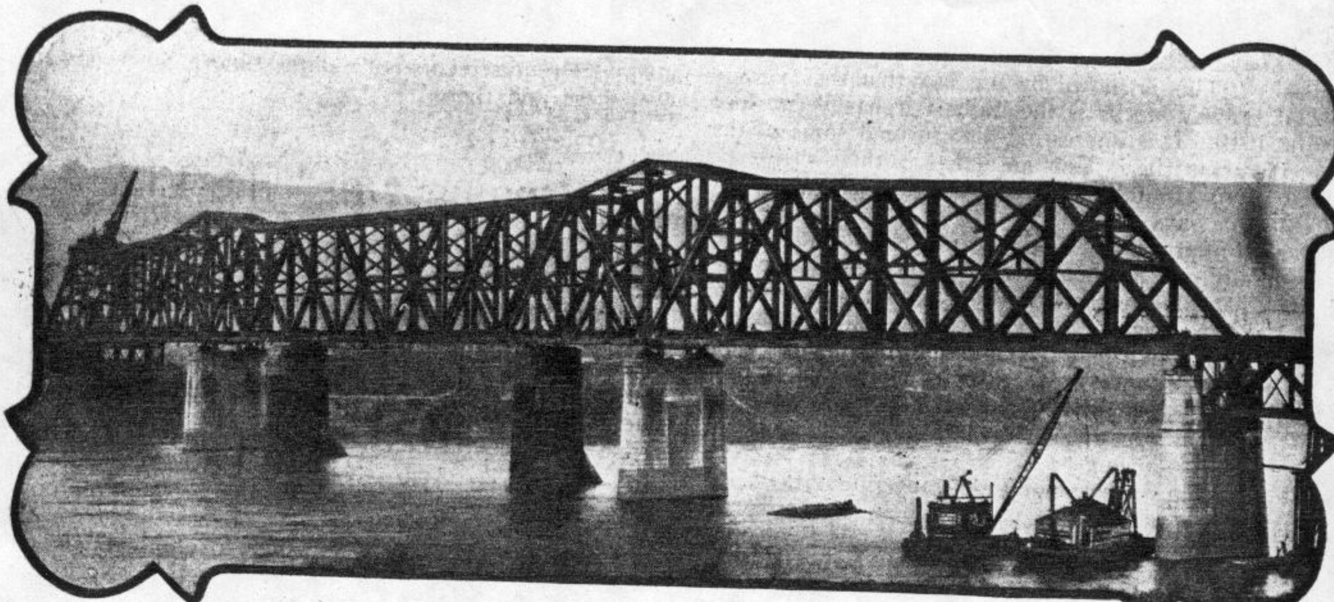
April 2, 1927



*The Steubenville Bridge After Completion of New Superstructure but Before Removal of Old Piers*

# Erection of Steubenville Bridge Introduces Novel Problems

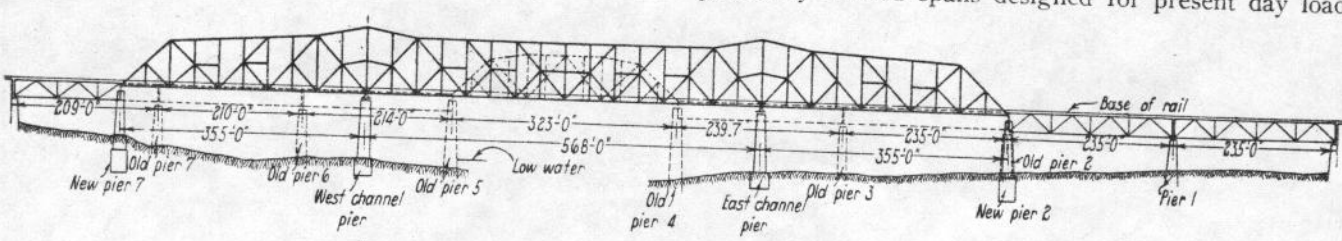
*Pennsylvania replaces old Ohio river structure by new one with trusses continuous over three spans*

THE sixth railroad bridge to be built across the Ohio river in the last 10 years and the third to be constructed by one road, the Pennsylvania, is now nearing completion at Steubenville, Ohio. Two of these six bridges represented the development of new railroad crossings of the river but the Steubenville bridge, like three of the others, comprises the replacement of an old structure. This newest bridge is somewhat comparable with the Southern's new bridge at Cincinnati, both having trusses continuous over three principal spans. Beyond this, however, there is little of definite similarity between the Cincinnati and Steubenville structures. Furthermore, the manner of erection of the new Pennsylvania bridge, because of peculiar conditions imposed, embraces features that are essentially distinctive.

Like other river crossings on important trunk lines, the story of the Steubenville bridge is one of successive replacements made necessary by the progressive increase in traffic and in the weight of locomotives and cars. The original bridge at this location was completed about 1868, shortly after the building of the eastern portion of what is now the Panhandle line of the Pennsylvania from Pittsburgh to Columbus, Cincinnati and St. Louis. The superstructure of the first bridge was replaced about 1888 on the original piers and as then rebuilt, it consisted of a through channel span 323 ft. long, flanked on the east by one deck span 239.7 ft. long and three deck spans 235 ft. long, and on the west by three deck spans 214 ft., 210 ft., and 209 ft. long respectively. All spans were pin-connected trusses and carried two tracks.

### Strengthened Bridge 18 Years Ago

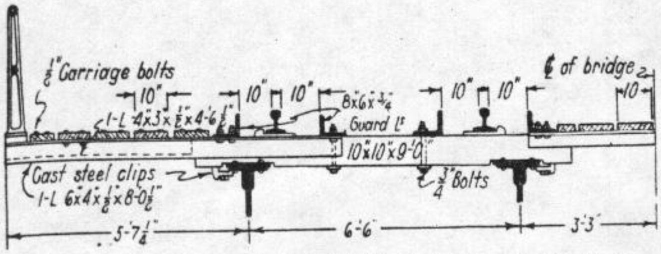
In 1908 and 1909 the 209-ft. span at the west end the two 235-ft. spans at the east end of the bridge were replaced by riveted spans designed for present day loading, and the rest of the old deck spans were strengthened by the introduction of center trusses taken from the old spans which had been removed. In 191[redacted] 323-ft. channel span was reinforced by introducing loop bars bearing against the curved ends of the bottom chord eyebars. However, the increase in load-carrying capacity of the bridge effected as a result of these measures, was not sufficient to permit operation over the bridge of the




**The Relation of the New Steubenville Bridge to the Old**

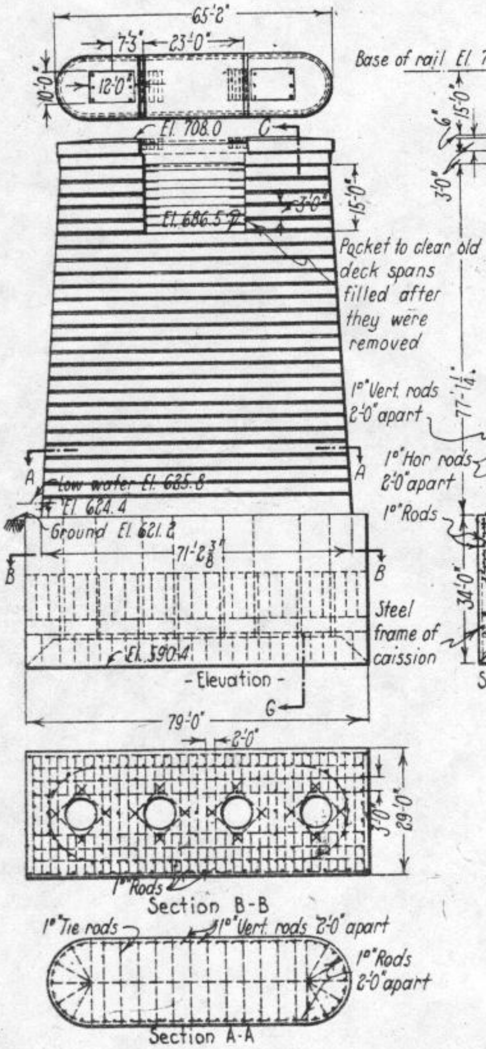
heavy power which was urgently needed on the line as a means of increasing the train loading over the one per cent grades which prevail between Steubenville and Pittsburgh.

This considration, together with the urgent demand on the part of river shipping interests for a wider chan-




**A Section Through One-Half of the Bridge Deck**

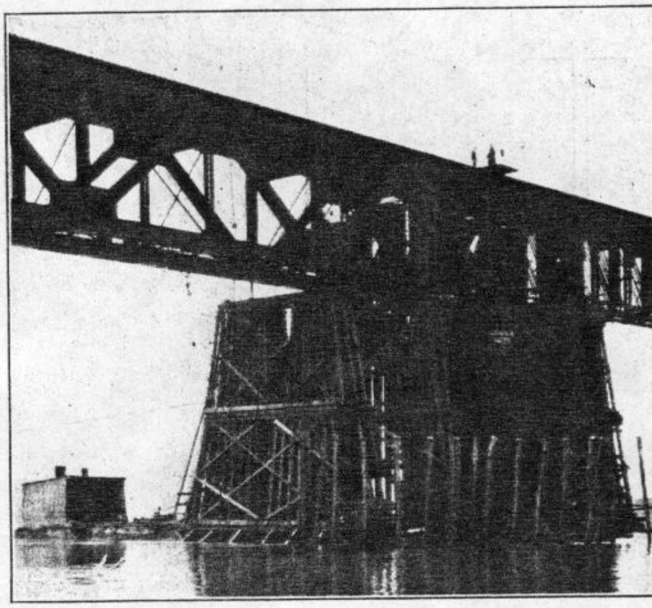
nel, led to the decision to build a new bridge to replace all of the old superstructure between old Pier 2 and a point about 55 ft. west of old Pier 7. In other words, all of Spans 3 to 7, inclusive, were removed, and Span 8 was shortened two panels to make room for the new




**Details of One of the Channel Piers**

structure but Spans 1 and 2 were retained as a part of the bridge as rebuilt.

The total length of the new superstructure is 1,278 ft., center to center of end bearings, and is divided into three spans, a center channel span of 568 ft., and two flanking spans of 355 ft. Under this span arrangement, the locations of three of the four points of support for the new superstructure are well away from any of the old piers but the location of the east support necessarily coincided with that of old Pier No. 2. The old piers were founded on timber grillages resting on sand and were not long enough to carry the new superstructure which is considerably wider than the old. New piers were therefore definitely required at all four locations and while the locations of the new piers were determined upon considerations other than those of avoiding the locations of the old ones, it was of considerable advantage from



**The Falsework for Supporting the Old Deck Spans While Removing Old Pier 2 and Building the New One to Replace It**

the construction standpoint that this was the case for three of them. In fact, the replacement of Pier No. 2 with a new pier at the same site comprised one of the critical features of the project.

### The Trusses Are Continuous Over Three Spans

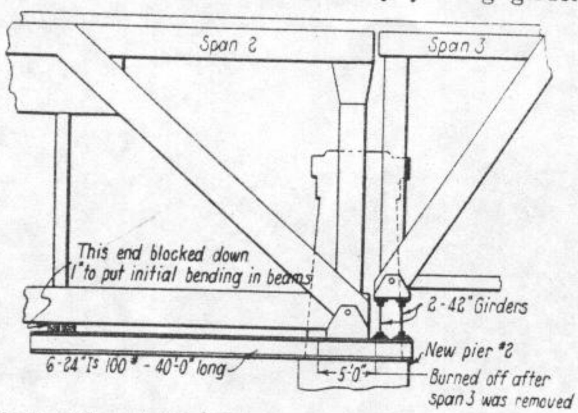
The new superstructure consists of two continuous riveted trusses spaced 37½ ft. center to center, and having a height ranging from 67 ft. at the portals to 95 ft. over the intermediate piers. It is designed for a live load consisting of two decapod locomotives with 32,000 lb. on a pony truck axle and 72,000 lb. on each of five driver axles followed by a uniform load of 6,000 lb. per foot of track. Impact was computed according to the formula $\frac{300}{300+L}\left(\frac{LL}{LL+DL}\right)$ except for members subject to reversal of stress where the formula $\frac{300}{300+L}\left(1+\frac{m}{2M}\right)$ was used. Unit stresses correspond to a stress in tension of 16,000 lb. per sq. in., the material in the superstructure being open-hearth carbon steel throughout.

The main members are of open box section. The heaviest section is that of the diagonal L-10 M-11 which has a cover plate 44 in. by ¾ in., eight angles 8 in. by 6 in. by ⅞ in., four plates 38 in. by 1 in., two plates 22 in. by ⅞ in., and two plates 22 in. by ⅝ in. The gross

... 342.8 sq. ... bott... heavy and are of an I-section comprising a plate 13½ in. by ½ in. and four angles 7 in. by 3½ in. by ½ in. The lacing of the larger members is out of the ordinary and consists of a double lacing in which the pieces against the member are 5-in. by ½-in. bars while the outer pieces are 5-in. by 3½-in. by 7/16-in. angles.

### Make Provision for Lifting the Spans

Provision for lifting the spans on jacks at each pier has been made by providing heavy jacking girders or




**Method of Supporting Old Span 3 on New Pier No. 2 Until It Was Removed**

special floor beams designed to transmit the weight of the bridge to jacks. These jacks are to be placed 9 ft. inside the plane of each truss for the jacking girders over the channel piers and 4 ft. for the end jacking girders. Over the channel piers these special floor beams are in duplicate. I-beam grillages have been provided in the pier tops under the jacking positions to afford adequate distribution of the jack concentrations.

Being a continuous structure, it has fixed bearings at only one point of support, the east channel pier. Owing to the allowance for longitudinal thrust made in proportioning the bearing area of these bearings, they are larger than the expansion bearings on the west channel pier. The base area is 129 sq. ft. and the lower shoe, which is the largest unit, weighs 51,425 lb. The six expansion bearings are of interest in that the segmental rollers are enclosed in oil-tight casings so that they may be completely covered with oil. The new superstructure weighs 7,6[illegible] tons and required the driving of 148,000 field rivets which are 1¼ in. in diameter in all main truss members and floor beam connections, 1 in. in diameter in hangers and sub-member connections and ⅞ in. in diameter for laterals and cross braces.

The floor deck for the two tracks on the bridge embodies several departures from usual practice. The ties, which are 10 in. by 10 in. by 9 ft., are spaced 16 in. center to center. They were slotted to clear rivet heads in the stringers before treatment with creosote. Guard rails, both inside and outside the running rails, consist of 8-in. by 6-in. by ¾-in. angles set with the backs of the 6-in. legs 10 in. from the sides of the rail heads. These angles are held in place by ¾-in. bolts passing through every alternate tie. Plank walks provided between the tracks and outside each track are supported on steel angles spaced 4 ft. center to center, which are bolted to the guard angles mentioned above.

### Details of the Substructure

The four new piers are of concrete throughout and are supported on blue shale at elevations ranging from 127 to 134 ft. below base of rail level or from 32 to 36 ft. below standard low water. As shown on the drawing, the faces of the piers are broken by horizontal rustications at intervals of 3 ft. which were formed by nailing V-molds 3 in. wide against the forms. These horizontal markings serve to break up the concrete surfaces and give the piers a finished appearance. By passing all form bolts through these molds and stopping the various runs of concrete at these points it was possible to conceal bolt marks and construction joints. The piers were reinforced with 1-in. bars 2 ft. center to center, both horizontal and vertical, set 9 in. and 12 in. back from the faces of the piers. In addition, grillages composed of 1-in. bars 12 in. center to center in both directions were placed in the bottoms and tops of the copings.

All of the piers had to be constructed with an opening 21 ft. to 23 ft. long, symmetrical about the center line of the bridge and extending to a depth of 21½ ft. below the coping to afford clearance for the old deck trusses. In the case of the two end piers which support deck trusses that will continue in use, the outer half of the notches in the pier tops is permanent but in the channel piers these openings were filled with concrete after the removal of the old deck span.

The foundation work was done by the pneumatic pro-

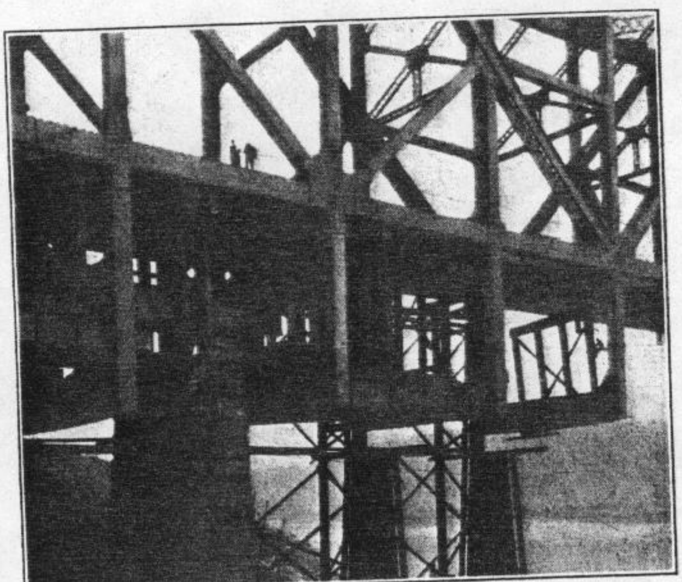
**An Erection Progress View—Note the Relative Proportions of the New and Old Channel Spans**

cess. The caissons had a height of 34 ft., a width of 29 ft. and a length of 79 ft. for the channel piers and a width of 23 ft. and a length of 69 ft. for the two end piers. Of the maximum depth of submergence to rock, 44½ ft., only 15 ft. represented depth of water over the bed of the stream. The maximum pressure developed in sinking the caissons was 22 lb. The rock surface presented an eroded appearance when exposed and varied but little from the horizontal, the maximum difference in elevation under the cutting edges in any one pier being 22 in. Caissons for the two channel piers and Pier No. 2 were of steel construction, while the caisson for Pier No. 7 was of reinforced concrete construction with a steel cutting edge.

### Construction of Pier 2 Was Difficult

As stated previously, the construction of new Pier No. 2 presented the greatest difficulty because it replaced an old pier on the same site which had to be removed before work on the new pier could be started. This involved the supporting of the adjacent deck spans on falsework during the entire substructure work. Owing to the fact that the piles supporting this falsework had to carry load while the caisson was being sunk, it was imperative that they should not be affected by any disturbance resulting from this work. This imposed the necessity for carrying these piles to rock, and as this required the driving of 256 piles with a cut-off length of 42½ ft. through sand and boulders for a depth of 37 ft., it proved to be a difficult and expensive feature of the project.

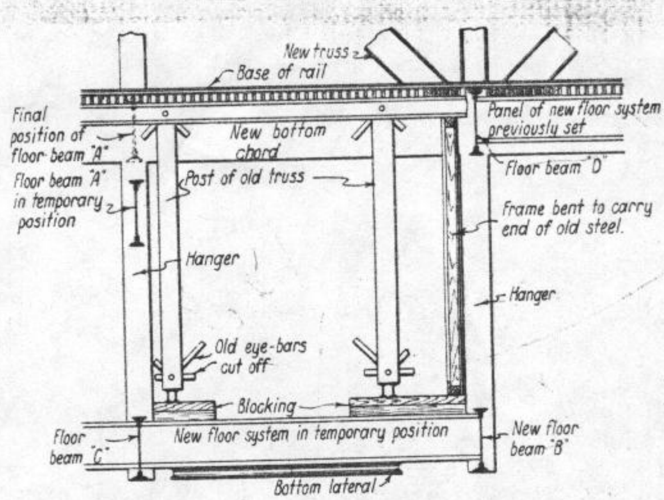
Owing to the fact that the center line of the new pier is 1.4 ft. east of the center line of the old pier, the old span No. 3 on the west side of this pier was left without adequate width of bearing on the new pier. To support this span until it was replaced by the new super structure, a cantilever grillage consisting of six 24-in. I-beams was used, as shown in the sketch. This afforded a cantilever support for the end of the span, the moment produced by this cantilever being counterbalanced by an uplift on the first panel point of the adjacent span. These beams were burned off after the old Span No. 3 was removed and used as a grillage under the bearings of Span No. 2.



View at Old Pier 7, Showing Progress in the Removal of the Old Deck Span and Method of Supporting It From the New Superstructure

### Heavy Traffic Interfered With Erection

The replacement of the old superstructure by the new involved an erection procedure that was subjected to serve limitations. The limited load-carrying capacity of the old spans precluded their use for supporting any part of the new spans during erection. Heavy traffic, an average of 54 trains during the eight-hour working time of the erection forces, imposed the necessity for a minimum use of the tracks on the bridge for construction purposes. The depth of water and the requirements of river shipping restricted the use of falsework to that required for the erection of the flanking spans, the channel span being erected by the cantilever method. However, falsework in the two flanking openings was provided only for the support of the new trusses for which piles could be driven from the falsework as it was advanced out into the river on either side of the old spans. This meant that there was no falsework under the old spans for their support during removal, a condition which imposed one of the most perplexing problems involved in the project and which was solved in an unusual manner as will be explained later.




How the Old Deck Spans Were Supported from the New Trusses

After erecting a short section of the new superstructure at each end of the bridge by means of locomotive cranes with long booms, bridge derrick cars mounted on heavy girders spanning from truss to truss were hoisted piece-meal to the top chords at each end of the bridge where they served as crawler travelers for the erection of the greater part of the new structure. Interference with traffic was minimized by delivering the members on a material track supported on brackets cantilevered on the outside of the north truss.

### Erect New Trusses Around Old Channel Span

The new trusses were spaced far enough apart to clear all parts of the old superstructure, the channel span being erected around the old channel span with provision for hanging the floor beams temporarily in a position below final location so that they would clear the floor of the old span and could serve as a means of supporting the old superstructure while it was being dismantled. The same general idea was applied to the removal of the old deck trusses which work also had to be conducted without the aid of falsework. But to carry these trusses from the new steel was a much more complicated problem because the under-side of these spans was over 20 ft. below base of rail. As a consequence, it was necessary to suspend long hangers from each bottom chord panel point in order that the new floor could be hung low enough to pass under the old deck trusses.

This introduced several complications. It precluded opportunity for any lateral bracing in the plane of the bottom chords until the old deck trusses were moved, which made it necessary to delay the complete erection of the two cantilever arms of the new channel span until after the removal of the deck span so as to avoid developing appreciable compressive stresses in the bottom chords of the two new side spans until they could be adequately braced by floor and lateral systems. Furthermore, the removal of the old deck spans without excessive delays to traffic entailed much more complicated procedure than that of releasing the old channel span. The removal of this old through span could be carried out in two stages; first, the dismantling of the trusses which entailed no obstructions to traffic; second, the removal of the floor, panel by panel, and the raising of the new floor to final position. On the other hand, the removal of the old deck trusses had to be carried out in an operation which involved the removal of a large part of the trusses as well as the floor each time that a change of a panel was made, traffic being interrupted in the meantime. This involved a complex sequence of operation which necessarily called for an interruption of traffic of much greater duration than in a case where only a change of floor systems was involved.

### How the Old Deck Spans Were Removed

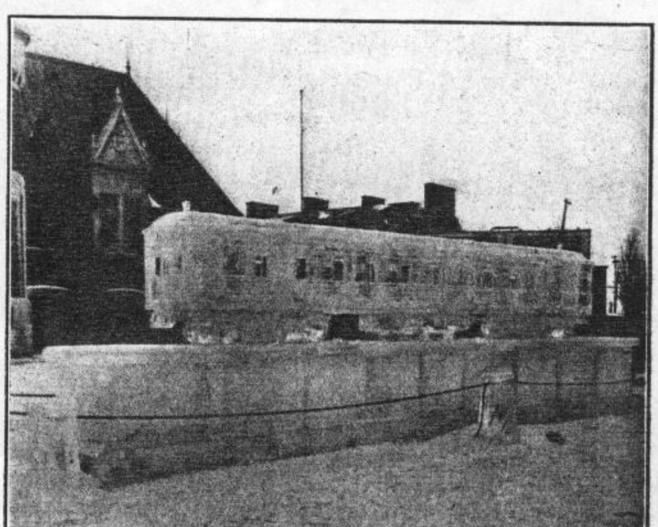
The preliminary step in this procedure was to erect the new floor in the suspended position complete with the bottom laterals attached to the stringers. In addition, another new floor beam, "A," as shown in the sketch, was bolted between the hangers just low enough to clear the floor of the old span. The posts of the old trusses were blocked up on the new stringers and the old bottom chords and diagonals were burned off and removed.

The removal of a panel of the old trusses involved the use of the bridge derrick traveler on the top chords and two locomotive cranes on the bridge tracks. The tracks were not dismantled but were simply held up by lines from the traveler until the operation was completed. The first step was to burn off the old truss members and floor into sections that could readily be lifted out between and outside of the tracks with lines from the locomotive cranes. After the old metal was all removed hitches were taken on the new stringers in such a way that they could be hoisted up as a unit. Then they were disconnected from the floor beams at "B" and "C" and floor beam "B" was disconnected from the hangers and allowed to swing out on slings previously attached to it so that the stringers would clear its top flange as they were lifted to final position and bolted to floor beam "D" of the panel previously set. In the meantime, the floor beam "A" had been disconnected from the hangers and was held by slings so that it could swing clear of the stringers as they were being raised and as soon as the stringers were connected to floor beam "D" floor beam "A" was raised to final position. After the remaining connections had been bolted, the track was brought to bearing on the new floor panel and traffic was resumed. The operation as described above entailed an interruption of traffic averaging about two hours.

The meeting ends of the cantilever arms of the channel span deflected about 13 in. This placed the lower panel point in mid span, at an elevation about 10¼ in. above the dead load position under continuous truss action. In addition, the bottom chords of the cantilever arms, being entirely in compression, and the top chords entirely in tension, were shorter and longer respectively than they would be under the elastic conditions obtained in the continuous structure. To permit of a junction of the two arms under these conditions, the following provisions were carried out in the design and erection procedure: The west half of the superstructure, which is carried entirely on expansion bearings, was erected with the bearings rolled forward about 6 in. In addition, a section one foot long was left out of the top chord at the point of juncture in mid-span while the holes for 12-in. pins at the meeting points of the bottom chords were elongated 3⅞ in. in the west arm.

The operation of closing the span was carried out as follows: Two 500-ton jacks on rollers were placed under each end floor beam. The ends were then jacked up and the 10½-in. bearing castings and 16-in. rockers were removed. The ends were then jacked down 2 ft. ¼ in. This brought the center line of the lower chord at the junction of the two arms to an elevation about 1 ft. 3½ in. above the level of the center line of the bottom chords over the two channel piers or about 10¼ in. above the dead load elastic line. The 12-in. pins were then driven in the slotted holes in the bottom chords and the 1-ft. sections of the top chords were placed. Following this the ends of the superstructure were jacked up until the top chords came to bearing at mid-span. The next step was to unlock the rockers on the west channel pier and jack the ends to normal elevation, replacing the 10½-in. castings and 16-in. rockers. Jacking for dead-load reaction was not done at this time but had to be done as a separate operation when the bridge was completed and the derrick cars had been taken from the top chords.

The design and construction of this bridge was carried out under the direction of Robert Trimble, assistant chief engineer; B. V. Sommerville, assistant to chief engineer, and J. F. Leonard, engineer of bridges and buildings, Pittsburgh, Pa., and under the general supervision of H. R. Leonard, chief engineer of bridges and buildings and A. C. Shand, chief engineer. F. J. Evans as representative of the office of the engineer of bridges and buildings, and L. E. Morrison as representative of the assistant chief engineer's office, supervised the detail of design and construction in the office and field. The Dravo Contracting Company of Pittsburgh had the contract for the substructure and the American Bridge Company had the contract for furnishing and erecting the superstructure.



**C. P. R. Car Modeled in Ice, Palais Station, Quebec, on Occasion of Winter Carnival**