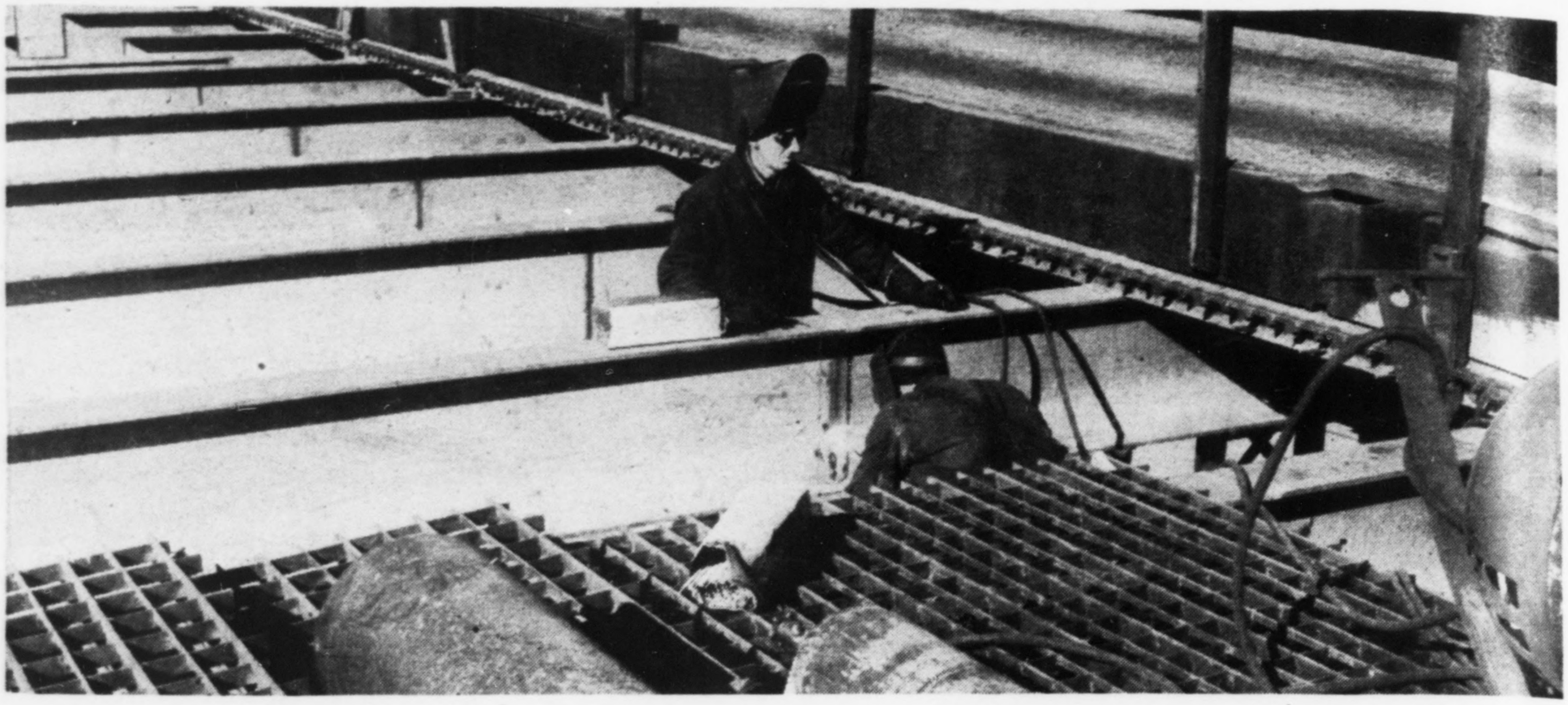

Fig. 1. Welding the wide-flange beams that carry the new steel and concrete deck on Eads Bridge at St. Louis.

Welded Highway Deck Cuts Dead Load on Eads Bridge

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***Contents in Brief**—Advantages of lessened dead load, improved gradients for vehicular traffic and increased vertical clearance for railroad tracks on the lower deck, added to economy in cost as compared with other plans, dictated the decision of the Terminal Railroad Association of St. Louis to replace the timber highway deck on steel floor beams of the famous Eads Bridge with a welded deck of steel grating on a floor system of wide-flange beams. Lightweight concrete fill was placed in the grating to minimize deck loading. By rebuilding one side of the four-lane roadway at a time, the owners completed the reconstruction without appreciable interference to highway traffic. Field welding of 11,000 connections facilitated the assembly of new steel members of the 73-year-old bridge.*

THREE possible plans received consideration by the Terminal Railroad Association of St. Louis early in 1946 when it became evident that the upper highway deck on the three main spans of the world-renowned Eads Bridge across the Mississippi River would have to be rebuilt. Except for renewals and strengthening of this deck and of the lower, railway deck during the intervening years, the bridge then stood essentially as built by James Buchanan Eads in 1867-1874. Several times during the 73 years of continuous use, the timber stringers and decking and the riveted steel and wrought-iron floor system of the highway deck had undergone repairs and renewals in kind, the last replacement of the timber portion having been made in 1934.

Renewal in kind was considered again in 1946, as was also construction of a new highway bridge superimposed on the present piers and entirely independent of the existing arches and railway deck. Neither of these possibilities could compete on a basis of cost and feasibility with a third plan, to construct a complete new welded steel floor system incorporating wide-flange floorbeams and stringers on existing columns, supporting a deck of steel grating filled with lightweight concrete. This plan best fulfilled the basic requirement of adequate strength with minimum weight, at reasonable cost.

A catalog could be enumerated of the advantages which persuaded the owner to adopt the welded steel floor system and deck grating, with lightweight concrete fill. Briefly they are these: (1) Eliminate 1,230,000 lb. of dead load on 1,536 lin. ft. of bridge; (2) increase railroad clearance from 16½ to 18 ft. on all spans, thereby decreasing locomotive blast effect; (3) increase the width of the four-lane roadway from 38½ to 41 ft.; (4) reduce highway grades and improve sight distances by lowering the deck 39 in. at the center of the bridge and raising it 9 in. at the ends; (5) increase the load-carrying capacity from a weak H-15 to a strong H-20;

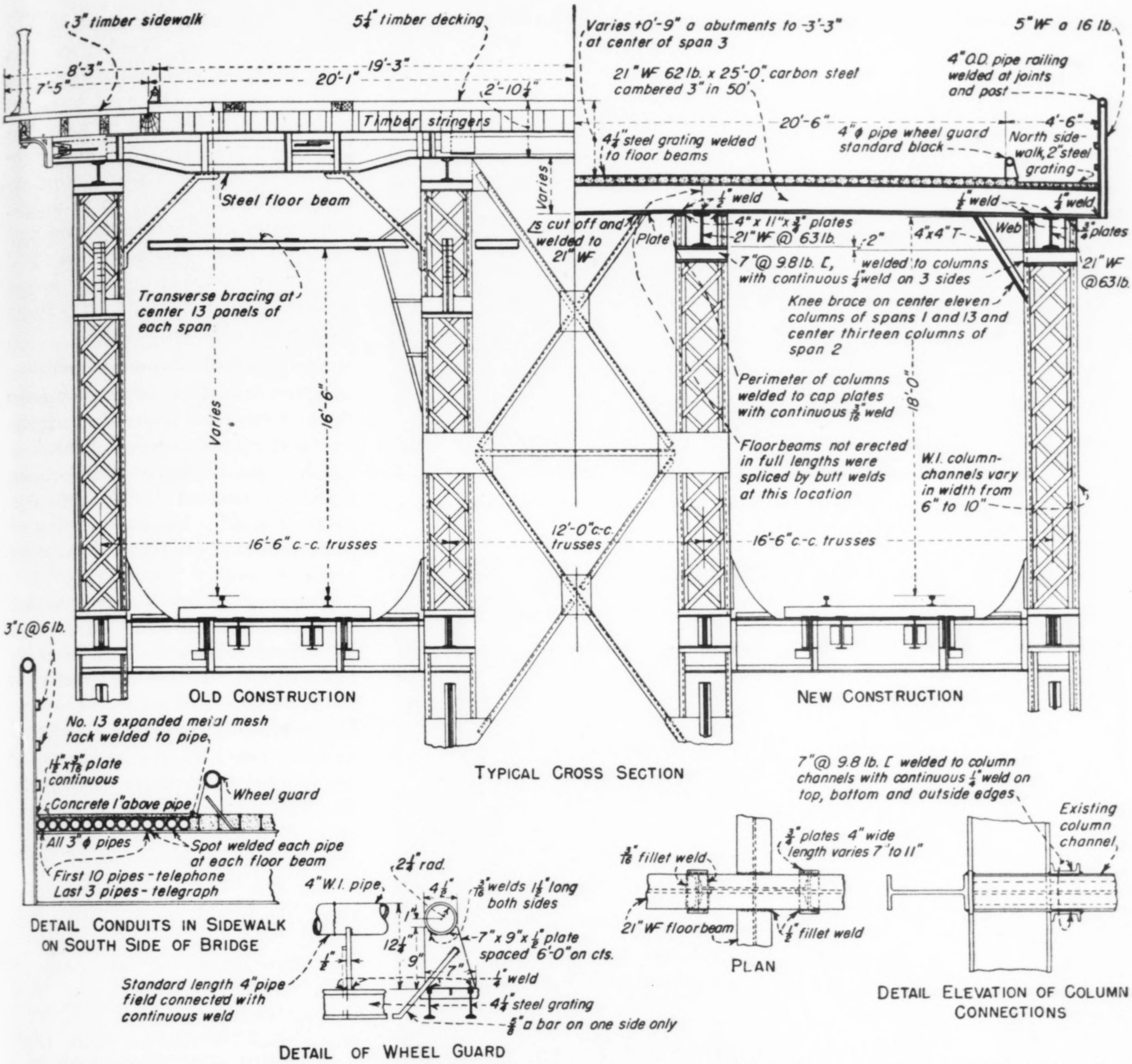

Fig. 2. Reconstruction of upper deck of Eads Bridge, using steel grating with lightweight concrete fill on wide-flange floor-beams and longitudinal beams, with all connections field-welded, reduced the dead load 810 lb. per lin. ft., improved the width and gradients of the four-lane roadway, and increased vertical clearance above railroad tracks on the lower deck.

(6) save an estimated $30,000 over replacement in kind; (7) extend the estimated service life from 15 years to 50; (8) obtain a non-combustible structure; (9) improve the lateral and longitudinal rigidity against wind; (10) improve the riding qualities of the roadway, with greater safety at high speeds.

The design that encompassed these advantages is shown in Fig. 2. As a foundation for understanding the overall scheme, a word should be said about the three channel spans of the Eads Bridge.

Scope of the new work was limited to replacement of the highway deck and its floor system on the three river spans, which are 502, 520, and 502 ft. long. Each of these spans is made up of four hingeless arches spaced on 16½-12-16½-ft. centers. Each arch consists of two tubular ribs 18 in., in diameter, spaced 12 ft. radially and tied together with a web system of eyebars. The tube forming each rib is made up of six chrome steel staves inside a wrought-iron envelope.

Limitations of steel manufacture, fabrication and erection in 1870 required the use of short structural members, and a panel length of about 12 ft. was adopted. Rib sections are of about this length, with the six staves in each section being banded and machined at the ends with grooves into which the split couplings fit. The staves were tested in a machine built for the purpose to a tensile stress of 50,000 to 60,000 psi. without reaching their elastic limit, indicating an ultimate strength of 120,000 psi. or more.

Steel specifications for this bridge are thought to be the first in the United States to employ the two terms, modulus of elasticity and elastic limit. Original design stresses for steel were 30,000 psi. in compression and 20,000 psi. in tension. A safe working stress today for main members is considered to be 40,000 psi. in compression, although few members are ever that highly stressed.

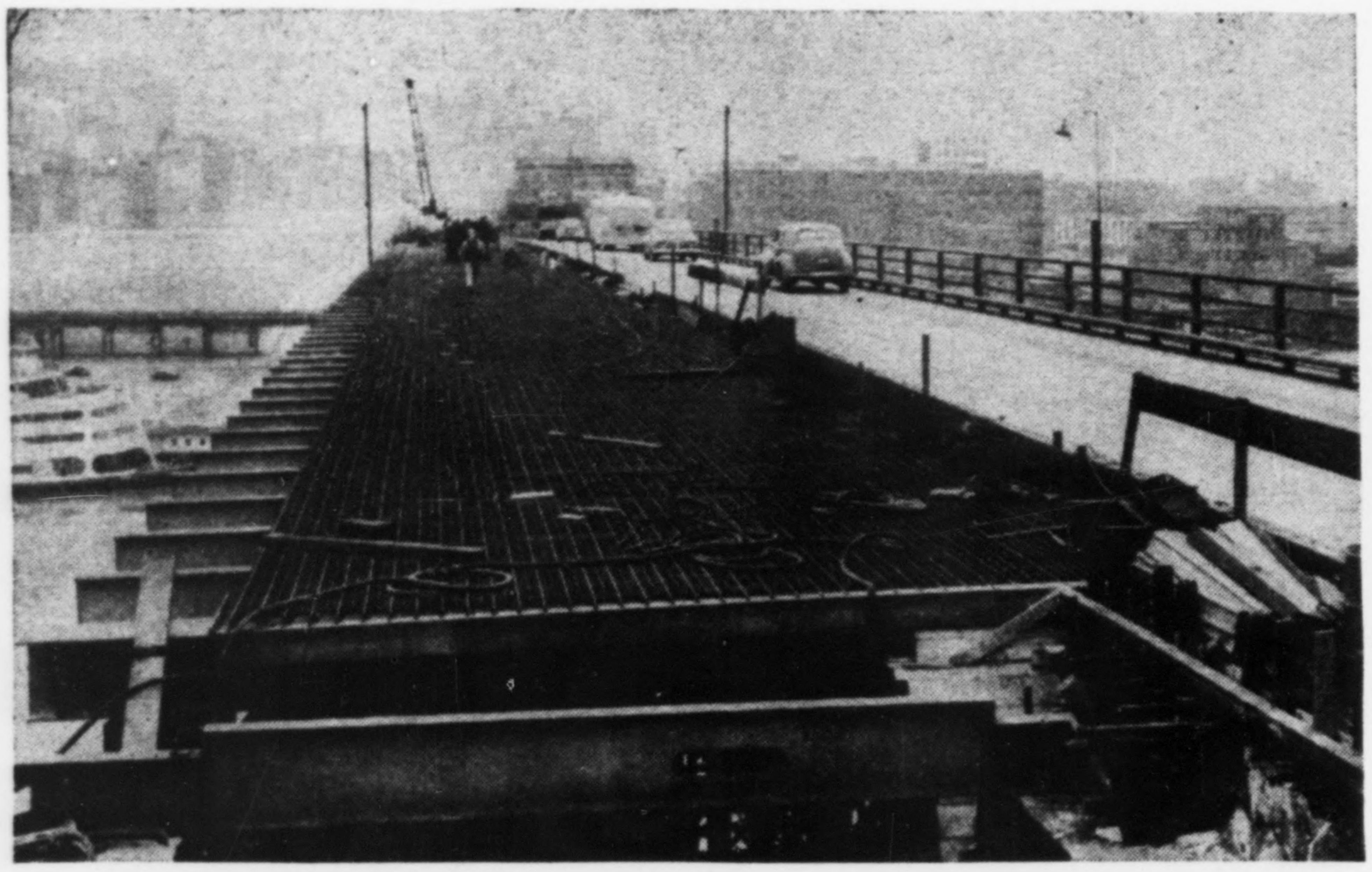

Fig. 3. Expansion devices transmit the wind load stresses to the masonry piers from the all-welded floor system and deck.

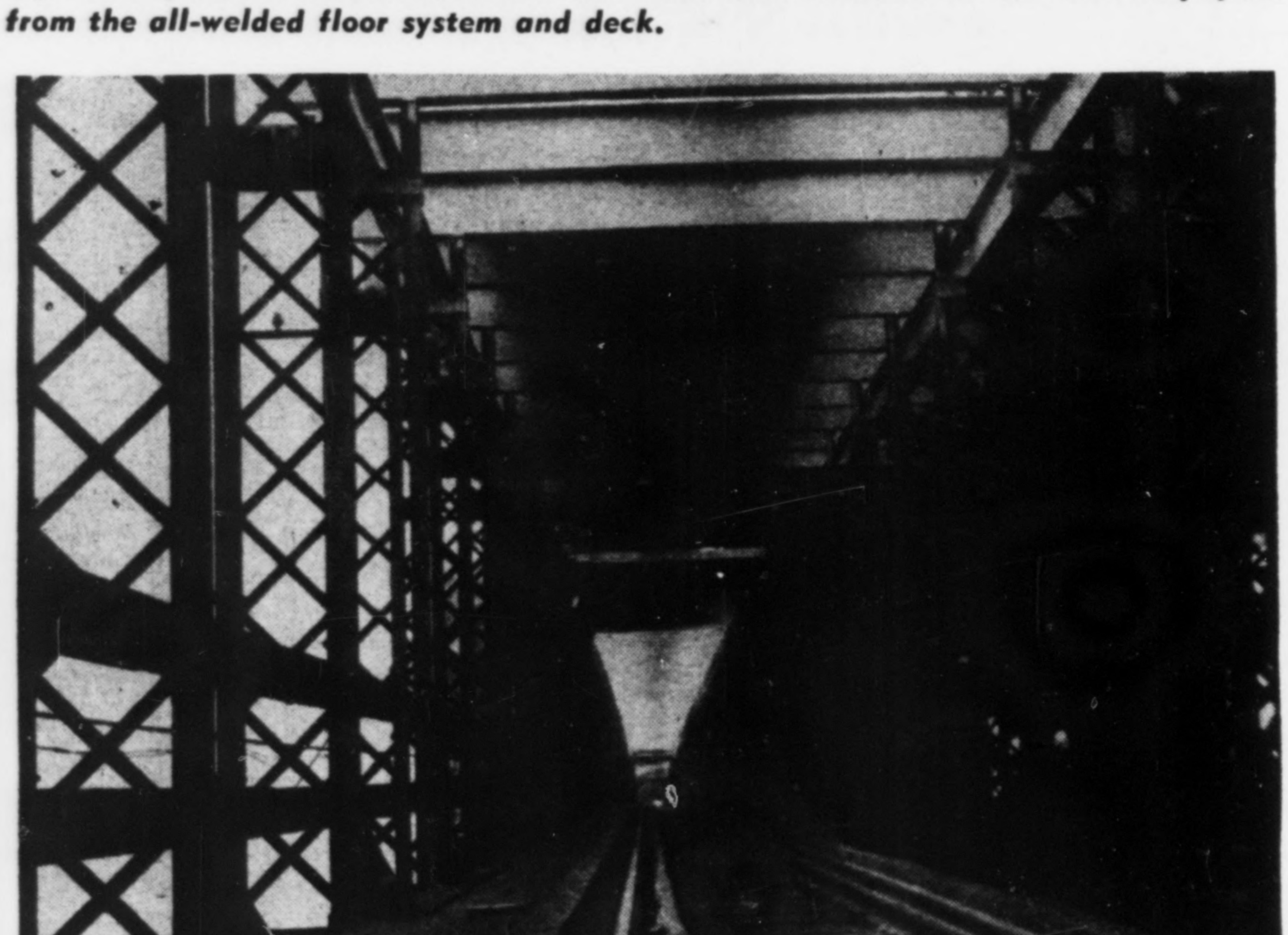

Fig. 4. Floor system and supporting columns as viewed from lower deck. Increased clearance is gained above the railroad tracks on the lower deck by eliminating the old lateral bracing below the roadway floor system. The old bracing is shown in Fig. 2 on the preceding page.

Arch ribs were erected by means of tiebacks without falsework. The double-ribbed, fixed arches are braced transversely by pipe struts and adjustable rods and diagonally by adjustable rods. Deck loads are carried to the upper ribs through channel columns to pins which pass through the couplings.

Use of short panels in the original design resulted in a profusion of joints and a multitude of surfaces in action. On the three arch spans there are 1,048 splices of main members, some of which have a reversal of stress with the passage of each train; fortunately these connections are few and are the least highly stressed. Despite the many surfaces in action during nearly three-quarters of a century, there is not now, nor has there ever been, a loose joint or connection of a main member or any signs of fatigue, distortion or wear. The bridge stands today as an admirable example of thoroughness of design and precision of fabrication and erection.

Reconstruction of the highway deck was a matter of necessity and not of choice. Studies undertaken several years ago showed that 90 percent of the floorbeams needed, or would soon need, replacement. Timber stringers were softening and failing rapidly at bearing points. The wind truss was so badly corroded that its value was highly questionable. Stability of the timber decking in a strong wind depended almost entirely on its weight. Portions of the floorbeams were remnants of those originally placed in the bridge; considering their loss in sectional area, they could carry 20-ton truck loads only out of habit.

Welding facilitates reconstruction

A forest of 524 columns supports the highway deck above the arch ribs on the three main spans. Because of the short panel lengths of the original design, a total of 11,000 field connections had to be made during replacement of the highway deck, to the grades as built.

This myriad of connections, and the necessity of carrying out the work on a field fabrication and assembly basis, dictated welded construction of the replacement structure. There was, for practical purposes, no standardization of panel lengths or spacing of the individual members of the highway floor system. For ease and economy of erection, it was imperative that a system be employed which would avoid the tedious and costly steps of riveted construction: individual field measurement, detailing and shop layout for fabrication of each member installed, plus field drilling and reaming of over 4,000 connections of two or more rivets each, and riveting of over 7,000 other connections.

For these and other good reasons, the new highway deck is all-welded. As indicated by Fig. 2, the design adopted and built consists of 4¼-in. steel grating (in fabricated panels incorporating longitudinal I-beam on 6-in. centers) welded to 21-in. 63-lb. wide-flange floorbeams spaced about 6 ft. c. to c. and supported by four lines of similar wide-flange longitudinal beams and the original wrought-iron columns. Without the use of welding, a steel grating deck could not have been used; weight of a reinforced-concrete slab on this bridge would have been prohibitive.

With the use of welding, a wind truss originally built into the plane of the highway deck has been eliminated, and its responsibility now falls

upon the welded decking and floor system. This improvement accounts for a large portion of the overall saving in weight. Welded construction, in addition, permitted the erection of 1,350,000 lb. of structural steel without any shop fabrication, allowing the purchase of steel at mill prices.

Structural steel for the new floor system and deck is all ASTM serial A-7. Silicon steel was considered but was discarded because of poor weldability. Steel grating employed for the deck incorporates its own bottom form for concrete. Lightweight concrete, delivered by truck mixer to the point of placement, was used to fill the grating. The concrete contained a lightweight aggregate produced by burning shale to clinker and crushing the clinkers to size. Weight of the steel grating, without concrete fill, is 13.2 lb. per sq. ft. A fill of ordinary concrete is estimated to increase this weight by 42.3 lb. per sq. ft. With the lightweight aggregate used in the concrete on the Eads Bridge deck, the weight is increased by only about 28 lb. per sq. ft. above the weight of the grating alone.

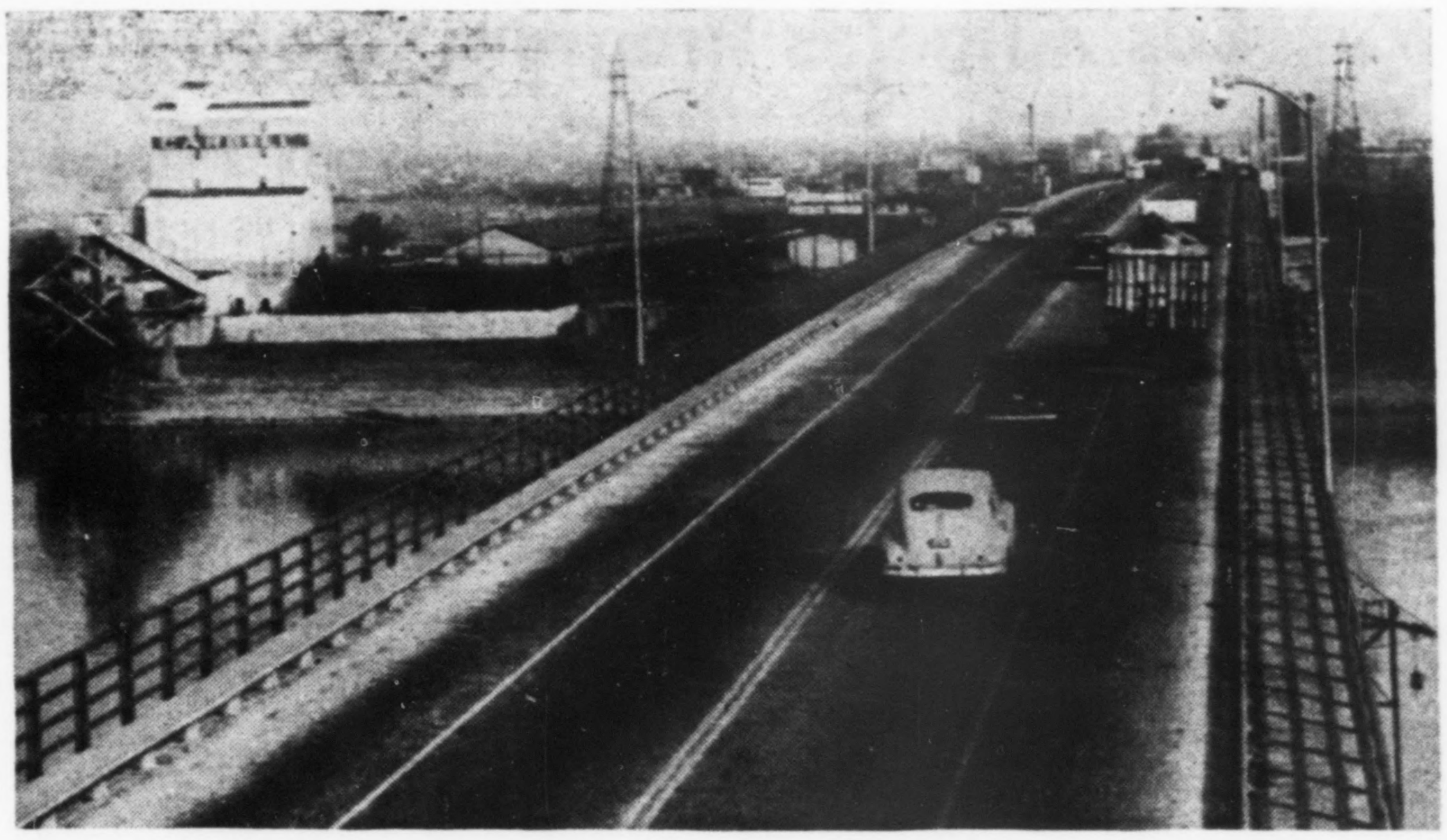

Fig. 5. The new deck has better grades than the old one due to being lowered 39 in. at the center and raised 9 in. at each end.

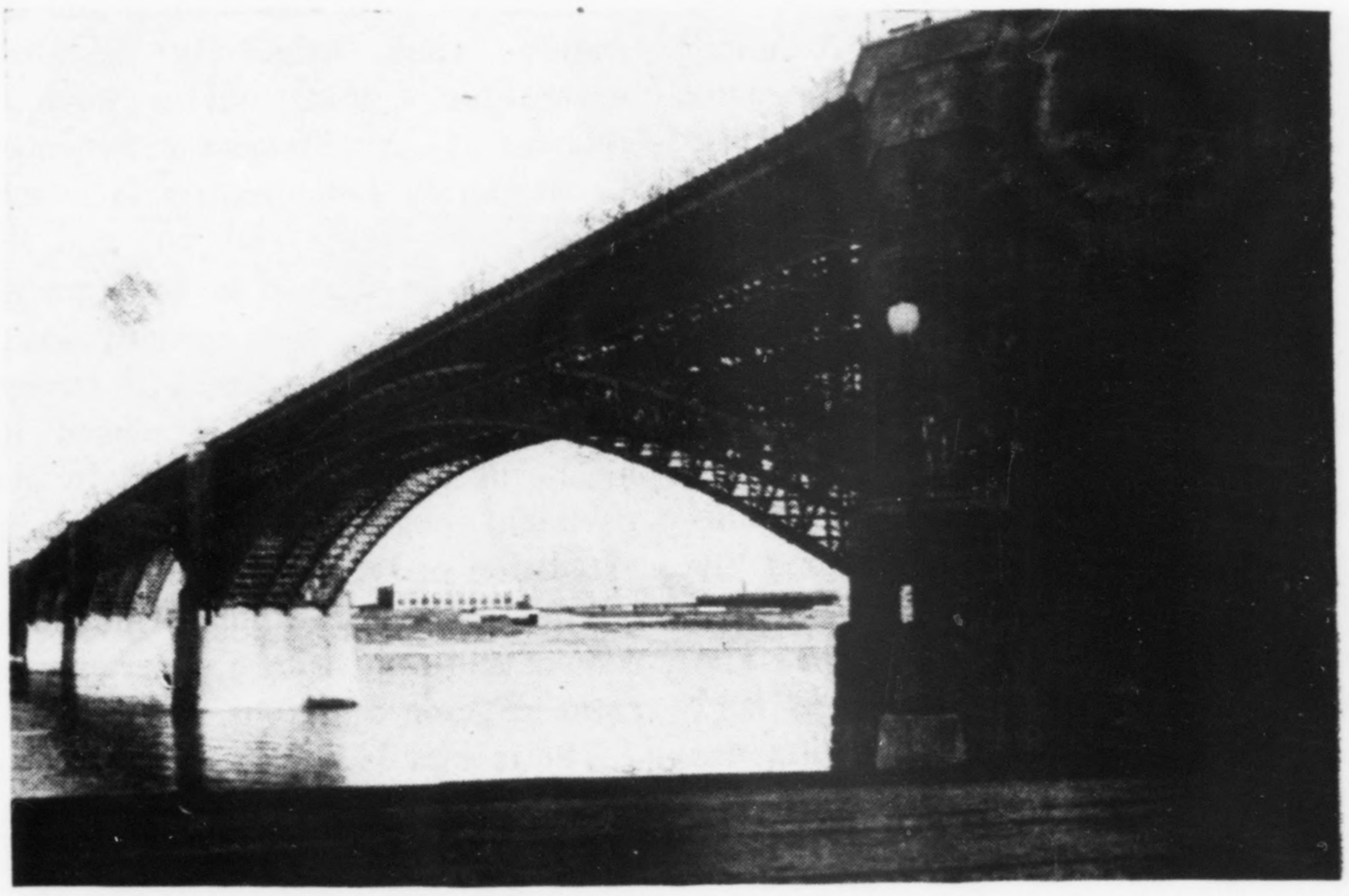

Fig. 6. The new deck has in no way detracted from the gracefulness of the Eads Bridge which has been a St. Louis landmark for 73 years.

Deck replacement operations

Contract for the erection was awarded on a cost-plus basis to William J. Howard, Inc., Chicago, and field operations began on June 10, 1946. Work of burning old beams and welding new ones in place was started in the center span on the downstream side and was prosecuted toward both ends simultaneously, returning on the upstream side.

It was required during construction that two lanes for highway traffic be kept open without interruption and one railroad track be live at all times and the other one live except during working hours. These requirements were met, and the reconstruction of the upper deck and floor system caused but few minor delays to highway and railroad traffic.

Delays in delivery of steel prevented scheduled completion of the work by Jan. 1, 1947, but the job was finished and the contractor released on April 22. Concreting of the entire vehicle deck was completed and the four lanes were open to traffic March 17, 1947.

All longitudinal beams were erected continuous for the full length of the spans by butt-welded splices, and likewise the floorbeams were erected continuous for the full width of the bridge by butt-welding those that could not be erected in full lengths, with 100-percent penetration obtained by welding both sides of the joint. In general, two passes welded each joint, usually a $\frac{5}{32}$-in. stringer bead followed by a $\frac{5}{32}$- or $\frac{3}{16}$-in. cover pass.

Nearly all welding on the job was standard $\frac{1}{4}$-in. fillet, requiring two passes. Coated welding electrode was used throughout. At the peak, the job operated nine welding machines, eight 300-amp. and one 400-amp. The maximum employment was about 90 men, working on one shift.

Total cost of the reconstruction, less $40,000 salvage value of materials removed, was $392,000, of which 71 percent represents construction cost. No separate record was kept of welding cost. Quantities of materials involved were: 1,345,000 lb. of structural steel; 941,400 lb. of $4\frac{1}{4}$-in. roadway grating; 45,000 lb. of 2-in. sidewalk grating; 850 cu. yd. of lightweight concrete, and 425 cu. yd. of structural concrete. Carnegie-Illinois Steel Co. supplied steel and grating.

The engineering work was performed by the engineering department of the Terminal Railroad Association, of which H. Austill is chief engineer, L. T. Casson, bridge engineer, and N. J. Law Jr. assistant bridge engineer. For William J. Howard, Inc., contractor, Chicago, Steve MacEachern was field superintendent, under A. S. Burns, general superintendent.