Pump delivers concrete for Dubuque bridge deck

CONCRETE FOR THE DECK of the Iowa approach of the highway bridge under construction across the Mississippi River at Dubuque, Iowa, was delivered by a concrete pump machine located at ground level. Rapid and economical construction with a small crew resulted.

The approach, which crosses 18 railroad tracks, is 1,460 ft. long and consists of 17 continuous plate girder spans varying in length from 44 to 187 ft. Where it joins the main river crossing the deck is about 50 ft. above ground level. A 24-ft. roadway, a 5-ft. sidewalk, and a 2-ft. safety walk are provided. The 8-in. thick deck is reinforced in the transverse direction by two layers of $\frac{5}{8}$-in. round bars on $5\frac{1}{2}$-in. centers and longitudinally by $\frac{5}{8}$-in. bars on about a 1-ft. spacing 2 in. from the under side and by $\frac{1}{2}$-in. bars on about a 9-in. spacing near the surface.

Placing starts at one end

Placing of the concrete started at the extreme west end and advanced eastward. The concrete was supplied at the rate of about 20 cu. yd. per hour by the 4-bag mixer shown in an accompanying photograph. The mixer was used at three different locations, and at each location concrete was pumped about 250 ft. each way by a single-chamber pump through a single 6-in. dia. pipe. At the last location the pump not only had to move the concrete 250 ft. horizontally but had to lift it 60 ft. vertically. A $1:2:3\frac{1}{2}$ mix requiring $7\frac{1}{4}$ sacks of cement and 5 gal. of water per cu. yd. was used. To move the mixer forward required but one day's work for a 10-man crew. Thus, once concreting started only two days were lost in moving the plant forward.

The full width of the roadway was paved in one operation and the sidewalk later with a small mixer operating on the completed portion of the deck. It was unnecessary to pave the safety walk as it was of steel construction.

Plywood forms used

Forms for the concrete deck consisted of $\frac{3}{4}$-in. thick plywood over 2x6-in. transverse joists on 16-in. centers spanning between the floor stringers, which were on 7-ft. centers. The joists were supported by 2x10-in. longitudinal timbers supported by wedges on the lower flange of the stringers. Sufficient materials were available for constructing the forms for 1,100 ft. of the roadway. The forms were left in place seven days and they were stripped by workmen on a swinging scaffold supported from the handrails of the bridge by four sets of blocks and falls.

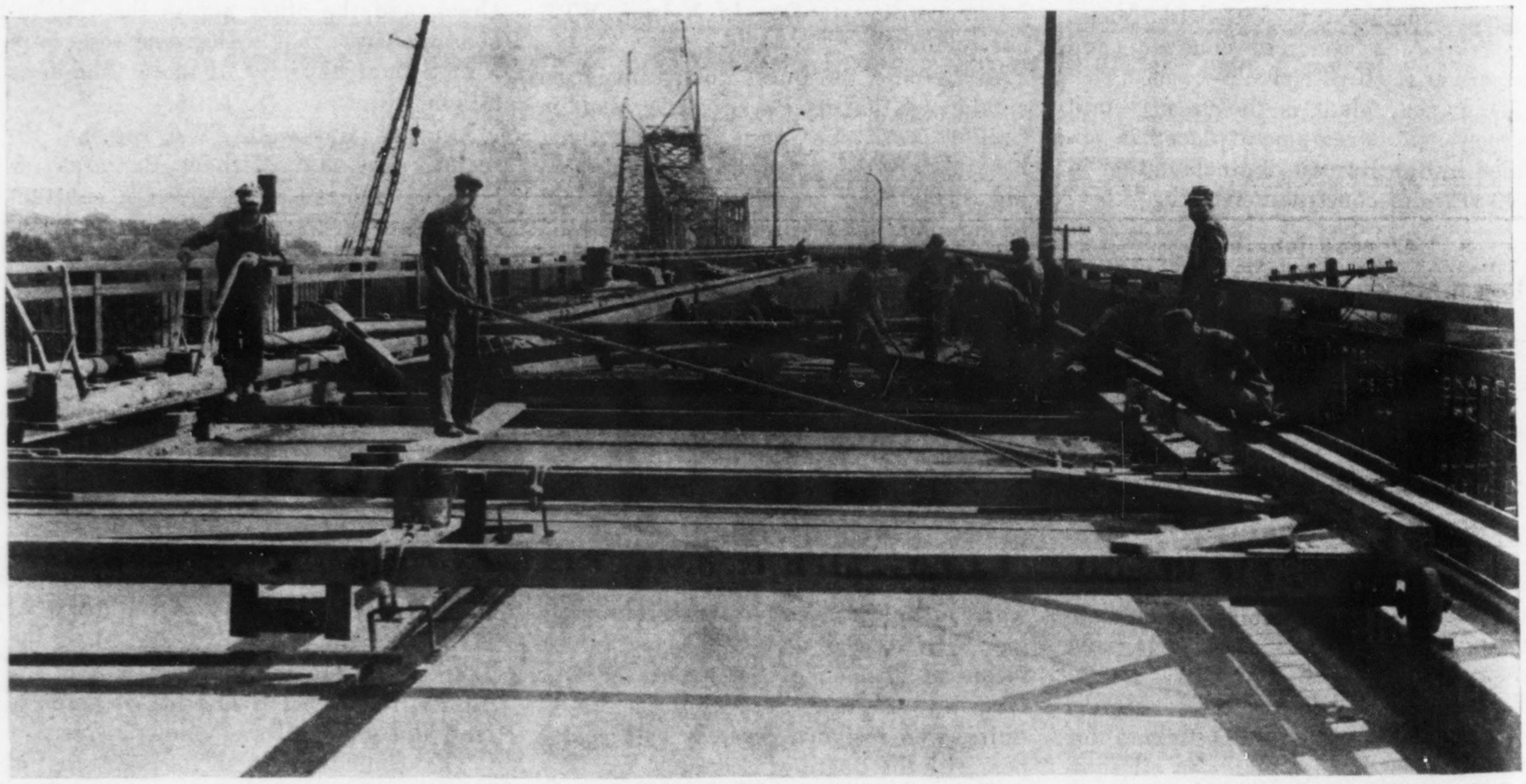
In paving the roadway a 20-man crew, including the foreman, timekeeper and superintendent, worked one 10-hour shift and on a good day concrete was placed for as much as 100 ft. of the deck. The concrete placing procedure was as follows: After the concrete had been vibrated in place with a single pneumatic vibrator, it was smoothed by a transverse hand screed, checked by a 10-ft. longitudinal straight edge, floated by a 12-in. wide longitudinal bull float handled by two workmen, and belted with a 15-in. wide belt handled by two workmen.

Integral center stripe required

Construction of an 8-in. wide integral marker along the centerline of the roadway was necessary. It was constructed about one hour after the concrete was placed by rubbing into the top $\frac{1}{4}$ in. of the 8-in. width magnetic iron oxide at the rate of $2\frac{1}{2}$ lb. per 100 ft. How two 10-ft. long steel angles were used to great advantage to confine this work to the desired 8-in. width is shown by an accompanying photograph.

Curing of the completed concrete roadway was by addition of a thin transparent sealing membrane. This surfacing was added after the center stripe had been colored and about 2 hr. after placing the concrete.

The only expansion joints in the deck are those corresponding with those in the



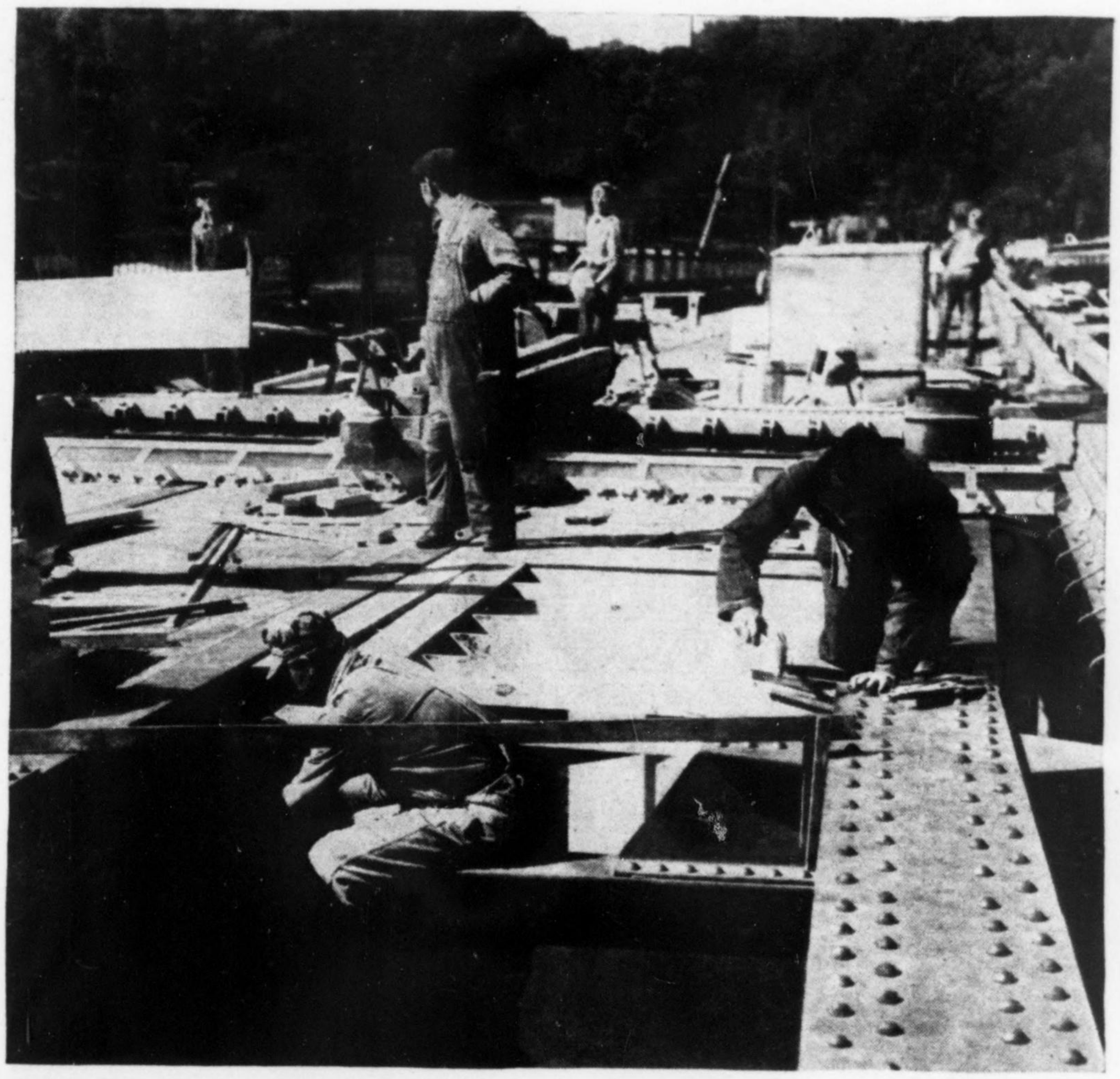
Hruskq Photos

Concrete for the deck of the bridge approach is delivered by a 6-in. pipe. Placing equipment shown includes a pneumatic vibrator, transverse screed, longitudinal 12-in. bull float and a 10-ft. long straight edge. Two steel angles are used to confine carbon black oxide to the upper ¼-in. of the 8-in. c enter stripe. Construction of the continuous, three-span trusses for the main channel is shown in the center background.

steel girders, which means that in some places they were as much as 530 ft. apart.

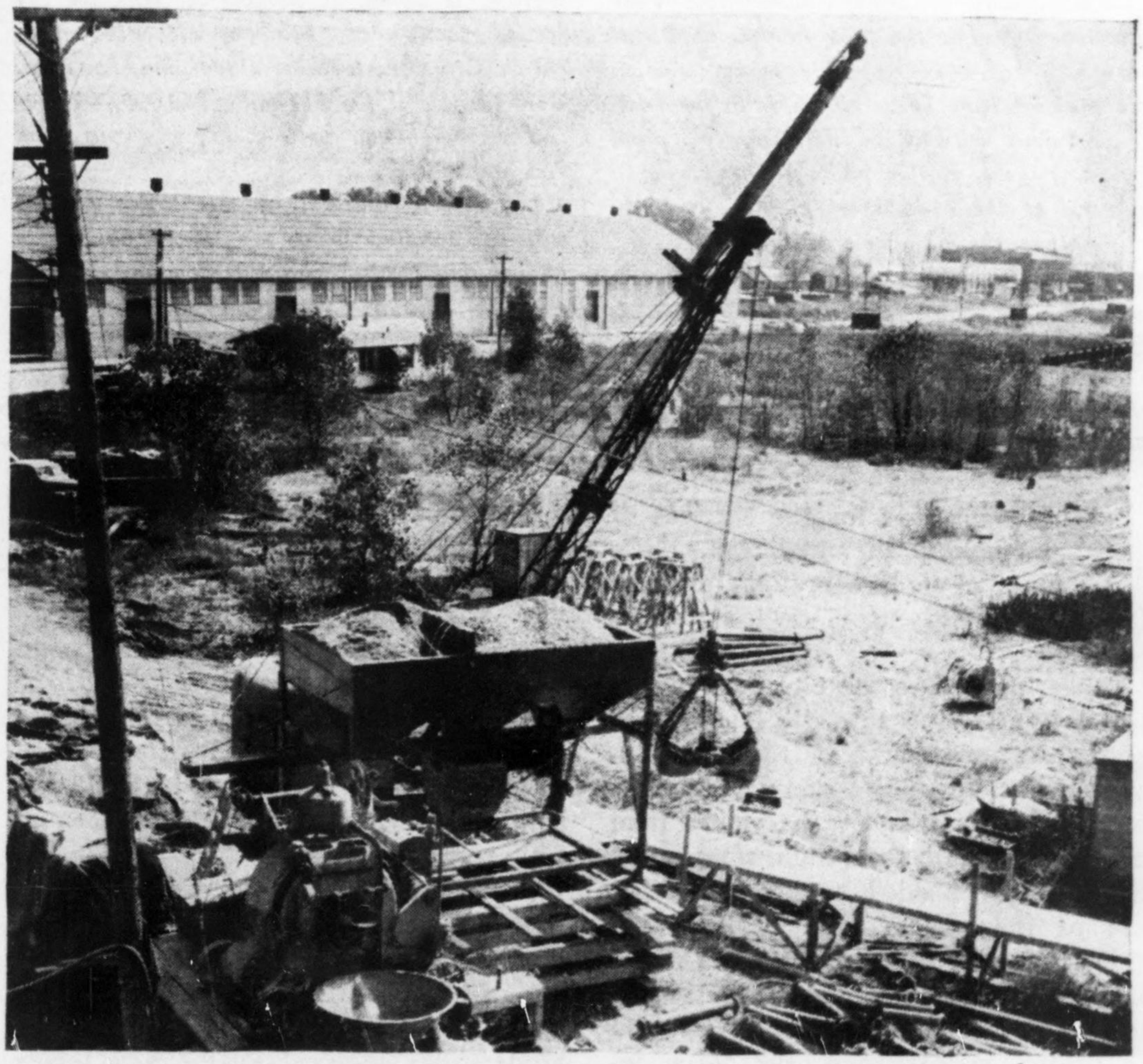
For the concrete deck and walk of the Iowa approach 890 cu.yd. of concrete and 118 tons of steel were required. Paving the approach required six weeks, including a week lost due to slow material deliveries.

Melberg & Taylor, Cedar Rapids and Decorah, Iowa, with C. B. Taylor, superintendent, did the work for Bethlehem Steel Co., the general contractor for the superstructure work. The latter organization, which is represented on the job by W. W. Oskin, resident engineer, supplied the steel and the paving contractor all other materials and the labor and equipment. The bridge is being built by the City of Dubuque Bridge Commission at a cost of $3,500,000. Howard, Needles, Tammen & Bergendoff, Kansas City, with Ivan P. Hanson, resident engineer, are the consulting engineers for the crossing, which is to be opened early in 1943.



Forms for the concrete deck consisted of 3/4-in. thick plywood over 2x6 in. joists on 16-in. centers, supported by 2x10-in. longitudinal timbers carried on the lower flange of the steel stringers. Wedges of the type at left proved very satisfactory.

Concrete was delivered at the rate of 20 cu. yds. per hour. It was spread by hand and vibrated in place. The deck was constructed in sections, according to a predetermined sequence.



Concrete plant consisted of a 4-bag mixer driven by a 35-hp. gasoline engine, and it was equipped with a single-chamber pump. Concrete was pumped 250 ft. each way from the mixer through a 6-in. dia. pipe. To move the plant forward required but one day's labor for a 10-man crew.

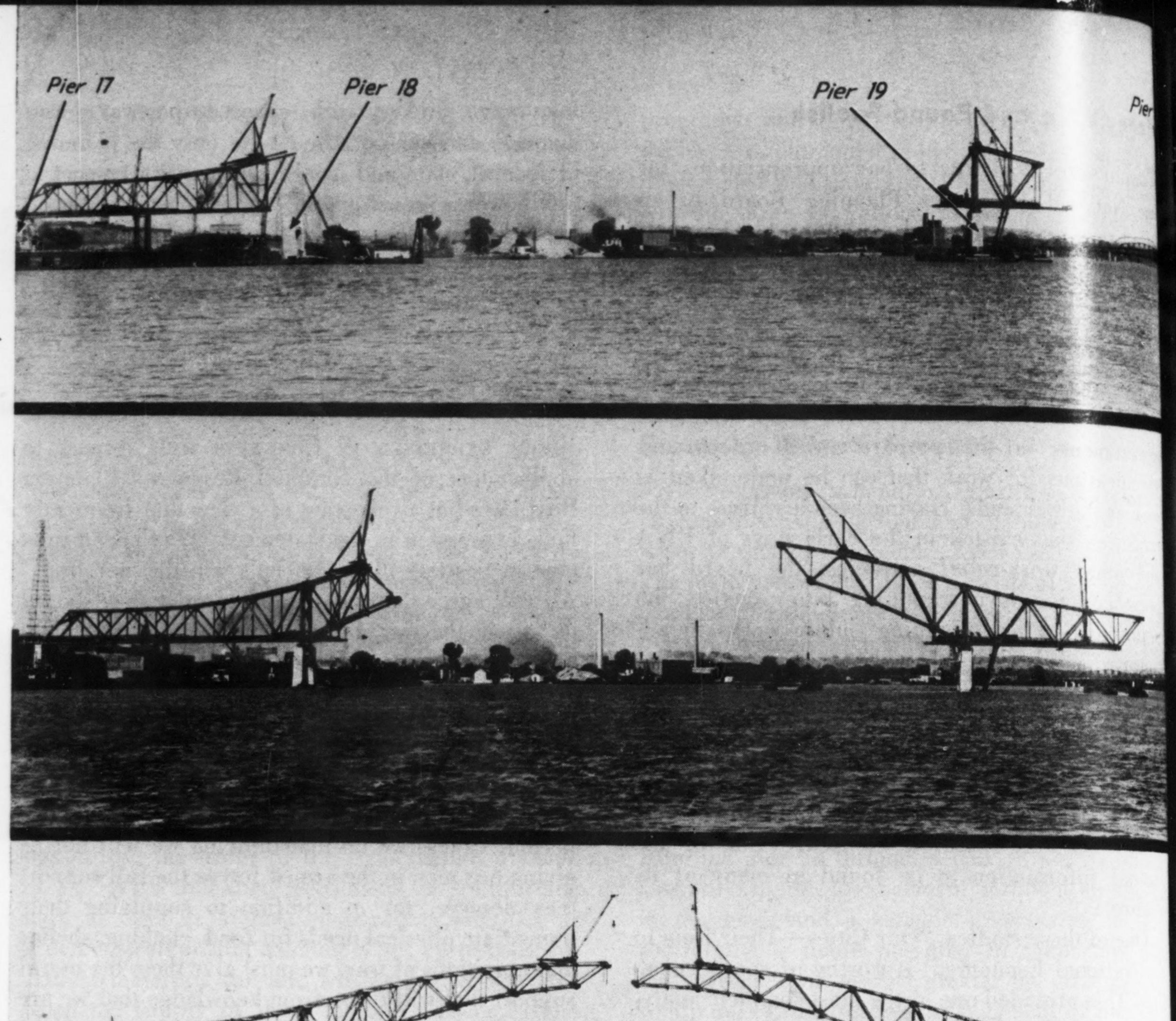


Fig. 1. Construction of the west half of the trusses eastward from Pier 17 required two falsework bents in the end span. One of the bents had been removed when the top picture was taken. By cantilevering both ways from Pier 19 no falsework bents were required in erecting the east half of the trusses. After the connecting members had been erected to complete trusses, top chord travelers erected the hangers, ties, and floorbeams as they backed away.

Fig. 2. Flanked by girder approaches, main crossing is a 3-span truss with central span a tied arch. View is from Iowa side.

A Three-Span Continuous Truss Bridge With the Middle Span a Tied Arch

***Contents in Brief*—Central portion of a new Mississippi River bridge at Dubuque is a 3-span continuous truss with an 845-ft. middle span built as a cantilever and made a tied arch by addition of bottom chord tie members. The structure also is uncommon, possibly unique, in the way expansion is accommodated. At the end piers 8-ft. long rocker columns are employed, at both ends of the arch the usual expansion shoes riding on nested rollers are provided under each truss, and at the east end of the arch a large pin embedded at the center of the pier extends upward into the floorbeam to carry the longitudinal wind load without producing torque in the pier.*

To REPLACE an old crossing built in 1887, a continuous truss structure of a type uncommon to American bridge building is now under construction across the Mississippi River at Dubuque, Iowa. A 3-span continuous truss unit with 347-ft. side spans and an 845-ft. central arch is employed for the main river crossing. The middle span was built as a cantilever, and when the trusses had been joined at the middle of the arch, the hangers, floor system and bottom chord ties were added to make what is believed to be the second continuous-truss, tied arch bridge in the United States; the first American crossing of this general type is the Meramec River Bridge south of St. Louis, which was described in *ENR*, June 5, 1941, p. 896. In addition to the design, the Dubuque bridge is of interest because of the erection methods followed.

One of the first designs considered for the main river crossing consisted of two central 600-ft. tied arch spans, but objection arose as to the location of the central pier and a longer span at the middle of the river was ordered by the Corps of Engineers. Other designs studied included a suspension bridge and a straight cantilever. However, the design now nearing completion proved most desirable on account of reduced steel requirements, other economies in construction, and general appearance.

The steel savings possible with the crossing soon to be completed result from two conditions: (1) inherent savings in the design followed and (2) few members had to be strengthened for erection purposes. This latter saving follows from the fact that the trusses during erection are considerably lighter than would be possible with a conventional cantilever or a continuous truss structure, since with the design used about 50 percent of the steel for the central span can be erected after the trusses have been completed. In addition, the long central span permits the west channel pier to be so located as to cause no interference to river traffic, which is especially important because of the Dubuque docks at the west end. Also, the limited number of steel members required at roadway level in the central span permits motorists and pedestrians to obtain an almost unobstructed view of the Mississippi River.

Bridge spans many railroad tracks

Overall length of the all-riveted structure being built, which will provide a 24-ft. roadway, a 5-ft. sidewalk, and a 2-ft. safety walk, is 5,760 ft. At the west or Iowa end, 17 continuous girder spans, varying in length from 44 to 187 ft., are used, and at the east end 23 similar girders of 85 to 184 ft. are employed. The bridge crosses over 29 tracks of four different railroads with many of the piers built on a skew. Clearance above high water at the middle of the central span is 50 ft. The new crossing will carry Highway U. S. 20 across the river on a new alignment that will require a 3-degree curve in the west approach and a 6-degree curve at the east end.

The design was for an H-20 live loading, conforming to the 1935 Specifications of the American Association of State Highway Officials, with supplemental provisions suitable to the unusual length of the main span. Center to center of the trusses for the 3-span unit is 35 ft. and the length of all panels is 38 ft. 5 in. The trusses, as measured from the center lines of the chords, are 70 ft. deep over the piers at the end of the central span and they reduce to 24 ft. at the center of the arch. The roadway at the arch center is about 102 ft. below the bottom chord of the trusses.

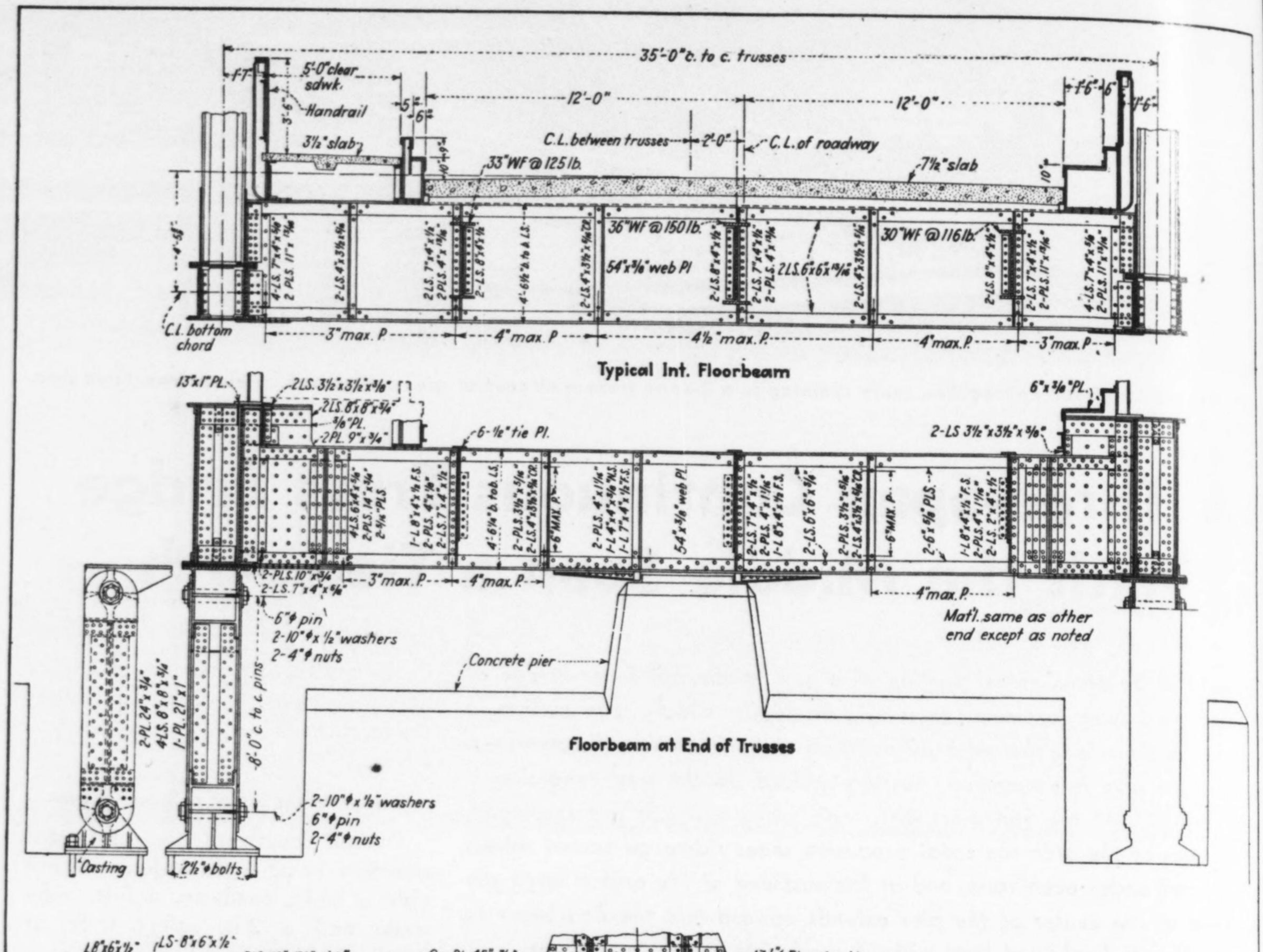


Fig. 3. Most floorbeams for truss spans are of top design, which also shows roadway details. Ends of trusses are supported by 8-ft. long rocker columns; since columns were not designed to carry transverse wind loads, this load is transferred to pier through floorbeam by strengthening this member at the ends and adding brackets each side of pier top. At each end of middle span floorbeams have double webs. That at Pier 19 accommodates pintle pin that carries the longitudinal wind and fraction loads for entire 3-span unit. A structural framework encased in concrete near top of pier is provided to support pin, as shown by lower right detail.

Top and bottom chords are of very similar construction and consist of two I-beams varying in depth from 24 to 36 in., cover plates top and bottom, and side plates as required. The aggregate cross sectional area of a single chord varies from 64.13 to 248.72 sq. in. The diagonals are mostly two channels and a cover plate on each side; these members vary in gross area from 28.8 to 85.9 sq. in. The typical hanger is a 19-in. wide plate and four bulb angles, giving a cross section of from 20.34 to 27.06 sq. in. The bottom chord ties in the central span are each made up of two 24-in., 120-lb. I-beams, a 32-in. cover plate top and bottom, and 20-in. side plates, varying in thickness from $\frac{3}{4}$ to $\frac{7}{8}$ in.

A typical interior floorbeam consists of a 54x$\frac{3}{8}$-in. web plate and two 6x6x$\frac{13}{16}$-in. angles. However, over the piers at the end of the arch 74-in. deep box girders with two 74x$\frac{5}{8}$-in. web plates, two 45-in. cover plates. and four 8x8x$\frac{3}{4}$-in. angles top and bottom are used. Three lines of stringers are employed. That at the center is a 36-in., 150-lb., wide flange beam, that on the sidewalk side a 33-in. 125-lb. member, and the third a 30-in., 116 lb. beam. Spacing of stringers and a cross-section through the roadway are shown by Fig. 3.

Rocker columns at the ends

At both of the end piers of the 3-span central unit rocker columns about 8 ft. high are used as expansion shoes. This height of rocker was necessary to conform to the space required for the vertical jacking operations during erection. Expansion shoes also are provided at both ends of the arch span. Each of these four shoes is carried by a nest of five 12-in. dia. carbon steel rollers 5 ft. 8 in. long.

At the east end of the arch, at Pier 19, a large pintle pin is embedded at the center of the pier. It is supported by an encased structural frame and extends up into the floorbeam. This pin, which is of forged steel with a 5-in. dia. hollow center, is 4 ft. $4\frac{1}{2}$ in. in overall length and varies in diameter from 12 in. at the top to 8 in. at the bottom. It extends 9 in. into the double floorbeam, where the thickness of the steel is 5 in. The pin will carry all longitudinal wind and traction loads for the entire 1,540 lin. ft. of truss. Its use eliminates any torque in the pier due to transverse wind loads; fixing both shoes of such a span would have introduced a heavy torque in the pier from the lateral deflection of the lower lateral system. Thus, the unique arrangement followed has great advantage for the long spans involved.

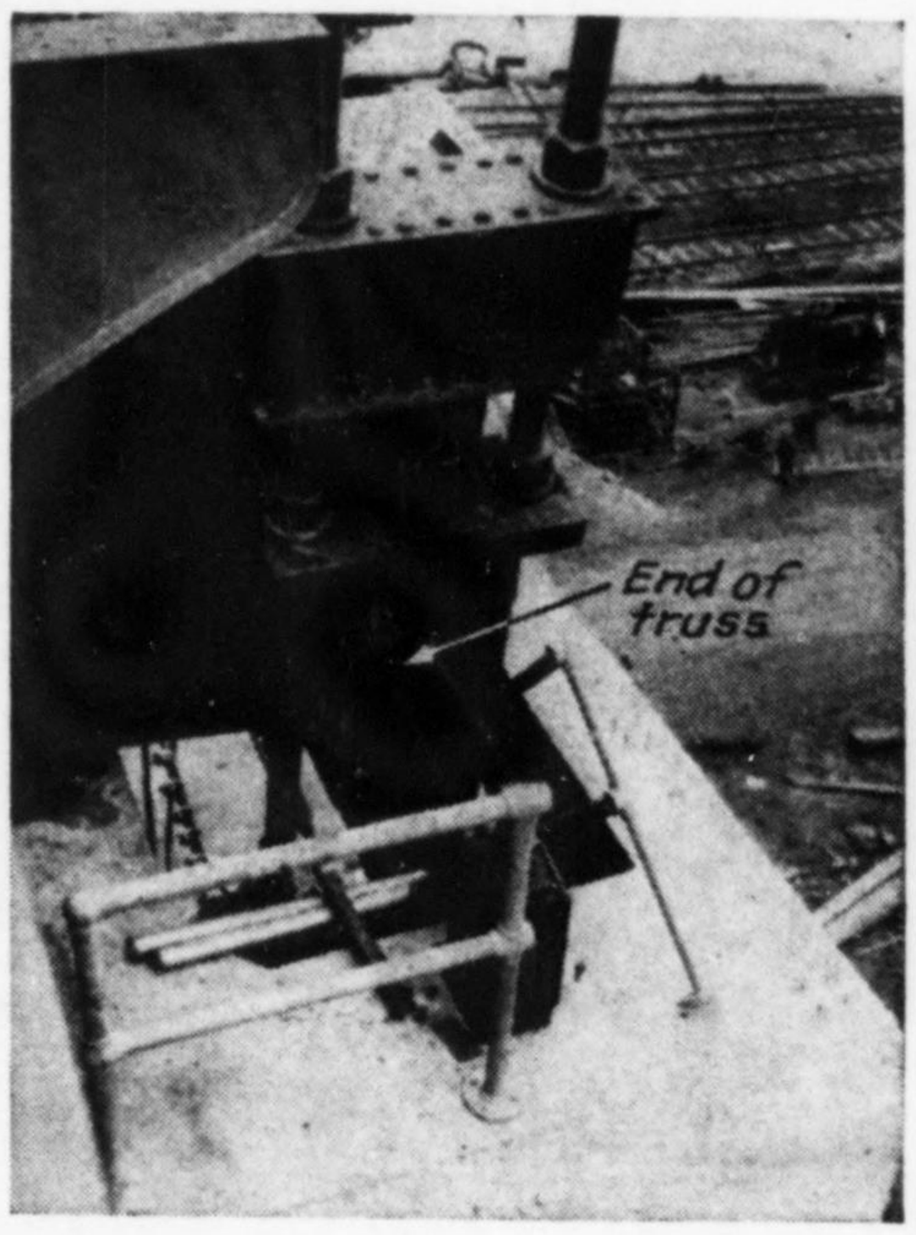


Fig. 4. During erection the end of each truss was tied down by two 4-in. dia. rods. A hydraulic jack in each tie permitted changing the elevation of the ends as desired. Truss was lowered by turning down bottom burrs and extending jack, and raised by turning up top burrs as jack was extended.

Fig. 5. Below each truss at Piers 18 and 19 shoes of the type above were used. When this picture was taken at Pier 19 that shoe had been frozen by welding to the top of the shoe Plate A, which is bolted to the bearing plate. Later the shoe was made free by cutting away Plate A.

The step-by-step operations followed in erecting the steel for the 3-span continuous truss are shown by Fig. 1. Work started on the landward pier at the Iowa end or at Pier 17 and by means of a falsework bent the first two panels were erected by a 60-ton capacity locomotive crane operating on the ground and a 40-ton capacity traveler operating on the adjoining approach span built previously. To start erection the floorbeam at Pier 17 was set 9 in. east of its theoretical position.

Instead of adding the 8-ft. long rockers required at the end of each truss a temporary tiedown of the type shown by Fig. 4 was installed. Each tie consisted of two 4-in. dia. rods tieing the truss to the permanent shoes, and in each tie a hydraulic jack of 250-tons capacity was installed. By means of two sets of nuts on the rods with the jack in between, it was possible to raise and lower the end of the truss as later required. In addition tiebacks extending from the pier to the second panel point were added. Each of these ties consisted of two parts of 1-in. dia. wire cable.

When the two panels had been completed, the 40-ton traveler erected on the deck of those panels a traveler of 16-ton capacity. The latter unit and the locomotive crane at ground level continued the erection work to Panel Point 4, which was supported on a falsework bent resting on hydraulic jacks. The 16-ton traveler next erected a 35-ton capacity traveler on the top chord at Panel Point 5. From here the 35-ton traveler completed erection of the steel, which was now delivered by barge, to Pier 18 by cantilevering. When the expansion rollers were erected on this pier the shoes were frozen with the trusses $10\frac{9}{16}$ in. east of their normal position.

Next the top traveler continued eastward to erect alone the remaining steel for the west half of the arch. During all of these operations Point L_0 of the truss (at Pier 17) had been held about $3\frac{1}{2}$ ft. below its final elevation by the tiedowns previously mentioned.

Cantilevered erection over Pier 19

The east end of the main span was erected by balanced cantilevering over Pier 19. Steel for this work naturally had to be delivered by barge. On the east side of this pier an inclined falsework bent extending from the base of the pier to the first panel point in the end span was required.

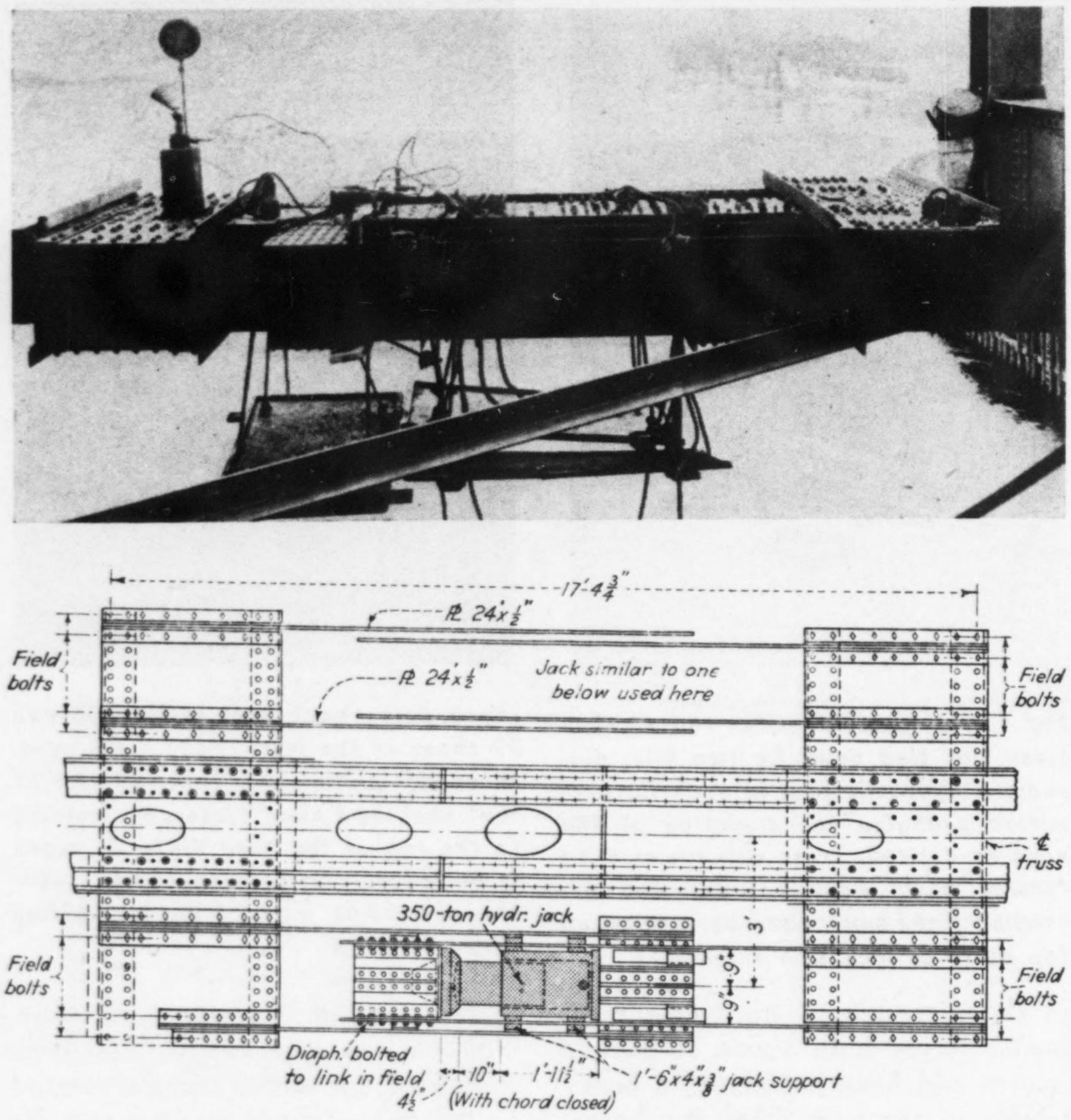


Fig. 6. To close the arch span a jacking device incorporating two 350-ton hydraulic jacks was installed in both bottom tie chords at the west end of the arch. Photograph shows side view of jacking arrangement and drawing a plan view. The four jacks, two for each chord, operated in unison.

This falsework was built of two sections of the longitudinal floor ties later to be used to make the central span a tied arch. Erection westward from Pier 19 in the main span was by a 35-ton capacity traveler working on the top chord of the trusses. In the end span a 30-ton capacity guy derrick advanced eastward on a movable platform on the floor system. At the start of the work Pier 19 plates were welded to the expansion rollers to make this joint fixed or frozen, as shown by Fig. 5.

The cantilevered construction over Pier 19 was maintained so evenly that maximum stress in each of the individual struts, which were each designed for 480 kips in compression and 510 kips in tension, was but 130 kips per strut. When erection in the east span had progressed to Pier 20, two 4-in. dia. tiedowns similar to those at Pier 17 were installed. When these rods were added the east end of the bridge was about 2 ft. below final elevation. The tiedowns were adjusted until Point L_0 (east end of trusses) was 3½ ft. below final elevation, as at the west end of the structure.

With the tiedowns in place, the remaining two central panels of the east half of the arch were erected, and the closing sections raised into place. At this time the opening at the bottom chord was 6⅞ in. and at the top chord 7¼ in. The calculated deflection of the cantilever arms was about 2.4 ft.

Shoes at Pier 18 cut loose

To close the bottom chord the fixed shoes at Pier 18 were cut loose to permit the western half of the trusses to move eastward 6⅞ in. or until the bottom chord sections were in bearing. Movement of the trusses was controlled by slacking off the tiebacks extending from Pier 17 to the second panel point of the west end span. This movement, which was very slow, was further aided by a 50-ton journal jack, shoving on the west end of each truss; the load on each jack was about 25 tons.

When the closing section in the bottom chord had been pinned up and bolted, the tiedowns at Piers 17 and 20 were slacked off in simultaneous 3-in. intervals until the steel in the top chord came into bearing. At this time, which called for pinning and bolting the top chord sections in place, the tiedowns still held the ends of the bridge 3.256 ft. below final elevation. From the time the shoes on Pier 18 were cut until the closing was complete less than 4 hours expired.

As soon as the closing sections were in place, the travelers backed down the arch and erected the hangers, ties, floorbeams, and bottom laterals of the roadway system. However, before this work was started, the tiedowns at the ends of the bridge were slacked off to permit the ends of the bridge to rise to 1½ ft. below final elevation.

Completing the tied arch

The design contemplated shortening the arch span by lowering the ends of the trusses at Piers 17 and 20 sufficiently to connect the bottom chord ties in the unstressed condition. The contractor, however, elected to make the final bottom chord splicing connection by pulling the bottom chords together by direct jacking on them (Fig. 6). At the winter temperatures prevailing, the open space between the last splice connection of the bottom chords was about 10 in. Temporary diaphragms were bolted across each bottom chord at the west end of the arch or between Panel Points T_{12} and T_{13}. Link members extended from each diaphragm to jacking beams arranged so that standard hydraulic lifting jacks could be used. Two 350-ton jacks were employed at each bottom chord and the four jacks were operated in unison.

The arch span was thus shortened and the parts of this last splice of each bottom chord drawn together for riveting. After the bottom chord tie closure was made, the ends of the truss span, at Piers 17 and 20, were adjusted to correct elevation, and the rocker columns shoes were installed. Next, the 16-ton floor traveler working eastward from Pier 18, proceeded with the erection of the remainder of the floor system, including stringers, cross-beams, curbs and handrails.

The bridge is being built by the City of Dubuque Bridge Commission.

but the highway departments of Iowa and Illinois are participating with public road funds in partial payment of the structure. Total cost is estimated at $3,500,000 and the crossing is to be opened early next summer.

Howard, Needles, Tammen & Bergendoff, Kansas City, with Ivan P. Hanson, resident engineer, are the consulting engineers. Fred J. Robers Construction Co., Burlington, Wisc., and La Cross Dredging Corp., Minneapolis, Minn., for whom P. C. Peterson is superintendent, are the foundation contractors. Bethlehem Steel Co. with W. W. Oskin, resident engineer, Wm. Williams, assistant resident engineer, and Joe Campbell, superintendent, is fabricating and erecting the steel.

Beams of Glued 1-in. Boards Carry Railroad Line to War Project

A Pile Trestle with caps and stringers of 1-in. boards laid flat and glued together is carrying locomotives and cars on a war project access line built by the Corps of Engineers in central Florida. Cap timbers are 12 in. wide by 14 in. deep and stringers are 9x20 in., 30-ft. long, spanning 15-ft. c. to c. of bents. Three stringers are used under each rail with 2 in. open space between.

Beams were designed for 1,400 psi. and tested to 2,000 psi.—the capacity of the testing machine—without sign of failure. They were made up of random length pieces of the full width of the beam and, for the sizes required, were made available more quickly than full size timbers could be secured.

Members were made up in a commercial shop where presses were installed at 2 ft. centers to apply pressure while the glue sets. A machine applies 1½ to 2 oz. of powdered glue to each square foot of joint surface and the boards are then placed on edge in the clamp like presses. Scarfed joints are used at all splices of the boards and are coated with glue. The glue is a powdered urea formaldehyde with catalyst included and is applied and worked at a temperature of 70 to 80 deg. F. No nails or other fastenings are used.

Glue requires 6-hr. to set

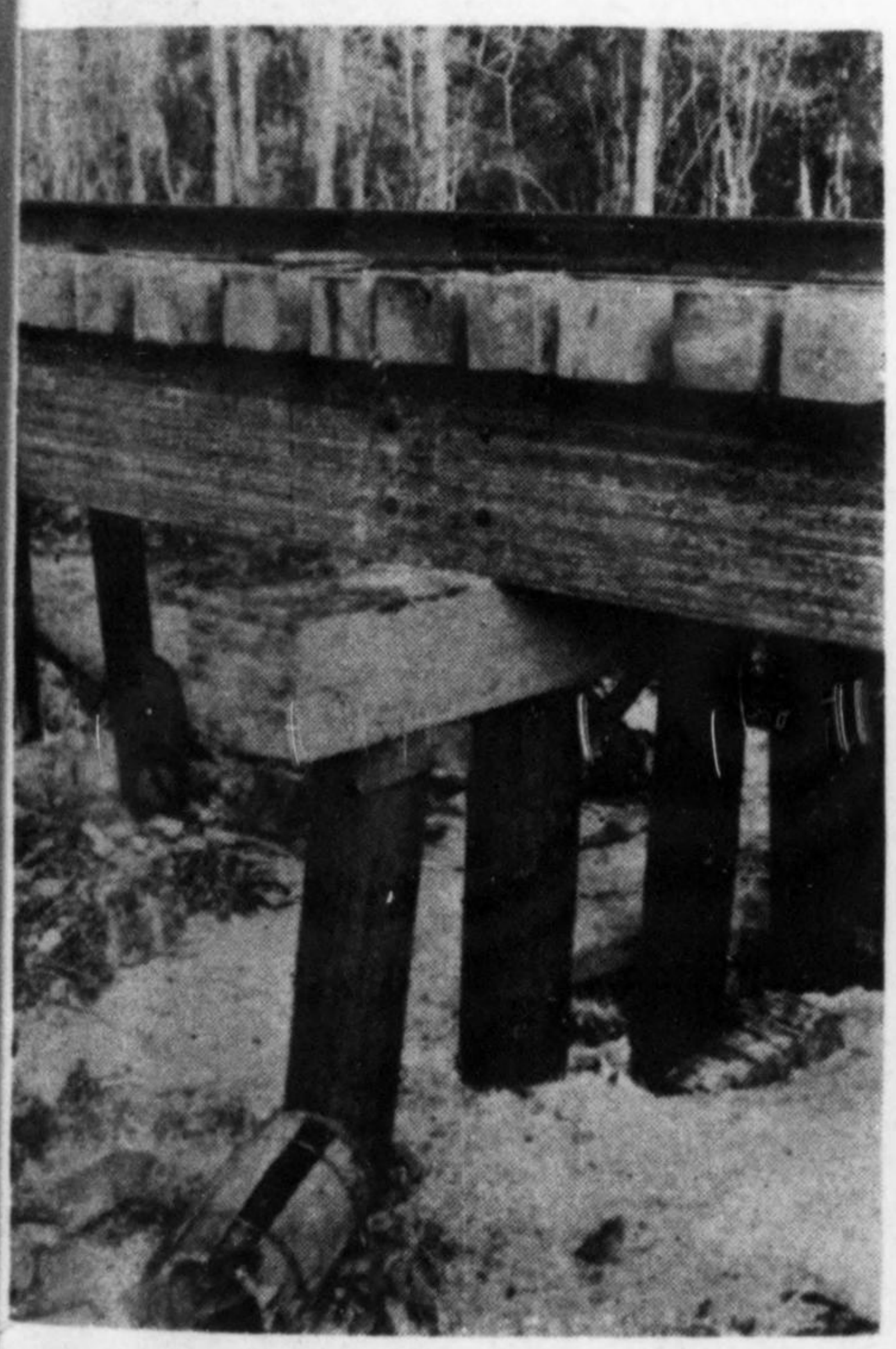
When the requisite number of pieces of board to make up the beam are in the presses they are pulled up to produce a uniform pressure, which is maintained for 6 hr. while the glue sets. The beam is then ready for shipment and immediate use.

For the bridge shown the built-up timber cap is set on a 5-pile bent. Piles are 36 ft. long with 12-in. butt; the center pile is vertical, the next ones at 2 ft. 3 in. centers on a 1:12 batter and the outside piles are 2 ft. 3 in. further out driven on a 2:12 batter. The 12x14-in. cap timbers are drift bolted to each pile.

The 30-ft. long stringers are butted over the caps with alternate pieces ending on every other one of the 15 ft. c. to c. bents. Stringers are bolted to the caps and the three stringers under each rail are bolted through horizontally with a 2 in. thick washer for a spacer. Ends of the stringers are cut to form an inverted narrow "V" to compensate for end movement due to deflection under load.

The rail is supported on untreated timber ties at 16-in. c. to c. Each third tie is bolted to a stringer and to a guard-rail placed at the outer end of the ties. Previously used 90-lb. rail is laid over the structure.

Insufficient equipment was available for handling the heavy timbers. Consequently, most of the stringers were moved out over completed sections of the structure and set in place manually. Ties and rail were handled in the same manner rather than wait for machines. Despite lack of equipment and a week's delay for material, construction of the 574-ft. long bridge was completed in 5 weeks.



Caps and stringers of this bridge are 1-in. boards glued together. Stringers are 30 ft. long and are spliced over alternate bents of piles, spaced 15 ft. c. to c. A guard-timber spaces and holds the ends of the ties. The structure will support the largest locomotives used on Florida railroads