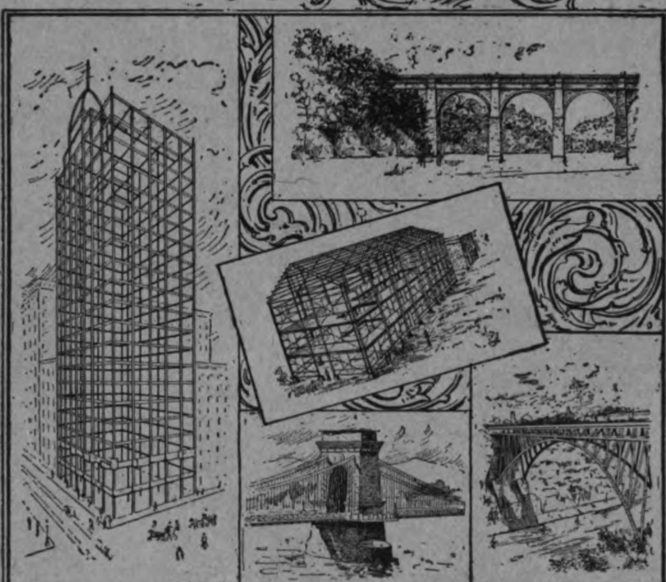
Vol. I, No. 1. April, 1899. Price 30 Cents.

BRIDGES

AND FRAMED STRUCTURES

AN ILLUSTRATED MONTHLY MAGAZINE



FOR
ENGINEERS
ARCHITECTS
INSPECTORS
SUPERINTENDENTS
MANUFACTURERS

VIADUCTS
BUILDINGS
MASONRY

LEADING FEATURES OF THIS NUMBER

THE D·H·RANCK· PUB· CO· CHICAGO·

BRIDGE EVOLUTION AS RELATING TO SOUTHERN CALIFORNIA.*

[Continued from May Number.]

THE endeavor will be made by the description of some recent municipal bridges, with which the writer was connected as chief engineer for the designing and constructing company* to bring out some of the up-to-date methods of design.

The United States has reached a period in its existence where public or municipal improvements are being made of a more permanent character. The former practice of building bridges which were simply structures of utility, is giving way to a desire for something of an æsthetic nature as well. Where the money is available stone arches are being considered, and in many places constructed. The proposition to build a stone arch bridge over the Tennessee River at Knoxville several years ago provided for the construction of four stone arches of 240 feet each! (Fig. 16.) Such a structure built of Tennessee marble or else granite would have been possible, but on account of the certainty that the cost would be very great and likely exceed the estimates that had been made, it was decided to build a steel bridge, and competitive plans and bids were called for, with the result that the bridge designed by the writer for the company with which he was connected was adopted (Figs. 16 to 22.)

The design was for a cantilever structure 1,512 feet in length, which has five spans of 252 feet—two of which are fixed spans and three cantilever, with two shore arms of 126 feet each. To comply with the desire for an arch bridge, the bottom chords were arched, with a rise of 30 feet, and the entire section of the bottom chord made of built members, of plates and angles, 30 inches deep, solely for appearance. The arching of the bottom chord of the fixed span was against economy, and to some extent against stiffness, but to have made it straight would have spoiled entirely the effect. The depth of trusses at the center of the span was 20 feet and over the piers 50 feet. The two panels of each span next the pier were subdivided trussing, the four panels at the center of triangular trussing to avoid the use of counters, while the other panels were of the Pratt type.

The bridge carries a 30-foot paved roadway and two 6-foot paved sidewalks, with a combined live load capacity of 4,200 pounds per lineal foot, the pavement being of concrete steel construction, on steel joist, with wearing surface of cement on both roadway and sidewalks. The sidewalks are protected by a close lattice railing 4 feet in height, which joins a cement balustrade on the abutments, of proportions which were adopted from the base of a Tuscan column. The floor beams were made of riveted lattice construction, riveted to the intermediate posts of the trusses to assist in making the bridge stiff sidewise, while at each panel below these beams were diagonals of angles. Between the pier posts the diagonals are of four angles latticed the full width of the posts, thus forming with the horizontal

* Read before the Engineers' and Architects' Association of Southern California.
* The Youngstown Bridge Company.

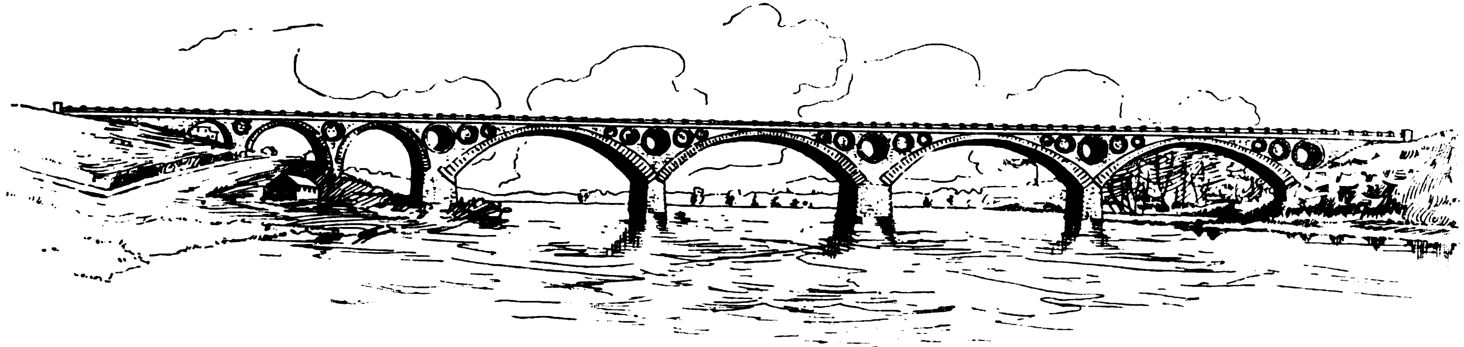


FIG. 16—KNOXVILLE STONE BRIDGE DESIGN.

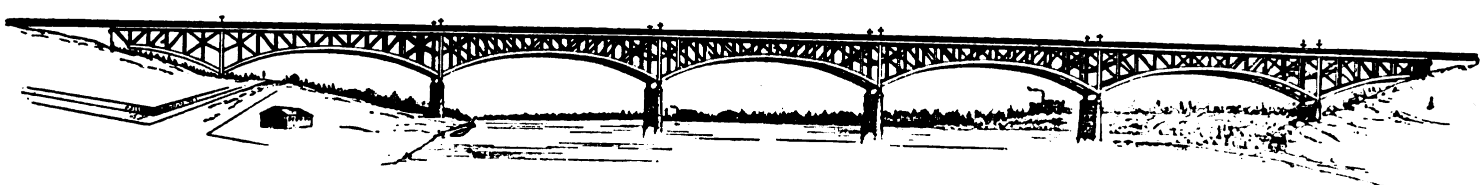


FIG. 17—KNOXVILLE ARCHED CANTILEVER.

struts a very stiff tower. The pins at the top and bottom of these posts were 7⅞ inches in diameter, the bottom one engaging the built steel shoe, which was 4 feet 6 inches in height and weighed about 4 tons. The expansion rollers on two piers were of the segmental type, 12 inches in diameter, providing for a movement of 5½ inches, and resting upon built steel bolsters.

Where the bottom chords of the anchor spans were subjected to large tensile strains, owing to the difficulty of making a tension splice between adjacent sections, eyebars 10 inches in depth were employed, and to insure perfect action it was necessary to have but a very small variation in length in both the built members and the eyebars in the same panel. Two steel tapes specially standardized for the purpose were purchased, with an

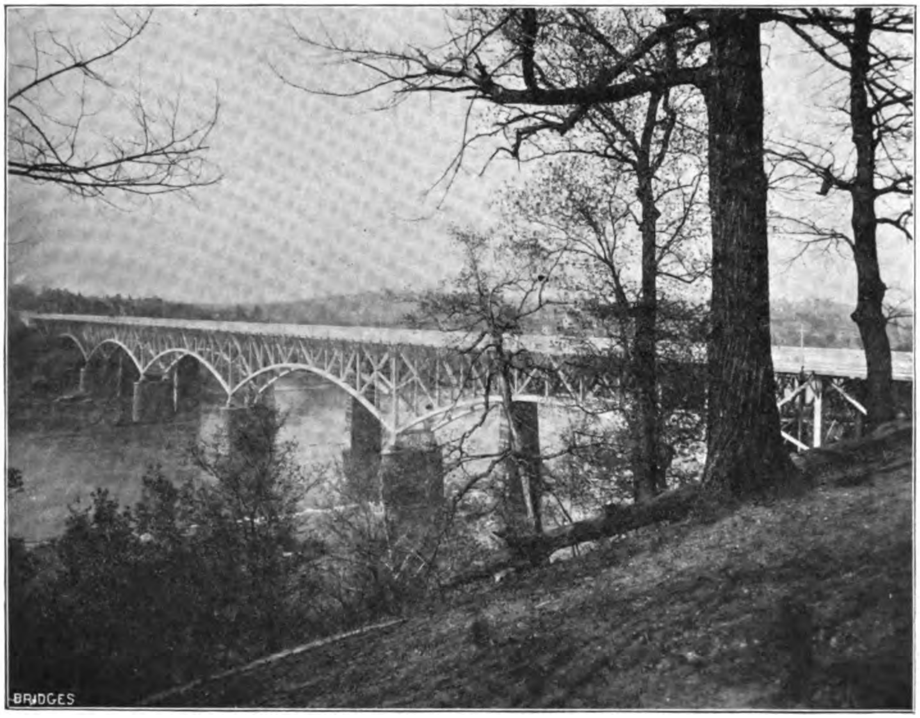


FIG. 18—KNOXVILLE ARCHED CANTILEVER.

extra foot graduated to 32nds of an inch, thus making it possible to measure the members and bars to 64ths.

The total height of the bridge was in the neighborhood of 110 feet, the piers being over 50 feet in height and built of iron limestone, with both ends of each pier lancet-shaped. The abutments were of Monolithic concrete construction, the proportions of the concrete being 1 of cement, 4 of sand and 7 of broken limestone, with a six-inch facing of 1-2-3 concrete. The structure with its five arched spans is very striking in appearance, and is believed to be a distinct advance over the usual broken outline which has been adopted for other cantilever bridges.

The Spring Common bridge at Youngstown, Ohio (Fig. 23), was designed to take the place of an old wrought iron arched truss. The span

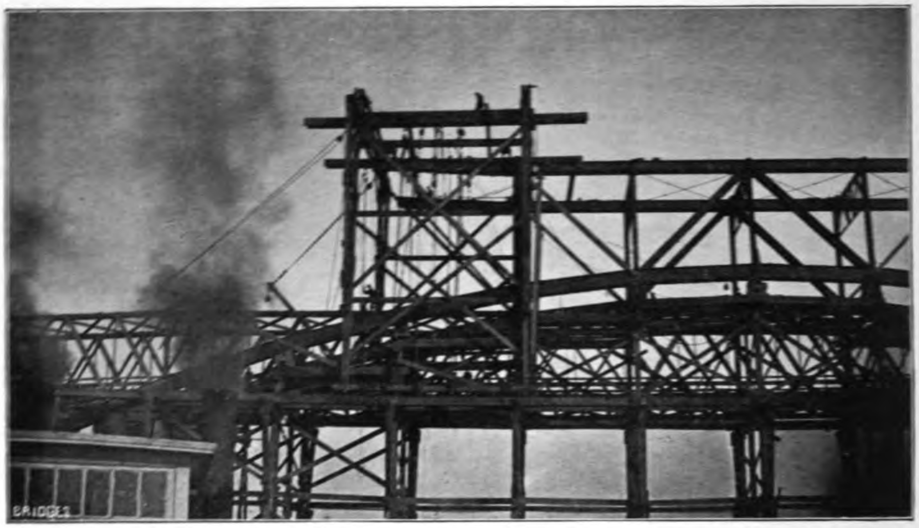


FIG. 19—KNOXVILLE ERECTION.

was 174 feet, the roadway 40 feet and the two sidewalks 10 feet each. The entire paving was of concrete—steel construction on steel joist, with cement wearing surface. Where the truss members passed through the floor, castings with checkered flanges were used, fitting around the members, and having the cement finished up to the flange.

The sidewalks are protected by a close lattice rail of similar design to the Knoxville, with newel posts of special design, which were also of the proportions of a Tuscan column, except as to height of shaft. The bridge trusses were of the Warren type, with sub-verticals of four angles and a plate. Where the two stiff diagonals meet at the center of the top chord, a three-pin detail was used to avoid staggering the members. The floor beams were of necessity very shallow and were riveted between the posts, with the steel joists resting on shelves, between the beams. The top lateral system was of struts with web plates punched out in ornamental forms, and the diagonals of two angles laced vertically; the portals and three of the intermediate struts were deep, with web plates, and provided with curved brackets, which were finished against the struts and truss members by curved castings. It was the endeavor to have everything present a finished appearance, and the success attained may be judged from the view. Attention is here drawn to the necessity of making trusses for carrying pavements much deeper than is the usual practice, the proportion of one-seventh the span for ordinary trusses should be increased to nearly one-fifth.

The Market street bridge at Youngstown (Figs. 24 to 26) illustrates four other types of construction for municipal bridges, the plate girder span, viaduct construction, riveted lattice spans and the plate girder arch span hinged at the abutments. The structure is 1,610 feet in length, with plate girder approaches, in spans ranging from 30 feet to 90 feet in length. These girders are carried on towers which have headroom for driveways underneath, the wind stresses being provided for by portals with curved brackets, which produce bending stresses in the columns which were provided for in the sections of the posts. The diagonals, instead of being light rods, are of two angles laced together, forming really stiff bracing. The span over the river which is 210 feet 6⅞ inches in length, is a plate girder arch of 60 feet rise, the girder being nearly eight feet in depth over all, and carrying the roadway by six columns on each of the two arch ribs, in addition to which there are two columns, resting directly upon the 10⅛ inch shoe pins, supporting lattice trusses 30 feet in length, on which the floor beams rest directly. The bracing of the arch ribs is of stiff construction entirely, angles latticed being the prevalent form.

The spans flanking this arch on either side are 165 feet 5⅜ inches riveted deck trusses of the Warren type, with an unusual form of sub-trussing which is triangular to be in harmony with the 30-foot trusses over the arch and to continue the horizontal effect of the girder approaches. These spans were made 30 feet in depth to give the effect of solidity on either side of the arch.

This bridge shows to what extent we in this country are adopting the European methods of bridge construction—making use of riveted methods in detail, but retaining the simple unambiguous forms of bracing.

The roadway on this bridge was 40 feet in width, while each of the two sidewalks was 7 feet in width with cement paving, but the roadway had an asphalt wearing surface 1½ inches thick. The live load capacity was 4,720 pounds per lineal foot. All of the bridges described were calculated to carry electric street cars and heavy road rollers.

The lessons to be learned from the evolution in bridge building as outlined in this paper are plain. Not only has steel become the material for use in permanent structures of moderate cost, but the types of trussing for use are well fixed upon. The Howe truss, the Pratt combination, as well as other forms in which wood is largely used for bridges in Southern California, have been entirely superseded by steel bridges in nearly all the country east of the Rocky Mountains. It is still possible to construct timber

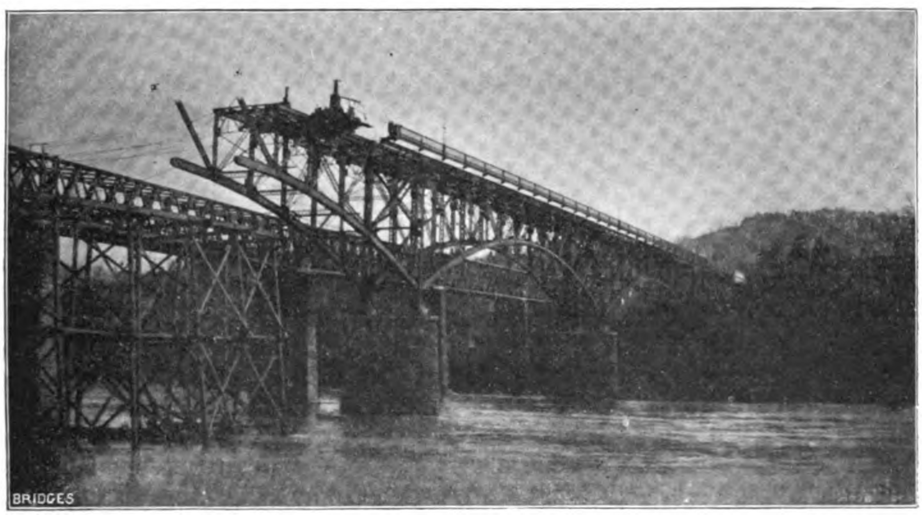


FIG. 20—KNOXVILLE ERECTION.

bridges in the east at less expense than for all metal structures, and at Denver, where they are building steel bridges and have a much higher rate of freight on structural steel from the east than has this coast, timber bridges can be built at less cost than steel ones, but at best the timber ones are but temporary structures, and they have been supplanted by something more permanent. In the case of a bridge of three spans of 100 feet, with 20-foot roadway, the additional cost for using steel in Southern California would only be about 15 per cent on the total cost of the structure, piers and abutments included.

The rapid destruction of wooden bridges by the eastern climate was one of the causes for substituting steel, which does not exist to so great an extent here in this dry atmosphere, but the shrinkage of the timbers away from the metal connections, leaves such a structure a loose-jointed affair, it being possible to make but a poor connection between the timber and iron

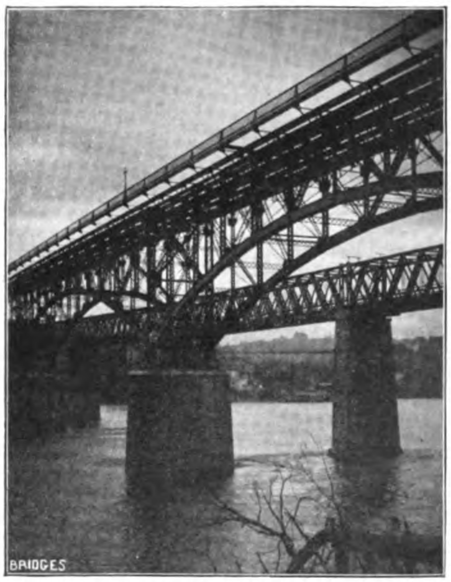


FIG. 21—KNOXVILLE DURING ERECTION.

or steel at best. The dryness which prolongs the life of timber is no less beneficial in the case of steel by causing little oxidation; on which account steel bridges in the east should be newly painted in from three to five years to preserve them, but here, if allowed to go unpainted, as is most often the case with municipal structures, but little damage results.

The greater demands upon the forests of the north coast country must before long cause a greater cost of timber to be a factor in deciding what class of structure to use, but we will assume that the engineer having the decision as to what material to employ will decide upon more permanent steel structures, and outline in a general way the best types to erect in various locations.

The first step toward a permanent bridge is to construct permanent foundations. Those of stone are, of course, the only kind to construct where good stone can be had at reasonable cost, but where it is not plenty, tubular steel shells filled with concrete are often used. This form of pier is so common here as to require no extended description. The materials for concrete are so plenty and of such fine character, while Portland cement can be obtained at so reasonable a cost that the use of monolithic concrete piers should be seriously considered. The practical absence of frost makes it possible to use such proportions for concrete that the cost will be but little more than for tubular piers of the best construction. The proportions for the heart of a pier may be one of cement, five of sand and eight of stone, with a facing of 1-2-3 concrete, and with care in doing the work excellent results may be had. Proportions of 1-3-6 for the heart concrete are, of course, much to be preferred, provided it is possible to increase the expenditure to that extent. The footing courses may be on piles and a grillage beneath scour line, but if rock can be found at less than 20 feet below low water, coffer-dams should be used and the pier built upon rock. For bridges the superstructures for which are of a permanent type and of considerable

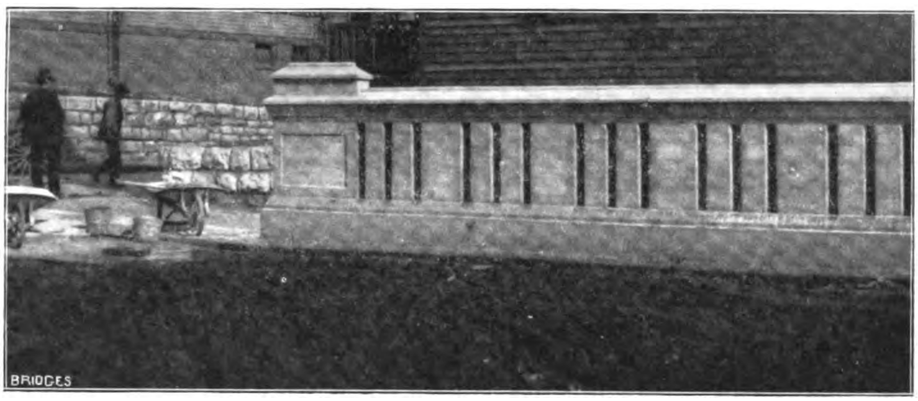


FIG. 22—KNOXVILLE BALUSTRADE.

cost, it would seem wise to found the piers on bed rock, even at a depth of 40 feet by using the pneumatic, or compressed air, process which is now in very common use, and can be employed at a cost of from $12 to $15 per cubic yard.

The superstructures should be designed with careful consideration of the economical span length, which is dependent upon the capacity of the trusses, the height above the stream or the cost of piers and abutments. As an example, may be cited the case of a large city erecting a span of 125 feet deck plate girders, with but 7 feet from the bottom of the girders to the bed of the stream, whereas the use of two spans of about 65 feet with a middle pier would have been much cheaper, as it would have been possible to build the pier at a very low cost. This has recently been done in building another bridge over the same stream. Had it been impossible for any reason to construct the center pier, then the span should have been an open web or riveted lattice structure, instead of the plate girders. The streams of Southern California are many of them broad and with low banks, indicating economy in the use of short spans—probably in many places less than 100 feet.

Where the crossing is exceptionally low, half through plate or lattice girders could be employed.

For bridges over the streams in the mountains or foot hills, where the height above the stream is great, longer spans will be necessary, often longer than economical, to avoid placing piers in a mountain torrent where they would be destroyed. The tendency is to make riveted spans for many bridges up to 200 feet in span, but for shipment overland it is wise to adhere to pin connections, making the end panels of the bottom chord and the long suspension members of stiff construction. The writer has gone so far in the interest of stiffness as to make all members in some 100 feet pin connected trusses of shapes or stiff construction, and in some 250 feet spans the end bottom chords, the hip verticals and the first main diagonals were four angle or stiff members.

Where a bridge is so situated that it will be in full view, especially in a

FIG. 23—SPRING COMMON BRIDGE.

city, some attention should be paid to making it artistic in appearance. The use of arches of various forms is very much in vogue, and they are readily constructed in steel at a slight increase in expense over the more prosaic kinds of bridges. The least that can be done is to use care in making a finished structure, designing each detail so that it is not only inoffensive but as pleasing as possible.

The use of the Melan arch for a number of prominent bridges and a host of smaller ones, warrants a brief mention of it. In appearance it is a concrete arch bridge, where the depth of the arch is very small at the key. In construction the arch proper is formed of concrete, having imbedded therein ribs of steel, that form a compound construction, in which the tensile stresses are provided for by the steel ribs and the compressive stresses by the concrete, thus making a very much lighter and cheaper arch than would be possible by the use of concrete alone. The concrete is susceptible of artistic treatment with small trouble, thus making such a bridge very

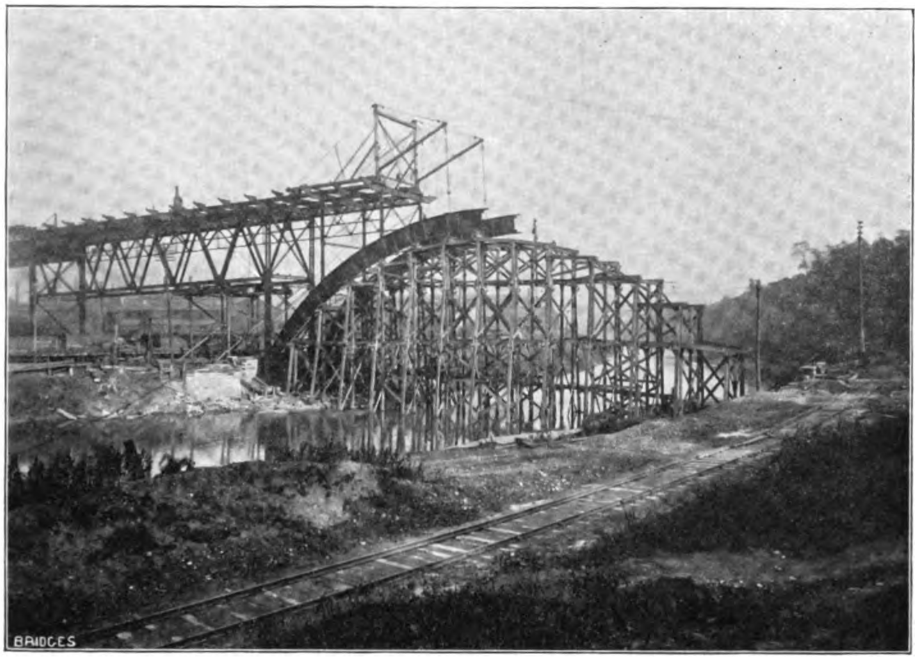


FIG. 24—MARKET STREET PLATE GIRDER ARCH.

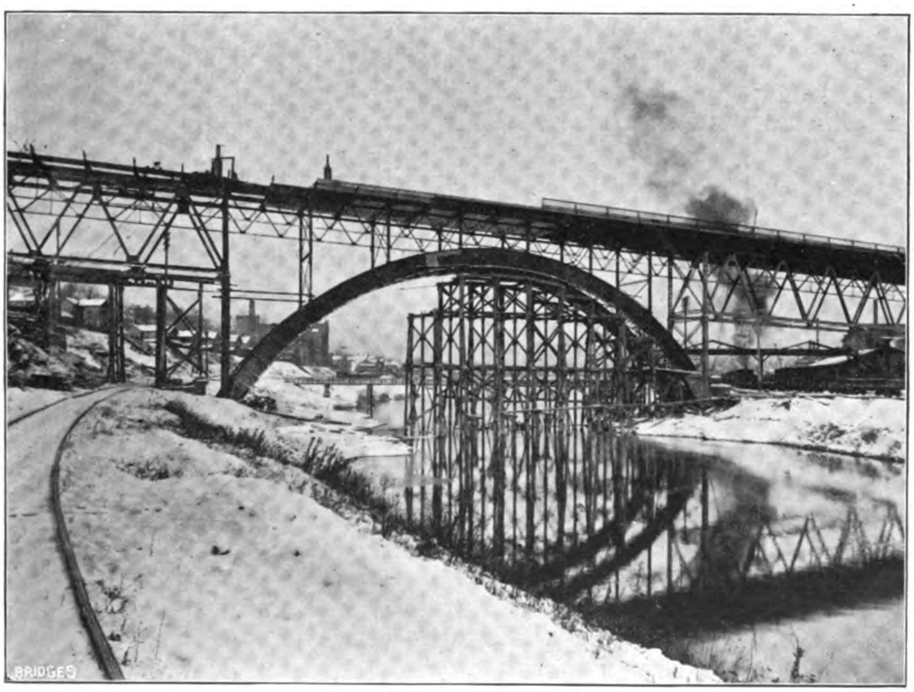


FIG. 25—MARKET STREET PLATE GIRDER ARCH.

suitable for locations where something especially attractive is desired. In many locations they can be built at about the same cost as a steel bridge and abutments. The Melan arch in Eden Park, Cincinnati, and the bridge at Topeka, Kan., with five spans, are handsome examples.

With permanent bridges, permanent roadways should be used for city traffic. The steel joist may be used to support buckle plate flooring, on which concrete is placed as a foundation for brick, cement, or asphalt paving. Or some form of galvanized sheet metal floor may be used on which to lay the concrete. Some bridges have recently been built with concrete arches built between the joist, with a thickness and strength sufficient to carry the pavement and the loads. To avoid the necessity for centering on which to construct the concrete arches, corrugated iron arches may first be

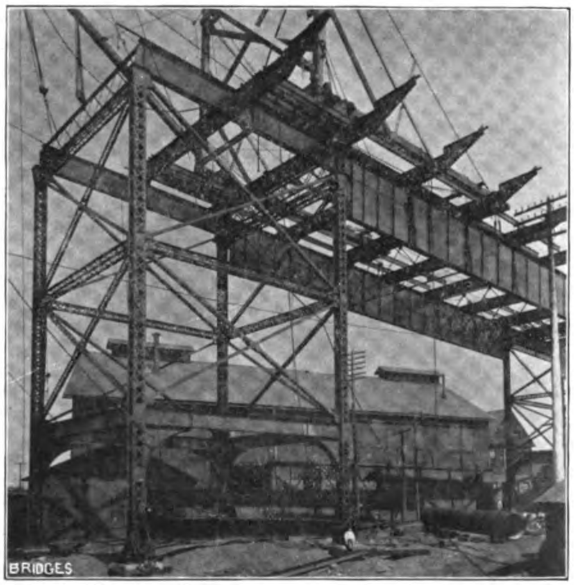


FIG. 26—MARKET STREET TOWER.

laid upon the lower flanges of the beams, which will serve as centering, and add to the strength of the floor.

Except in some few localities, where stone is to be had of fine quality and at low cost from quarries near to bridge sites, the building of large stone arch bridges has not become at all common, even in the more thickly settled and richer portions of the United States east of the Mississippi, nor does it seem likely that in the near future the building of them will be much more frequent, except as monumental or memorial structures. For short spans, up to 50 feet perhaps, they are quite frequently built where permanent bridges are desired. In the more thickly settled portions of Southern California not expense alone is against their being built, but the character of the streams make them undesirable. Where the streams are narrower and the banks higher, as in the mountains, there is not travel sufficient to be expected to call for such bridges.

The part which the suspension bridge has played in the evolution of bridges has not been discussed, because of the fact that a suspension bridge of first class design costs as much or more than some other type of bridge, except for very long spans, while one of poor or even medium design is such an unsatisfactory, if not dangerous, form of bridge that it should not be built. The designer of the Victor wire bridge which collapsed about eight years ago, had evidently convinced officials to the contrary when securing the contract, but the failure showed that an error had been made which need never be repeated in this glorious sunny country.

It is hoped that this association will use its influence for the construction of artistic and permanent engineering works, even though the expense may *seem* injustifiable, in the firm belief that the near and exceedingly prosperous future, to which all signs point, will be the vindication.

C. E. Fowler,
M. Am. Soc. C. E.