An Overview of Prestressed Segmental Concrete Bridges

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Free cantilever construction was pioneered by Dr. Ulrich Finsterwalder of Dyckerhoff and Widman, AG (DYWIDAG) in Germany during the early 1950's. During the last three decades, hundreds of segmental concrete bridges have been built throughout the world.

Synopsis

This paper cites twelve projects which, although all built segmentally, employed different construction techniques. The selection of a specific technique is based on several factors, including availability and cost of labor, equipment, and materials; time restrictions; environmental restrictions; soil conditions; and accessibility of work areas.

The word "segmental," although supposedly defining a specific type of construction, actually covers a wide range of different construction techniques. The most appropriate and economical technique for a particular site depends on many factors.

Some of the more significant factors are as follows:

1. Availability and cost of labor and materials.
2. Availability of specialized and/or heavy equipment.
3. Allowable construction time.
4. Environmental restrictions.
5. Accessibility of the work areas.
6. Soil conditions.

The above conditions change with every project. Therefore, when these variations are combined with the constantly emerging new technology, it often makes the selection of a particular construction technique very difficult. The design consultant, in most cases, is called upon to predict the most

Fig. 1. Pine Valley Creek Bridge, San Diego, California.

economical solution and then design it based on today's factors. Unfortunately, the actual construction may not take place for several years. For this reason, the design must be as uncomplicated and as flexible as possible in order to accommodate all these variables and take into account state-of-the-art changes.

The following segmental projects illustrate this point in that they employ several different construction techniques, ranging from cast in place on falsework and cantilever to precast cantilever. In most cases, the contractor employed alternate designs and/or techniques from those originally designed.

Pine Valley Creek Bridge (Fig. 1)

This classical free cantilever cast-in-place segmental box girder bridge in San Diego, California, was the first of its kind in the United States and only the second in North America. The bridge was free cantilevered from the piers, with sliding forms on falsework used for a portion of the end spans.

This project was redesigned under a value engineering proposal. The original design called for the closure of the center span 90 days prior to closure of the adjacent spans. This aspect of the design was intended to compensate for creep and shrinkage and their effect on the piers.

The value engineering proposal called for the bridge to be built from one end. Vertical jacking at the closures was used to adjust initial moments and meet the original intents.

Note: This paper is based on a presentation given at the Segmental Concrete Bridge Conference in Kansas City, Missouri, March 9-10, 1982. The Conference was sponsored by the Associated Reinforcing Bar Producers — CRSI, Federal Highway Administration, Portland Cement Association, Post-Tensioning Institute, and Prestressed Concrete Institute.

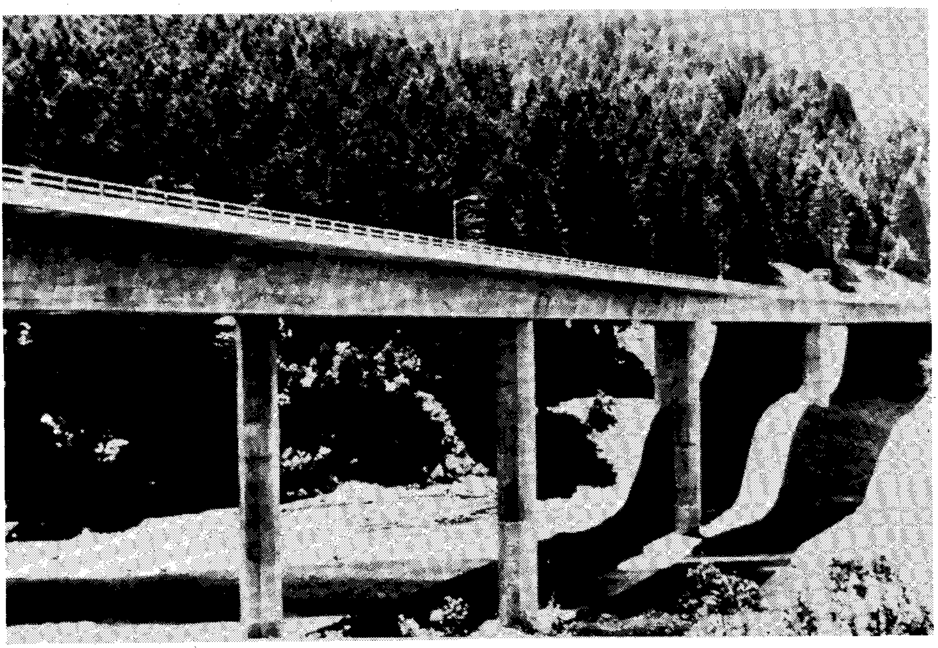

Fig. 2. Eel River Bridge, California.

Eel River Bridge (Fig. 2)

The Eel River Bridge in California was originally designed as a cast-in-place continuous prestressed concrete box girder built on falsework. The contractor made a value engineering proposal to construct the bridge segmentally, using sliding forms. Only a portion of the bridge was falseworked, including bottom slab soffit, at any one time.

The segments were then cast in lengths varying between 40 and 75 ft (12.2 and 22.9 m) with the use of sliding forms, and post-tensioned as the work progressed. The total length of falsework required at any one time was approximately 25 percent of the total length of bridge. The formwork required was approximately 3 percent of the total contact form surface.

The method selected provided economy by allowing repetitive uses of the same falsework and forming material. It also allowed the first few spans to be constructed and stressed before falsework was removed during the winter and spring high water seasons.

Kipapa Stream Bridge (Fig. 3)

The Kipapa Stream Bridge in Honolulu, Hawaii, was originally designed as a cast-in-place continuous prestressed concrete box girder built on falsework. This $12 million bridge was value engineered at considerable savings and built by the free cantilever method.

The twin superstructures, providing a roadway approximately 120 ft (36.6 m) wide and 2000 ft (609.6 m) long, were constructed using a combination of form travelers and falsework. One interesting aspect of the design which also facilitated the construction was the absence of transverse expansion joints except at each abutment.

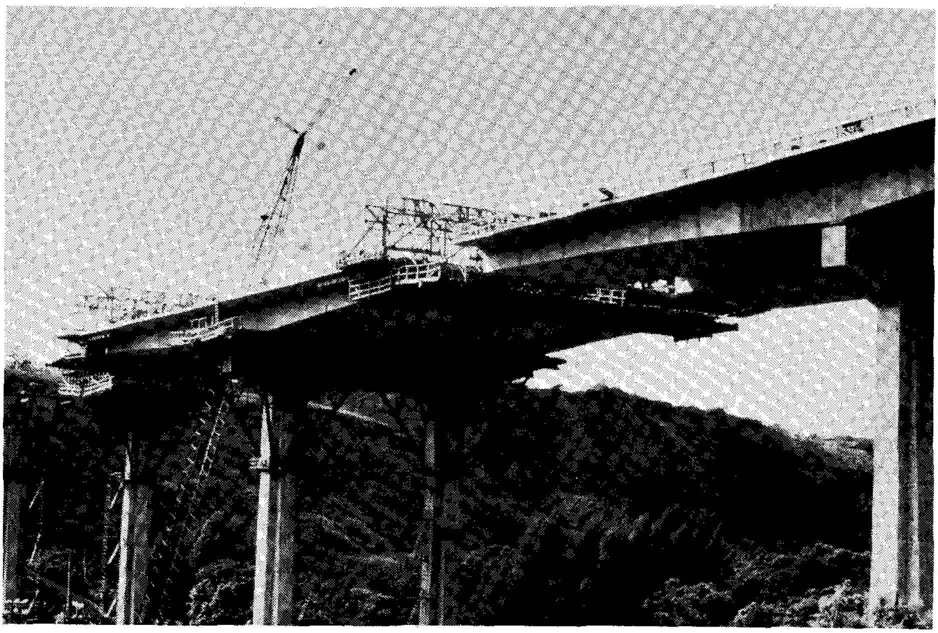

Fig. 3. Kipapa Stream Bridge, Honolulu, Hawaii.

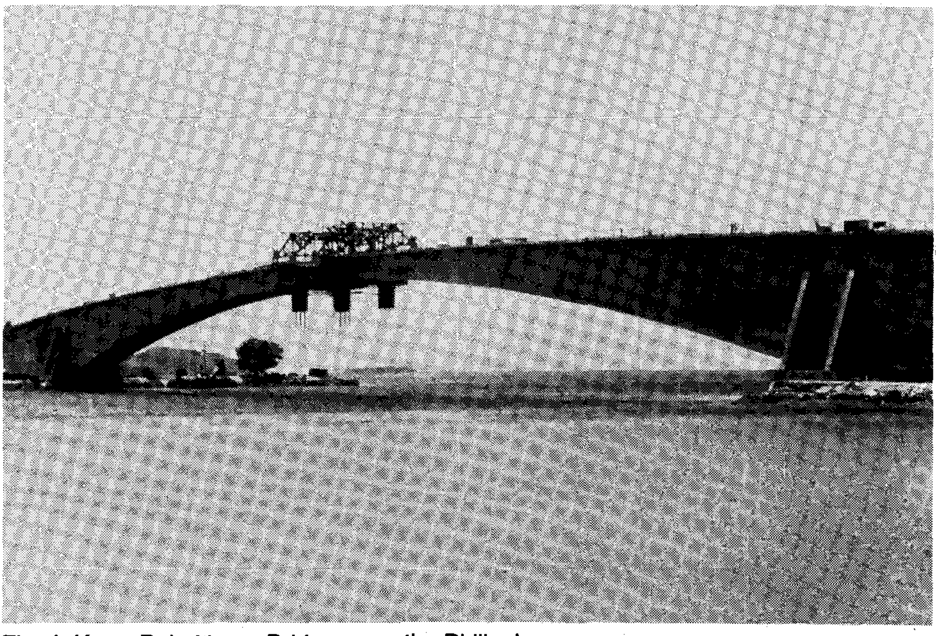

Fig. 4. Koror-Babelthaup Bridge, near the Philippines.

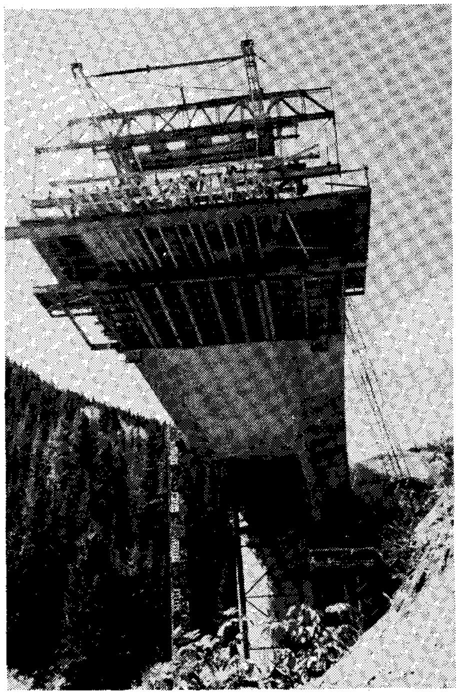

Fig. 5. Vail Pass Bridges, Colorado.

Kororr-Babelthaup Bridge (Fig. 4)

The Koror-Babelthaup Bridge, located in the Palau District of Micronesia near the Philippines, is the world's longest concrete box girder span. The 790 ft (240.8 m) main span links the two islands from which the bridge gets its name.

Due to deep, swift water in the channel, it was decided to maximize the main span, allowing the pier foundations to be built on dry ground. The end spans, built totally over the approach causeway, serve only to counter-balance the main span. For this reason, the spans were shortened significantly and filled with rock and concrete ballast. The end spans were built segmentally on falsework concurrently with free cantilevering in the main span.

Vail Pass Bridges (Fig. 5)

The Vail Pass Bridges in Colorado, with spans varying from 140 to 260 ft (42.7 to 79.2 m), were originally designed as precast segmental cantilevers. All four structures were eventually built by cast-in-place cantilever construction.

The concept was different from free cantilever in that the bridges were not constructed as balanced cantilevers just from the piers. The form travelers were set up at the abutments and moved through the spans, past the piers and through the next span. Fig. 5 shows the method of construction.

Temporary towers were installed periodically to support the structure, control the reactions, and balance the bridge. With the help of superplasticizers, extremely high early concrete strengths, and staggered shifts, a 2½-day casting cycle was achieved. As a result, the four bridges were constructed using five form travelers in one construction season.

Bedford Bypass Bridges (Figs. 6 and 7)

The Bedford Bypass #1 and Bedford Bypass #2 Bridges in Bedford, Nova Scotia, are examples of bids which included alternate designs. Bedford Bypass #2 provided the contractors with a choice of (1) a combination of cast-in-place reinforced concrete and precast prestressed I girders vs. (2) a cast-in-place prestressed concrete double tee constructed span by span on the falsework.

Bedford Bypass #1 was bid as: (1) structural steel with concrete deck vs. (2) a cast-in-place span-by-span design similar to Bedford Bypass #2. In both cases, the cast-in-place span-by-span solution was successful.

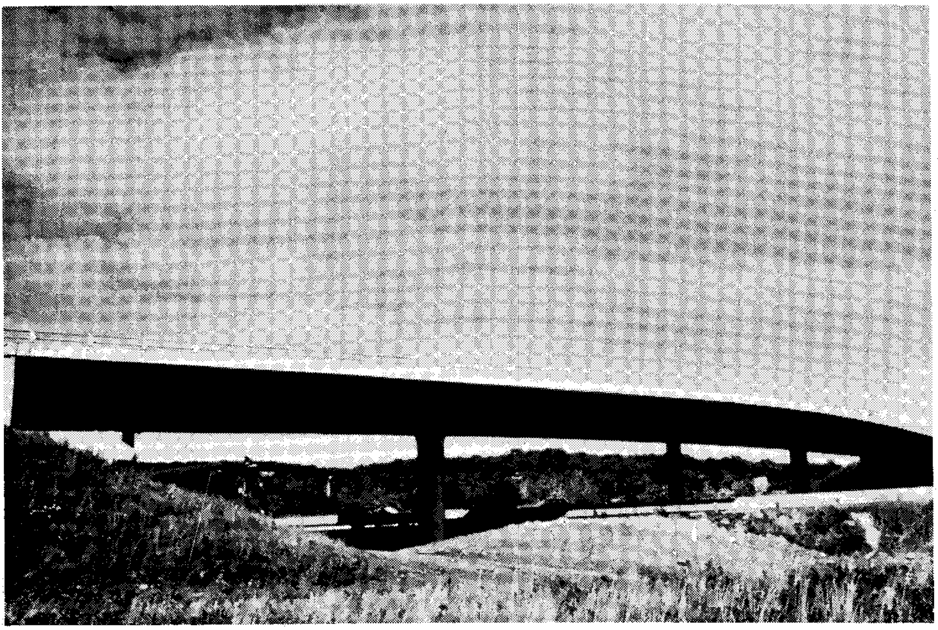

Fig. 6. Bedford Bypass Bridge No. 2, Bedford, Nova Scotia.

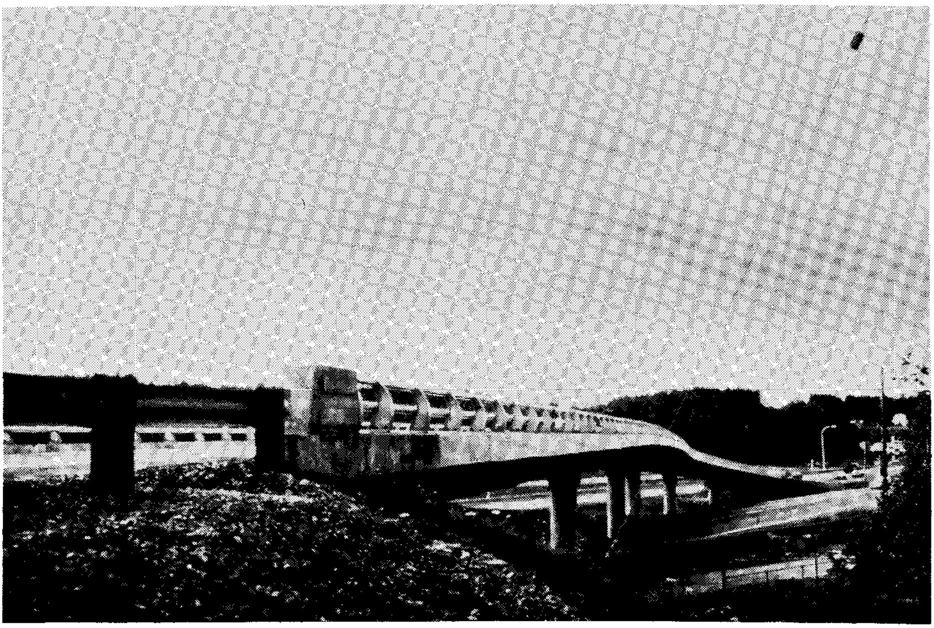

Fig. 7. Bedford Bypass Bridge No. 1, Bedford, Nova Scotia.

Fig. 8. Grand Mere Bridge, St. Maurice, Quebec.

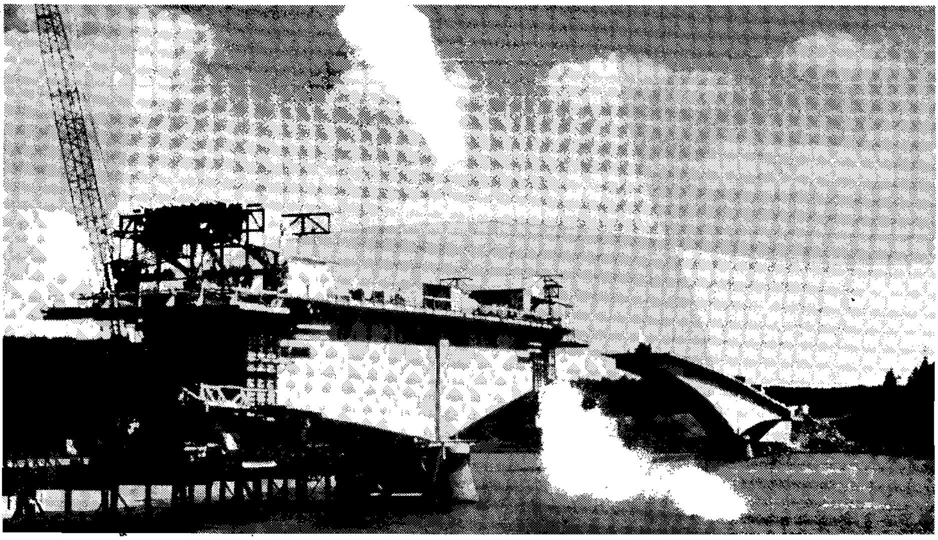

Fig. 9. Shubenacadie River Bridge, Nova Scotia.

Grand Mere Bridge (Fig. 8)

The Grand Mere Bridge in St. Maurice, Quebec, with a 595 ft (181.4 m) main span, was a similar but smaller version of the Koror-Babelthaup Bridge. The shortened ballasted end spans were also built on falsework. However, in this particular case they were constructed prior to and not concurrently with the main span.

Shubenacadie River Bridge (Fig. 9)

The Shubenacadie River Bridge in Nova Scotia has a 700 ft (213.4 m) main span flanked by 375 ft (114.3 m) side spans. Single temporary falsework bents were used in the side spans. The bents reduced the unbalanced dead load moment and allowed the total side span to be built with form travelers.

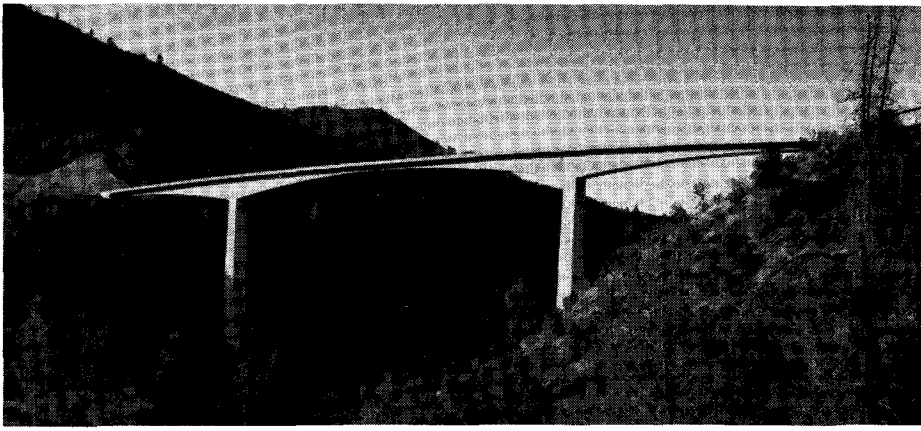

Fig. 10. Parrots Ferry Creek Bridge, Vallecito, California.

Parrots Ferry Creek Bridge (Fig. 10)

The Parrots Ferry Creek Bridge in Vallecito, California, was also a cast-in-place cantilever segmental box girder. It was the first bridge of its kind to be built in the United States, using lightweight concrete while also employing the classical free cantilever method with form travelers.

Kishwaukee River Bridges (Figs. 11 and 12)

The Kishwaukee River Bridges in Winnebago County, Illinois, consist of two structures: two single cell box girders, each with five spans [170 - 3 at 250 - 170 ft (51.8 - 3 at 76.2 - 51.8 m)]. The Illinois Department of Transporation developed plans for a precast box superstructure. Cast-in-place alternative designs were encouraged. Five of the seven bids submitted were for the precast scheme. Two alternate designs using cast-in-place techniques completed the bid tabulation. The successful bidder chose the precast scheme, with post-bid modifications by DSI.

A significant factor in the economy of the contractor's proposal was a unique redesign which used larger segments and eliminated the need for temporary post-tensioning. The use of Dywidag high tensile bars both transversely and longitudinally allowed the initial longitudinal post-tensioning required for erection of the segments to be incorporated into the permanent post-tensioning required for the final structure.

The above provided economy of erection time in addition to savings in materials and labor. This was evidenced by the record pace of erection (up to seven segments per day). The fact that the post-tensioning tendons were all straight and completely contained within the top or bottom slab also produced a significant economy.

The bridge superstructures were erected by free cantilever construction using an overhead launching truss. During cantilever erection the truss was supported on the preceding cantilever and pier segment of the cantilevers being erected. A portion of the end spans adjacent to the abutments was erected on falsework.

A detailed report on the Kishwaukee River Bridges appeared in the November-December 1982 PCI JOURNAL, pp. 22-47.

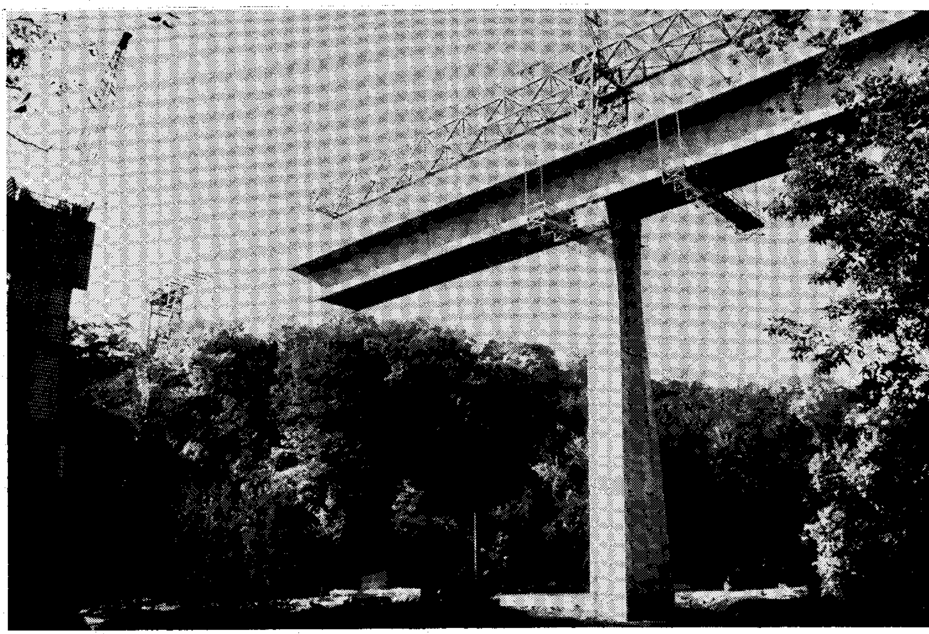

Fig. 11. Kishwaukee River Bridges, Winnebago County, Illinois, during construction.

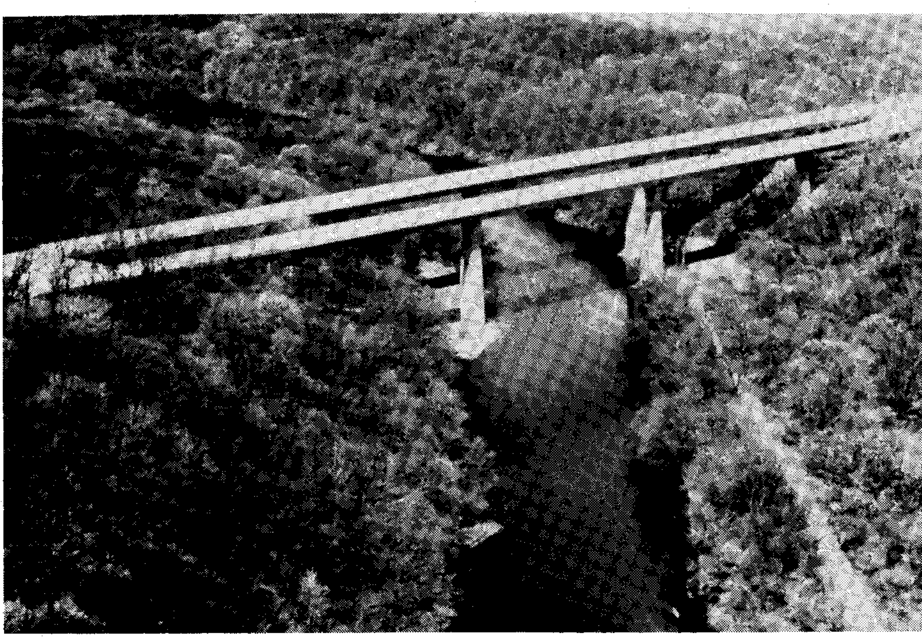

Fig. 12. Kishwaukee River Bridges, Winnebago County, Illinois, after completion.

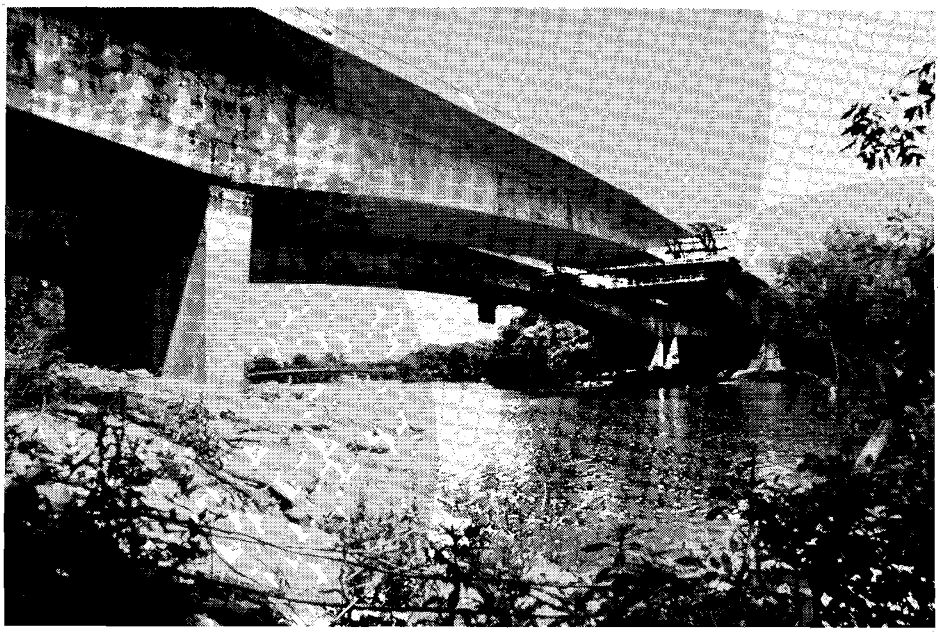

Fig. 13. Genessee River Bridge, Rochester, New York.

Genessee River Bridge (Fig. 13)

The Genessee River Bridge in Rochester, New York, is a good example of the combination of two segmental construction techniques. The twin structures consist of two two-cell concrete box girders and have a combined width of 120 ft (36.6 m) and a total length of approximately 2050 ft (624.8 m).

The river span and two adjacent spans [270 - 430 - 270 ft (82.3 - 131.1 - 82.3 m)] were built as free cantilevers using form travelers. The approach spans [seven spans varying from 140 to 180 ft (42.7 to 74.9 m)] were constructed segmentally — span by span on falsework.

For the cantilever portion of the bridge, four form travelers were used, two for each structure. Segments of 16 ft 3 in. (4.95 m) were cast in alternating sequence about the centerline of the pier. The unbalanced moment about the pier was taken by a temporary concrete pier supported on piling and tied down with post-tensioned anchors. The temporary bearings and bents were removed after the spans were closed.

Cantilever work progressed at a rate of approximately one segment per form traveler per week [65 ft (19.8 m) of two-cell box girder per week].

This pace is noteworthy because considerable time was needed for the concrete to reach the required stressing strength. Ordinarily, the use of additives and/or high early strength concrete permits stressing the second day of the cycle (first day after concrete placement). In this case, the concrete did not reach initial stressing strength of 2500 psi (17.2 MPa) until the third day and sometimes the fourth day.

The use of high early strength cement could have reduced the cycle time by approximately 2 days. When the concrete reached 2500 psi (17.2

MPa), longitudinal, transverse, and vertical bar tendons were stressed to allow stripping and form traveler movement. The longitudinal strand tendons were stressed at 4000 psi (27.6 MPa) before casting the next segment.

The approach spans were built using conventional falsework supported by steel piles. The box girder section was cast using mobile steel forms. The bottom slab was cast first, with webs and top deck cast second. Transverse post-tensioning was done with bars and longitudinal post-tensioning was done with strand. The final closure between the river portion and the approach spans was accomplished using form travelers.

Red River Bridge (Figs. 14 and 15)

The Red River Bridge in Boyce, Louisiana, is now under contract. Substructure work is progressing concurrently with superstructure work. This six-span structure [229 - 300 - 310 - 370 - 360 - 229 ft (69.8 - 91.4 - 94.5 - 112.8 - 109.7 - 69.8 m)] will be constructed using four form travelers. Temporary bents will be used in the end spans to allow the use of form travelers for the entire span.

This bridge was originally designed as a precast segmental project, and was bid against a structural steel alternate. The specifications also allowed the submission of contractors' alternate designs. Interestingly enough, six out of seven bidders submitted and bid on alternate cast-in-place designs. The high bidder was the only bidder on the conforming design.

Concluding Remarks

It should be noted that there are many different methods of approach to segmental construction. Only a few

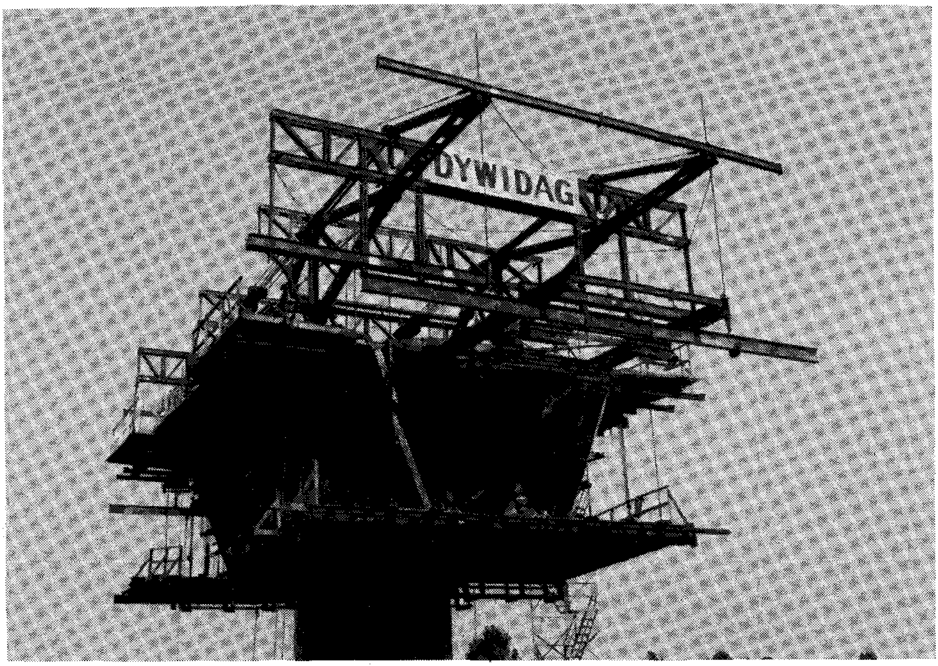

Fig. 14. Red River Bridge, Boyce, Louisiana.

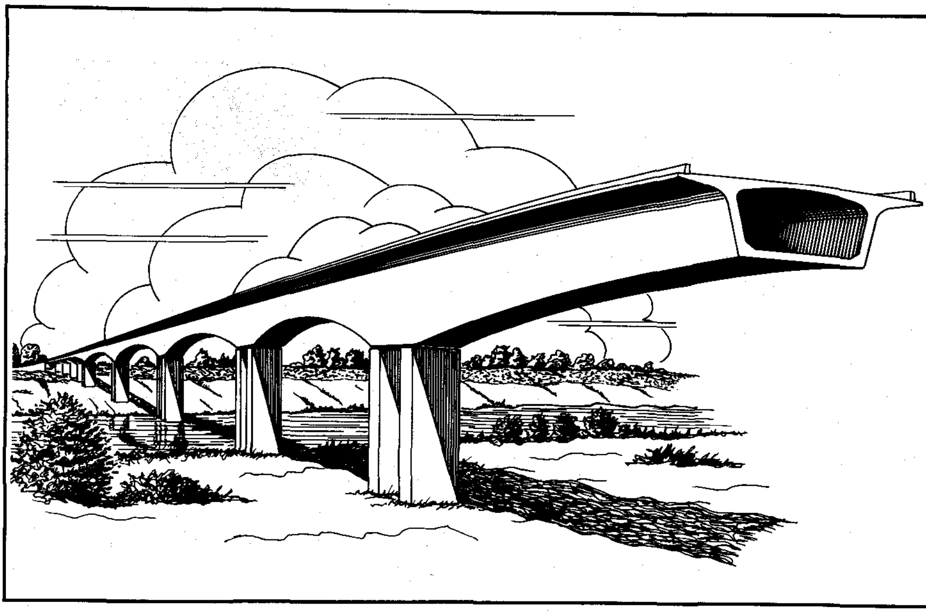

Fig. 15. Artist's rendering of Red River Bridge, Boyce, Louisiana.

have been discussed here. Innovative engineers and contractors are still finding different methods to get the job done efficiently and economically.

Perhaps the most important point that the owner, engineer, and contractor must recognize is that no person has a monopoly on ideas. Flexible design and/or specifications which allow the contractor to make use of special capabilities, equipment, and ingenuity have contributed greatly to the advancement of the state-of-the-art, and have also been able to save the owner (and public) considerable money in the process.

Unquestionably, the many advantages afforded by segmental construction will continue to make this method a very viable technique in bridge building for many years to come.

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NOTE: Discussion of this paper is invited. Please submit your discussion to PCI Headquarters by Nov. 1, 1983.