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West Garfield St. bridge in Seattle, a notable example of concrete viaduct design, carries through, fast traffic over railroad yards and docks

Concrete Trusses and 47-Ft. Flat Slabs in New Seattle Viaduct

Structure solves major traffic problem—Slab design aids formwork and placement—Concrete-truss economy proved by bids

By CLARK H. ELDRIDGE
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THE West Garfield St. bridge, recently completed in Seattle at a cost of about $750,000, constitutes a major development in the city's traffic system and contains some distinguishing features of reinforced-concrete design, including heavy flat-slab construction on spans up to a maximum of 47 ft. and reinforced-concrete trusses 60 ft. long. The structure was built to provide direct traffic access to a choice residential district which had been handicapped by an indirect timber-trestle approach on steep grades. Securing of proper clearances for this 3,000-ft. structure over industrial areas and the high connection to the Bluff district necessitated a maximum height of 107 ft. above tidewater.

Position and Use—Separated from the rest of the city by an industrial zone of low elevation and extensive railroad yards, the choice Magnolia Bluff residential district has been hampered in development by lack of direct and adequate traffic connection to the business district. The old timber-trestle approach by a circuitous route tended to discourage traffic. In addition, the Smith Cove terminals of the port of Seattle in the intervening industrial area did not have satisfactory or permanent approaches. The present project, initiated in 1925 and completed with formal opening on Dec. 6, 1930, provides the necessary traffic solution for both developments and constitutes a major improvement in the city's street and traffic system.

Proper clearances above the railroad trackage and the established elevation of the upper passenger floors at the dock structures practically predetermined bridge elevation at the east approach. At the west end it was essential to provide a connection to the existing street system on the high ground of the Bluff district, which required a grade of 6.32 per cent and a 500-ft. radius curve. This western section of the bridge traverses low mud flats flooded at high tide and constitutes the point of maximum height, which is 107 ft. above high tide. The structure is 3,010 ft. long between abutments, and 286 ft. of the east approach consists of retained fill with concrete pavement. The minimum width consists of a 36-ft. roadway and two 6-ft. walks, and this roadway width is increased in front of the dock property to 60 ft. 8 in. The lower level of the dock property is served by a ramp which descends from the middle of the roadway. The west approach required the grading and paving of approximately 2,000 ft. of street to furnish the necessary connection. General features of the structure are shown in Fig. 1.

With the exception of a crossing over railroad property near the east end, which is carried by plate girders, the structure is entirely of reinforced concrete. One-way slab design was used throughout, except for 709 ft. of truss spans at the high portion near the west end.

Loads and Concrete—The design specifications were based on a live load of two 20-ton trucks with a 100 per cent impact allowance on the rear axle of one truck. A concrete mix of approximately 1 : 2 : 3, developing 3,000 lb. per sq.in. in 28 days, was specified, and a working stress of 1,200 lb. per sq.in. was used in design. Test cylinders taken during the progress of the work showed strengths ranging from 2,740 to 5,489 lb. per sq.in., grouped according to strength as follows:

4 cylinders broke below 3,000 lb. per sq.in.
15 cylinders broke between 3,000 and 3,500 lb. per sq.in.
28 cylinders broke between 3,500 and 4,000 lb. per sq.in.
16 cylinders broke between 4,000 and 4,500 lb. per sq.in.
10 cylinders broke above 4,500 lb. per sq.in.

The 73 cylinders averged 3,867 lb. per sq.in.

Slab Design—The design for the one-way slab section of the bridge is the same as has been used in similar bridges built in Seattle during recent years. It consists of bents of two or more columns capped with wide shallow beams. A heavy slab, reinforced primarily in one direction only and thickened for negative moment at the supports, spans directly from bent to bent. There are no longitudinal beams, stringers or girders in the roadway portion, the slab itself with its wide effective breadth constituting the sole structural element. Among the advantages that result from this type of construction are: (1) formwork is of maximum simplicity; (2) reinforcing bars are large and uncrowded; (3) concrete can be placed with ease, although stiffer and of lower water content than would be possible with ordinary beam and girder framing; (4) concrete can be more thoroughly cured; (5) a construction providing maximum clearances

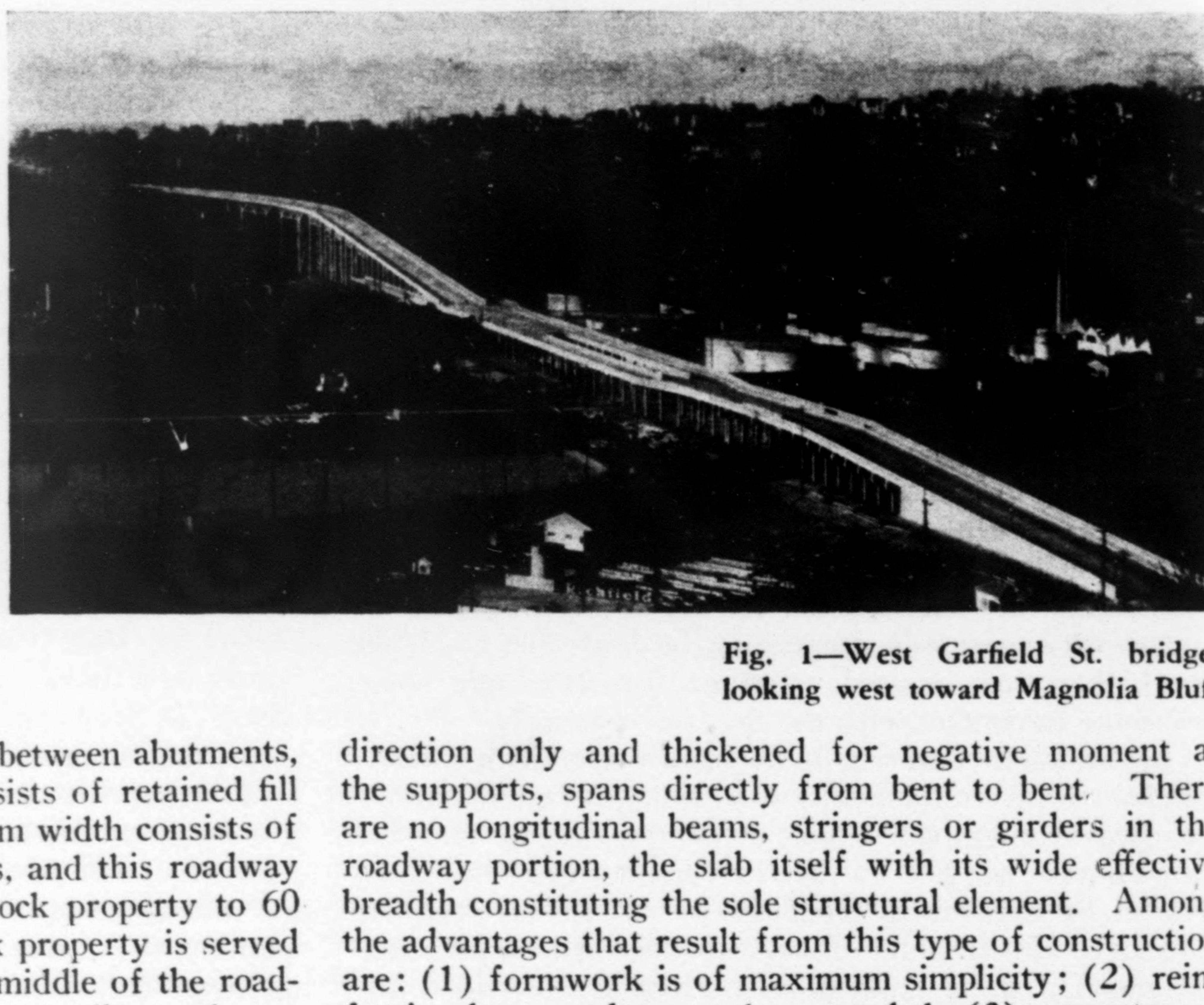

Fig. 1—West Garfield St. bridge, looking west toward Magnolia Bluff

or shallowest depth of deck is obtained; (6) the distribution of heavy concentrated wheel-loads is accomplished very effectively; and (7) the cost appears to be consistently lower than with other forms of reinforced-concrete framing.

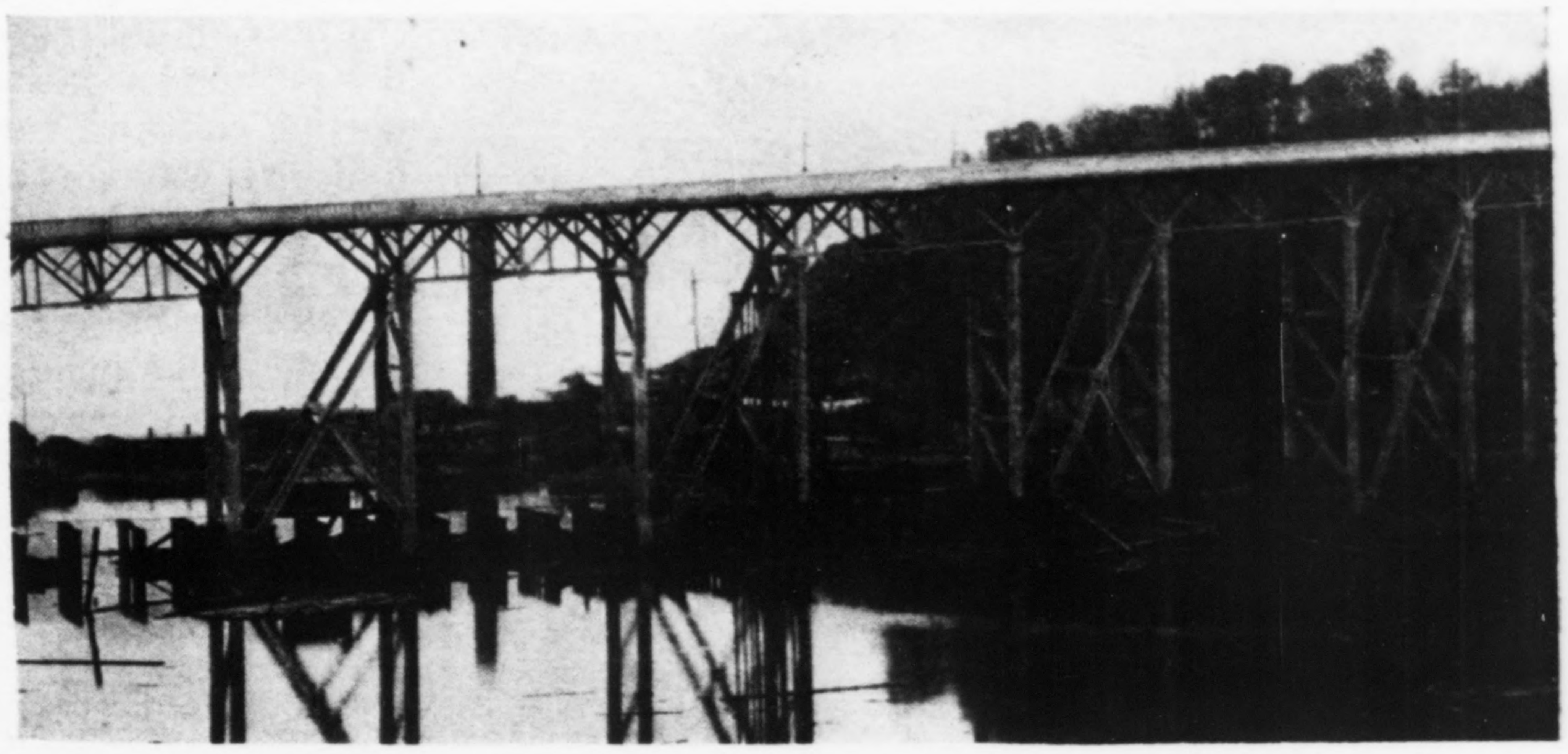

Fig. 3—Trussed section of viaduct

The length of the structure warranted a careful study to determine economic spans and bent spacing. The result was the adoption of a standard unit consisting of four full continuous spans, with the two outer ones 32 ft. and the two inner ones 36 ft., center to center of bents. At both ends of this four-span unit the deck slab cantilevered 5 ft. beyond the center of the supporting bent, terminating in the joint which provided support for the 18-ft. suspended slab between adjacent units. This suspended slab provided for expansion and contraction in the deck as a whole and also provided a certain adjustment and relief of stress should there be any slight unequal settlement in adjoining bents. This combination of spans, analyzed as a continuous structure, gave a constant slab depth of 12 in.

It was considered more advantageous to keep the slab thickness constant than to maintain a uniform bent spacing. Deflection beyond the edge of the supporting cap beams, which were 5 ft. wide, being impossible, the span length used in the calculations was the clear span only. Garfield St. is crossed at frequent intervals by switching tracks and intersecting streets, and in order to provide necessary horizontal clearances the typical span layout had to be modified somewhat, but it was possible to space the bents to maintain a 12-in. slab depth.

The expansion joint used was originated by the Seattle bridge department and has been used on several recent bridges with entire satisfaction. It was described and illustrated in the author's description of the Second Ave. extension, *Engineering News-Record,* Dec. 18, 1930, p. 981. Essentially, it consists of 3½-in. steel dowels with one end embedded in the concrete and the other incased in a steel cap. Spaced at 6-ft. centers these dowels transfer the load across the joint and permit expansion.

The four-span construction as described was continued until the height of the viaduct rendered it uneconomical. At this point the span layout was changed to three-span units (42, 47 and 42 ft.) with 6-ft. cantilevers, 6-ft. cap beams and a 25-ft. suspended slab. The slab depth for these units was constant at 14½ in.

Reinforcing steel for these roadway slabs was designed according to standard practice for one-way construction. For the 47-ft. c. to c. span the bars consist of two ⅞-in. round and one 1-in. round in a 10½-in. width of 14½-in. slab, or at a spacing of 3½ in. Over the supports at the ends of this slab the reinforcing consists of one ⅞-, 1- and 1¼-in. round bar in a 10½-in. width.

Truss Design—For the truss portion alternate designs were prepared, and alternate bids were invited on two constructions; one used a concrete deck, concrete trusses and concrete columns and footings; the other used a concrete deck, structural-steel floor beams, steel trusses and columns, and concrete footings. This section was 709 ft. long and 71 to 107 ft. high.

Estimates indicated that despite the high unit cost of the concrete in the truss members themselves the concrete construction was the more economical in first cost, as well as more economical in subsequent maintenance expense. The bids verified this conclusion. The bid for the steel-truss portion totaled $164,500.79, while the bid on the concrete alternate amounted to $139,624.99, a difference of about 18 per cent.

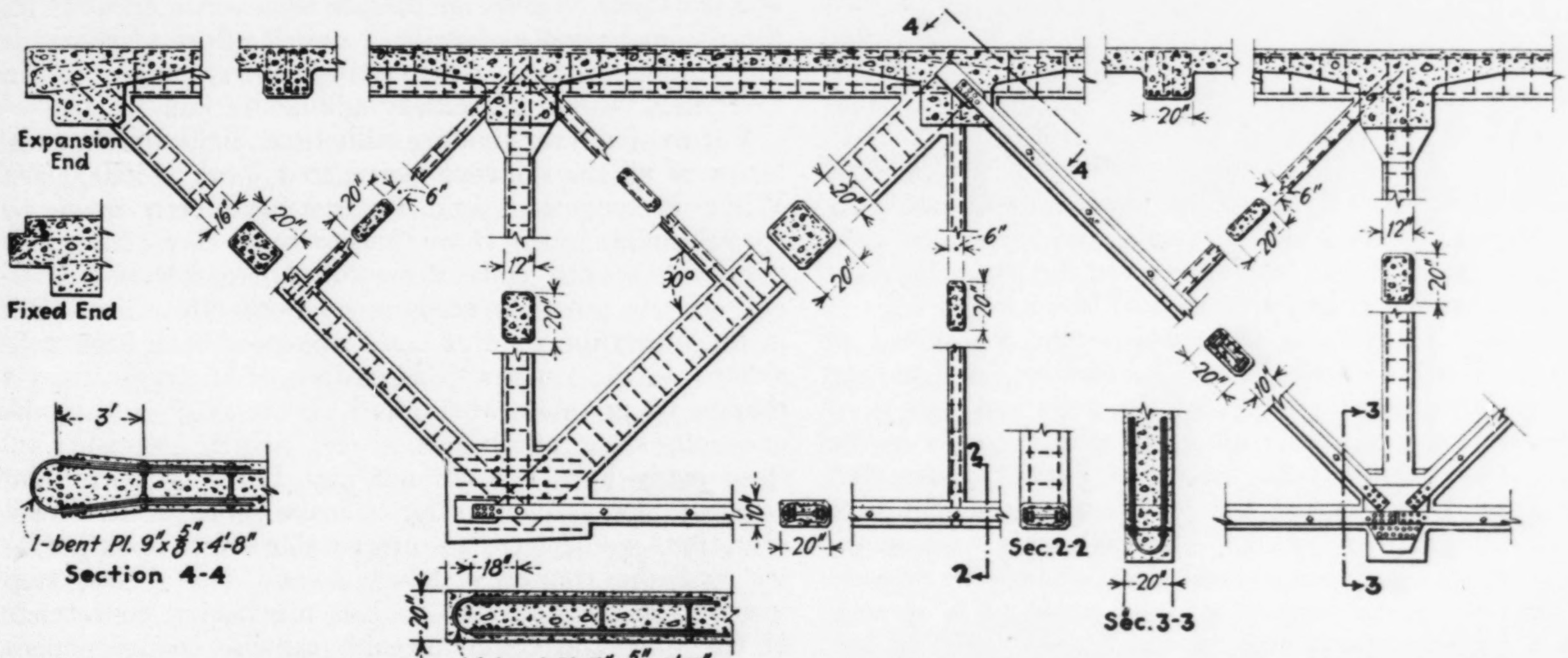

Fig. 2—Member make-up of 60-ft. reinforced-concrete truss

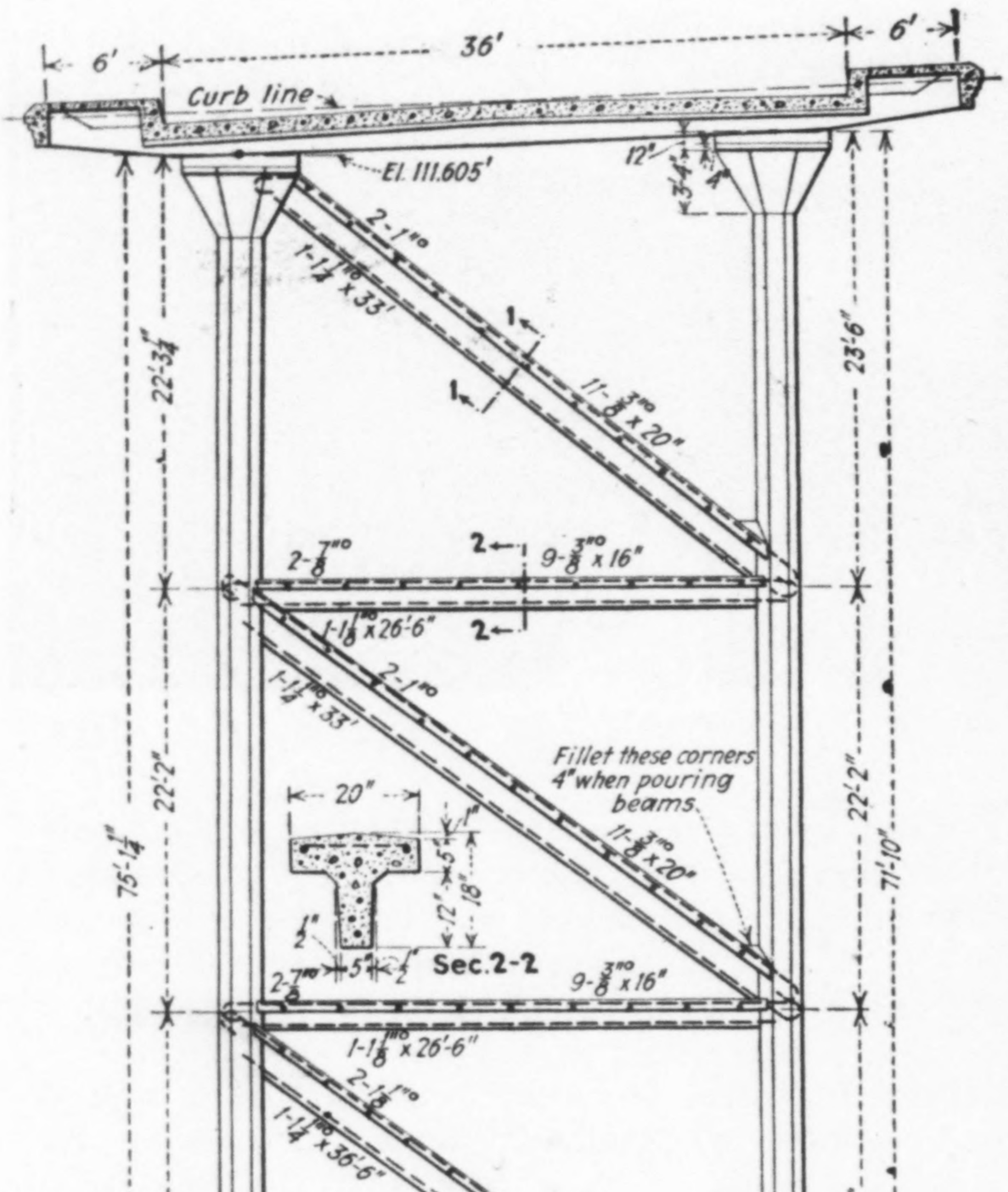

Fig. 4—Crossbracing for high-column bent

This truss portion was complicated by an alignment involving a roadway on a 500-ft. radius curve with a 6.32 per cent grade and a superelevation of 1.6 ft. in the 36-ft. width. The condition necessitated fairly short spans, and, after an economic analysis, 60 ft. was adopted for the concrete trusses and 70 ft. for the steel.

The design of the concrete trusses is similar to that used on the Admiral Way Bridge, built in 1927 and described briefly in *Engineering News-Record*, March 15, 1928, p. 440. The layout provides for 60-ft. truss spans with 15-ft. cantilever panels at both ends. A 13-ft. suspended slab spans between the cantilever ends of adjacent trusses. Dead-load moments, developed over the supports by the cantilever ends, and suspended slabs materially reduce dead load stresses in the truss chords at midspan, leaving chiefly live load to be provided for.

Principal features of the truss design are shown in Fig. 2. The lower chords and the tension diagonals are the most distinctive features of the truss and consist of flat structural-steel bars connecting with the ends of the compression members by means of curved plates that loop around and engage the concrete. These flat bars of the tension members are wrapped with wire mesh, and concrete is poured around the assembly to provide the desired size of members. It is pertinent to remark that a recent examination of the trusses built on the Admiral Way Bridge shows them to be in excellent condition without cracks in the concrete.

Concrete Placing—Both truss and deck, constituting the portion of the structure above the top of the supporting columns, were concreted in one operation. Less difficulty was encountered in these concrete operations than would have been anticipated from the experience with the Admiral Way job. A great improvement was effected by the omission of certain structural-steel bars and mesh wrapping from the top chords in the present structure. Concrete in the inclined web members was thoroughly rodded and tamped, and the forms were hammered, with the result that almost perfect placement was obtained. To eliminate the stresses that might develop in the fresh concrete as a result of unequal settlement of the supports, the trusses were carried entirely by wooden forms until the concrete had developed its full design strength. Not until that time were they grouted in to their permanent column supports and bearings.

The total cost of the improvement will be about $750,000 and is divided between the railroad companies, the port of Seattle, the general fund and an assessment district covering Magnolia Bluff.

The bridge was designed in the office of the city engineer by the late A. W. Munster, consulting engineer, with the writer in direct charge of design. Construction was executed by J. M. Clapp, engineer and contractor, under the supervision of the city engineer's forces.

Railway Consolidation for Australia

WITH THE 26,000-mile railway system of Australia owned and operated as six distinct systems by five state governments and the federal or commonwealth government, and with all of these roads suffering from continued and increasing losses of revenue, a consolidation of all the lines into one national system has been recommended on economic grounds by George A. Gahan, commonwealth railway commissioner. While federation of the states, as effected some years ago, has resulted in uniform mail and telegraph service, the railroads remain as separate systems, with no common policy to facilitate operation, effect a uniform gage, establish uniform rates, eliminate frontier boundaries or reduce operating expenses. After referring to the difficulties involved, Mr. Gahan says, "Never was it more necessary that the governments of the commonwealth and the states should subordinate local considerations for the national good and make a united effort to eliminate the economic waste which now occurs, owing to the diversified system of railway administration."

For the five years ending with June, 1930, the financial losses of all the railways aggregated some $155,000,000. While investigations and reports have been made by special commissions from time to time, these have produced no results, since these commissions have had no authority to put their recommendations into effect. But in the meantime road and air transport have been subsidized, to the further disadvantage of the railways. A change to private ownership is considered out of the question, since purchasers would find it necessary to close many lines that do not pay, reduce services and establish new rates in order to make some profit. Such conditions would have an unfavorable effect upon industry and the country's development. As a first step toward consolidation Mr. Gahan proposes a conference of the state and commonwealth railway commissioners to study the situation on a national basis and make uniform recommendations to their governments.