Design and Construction of the Texaco Wharf Maritime Port Facility, Puerto Cortés, Honduras

Li Zhenqiang
Senior Engineer
Beijing, China
and Chief Engineer
Conhsa-Payhsa Group
San Pedro Sula, Honduras

Rigoberto Ramirez C.
Structural Engineer
Conhsa-Payhsa Group
San Pedro Sula, Honduras

The Texaco Wharf Maritime Port Facility is a major marine docking structure located off the northern coast of Honduras that has replaced a 1940s-era steel frame docking structure and access bridge. The structure comprises precast concrete piling and superstructure components that combine precast and cast-in-place concrete. The construction methodology almost completely eliminated the need for on-site formwork and proved to be very successful in producing a high quality docking project in a short time frame. This article presents the design parameters, construction challenges, and erection highlights of the project.

The Texaco Wharf Maritime Port Facility is a docking structure that was built to replace a 1940s-era steel frame docking structure and access bridge. The structure was designed to accommodate berthing for oil tankers as large as 80,000 tons (72500 Mg). The facility is located on the northern coast of Honduras near the city of Puerto Cortés, approximately 40 km (25 miles) east of the Guatemala-Honduras border and 50 km (31 miles) north of the town of San Pedro Sula, Honduras.

The project was completed in August 2000 after a two-year collaboration between Texaco Caribbean, Inc., and Conhsa-Payhsa Group of Honduras. The design of the project began in the summer of 1998, while construction took place from the spring of 1999 to mid-summer 2000. The facility officially opened on August 18, 2000.

The new structure combines precast and cast-in-place concrete, the precast components making up 77 percent, based on the volume of concrete

Fig. 1. Construction in progress on the Texaco Wharf Maritime Port Facility, Puerto Cortés, Honduras. A total of 533 precast concrete components were used on the project.

placed. The concrete quantities for each portion of the facility are presented in Table 1. The complex, shown under construction in Fig. 1, includes a 33.55 m (110.1 ft) long operations platform, two 10.6 m long, 6.0 m wide (34.8 x 19.7 ft) berthing dolphins (one at each end of the operations platform), four octagonal moorings for vessels waiting to dock, a 126.3 m (414 ft) long primary access

Table 1. Quantities of precast and cast-in-place concrete.

Project elements	Precast concrete: Number of components	Precast concrete: Volume of concrete (m^3)	Cast-in-place concrete: Volume of concrete (m^3)
Operations platform	128	678	340
Two berthing dolphins	92	502	102
Four moorings	104	433	64
Access bridge	174	685	172
Western pedestrian bridge	35	14	–
Total	533	2312 (77 percent)	678 (23 percent)

Note: 1 m^3 = 1.308 yd^3.

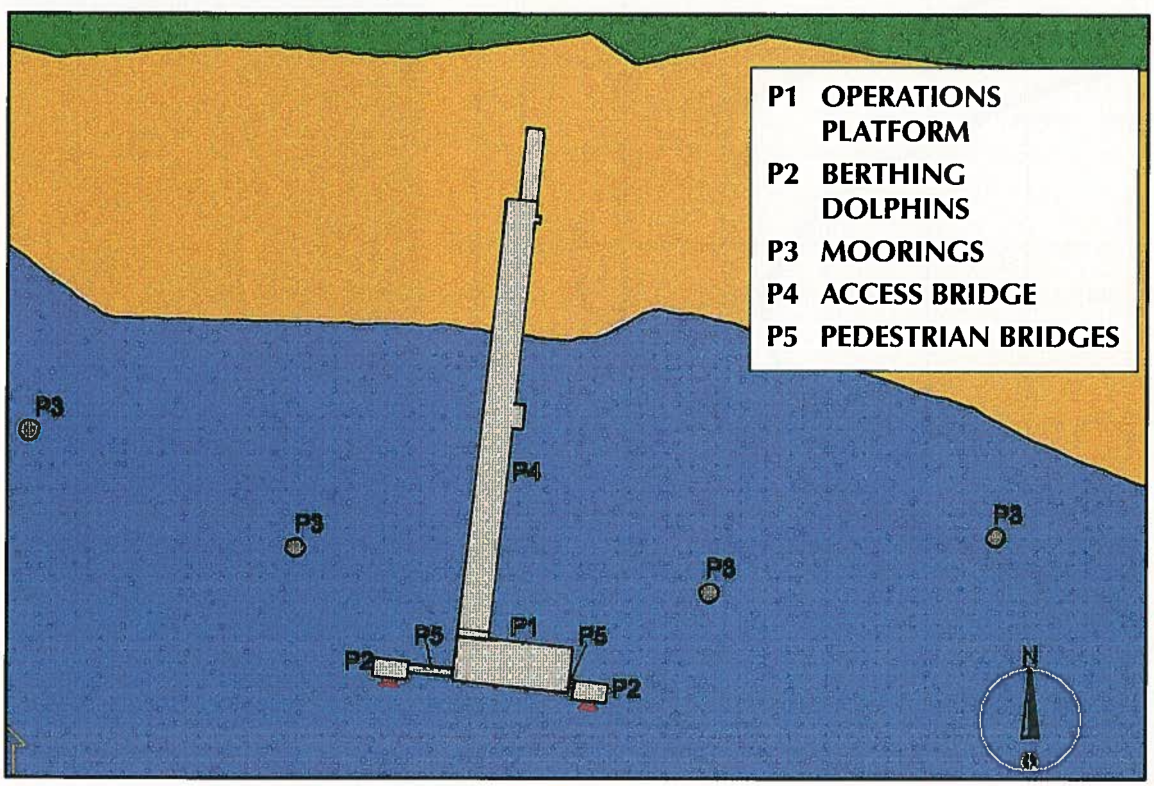

Fig. 2. General plan of the complex with each portion of the project identified.

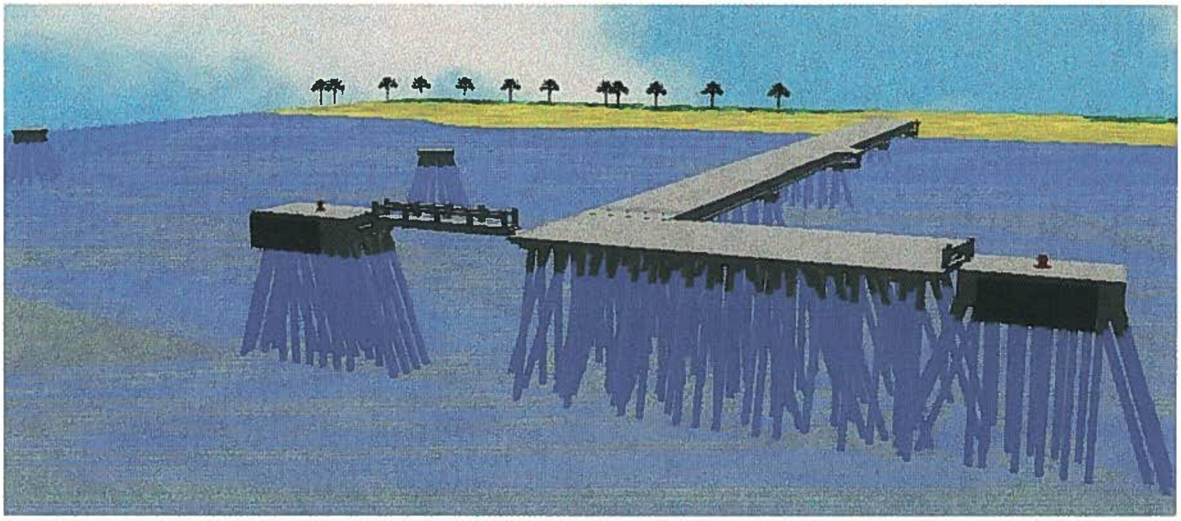

Fig. 3. Artist's conceptual drawing of the project layout.

Table 2. Quantities of precast concrete piles.

Project elements	Number of vertical piles	Number of battered piles	Total
Operations platform	32	66	98
Two berthing dolphins	6 x 2 = 12	28 x 2 = 56	68
Four moorings	0	16 x 4 = 64	64
Access bridge	10	46	56
Total	54 (19 percent)	232 (81 percent)	286

bridge, and two pedestrian bridges. The general plan scheme and a conceptual drawing of the facility are presented in Figs. 2 and 3, respectively.

The structural design included considerations for the active marine environment, including significant wave

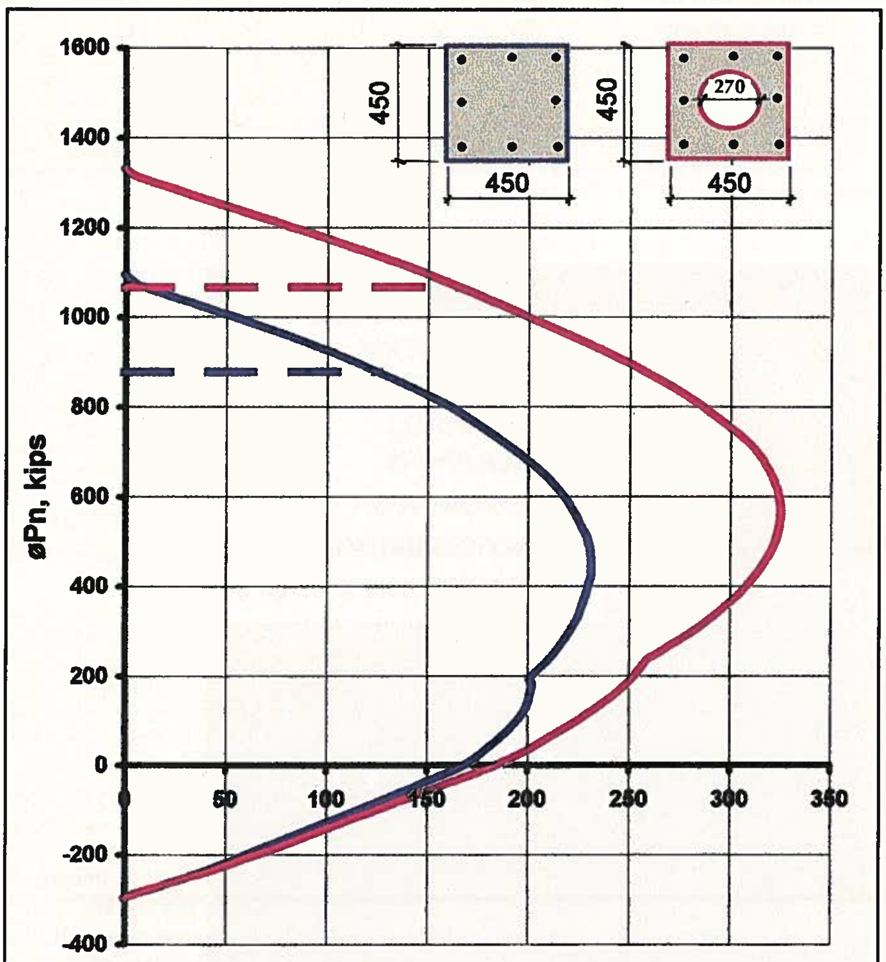

Fig. 4. The two different pile cross sections and a graphical representation of their structural capacities.

Fig. 5. A precast concrete pile being jetted down into the soil.

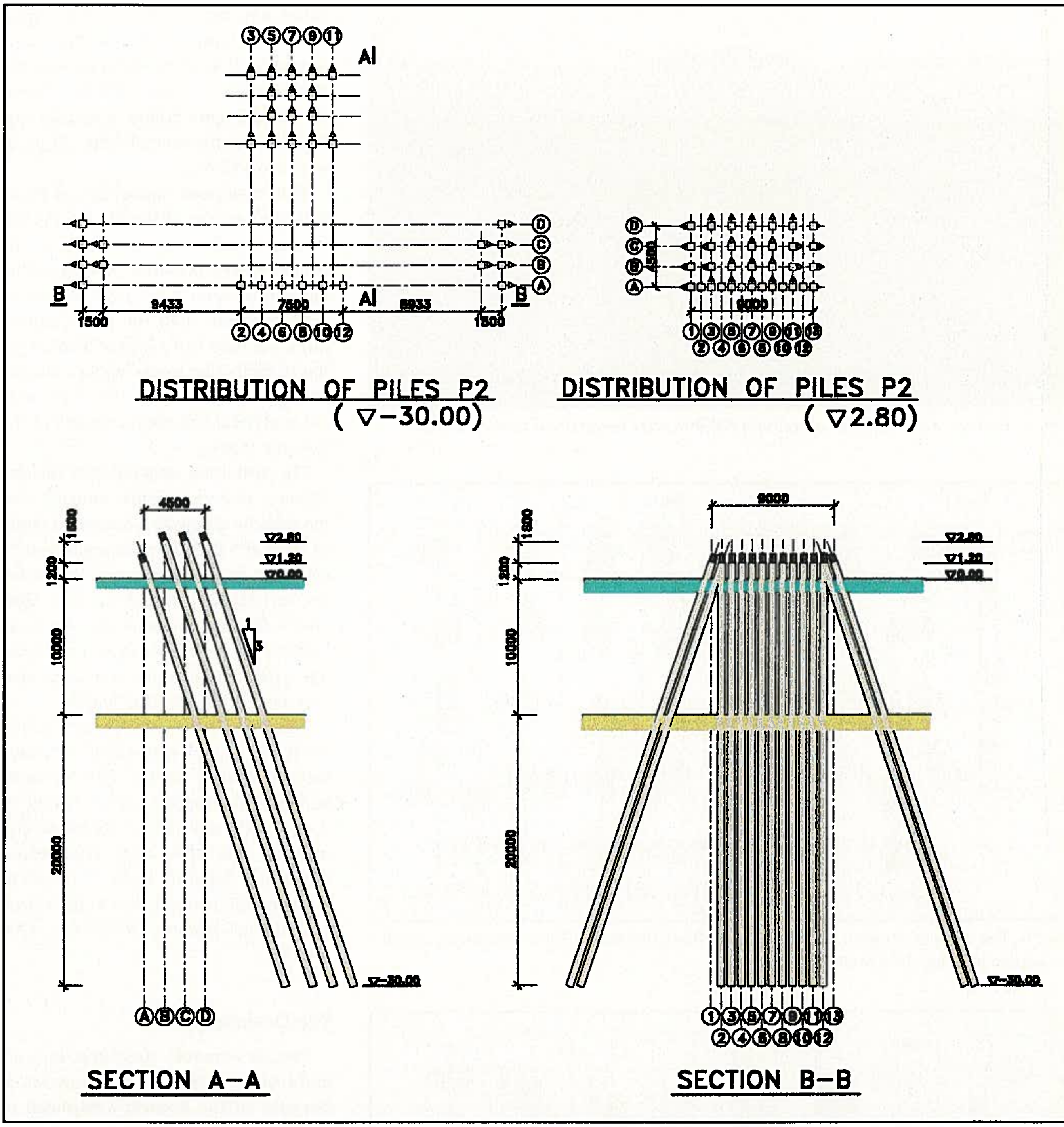

Fig. 6. Design locations of the piling for the berthing dolphin structures.

action and loadings from hurricane force storms. This tropical region encounters a major hurricane approximately every 25 years.

Precast concrete was selected for the principal elements of the structure because of its availability, its intrinsic durability in the severe marine environment, and the high level of quality control that could be achieved. The operations platform, access bridge, two berthing dolphins, and four mooring structures are all supported by precast concrete piling.

Driving the piles had to be done very carefully because the final position of the pile tops had to be achieved with sufficient accuracy to accommodate construction of the structural components to follow. This aspect of the construction was one of the keys to the project's success. The movements of the piles were monitored very closely in the days and weeks after they were driven to make sure their final positions remained reasonably close to their design positions.

PILE FOUNDATIONS

A total of 286 precast, prestressed concrete piles were used on the project, comprising 54 vertical piles and 232 battered piles (see Table 2). Two different pile cross sections were configured on the project. The first was a

Fig. 7. A view of the piles for a berthing dolphin after being driven into position.

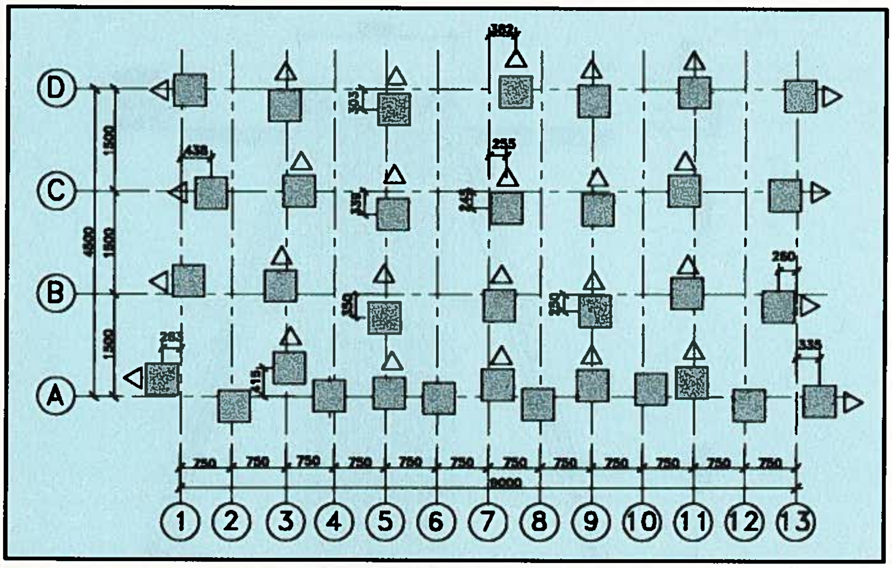

Fig. 8. The as-built position of piles for a berthing dolphin, 3 days after being driven. Triangles indicate the direction of batter.

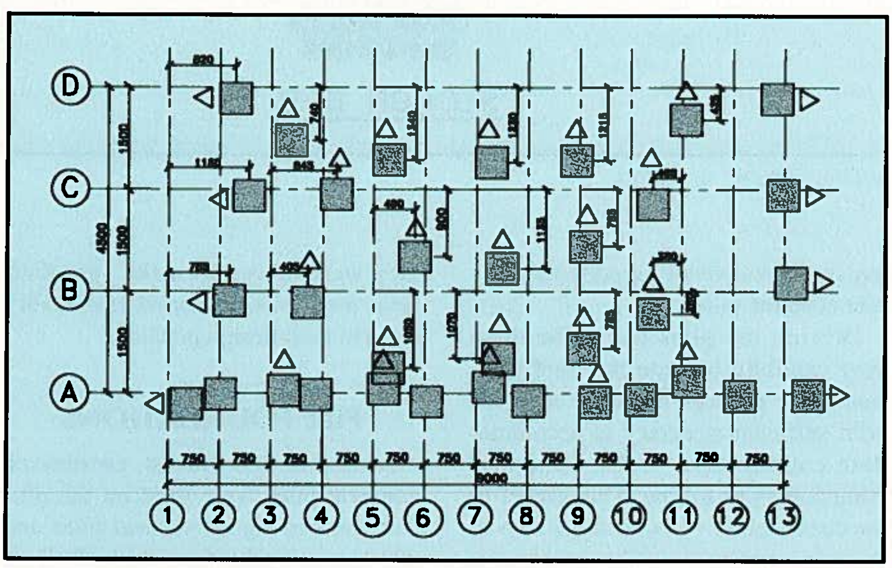

Fig. 9. The as-built position of piles for a berthing dolphin, 80 days after being driven. Triangles indicate the direction of batter.

450 x 450 mm (17.7 x 17.7 in.) solid square section, and the second was a square section of the same dimensions but having a 270 mm (10.6 in.) diameter circular spun hollow core (see Fig. 4). Pile lengths ranged from 28 to 34 m (92 to 112 ft).

The structural capacities of these two pile sections differed, and the advantages of each were used to the fullest extent possible. For example, the hollow-spun piles used 28 percent less concrete than the solid square piles, yet they had a higher load-carrying capacity due to the higher concrete strength that was used. Fig. 4 presents the analytical structural capacity of the two pile types.

The structural analysis and the designers' past experience dictated that the piles be driven to a minimum depth of 20 m (66 ft) below the sea bed to be effective in resisting wave action for the structure's design service life. Given that the water at the site is as deep as 11 m (36 ft) in some places, the typical vertical pile was fabricated to at least 30 m (98 ft) in length.

The piles were driven into place with a diesel-powered hammer mounted on a barge. The hammer weight was dropped from a height of 3 m (10 ft) at a rate of 59 blows per minute. The piles were first jetted down to a depth of 15 to 17 m (49 to 56 ft) before being driven to their final embedment depth of 20 m (66 ft) (see Fig. 5).

Pile Deviations

Precast concrete structures in general require tight fabrication tolerances because of the accuracy required in connecting the individual components together during erection. In the case of the precast piling used on this project, the changes in pile position over time had to be monitored very closely because the installation of the other components depended on the accurate location of the piles.

Deviation in pile alignment occurs from two principal causes: the pile driving process itself (primarily human error) and the time-dependent movement of the piles due to wave action after the piles are driven. Time-dependent deviations from the design position and alignment had to be considered in both the design of the structure and in the construction schedule. For that reason, the superstructure was designed to fit the as-built position of the piles. Fig. 6 illustrates the design pile location and alignment for each berthing dolphin, and Fig. 7 shows these piles after being driven into position. The time-dependent dolphin pile movements at 3 and 80 days, respectively, after being driven are depicted in Figs. 8 and 9.

A summary of the pile deviations due to pile driving activities and time-dependent movement is as follows:

Deviation of vertical piles: At 3 days after being driven, 90 percent of the vertical piles deviated less than 200 mm (8 in.) from their design location. In addition, 60 percent of the vertical piles deviated less than 100 mm (4 in.), and 100 percent deviated less than 300 mm (12 in.) The average time-dependent deviation of the vertical piles at 80 days was approximately two times the deviation at 3 days.

Deviation of battered piles in the direction of incline: At 3 days after being driven, the battered pile deviation in the direction of incline was 300 mm (12 in.) or less in 79 percent of the cases (see Table 3). At 80 days, 25 percent of the piles had deviated over 1 m (3.3 ft) (see Table 4).

Deviation of battered piles in the direction perpendicular to incline: The battered pile deviation perpendicular to the incline, measured 3 days after being driven, was less than 300 mm (12 in.) in 96 percent of the cases (see Table 3). After 80 days, the total time-dependent deviation increased approximately 20 percent (see Table 4).

The magnitude of pile deviation in the inclined direction was much greater than in the perpendicular direction. As can be seen from the measurements of pile deviation (see Figs. 8 and 9), the idea to design and detail the superstructure based on the as-built position of the piling was a prudent decision.

THE SUPERSTRUCTURE SYSTEM

The development of the structural superstructure system for the structure began early in the design process. The incorporation of precast concrete elements into the design of the facility provided an efficient solution that resulted in rapid construction and a low overall project cost.

Operations Platform

The 33.55 m long, 13.6 m wide (110.1 x 44.6 ft) platform superstructure utilized a series of twelve 850 mm (33.5 in.) deep precast concrete box units. The units were assembled

Table 3. Deviation of battered piles of the dolphin, 3 days after being driven.

Deviation (mm)	Number of piles: Direction of incline	Number of piles: Perpendicular to direction of incline
< 100 (4 in.)	6 (21 percent)	17 (61 percent)
< 200 (8 in.)	15 (54 percent)	24 (86 percent)
< 300 (12 in.)	22 (79 percent)	27 (96 percent)
< 400 (16 in.)	26 (93 percent)	28 (100 percent)
< 500 (20 in.)	28 (100 percent)	–

Note: 1 in. = 25.4 mm.

Table 4. Deviation of battered piles of the dolphin, 80 days after being driven.

Deviation (mm)	Number of piles: Direction of incline	Number of piles: Perpendicular to direction of incline
< 100 (4 in.)	3 (11 percent)	10 (36 percent)
< 200 (8 in.)	9 (32 percent)	21 (75 percent)
< 300 (12 in.)	12 (43 percent)	23 (82 percent)
< 400 (16 in.)	13 (46 percent)	27 (96 percent)
< 500 (20 in.)	15 (54 percent)	28 (100 percent)
< 600 (24 in.)	15 (54 percent)	–
< 700 (28 in.)	15 (54 percent)	–
< 800 (31 in.)	19 (68 percent)	–
< 900 (35 in.)	21 (75 percent)	–
< 1000 (39 in.)	21 (75 percent)	–
< 1100 (43 in.)	23 (82 percent)	–
< 1200 (47 in.)	25 (89 percent)	–
< 1300 (51 in.)	27 (96 percent)	–
< 1400 (55 in.)	28 (100 percent)	–

Note: 1 in. = 25.4 mm.

Fig. 10. Positioning one of the precast box units, with reinforcing steel cage, over the precast concrete piling of the operations platform.

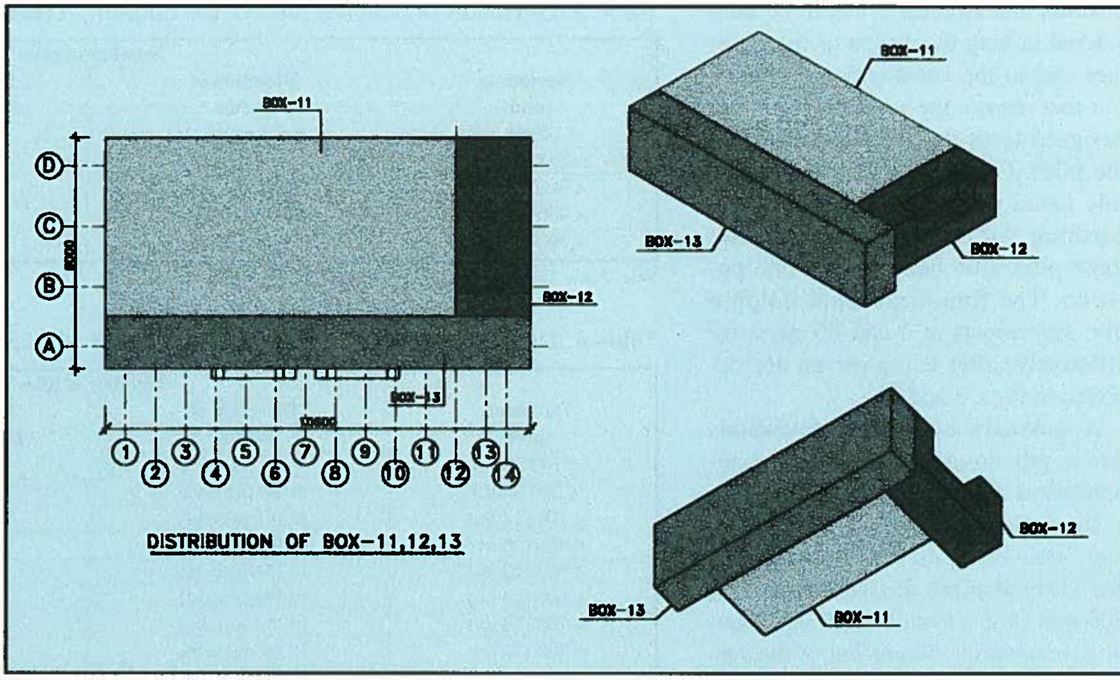

Fig. 11. Three views of the berthing dolphin superstructure, illustrating its division into three separate precast pieces.

Fig. 12. Front and rear view of "Box 13," assembled at the precast plant from five precast, prestressed concrete panels and reinforcing steel cage for the cast-in-place concrete.

Fig. 13. View of the dolphin system complete with fender and face panel.

using precast, prestressed concrete panels and reinforcing steel cages, which were fabricated and partially assembled at a precast plant some 50 km (31 miles) away. The elements were transported over land to the site by truck-trailer and through the water by barge.

The precast box units were supported on 98 piles and served as stay-in-place formwork for the placement of continuous, cast-in-place concrete within each box unit (see Fig. 10). The precast box elements were designed to act monolithically with cast-in-place concrete construction to form the completed structure.

Berthing Dolphins

The two berthing dolphins are identical in structure and dimensions. One sits on the eastern end of the platform and the other is on the western end. Each dolphin deck is 10.6 m long and 6.0 m wide (34.8 x 19.7 ft), and supported by 34 piles, of which 28 are battered. Each dolphin deck employed an irregular box-shaped structure composed of 15 separate precast, prestressed concrete panels, and divided into three separate units during construction (see Fig. 11).

As with the operations platform, each berthing dolphin unit was fabricated and partially assembled at the precast plant before being transported to the site by truck and barge (see Fig. 12). The dolphin structure was completed by adding reinforcing steel between the units and pouring concrete inside the box structure. Lastly, a fender and face panel were added to the dolphin to protect it from damage during docking of large tankers (see Fig. 13).

Moorings

The four moorings, two on each side of the dock, are identical in their design and spaced evenly apart. Each mooring was built on a base of 16 battered piles, and each has a 5.4 m (17.7 ft) wide octagonal-shaped deck.

As with the operations platform and berthing dolphins, the mooring deck was built using a system of precast concrete panels and reinforcing steel cages, all fabricated and partially assembled at the precast plant before being shipped to the site. Cast-in-place concrete was fed into the precast concrete shell by pump to complete the structure (see Fig. 14).

Access Bridge

Access to the primary operations platform is provided by a bridge structure that accommodates petroleum pipelines and a one-lane road for vehicles. The bridge is 126.3 m (414 ft) long and comprises longitudinal precast concrete girders, diaphragms, and deck panels.

Each pier cap was created from five precast concrete panels and a reinforc-

Fig. 14. View of a completed mooring structure.

Fig. 15. The precast portion of the pier cap consisted of five individual precast panels that were fabricated and assembled together, along with the reinforcing steel cage, at the precast plant.

Fig. 16. A precast pier cap box unit being lowered into position atop the precast piling. Note the extension of reinforcement from the top of the pier cap.

Fig. 17. Precast girders bearing on a completed pier cap.

Fig. 18. A longitudinal perspective of the access bridge, showing the precast girders, diaphragms, and deck panels. Note the projection of reinforcement from the top of the girders into the deck topping.

Table 5. Concrete volume of components of the western pedestrian bridge.

Component	Number of components	Concrete volume (m^3)	
		Each	Total
Main beams	2	2.84	5.68
Beam diaphragms	6	0.27	1.64
Deck slab	1	3.44	3.44
Hand railing columns	14	0.12	1.73
Hand railing beams	12	0.13	1.54
Total	35	—	14.03

Note: 1 m^3 = 1.308 yd^3.

ing steel cage, all fabricated and assembled together at the plant before being delivered to the site for erection (see Fig. 15). After setting the precast assembly into the final position, cast-in-place concrete was poured inside it to complete the pier cap. The cap was connected to the superstructure by reinforcing steel bars that extend from the beam and into the deck (see Fig. 16).

The bridge superstructure consists of precast concrete girders with spans of 25 and 32 m (82 and 105 ft), with 5.25 m (17.2 ft) long cantilever beams at each end of the bridge. The span length was governed by transportation and handling limitations, and the cantilever beams were specifically chosen to avoid contact with the battered piles of the operations platform (see Fig. 17).

The precast, prestressed bridge deck panels were 8.6 m long and 1.3 m wide (28.2 x 4.3 ft), with holes formed into them to allow reinforcing steel bars to project from the top of the longitudinal girders and into the deck topping (see Fig. 18). Partially prefabricated diaphragms were placed every 8 m (26 ft) along the span. Each one has a large hole and was cast-in-place at both sides.

Steel bars were passed through the beam in the horizontal direction, allowing a connection without welding of steel plates. On top of the deck panels and diaphragms is a 100 mm (4 in.) thick cast-in-place concrete topping reinforced with 12 mm (0.5 in.) steel bars.

Pedestrian Bridges

Two pedestrian bridges were constructed to provide access between the operations platform and berthing dolphins on each end of the platform. There were several design considerations that went into the construction of the bridges, including overall dimensions, the determination of support points at both ends of the bridges at discrete anchor points, and end fixing conditions that were occasionally put into tension in order for the bridge to resist vertical uplift forces. The western pedestrian bridge, the much longer of the two, will be the focus of the discussion that follows.

A total of 35 precast concrete components were used in the construction of the western pedestrian bridge (see Table 5). These components made up the main beams [450 x 450 mm x 14.0 m (17.7 x 17.7 in. x 46 ft)], deck slab [2.45 x 14.0 m x 100 mm (8.0 x 46 ft x 4 in.)], hand railing columns, and hand railing beams [300 mm (12 in.) deep]. These design considerations, in combination with the marine environment and architectural factors, made this pedestrian bridge rather unusual.

The bridge itself was constructed in three stages at the precast plant. First,

PROJECT COMPONENTS

- Operations platform — 33.55 m long x 13.60 m wide (110 x 45 ft)
- Two berthing dolphins — 10.6 x 6.0 m (34.8 x 19.7 ft)
- Four moorings — octagonal, 5.4 m (17.7 ft) wide
- Access bridge — 126.3 m long x 8.6 m wide (414 x 28 ft)
- Western pedestrian bridge — 14.0 m long x 2.45 m (46 x 8 ft)
- Eastern pedestrian bridge — 2.4 m long x 2.45 m wide (8 x 8 ft)

Fig. 19. Partial assembly of the western pedestrian bridge at the precast plant.

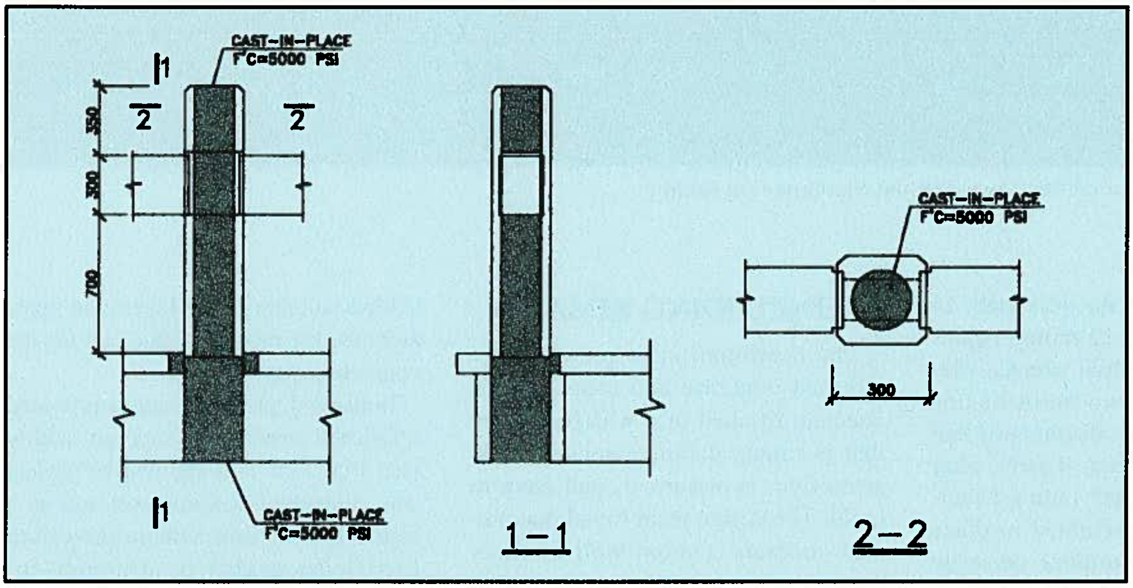

Fig. 20. Connection detail of railing columns, railing beams, and main beams.

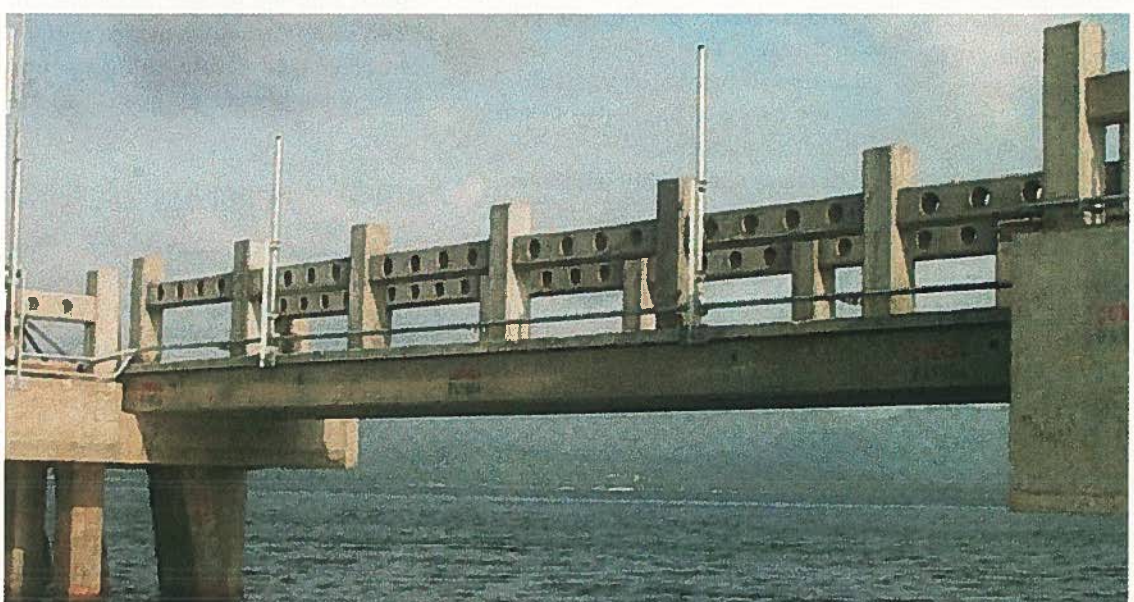

Fig. 21. The completed western pedestrian bridge in final position.

Fig. 22. View of the completed Texaco Wharf Maritime Port Facility.

the two main beams, the deck slab, 14 railing columns, and 12 railing beams were cast as individual precast elements. Then, the two main beams were connected by six diaphragms that were cast between them. Lastly, after the railing columns and railing beams were temporarily assembled in place (see Fig. 19), cast-in-place concrete was poured into holes in the top of the railing columns. This final pour connected the railing columns to the railing beams, main structural beams, the beam diaphragms, and the deck slab (see Fig. 20).

The completed pedestrian bridge was hauled 50 km (31 miles) by truck-trailer to the project site and then by boat another 200 m (660 ft) to its final location. Transportation of the pedestrian bridge was completed in the morning, with its installation taking place before mid-afternoon on the same day (see Fig. 21).

CONCLUDING REMARKS

The combination of precast, prestressed concrete and cast-in-place concrete resulted in a wharf structure that is strong, durable, architecturally attractive, economical, and easy to build. The design team found that precast concrete worked well in every portion of the complex – the operations platform, berthing dolphins, moorings, access bridge, and pedestrian bridges. The pedestrian bridges were erected particularly quickly, essentially taking a single day to transport and install them.

The plant-controlled conditions facilitated the precision in fabrication that was needed on this close-tolerance project. Precast concrete greatly reduced labor costs and eliminated many safety concerns, especially in terms of the unnecessary formwork at the project site. The most important skilled laborers needed were the operators for the erection crane and for the concrete pump.

In the end, precast concrete provided a finished structure of superior quality (see Fig. 22). This innovative project was completed at a low cost and on a tight construction schedule without sacrificing quality or structural integrity. The success of the project proves that the design principles applied in constructing these facilities can be adapted readily to many other types of marine and other construction.

CREDITS

Owner: Texaco Caribbean, Inc. (Michael Jones and Tomas Alonso)

Design-Build Contractor: Conhsa-Payhsa Group (Xavier Argüello, Joaquin Torre, Eduardo Toro, Otto Umaña, and Hector Bustillo)