Segmental Bridge Construction—The Wave of the Future

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There is today a resurgence in highway bridge construction across North America spurred on by the demand for new bridges and a pressing need for the rehabilitation and replacement of existing bridges. It would appear then that the members of the Prestressed Concrete Institute, both individually and collectively, are interested in expanding their businesses by taking advantage of this burgeoning bridge market.

If we are to properly assess the prospects for growth, however, we need to examine past performance.

In a 1976 report, W. Burr Bennett, Jr., at the time PCI executive director, stated that the precast prestressed concrete industry started with no producers in 1949, exceeded $10 million production in 1959, and had reached a total volume of $1.4 billion in 1975 from 350 manufacturers. Unfortunately, since then, the industry's exponential growth of the past 2½ decades has slowed down to a trickle. For an example of what has happened to transportation structures, and particularly highway bridges, let us look at some statistical data obtained from the Federal Highway Administration (FHWA).

These unpublished annual reports show the number, costs, and percentage of bridges constructed each calendar year since 1966 with federal highway funds for the three major categories of structure, namely, reinforced concrete, structural steel, and prestressed concrete. These data are summarized in Table 1. Similar data are not available for bridges built without federal funds, but the trends and percentages would not vary appreciably.

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Based on federal statistical data and his many years of experience in the bridge field, the author contends that the time is ripe for producers to make the quantum jump to precast concrete segmental construction.

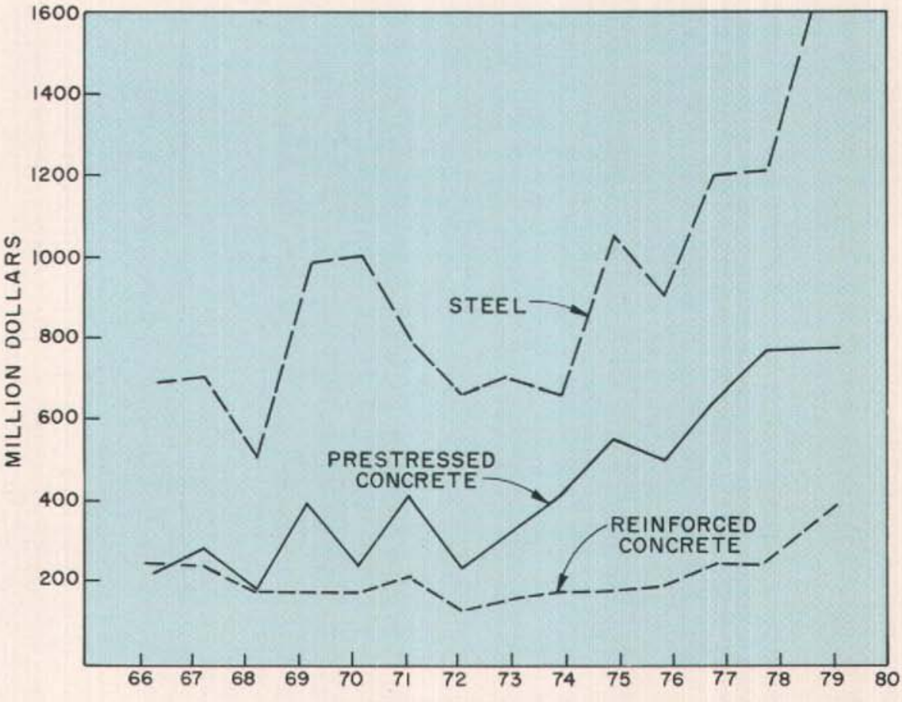


Fig. 1. Dollar volume of bridges financed with federal funds by structure types. (Source: FHWA unpublished reports.)

There are obviously some inaccuracies in the figures shown in Table 1 due to the method of collecting data and interpreting the results on the categories of bridges. For example, a bridge consisting of 2 miles (approx. 3 km) of concrete trestle approach with a steel girder main span would be coded as a steel bridge. The information shown in Table 1 has been expanded to show bridge costs to a constant dollar amount. The FHWA bid price index was used to correct the cost data to the 1967 base price.

The reported cost data for the three types of structures are shown in Fig. 1.

Table 1. Number, total costs, and percentage of bridges built in the United States through FHWA funding during the past 14 years.

Calendar Year	Number of Bridges			Total Costs, $ Millions			Total Costs, Constant $ Millions			Percent of Costs		
	Reinforced Concrete	Structural Steel	Prestressed Concrete	Reinforced Concrete	Structural Steel	Prestressed Concrete	Reinforced Concrete	Structural Steel	Prestressed Concrete	Reinforced Concrete	Structural Steel	Prestressed Concrete
1966	2295	1876	945	234	663	202	234	663	202	21.3	60.3	18.3
1967	2114	1690	966	232	679	274	232	679	274	19.5	57.3	23.1
1968	1301	1201	662	161	491	171	159	485	169	19.5	59.7	20.8
1969	1722	1528	965	236	967	383	200	824	325	14.9	61.0	24.1
1970	1108	1291	736	170	963	226	129	733	172	12.5	70.8	16.7
1971	1433	1259	1051	210	763	399	153	554	290	15.3	55.6	29.1
1972	923	1019	672	122	647	223	87	461	159	12.3	65.2	22.5
1973	757	925	625	165	680	320	105	435	204	14.1	58.4	27.5
1974	705	609	536	175	641	408	82	299	190	14.3	52.4	33.3
1975	1034	1000	941	174	1022	534	83	486	254	10.1	59.1	30.9
1976	964	1133	1027	186	877	485	94	445	245	12.0	56.6	31.4
1977	1209	1219	1192	249	1185	639	120	573	309	12.0	57.1	30.8
1978	1305	1132	1115	248	1193	754	101	488	309	11.3	54.4	34.3
1979	1146	1151	1282	339	1665	752	108	532	240	12.3	60.4	27.3

*Source: FHWA Unpublished Annual Reports and Bid Price Index

The constant dollar value for the three types is shown in Fig. 2. The curves tell us that what appeared to be a continual growth for prestressed concrete bridges (see Fig. 1) is in reality no growth at all for the last 10 years. This is despite the fact that the funding for the Federal Assisted Bridge Replacement Program should have produced almost a one billion dollar increase in bridge construction for 1979. Perhaps this growth will show up in the 1980 results, but I doubt it.

Each of us can form our own opinion for this lack of growth, but let me give you my thoughts on the subject.

Until recently, prestressed concrete bridges in North America could be categorized into two general types: precast prestressed I-girder spans and post-tensioned box girder spans. The prestressed I-girder designs or the familiar AASHTO-PCI standard sections are simple substitutions for conventional reinforced concrete or steel beams. The prestressed I-girder designs have dominated short-span bridge construction in most parts of the United States. However, in California, the most common structure for moderate span lengths has been cast-in-place concrete box girder designs.

In both the I-girder (although to a much less degree) and box girder constructions, extensive on-site labor, materials, and equipment are required. Conventional construction methods are utilized: falsework, forms, steel placing and tying, concrete batching, mixing, placing, and finishing. These are essentially the methods and techniques that have been used for the last 100 years.

If we are to make significant progress in the bridge market, we have to find a better way to perform these operations. It should be no surprise that the pioneers in this field have not only found a better way but they have found the best way! The *better way* is cast-in-

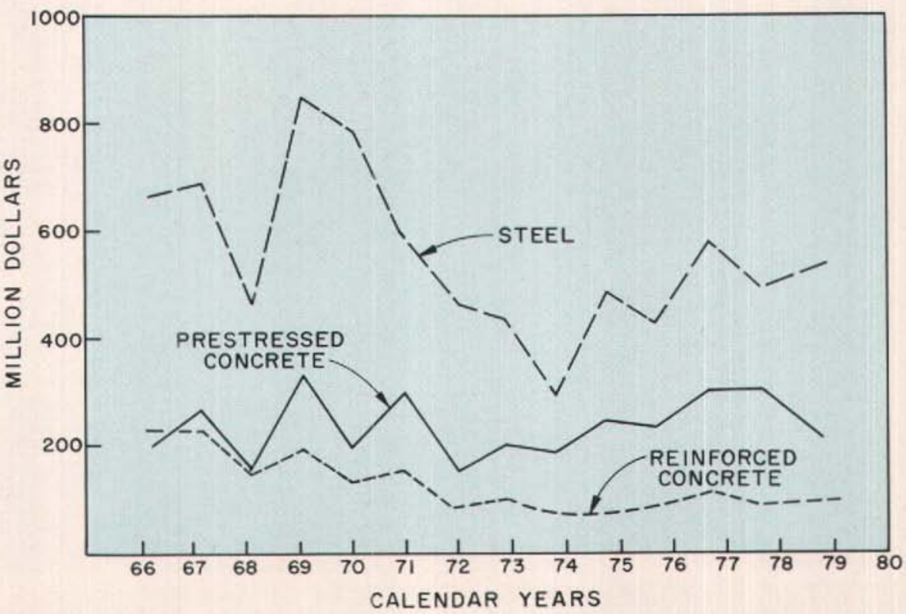


Fig. 2. Constant dollar volume of bridges financed with federal funds. (Source: FHWA bid price index.)

place segmental concrete box girders which is still necessary for very long span construction but the *best way* is precast segmental concrete box girders.

The principal disadvantage of cast-in-place construction is that it is subject to the same difficulties that the other on-site construction methods suffer from. The most obvious advantages of precast segmental construction are: speed of construction, quality control of factory production, reduction of on-site labor and operations, maximum reduction of materials and as a result is much more economical where multiple spans are required. These benefits are in addition to the vastly improved aesthetic appearance and elimination of future maintenance costs which are common for all concrete box girder structures.

Let us now take a quick look at the track record of recent precast and cast-in-place segmental concrete box girder bridges built in the United States. When alternate designs are offered, the segmental designs have been 10 to 20 percent lower than conventional designs which sometimes included precast prestressed girders. The span lengths vary from 100 to 400 ft (30 to 122 m) for precast segmental designs and up to 750 ft (229 m) for cast-in-place segmental designs. If we look into designs that have been prepared and studies that are already underway, we can anticipate that precast segmental designs are economical for spans as short as 40 ft (12 m) and for cast-in-place segmental spans up to 850 ft (259 m).

The examples for the above cited span lengths are the Long Key Bridge in Florida with 118-ft (36 m) spans and the Dauphin Island Bridge in Alabama with the 400-ft (122 m) span using precast segmental construction. The longest span cast-in-place segmental bridge in North America is the Houston Ship Channel Bridge [750 ft (229 m)].

Span ranges for segmental concrete construction have been expanded to truly

One of the 9 ft (2.75 m) deep precast segments for Linn Cove Viaduct being trucked to construction site. The segments were cast inside a building about a mile (1.6 km) from bridge. Indoor casting was necessary due to severe weather of the Blue Ridge Mountain region of North Carolina.

monumental proportions by using cable-stayed designs. Bridges with 1050-ft (320 m) center spans have been constructed and designs have been completed for a 1300-ft (397 m) center span for the Dames Point Bridge in Jacksonville, Florida. There seems to be no limit to the future of segmental concrete concepts.

At one time bridge engineers were able to estimate at the preliminary design stage what structural type and material would be the most economical. In today's inflationary period of material prices, it is almost impossible for bridge engineers to determine with any degree of certainty the most economical design until actual bids are received. The bidding documents must provide many options of materials, construction methods, and designs. "Value Engineering" done during the design stage pays off much more than that done during construction.

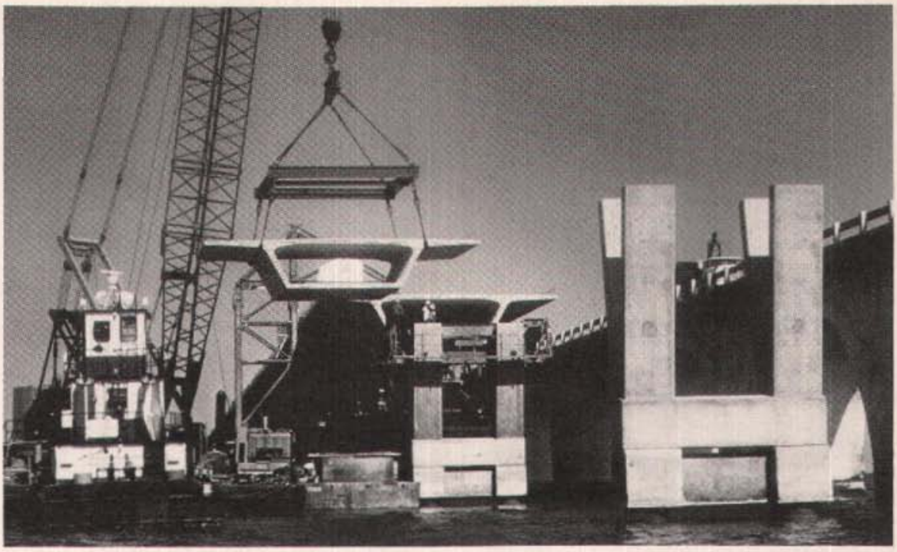
What can now be done to take advantage of this new technology? First, we should advocate as national policy the concept of alternate designs. The FHWA has issued instructions to their field offices that all "major bridges" must provide for alternate designs. The definition for "major bridge" is somewhat flexible, but a bridge costing as much as \$5 million should in my opinion have alternate designs prepared. The wisdom of this policy has been proven time after time. When alternate designs are offered for bridge projects, not only is competition between materials offered, but additional contractors are attracted to bid on each type of structure. Competition is the name of the game to reduce costs!

On the subject of competition, I do not understand why so few prestressed concrete producers have been involved in segmental concrete bridge projects in the United States. In practically every segmental project to date, the successful contractor has had to set up his own precast operation. When this occurs it

Aerial view of completed portion of 12,144 ft (3704 m) Long Key Bridge. Contractor has been able to place five spans in one week–590 ft (180 m) of completed bridge deck.

means the contractor must charge the total cost of the special forms and casting yard to that particular project. Contractors don't like to invest money in this kind of operation and do it only as a last resort. For example, contractors don't as a general rule do the post-tensioning of the box girders because there is a highly competitive industry ready and willing to do this specialized work for them.

I believe that the time is ripe for some or several ambitious precasters to develop the capability for producing concrete segments on a regular and continuous basis to any and all bridge contractors. For some designs, the concrete



Placing precast segment with barge crane (Long Key Bridge).

segments are heavy (up to 150 tons) and the casting yard must either be located near the project or must be accessible to water transportation. However, in the near future, we will see designs that provide precast segments that can be hauled over the road within legal load limits. The "one-time move-in move-out" operation for a casting yard has to be much more economical than amortizing the casting equipment and forms for each project.

The reluctance of precasters to make the initial investment in a fixed or portable casting yard is undoubtedly due to the lack of standard sections. An optimistic prediction is that standardization is at least 2 years away, and maybe 4 years. I don't want to minimize this problem, but it is much like the chicken and the egg syndrome. The sections most likely to become standard are those in greatest use.

In conclusion, I believe that the prestressed concrete industry has gone about as far as it is going to go in capturing the highway bridge market unless it is prepared to make that quantum jump to precast concrete segmental construction.

The sky is the limit if we will only use the "best way" or even the "better way," now that we have an efficient and economical construction method at our disposal. So let's get on the segmental bandwagon now before we are left behind!

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Discussion of this paper is invited.
Please forward your comments to
PCI Headquarters by May 1, 1981.