Precast Concrete Segmental Bridges — America's Beautiful and Affordable Icons

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How did precast concrete segmental construction become a major player in the modern American bridge industry? While the continuing growth in market share for precast, prestressed concrete systems can be attributed to numerous competitive advantages, this article presents an overview of the proliferation of segmental bridges in the United States based primarily on five advantages – economy, construction efficiency, durability, design innovation and aesthetics.

For a bridge type that would become an increasingly popular and successful competitor over alternative building systems, precast concrete made a rather unpretentious debut in the United States. Indeed, one wonders if the engineers who designed and built America's first precast concrete segmental box girder bridge in 1973 – the John F. Kennedy Memorial Causeway Bridge connecting Corpus Christi and Padre Island, Texas – could have imagined that this simple, unadorned structure would be the harbinger of some of the nation's most beautiful and affordable bridges.

Indeed, thirty years later, precast concrete segmental construction has produced some of the most technologically advanced, visually dramatic, and environmentally sensitive structures in North America as well as in many other countries throughout the world. Typically, the precast, prestressed concrete bridge also proves to be the most cost-effective alternative for owners, particularly when life-cycle costs such as maintenance and repair are taken into account.

EVOLUTION OF PRECAST CONCRETE SEGMENTAL BRIDGES

The European Experience

Originating in Europe, this versatile and economical bridge type emerged shortly after World War II. With the urgent need to reconstruct bombed-out bridges quickly and efficiently, and with steel production capacity debilitated by war efforts, European designers and builders turned to prestressed concrete.

The first precast concrete segmental bridge, the Luzancy Bridge across the Marne River in France, was erected in 1946. It was designed and built by Eugene Freyssinet, the French engineer and pioneer whose technical investigations and ingenious advances during the first half of the 20th Century made prestressed concrete a viable construction material.

While numerous precast, prestressed concrete bridges were built throughout Europe between 1946 and 1973, American bridge designers did not immediately embrace this new technology, in part because many conventional bridge engineers of the time questioned the suitability of using precast concrete segments for major or long-span structures. However, with further advancements in technology, precast, prestressed concrete emerged as a strong competitor to conventional construction.

Lee Roy Selmon Expressway

A compelling example of the phenomenal evolution of precast concrete segmental bridges since 1973 is presently under construction in Tampa, Florida – where the Prestressed Concrete Institute (PCI) was founded in 1954. The three-lane *reversible* structure erected span-by-span within the median of the Lee Roy Selmon Expressway, on single piers only 6 ft (1.8 m) wide at the base, will more than double the toll highway's capacity within the existing right-of-way while maintaining essential traffic flow during construction (see Fig. 1). Operating in the direction of peak demand (westbound from the suburbs to downtown Tampa in the morning and eastbound in the evening), the 5-mile (8 km) long structure will provide "six lanes in 6 feet," preserving most of the median for future use.

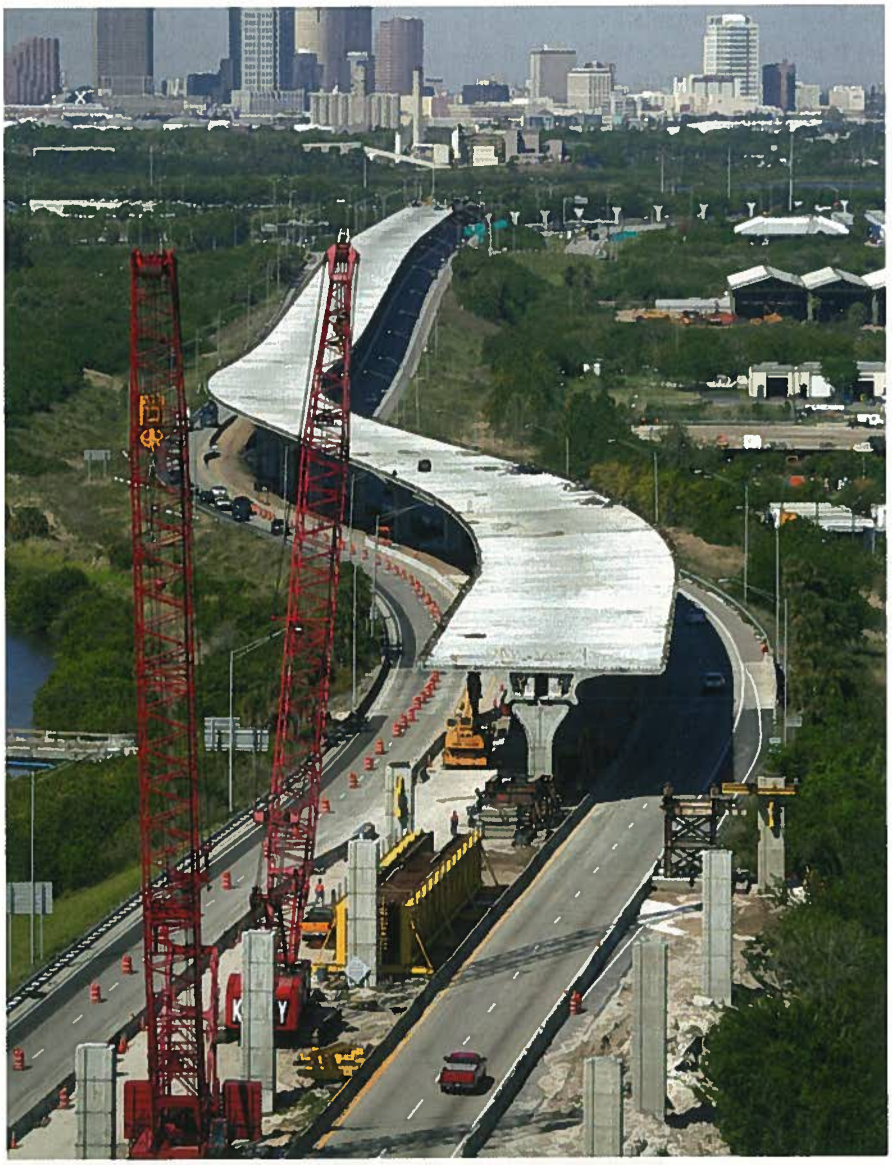

Fig. 1. Presently under construction over moving traffic, the Lee Roy Selmon Expressway in Tampa, Florida, supports six lanes of traffic on single piers only 6 ft (1.8 m) wide, and demonstrates the extraordinary evolution of precast concrete segmental bridges in the last thirty years.

The 3032 prestressed segments [59 ft (18 m) wide, about 70 tons (64 tonnes)] are precisely cast at a nearby factory and delivered by truck during off-peak hours. In the immediate area of the worksite, the inside lanes of the four-lane roadway are temporarily closed while the segments are lifted onto the self-launching, underslung erection girder. During peak commuting hours, all lanes are open while workers apply epoxy between the segments and post-tension the tendons, without impeding traffic below. A typical 140 ft (42.7 m) span requires about three days to complete.

Designed by Figg Bridge Engineers and built by PCL Civil Constructors, the sculpted curved forms of the superstructure and piers embody the vision of the Tampa-Hillsborough Expressway Authority for an aesthetically unique bridge – truly, a landmark structure. The precast concrete box girder has curved geometry in the webs, corners, and the underside of the barrier.

The bridge piers also present sculpted shaping, with curved flares at the top and a 3 in. (76 mm) recess along the vertical faces. With a soft color finish and accent lighting from below, the bridge will be a striking feature of the Tampa landscape when completed in 2006.

Part of a $350 million expansion program that includes several miles of park-like boulevards providing local access to and from the reversible express lanes at each end, the segmental bridge contains approximately 1.6 million sq ft (148,640 m^2) of deck. According to the Expressway Authority, the Lee Roy Selmon Expressway bridge is being constructed for $65 per sq ft ($700/m²), or currently about 30 percent less than other major bridges in Florida.

This rapid transit bridge is only one example of several other significant segmental bridge projects currently under construction.

Fig. 2. With the first "as cast" riding surface in the United States, the 2.3 mile (3.7 km) Long Key Bridge in the Florida Keys was completed at a cost of $32.66 per sq ft ($352/m²) in 1980, confirming the economic feasibility of precast concrete segmental technology.

COASTAL ENVIRONMENTS

Among the advantages touted by its champions was the ease and economy of maintenance for precast concrete bridges, particularly in coastal environments. Bridge maintenance was one of the concerns of the Florida Department of Transportation (FDOT) engineers in the mid-1970s as they considered replacement options for the decaying bridges of the Overseas Highway, the transportation lifeline of the Florida Keys.

Long Key Bridge

A Tallahassee, Florida-based civil engineer with a penchant for innovation, Eugene Figg, proposed precast concrete segmental bridges as the solution. And further, he suggested that FDOT request federal funds to finance a demonstration project of precast concrete technology for bridges in coastal environments. When the Federal Highway Administration agreed to his proposal, Figg designed and inspected the construction of the Long Key Bridge. Michael Construction Co. completed the 12,040 ft (3670 m) structure in 1980 – five months ahead of schedule – at a cost of $15.3 million, at a remarkable cost of $32.66 per sq ft ($352/m²).

Erected using the span-by-span method, the 103 spans, with typical lengths of 118 ft (36 m), were delivered by barge, installed as a unit, aligned, and then post-tensioned. The

Fig. 3. The longest continuous precast segmental bridge in the world in 1982, the Seven Mile Bridge in the Florida Keys was the first use in North America of precast, match-cast box piers, assembled with vertical post-tensioning.

post-tensioning tendons were external to the box girder web, which reduced material costs and construction time. The Long Key Bridge was the first "as cast" riding surface in the United States (see Fig. 2).

Seven Mile Bridge

Soon thereafter, Misener Marine Construction started the nearby Seven Mile Bridge. Spanning 35,867 ft (10,932 m), it was the longest continuous precast segmental bridge in the world in 1982. The precast segments for the piers and superstructure were manufactured in Tampa and barged 450 miles (724 km) to the erection site south of Marathon Key.

An overhead gantry lifted each of the 268 spans [135 ft (41.2 m) typical length] into position as a unit. The superstructure was erected on precast, match-cast box piers that were assembled with vertical post-tensioning (see Fig. 3). These design innovations allowed a 60 ft (18.3) tall pier to be constructed in one day and three 405 ft (123 m) spans to be erected per week. The $45 million Seven Mile Bridge was $7 million less than the alternative solution, and was completed six months ahead of schedule. The project won a PCI Design Award in 1982.

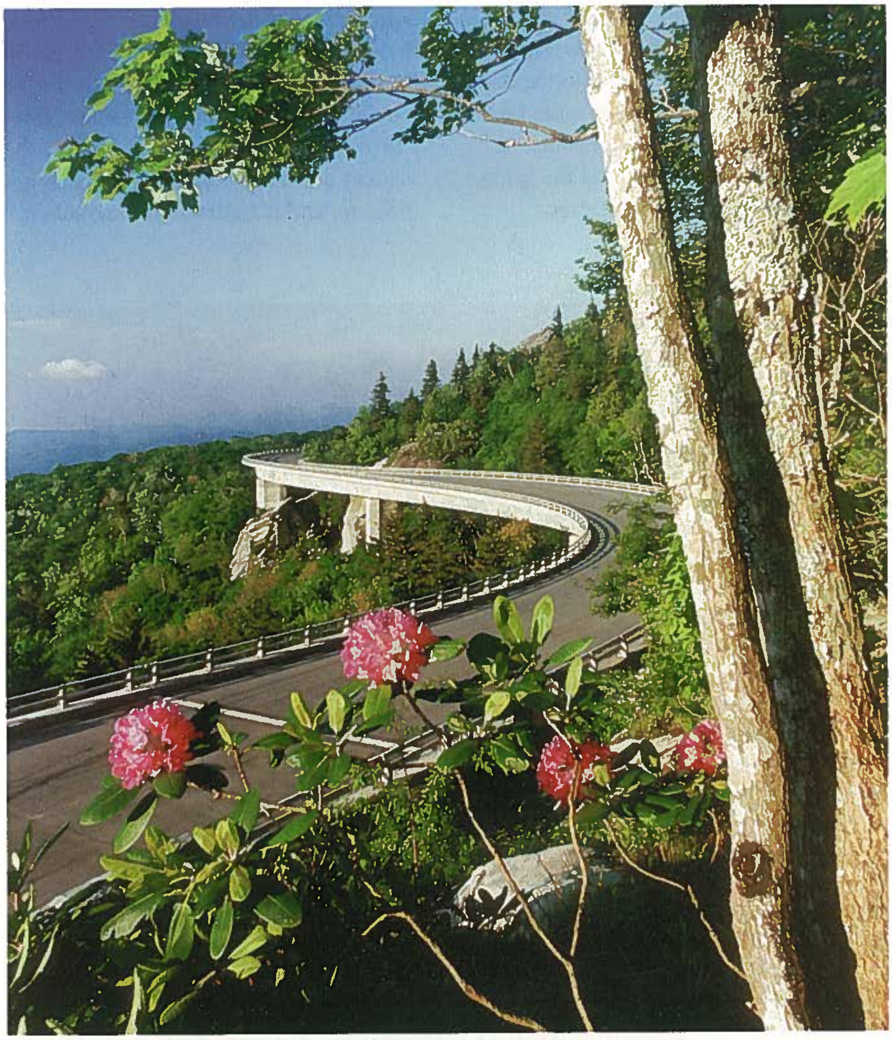

Fig. 4. Completed in 1982, the Linn Cove Viaduct, part of North Carolina's Blue Ridge Parkway, was the first concrete segmental bridge in America to be built in one directional cantilever from the top down to protect the fragile environment. Black iron oxide in the concrete mix allows the bridge to blend into the natural mountain hues.

ENGINEERING AND AESTHETICS

Eugene Figg's designs were a decisive demonstration of the constructability, efficiency and economy of precast concrete segmental construction. Founded in 1978, the firm, now known as the Figg Engineering Group (FIGG), has continued to pioneer segmental bridge technology through advancements in design, construction techniques, and materials.

With numerous "signature structures" built in 34 states, and with construction values exceeding $7 billion, FIGG's forward-thinking design and construction engineers are as focused on aesthetic achievement as they are on cost and time-saving innovations. The firm's vision is to create bridges as timeless works of art that reflect the natural environment and the spirit of the communities they serve.

As a consequence of the firm's vision, its clients' projects have earned more than 200 awards, including three of the five bridges ever honored with the Presidential Award for Design Excellence by the National Endowment for the Arts (Linn Cove Viaduct, the Sunshine Skyway and the Natchez Trace Parkway Arches discussed below).

Linn Cove Viaduct

The 1248 ft (380.4 m) S-shaped Linn Cove Viaduct in North Carolina was an extraordinary engineering feat. At 4400 ft (1341 m) above sea level, the challenges of the rugged terrain and sensitive ecology of the Blue Ridge Parkway's Grandfather Mountain had perplexed highway engineers for years, resulting in a "missing link" in this scenic region (see Fig. 4).

The first in America, a precast concrete segmental bridge proved to be the solution, constructed from the top down in unidirectional progressive cantilever. The segments were delivered by truck onto the completed structure as it advanced. This picturesque, $7.9 million viaduct, built by Jasper Construction, contains every type of alignment geometry used in highway construction. This project won a PCI Design Award in 1983.

The Linn Cove Viaduct includes reverse curvature, with radii as short as 250 ft (76.2 m) and super-elevations ranging from a 10 percent slope in one direction to a 10 percent slope in the other direction – in less than 200 ft (61 m). The concave, octagonal-shaped precast piers – some as tall as 65 ft (19.8 m) – were vertically assembled. Black iron oxide was added to the concrete so that the viaduct and piers blend with the rock outcrops. The last segment was placed in 1982 and the bridge was in operation soon thereafter.

In the presentation of the first Presidential Award for a bridge, President Ronald Reagan said, "Linn Cove Viaduct is not just a roadway on North Carolina's Grandfather Mountain; the viaduct has been designed so that it belongs to, and is a part of, the mountain."

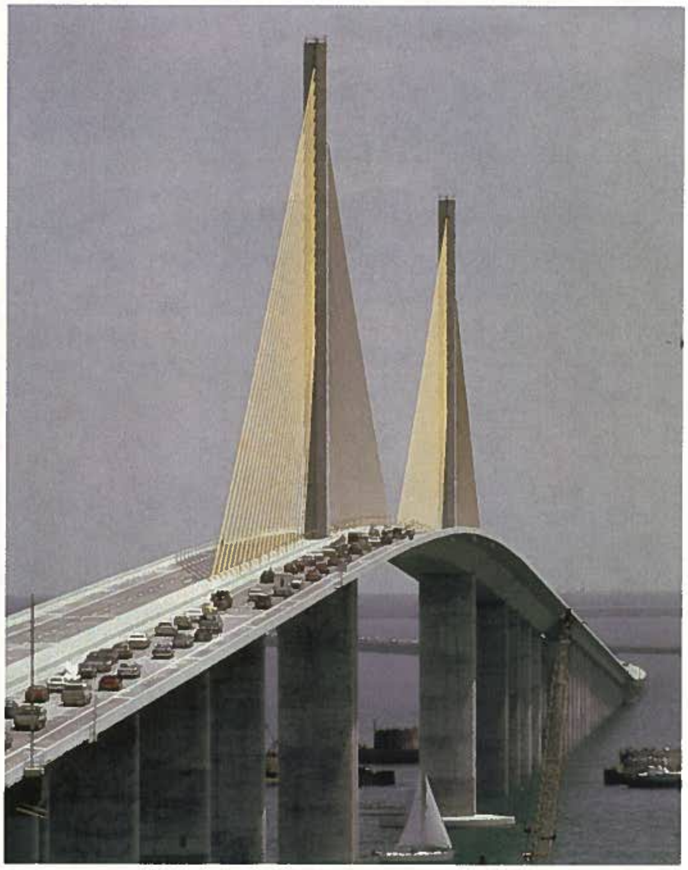

Fig. 5. At a length of 1200 ft (366 m), the Sunshine Skyway Bridge over Tampa Bay, Florida, features the longest precast concrete segmental cable-stayed main span in the United States. Able to withstand winds of up to 240 miles per hour (386 km/hr), the elliptically-shaped piers are a critical design to withstand Florida's notorious hurricanes.

Fig. 6. The impecably beautiful Natchez Trace Parkway Arches is America's first use of precast concrete segmental technology for an arched structure. It was completed for $11.3 million in 1994.

DESIGN INNOVATIONS

Sunshine Skyway Bridge

Carrying Interstate 275 traffic 175 ft (53.3 m) above the mouth of Tampa Bay, Florida, the Sunshine Skyway Bridge was the first U.S. precast concrete cable-stayed bridge with a single plane of stays attached to single pylons, towering 431 ft (131 m) above the water (see Fig. 5).

Its 1200 ft (365.8 m) main span is the nation's longest precast concrete cable-stayed span, and the superstructure's mammoth trapezoidal box sections, each weighing about 220 tons (200 tonnes), were, at the time, the largest ever erected for a precast segmental bridge. The precast concrete box sections were manufactured by POMCO at nearby Port Manatee, barged 4 miles (6.4 kilometers) to the bridge, lifted by an overhead gantry, and assembled using the balanced cantilever method.

Constructed by Paschen Contractors and completed in 1987, this Floridian icon is famous for its sleek, graceful lines and golden cable stays, that shimmer in the bright Florida sun and radiate with accent lighting at night. While the elliptical contours of the main span's massive twin piers provide aesthetic appeal, the shape was primarily chosen because it best fulfilled the design mandate of a structure able to withstand sustained hurricane force winds of up to 240 miles per hour (386 km/hr). This project won a PCI Design Award in 1987.

Natchez Trace Parkway Arches

The graceful Natchez Trace Parkway Arches near Nashville, Tennessee, completed in 1994 at a cost of $11.3 million, is America's only precast concrete segmental arch bridge. The 582 ft (177.4 m) main span is symmetrical, while the 462 ft (140.8 m) second span is asymmetrical. Depths of the precast box girder superstructure vary from 7.5 ft (2.3 m) at midspan to 14.33 ft (4.4 m) at the piers. The side slopes of the trapezoidal box are constant, resulting in a variable-width soffit.

While these diverse geometries provide a stunning finished product (see

Fig. 6), the design presented challenges requiring creative solutions by the FIGG designers and the builder, PCL Civil Constructors. In selecting the Parkway Arches for the 1994 Portland Cement Association Award of Excellence, the jury commented, "...the clean and simple, yet elegant and functional arches fit gracefully into the rural setting...one can feel the flow of forces in this structure without having to do any [structural] analysis."

Fig. 7. The Dauphin Island Bridge in Mobile, Alabama, was built in just 34 months, featuring a 400 ft (122 m) main span – the longest precast concrete segmental span at the time of completion in 1982.

STRENGTH AND DURABILITY

Dauphin Island Bridge

Precast concrete segmental bridges have repeatedly proved their strength and endurance when tested by extreme natural forces. For instance, since its 1982 completion, the Dauphin Island Bridge near Mobile, Alabama, has withstood five hurricanes and severe tropical storms without damage (see Fig. 7). The 17,814 ft (5429.7 m) long bridge replaced a conventional bridge destroyed by Hurricane Frederick in 1979. Under the owner's mandate for rapid design and construction, the $32 million replacement structure was finished in just 34 months.

The center span of the 822 ft (250.5 m) main span is 400 ft (121 m) long, an American record at the time for precast segmental balanced cantilever construction. Brown & Root erected the three continuous main spans, which vary in depth from 7 ft (2.1 m) at midspan to 21.42 ft (6.53 m) at the piers. Twin-walled I-shaped piers helped to counter the unbalanced loads on the foundations during construction. The bridge's higher level has twenty-six 118 ft (35.96 m) spans built span-by-span on vertically post-tensioned, hollow precast concrete segmental box piers. This bridge won a PCI Design Award in 1983.

Varina-Enon Bridge

A good demonstration of the durability of precast concrete segmental construction is the Varina-Enon Bridge that carries six lanes of Interstate 295 over the James River southeast of Richmond, Virginia. In August 1993, a tornado directly hit the 630 ft (192 m) cable-stayed main span. Although trucks traveling across it were overturned, the bridge sustained no damage.

The sturdy structure, completed in 1990 by S. J. Groves Construction at a cost of $34.4 million, featured the

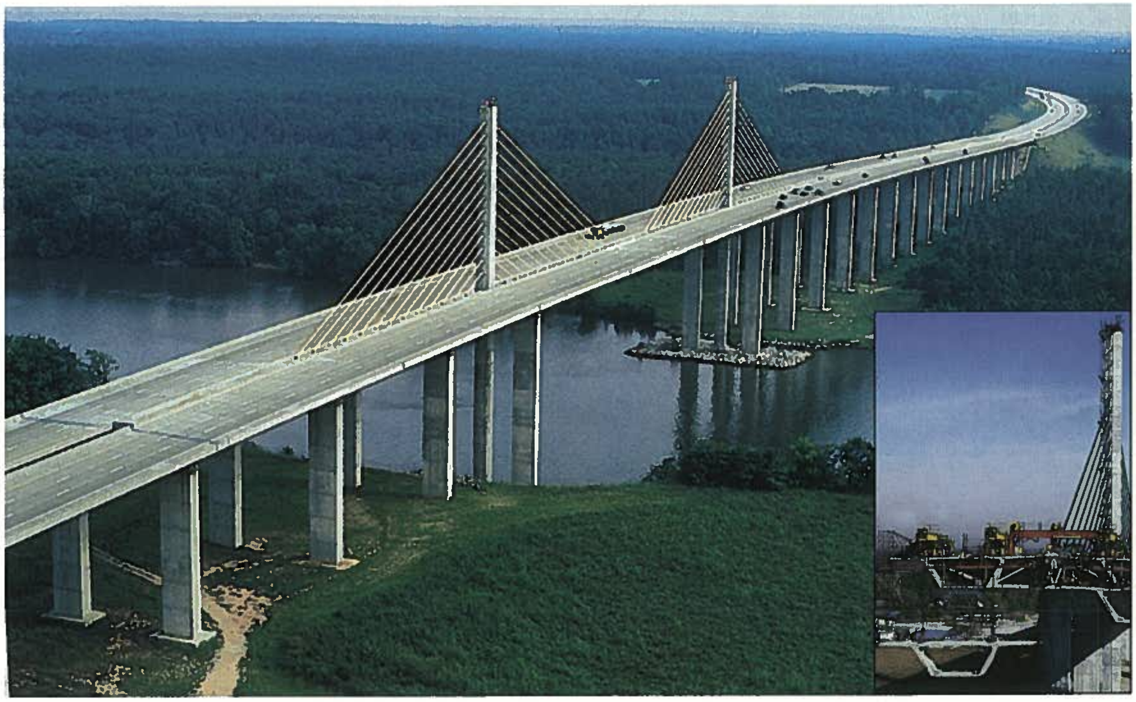

Fig. 8. The Varina-Enon Bridge near Richmond, Virginia, features the world's first use of precast concrete delta frames for construction of its 630 ft (192 m) cable-stayed main span. This elegant and durable structure sustained a direct tornado impact without damage.

Fig. 9. Sagadahoc Bridge in Maine has a 420 ft (128 m) precast segmental main span and was completed in 2000. Precast concrete segments weighed 100 tons (91 tonnes).

first-ever use of precast concrete delta frames to help support the main span's twin parallel segmental box girders (see Fig. 8). The innovative delta frames allowed the cable stays to be arranged in an aesthetically pleasing single plane and the superstructure to remain the same size from abutment to abutment, saving construction time and equipment costs.

Named one of the "Twelve Most Spectacular Bridges in America in 1995" by the American Council of Engineering Companies, its 300 ft (91.4 m) tall single pylons and single plane of stays support the main span with 147 ft (44.8 m) of vertical navigation clearance. The approach spans [150 ft (45.7 m) typical length] were constructed span-by-span up to the main pylon, permitting the main span to be constructed in unidirectional cantilever. Precast concrete segments were used for the piers, bridge deck, cable towers and delta frames.

SPAN LENGTHS INCREASE

Sagadahoc Bridge

As materials and construction technologies have advanced, so have the lengths of precast concrete segmental main spans using balanced cantilever erection (see Fig. 9). The 400 ft (121 m) record of the Dauphin Island Bridge was broken in 2000 by the Sagadahoc Bridge in Maine.

Carrying U.S. Highway 1 traffic over the Kennebec River between Bath and Woolwich, the main span of this $46.6 million bridge is 420 ft (128 m) long. Each of the two-cell precast box girder segments, erected by Flatiron Structures, is 69 ft (21 m) wide and varies in depth from 9.17 (2.8 m) at midspan to 19.58 ft (5.97 m) at the piers, and weighs up to 100 tons (91 tonnes).

Victory Bridge

In 2004, the record for a balanced cantilever span length in America was broken again. With a fully match-cast, precast concrete main span of 440 ft (134.1 m), the current record holder is the new twin-span Victory Bridge in northern New Jersey. The 3971 ft (1210 m), $109 million precast concrete segmental bridge will carry traffic 110 ft (33.5 m) above the Raritan River between Perth Amboy and Sayreville, replacing a 1927 steel swing bridge (see Fig. 10).

Built in stages by George Harms Construction, the second of the twin spans will be constructed at the location of the old bridge. Victory Bridge's final span is scheduled for completion in 2005, less than three years from the start of construction. To expedite construction speed, the approach spans are being erected span-by-span, simultaneously with the balanced cantilever main span.

Fig. 10. The 440 ft (134 m) precast fully match-cast main span of the Victory Bridge in northern New Jersey was dedicated on June 5, 2004; the twin span is scheduled for completion in 2005.

CONGESTED URBAN CORRIDORS

A significant and growing competitive advantage of precast concrete segmental construction is its ability to be constructed in congested urban corridors, with erection next to or over traffic – with minimal transportation delays or detours.

In addition to the Lee Roy Selman Crosstown Expressway project discussed above, other applications of this innovative design solution include:

Interstate 110, a 7.8 mile (12.6 km) elevated connection between Interstate 10 and U.S. 90 in Biloxi, Mississippi – This elevated roadway opened in 1988 after construction by Harbert International and Dement Construction with a bid of $29.6 million (see Fig. 11). The Interstate 110 infrastructure was the first use of the modified balanced cantilever method of construction and was the recipient of the PCI Award of Excellence in 1989.

Interstate 10 and Interstate 35 "Y" bridges in San Antonio, Texas – Prescon Corporation and Austin Bridge Company completed the 1.3 million sq ft (120,770 m^2) of bridge work in 1989, with a bid of $65.4 million, or about $8 million less than the competing design (see Fig. 12).

Illinois Tollway Interchange between the North-South and East-West Tollways in Chicago, Illinois – Completed in 1989 by Paschen Constructors, the 186,000 sq ft (17,279 m^2) interchange presented complex alignments with tightly curved geometry (see Fig. 13). The precast concrete segmental box girder structures bid was $10.3 million, saving $4.5 million over the alternate design.

Interstate 93 ramps and viaduct, part of the Central Artery project in Boston, Massachusetts – Built by Modern Continental in 2003, the $79 million project totaled about $27 million less than the competing solution. This interchange has the smallest radii and tightest horizontal curvature – only 212 ft (64.6 m) – of any precast concrete segmental bridge in the United States (see Fig. 14).

Fig. 11. Biloxi I-110 in Mississippi was built over the four-lane U.S. 90 to minimize traffic interruptions. $4.2 million was saved over the alternate construction system at the time of bidding.

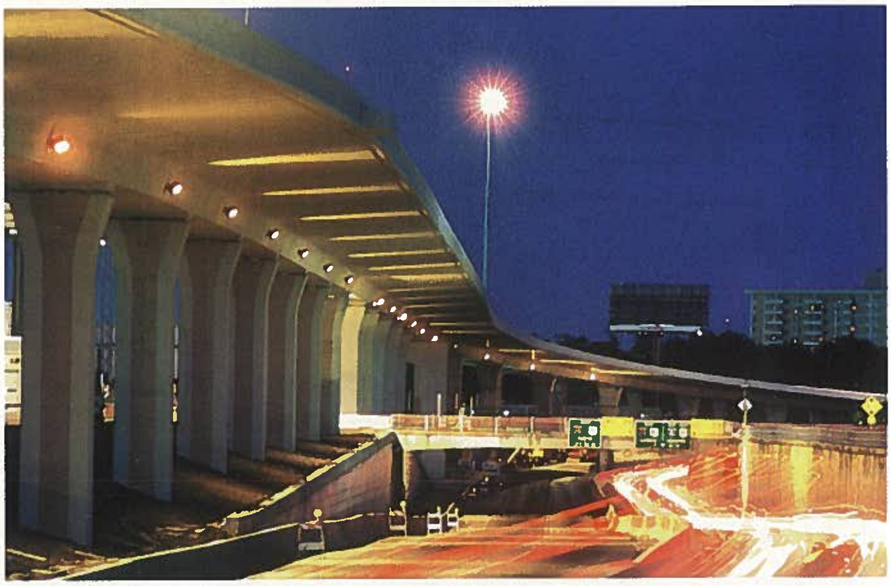

Fig. 12. The San Antonio, Texas, "Y" bridges, built in the existing right-of-way (downtown I-10 and I-35), exemplify the value of precast concrete segmental bridges for construction in extremely restricted urban areas while maintaining traffic flow.

Fig. 13. The Illinois Tollway Interchange, near Chicago, Illinois, demonstrates that segmental concrete structures can be built over major traffic flows.

New Strand Cradle System – Maumee River Bridge

An outstanding illustration of innovation in precast concrete segmental bridges, presently under construction, is the Maumee River Bridge in Toledo, Ohio, that will carry Interstate 280 with a unique cable-stayed structure (see Fig. 15).

The top 190 ft (57.9 m) of the 435 ft (132.6 m) pylon is clad with specially engineered glass on all four sides, and will be illuminated by internal LED (Light Emitting Diodes) spotlights that can produce a virtually unlimited array of vivid colors. This dramatic aesthetic feature of the bridge (see structure below) was selected by the participants of community design workshops as a tribute to the heritage of the area's glass industry.

To accommodate the desired slender shape of the pylon and single plane of stays, FIGG designed a first-of-its-kind cradle system to carry the stays through the pylon, thus eliminating pylon anchorages. As a result, the cables supporting the 1225 ft (373.4 m) main span will contain as many as 156 strands – 70 percent more than any previously used on a bridge.

Extensive testing of the new cradle system verified that the cable strands would move through the cradle independently, even when subjected to more than 3000 times the projected loads on the stays. The cradle system will also facilitate inspection and maintenance by permitting easy removal and replacement of the strands to monitor their condition throughout the life of the bridge.

Fig. 14. An aerial view of the I-93 ramps illustrates traffic congestion all-to-familiar to Boston, Massachusettes, commuters. Horizontal curvature as small as 212 ft (64.6 m) and other precast concrete design advantages saved the Massachusetts Turnpike Authority over $27 million at the time of bidding.

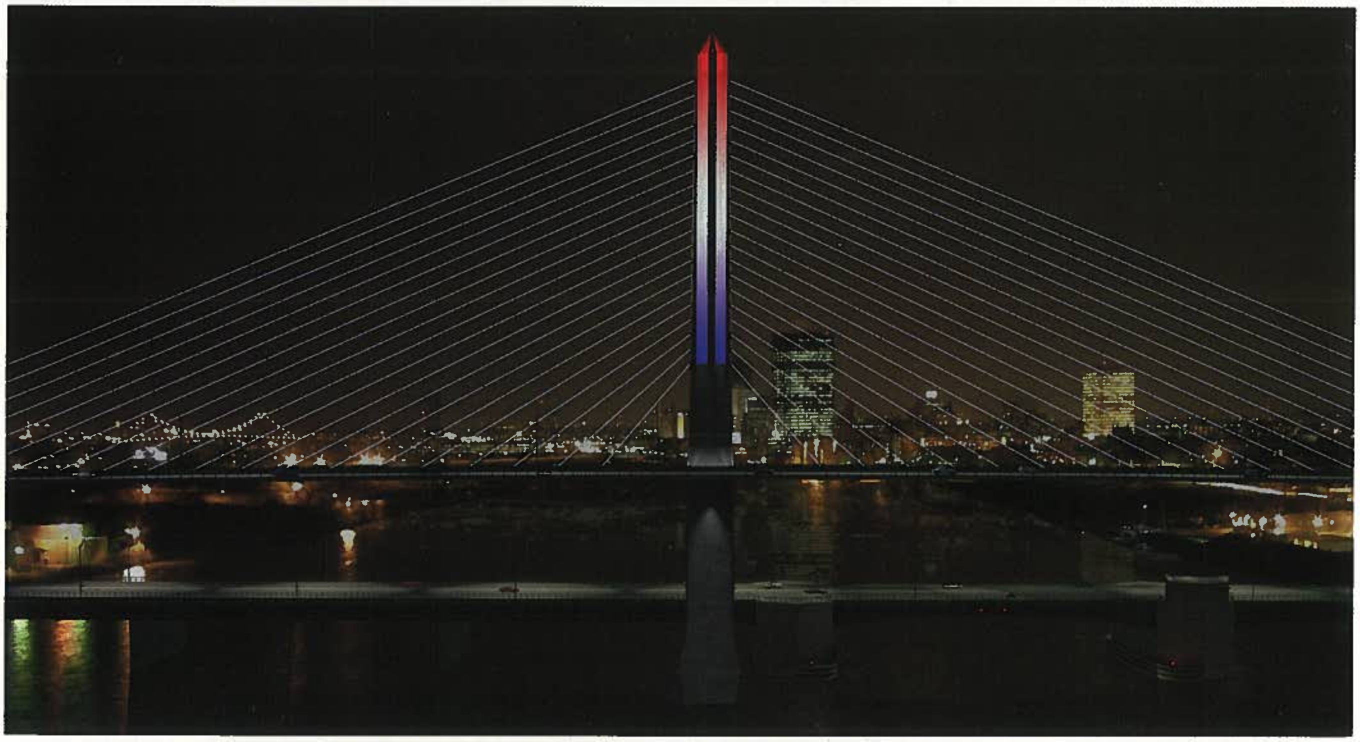

Fig. 15. Displaying patriotic colors, this dramatic night photo of the I-280 Maumee River Crossing in Ohio illuminates a new Toledo landmark. Specially engineered, the top 190 ft (57.9 m) of the single pylon is glass-clad, a community tribute to its glass industry. A first-of-its-kind cradle system carries the cable stays through the central pylon.

Constructed by Fru-Con, the $220 million project includes 2.75 miles (4.43 km) of ramps, roadway and bridge, and 1.2 million sq ft (111,480 m^2) of bridge deck. The 12 ft (3.7 m) deep segments of the main span will be constructed in balanced cantilever. Ramps and approaches will be erected span-by-span. There will be 108 ramp and approach spans, ranging in length from 106 to 151 ft (32.3 to 46.0 m). This landmark structure is scheduled for completion in 2007.

RAIL TRANSIT BRIDGES

The MARTA

Precast concrete segmental construction has also been used for railway bridges, both mass transit and heavy rail lines. The first use in the United States of segmental bridges for passenger rail lines was completed in 1983 for the Metropolitan Atlanta Regional Transit Authority (MARTA) in Georgia. Constructed by J. Rich Steers for $30.9 million, the two bridges total 7130 ft (2173 m) with span lengths between 70 and 143 ft (21.3 and 43.6 m).

The 7 ft (2.1 m) deep precast segments are 30 ft (9.1 m) wide and carry two tracks (see Fig. 16). The first segmental bridge project to use twin triangular trusses under the wings to support the box girder during span-by-span erection, the MARTA line resulted in the maximum vertical clearance for construction over traffic. This project won a PCI Design Award in 1985.

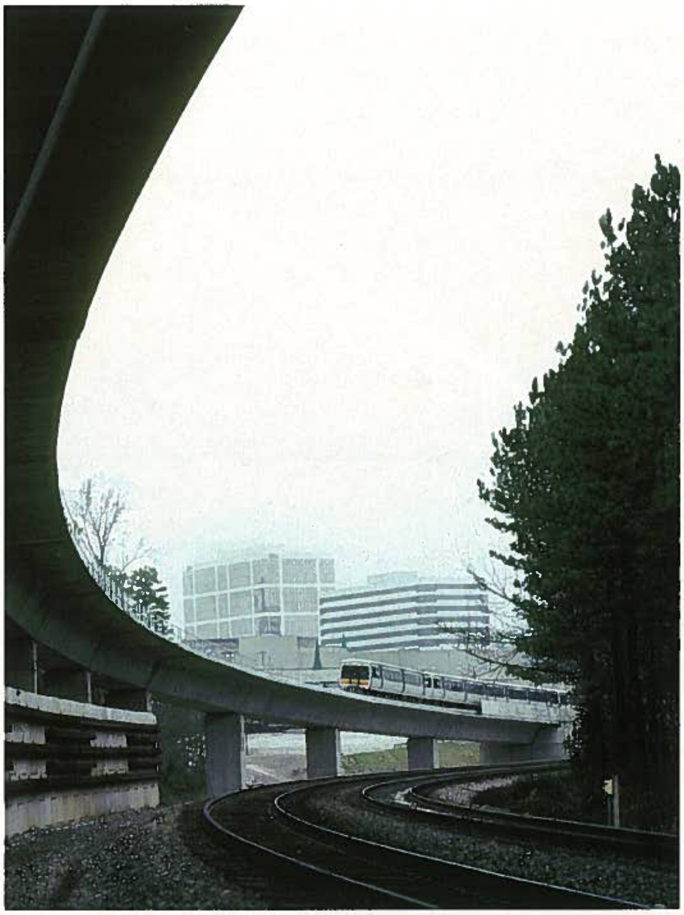

Fig. 16. Completed in 1983, the first precast concrete segmental bridges built for railway use in the United States were designed for the Metropolitan Atlanta Rapid Transit Authority (MARTA) in Georgia.

The JFK AirTrain

The AirTrain is another passenger train segmental bridge built over traffic at New York's John F. Kennedy International Airport, and opened in 2003. Providing convenient access to six airport terminals, parking areas, and the Jamaica Station transportation hub, the facility has 9 miles (14.5 km) of superstructure – with over 5409 precast concrete segments, the most of any segmental bridge in America.

About 3 miles (5 km) of the elevated structure was erected in the narrow 10 ft (3.1 m) median of the very congested, six-lane Van Wyck Expressway. The JFK AirTrain is a major design/build/operate/maintain project, undertaken by the AirRail Transit Consortium. Erection of the superstructure was completed by Koch Skanska.

Fig. 17. AirTrain, New York's John F. Kennedy International Airport passenger train, proudly opened 9 miles (14.5 km) of precast concrete segmental bridge transport to the public in 2003. Within the confines of a narrow right-of-way, the AirTrain rises above the six-lane Van Wyke Expressway.

The 10 ft (3.1 m) deep precast concrete segments are 19.25 ft (5.87 m) wide for the one-rail guideways and 31 ft (9.5 m) wide for the two-rail guideways. Weighing up to 25 tons

Fig. 18. The John T. Collinson Rail Bridge near Pensacola, Florida, is the first use of precast concrete segmental technology for a heavy rail bridge in North America. The bridge is designed to handle the heaviest train loadings, hurricane force winds, and barge impacts.

Fig. 19. Completed in 1995, the Chesapeake & Delaware Canal Bridge near St. Georges, Delaware, was the first precast concrete cable-stayed bridge in the northeast United States. Using innovative design solutions, including precast concrete delta frames, this bridge delivered a savings of $6.2 million over alternate bid designs.

(22.7 tonnes) each, they were fabricated in Cape Charles, Virginia by Bayshore Concrete Products Corporation. Segments were barged 250 miles (402 km) to New Jersey and then trucked 100 miles (161 km) to the site. Nearly all of the precast concrete segments are individually unique so as to accommodate the complex curvature of the bridge project.

This won the 2003 PCI Design Award for Best Non-Highway Bridge (see Fig. 17). The American Railway Engineering and Maintenance Association also honored the JFK AirTrain project with the 2003 Dr. W. W. Hay Award for Engineering Excellence.

John T. Collinson Rail Bridge

The first segmental bridge for heavy rail in America was the John T. Collinson Bridge over Escambia Bay near Pensacola, Florida. Completed in 1988, it is part of the CSX Transportation line between Jacksonville, Florida and New Orleans, Louisiana, and was designed to withstand the full weight of the heaviest train loading (Cooper E90 rating). The rail bridge was also designed to resist hurricane force winds, as well as a 1400 kips (6228 kN) barge impact force on the navigation channel piers (see Fig. 18).

Over two miles (3.2 km) long, the bridge rises on a one percent grade to a 50 ft (15.2 m) vertical clearance over the channel. The 370 ft (113 m) main span was erected in modified balanced cantilever, using triangular trusses for the back span. The piers are precast concrete boxes assembled with vertical post-tensioning.

Economical, efficient, durable, versatile, constructable (in confined spaces and over traffic), and environmentally sensitive – these valuable benefits have allowed precast concrete segmental construction to make a remarkable contribution to the U.S. bridge industry. But what has made segmental bridges an enthusiastic favorite of the communities they serve is the intrinsic beauty of their shapes.

ART IN STRUCTURE

The following bridges are just two examples of such works of art.

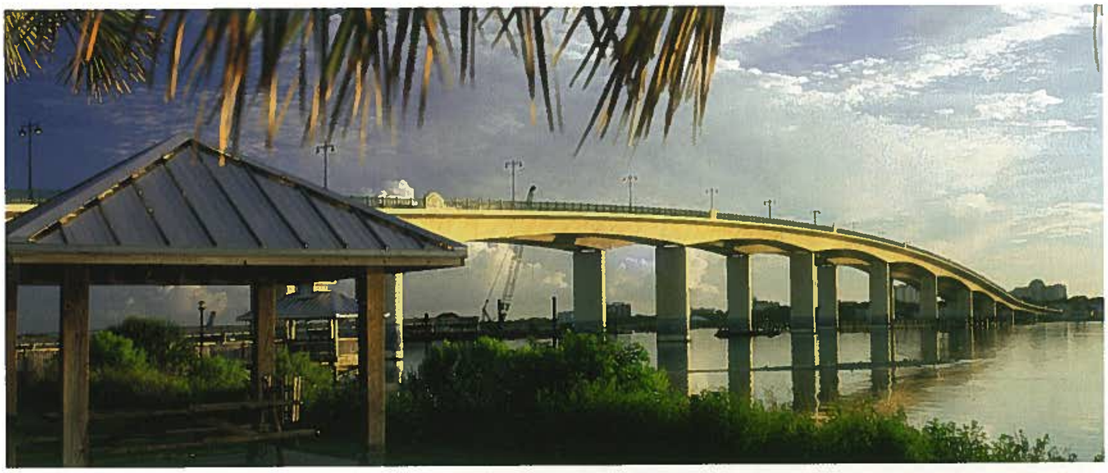

Fig. 20. Broadway Bridge in Daytona Beach, Florida, was completed in July 2001. Twin segmental bridges cross over 3000 ft (914 m) of the Intercoastal Waterway. Based on community input, the bridge features elliptical piers and 262 ft (79.9 m) long precast segmental spans.

Chesapeake & Delaware Canal Bridge

A spectacular example of the grace and beauty of precast concrete structures is the majestic Chesapeake & Delaware Canal Bridge in St. Georges, Delaware (see Fig. 19). This cable-stayed precast concrete segmental bridge – the first of its kind in the northeastern United States – is a signature landmark of the region. Its slender profile and unobtrusive substructure, coupled with its dramatic cable-stay arrangement, is widely acclaimed. This innovative bridge design earned PCI's prestigious Harry H. Edwards Award in 1995.

Completed in 1995 by Recchi America (now Condotte America), the $58 million bridge showcased precast concrete technology that resulted in a $6.2 million savings over the alternate design. The superstructure was an early application of precast delta frames, an innovation that simultaneously helps support the box girders of the 750 ft (229 m) main span and provides anchorages for the visually appealing single plane of stays. The 150 ft (45.7 m) approach spans were erected span-by-span on precast concrete box piers as quickly as one span every four days. The main span was constructed in unidirectional cantilever without interference to ships navigating the canal 138 ft (42.1 m) below.

The precast segments were produced by Bayshore Concrete Products Corporation in Cape Charles, Virginia, and shipped to the bridge site by barge.

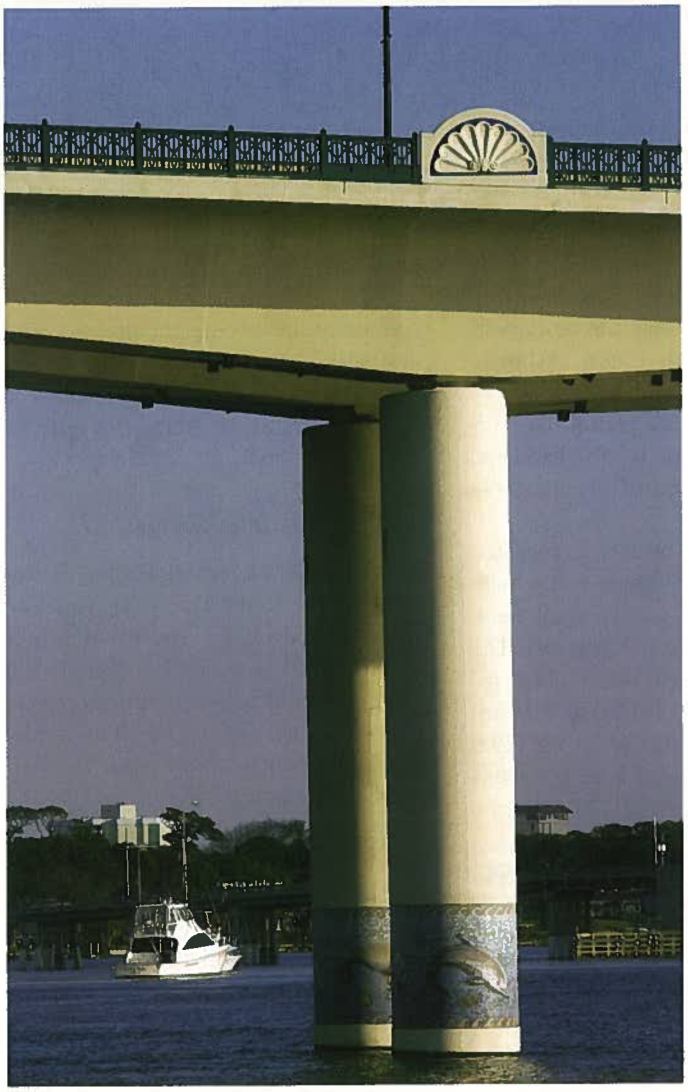

Fig. 21. Artistic glass mosaics on the Broadway Bridge piers display manatees and leaping dolphins, reflecting the structure's "Timeless Ecology" theme.

Broadway Bridge

Community preference for structures that become enduring works of art was evidenced by the Daytona Beach, Florida, residents who participated in design workshops for the Broadway Bridge over the Halifax River. Through public consensus, by voting on affordable aesthetic features, local citizens selected detail elements reflecting the design theme of "Timeless Ecology."

Fig. 22. An artist's rendering of the proposed Indian River Inlet Bridge, in Delaware's Seashore State Park, captures the intrinsic beauty of a 1000 ft (305 m) precast concrete arch cable-stayed span.

Colorful glass mosaic tile designs of wildlife indigenous to the Atlantic coast enrich the visual experience of bridge passengers and pedestrians. Finally, mosaic murals of dolphins and manatees wrap around the 26 piers (see Fig. 20).

The $37 million project, completed in 2001 by Misener Marine, has twin parallel structures with a total deck area of 260,152 sq ft (24,168 m^2). The 352 precast segments, 48 ft (14.6 m) wide and 13 to 7.75 ft (4.0 to 2.36 m) deep with span lengths of 262 ft (79.9 m), create a graceful and timeless arching expanse (see Fig. 21).

THE FUTURE FOR PRECAST SEGMENTAL BRIDGES

So, after presenting numerous examples of a dynamic tradition of continuously advancing technology and aesthetics, what type of future awaits precast concrete segmental bridges in America? With the following glimpse – a glowing one!

Indian River Inlet Bridge

Consider the novel Indian River Inlet Bridge in the Delaware Seashore State Park slated for construction bids in early 2005 (see Fig. 22). The design theme selected in community workshops for this 1000 ft (304.8 m) cable-supported concrete arch span is "Harmony with Nature."

Rising out of a dune-like, land-based substructure, the organic curves and colors of the tulip-shaped arch with its radial plane of stays will create the impression that this bridge might, indeed, be "born of the earth." At night, the stays will glow with soft, blue hues, silhouetting the arch as a distinctive beacon for mariners seeking the inlet gateway.

The Indian River Inlet Bridge and other precast concrete structures presented here are magnificent beacons toward a future of continuing innovation in design and untapped aesthetic potential that excites the imagination. More than any other construction type, precast concrete segmental bridges provide an unequaled opportunity to marry engineering and art, the utilitarian and the ethereal, and intellect with the human spirit.

The fruit of such unions are elegant, functional sculptures that inspire universal feelings of awe and admiration. The future of precast concrete segmental bridges is indeed bright.

ADDENDUM
PERFORMANCE OF SEGMENTAL CONCRETE BRIDGES IN 2004 HURRICANE SEASON

On September 16, 2004, Hurricane Ivan roared ashore on the Gulf coast, near Mobile, Alabama and Pensacola, Florida. It came ashore as a strong Category 3 storm with winds up to 130 miles per hour (210 km/hr). According to the National Oceanic and Atmospheric Administration (NOAA), hurricane strength winds spread over a 160-mile (257 km) wide area, with storm surges as high as 30 ft (9 m) recorded on Pensacola Bay, east of the storm's eye.

The following concrete segmental bridges stood strong despite a direct hit of Hurricane Ivan, with no structural damage:

- **John T. Collinson Bridge over Escambia Bay**
  [11,370 ft (3465 m) length], Pensacola, Florida
  (owned by CSX Railroad)
- **Garcon Point Bridge over Pensacola Bay**
  [18,425 ft (5616 m) length], east of Pensacola, Florida
  (owned by Santa Rosa Bay Bridge Authority)
- **Mid-Bay Bridge over Choctawhatchee Bay**
  [19,265 ft (5872 m) length], between Niceville and Destin, Florida
  (owned by Mid-Bay Bridge Authority)
- **Dauphin Island Bridge over the Intracoastal Waterway**
  [17,814 ft (5430 m) in length], connecting to a barrier island near Mobile, Alabama
  (owned by Alabama Department of Transportation)
- **Cochrane Bridge in Mobile, Alabama**
  [1500 ft (457 m) cable stayed bridge]
  (owned by Alabama Department of Transportation/FIGG Design check/CEI)

As four hurricanes have pounded Florida's coastlines in the record-setting 2004 hurricane season, segmental bridges have proven to be strong and durable during extreme wind conditions, including:

- **Broadway Bridge**
  [3008 ft (914 m) length], over the Intercoastal Waterway, Daytona Beach, Florida –
  Hurricane Frances, Category 2, September 5 and
  Hurricane Jeanne, Category 3, September 26
- **Sunshine Skyway Bridge over Tampa Bay, Florida –**
  [1200 ft (366 m) length]
  Tropical Storm Frances (winds to 70 miles per hour (113 km/hr), September 5 and
  Hurricane Jeanne, Category 1, September 26