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## Twenty Years Experience with Segmental Bridges

Vingt ans d'expériences sur les ponts à voussoirs

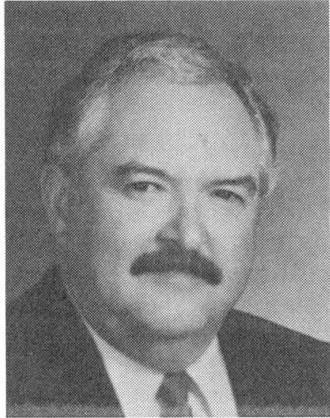
Zwanzig Jahre Erfahrung in der Segmentbauweise

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### SUMMARY

This paper presents a brief history of segmental concrete bridges in the United States. The early days of segmental design and construction are addressed along with the detailing of revisions and innovations to US design, construction and contracting practices initiated by the introduction of segmental bridges. A brief description of some of the projects realised including illustrations of lessons learned from each one are also included.

### RESUME

Cet article présente brièvement l'histoire des ponts à voussoirs en béton exécutés aux Etats-Unis. Il décrit les premiers pas dans l'étude et la construction des voussoirs, en énumérant les révisions et les innovations apportées aux Etats-Unis dans les pratiques du projet, de la construction et de l'adjudication lors de l'introduction de ces types de ponts. L'article fournit une description succincte de quelques uns des projets réalisés, en y incluant les leçons acquises pour chacun d'eux.

### ZUSAMMENFASSUNG

Dieser Beitrag gibt einen geschichtlichen Abriss der Betonbrücken in Segmentbauweise in den Vereinigten Staaten. Die Bemessung und Konstruktion in den frühen Tagen sowie die Revisionen und Erneuerungen in Entwurf, Bemessung und Vergabe der Segmentbrücken werden behandelt. Anschliessend werden einige ausgeführte Projekte besprochen und die jeweiligen Erfahrungen illustriert.



## 1. SEGMENTAL CONCRETE BRIDGES INTRODUCED TO U.S.

### 1.1 European vs American Contracting Systems

The beginning of the 90's ends a 20-year period since the United States began using the European bridge design and construction technology called segmental concrete bridge construction. We are now entering a second phase by incorporating new design and construction technologies brought about by increasing maintenance costs and tighter budgets. It is time to look back at the lessons learned during the past 20 years and to evaluate our errors and successes to benefit engineers worldwide.

Segmental bridge concepts were brought to the United States in the late sixties and early seventies. Initial advances were made by Engineers from the Netherlands and France. Germany soon followed. They had a tremendous task to accomplish because the U. S. was just completing the massive Interstate Highway system and budgets were beginning to become very limited. Additionally, the system of design and construction used in Europe was completely different than that used in the United States.

The system prevalent in the U. S. for constructing public works projects may be described as the "Father Knows Best System". Essentially, the designer whether it be a consulting engineer or owner, e.g. a state highway department directed the contractors in their entire operation. Segmental bridge techniques are more engineering oriented and permit many design and construction alternatives to be successfully accomplished during construction. The construction industry in this country had no engineering staffs commensurate with their counterparts in Europe. Therefore, the importers of segmental technology not only had to introduce a new design and construction technology but also had to introduce a modification of the North American system.

### 1.2 Alternate Designs

The single most significant development in the U.S. system was the development of alternate designs for large bridge projects. Alternate designs was the tool which allowed segmental bridges to be considered for projects with costs in excess of \$10M. The owners were told that the competitive savings would be enough to offset the extra design costs and simultaneously permit the segmental bridge market to grow as economics dictated. Even though the policy was written in terms of alternate designs based upon two differing construction materials, nine out of ten alternates were based upon segmental concrete, either precast or cast-in-place, versus some type of steel design.

The alternate design concept has been extremely successful and has saved the taxpayers millions of construction dollars. But even more importantly, alternate designs provided an avenue for a phenomenal amount of bridge design innovation in a system which had previously been practically closed to innovation.

We are now seeing a rebound effect from alternate designs and segmental bridge construction from the construction industry. This will be discussed more completely in the Closing Remarks.

### 3. PROJECTS

This section contains a brief discussion of several significant projects which have been completed in the United States which have either incorporated innovative ideas or have prepared a valuable lesson for our consideration and knowledge enrichment.

#### 3.1 Corpus Christi Bridge

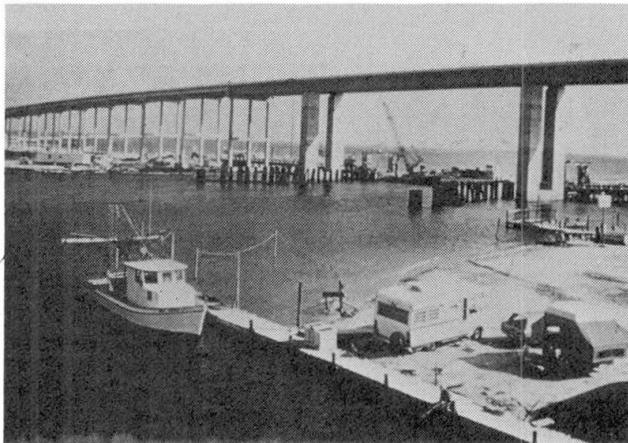


Fig. 1 John F. Kennedy Memorial Causeway, Corpus Christi, TX

The precast segmental concrete bridge located at Corpus Christi Texas was the first of its kind in the United States. The construction method was precasting by the long line method and erecting by balanced cantilever with the segments being delivered with barge mounted cranes. It represented a modest beginning as related to the size of project. The structure consisted of three spans of 31m - 62m - 31m. [1]

This project's contribution to the advancement of bridge engineering in the U.S. was by no means modest. The segmental portion of the bridge was designed by a cooperative effort between the Bridge Division of the Texas Highway Department and the University of Texas at Austin. As the design neared completion and construction commenced in 1972, the designers along with the Federal Highway Administration (FHWA) sponsored a series of seminars to educate other State Engineers in segmental concrete design and construction. Therefore, this project laid the foundation for extensive development of new ideas for the next twenty years.

Another extremely important contribution was the research and development of epoxy specifications. The University developed an epoxy specification which they believed to be appropriate for use in precast segmental bridges. They then invited epoxy manufacturers to submit samples of their materials for testing for compliance with the specifications. At that time, the epoxy industry in the United States had little experience in that regard. Thus it was not surprising that all of the samples submitted failed. By compromise and formulation changes an epoxy material was finally accepted for the project. But the need for development of an acceptable specification and materials was clearly evidenced.



The University called a meeting to develop a new epoxy specification for precast segmental bridges. They invited Texas research engineers, state design engineers, FHWA engineers, consulting engineers, epoxy manufacturers and construction engineers. This meeting and a subsequent one developed the epoxy specification which continues to be used today with only minor modifications.

It is interesting to note that the Corpus Christi segmental is one of the few out of more than two hundred bridges which was constructed exactly as it was designed. The bridge was opened to traffic in 1974.

### 3.2 Pine Valley Creek

The Pine Valley Creek Bridge was the first segmental project in the U.S. to be cast-in-place with traveling forms. The California Department of Transportation evaluated several types of construction including a steel arch, steel truss, and orthotropic steel box girder. But because the semi-arid area is highly erodible when the ground cover is disturbed the Department selected segmental construction because of its ability to be completely constructed from the top.

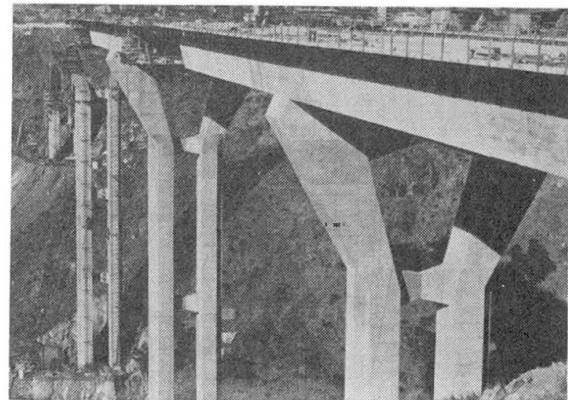


Fig. 2 Pine Valley Creek Bridge

The bridge is 523m in length with a main span of 137m. The crossing is 137m above the creek bed at the bottom of the canyon; another reason for segmental construction. Completed in 1975, this was the first use of a contractor redesign for a segmental bridge.

The contractor's design and construction recommendation reduced the cost of the bridge \$453,200, or about 5 percent of the total contract. The saving were equally divided between the contractor and the State according to the cost reduction incentive provisions of the contract. [2] This proved to be one of the major advantages of the many construction options available with post-tensioned, cast-in-place segmental construction. Also after Pine Valley, most of the major projects were contracted with alternate designs.

### 3.3 Kishwaukee River Bridge

The Kishwaukee River Bridge was the first segmental concrete bridge in the U.S. to be built with the use of an erection gantry to place the precast segments in a balanced cantilever manner. The construction of the erection gantry demonstrated that segmental erection equipment could be obtained economically.

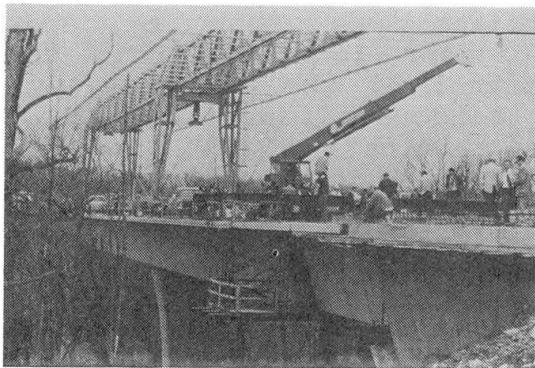


Fig. 3 Kishwaukee Launching Gantry

For the most part, the erection gantry was made of used parts which the contractor had in his construction yard. He salvaged the hydraulics from used cranes and travel lifts. The rubber tires and wheels upon which the gantry moved were old airplane wheels. To move the gantry the contractor simply hooked it to a tractor and moved the gantry down the bridge. Construction was completed in 1979.

During this project, we learned another lesson related to epoxy joints. At one point the epoxy did not harden in a joint. The problem was reportedly due to poor mixing and a single piece shear key failed. After extensive investigation and repairs, a policy was established throughout the country that all precast segmental bridges would be designed and detailed with multiple shear keys.

### 3.3.1 Precaster Participation

The Kishwaukee Bridge was one of the last precast segmental projects which was cast by a Precaster. In the early days of segmental construction in the U.S., we assumed the relatively large precast industry would play a major role. This was an industry created in the late 50's which played an extensive role in constructing the Interstate System by manufacturing precast prestressed bridge beams.

However, the precast industry has been involved in very few precast segmental projects. It turned out that as a generally small family business, the precasters could not afford the initial costs necessary to set up and equip to cast segments for the large bridges which were being designed. Therefore, most of the precast segments have been cast in yards created for each project by the contractors. It is believed that if we ever standardize some segment cross-sections, the precasters may be able to compete in the manufacture of the segments. Engineers would welcome the expertise they possess.

### 3.4 Keys Bridges

In the early eighties, there were a series of precast segmental bridges built in the U.S. which advanced the art of segmental construction substantially more than the rest of the projects in the country built in subsequent years. The bridges are located in the Keys off the South coast of Florida. They are replacement structures with short spans ranging generally from 36m to 41m. The conventional design alternate was precast pretensioned I-Beams.



Among the innovations in this project was span by span construction with external unbonded tendons located within the void of the box girder. The good control of the segments with span by span erection and the external tendons allowed the use of dry joints between the segments thus eliminating the need for epoxy. These bridges were the first not to incorporate a wearing surface applied after erection was completed. The traffic rode on the bare deck which provided excellent rideability.

External unbonded tendons have been tested- [3] and detailed extensively by a number of designers in the U.S. In addition, the technique has also been used in Europe and Asia for precast segmental bridges. Another contribution is the technique of strengthening steel and timber bridges with the use of external post-tensioning tendons. Unbonded tendons were not considered to be a good idea in bridges until the Keys bridges were constructed.

#### 4. CLOSING REMARKS

In the past few years, a disturbing condition has arisen. There are a significant number of litigations between contractors, owners and engineers relating to the details used when designing segmental concrete bridges. It seems contractors have become familiar with segmental construction to the point that they think they can apply conventional construction techniques. This is not true nor will it ever be true. It seems we have much more to learn from our experience and much more to teach contractors if new innovative ideas are to be successfully constructed.

Space will not permit the inclusion of the many other projects which have contributed to the advancement of segmental technology in the U.S. Other projects include Linn Cove Viaduct, the joint failure and subsequent footing failure on the Zilwaukee Project. Also, cable-stayed structures e.g. Sunshine Skyway, Pasco-Kennewick and Dames Point have contributed greatly to our knowledge. But more importantly these projects have opened the doors to the future. A future which will see composite construction of steel and concrete taking advantage of the desirable properties of both materials. We foresee the ability to successfully build cable-stay spans of 1600m and more. Some are already on the drawing board.

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