = 25.4 mm; 1 ton = 0.907 tonne.

Fig. 6 is a plan and profile of the entire bridge, while Fig. 7 is a plan and elevation of the main span of the bridge. Fig. 8 shows a half section of the variable depth box segments of the main span.

On each side of the main span are 13 spans of 118 ft (36 m) each, which consist of a uniform depth, single-cell box made up of precast segments that were erected by the span-by-span method.

The table on the opposite page provides a summary of the total number and size of precast segmental components used in both the substructure and superstructure of the bridge.

The balance of the bridge structure consists of 178 65-ft (19.8 m) spans made up of monolithically precast units of five girders, a deck, and two safety shape parapets (Fig. 9). These were supported on piers consisting of two or three 54-in. (1372 mm) diameter precast cylinder piles and precast pier caps (Fig. 10). In addition, there are 37 spans constructed with AASHTO girders with cast-in-place deck.

The precast box segments, pier boxes, and monolithic spans (Figs. 11 and 12) were manufactured at a plant in Mandeville, Louisiana. A single casting machine was used to precast the 80 segments necessary for the main spans. Control of production had to be particularly high because the

Fig. 9. Monolithically precast 65-ft (19.8 m) spans each consisted of five girders, a deck, and two safety shape parapets. These units weighed 270 tons (245 tonnes) each.

Fig. 10. A total of 178 65-ft (19.8 m) monolithically precast spans were used in the low-level approaches of the bridge. The piers are made up of three 54-in. (1372 mm) diameter cylindrical precast piles and a precast cap.

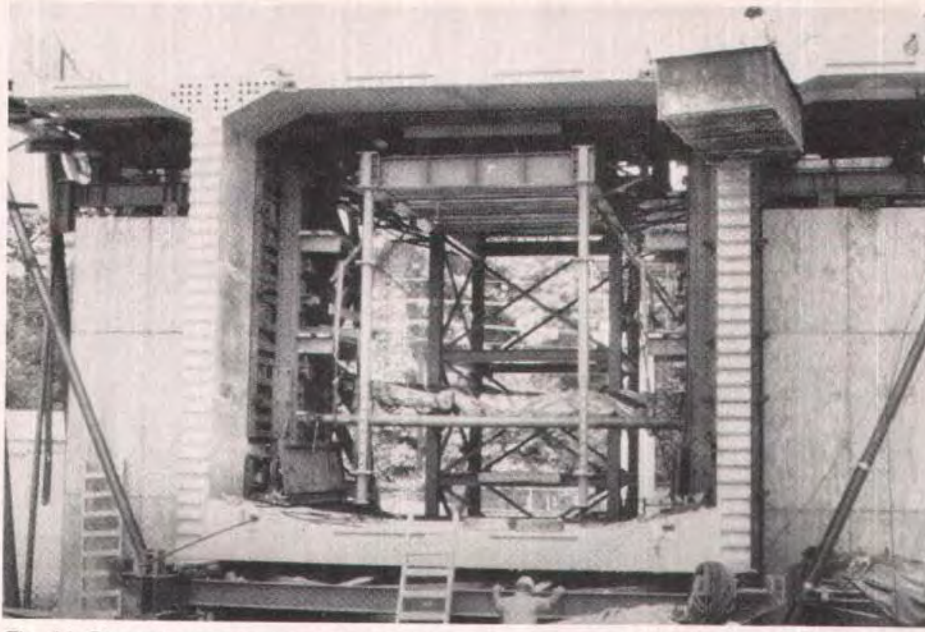

Fig. 11. Precast segment ready for match casting in forms at Mandeville plant. Note multiple keys.

Fig. 12. Several variable depth, match-cast segments for main spans are being air cured prior to shipment to bridge site.

Fig. 13. Precast segments for 400-ft (122 m) main span were barged 150 miles (240 km) to construction site.

cast surface was the final riding surface. This is the first precast segmental bridge erected by balanced cantilever to specify a finished precast deck surface.

The segments were post-tensioned transversely across the deck slab prior to shipment. All superstructure concrete was specified for 5500 psi (38 MPa) at 28 days. Maximum segment weight was 90 tons (82 tonnes).

The precast segments were barged 150 miles (240 km) to the construction site (see Fig. 13).

Piers for the approach span segmental

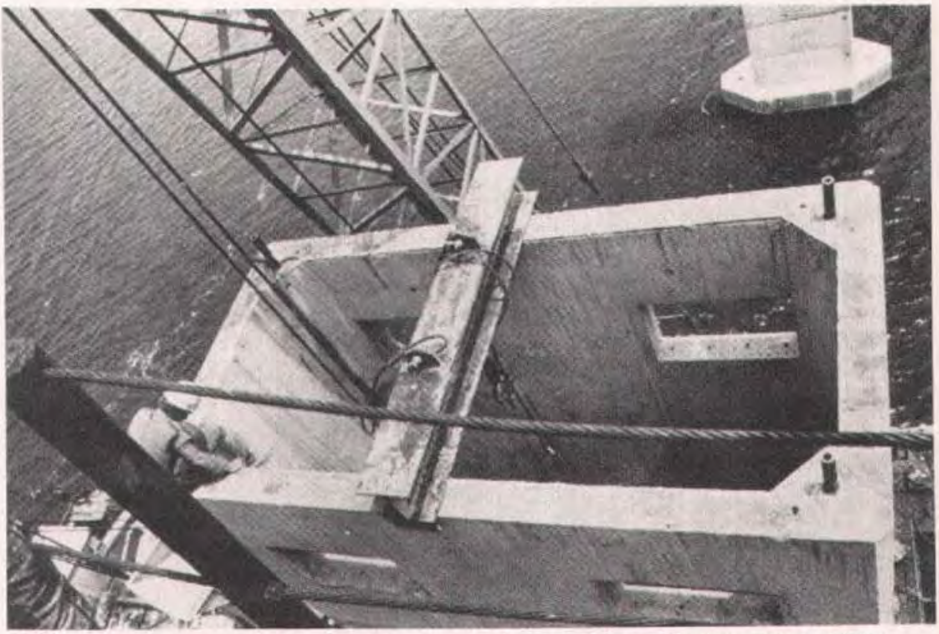

Fig. 14. Pier segments for all precast segmental approach spans were precast. The dimensions are 16 x 8 ft (4.88 x 2.44 m) with 10-in. (254 mm) thick walls.

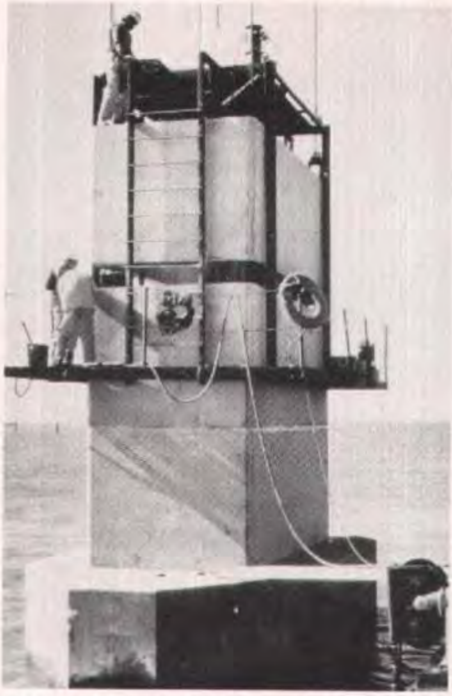

Fig. 15. Workers' platform, which surrounded the piers, was jacked up as the pier progressed upward to provide access to joints where epoxy was used.

Fig. 16. The top segment of each pier contained rectangular blockouts to support the steel erection trusses for span-by-span erection.

box portions of the bridge are made up of precast hollow-box segments up to 90 ft (27.4 m) high. They are 16 x 8 ft (4.88 x 2.44 m) with 10-in. (254 mm) thick walls and were cast and post-tensioned vertically with epoxy in the joints.

Figs. 14 through 16 show the various erection stages of the pier segments.

The twin walled I-section piers were cast in place on a footing of prestressed concrete cylinder piling. They are moment-connected to the superstructure, thus allowing the balanced cantilever erection to continue without falsework.

After completion of the four precast and two cast-in-place segments of the pier table, the falsework was removed (Figs. 17 and 18).

The erection of the main spans was accomplished using the well-known balanced cantilever construction method. In this technique pairs of box segments are progressively erected on each side of a pier (Fig. 19) for a half span. The same procedure is performed simultaneously on the adjacent pier until both segment cantilevers reach midspan, where they are joined by a closure strip.

Each box segment was held temporarily in position (Fig. 20) with a barge-mounted crane. Epoxy was applied to the match-cast faces (Fig. 21) and the joint was closed by stressing four post-tensioning bars (Fig. 22).

After each pair of segments was erected, permanent post-tensioning in the form of two or four 12 x ½-in. (12.7 mm) strand tendons was installed and stressed at anchorages located in the segment webs. The contractor erected two segments in a 12-hour day (Fig. 20). Fig. 23 shows an inside view of a completed box.

Fig. 17. Barge-mounted crane lifting pier segment for main span. Note that main piers were twin walled.

Fig. 18. Pier segments, precast and cast-in-place, ready for adding precast box segments.

Fig. 19. One of two main piers supporting balanced cantilever of precast box segments.

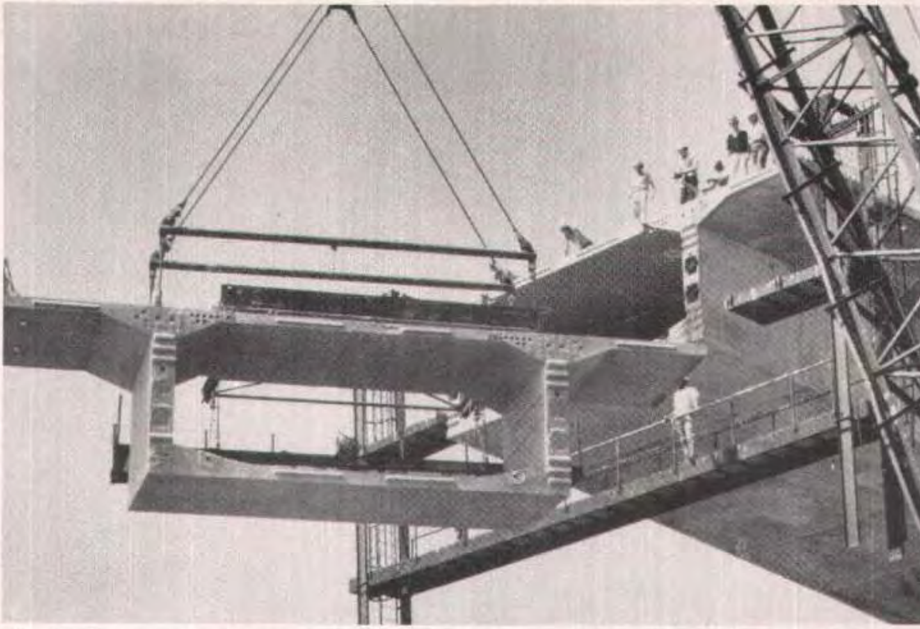

Fig. 20. Barge-mounted crane lifting precast segment to attach to cantilever. Shallow depth of box indicates span is nearly complete.

Fig. 21. Workmen coating faces of precast segments to insure good bond between match-cast segments. Note reinforcing bars along box edges for cast-in-place safety shape parapet.

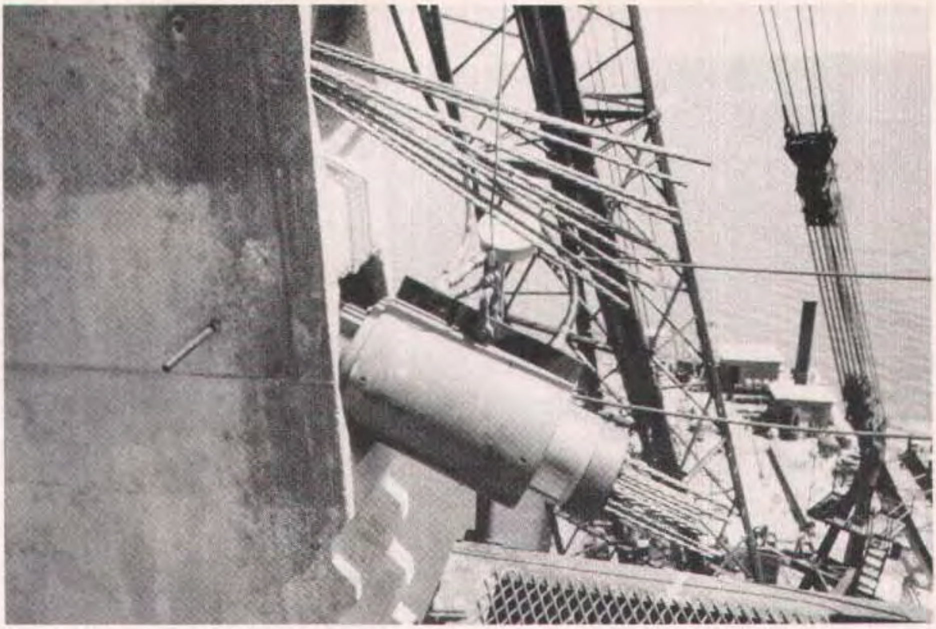

Fig. 22. Hydraulic jack being used to tension tendons for erection stresses.

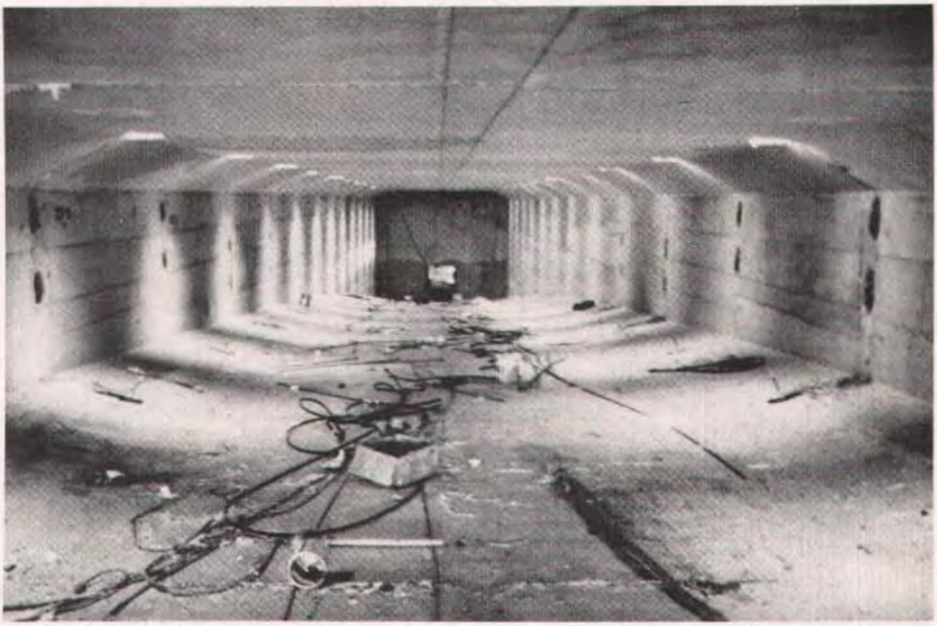

Fig. 23. View inside box looking toward main span pier diaphragm. The variable depth of the box, 7 ft (2.13 m) at the midspan to 21½ ft (6.56 m) at the piers, is noticeable. Empty space can be used for inspection purposes.

Fig. 24. Balanced cantilever construction in progress on 400-ft (120 m) precast main span and 211-ft (64.3 m) side spans. Note that segments vary in depth from 21 ft 5 in. (6.5 m) at the piers to 7 ft (2.1 m) at midspan.

After completion of the balanced cantilevers, the 7 ft 6 in. (2.3 m) midspan closure segment was placed (Figs. 25 and 26). Continuity tendons were installed and stressed from anchorages located in blockouts in the bridge deck, using a total of twenty-two 12 x 0.6-in. (305 x 15 mm) strand tendons.

After grouting and filling the blockouts, the deck was ready for traffic without the addition of any surfacing. Figs. 24-26 show various shots of the balanced cantilever erection sequence.

The span-by-span erection method was used for the approach spans. Casting machines were used to match-cast 184 segments. Typical segments 18 ft long and 7 ft deep (5.5 x 2.1 m) were produced from one machine at the rate of one each day. Pier segments, 9 ft 8 in. (2.9 m) long (including diaphragms and post-tensioning anchorages) were produced by the second machine.

Fig. 27 is a closeup of the erection truss. Six typical segments and one pier segment comprising one 118-ft (36 m) span were installed on an erection truss. Figs. 28 through 30 show various stages of erection using the span-by-span method.

The truss rested in blockouts left in the precast pier segments. After all match-cast segments were set on pier and truss, the closure gap was placed before the entire span was post-tensioned. The truss was then lowered and moved to the next span. Erection proceeded at the rate of two spans per week (Fig. 31).

Fig. 32 shows the completed approach spans except for the casting of the safety shape parapet.

Precast box piers varying from 20 to 90 ft (6.1 to 27.4 m) in height were used for the high-level approach spans. The 9-ft (2.7 m) high segments were match-cast in a vertical position at the rate of eight segments per week using two casting machines.

In the field, the bottom segment was carefully located before a cast-in-place footing was made around it. Subsequent segments were added using epoxy at the joints. Each segment was vertically post-tensioned using anchorages buried in the footing concrete.

Construction of the bridge began in June 1980 and was completed 2 years later. The bridge was open to traffic in July 1982. The 40-ft (12.2 m) wide roadway provides two traffic lanes and two emergency shoulders.

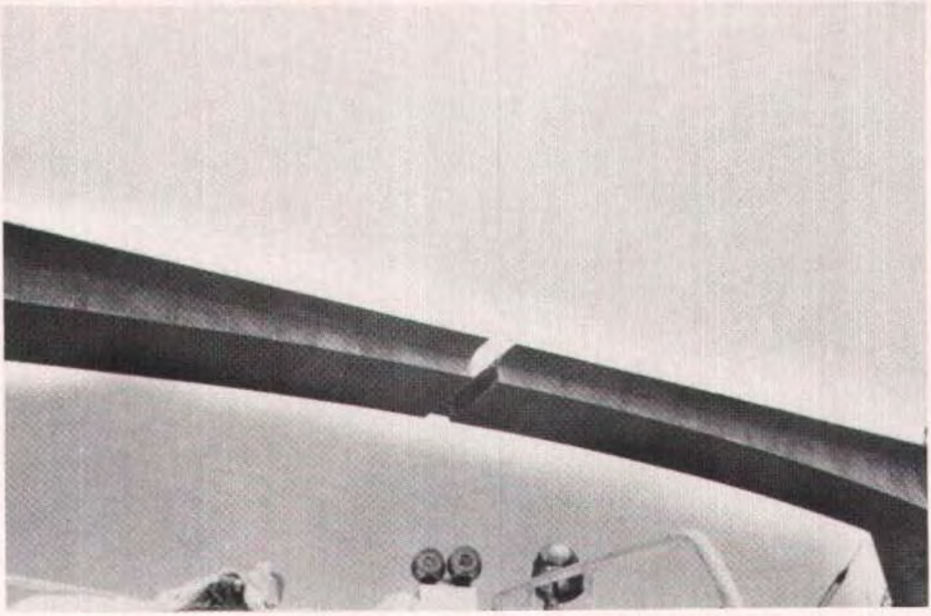

Fig. 25. Gap at centerline of main 400-ft (120 m) span ready for cast-in-place closure. Approximately two precast segments per 12-hour day were erected.

Fig. 26. Main spans almost complete. Structure is now ready for adjacent spans which were erected by span-by-span method.

Fig. 27. Closeup of erection truss used for span-by-span construction of 118-ft (36 m) high level approaches.

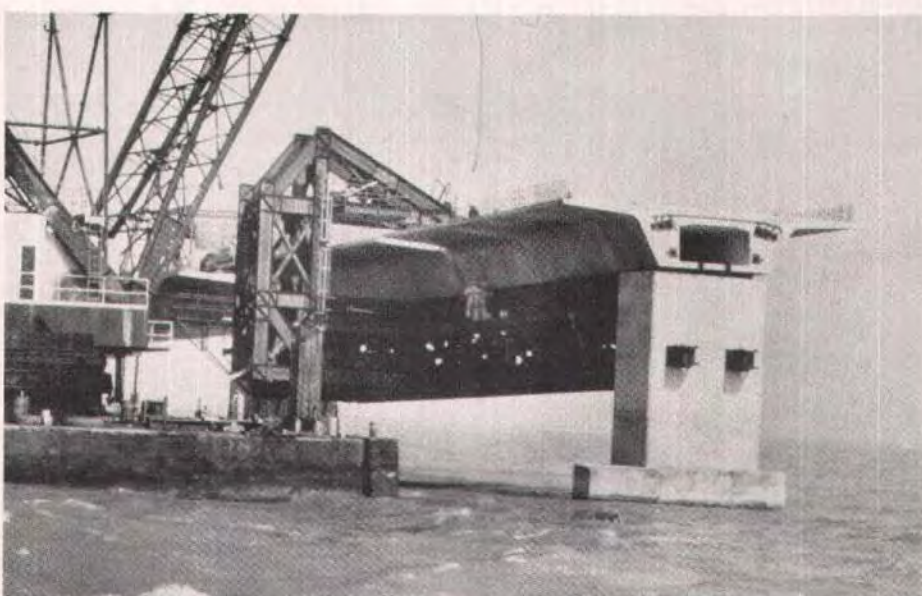

Fig. 28. A large steel truss hanger is used to move truss, which supports segments until post-tensioning is complete. Note blockouts in piers to support truss.

Fig. 29. Approach span with all segments in place on truss. After pier segment is placed the final post-tensioning will be done and truss moved to next span.

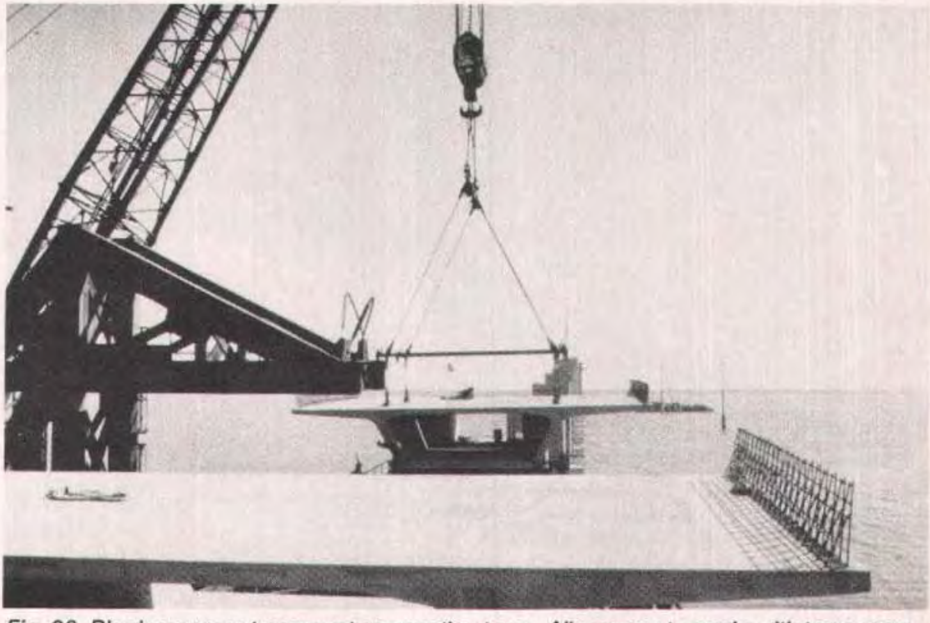

Fig. 30. Placing precast segment on erection truss. All segments made with transverse grooves in deck with steel tines. No additional surfacing is necessary.

Fig. 31. Large barge-mounted crane ready to move erection truss to next span.

Fig. 32. Approach spans complete and ready for casting the safety shape parapet, the last step in erection procedure.

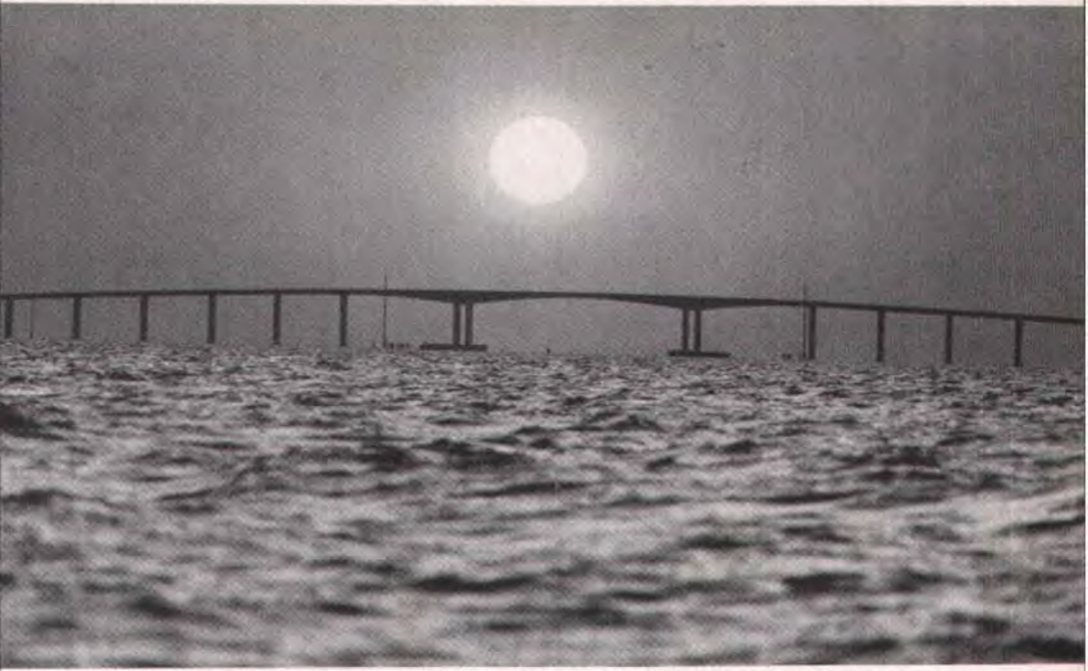

Fig. 33. Completed Dauphin Island Bridge silhouetted against the beautiful sunset.

Motorists using the bridge have expressed satisfaction in the ease of driving across the span and the smooth ride over the as-cast surface.

The total construction cost of the bridge was \$32 million. With the gross surface area estimated to be 750,000 sq ft (70000 m^2), the unit price amounted to approximately \$43 per sq ft (\$463 per m^2). The unit bid prices for the precast segmental box girders were \$115 per sq ft (\$1238 per m^2) for the main cantilevered spans and \$55 per sq ft (\$592 per m^2) for the span-by-span erection of the box girders.

The unit bid prices for the precast segmental box girders and the main cantilevered spans was about \$78 per sq ft (\$840 per m^2). The segmental part of the bridge was 3900 ft (1190 m) and the bid price was \$13 million.

The Dauphin Island Bridge won an award in the 1983 Awards Programs of both the Prestressed Concrete Institute and the Post-Tensioning Institute.

In retrospect, the new Dauphin Island Bridge is significant in that it successfully combined several construction techniques, and was built on schedule and within budget. The end product is a low-maintenance structure which will save future tax dollars. The slender piers and elegant spans are well integrated to produce a well proportioned structure that is visually pleasing to approaching motorists and navigators alike (see Fig. 33).

The experiences gained from this project are sure to be important to those designing and building future bridges for both emergency and long-term situations.

Credits

Design Engineer: Figg and Muller Engineers, Inc., Tallahassee, Florida.

General Contractor: Brown and Root, Inc., Houston, Texas.

Owner: State of Alabama Highway Department, Montgomery, Alabama.