Precast Concrete Canopy Offers Innovative Design and Fast Track Construction

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The canopy for the Port of Miami Terminals 3, 4, and 5 in Miami, Florida, provides shelter for embarking and disembarking cruise ship passengers as they transfer to buses, taxis and cars.

Precast/prestressed concrete proved to be the fastest and least expensive solution to an innovative architectural and structural design.

By creatively combining and connecting the precast components together, the elegant lines and soaring architectural motif intended by the architect was achieved on the fast track construction schedule demanded by the owner.

This article presents the architectural features, structural design considerations and construction highlights of the project.

The terminal complex at the Port of Miami Terminals 3, 4 and 5 in Miami, Florida, was completed in 1999 and is now in full operation. One of the last portions of the terminal facility to be designed were the canopy/pedestrian bridge structures.

The terminal receives very large cruise ships that can have capacities close to 3500 passengers. It takes nearly two hours for all of the passengers to disembark from one ship. This operation creates significant congestion for passengers and terminal workers as passengers transfer to ground transportation. A complex of canopies with a pedestrian bridge was developed to provide shelter for passengers and porters as they load and unload cars, taxis, vans and buses (see Fig. 1) or proceed to the nearby parking structure.

The terminal building is a large open plan type building that serves as a gathering place for passengers as they embark or disembark the large cruise ships docked there. The main terminal has a tent-like roof form.

A two-segment intermodal canopy provides shelter for vehicles in two lanes on either side of the central pedestrian aisle (see Fig. 2). Buses, cars and taxis load and unload passengers and luggage under the shelter. At the ends of the canopy segments, entry canopies (see Fig. 3) provide shelter over the walkway to the main terminal building.

The canopies also serve as architectural focal points for the design scheme. A pedestrian bridge provides covered and elevated access from an adjacent precast concrete parking structure to the terminal building (see Fig. 4).

These elements form a very elegant front entrance to the $76 million terminal complex that includes the terminal building, parking structure, site improvements, and canopies and pedestrian bridge. The budget for the canopy structures was approximately $2.8 million. The canopies and bridge structure were the last portions of the project and consequently had a very tight construction schedule.

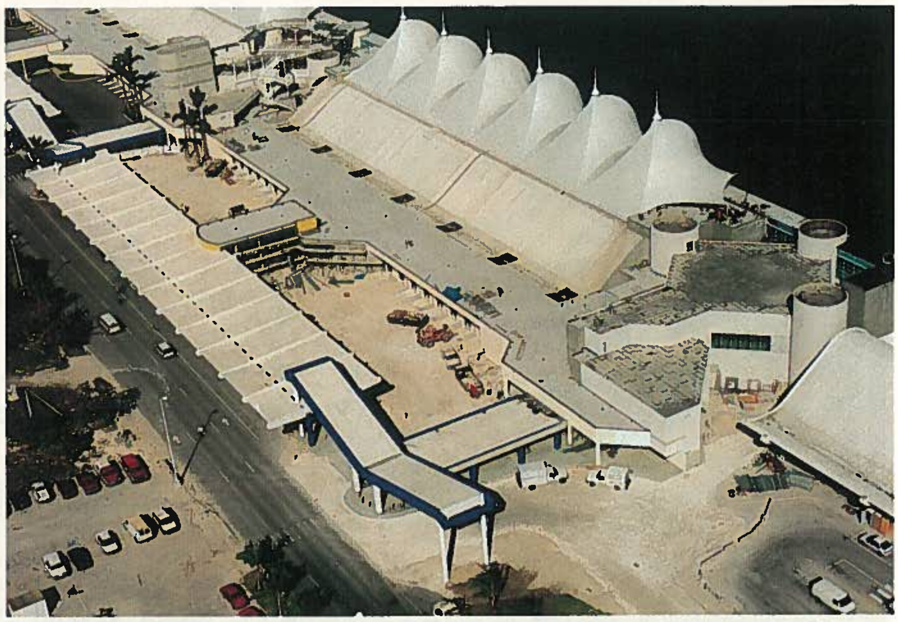

Fig. 1. Overview of terminal complex. Tent-like roofs are the main terminal building. The blue entry canopies are visible as are the two segments of the intermodal canopy.

Fig. 2. Underside view of the intermodal canopy showing double tees and cross-beams.

DESIGN APPROACH

The program for the design of the canopies and bridge was to provide those elements, delivered on time and within budget, but to provide a structure that related to the main canopy building architecturally. The owner also wanted to have a low-maintenance structure that would perform well and without corrosion in the strong wind and high salty-moisture environment.

The architects initially investigated several alternative designs. A tensile-fabric structure was considered in order to acknowledge the design of the main terminal building, but was not selected because it exceeded the budget. Structural steel and cast-in-place concrete solutions were also evaluated and found to be more expensive and were not able to be completed within the required completion time.

The design solution was to use precast concrete because of its low maintenance, low cost and fast delivery time. The design includes principally bolted connections, which are grouted for maximum weather protection. The hidden connections also help achieve the architectural design intent. The

Fig. 3. V-shaped entry canopy.

Fig. 4. The pedestrian bridge, with an entry canopy beyond.

Fig. 5. The intermodal canopy and terminal in use with cruise ship in background.

cantilevers and soaring forms of the entrance canopies also help the canopy structure respond architecturally to the design motifs of the main terminal building.

INTERMODAL CANOPY

The design concept of the intermodal canopy was to provide shelter for the maximum number of vehicles possible, but also to be as open as could be achieved with the materials selected. The canopy shelters vehicles along a length of 1500 ft (457 m). It is broken into two segments by entry canopies, that lead the way to the three entrance points which convey passengers from the loading area into the actual terminal building.

During the initial stages of design, precast/prestressed concrete was identified through value engineering as the best choice for the canopy. Precast concrete was selected because it would create a structure that was easy to maintain, could readily comply with the high wind design requirements of the tropical coastal region, could be delivered very quickly, and would have a lower initial and maintenance cost than competing solutions.

The canopy portion of the structure provides shelter for travelers and employees as they load and unload from ground transportation (see Fig. 5). The canopy has a total of 28 structural bays divided into two segments. The structure is comprised of 24 x 24 in. (610 x 610 mm) columns on pile caps. The columns are spaced 20 ft (6.10 m) apart. The column interval along the axis of the canopy is 28 ft (8.53 m).

The canopy covers a width of 56 ft 10 in. (17.3 m). The roof cantilevers approximately 18 ft 6 in. (5.64 m) from the columns to provide shelter for vehicles on both sides. Both segments of the canopy together provide a sheltered area of approximately 11,000 sq

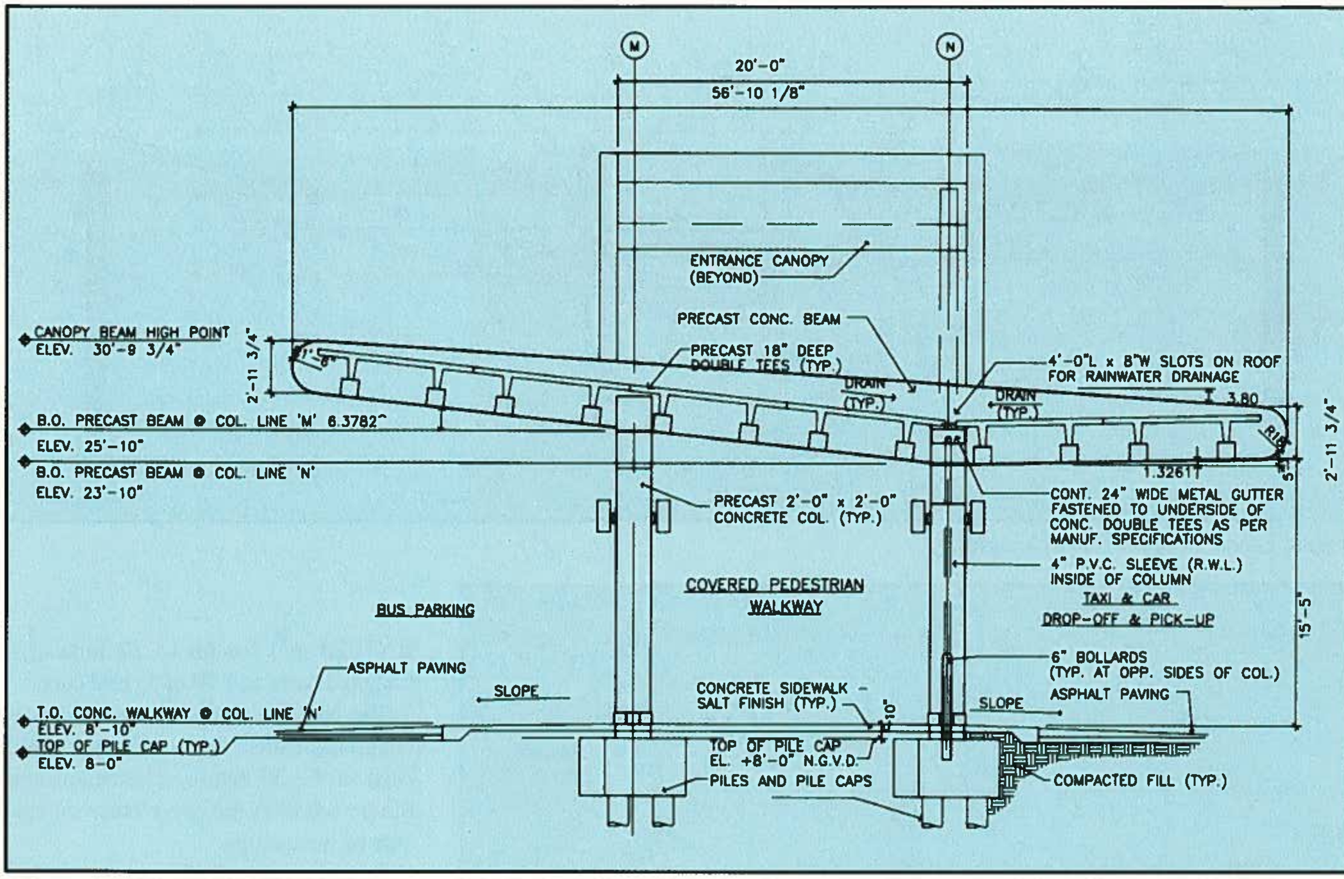

Fig. 6. Section of the intermodal canopy.

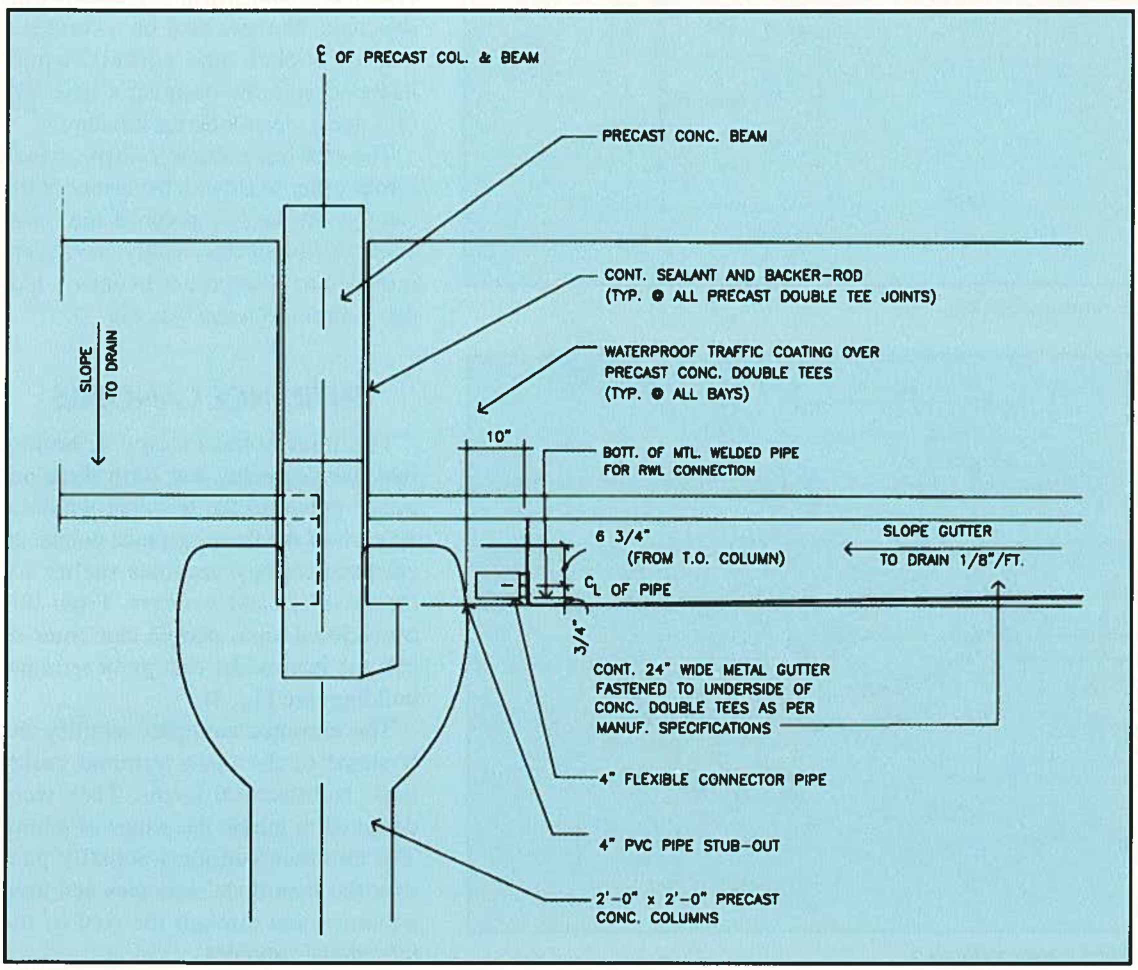

Fig. 7. Guttering detail at the intermodal canopy.

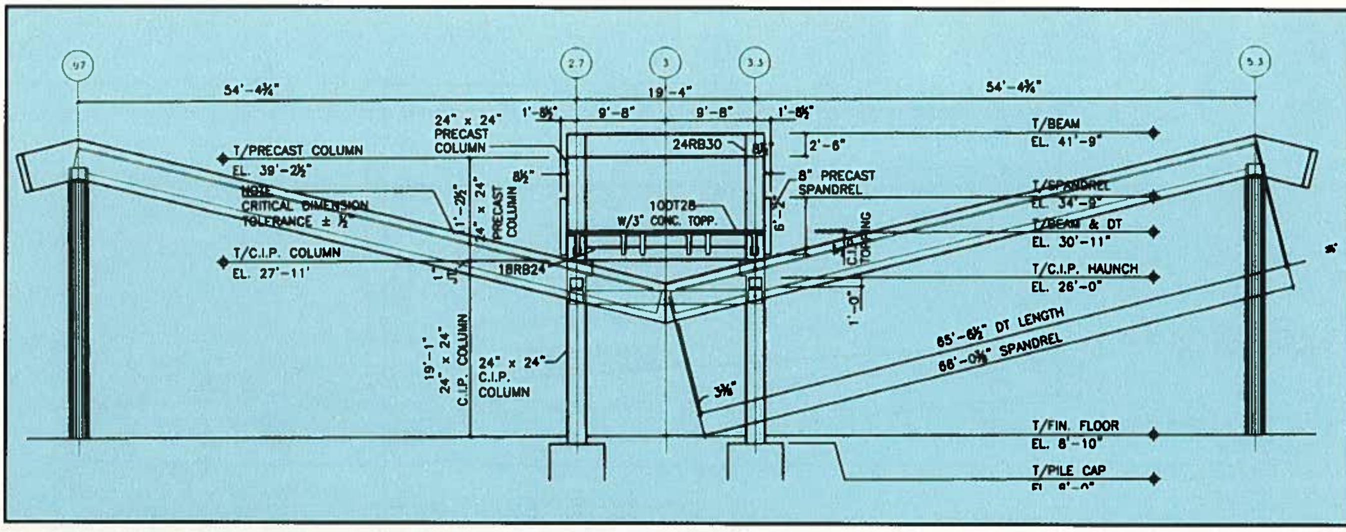

Fig. 8. Elevation of the entry canopies.

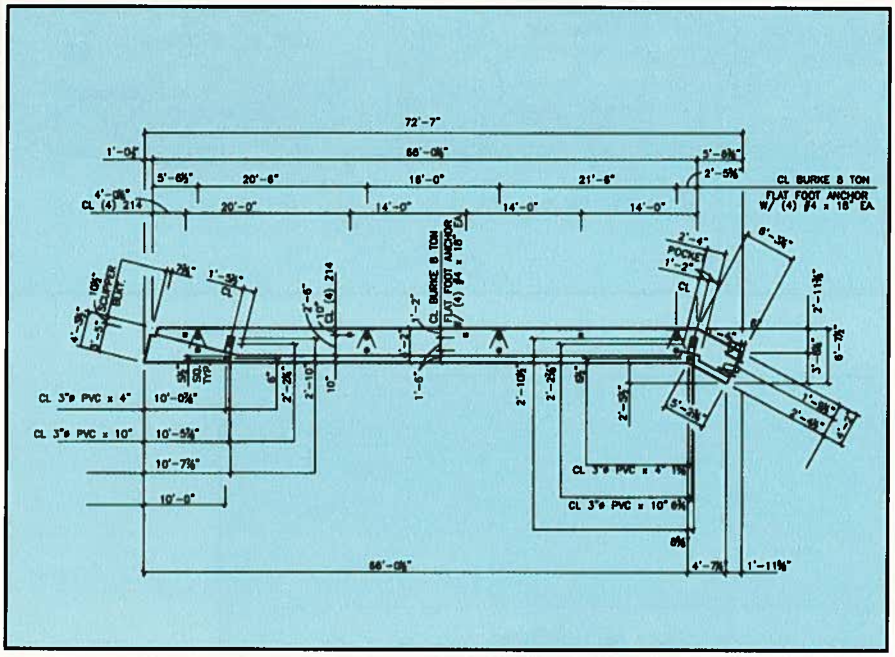

Fig. 9. One of the entry canopy beams.

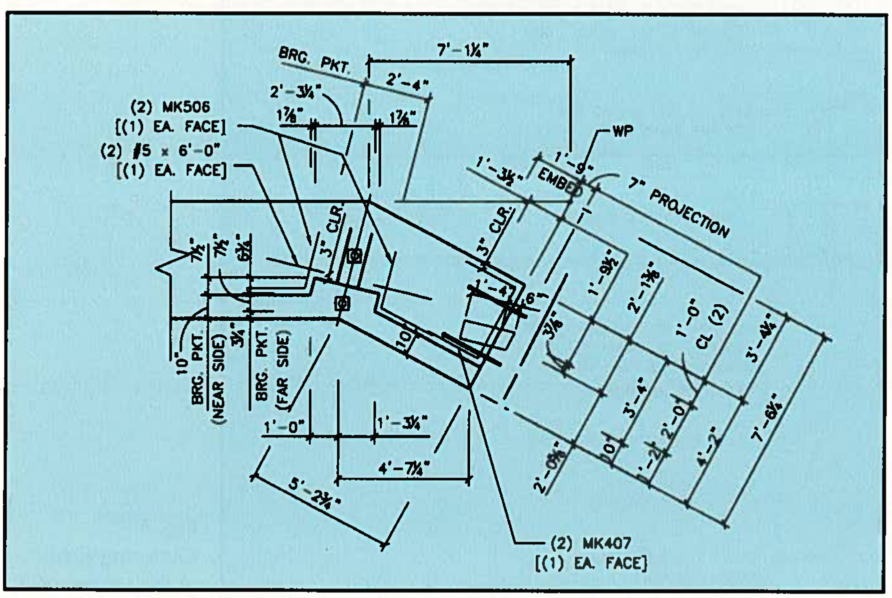

Fig. 10. Detail of the entry canopy dog leg.

ft (1020 m²) for up to 22 buses, 32 baggage carts and 70 taxis and cars.

The columns support tapered precast concrete beams. Two columns support each of the 30 beams. The beams cantilever out over the drive lanes on each side of the canopy.

Between each of the beams, six precast double tees span between the columns which form the actual roof structure. The tees bear on a combination of pockets and corbels, which helps achieve the designer's objective of a sleek, clean-looking structure.

The roof has a slight V-shape, which forces water to flow to the center of the canopy. At the low point of the transverse section of the canopy, slots were provided to allow water to enter a hidden guttering system (see Fig. 7).

ENTRANCE CANOPIES

The intermodal canopy is broken into two segments that form three entrance points to the terminal building. At each of the three entrance points, an entrance canopy provides shelter for the travelers and workers. From this transitional area, people can enter or exit the intermodal canopy or terminal building (see Fig. 8).

The entrance canopies amplify the V-shape of the main terminal buildings' architectural forms. They were designed to mimic the wings of a bird. The entrance canopies actually pass over the intermodal canopies and their columns pass through the roof of the intermodal canopies.

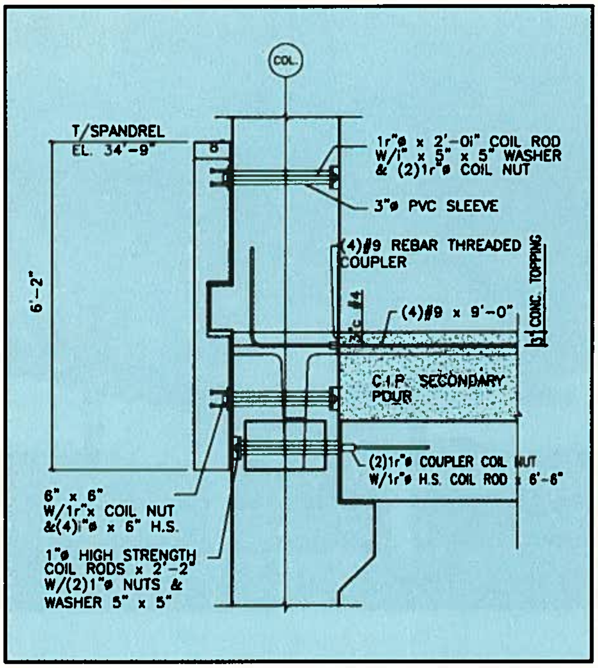

Fig. 11.
Typical connection detail of pedestrian bridge.

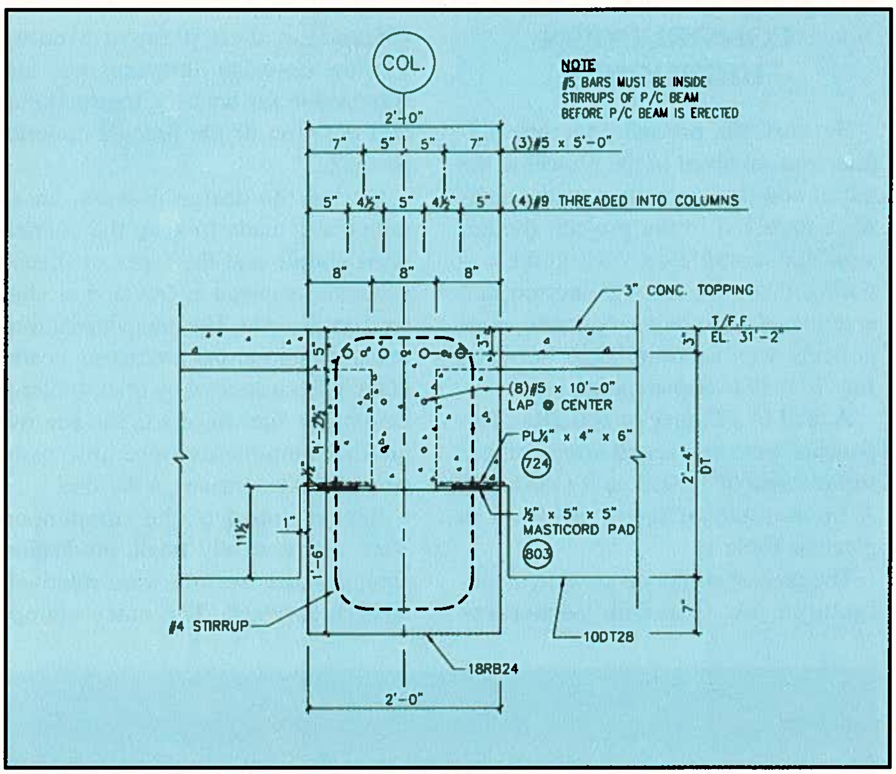

Fig. 12. Detail showing encasement of double tee.

The initial design of the entrance canopies was contemplated by the architects to be curved. Subsequent discussions with the precast concrete producer indicated that curved components would ultimately be difficult to move and produce, and would unnecessarily add time and expense to the project. Regardless, the design intent was ultimately achieved with straight components.

The winged-shaped canopy structures are each 21 ft wide, 142 ft long and 33 ft high (6.40 x 43.3 x 10.1 m). The three entry canopies are each comprised of four double tees, four dog leg spandrels and two closure spandrels supported on soffit beams and columns. Each of the structures are supported by eight columns. The span between the columns is 54 ft 5 in. (16.6 m). The overall length of the components is 72 ft 7 in. (22.1 m).

Since the entry canopies are intended to mimic the shape of a bird's wing, the main canopy spandrels were cast with a dog leg monolithically appended to the ends at an angle of 14 degrees. All members are set at a 14-degree slope. Horizontal bearing surfaces are used on all members to eliminate sliding forces from gravity loads. A precast concrete closure piece was added to provide the finished form (see Figs. 9 and 10).

PEDESTRIAN BRIDGE

A pedestrian bridge connects the 750-car, four-story precast concrete parking structure, the intermodal canopy and the terminal building. It creates an elevated walkway as well as a canopy for pedestrians. The bridge connects the third level of the garage with the terminal building by passing over one of the three V-shaped entry canopies (see Fig. 4).

Architecturally, the pedestrian bridge exhibits a somewhat different design motif from the entry canopies and the intermodal canopies. Where the other two elements have V-shapes that relate back to the "soaring" architecture of the terminal building, the pedestrian bridge is comprised of entirely rectilinear structures acknowledging the design of the parking structure. This design keeps the sleek motif of the other canopies, however. Almost all of its connections are bolted and grouted, as was done elsewhere, so as to eliminate the need for corbels or exposed connections.

The pedestrian bridge is 250 ft (76.2 m) long and 33 ft (10.1 m) high. Its width varies from 20 to 30 ft (6.10 to 9.14 m). The pedestrian bridge floor structure consists of composite soffit beams which support double tees. The tee stems are pocketed into the beam with a cast-in-place concrete pour that encases the tee stems (see Figs. 11 and 12). This creates a monolithic look from below for the double tee to beam interface. It also hides the connections and seals them from the aggressive environment.

The composite floor beams and the conventionally reinforced precast concrete roof beams act as a moment frame to provide lateral stability for the pedestrian bridge structure. No cross

Fig. 13. Close-up of V-shaped entry canopy.

bracing is necessary to stabilize the structure and thus a more open architectural form is maintained.

The connection between the floor beams and the columns is through-bolted to connect the bottom reinforcement. The top reinforcement is connected with threaded rod couplers.

Note that bolted connections were used throughout the pedestrian bridge structure to maximize head room, and maintain the clean uninterrupted lines the designers intended. As a result, no corbels are visible anywhere on the bridge walkway.

Table 1. Types of precast components and principal dimensions.

The precast concrete products used for the entrance canopies and pedestrian bridge are listed below.

Prestressed Products:
- Composite soffit beams, 18 x 24 in.
- Beams, 24 x 30 in.
- Double tees, 16 in. deep
- Double tees, 28 in. deep
- Spandrels, 14 x 50 in.

Mild Steel Reinforced Products:
- Columns, 24 x 24 in.
- Composite L-beams, 24 x 24 in.
- L-beams, 24 x 40 in.
- Spandrels, 8 x 40 in.
- Spandrels, 8 x 50 in.
- Spandrels, 8 x 74 in.

Note: 1 in. = 25.4 mm.

CONSTRUCTION HIGHLIGHTS

Because the precast concrete supplier was involved in the project at the outset and many standard components were involved in the project, the design was completed very quickly – within three weeks. Production and erection of the precast concrete components was accomplished between July 7, 1999 to September 9, 1999.

A total of 173 precast concrete components were fabricated comprising a surface area of 17,000 sq ft (1581 m^2). A breakdown of these products is given in Table 1.

The precast components were manufactured by Coreslab Structures (Miami) at their plant in Medley, Florida. Coreslab Structures was also responsible for both the transportation and erection of the precast concrete products.

During the design process, an attempt was made to keep the connections simple and the types of precast concrete members as few and as standard as possible. The components were manufactured at the precaster's nearby plant and transported by truck-trailer to the project site. Access to the site was good. Components were able to be erected as they arrived at the site.

Because most of the components were comparatively small, production, shipping and erection were relatively straightforward. The entry canopy

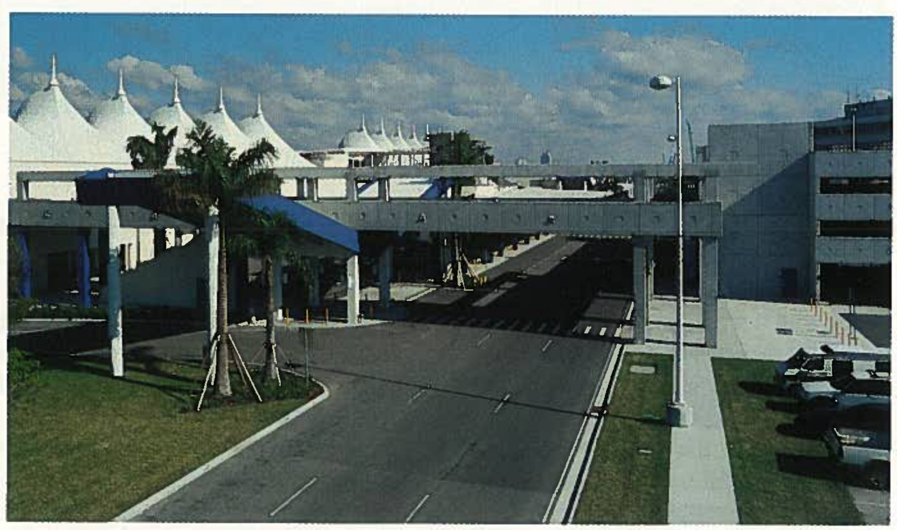

Fig. 14. Pedestrian bridge linking terminal building with parking structure.

Fig. 15. Finished view of intermodal canopy.

beams, which are 72 ft 7 in. (22.1 m) long, were shipped on their sides and then rotated after being lifted from the truck-trailer and set into place.

Because precast concrete was used, the structural frame served as a platform, on which work on secondary elements such as the guttering, lights, signs and painting could begin very shortly after each bay was erected.

The repetition and symmetry of the project simplified erection and greatly enhanced the ability of the design-construction team to meet the owner's very tight schedule. Because the canopy structure was developed from essentially standard components and contained a large amount of repetition, the project could be designed in approximately three weeks.

The precast components were produced and erected in approximately two months. The components were cast in steel forms and conventionally shipped. The entrance canopies' spandrels components were placed on their sides for stability and stress reduction during shipping.

The project was essentially completed by the end of 1999 and was in service not long thereafter.

Fig. 13 through 15 show various views of the canopy structures and pedestrian bridge.

CONCLUDING REMARKS

The canopy structures and pedestrian bridge structure were constructed out of precast concrete because of the time and cost constraints of the project. By careful design and detailing, many of the elements that are ordinarily maintenance items, namely, gutters, downspouts and precast concrete connections, are hidden from view. The result is a clean looking structure, which radiates architecturally within the entire terminal complex.

The project was able to be delivered very quickly, because the general contractor and the precast producer assisted the architect with value engineering the structure and ultimately in selecting materials and systems that would meet the budget and schedule. The architect was able to fulfill the design intent within the capabilities of the materials and systems ultimately chosen.

Precast concrete is able to be exposed and has very good weathering properties especially in moist, salty environments. The connections are grouted solid and other potential areas of corrosion are provided with substantial weather protection. The combination of a nearly maintenance-free material and with the addition of protection for the connections yields a structure that will serve the owner for a long time to come with very little maintenance.

Because the precast concrete producer and contractor were involved in the project early on, they were able to shorten the design and delivery process dramatically and make the project successful for all of the project participants and the passengers using the complex.

During the past year, the facility has been fully operational and has been performing very well as initially expected. Indeed, the owner, design-construction team, and the cruise ship passengers are all pleased with the architecture and convenience of the new facility.

CREDITS

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Architect and Engineer: BEA International, Inc., Coral Gables, Florida.

Precast Concrete Manufacturer-Designer: Coreslab Structures (Miami) Inc., Medley, Florida.

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General Contractor: C. G. Chase, Miami, Florida.