Ten Years of Segmental Achievements and Projections for the Next Century

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The last 10 years have seen dramatic growth in the construction of segmental concrete bridges in North America, which is estimated to have an annual construction volume exceeding one billion dollars. The bridges have been built using both precast and cast-in-place concrete segments. Many of these projects have won national and regional awards. This article presents summaries of the major structural features of some of the most outstanding segmental bridges constructed in North America during the last 10 years. Details concerning the design and method of construction of each project are discussed. Finally, the future prospects and potential for segmental bridge construction in the next century are addressed.

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From Bangkok to Boston, the past 10 years have witnessed the emergence of segmental concrete bridge construction as the method of choice for major transportation projects. In the United States, this result has primarily been achieved due to the initial cost advantages of segmental concrete bridges in direct competition with alternative designs using other construction materials and methods of construction.

Other important factors contributing to the growing dominance of segmental concrete bridges are its unequaled speed of construction, lower life cycle costs (and longer design life), appealing aesthetics, minimal traffic disruption during construction, and adaptability to curved roadway alignment.

It is estimated that since 1980, the cost of segmental construction (precast and cast-in-place) completed in North America is about $5 billion. Today, the annual construction volume of this industry is around $1 billion and is expected to grow in the next century.

The success of segmental and cable-stayed concrete bridge projects over the last 10 years is reflected by unprecedented recognition in the form of prestigious national and regional awards. Over the years, the Precast/Prestressed Concrete Institute has recognized several of these projects in its annual Design Awards Program.

Projects largely or wholly based on segmental bridge construction were selected by the American Society of Civil Engineers (ASCE) for their Outstanding Civil Engineering Achievement Award in 1992, 1993, and 1998, as well as Awards of Merit in 1994 and 1995. These awards were achieved in competition with a large number of important civil engineering projects nominated by ASCE districts as contributing to the well being of people and communities, and embodying innovative planning, design, and construction methods.

As a means of recognizing and celebrating the achievements of the past ten years in the United States, Canada, and Mexico (largely reflecting the work of members of the American Segmental Bridge Institute), this presentation reviews some of the notable projects and construction milestones during this time period. The article concludes with discussion of topics and issues that are anticipated to contribute to even more widespread use of segmental concrete bridge construction in the 21st century.

TEN YEARS OF SEGMENTAL ACHIEVEMENTS

The projects presented in this section were selected from a much larger number of outstanding bridges completed during the period of 1989-1998. The projects illustrate diversity in design details and construction procedures, as well as the adaptability of segmental construction to a wide variety of demanding project constraints.


Fig. 1a


Fig. 1b

WEST SEATTLE SWING BRIDGE, WASHINGTON (Figs. 1a and 1b)

Type of Bridge: The only hydraulically operated double-leaf concrete swing bridge in the world.

Description: This two-lane bridge spans 480 ft (146 m) center to center of the two pivot piers. Each movable leaf is 413 ft (126 m) long and weighs 7800 tons (7075 t). The leaves rest on 9 ft (2.74 m) diameter hydraulic "lift/turn" cylinders as they are turned into the open position. Each leaf consists of 25 single-cell segments and a 58.5 ft (17.8 m) pier table. Because the tail span is 62 ft (18.9 m) shorter than the main span, thicker webs are used to serve as ballast. Typical segment lengths are 16 ft (4.88 m) on the main span side and 12 ft (3.66 m) on the tail span side.

The superstructure was constructed by the cast-in-place balanced cantilever method with the leaves in the open position. The 55 ft (16.8 m) vertical clearance is 12 ft (3.66 m) higher than the previous bascule structure, which has reduced the need for openings for river traffic by about 30 percent. The new swing bridge opens in 2 minutes.

Number of Spans: 3

Span Lengths: 173, 480, 173 ft (52.8, 146, 52.8 m)

Construction Cost: $33,500,000

Year Completed: 1991

Award: 1992 ASCE Outstanding Civil Engineering Achievement.

PORT OF MIAMI — DADE COUNTY, FLORIDA (Fig. 2)

Type of Bridge: First double cell precast concrete segmental box in Florida, linking the Port of Miami with the downtown district.

Description: The Port of Miami Bridge over the Intracoastal Waterway is a high-level, fixed structure providing vehicular access to and from the Port of Miami, with at grade connections to Biscayne Boulevard (U.S. 1) on the mainland and the existing Port Boulevard on Dodge Island. The width of this twin bridge is 106 ft 8 in. (32.5 m). The longest span is 195 ft (59.4 m). The overall bridge length is 2522 ft (767 m) and it provides 65 ft (19.8 m) of vertical clearance above the Intracoastal Waterway.

Number of Spans: 16

Span Length: 96 to 195 ft (29.3 to 59.4 m)

Construction Cost: $39,000,000

Year Completed: 1991

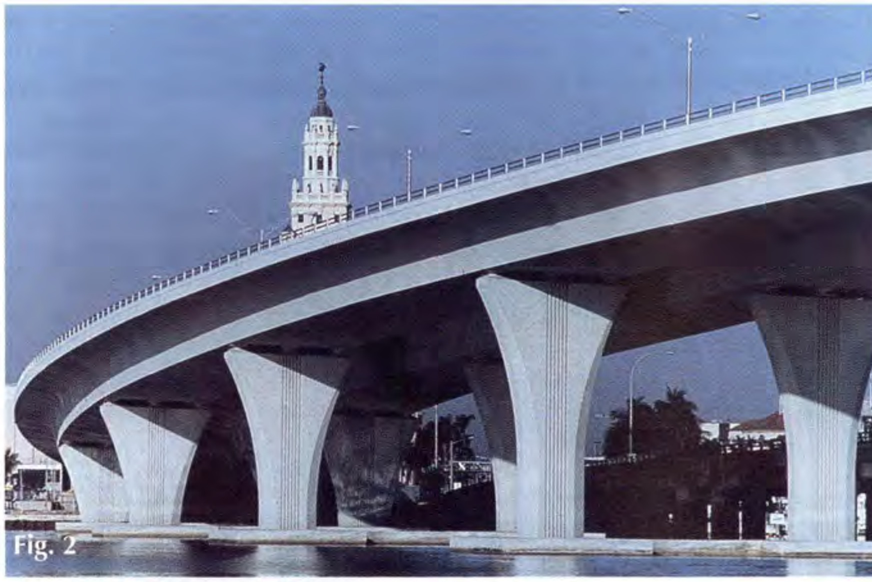

Fig. 2

Awards: 21st Annual Outstanding Concrete Structures in Florida by the Florida Concrete and Products Association, Inc.

1994 Award of Excellence in Design for Major Structures by the Federal Highway Administration.

1997 International Illumination Design Award Regional in the category of Outdoor Lighting by the Illuminating Engineering Society of North America.

Fig. 3

GLENWOOD CANYON (HANGING LAKE VIADUCT), COLORADO (Fig. 3)

Type of Bridge: Two-lane precast balanced cantilever bridge constructed in a deep and constricted canyon environment by use of an overhead gantry.

Description: The Hanging Lake Viaduct along I-70 through Glenwood Canyon in Colorado includes three precast concrete segmental bridges totaling approximately 8400 linear ft (2560 m), and incorporating 1156 segments. The structures consist primarily of 200 ft (61.0 m) spans with two parallel 300 ft (91.4 m) main spans over the Colorado River.

The 33 ft 6 in. (10.2 m) wide roadway is made up of a single trapezoidal precast box girder typically 10 ft (3.05 m) deep, with a linear transition to 12 ft 6 in. (3.81 m) at the main piers. Due to the severe environmental restrictions and the requirements for not interrupting traffic flow in the narrow canyon, ground access was limited for superstructure erection. Therefore, the structure was built with an overhead launching gantry using the balanced cantilever erection method.

Span Length: 200 to 300 ft (61.0 to 91.4 m)

Construction Cost: $34,091,025

Year Completed: 1992

Awards: 1986 PCI Design Award

1993 ASCE Outstanding Civil Engineering Achievement (Overall Glenwood Canyon Project).

NATCHEZ TRACE PARKWAY ARCHES, TENNESSEE (Fig. 4)

Type of Bridge: America's first precast segmental concrete arch bridge.

Description: America's first precast segmental concrete arch bridge, one of the Natchez Trace Parkway's most challenging engineering projects carries parkway traffic 155 ft (47.2 m) over Tennessee Route 96. The principal arch span for the structure has a clear span of 582 ft (177 m) and the deck spans are 204, 246, 90, 246, 246, 90, 246, and 204 ft (62.2, 75.0, 27.4, 75.0, 75.0, 27.4, 75.0, and 62.2 m). The depth of the superstructure segments varies from 7 ft 6 in. (2.29 m) at the midspan to 14 ft 4 in. (4.37 m) at the piers. The structure's 34 ft (10.4 m) roadway provides two 11 ft (3.35 m) travel lanes and two 6 ft (1.83 m) shoulders.

The arch segments are precast hollow boxes, 16 ft 1 in. (4.90 m) wide with 12 in. (3.66 m) thick walls and vary in depth from 10 ft (3.05 m) at the base of the arch to 13 ft (3.96 m) at the centerline of the superstructure bearings [45 ft (13.7 m) off the arch centerline]. The depth of the arch segments then tapers back to 10 ft (3.05 m) at the arch centerline.

Construction Cost: $14,289,000

Year Completed: 1993

Awards: 1994 Florida Institute of Consulting Engineers Engineering Excellence Grand Award.

1995 ASCE Award of Merit.

Fig. 4

NEW BALDWIN BRIDGE, CONNECTICUT (Fig. 5)

Fig. 5

Type of Bridge: Precast balanced cantilever bridge over water. Erection by overhead gantry.

Description: The new bridge carries I-95 over the Connecticut River replacing a steel structure that was deemed inadequate for the volume of traffic. It is an 11-span, 2522.5 ft (769 m) long structure, with span lengths varying from 177.5 ft up to 275 ft (54.1 to 83.8 m).

The bridge is a constant depth twin box segmental concrete structure and was constructed utilizing the balanced cantilever erection scheme. The segments were barged beneath the cantilever arm being erected and then lifted into place. The single-cell internally stiffened box girder is an efficient cross section for the 87 ft (26.5 m) westbound and 77 ft (23.5 m) eastbound deck. The box girder is a 12 ft (3.66 m) constant depth section and is post-tensioned in all three directions.

The girder is continuous from abutment to abutment, thus eliminating intermediate joints. The superstructure/substructure interaction is accomplished by fixing four piers while other piers rest on high load disc or spherical bearings. Earthquake restrainers are used to transfer seismic loads. All the substructure units are founded on piles except the abutments.

Construction Cost: $93,811,427

Year Completed: 1993

Award: 1994 ASCE Award of Merit.

NO. 2 ROAD BRIDGE, RICHMOND, BRITISH COLUMBIA, CANADA (Fig. 6)

Type of Bridge: Precast segmental balanced cantilever bridge over water.

Description: Environmental concerns related to minimizing interruption of the intertidal zones important to the life cycle of salmon were a key challenge in building this bridge over the Fraser River estuary. The use of a precast segmental bridge with typical spans of 197 ft (60.0 m) and a maximum span of 210 ft (64.0 m) permitted a construction schedule that reduced foundation work during the river's peak season and minimized the number of piers, which in turn limited disruptions to the environment. The river also permitted water access to the bridge for about 80 percent of its length, which facilitated delivery and installation of the precast segments. The project was completed two months ahead of schedule, just one year after the contract was awarded.

The deck's 82 ft (25.0 m) width consists of two precast concrete trapezoidal boxes connected via transverse post-tensioning. The total bridge length is 1857 ft (566 m). The constant box depth of 7 ft $10^1/_2$ in. (2.40 m) results in a span-to-depth ratio of 26.7, producing a pleasing, slender-looking structure.

Construction Cost: $22,000,000

Year Completed: 1993

Award: 1993 PCI Design Award for "Best Bridge with Spans Greater than 135 ft (41.1 m)."

Fig. 6

ACOSTA BRIDGE REPLACEMENT, JACKSONVILLE, FLORIDA (Fig. 7)


Fig. 7

Type of Bridge: Asymmetrical cast-in-place balanced cantilever bridges with a main span of 630 ft (192 m). Due to the 75 ft 8 in. (23.1 m) deck width of each bridge span, twin cell boxes were used.

Description: The replacement of the Acosta lift bridge, constructed in 1921, incorporates two identical structures separated by a 10 ft 4 in. (0.30 m) opening between bridge decks and having a 75 ft (22.9 m) fixed vertical channel clearance. Five spans, progressing from the south bank northward, are spaced, progressively, at 220, 360, 630, 275, and 160 ft (67.1, 110, 192, 83.8, and 48.8 m) forming continuous 1645 ft (501 m) long decks, each 75 ft 8 in. (23.1 m) in width. They will carry three 12 ft (3.66 m) lanes bordered on each side by 10 ft (3.05 m) shoulders and a full walkway along the outside edge of the deck.

Both inside wings of the boxes are designed for the later installation of the twin-rail, Jacksonville Automated Skyway Express people mover. The required navigation clearance at the north side span reduced the girder depth in these areas to 9 ft 6 in. (2.90 m). This shallow girder depth did not permit a north-side span that was long enough to balance the 630 ft (192 m) mainspan in a symmetrical pattern. Considering this constraint, an asymmetrical box girder solution was developed. A proportionately longer span at the south side of the main span was selected to balance a larger portion of the main span, allowing the north half balanced cantilever to remain at 275 ft (83.8 m).

Construction Cost: $45,400,000

Year Completed: 1994

Award: 1993 Florida Institute of Consulting Engineers.


Fig. 8

MID-BAY BRIDGE, DESTIN, FLORIDA (Fig. 8)

Type of Bridge: Span-by-span precast segmental bridge over water with dry joints. Total length 3.6 m (1.10 m).

Description: The 19,265 ft (5872 m) precast segmental bridge consists of the following elements: 1169 piles, 966 typical segments, 116 pier segments, 50 expansion joint segments, 50 expansion joint segments, 118 I-pier segments, and 36 I-pier cap segments. The typical approach spans were constructed using the span-by-span erection method. Typically, $4^1/_2$ spans [600 ft (183 m) of bridge] were erected per week for the span-by-span portions of the bridge. During the week of September 14, 1992, a world record of seven spans were erected in 7 days [952 ft (290 m) of bridge]. The 225 ft (68.6 m) main span of the bridge structure was constructed using the modified balanced cantilever erection method. The main span provides 65 ft (19.8 m) of vertical clearance over the Intracoastal Waterway channel.

Number of Spans: 140

Span Length: 136 ft (41.5 m)

Construction Cost: $40,440,798

Year Completed: 1993

Awards: 1993 Florida Transportation Builders "Best in Construction Award."

1994 Florida Institute of Consulting Engineers Engineering Excellence Grand Award.

C & D CANAL BRIDGE, DELAWARE (Fig. 9)

Type of Bridge: Precast segmental span-by-span bridge with spans of 150 ft (45.7 m) and a 750 ft (229 m) cable-stayed main span over the C&D Canal.

Description: The cable-stayed main span unit is 1650 ft (503 m) between expansion joints, providing a 750 ft (229 m) main span from pylon to pylon. The spans between the abutments and pylons are 150 ft (45.7 m) long and are supported on precast, vertically prestressed, voided box piers. In turn, the piers and pylons are supported by 24 in. (610 mm) square precast, prestressed concrete piles, ranging from 23 to 102 ft (7.01 to 31.1 m) in length.

The project requirements called for a roadway with three 12 ft (3.66 m) wide travel lanes and two 10 ft (3.05 m) shoulders in each north and south direction. The bridge deck width (including roadway and shoulders) is 127 ft (38.7 m).

The geometric alignment provides a high degree of safety by having no horizontal curvature and a minimal vertical curvature of 1900 ft (579 m) with tangent grades of 3 percent. The transverse cross section of the bridge has a constant cross slope of 2 percent with no super-elevation transitions into the roadway embankments. As a result of this geometry, a motorist will have a very safe and smooth ride.

The 4650 ft (1417 m) long bridge comprises twin parallel trapezoidal box girders. Each box girder is 58 ft 8 in. (17.9 m) wide, and 12 ft (3.66 m) deep. A typical segment is 10 ft (3.05 m) long, and has a cross-sectional area of 90 sq ft (8.36 m^2), and weighs about 70 tons (63.5 t). In all, 984 superstructure box girder segments were used. Typical box girder spans have six external tendons with 31 $^1/_2$ in. (13 mm) diameter strands each, and two external tendons with seven $^1/_2$ in. (13 mm) strands. The parallel box girder spans act independently in the approach spans, but in the main span they are integrated with a cast-in-place median slab.


Fig. 9

Construction Cost: $57,724,203

Year Completed: 1995

Award: 1995 PCI Harry H. Edwards Industry Advancement Award.

PAPALOAPAN BRIDGE, MEXICO (Fig. 10)

Type of Bridge: Cable-stayed bridge over water with a main span of 203 m (666 ft).

Description: The Papaloapan Bridge was a design-build project completed in 18 months. The project length is 404 m (1325 ft), and the deck width is 23 m (75.4 ft). Elimination of cross beams between pylon columns allowed cranes to turn 360 degrees. Solid, rather than hollow, concrete sections were used for the pylons. The cable stays were attached to threaded connectors embedded in the column concrete. External sheathing for the cable stays was provided by means of an elastomeric wrap directly over the strand bundle. Three levels of corrosion protection were provided for the strand: epoxy coating, grease, and high density polyethylene.

Year Completed: 1995

Fig. 10

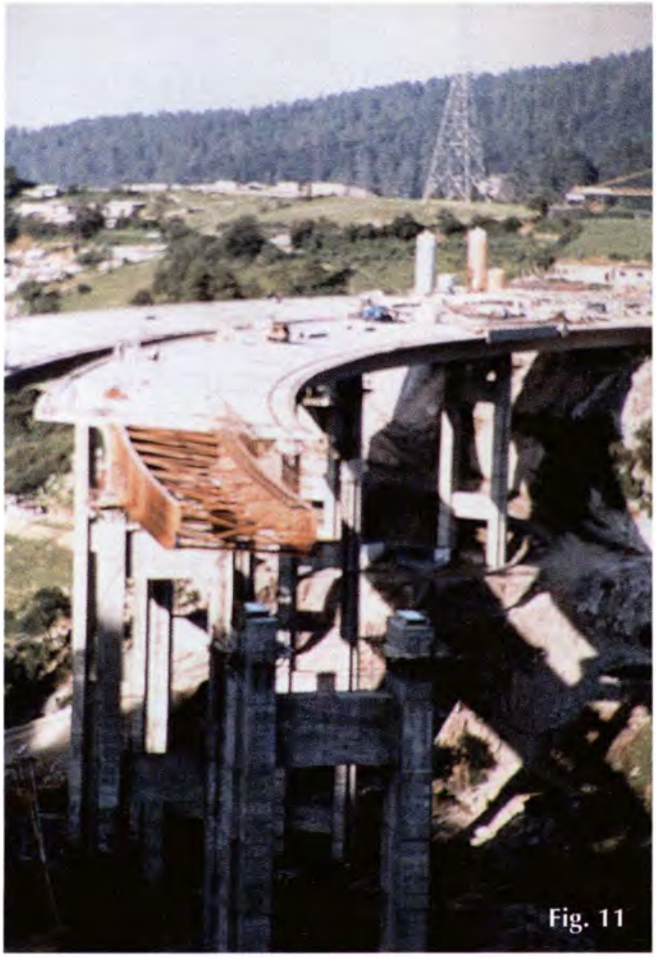

Fig. 11

MARQUESA BRIDGE, MEXICO (Fig. 11)

Type of Bridge: Incrementally launched highway bridge crossing a deep valley and creek. Built on a 350 m (1148 ft) radius.

Description: Twin incrementally launched bridges 330 m (1082 ft) long, each bridge with 18 m (59.0 ft) roadways for three lanes of traffic. Typical spans are 60 m (197 ft) built 60 m (197 ft) over high water. Incremental launching was used due to difficult access at the construction site. Launching was complicated by the 350 m (1148 ft) radius and the 3.5 percent grade of the roadway. Only a very small area was required for the casting yard and launching site.

Year Completed: 1998

H-3 VIADUCTS, HAWAII (Fig. 12)

Type of Structure: A precast segmental balanced cantilever bridge erected by a gantry designed to erect the twin structures simultaneously, limiting the impact on the sensitive environment of the Haiku Valley.

Description: Parallel precast balanced cantilever segmental bridges approximately 6600 ft (2012 m) in length. Typical spans are 300 ft (91.4 m). Column heights range from 12 to 160 ft (3.66 to 48.8 m). Originally designed as a cast-in-place balanced cantilever bridge and changed to precast balanced cantilever construction by a value engineering proposal submitted by the contractor.

Because of the tight contract time, it was necessary to develop an efficient erection scheme. A special self-launching erection gantry was designed to allow both structures to be built simultaneously, thereby reducing the contractor's erection time. The gantry was designed to be supported on both structures and accommodate variable cross slopes, curves, differential elevations and variable distances between the two structures. The contractor was able to erect twin 300 ft (91.4 m) cantilevers in a 13 working day cycle. As many as 14 precast superstructure segments were erected in one day. The project was completed seven months ahead of the owner's original schedule.

The precast segments varied in length from 8 to 11 ft (2.44 to 3.35 m), and in depth from 8 to 16 ft (2.44 to 4.88 m) with the cross section and post-tensioning detailed for precast construction. Maximum segment weight was 75 tons (68.0 t). Four typical segment casting machines and one special segment casting machine were used for precasting at the plant, which is located 7 miles (11.3 km) from the bridge site.

Year Completed: 1993

Award: 1998 ASCE Outstanding Civil Engineering Achievement Award.

Fig. 12


Fig. 13a


Fig. 13b

NORTH HALAWA VALLEY VIADUCT, HAWAII (Figs. 13a, 13b, and 13c)

Type of Bridge: Cast-in-place balanced cantilever bridge with 360 ft (110 m) typical spans. Form travelers supported by a 430 ft (131 m) moveable truss due to difficult terrain and no ground access at midspan.

Description: The North Halawa Valley Viaduct extends the H-3 interstate highway from the Trans-Koolau Tunnel westward into the environmentally sensitive North Halawa Valley. The parallel 6000 ft (1829 m) long segmental concrete viaducts, each 41 ft (12.5 m) wide, are divided into three units of approximately 2000 ft (610 m) lengths between expansion joints. Typical spans are 360 ft (110 m) long with spans as short as 300 ft (91.4 m) to accommodate the terrain. Each viaduct is aligned on large radius curves and are on a nearly constant 6 percent grade sloping upwards towards the mountains.

Based on cost, difficult road access and no convenient area for a casting yard, the selected bridge type is a single cell cast-in-place segmental box girder constructed by the balanced cantilever method using overhead gantries. The contractor elected to build the 24 ft (7.32 m) long segments instead of the 21 ft (6.40 m) segments proposed in the design to permit construction with three rather than four gantries. Each gantry is 460 ft long, 20 ft wide, and 26 ft high (140, 6.10, and 7.92 m), and weighs 1350 kips (6005 kN). Typically, 14 superstructure segments were erected in a 4-day cycle each month.

Construction Cost: $140,566,309

Year Completed: 1995

Awards: 1998 ASCE Outstanding Civil Engineering Achievement Award.

1997 American Consulting Engineering Council Engineering Excellence Grand Award.


Fig. 13c

U. S. 183 VIADUCTS, AUSTIN, TEXAS (Figs. 14a and 14b)

Type of Bridge: Precast segmental span-by-span and balanced cantilever urban viaduct with special attention to aesthetic features.

Description: In order to both carry express traffic and provide access to homes and businesses, the corridor consists of twin elevated structures that cantilever over frontage roads. The necessity of overhead construction in a congested urban area and aesthetics prompted planners to choose precast, post-tensioned, segmental concrete construction. A total of 206 of the spans were designed as precast, span-by-span, segmental box girder structures with a maximum span length of 41 ft (12.5 m). One entrance ramp has spans of 55 ft (16.8 m) and was partially constructed by the balanced cantilever method. The total project incorporates 1.3 million sq ft (120770 m^2) of deck area. The viaduct was built at a very competitive cost of $39 per sq ft.

Traffic volumes dictated that the mainline cross section be very large. An overall width of 58 ft (17.7 m) was necessary to support three lanes and shoulders. A 16 ft (4.88 m) nominal width box base was required for stability. Entrance and exit ramp overall widths are 26 ft (7.92 m), and the box base width is 8 ft (2.44 m). Transition girders with varying box base widths [16 to 38 ft (4.88 to 11.6 m)] and wing lengths are required to merge the disparate cross sections of the mainlane and ramp girders. The girder depth for the entire project is 7 ft (2.13 m).

A smaller scale was achieved by chamfering and thus accentuating the transverse joints between the segments. Thus, the segmental characteristic of the bridge is suggested rather than hidden. Box girders are typically cast with a single, sharp corner at the intersection of the web and bottom slab of the box. A large chamfer created a more organic feel that visually lightened the superstructure.

All of the columns on this project were originally designed as precast segmental piers post-tensioned with vertical tendons. Precast starter segments were to be encased in an oversized base that would provide a connection to the footing. After much deliberation, the contract opted to construct the mainlane and small ramp piers cast-in-place. The large ramp piers were constructed with precast segments. The segmented appearance of the columns reflects the construction history and creates a more human scale presented at the all-important frontage road level.

Construction Cost: $71,328,098

Year Completed: 1996

Fig. 14a

Fig. 14b

BRANCH ROUTE NAYLOR ROAD STATION AND LINE, WMATA, WASHINGTON, D.C. (Fig. 15)

Type of Bridge: Rapid Transit aerial structure.

Description: The Branch Route Naylor Road Station and Line for the Washington Metropolitan Area Transit Authority in Washington, D.C. includes a station and approximately 100,000 sq ft (9290 m^2) of precast segmental aerial structure. A VECP modified the superstructure to allow span-by-span erection using the contractor's existing trusses, which were first used in a Metropolitan Atlanta Rapid Transit Authority project in the early 1980s.

The aerial structure consists of dual boxes with an average width of 17 ft (5.18 m). Each single-cell box carries one track. A 12-span structure carries the tracks into one end of the station while a nine-span exits the other end of the station. Span lengths range from 106 to 149 ft (32.3 to 45.4 m) with typical spans of 117 ft 6 in. and 131 ft 6 in. (35.8 and 40.1 m). Approximately 600 precast segments were cast by a precast producer, and shipped to the site using a barge and truck.

Construction Cost: $48,000,000

Year Completed: 1997


Fig. 15

CONFEDERATION BRIDGE, CANADA (Figs. 16a and 16b)

Type of Bridge: Structure comprising a 13 km (8.13 m) water crossing utilizing segment weights ranging from 1200 to 7500 tons (1089 to 6804 t). Erection was accomplished by a special heavy-lift catamaran-barge.

Description: One of the world's largest over water bridges, this 13 km (8.13 miles) crossing from the island to the mainland was constructed utilizing a 10990 m (36,047 ft) long main bridge with spans of 250 m (820 ft), and two approaches of 1320 and 600 m (4330 and 1968 ft) with spans of 93 m (305 ft).

Because of the short open-water season, the contractor elected to remove as much of the construction activity as possible from the marine environment by the comprehensive use of precasting. The approaches were precast on the mainland employing conventional segmental technology, while the main bridge was prefabricated on the island in massive modules.

Innovations used throughout the construction of the bridge include:

- Inverted V-shaped composite steel diaphragm in the pier segment.
- Use of tremie concrete to mate precast foundation elements with the underlying sandstone, which kept settlement to a minimum.
- Connection of the pier shaft and its integrated ice shield to the pier base with a grouted post-tensioned joint, eliminating exposure to cast-in-place concrete to the aggressive splash-zone environment.
- A precast template match-cast with the bottom of the main pier segment, eliminating the need for adjustment of the 7500 ton (6804 t) girder after erection on top of the pier.

The Confederation Bridge was designed and constructed to achieve a 100-year life.

Construction Cost: $630,000,000

Year Completed: 1997

Awards: 1998 American Consulting Engineers Council Engineering Excellence Grand Award.

1998 PCI Design Award (co-winner) for "Best Bridge with Spans Greater than 135 ft (41.1 m).

Fig. 16a

Fig. 16b

BOSTON CENTRAL ARTERY/TUNNEL PROJECT, MASSACHUSETTS (Fig. 17)

Type of Bridge: Multi-level urban viaduct.

Description: A total of 16 miles (25.6 km) of precast segmental viaduct were selected for the Boston Central Artery/Tunnel Project on the basis of competitive bids against alternative steel box girder structures. The initial cost savings provided by the precast segmental alternatives on three large projects ranged to 25 percent. Due to a lack of space for segmental production and storage near the construction site, segments are being produced at precast plants in Maine and Massachusetts and delivered by truck to the construction site as required for erection. Both span-by-span and balanced cantilever erection is accomplished on the various projects by use of overhead gantries, beam and winch, and a conventional crane. Horizontal curve radii range from 200 to 6500 ft (61.0 to 1981 m).


Fig. 17


Fig. 18


Fig. 19

MILESTONES

During the past decade, several important milestones have been achieved with segmental construction. The following projects represent some of the significant records.

GARCON POINT BRIDGE, FLORIDA (Fig. 18)

Seven 140 ft (42.7 m) spans of the Garcon Point Bridge were erected in 7 days in May, 1998. The total bridge length of 980 ft (299 m) represents what is believed to be a new world record, surpassing the Mid-Bay Bridge for which seven 136 ft (41.5 m) spans were erected in 7 days.

WABASHA STREET BRIDGE, ST. PAUL, MINNESOTA (Fig. 19)

Construction of cast-in-place segments during the cold winters of St. Paul demonstrated the adaptability of cast-in-place construction to areas with cold winter weather.

LOS ANGELES GREEN LINE BRIDGE, CALIFORNIA (Fig. 20)

Construction of the cast-in-place segmental structure without disruption of traffic on one of the most heaviest traveled interchanges in Los Angeles dramatically illustrated the advantages of segmental construction.

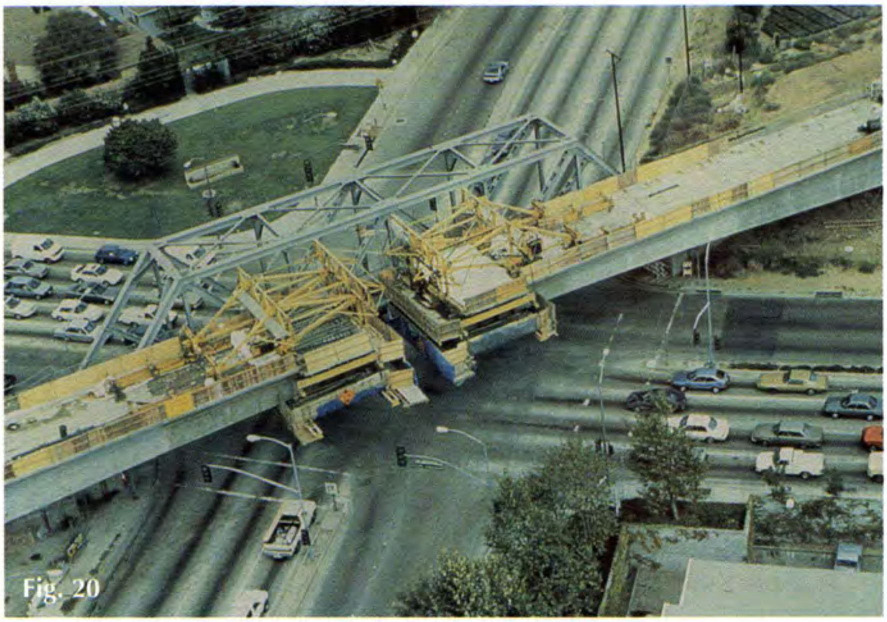
Fig. 20


Fig. 21

BATH-WOOLWICH BRIDGE, MAINE (Fig. 21)

This successful design-build alternative set a new record for precast segmental spans at 420 ft (128 m).


Fig. 22a

CHANNEL BRIDGES, NEW YORK (Figs. 22a and 22b)

The United States debut of the Channel Bridge at two locations in New York in 1997 provided 2 ft 6 in. (0.76 m) of additional clearance without adjustment of the roadway alignment or grade.


Fig. 22b

PROJECTIONS FOR THE NEXT CENTURY

Reconstruction of existing transportation facilities will, without question, dominate bridge construction activities in the 21st century. The present reconstruction of the interstate highway system in Salt Lake City, Utah, the planned interstate reconstruction in Albuquerque, New Mexico (see Fig. 23), the replacement of the east spans of the San Francisco-Oakland Bay Bridge in California (see Figs. 24 and 25), and the replacement of the Woodrow Wilson Bridge in Washington, D.C. are symptomatic of future work. These four projects alone will cost $4 to $5 billion. It should be noted that the interstate systems in Salt Lake City and Albuquerque are less than 50 years old.

The ASCE "report card" on the condition of the U.S. infrastructure indicated $1.3 trillion would be required to replace and/or repair existing facilities. Of this total, ASCE estimated that an expenditure of $80 billion in bridge replacement projects was currently needed. On this basis, at present funding levels for bridge replacement, it would take about 100 years to replace the present stock of structurally deficient bridges.

The United Nations has defined "sustainable development" as meeting the needs of people today without destroying the resources that will be needed by future generations. It is apparent that achieving a sustainable level of development for highway facilities in the next century will require increasing the minimum bridge design life to at least 100 years, and consideration of life-cycle cost analysis in the selection of construction materials and construction methods.

Fig. 23. Proposed section for the I-25/I-40 Interchange in Albuquerque, New Mexico. Courtesy: Rendering provided by URS Greiner Woodward Clyde.

Fig. 24. Proposed approach spans for San Francisco-Oakland Bay Bridge in California.

Fig. 25. Proposed cable stayed spans for San Francisco-Oakland Bay Bridge in California.

There is extensive evidence from existing experience that prestressed concrete bridges in general, and segmental concrete bridges in particular, are the most attractive from the perspective of minimizing life-cycle costs. Design and construction features to achieve a 100-year life have already been implemented in major segmental bridge projects located in very aggressive environments.

High performance concrete will provide some future structural economies through reduction of cross section dimensions and increased structural capacity. However, the primary advantages for segmental bridges will be in reducing construction time and further enhancement of durability characteristics.

As an example, the Rhone River cast-in-place segmental bridge in France achieved a 3-day per segment construction cycle through the use of an 8400 psi (58.0 MPa) high performance concrete. This represents a 40 percent reduction in the normal construction rate of 5 days per segment. The Rhone River Bridge also used precast panels in the sloping webs, new form traveler details, and external tendons inside the box cross section. Because none of these features have yet been applied to cast-in-place segmental bridge construction in North America, it appears that the United States may still have a long way to go to catch up to European bridge construction technology.

Lightweight concrete has performed well in the Knight Street Bridge in Vancouver and the Napa River Bridge in California over more than 25 years. Lightweight concrete has been more extensively used in the construction of large cast-in-place segmental bridges in Europe, particularly in Norway.

The planned large scale use of lightweight concrete in the Benecia Martinez Bridge in California will provide momentum for more widespread use of lightweight concrete for reduction of the dominant dead load moments in segmental bridges. While lightweight concrete is particularly attractive in zones of high seismicity, it is considered to offer economic benefits in non-seismic areas as well, particularly in those parts of North America where high quality coarse aggregate is not readily available.

In addition to initial and life-cycle costs, construction time will be a critical issue in the reconstruction of existing highway facilities. It is apparent that no other construction method or material can match the construction speed provided by precast segmental bridges. In this context, the AASHTO-PCI-ASBI Standard Segments are expected to be widely used in the next century.

Several projects are now under design that use the standard segments. The segmental standards and the large industrial base provided by PCI Producer Members with plants located near most major cities provides a means of extending the advantages of precast segmental bridges to projects costing less than $10 million.

Finally, light rail and high speed rail projects will become major markets for segmental bridges in the next century. The project now under development in Florida is estimated to require 140 bridges. An 8.4 mile (13.4 km) bridge is included in the design-build plans for mass transit at JFK Airport in New York.

As indicated by *Engineering News-Record* last spring, high speed rail projects are now in various stages of development in the major transportation corridors in the United States. Segmental concrete bridges appear to be the only logical choice for the large number of structures required by these projects.

CONCLUSIONS

Over the past 10 years, the competitive advantages of segmental concrete bridges have been demonstrated on a world-wide basis. The sample of completed projects in North America presented in this article has also shown that segmental construction is adaptable to very demanding construction sites, provides unequaled speed of construction, minimizes impact on the environment, and results in bridges with very appealing aesthetic characteristics.

It is anticipated that the 21st century will be dominated by bridge replacement projects and by the construction of high speed rail facilities. In order to achieve a sustainable level of development of the transportation infrastructure, it will be necessary to build structures with minimal life-cycle costs and a minimum design life of at least 100 years. Segmental concrete bridges meet these criteria. The use of high performance concrete, lightweight concrete, and the AASHTO-PCI-ASBI standard segments are also expected to contribute to an increasing dominance of segmental concrete bridges in construction of transportation facilities in the next 100 years.