AASHTO-PCI-ASBI Segmental Box Girder Standards: A New Product for Grade Separations and Interchange Bridges

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With the introduction of the soon to be ratified AASHTO-PCI-ASBI Segmental Box Girder Standards, precast, prestressed concrete producers have the opportunity to more fully participate in the segmental bridge market, which is estimated to have an annual construction volume of about one billion dollars in North America. The purpose of this article is to provide background material on the segmental standards, to review past segmental grade separation and interchange projects both in this country and around the world, and to present future prospects for segmental bridge construction. The general consensus is that segmental construction, in its various forms, holds a viable and promising future for the precast concrete industry.

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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.

In July of 1982, the Federal Highway Administration (FHWA) published a research report developed by T. Y. Lin International titled "Feasibility of Standard Sections for Segmental Prestressed Concrete Box Girder Bridges."[1] This report concluded that the "development of standard sections for segmental prestressed concrete box girder bridges is feasible and can be immediately initiated. However, the range of sections and related items to be standardized should be prescribed and somewhat limited."

Continued growth in the use of segmental concrete bridges during the following 12 years led to the formation of the Joint PCI-ASBI (Precast/Prestressed Concrete Institute-American Segmental Bridge Institute) Committee in 1994 with the mission of developing standard precast segmental box girder sections for grade separation and interchange bridges with spans of up to 61 m (200 ft).

The first meeting of the PCI-ASBI Joint Committee was held in October 1994 at PCI Headquarters in Chicago. Development of the proposed standards by the 19-member committee (including representatives of AASHTO, FHWA, PCI and ASBI) was completed with submission of the proposed "AASHTO-PCI-ASBI Segmental Box Girder Standards for Span-by-Span and

Fig. 1. I-75/I-595 Interchange, Broward County, Florida. This four-level fully directional interchange is the largest interchange in the state of Florida. The bridge structures are composed of curved precast concrete segmental box girders erected by the balanced cantilever method (Designer: Beiswenger Hoch & Associates).

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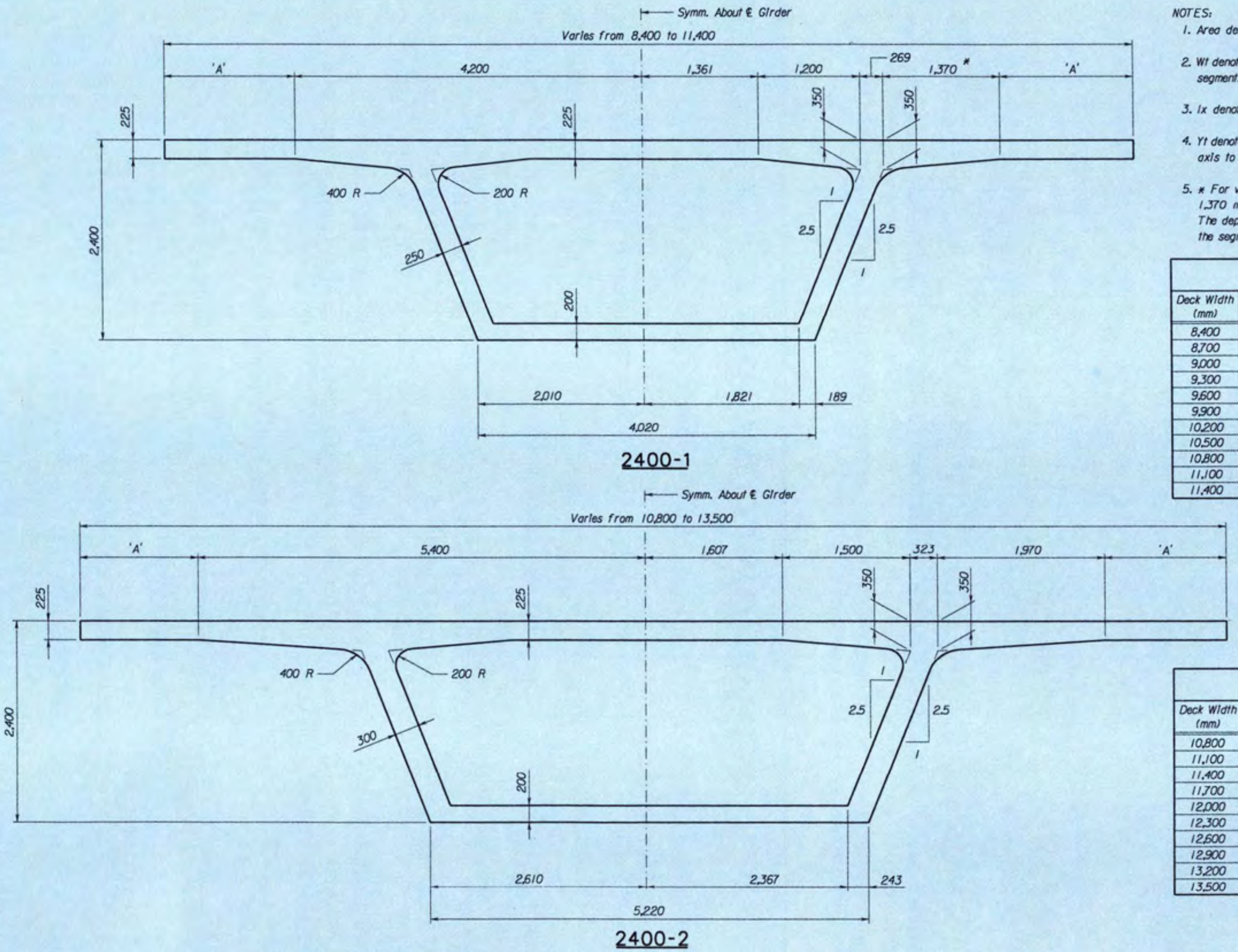


NOTES:

1. Area denotes cross-sectional area.
2. Wt denotes segment weight for 3000 mm segment.
3. Ix denotes bending moment of inertia.
4. Yt denotes distance from the centroidal axis to the top of section.
5. * For widths less than 8,400 mm, the 1,370 mm dimension is decreased. The depth of the slab at the edge of the segment increases accordingly.

2400-1

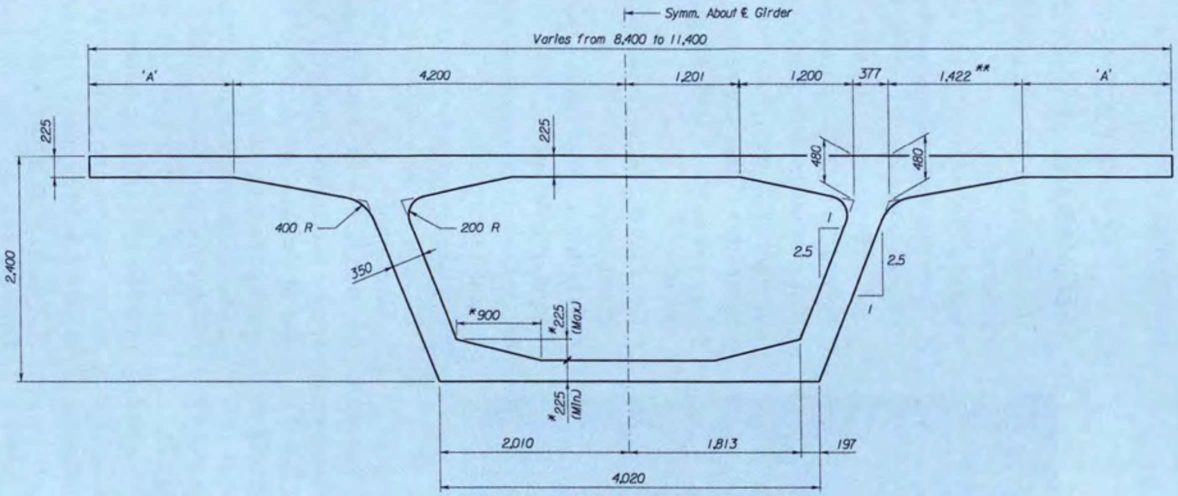
Deck Width (mm)	'A' (mm)	Area (mm²)	Wt/3,000 mm (Kn)	Ix (m⁴)	Yt (mm)
8,400	0	4,147,000	304	3.366	842
8,700	150	4,214,000	308	3.402	830
9,000	300	4,282,000	313	3.437	819
9,300	450	4,349,000	318	3.470	808
9,600	600	4,417,000	323	3.502	797
9,900	750	4,484,000	328	3.534	787
10,200	900	4,552000	333	3.565	777
10,500	1,050	4,619,000	338	3.594	767
10,800	1,200	4,687,000	343	3.623	758
11,100	1,350	4,754,000	348	3.651	749
11,400	1,500	4,822,000	353	3.678	740

2400-2

Deck Width (mm)	'A' (mm)	Area (mm²)	Wt/3,000 mm (Kn)	Ix (m⁴)	Yt (mm)
10,800	0	5,256,000	385	4.303	836
11,100	150	5,323,000	390	4.339	827
11,400	300	5,391,000	395	4.373	818
11,700	450	5,458,000	400	4.406	809
12,000	600	5,526,000	404	4.439	801
12,300	750	5,593,000	409	4.471	792
12,600	900	5,661,000	414	4.502	784
12,900	1,050	5,728,000	419	4.532	776
13,200	1,200	5,796,000	424	4.562	769
13,500	1,350	5,863,000	429	4.591	761

PROPOSED AASHTO - PCI - ASBI SEGMENTAL BOX GIRDER STANDARDS	FOR SPAN-BY-SPAN CONSTRUCTION SPANS 30.5 TO 45.7 METERS	2400 mm SEGMENT DEPTH

Fig. 2. Standard section: 2400 mm (8 ft) segment depth for span-by-span construction.



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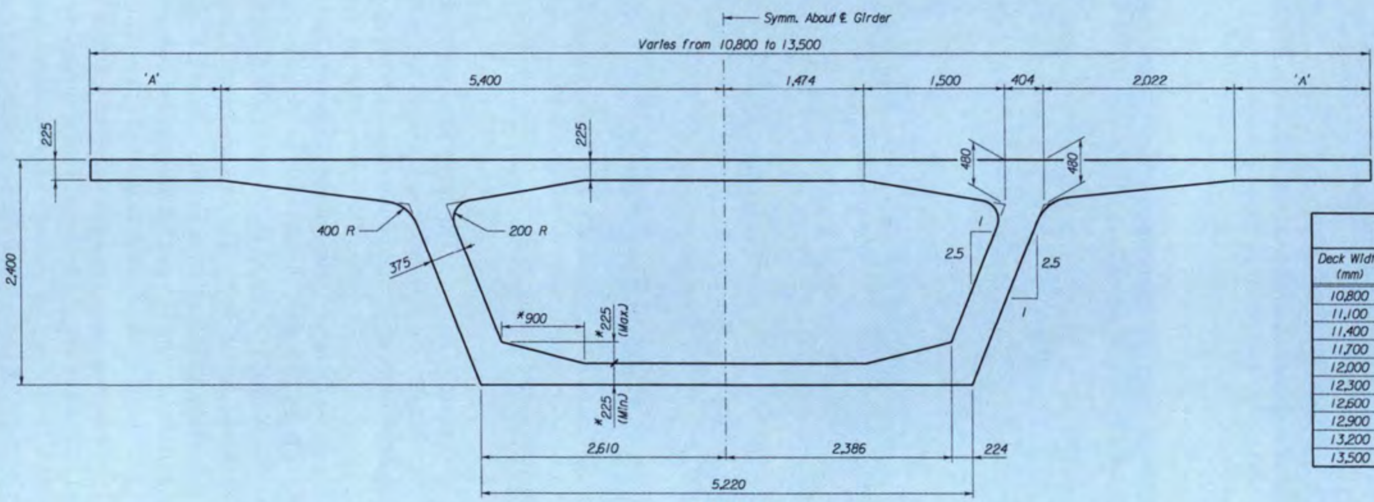

2400-2

2400-1					
Deck Width (mm)	'A' (mm)	Area (mm^2)	Wt/3,000 mm (Kn)	Ix (m^4)	Yt (mm)
8,400	0	5,177,000	379	4.064	908
8,700	150	5,245,000	384	4.107	898
9,000	300	5,312,000	389	4.148	888
9,300	450	5,380,000	394	4.188	878
9,600	600	5,447,000	399	4.228	869
9,900	750	5,515,000	404	4.266	859
10,200	900	5,582,000	409	4.304	850
10,500	1,050	5,650,000	414	4.340	841
10,800	1,200	5,717,000	419	4.376	833
11,100	1,350	5,785,000	423	4.411	824
11,400	1,500	5,852,000	428	4.445	816

NOTES:

1. Area denotes cross-sectional area.
2. Wt denotes segment weight for 3000 mm segment.
3. Ix denotes bending moment of inertia.
4. Yt denotes distance from the centroidal axis to the top of section.
5. * Bottom slab thickness may increase to a maximum of 450 mm at piers. 900 mm dimension adjusts accordingly
6. ** For widths less than 8,400 mm, the 1,422 mm dimension is decreased. The depth of the slab at the edge of the segment increases accordingly.

2400-2					
Deck Width (mm)	'A' (mm)	Area (mm^2)	Wt/3,000 mm (Kn)	Ix (m^4)	Yt (mm)
10,800	0	6,327,000	463	5.045	882
11,100	150	6,395,000	468	5.085	874
11,400	300	6,462,000	473	5.124	866
11,700	450	6,530,000	478	5.162	858
12,000	600	6,597,000	483	5.199	851
12,300	750	6,665,000	488	5.236	843
12,600	900	6,732,000	493	5.272	836
12,900	1,050	6,800,000	498	5.307	829
13,200	1,200	6,867,000	503	5.342	821
13,500	1,350	6,935,000	508	5.376	815

PROPOSED AASHTO - PCI - ASBI SEGMENTAL BOX GIRDER STANDARDS	FOR BALANCED CANTILEVER CONSTRUCTION SPANS 30.5 TO 61.0 METERS	2400 mm SEGMENT DEPTH

Fig. 3. Standard section: 2400 mm (8 ft) segment depth for balanced cantilever construction.

Fig. 4. Span-by-span erection, U.S. 183 Viaduct, Austin, Texas (Designer: Texas Department of Transportation).

Fig. 5. Balanced cantilevers under construction at U.S. 441/I-595 Interchange (Designer: Greiner Engineering Sciences, Inc.).

Balanced Cantilever Construction" to the AASHTO Subcommittee on Bridges and Structures in September of 1996.

The proposed standards were accepted as an item for the official ballot at the 1997 meeting of the AASHTO Subcommittee on Bridges and Structures, held June 8 to 12 in Jackson, Wyoming. It is anticipated that the proposed standards will be approved in the official AASHTO balloting in the Fall of 1997. When ratified, a joint publication of the standards and related information by PCI and ASBI is planned for early 1998.

The rationale for the use of precast segmental bridges for grade separation and interchange bridges (see Fig. 1), and the importance of involvement of the precast concrete industry, is outlined in the accompanying editorial by ASBI President, Eugene C. Figg, Jr.

The box girder standards are viewed as a means of extending the bridge market for precast concrete producers, and not as a product competing against existing I-girder and bulb-tee sections. In the limited range of applications where competition might exist between sections, precast producers would be in the enviable position of providing quotations on both of the alternatives.

The purpose of this article, as reflected in the following sections, is to provide background material on the segmental standards, to review past segmental grade separation and interchange projects in both the United States and other countries, and by use of current or proposed projects, to illustrate the present reality of the market for use of the segmental standards. It is fervently hoped that this article will encourage owners, designers, precast producers, and contractors to utilize the segmental standards as a viable and attractive construction option for grade separation and interchange bridges in the next century.

SCOPE OF THE SEGMENTAL STANDARDS

The 17 sheets of standard drawings include:

- General Notes
- Three drawings for span-by-span segments with depths of 1800, 2100 and 2400 mm (6, 7, and 8 ft)
- Five drawings for balanced cantilever segments with depths of 1800 through 3000 mm (6 through 10 ft) in 300 mm (1 ft) increments
- Two drawings of standard bulkhead details
- One drawing of deviation diaphragm dimensions
- Two drawings of interior pier segment dimensions
- One drawing of expansion joint segment dimensions
- One post-tensioning layout drawing for span-by-span construction

As examples, Fig. 2 shows one of the standard drawings for span-by-span construction and Fig. 3 shows one of the standard drawings for balanced cantilever construction.

The standards provide sections applicable for span-by-span bridges with spans ranging from 30.5 to 45.7 m (100 to 150 ft). For balanced cantilever bridges, the standard segments are intended for spans ranging from 30.5 to 61.0 m (about 100 to 200 ft). For both span-by-span and balanced cantilever bridges, standard segment widths range from 8.40 to 13.50 m (27 to 44 ft). The span and width dimensions of the standards were selected as

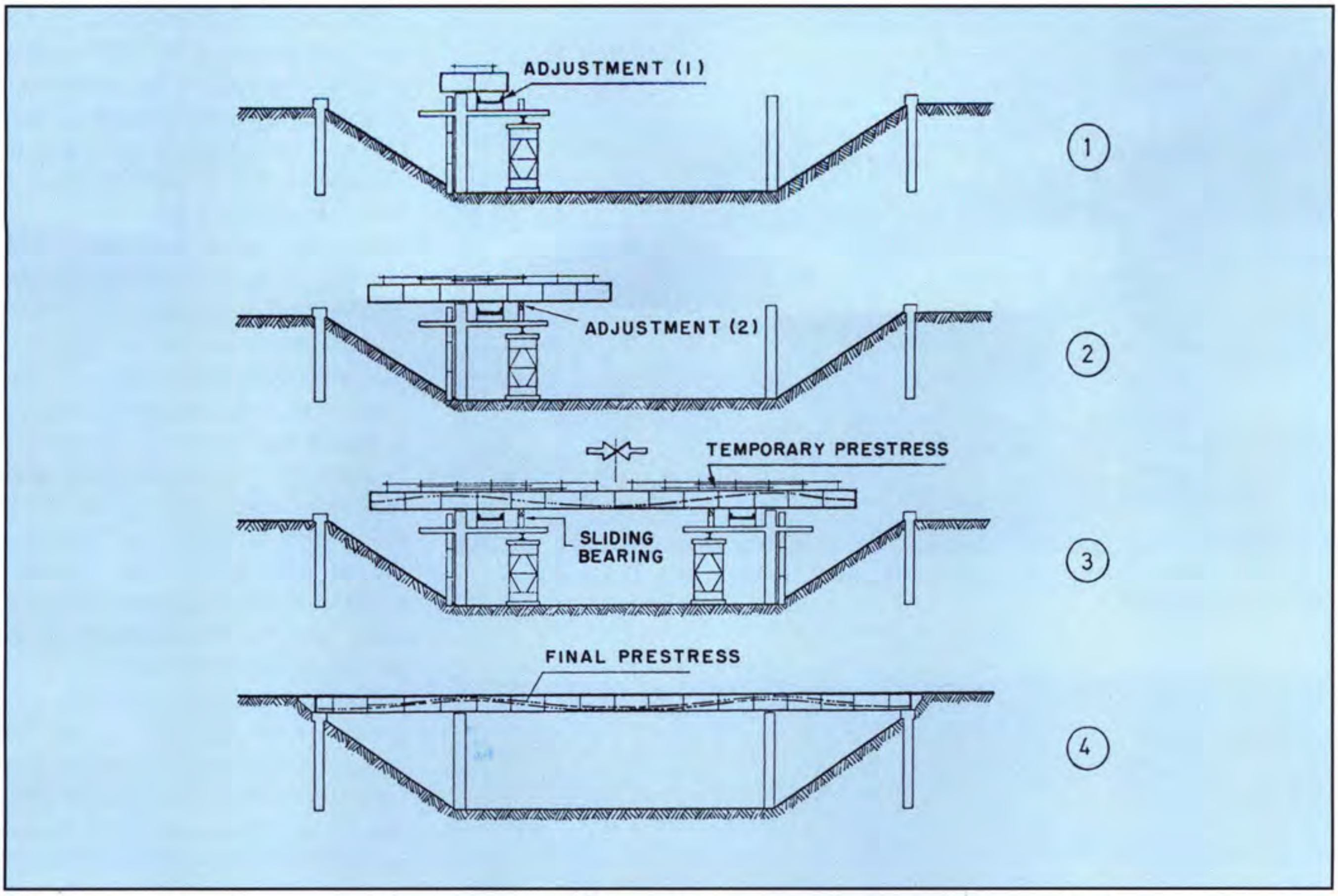

Fig. 6. Segmental erection stages used in construction of Rhone-Alps Motorway Overpasses, Switzerland, 1970s.

representative of a large majority of the potential superstructures for which use of standard sections might be appropriate.

The segmental standards have been developed to accommodate span-by-span or balanced cantilever erection of segments. Span-by-span erection is shown in Fig. 4 and balanced cantilever erection is illustrated in Fig. 5.

The segment dimensions were developed to be compatible with the heavier live load requirements of the AASHTO LRFD Specifications. The recommended minimum concrete strength is 34 MPa (5000 psi). Concrete of greater compressive strength may be used and may be required for structural considerations in some cases.

To facilitate truck delivery of precast segments, the maximum length is 3000 mm (10 ft) and the maximum weight is 356 kN (80,000 lbs). The length of the larger segments has to be reduced to meet the 356 kN (80,000 lbs) weight limitation. It is generally anticipated that the segments will be erected by crane.

COMPLETED GRADE SEPARATION AND INTERCHANGE PROJECTS

One of the earliest and largest applications of precast segmental construction to shorter span bridges occurred in the 1970s with construction of the Rhone-Alps Motorway in Switzerland. This project involved construction of 150 overpasses over a 5-year period.[2] These bridges were typically three-span structures with main spans ranging from 18 to 30 m (60 to 100 ft). The construction procedure for these bridges is shown in Fig. 6.[3] The total construction time for a single overpass (foundations, piers, and superstructure) using this technique was less than 2 weeks.

Fig. 7. Ayalon Interchange construction, Israel, 1995.

Fig. 8. Second Stage Bangkok Expressway System, Thailand, 1995 (Designer: J. Muller International).

Fig. 9. Precast segmental construction at Vail Pass, Colorado, 1976.

Fig. 10. Ramp 1, Florida — A precast segmental, post-tensioned, balanced cantilever viaduct (Designer: Beiswenger Hoch & Associates).

Precast segmental technology has been widely used in the 1990s outside of North America for the construction of grade separation and interchange bridges. Construction of the Ayalon Interchange in Israel (1995) is shown in Fig. 7. In this case, the structure was erected using an overhead gantry. As illustrated in Fig. 7, this type of erection involved minimal disruption of traffic.

A portion of the Second Stage Expressway System in Bangkok, Thailand (1995), that incorporates an interchange is shown in Fig. 8. This project included 1130 precast segmental spans ranging in length from 24.9 to 48.7 m (82 to 160 ft) with a typical span length of 45 m (148 ft). If placed along a single alignment, the 1130 spans would produce a length of approximately 48 km (30 miles).

Construction was completed on a series of four precast segmental bridges on Interstate 70 west of Denver, Colorado, at Vail Pass in 1976[3] (see Fig. 9). The lengths of the bridges ranged from 119 to 253 m (390 to 830 ft), and the main span lengths were either 61 or 66 m (200 or 210 ft). A single-cell box section was used for the 12.8 m (42 ft) wide segments.

Twenty-five precast segmental grade separations and interchange bridges were constructed in Florida in the 1980s.[4] These were balanced cantilever bridges with spans ranging from 22 to 68 m (71 to 224 ft). The total deck area of these structures was about 130,000 m^2 (1,400,000 sq ft). The average cost of these bridges (1987) was $559 per m^2 ($52 per sq ft). As illustrated by Figs. 10 and 11, many of these bridges were constructed on curved roadway alignments.

The I-110 bridge in Biloxi, Mississippi (see Fig. 12), was opened to traffic February 19, 1988.[5] The 1626 m (5332 ft) long mainline structure provides four traffic lanes and crosses U.S. 90 with 49 and 55 m (160 and 180 ft) spans. The same box girder depth was used throughout the superstructure, and the cast-in-place piers were given a special rustication. Ramp structures were also effectively incorporated into the system. The balanced cantilever precast segmental superstructure was erected by crane with minimal disruption of traffic on U.S. 90.

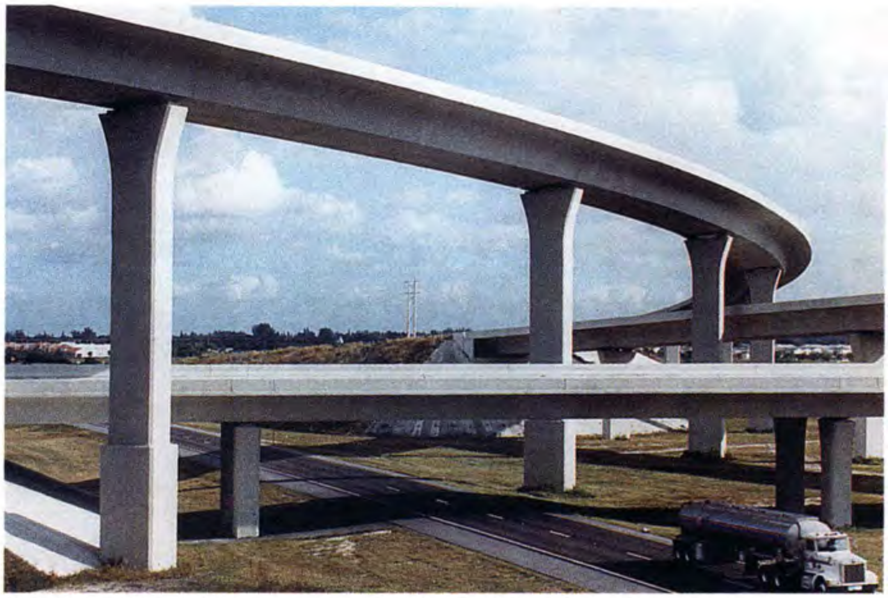

Fig. 11. I-75/I-595 Phase 2 project, Florida (Designer: Beiswenger Hoch & Associates).

Fig. 12. I-110/U.S. 90 Bridge, Biloxi, Mississippi (Designer: Figg Engineering Group).

Four precast segmental box girder grade separation and interchange bridges were completed on the North-South Tollway near Chicago in 1989. These bridges incorporated both span-by-span and balanced cantilever erection techniques. Complex substructures were required for these bridges, including post-tensioned straddle bents and C bents.

A construction view of the Kaneohe Interchange Project on the island of Oahu, Hawaii, is shown in Fig. 13. The 488 m (1600 ft) main span portion of this interchange was built in balanced cantilever with an overhead gantry used on the adjacent H-3 Windward Viaduct. The precast segmental ramp structure was constructed on a 183 m (600 ft) radius using span-by-span construction.

The variable width precast section shown in Fig. 14 was used to complete the transition between the ramp and the mainline structure. The pier segments for the mainline structure were cast-in-place with the piers due to seismic considerations. Also, due to seismic requirements, all post-tensioning was accomplished with internal tendons (inside segment slabs and webs). This interchange project was completed in September 1994.

The magnitude of the U.S. 183 Viaduct in Austin, Texas (see Fig. 15), incorporating 3332 segments, is beyond that envisioned as a primary application of the segmental standards. However, at several locations, this project involved span-by-span erection of segments over traffic. Details of the span-by-span erection are shown in

Fig. 13. Kaneohe Interchange Bridge, Oahu, Hawaii (Designer: J. Muller International).

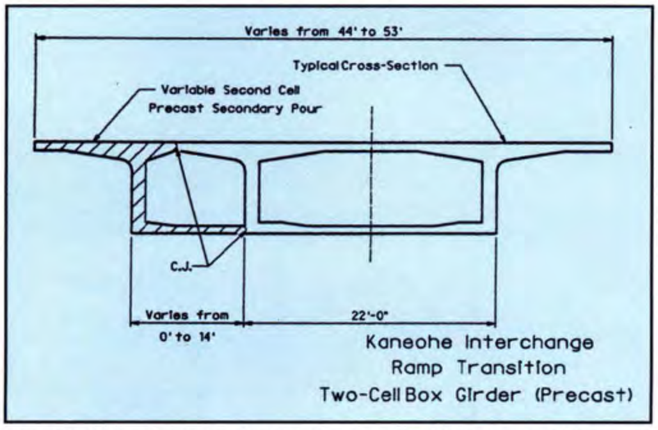

Fig. 14. Kaneohe Interchange Ramp transition two-cell box girder (precast).

Fig. 15. U.S. 183 Viaduct, Austin, Texas (Designer: Texas Department of Transportation).

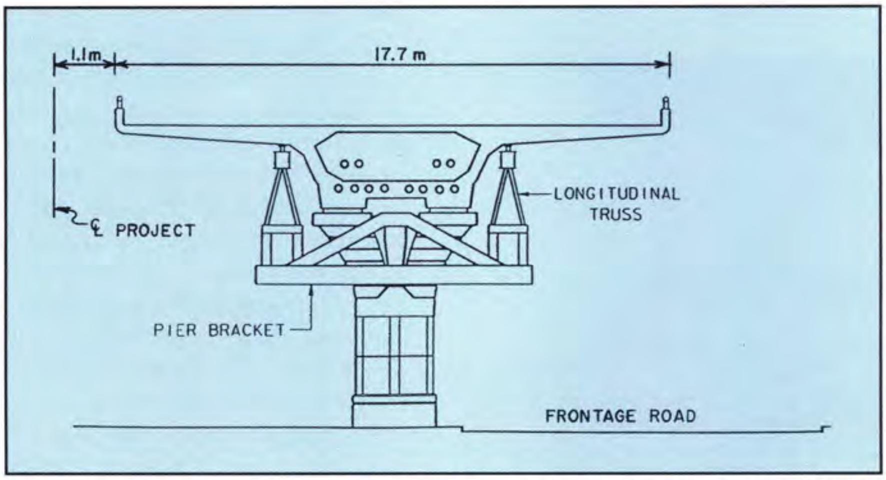

Fig. 16. Mainline column, U.S. 183 Viaduct, Austin, Texas, showing Frontage Road, tendons and pier bracket (Designer: Texas Department of Transportation).

Fig. 17. U.S. 183 Viaduct, Austin, Texas, view of balanced cantilever construction (Designer: Texas Department of Transportation).

Figs. 4 and 16. Also, the curved ramps of the interchange between U.S. 183 and I-35 were built in balanced cantilever construction, as illustrated in Fig. 17. The last of the 3332 segments in the U.S. 183 Viaduct was placed in November 1996, and the project was completed early in 1997.

PROPOSED SEGMENTAL GRADE SEPARATION AND INTERCHANGE PROJECTS

Four ramps of the I-15/U.S. 95 Interchange in Las Vegas, Nevada (see Fig. 18), with lengths ranging from 490 to 743 m (1607 to 2438 ft), have been designed for precast segmental construction with segment details adapted from the AASHTO-PCI-ASBI segmental standards. These bridges incorporate seismic connection details between the piers and the precast pier segments. This project is scheduled for bids in November 1997.

The S.R. 9/I-95 Palm Beach International Airport Interchange in Florida (see Fig. 19) is a four-level fully-directional interchange that provides access to the Palm Beach International Airport. This project includes nine precast segmental bridges totaling 4.7 km (2.92 miles) in length. The bridge superstructures are composed of curved precast segmental box girders. The single-cell boxes will carry one and two traffic lanes with superelevations as high as 10 percent. The typical span is 55 m (180 ft), and the typical segment is 3 m (10 ft) long. The expected bid date for this project is October 1998.

The monumental Boston Central Artery Project includes five interchanges with precast segmental alternates totaling 105,750 m^2 (1,137,700 sq ft). Bid dates for these projects range from October 1997 to mid 2003.

One of the largest and most visible of the Central Artery projects is the I-93 Viaducts and Ramps North of the Charles River (see Fig. 20). This elevated bridge structure comprises approximately 71,570 m^2 (770,000 sq ft) of bridge deck. The precast concrete segmental alternate design uses both span-by-span and balanced cantilever construction techniques for the erec-

Fig. 18. I-15/U.S. 95 Interchange, Las Vegas, Nevada (Designer: Parsons Brinckerhoff).

tion of more than 7620 m (25,000 ft) of precast segments.

Typical span lengths range from 30 to 61 m (100 to 200 ft) and horizontal curve radii range from 61 to 1980 m (200 to 6500 ft). Three distinct superstructure box girder types will provide roadway widths from 6.7 to 23.3 m (22 to 96 ft). The substructure will consist of three column sizes to support the box girders throughout the project including areas of double decked roadway.

Other grade separation and interchange projects now being developed include:

- I-355 South Extension, Illinois. This project was originally bid on December 19, 1996, with steel and precast segmental alternates. The low bid for the concrete alternate was $79,122,000, and the low bid for the steel alternate was $83,603,000. This project has not yet been awarded.
- Miami Airport, Dade County, Florida. This project includes 49 bridges. The preliminary design study has recommended that 12 of the bridges with 120770 m^2 (1,300,000 sq ft) of deck area be precast segmental construction utilizing the AASHTO-PCI-ASBI Standard Box Girder Segments.
- Ft. Lauderdale Airport, Broward County, Florida. Six bridges ranging from 76 to 457 m (250 to 1500 ft) in length.
- Foothills Parkway, Tennessee. Five grade separation bridges to be constructed by the progressive placement method with precast segmental piers. These projects are tentatively scheduled for bid in 1998 and 1999.

CONCLUDING REMARKS

Completed precast segmental grade separation and interchange bridges have demonstrated significant advantages with respect to alternative methods of construction, which will become increasingly important in the next cen-

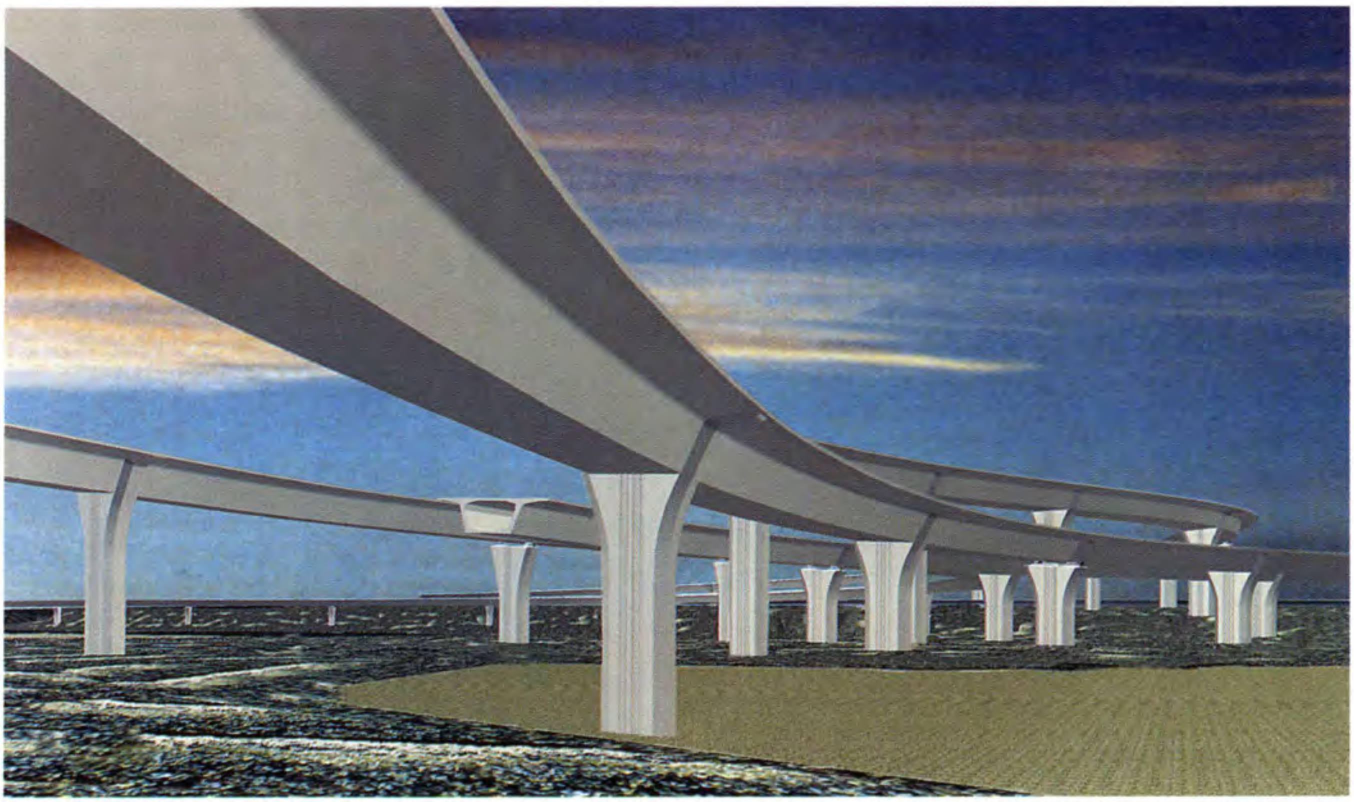

Fig. 19. Rendering of the S.R. 9/I-95 Palm Beach International Airport Interchange, Florida (Designer: Beiswenger Hoch & Associates).

Fig. 20. Rendering of the I-93 Viaduct and Ramps north of the Charles River, Boston (Designer: Figg Engineering Group).

tury. These advantages include:

- Low initial and life-cycle cost
- Rapid construction
- Minimal disruption of traffic
- Adaptable to longer spans and curved roadway alignment
- Outstanding aesthetics

The AASHTO-PCI-ASBI Standard Box Girder Segments will further enhance the economy of precast segmental construction for grade separation and interchange bridges through involvement of the industrial base and expertise of local precast/prestressed concrete manufacturers in producing segments, and to a lesser extent through reduction of form costs. It seems clear that the widespread availability of the standard segments at the local level will be a major determinant of the success of this new product in the marketplace.

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