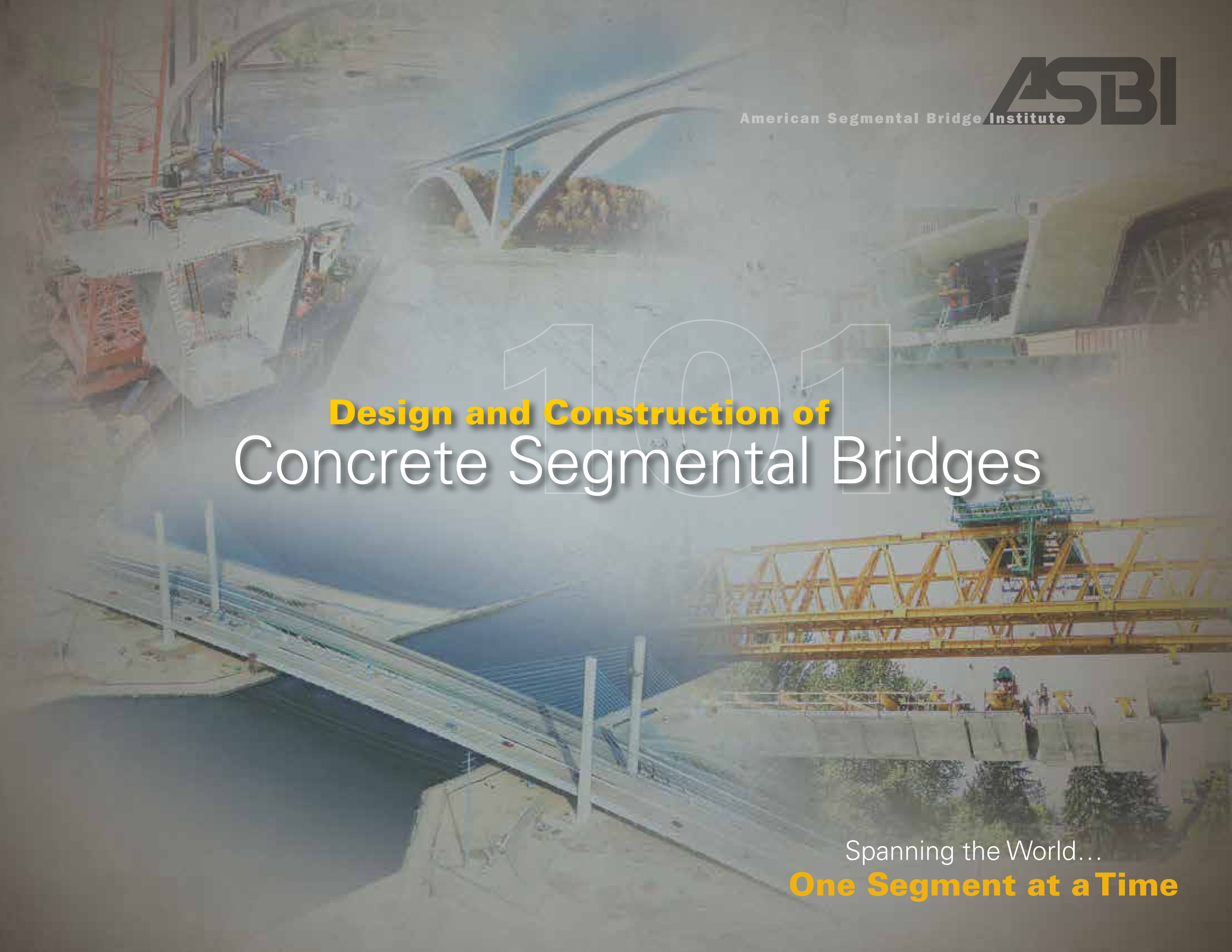


ASBI
American Segmental Bridge Institute

101

Design and Construction of Concrete Segmental Bridges

Spanning the World…
One Segment at a Time

Cover Photos: Top Left, Courtesy of FIGG; Top Center, Courtesy of FIGG.
Bottom Left, Courtesy of Shoreline Aerial Photography; Bottom Right, Courtesy of PCL.

Highway Bridge.

Transit Bridge. Photo Courtesy of URS Corporation.

Railway Bridge. Photo Courtesy of AMTRAK, Jim Loomis.

Pedestian Bridge. Photo Courtesy of OBEC Consulting Engineers.

Introduction

The first long-span segmental concrete bridge in the United States was built over the Gulf-Intracoastal Waterway in Texas in 1973. This was a three-span bridge with a main span length of 200 ft. Since that time, over 460 segmental bridges have been built in the United States.[1] The maximum span length has extended to 760 ft for segmental box girder bridges and 1300 ft for cable-stayed bridges.

The early applications of segmental construction were for highway bridges. Subsequent applications have included highway, transit, railway, and pedestrian bridges.

[1] Pielstick, B. and Offredi, L., *Durability Survey of Segmental Concrete Bridges, Fourth Edition,* ASBI, 2012. Publication is available through ASBI at www.asbi-assoc.org.


Photo Courtesy of FIGG.

"…segmental construction's potential…is only limited by the innovation and imagination of the designer and contractor.[2]"

Advantages

Segmental bridge construction offers the advantages of repetitive construction procedures, minimum impact to traffic and the environment during construction, economical construction, and a durable structure. Segmental construction can be used in a variety of difficult site conditions: piers can be placed on small footprints; superstructures can go over natural hazards and community landmarks; and segmental bridges may be used on a small radius such as curved highway access ramps as well as large-radius bridges.

The bridges can be aesthetically pleasing because of their slender piers, their long, shallow superstructures, and the concrete can be colored to blend into the environment. For box girder bridges, the cross section may consist of a single cell or several cells depending on the required width of the deck. The outer webs or fascias are generally inclined for aesthetic and structural reasons, though the fascias may be vertical, and internal webs are usually vertical. For shorter spans, the section depth remains constant along the span, while longer spans use a curved soffit to produce a deeper section at the piers compared to midspan.

Durable Structures

One of the key advantages of segmental construction is the use of both longitudinal and transverse post tensioning for the deck. This prevents the concrete deck from cracking due to tensile stresses caused by restrained concrete deck shrinkage, live loads, and thermal stresses. The benefit of a crack free deck is that water and deicing salts cannot penetrate into the cracks and lead to reinforcement corrosion.

In addition to the structural concrete used in the deck, the American Segmental Bridge Institute recommends a concrete overlay with a thickness of 1.0 or 1.5 in. be used on segmental bridges exposed to freeze-thaw cycles and (the application of) deicing chemicals. This layer should be placed monolithically with the deck concrete and provides an additional layer of protection against corrosion. Similar provisions are included in the *AASHTO LRFD Bridge Design Specifications*.

Cracking in the webs of segmental bridges is prevented by designing to ensure that the principal tensile stresses do not exceed the tensile stress limits of the *AASHTO LRFD Bridge Design Specifications*.

The durability of segmental bridges is further enhanced through the use of low-permeability concrete. This is usually achieved through the use of supplementary cementitious materials such as fly ash, silica fume, and slag cement in combination with a low water-cementitious materials ratio.

A 2012 *ASBI Durability Survey of Segmental Concrete Bridges*[1] showed an average Federal Highway Administration bridge inspection rating of 6.9 for the decks and superstructures of bridges built from 1973 to 2010. The bridge inspection rating is on a scale of 0 to 9 with a rating of 7.0 defined as a good condition with some minor problems. The inspection data indicates that segmental bridges are performing extremely well compared to other bridge types.


Photo Courtesy of FINLEY Engineering Group, Inc.


Photo Courtesy of Ray Stanyard Photographer.

[2] Podolny, Jr., W., An Overview of Precast Prestressed Segmental Bridges, *PCI Journal*, V. 24, No. 1, January 1979, pp. 56-87.

Photo Courtesy of PCL.

Construction

Segmental bridges have the advantage that they may be constructed using a range of construction methods which can be tailored for each individual bridge and its location. Segmental bridges may be built using precast concrete segments, cast-in-place concrete segments, or a combination of the two methods.

Short-line casting.

Span-by-span method. Photo Courtesy of Corven Engineerring Group, Inc.

Long-line casting. Photo Courtesy of FIGG.

Precast Segments

The use of precast concrete segments has the advantage that the superstructure can be erected at a faster rate compared to cast-in-place construction. The precast concrete segments are made while the substructure is being built and then stored until needed for erection. The precast segments are built using either the short-line or long-line method.

In the short-line method, each segment is cast next to the previous segment in a special adjustable casting machine. This ensures that the interface between the two segments matches exactly when erected. Each successive segment is then cast next to the previous one.

In the long-line method, formwork matching the shape of the soffit is erected on the ground. A traveling form for the webs and deck is moved along the soffit form for the casting of each segment.

Precast segments are usually erected using the span-by-span method, balanced cantilever method, or progressive placement method.

Precast, Span-by-Span Method

In the span-by-span method, an entire span is assembled, post-tensioned, and erected so that it is self-supporting before the next span is erected. The method is appropriate for span lengths up to about 150 ft. Beyond 150 to 180 ft, the method is less cost effective.

In one variation of this method, all the segments are supported by an erection truss before the segments are post-tensioned together. The erection truss may be located either above or below the segments. Once the segments are post-tensioned together and the span is resting on its bearings, the erection truss is moved to the next span. When space permits, the segments may be assembled at ground level, post-tensioned together, and the entire span lifted into place.

Precast, balanced cantilever method. Photo Courtesy of URS Corporation.

Cast-in-place, balanced cantilever method. Photo Courtesy of FIGG.

Precast, Balanced Cantilever Method

In the balanced cantilever method, the superstructure is erected by cantilevering out from opposite sides of the pier. The segments are added either at the same time or alternately to each cantilever to maintain a relatively balanced system. Often segments are offset by one-half segment length to reduce the out-of-balance moment. After the cantilevers from each adjacent pier reach midspan, a cast-in-place closure segment is placed followed by additional post-tensioning.

The balanced cantilever method is most economical for span lengths greater than about 160 ft. For span lengths greater than about 450 ft, the weight of the segments near the piers reduces the feasibility of using precast segments in balanced cantilever construction.

In the balanced cantilever method, segments are lifted into place using ground- or water-based cranes, deck mounted lifters at the end of each cantilever, or an overhead gantry. The selected method depends on the number of spans, contractor's preference, and available access. An overhead gantry will typically be supported at three piers.

Precast, Progressive Placement Method

The progressive placement method involves starting at one end of the bridge and erecting segments in sequential order. This method of construction is particularly suitable for environmentally sensitive areas or where construction access is limited. It is often called "top-down" construction because the substructure and superstructure can all be erected from the superstructure. The method usually requires the placement of temporary piers at about the middle of each span and is suitable for span lengths of 100 to 300 ft.

Precast, progressive placement method. Photo Courtesy of Hugh Morton.

Cast-in-Place, Balance Cantilever Method

Cast-in-place segmentally constructed bridges are generally built using the balanced cantilever method. A form traveler is used at the end of each cantilever to support the formwork and new concrete segment prior to post-tensioning. The form travelers at opposite ends of the cantilevers may be advanced simultaneously or alternately.

Cast-in-place segmental construction is used when the precast segments are too heavy to be shipped or access is too restrictive. It has been used for span lengths up to 760 ft in the United States.

The superstructure at the abutment ends cannot be easily constructed as part of the cantilevering process because of the large out-of-balance moment, so these are often constructed on falsework resting on the ground.

Cable-stayed bridge. Photo Courtesy of Shutterstock.

Cable-Stayed Bridges

A cable-stayed bridge is a segmental bridge in which the superstructure is supported by inclined cables extending from a pylon above the deck. This type of structure provides economic and aesthetically pleasing solutions for bridge spans from 300 to 2500 ft. The bridges can be built using either precast or cast-in-place concrete segments and are built in a similar manner to the balance cantilever method for box girder bridges.

The cables are generally arranged in one of three configurations:

- Harp in which the inclined cables are parallel.
- Fan in which the inclined cables emerge from a point near the top of the pylon.
- Semi-fan in which the inclined cables emerge over a vertical length near the top of the pylon.

Each of these configurations may be combined with a central cable plane or twin edge cable planes. The planes, as viewed along the bridge, may be vertical or inclined. The cross section of the superstructure may be rigid as in a box section or flexible as in an edge girder system. Usually, the edge girder system is used with twin cable planes, whereas a single cable plane requires the torsionally rigid cross section of the box. These factors influence both the visual appearance of the bridge and its structural design.

The pylon configuration is influenced by the number of cable planes. A single pylon or an A-frame is generally used with a single plane of cables, whereas a portal or H-frame is used with two planes of cables.

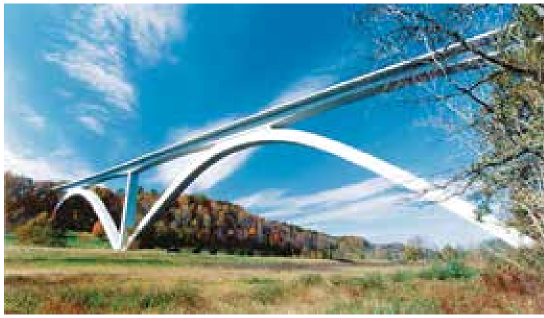
Extradosed bridge. Photo Courtesy of Shoreline Aerial Photography.

Extradosed Bridges

Extradosed bridges are similar in appearance to cable-stayed bridges but have shorter pylons and a flatter stay-cable inclination. As such, the deck system becomes the primary load carrying member for dead and live loads. This type of bridge has been described as a hybrid of a cable-stayed bridge and a post-tensioned box girder bridge. The bridges are constructed in a similar manner as cable-stayed bridges. They are particularly useful where there are restrictions on the height of the pylon.

Segmental Arches

Concrete arches may be constructed segmentally using either precast concrete segments or cast-in-place segments. In both methods, the arch is erected by cantilevering out from the base of the arch. Temporary inclined cables are used to support the arch until the two halves meet at midspan. At that point, the arch is self supporting and the cables removed. This type of construction allows the arch to be built without any interference on the ground below. As such, segmental arches may be used to span environmentally sensitive areas and deep gorges.



Segmental arch bridge. Photo Courtesy of FIGG.

Segmental Columns

Segmental methods may also be used for the construction of concrete columns for bridges. The method is similar to that for precast segmental superstructures using the short-line method of casting except the match casting is done vertically and not horizontally. During erection, the segments are stacked vertically on top of each other and incrementally post-tensioned. The primary advantage of using segmental columns is speed of erection.

Growth of Concrete Segmental Bridges

From visionary thinking in 1973 the use of segmental bridges has grown to over 460 bridges in 37 states. Segmental concrete bridges are economical, durable, and aesthetically pleasing while providing minimum impact to traffic and the surrounding environment both during and after construction.

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