Prestressed Concrete Bridge Costs

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● THE original intention in preparing this paper on "Prestressed Concrete Bridge Costs" was to detail fully the cost of work done in Massachusetts on this type of construction since the Department's first venture into this field in August of 1951, but the pressure of emergency flood replacement work, in addition to an accelerated highway program, has prevented a complete analysis and breakdown of these costs.

This paper, however, enumerates the post-tensioned projects, giving a brief description, including their square-foot costs, and covers the more recent pretensioned work on flood bridges. These earlier projects are summarized in Table 1.

The first contract, in 1951, was for a railroad overpass bridge in Danvers. It is a 27-ft span structure and contains 47 inverted T-type beams. The beams are 14 in. deep and have a width of flange of 12 in. The bottom flanges are butted in place on the bridge seats, and the areas between and over the flanges are filled with concrete, making in effect a composite concrete slab. This is the only post-tensioned structure built by the Department in which the strands were not grouted in place. The beams were fabricated under a separate contract and the cost of the deck was $7.50 per sq ft.

All six of the other post-tensioned structures have beams of an I-shape, spaced generally about 4.5 ft on centers, with a poured-in-place slab on top of the beams. The spans of these bridges vary from 58 ft to 67 ft.

The beams for the four bridges in Newbury and Newburyport on the Newburyport Turnpike were furnished under a separate contract; those in the Wenham and Bridgewater projects were included in the general contract.

All the beams for these bridges, except those for the Scotland Road Bridge, have a depth of 36 in., a bottom flange width of 24 in., a top flange width of 20 in., and a web thickness of 6 in. The Scotland Road Bridge has a depth of 3 ft 8 in.; otherwise, the dimensions are the same.

The cost of the deck of the Wenham Bridge was $13.75 per sq ft; that of the Bridgewater Bridge, $11.10; the Scotland Road Bridge, $10.00; the Hale Street Bridge, $9.60; the Storey Avenue Bridge, $8.50; and that of the Pine Hill Road Bridge, $10.60.

Earlier designs were very conservative and did not take full advantage of high strength concrete. If the same structures were designed today, a 15 percent reduction in cost could be effected.

All of the post-tensioned beams were manufactured by one company, and all, except those on the Danvers project, were manufactured in an outdoor yard and under adverse weather conditions.

The storm of August 1955, whose axis coincided approximately with the Massachusetts - Connecticut state line, destroyed or badly damaged about 220 small bridges in 80 cities and towns in Massachusetts.

The estimated cost of replacement of these structures and their immediate approaches is about $9,000,000. The work of this rehabilitation program will be financed by a flood bond issue with reimbursement to the state by the Bureau of Public Roads on federal-aid projects and by the Army Engineers to the extent of the estimated cost of temporary bridges if their construction is not required.

The damage was confined primarily to bridges on small streams. Many of these were destroyed because of the failure of old and inadequate dams to withstand a flash flood of such magnitude.

In order to speed replacement, 17 boring crews were put into the field on September 1, and, shortly thereafter, 22 consulting engineers were engaged to prepare plans for the new bridges and their approaches. The devastated portion of the state was divided into 22 geographical areas, made up generally of a group of adjacent towns, and a consultant was assigned to each area.

A cursory survey of the damaged areas showed that by far the greater percentage of the bridges to be replaced would have spans under 40 ft, and a study indicated that rectangular pretensioned units would be particularly suited for this span range.

TABLE 1

SUMMARY OF BRIDGE SUPERSTRUCTURE COSTS
POST-TENSIONED PRESTRESSED CONCRETE

Municipality	Location	Date Built	Span	Cost per sq ft
Danvers	Endicott Street over B & M. R. R.	1951	27'	$ 7 50
Wenham	Grapevine Road over Route 128	1952	2 at 60'	13 75
Bridgewater	Pleasant Street over Fall River Expressway	1953	2 at 67'	11 10
Newbury	Newburyport Turnpike over Scotland Road	1953	65'	10 00
Newbury	Hale Street over Newburyport Turnpike	1953	2 at 64'	9 60
Newburyport	Storey Avenue over Newburyport Turnpike	1953	2 at 58'	8 50
Newburyport	Pine Hill Road over Newburyport Turnpike	1953	2 at 59'	10 60

It was decided to replace all the structures having spans of from 20 to 40 ft with this type of superstructure, the Department preparing the plans and advertising for separate bids for the furnishing of the units. At the time of this decision, the exact number and locations of the bridges in this span range were not known, but it was planned to advertise for the construction of about fifty bridge decks.

To keep the form requirements and the costs to a minimum, two depths of beams were selected, 17 in. for the 20- to 30-ft span beams and 21 in. for the 30- to 40-ft span lengths.

The proportion between the two depths was an arbitrary one based on meager information and was at the ratio of about three for the 17-in. depth beam and one for the 21-in. depth beam.

The majority of these bridges are located on secondary roads where the general roadway design width is either 26 ft or 30 ft. Allowing for a 12-in. width of curb, a 4-ft width of beam satisfied the requirements, both for roadways and for sidewalks. Consequently, this width was adopted, reducing to a minimum the number of units necessary for each bridge.

Two basic sections were detailed for each depth of beam: Type A, or roadway beam, and Type B, or curb beam. A third basic beam section, 17 in. deep, was detailed for the sidewalks for all spans.

All 17-in. depth beams contain three $8\frac{1}{2}$-in. diameter economy holes, and all 21-in. depth beams contain three $10\frac{1}{2}$-in. holes. These holes are blocked at the ends and at the center to allow for the insertion of pipe sleeves, placed parallel to the abutments, through which $\frac{7}{8}$-in. diameter lateral rods are to be threaded.

Since the majority of these beams are to be erected in the dead of winter when the grouting can not be done, a 1-in. space is to be left between the beams and for the full depth, so that water will not be pocketed between the beams and, in freezing, damage them.

Where the beams are erected before spring, a gravel surface will be placed on the deck and the bridge opened to limited traffic. When the weather is suitable, the gravel will be removed, the space grouted, membrane water-proofing applied, and a bituminous concrete surface laid.

The only variable of any consequence in the beams is the amount of prestressing steel required. Because of the variation of spans from 20 to 40 ft and loadings from H15 to H20 S16 with a modified military provision, a table of $\frac{3}{8}$-in. diameter strand requirements was prepared for span lengths increasing by 5-ft increments, under four

TABLE 2

STRANDS REQUIRED FOR RECTANGULAR PRESTRESSED CONCRETE BEAMS

Type of Beam	Loading	17" Depth No. of $\frac{3}{8}$" Strands		21" Depth No. of $\frac{3}{8}$" Strands	
		Spans 20' to 25' incl	Over 25' to 30' incl	Over 30' to 35' incl	Over 35' to 40' incl
A Standard and B Curb	H-15	5 top, 22 bottom	6 top, 28 bottom	6 top, 30 bottom	8 top, 36 bottom
	H-20	5 top, 26 bottom	7 top, 32 bottom	8 top, 34 bottom	10 top, 44 bottom
	H-20-S16	6 top, 26 bottom	8 top, 36 bottom	8 top, 40 bottom	11 top, 50 bottom
	H-20-S16(M)	6 top, 30 bottom	8 top, 40 bottom	8 top, 40 bottom	11 top, 50 bottom
C Sidewalk	Sidewalk	All spans - 17" Depth - 6 top, 26 bottom. All $\frac{3}{8}$" strands.			

H-20-S16(M) = Modified for military loading.

December 15, 1955 - Revision of Number of Strands in Type B Curb Beams

Where there are more than five $\frac{3}{8}$" strands at top of slab, move two strands to top of curb and add one strand, making three strands at top of curb.

Where there are only five $\frac{3}{8}$" strands at top of slab, move one strand to top of curb and add one strand, making two strands at top of curb.

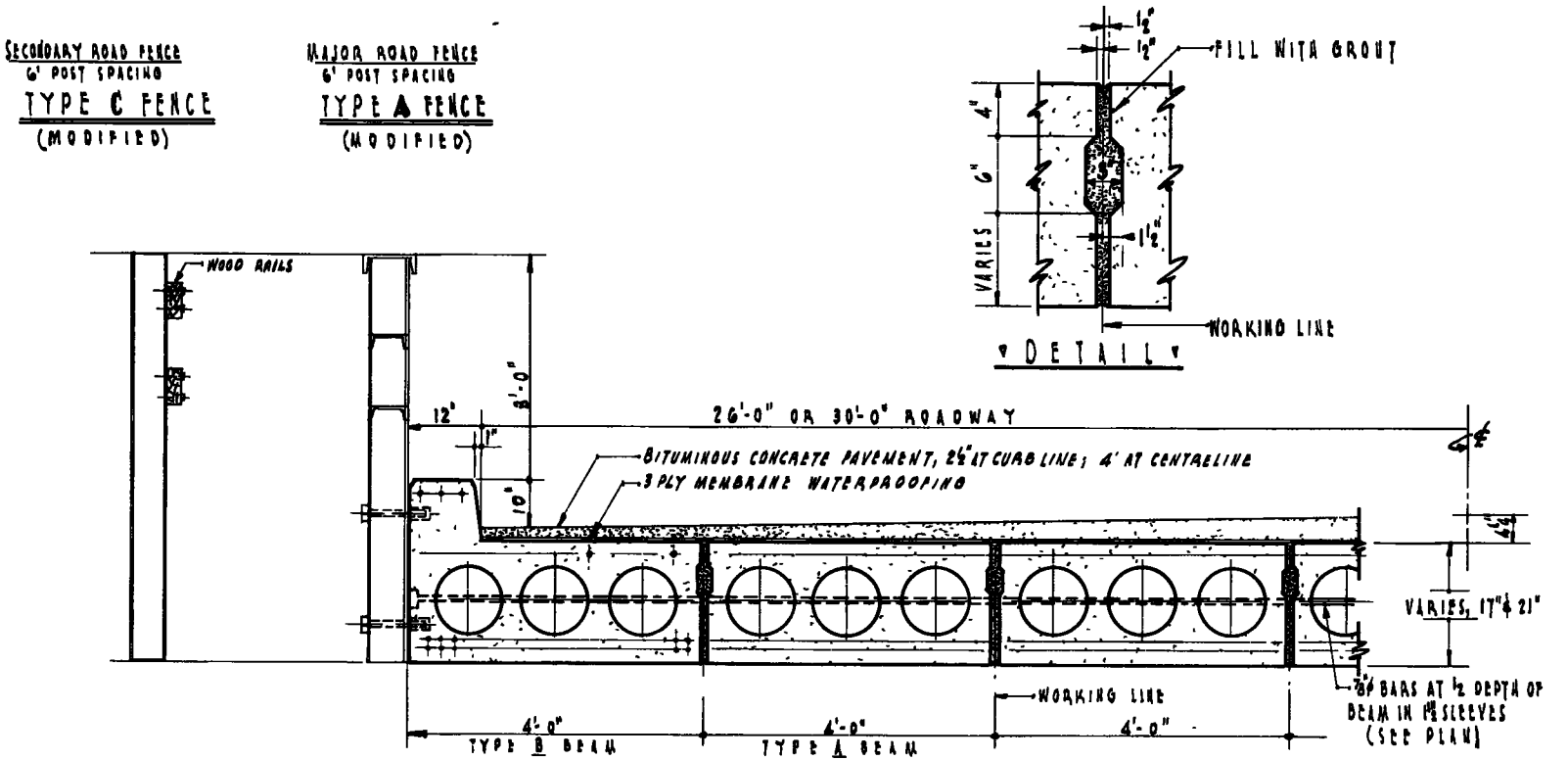

Figure 1. Partial cross-section, prestressed concrete deck.

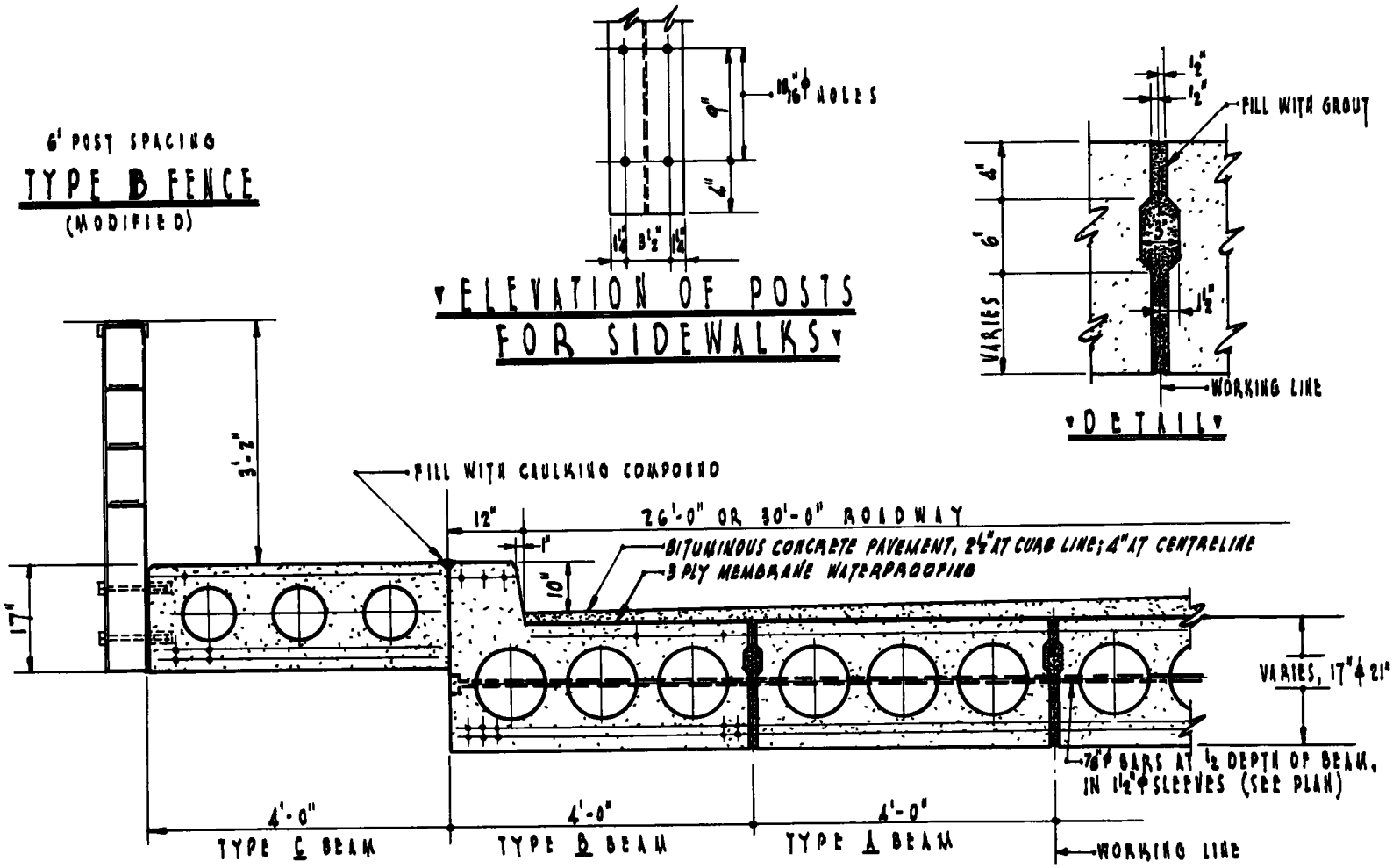

Figure 2. Partial cross-section, prestressed concrete deck with sidewalk.

design loadings, for the two depths of beams, and for the sidewalk beams. Thus, although the size of beams is limited to two depths, the number of strands in a 17-in. roadway beam varies from 27 to 48, and those in the 21-in. beams vary from 36 to 61. The sidewalk beam contains 32 strands.

The top strands in the curb beams were specified as 2 in. from the top of the slab,

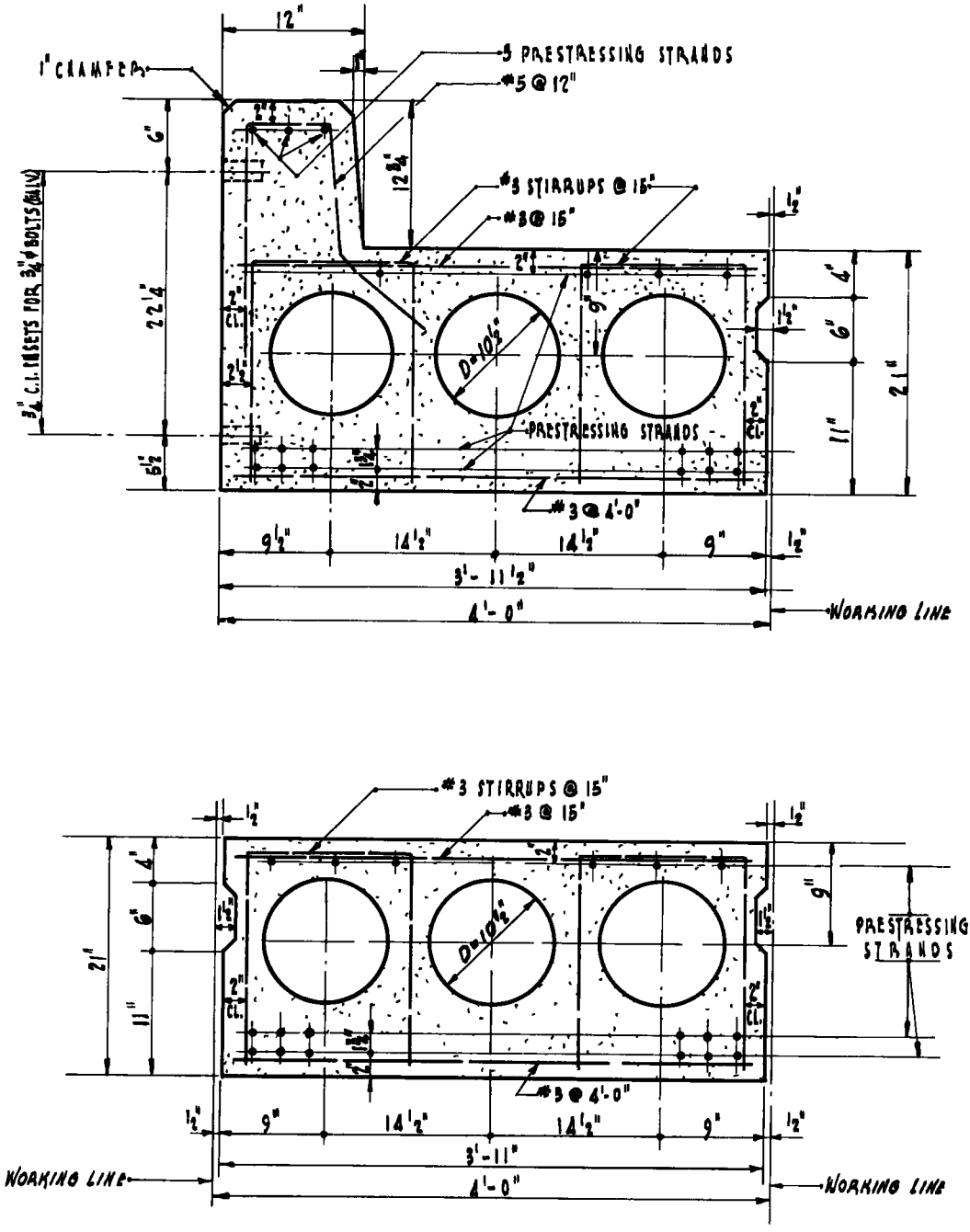

Figure 3. Type A (lower) and Type B (upper) beams, 30-ft to 40-ft span.

but tension in the top of the monolithically poured curb section requires the moving of some strands to the top of the curb and the addition of another strand.

A proposal was prepared containing 5 items for the furnishing of beams for about 50 bridges, and bids were received on October 11. This proposal called for payment by the lineal foot for Type A and Type B beams for each depth and contained a separate item for prestressing strands, with payment by the pound. Because the actual delivery sites were still not known for all bridges, the prices quoted were f. o. b. Worcester.

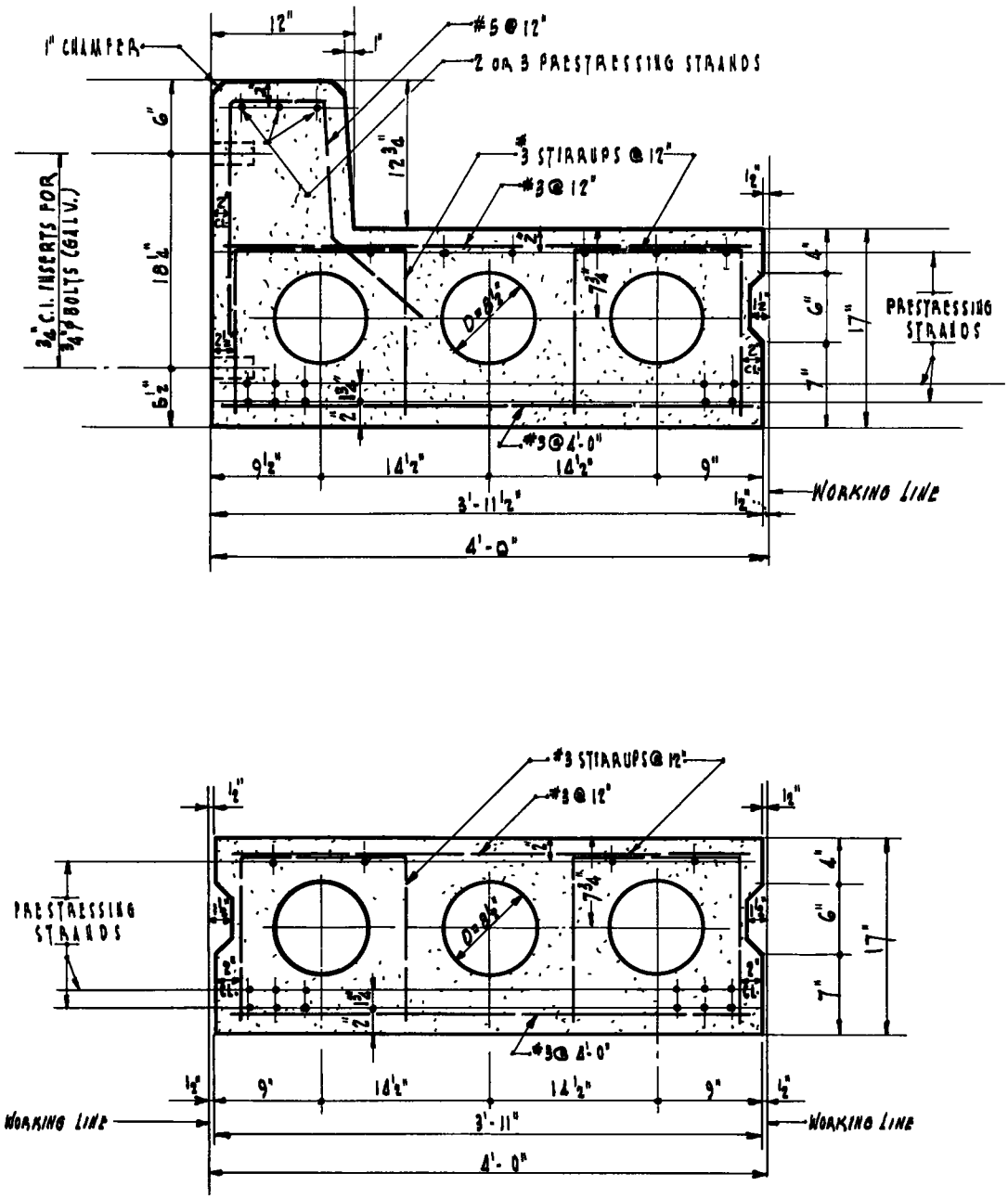

Figure 4. Type A (lower) and Type B (upper) beams, 20-ft to 30-ft span, inclusive.

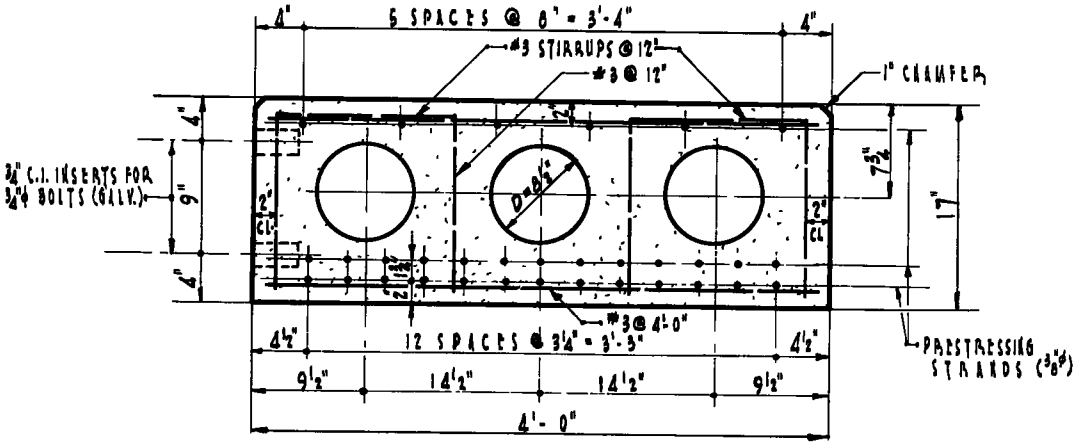

Figure 5. Type C beam, sidewalk, 20-ft to 40-ft spans.

By the time bids were opened, it was apparent that at least 30 more bridges in the selected span range could be constructed of prestressed concrete, and bids were received on November 1 for these additional beams.

There were 5 bidders on the first contract and 4 on the second. The low bid on the first contract was $185,000; the low bid on the second, $102,000.

The average detailed costs of the low bids, together with the average erection cost on bids taken to date, are shown in Table 3. These data indicate that the costs under the second contract are approximately 6 percent below the first, but that both are very economical.

The average cost per square foot of deck complete in place for spans 20 to 30 ft in length under Contract No. 1 is $5.77, and under Contract No. 2 is $5.41. For spans from 30 to 40 ft the cost is $6.37 under Contract No. 1 and $5.98 under Contract No. 2. Approximately 65 percent of the cost is in the manufacture and delivery to Worcester, and 35 percent is in the transportation from Worcester and erection on the bridge seats.

Because of the geographical location of both the plants and because of transportation arrangements between the general contractors and the suppliers, deliveries will probably be made direct to the bridge sites, and the transportation charges will be covered in the manufacturer's bid. Therefore, the general contractor's bid can be considered primarily for erection, grouting, and for the placing of the lateral ties. On the average, about 10 percent of the total cost is for the prestressing strands.

An analysis of the bid of $0.24 per pound for the strands indicates a figure of $0.44

TABLE 3

AVERAGE COSTS OF 1955 FLOOD BRIDGES WITH PRETENSIONED PRESTRESSED CONCRETE DECKS

Spans	Size of Beams	Type of Beams	Contract No. 1, 50 Bridges sq ft costs				Contract No. 2, 30 Bridges sq ft costs			
			Beams Furnished	Strands	Erection	Total	Beams Furnished	Strands	Erection	Total
20'-30'	4' x 17"	Roadway and sidewalk	3.09	$0.58	$1.87	$5.54	3.02	$0.52	$1.87	$5.41
	4' x 17"	Curb	3.92	0.58	1.87	6.37	3.02	0.52	1.87	5.41
30'-40'	4' x 21"	Roadway	3.32	0.77	2.04	6.13	3.25	0.69	2.04	5.98
	4' x 21"	Curb	4.18	0.77	2.04	6.99	3.25	0.69	2.04	5.98

Note: Costs exclusive of fences and surfacing.

AVERAGE COST PER SQUARE FOOT OF DECK

Spans	Contract 1	Contract 2
20'-30'	$5.77	$5.41
30'-40'	$6.37	5.98

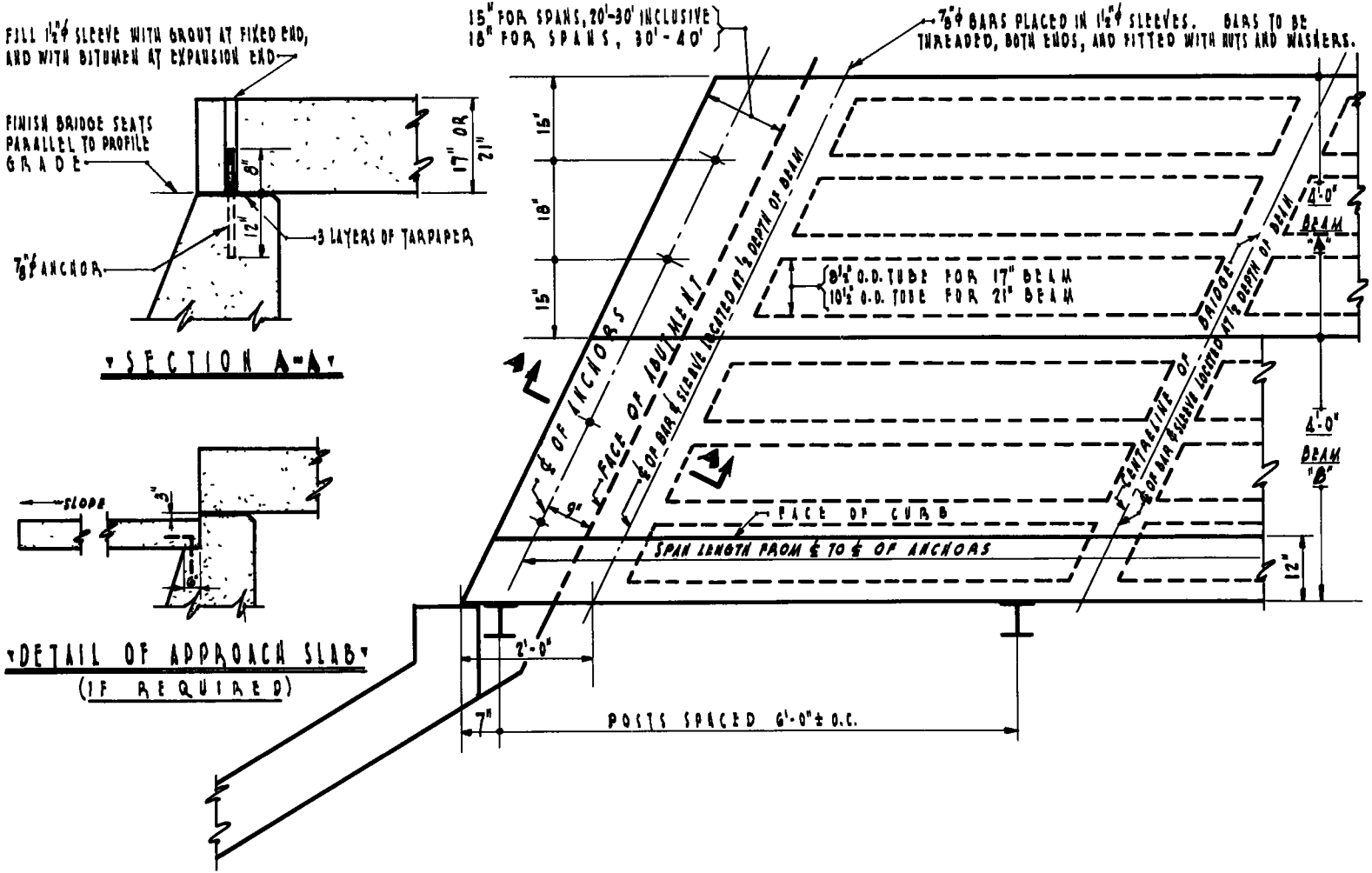

Figure 6. Plan of prestressed concrete deck.

per sq ft for a 17-in. depth beam for an H15 loading and for a 20-ft span, and a cost of $0.78 per sq ft for the same depth beam on a 30-ft span and an H20 S16 loading. For similar loadings and for the minimum and maximum spans of the 21-in. depth beam, the cost varies from $0.59 to $1.00 per sq ft.