Speedy Erection of Parallel-Strand Cable Bridge

On Ohio River structure of 1,060-ft. span at Maysville, Ky., towers were erected in eight days and cables in nine days using footbridges—Aluminum fillers transform hexagonal cable to a 13-in. circle for wrapping

CHARACTERIZED by several important innovations in design and an unusual erection speed, the new suspension bridge over the Ohio River at Maysville, Ky., which was opened to traffic Nov. 25, assumes a place among the four long-span bridges of parallel-strand type built since the manufacture of bridge strands of high and uniform modulus of elasticity was perfected about three years ago. The design elements of interest center in the cable make-up and anchorage details. That erection speed was unusual is evident from examination of the statistics of the job which show that the towers were erected (not riveted) in 3½ and 4½ working days, respectively, and that the cables were erected in nine days. Contrary to previous practice (except for the bridge at Bucksport, Me., under construction simultaneously) and even to general opinion concerning the economics of strand cable erection, footbridges were used with satisfaction and success.

The Maysville bridge is one of the large group of public toll structures being built by the Kentucky state highway commission to replace many old ferry crossings. It connects Maysville, Ky., with the village of Aberdeen, Ohio, and ties the highway systems of the two states together. This bridge has a main span of 1,060 ft., with suspended side spans 465 ft. long. Plate-girder approaches provide access to the bridge at either end. Gravity anchorages are used. The two towers are 165 ft. high above the piers (225 ft. above pool stage) and each contains 350 tons of structural steel. Both towers rest on offshore piers sunk with air caissons. Each cable is made up of 61 prestressed twisted strands laid parallel in the cable, giving a finished diameter of 13 in. Cable bents are utilized at each end of the bridge to change the slope of the cable and shorten the distance between anchorages. Stiffening trusses 14 ft. deep and 28 ft. apart are suspended from 1¾-in. diameter suspender ropes and support a 20-ft. concrete slab roadway and one 4 ft. 8 in. sidewalk at about midpoint between the chords. The bridge provides a 45-ft. clearance at the center of the river at highest high water.

At the present time "innovations" in design of strand cable bridges mean departures from practice used on the three other structures of the type, the Grand' Mere bridge in Quebec, the St. Johns bridge in Portland, Ore., and the Waldo-Hancock bridge at Bucksport, Me. In this article only the St. Johns bridge is considered for comparison, because it is the largest and most notable and because the Grand'Mere bridge is not a typical structure in most particulars; the Waldo-Hancock bridge was under construction simultaneously with the bridge at Maysville and involves numerous innovations on its own account. These features will be covered in a future article.

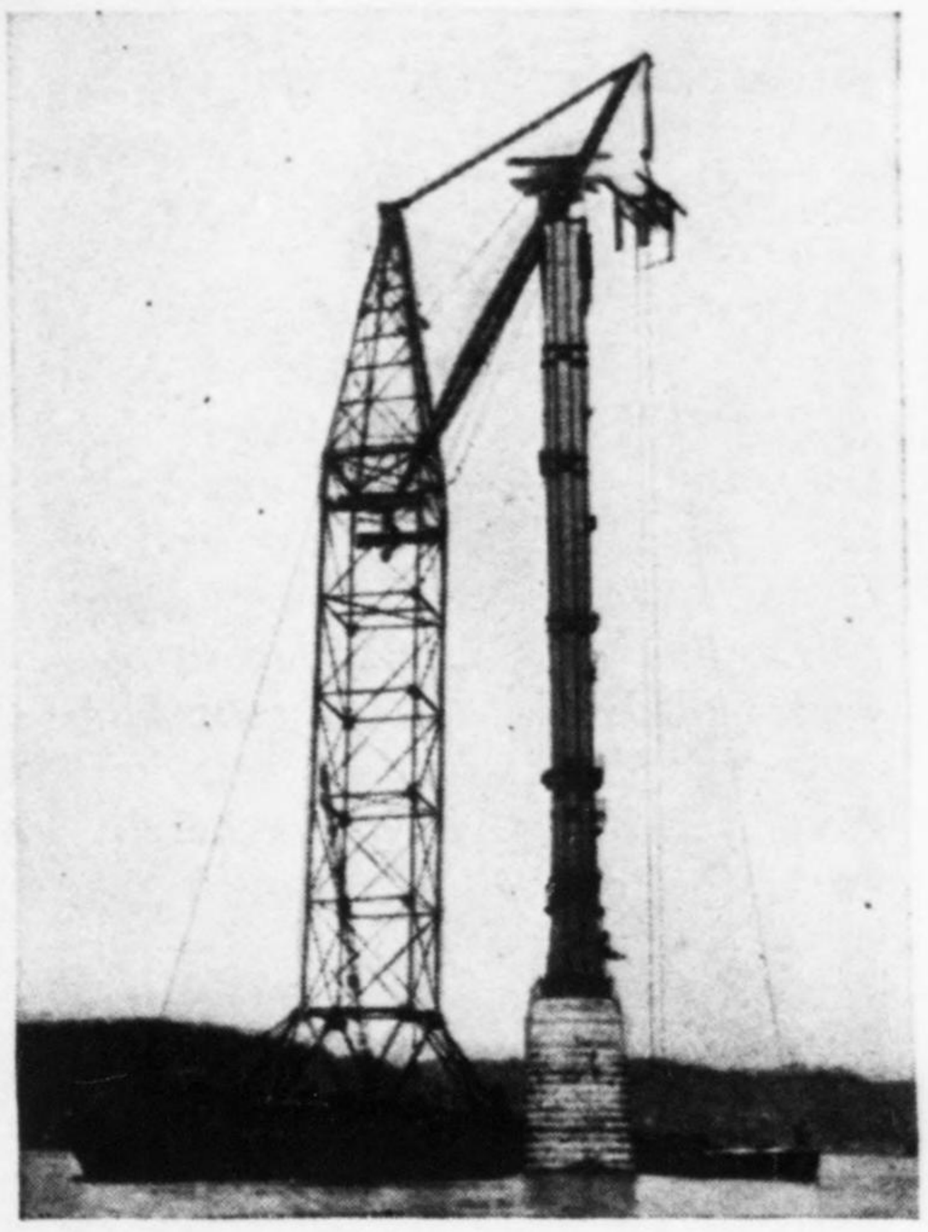
On the Maysville bridge, the make-up of the hexagonal cable claims first importance. Instead of making all strands the same diameter as was done at St. Johns, the strands forming the corners of the hexagon are 0.942 in. in diameter, while the remainder of the 55 strands are 1.556 in. in diameter. Such an arrangement provides the same steel area as if all the strands had been made uniformly 1½ in. in diameter and at the same time reduces the over-all diameter of the finished circular cable, effecting a saving in wrapping costs as well as reducing the size and therefore the cost of saddle castings and cable clamps. The modulus of the large and small strands is the same, since the lengths of the various wires measured along the helix do not vary.

It is also a fact that in a hexagonal cable made up of a number of equal diameter strands, the strands forming the corners of the hexgon protrude to such an extent that segmental fillers of considerable size are required to fill out the cable to a circular cross-section. Eliminate these corners by using smaller strands and much smaller fillers are required to fill out the circle. This possibility of using small fillers had much to do with the decision to use two sizes of strands in the Maysville cables, for the engineers had prohibited the use of wood fillers, and aluminum fillers costing about three times as much as the wood fillers in the St. Johns cables, had been adopted. These aluminum fillers were in line with the engineers' desire to assure maximum permanence in the cables. They were installed in 24-ft. lengths and their arrangement in the cables is shown in Fig. 4.

At the cable bents an abrupt change in cable inclination occurs, with the result that the cable stress in the backstay is considerably larger than the adjacent stress in the side-span cable. To compensate for this increased stress and to prevent the cable bent saddle from slipping along the cable a tier of four 1½-in. diameter strands was added to the bottom of the cable between the cable bents and the anchorages. It was not practicable to utilize aluminum for the large segmental fillers required to finish out

Fig. 2—Maysville bridge furnishes a 20-ft. highway over the Ohio River.

Fig. 1—Strand-cable suspension bridge joining Maysville, Ky., and village of Aberdeen, Ohio, is an important structure in Kentucky's current tollbridge building program.



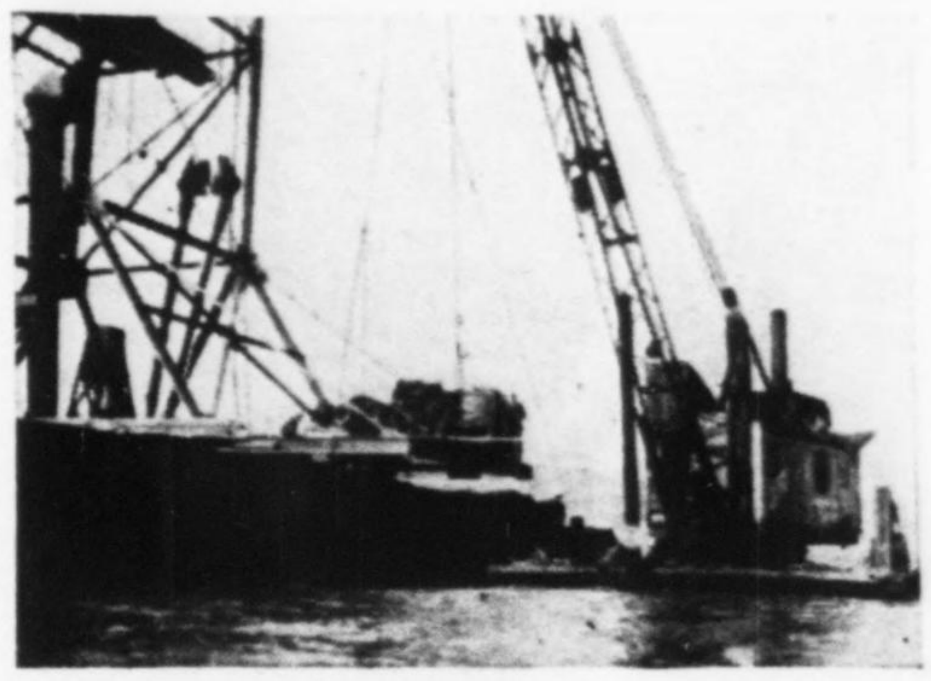
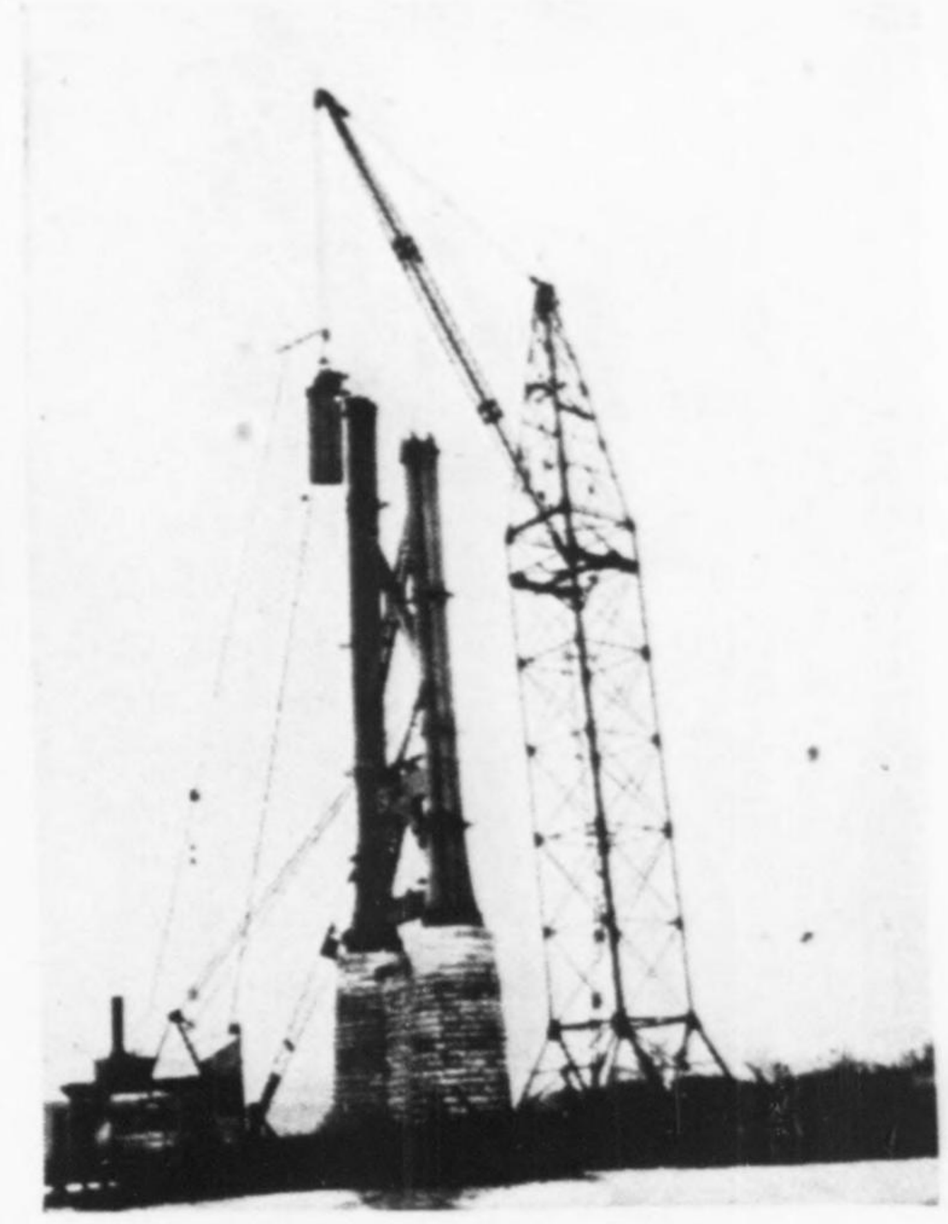


Fig. 3—Floating tower-derrick erected both bridge towers in eight days, including placing cable-erection equipment, as shown at left. The electric hoisting engine placed on an outrigger platform served as counterweight for derrick boom (above). (Right) Steel picked direct from supply barge. Note riveting scaffolds which were attached to leg sections of tower in the barge before erection.



the circle in this portion of the cable, and zinc castings, cored out for lightness, were used as shown in Fig. 4.

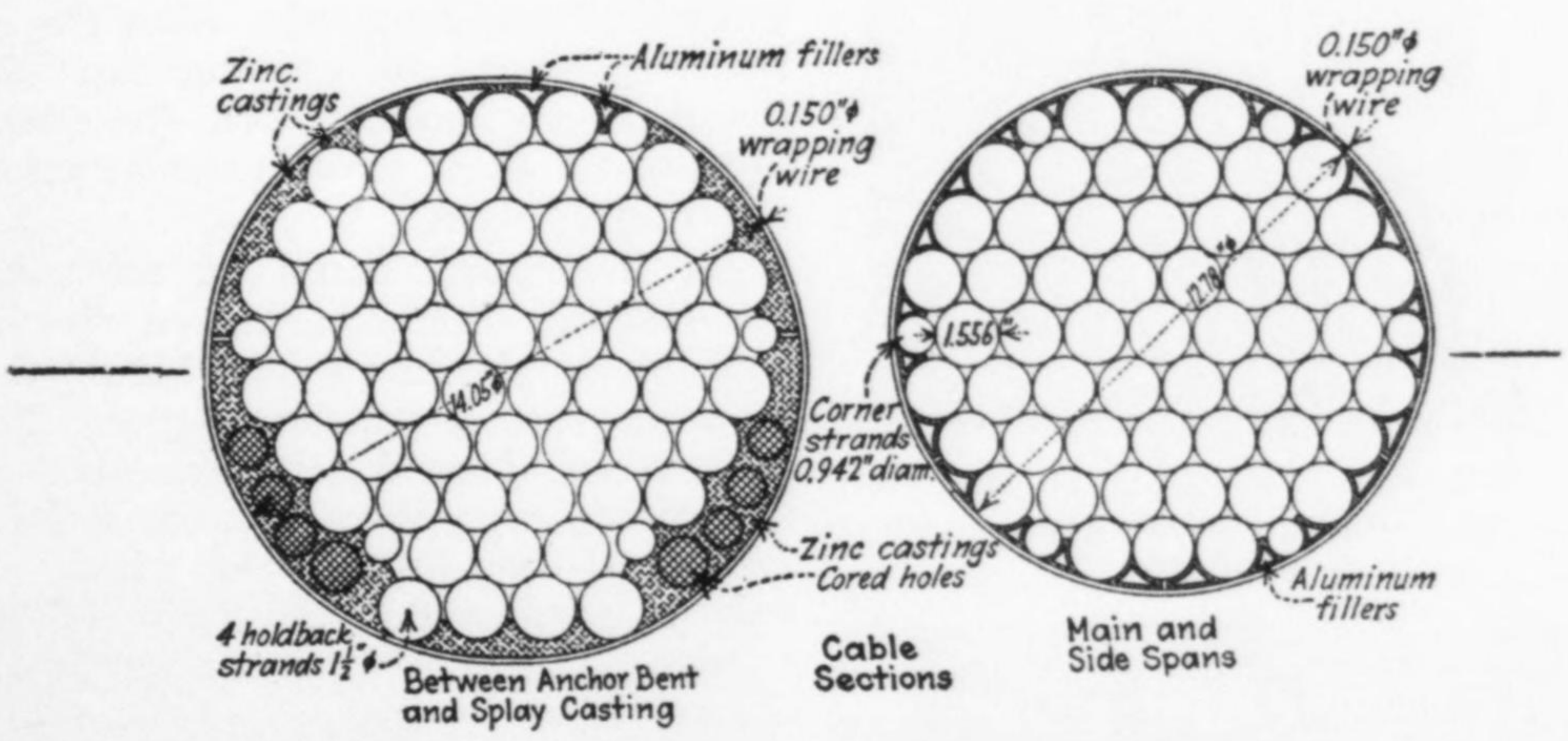
In the St. Johns bridge these additional backstay strands were fastened to the sides of the cable bent saddles several inches below the bottom strands of the cable in the saddle grooves. As a result the added strands did not become tangent to the bottom strands of the cable for some distance from the saddle casting, making wrapping in this section impossible and requiring a metal hood for weather protection. At Maysville an ingenious design of saddle casting was worked out (Fig. 4) that keeps the added strands tangent to the main cable strands throughout their entire length. Wrapping was applied right up to the casting, as may be seen in Fig. 2. Lead wool calking sealed the annular opening at the face of the casting, and no hood was necessary.

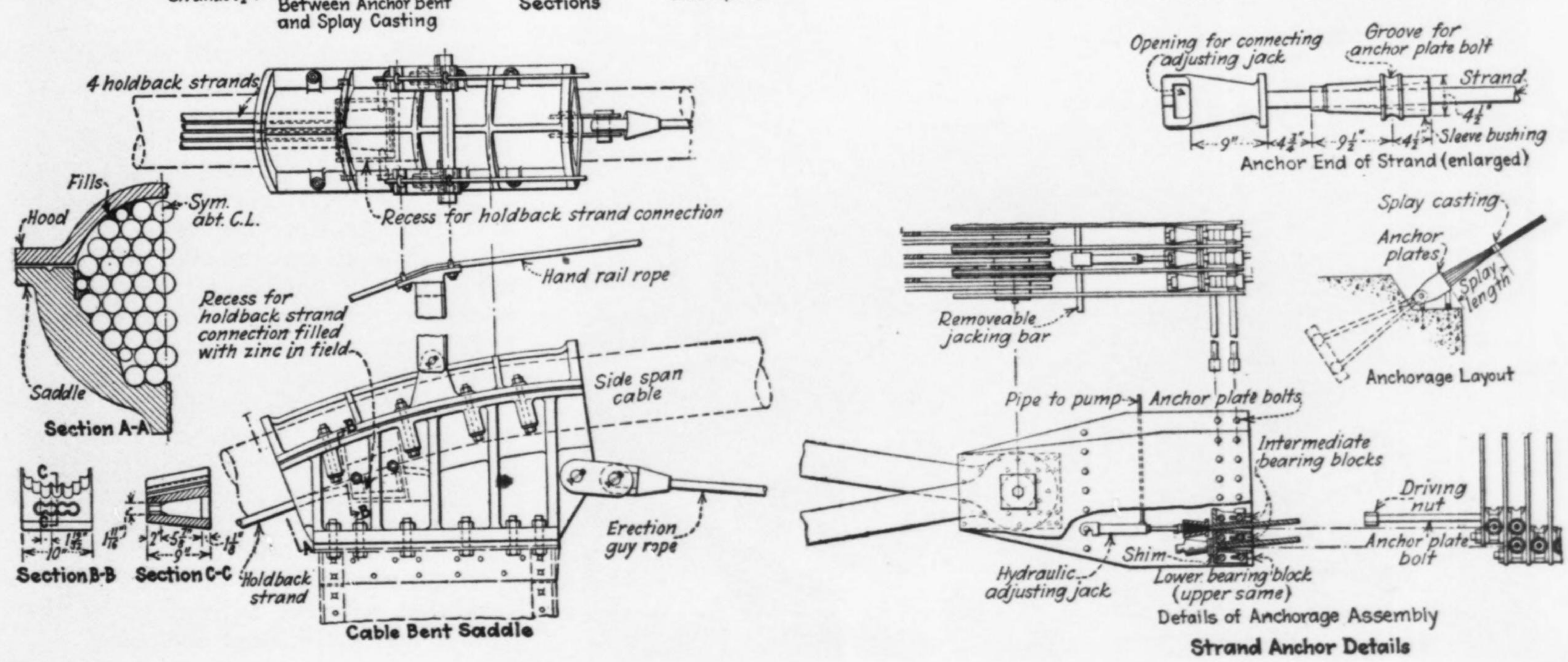
A change from the anchorage arrangement used at St. Johns was also effected at Maysville. Beyond the splay point at St. Johns the strands of each cable were divided into nine parts terminating in nine sets of anchorage plates. At Maysville a single set of plates is placed symmetrically about the center line of the cables. This simplifies the splay arrangement and produces a more compact anchorage, making possible a reduction in the over-all width of the anchorage block. The strands are fastened in the anchorage plates by steel end sockets that bear against cast-steel blocks bolted between the plates. Cast-steel sleeves attached to the strands in the shop protect the strand where it passes between the bearing blocks. These sleeves are cast with an interior radius to accommodate the inclination of the strand as it leaves the anchorage plates. This assures against any bending or damage of the strand (see Fig. 4). The bearing blocks were machined square with the cable centerline.

Erection

These design features, while important, are largely matters of detail. It is in the erection procedure that major departures from recently used methods are most prominent. Towers were erected by a floating derrick tower. Footbridges were used, supported by special ropes and not by the

Fig. 4—Cable and anchorage details, Maysville bridge.





suspender ropes, as is usual practice. Stiffening trusses and floor steel were placed by a derrick boat with a 130-ft. boom.

Tower Erection—Inasmuch as both towers are located in the river, the contractor elected to erect them with floating equipment. Their height precluded the use of a standard derrick, and a special derrick-tower plant was developed. This erection tower is of steel, 200 ft. high, and consists of three principal parts—a wide base made up of trusses resting on timber grillages and spread across two steel barges tied together, a main shaft 21 ft. square, and the derrick mast and boom which are mounted on top of the main shaft. The mast is a pyramid-shaped extension of the main shaft and was in fact used as a cableway tower in constructing the New Jersey anchorage of the Hudson River bridge in New York. The boom of the derrick is 125 ft. long, a boom seat being provided on the center line of the tower. Guy lines attached to the corners of the barges serve to brace the tower. In addition, the three-drum, 125-hp. electric hoisting engine that is used is set on an outrigger platform at the base of the tower to serve as a counterweight for the derrick boom. In assembling the erection tower, a derrick boat placed the lower panels on the barges, while the remainder of the tower was erected by a gin pole jumped up inside the tower. Two drums of the hoist were used for load and boom lines. The third drum operated a line guy from the top of the erection tower to the anchorage, the tower being maintained in a vertical position by manipulation of the guy line drum.

All erection equipment on the job was electrically operated. Since electric power was not available on the Ohio shore, a special submarine cable was laid from Maysville, Ky., across the river, to furnish current to the Ohio tower and anchorage.

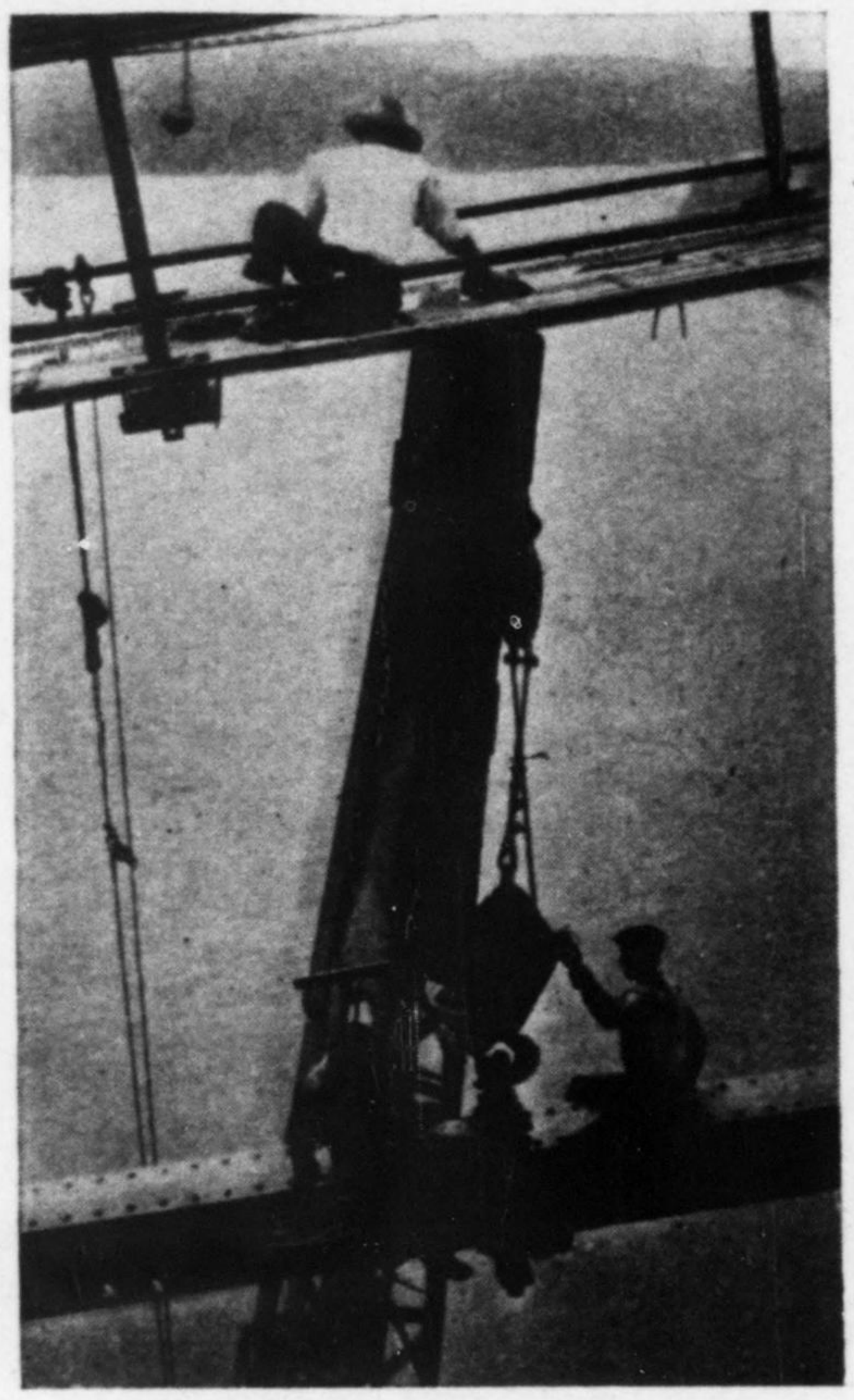


Fig. 5—Use of footbridges for parallel-strand cable erection was important innovation on Maysville bridge. View shows boom of floating derrick setting stiffening truss but also gives good idea of footbridge make-up. Note wood crossbeams held between angle clamps, also perforated channel posts permitting vertical adjustment of footbridge.

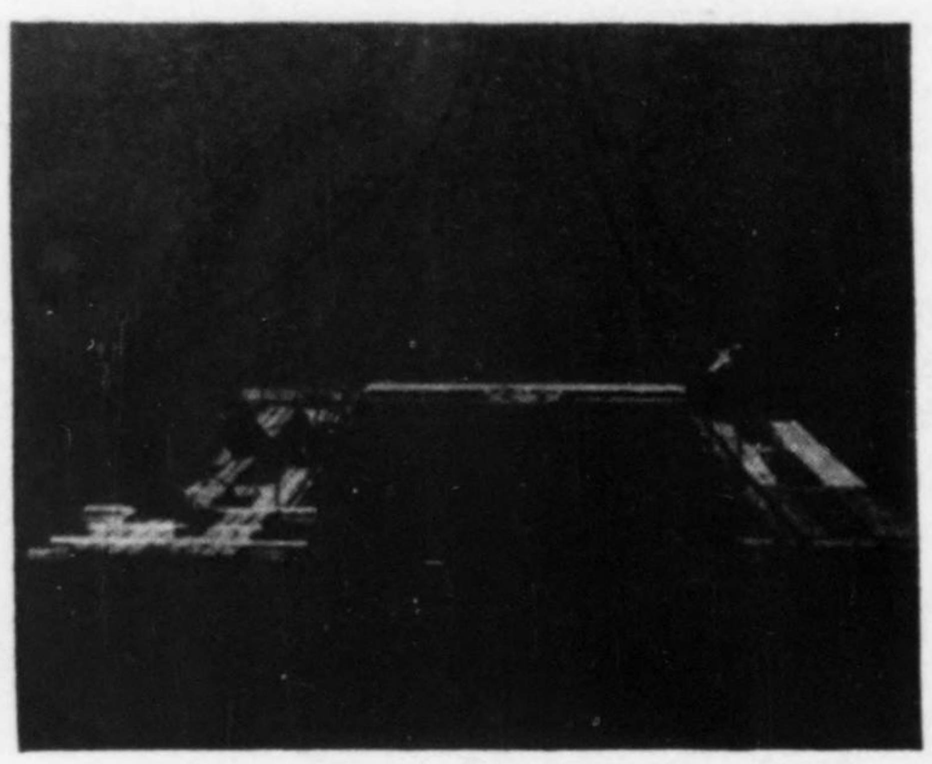


Fig. 6—Erecting footbridges by sliding trains of platform sections down ropes from tower tops.

The bridge towers are of the usual braced-leg fixed-base type. Silicon steel is used. Above the roadway the legs are braced by 2½ panels of X-bracing. A horizontal strut is used at the top of the tower. Below the floorbeam is one-half panel of X-bracing and a horizontal strut, 7½ ft. above the top of the pier. Each leg is cellular in cross-section, consisting of a comparatively wide center cell with narrow cells front and rear. Erection pieces varied in length up to 46 ft. maximum and in weight up to 28 tons.

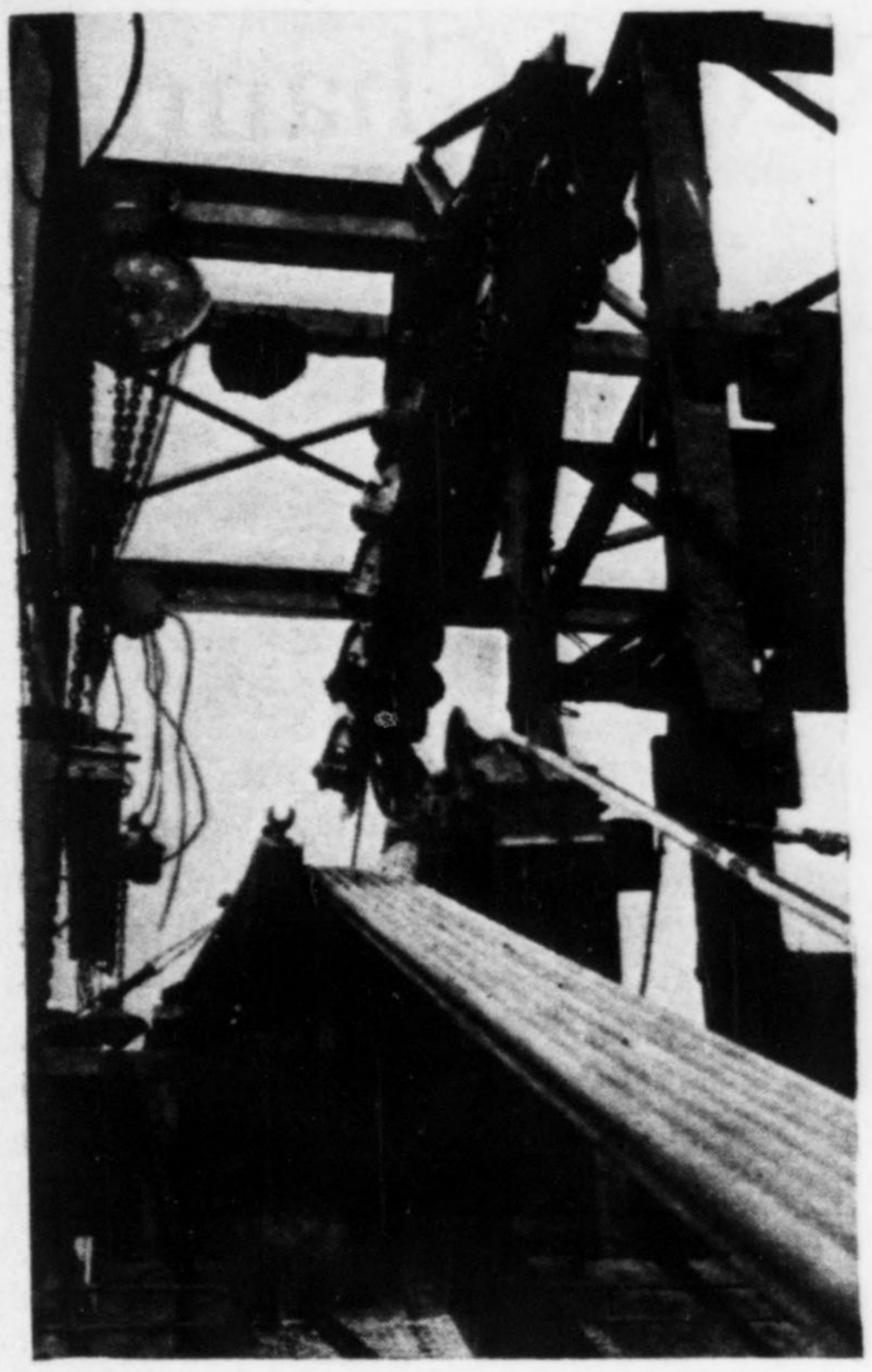
The Ohio tower was erected first. Steel came to the job in barges, carefully loaded so that no sorting on the job was necessary. The column bases were set by a derrick boat. Then with the derrick-tower plant lashed to the landward side of the pier, the steel supply barge was anchored to the opposite side. This permitted the erection derrick boom-line to be dropped directly to the steel barge and the steel to be lifted almost vertically into place. Inasmuch as the derrick boom had only about a 10-ft. swing, it was possible to erect only one leg and the bracing from the first position. The derrick tower was then dropped down the river about 20 ft. and the second leg erected. All steel in the Ohio tower was placed in 4½ working days, after which a stern-wheel steamboat moved the erection equipment to the Kentucky tower where the procedure was repeated. With the experience gained in erecting the Ohio tower, it was possible for the erector to place all of the steel in the Maysville tower in 3½ days.

An interesting detail of the tower erection was the attaching of riveting scaffolds to the tower legs before they were hoisted from the barges. This made them immediately available for the raising gang as well as for riveters, and saved time in the field, which was particularly advantageous, since riveting was by far the most time-consuming element of the erection procedure.

The contractor was well satisfied with the use of the floating derrick tower. Work continued in spite of a protracted period of high water, the only difficulty occurring from driftwood that lodged against the barge and pier. Inasmuch as the barges were lashed to the pier, this driftwood was removed with difficulty. On a similar future job, the tower derrick barges would probably be held in position by anchor lines, which will permit easier maneuverability.

Footbridges—The engineers' specifications for the Maysville bridge required that footbridges be used when erecting the cables. This is contrary to previous practice on parallel-strand cable bridges, but was believed advisable by the engineers in order to assure proper inspection, efficient adjustment of the strands and satisfactory wrapping.

Fig. 7—Cable strands wound on special reels in the field were pulled across the river by an endless tramway rope. Note the compact anchorage requiring a minimum splay of the strands.



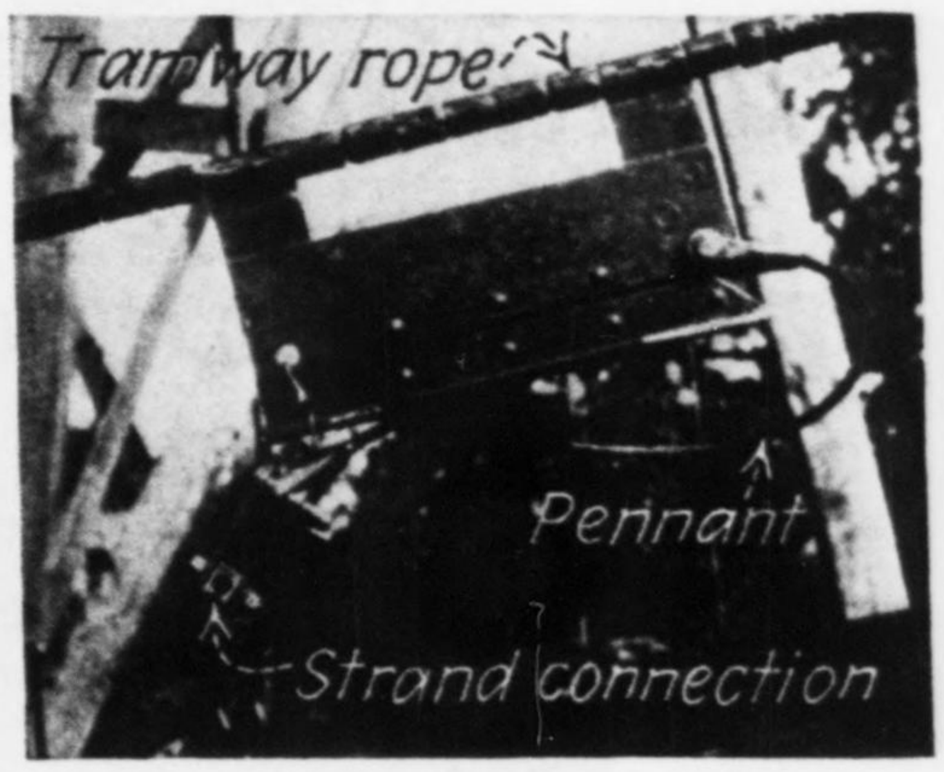
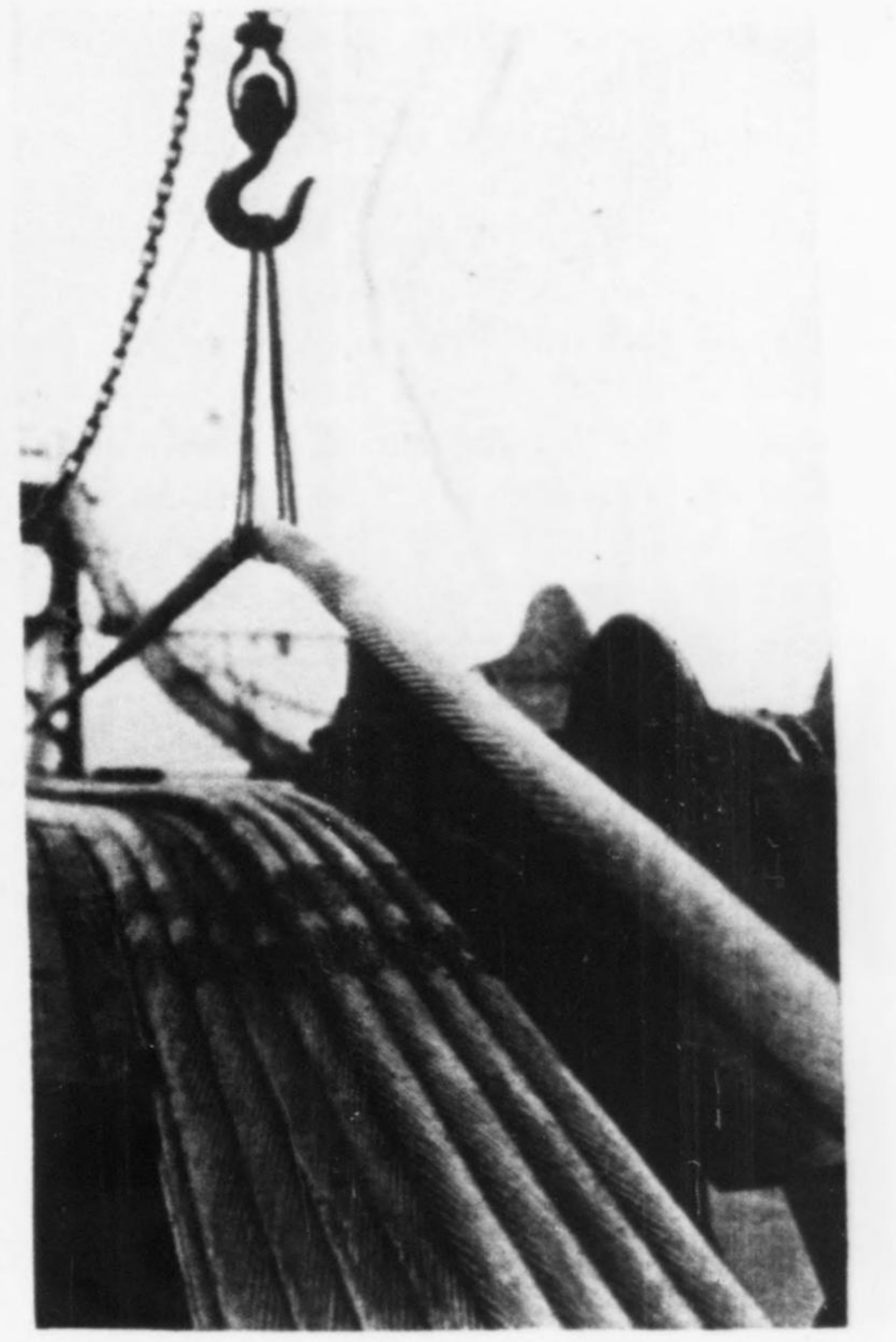


Fig. 8—In constructing the Maysville bridge cable the tramway rope to which strands were connected through a plate and pennant-line (center) was carried at the tower top by a line of deflector sheaves (left). Strands which were supported at the tower tops on four rollers while being hauled across the river were lifted into the saddle by a chain hoist (left and right). In right-hand view note right- and left-lay strands in adjacent layers.



Suspender ropes on this bridge were prestressed, cut to length and socketed in the shop and sent to the job ready for erection. This precluded the use of the suspender ropes for footbridge ropes, as has been previous practice. Accordingly, four ungalvanized ropes $1\frac{3}{4}$ in. in diameter and long enough to reach from anchorage to anchorage formed a part of the footbridge equipment.

The footbridges designed by the contractor were entirely of wood, with the exception of the channel-iron uprights placed at the end of each 10-ft. floor section. Thus they were light and easy to handle. The floor sections were 6 ft. wide, made up of three 8-in. wide planks at either side with a 2-ft. strip down the center covered with wire mesh which served the twofold purpose of lessening the weight of the footbridges and later of permitting openings for the suspender ropes to be made easily. Cross beams (Fig. 5), placed at the end of each floor section, were two 4x4-in. timbers fastened to the channel-iron posts by small angle clamps, which eliminated the necessity for any bolt holes in the timbers. Bent-plate clevises fastened to the channel posts served as hooks to attach the footbridge to the footbridge ropes. Holes punched in the webs of the channel posts on about 3 in. centers made it possible to place the footbridges at variable distances below the ropes. Such adjustment permitted the footbridges to be lowered as the main cable, under its own weight and the weight of the suspended floor steel, sagged down. On previous suspension bridges the foot bridges have been transferred to lashings passing over the main cables when it became necessary to remove the footbridge ropes and cut them up for suspenders. Under such an arrangement the distance between the cables and the footbridges did not vary as the cable sagged down, but with the footbridges entirely independent of the cables their vertical adjustment became a necessity. The adjustment provision at Maysville proved entirely satisfactory.

Fig. 9—Wrapping the Maysville strand cable which was brought to a circular section by the use of aluminum fillers.

As an initial operation in erecting the footbridges, a 1-in. diameter endless tramway rope was carried from the Kentucky to the Ohio shore and back again by a steamboat, and lifted to supports on top of the towers. Machinery for operating the tramway was placed on the Ohio anchorage. This tramway pulled the footbridge ropes across the river and later erected the cables.

With the footbridge ropes in place, the footbridge sections were hoisted to the tops of the towers and slid down the ropes in trains (Fig. 6). This proved an unusually rapid means of erection, and the footbridges, including ropes and platforms, were placed in six days. The final operation in the erection of the footbridges involved the placing of the storm system. This included a single rope for each footbridge, fastened near the base of each tower and pulled up into an arch outline by means of bridles hung from the footbridges.

Cable Construction—With the completion of the footbridges, headframes were erected along them to support the tramway ropes that hauled the bridge strands of the cable across. Deflection sheaves were also placed on top of each tower and at the cable bents to support the tramway rope at these locations. A strand connection consisting of a plate with a pennant line and clevises (Fig. 8) was attached to the tramway line at both the Maysville and Aberdeen anchorages, one serving each cable. By shuttling these connections back and forth across the river, the strands were laid and the cables built up.

All strands were received by rail on the Kentucky shore and transferred to a special reel stand on the Maysville anchorage block. The tramway carried the Ohio end of only one strand per

Fig. 10.—Stiffening trusses and floor steel were lifted into place with 130-ft. boom of crane mounted on float.

trip, and strands were placed alternately in each cable.

At the tower tops the strand as it was hauled across was supported on four large cast-iron wide-mouthed sheaves set tandem. After attaching the ends of a strand at both anchorages, the strand was transferred from the sheaves to the saddle by means of a chain hoist and a balance beam. The strands were placed in the cable in layers, strands in adjacent layers being of opposite lay to assure line bearing instead of point bearing between the wires of strands in adjacent layers at all turning points of the cable. Also, the use of alternate layers of right- and left-lay strands provides resistance against a rolling effort on the part of the cable caused by the inherent tendency of each strand to rotate as load is applied. In the right- and left-lay construction the rotational tendency of one layer of strands is resisted by the same tendency but in the opposite direction in the adjacent layer.

The cables were erected in nine days, or a layer per day in both cables. No faster progress was possible because each layer had to be adjusted before another layer was added, and this adjustment could only be done correctly after the sun had gone down.

The suspenders were hoisted to the tower tops and slid down the footbridges to their proper locations. The stiffening trusses and floor steel in the main span and in the portions of the side spans near the towers were lifted into place from barges by means of a derrick boat with a 130-ft. boom. On the portions of the side spans on shore that could not be reached by floating equipment a cable-traveler operated by an engine on the shore set the stiffening trusses and floor steel. No compacting of a bridge strand cable is necessary but after the aluminum fillers had been applied to fill out the cable to a circular section, a double-spool wrapping machine similar to the one used on the Hudson River bridge wrapped the cable with No. 9 soft-annealed galvanized wire.

Administration — Contracts for the Maysville bridge were let Oct. 8, 1930. The bridge was opened to traffic on Nov. 25, 1931. The Dravo Contracting Co., of Pittsburgh, started work on the foundations immediately after the contract was let and had the piers and anchorages ready so that steel erection started April 1, 1931. The John A. Roebling's Sons Co., Trenton, N. J., erected the entire bridge as well as manufactured and furnished the cables. For this company C. C. Sunderland was chief engineer, C. M. Jones assistant chief engineer, R. J. Cole resident engineer, and Wade Klein superintendent of erection. The Maysville bridge was designed and the erection supervised by Modjeski, Masters & Chase, Harrisburg, Pa., for whom C. W. Hanson was resident engineer. For the state of Kentucky, H. D. Palmore is chief engineer and H. R. Creal bridge engineer.

Maintaining River Channels by Shoal Dredging

Location and occurrence of shoals—Mobilizing for dredging—Parallel cut system employed—Dustpan suction head preferred

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Two Successive Seasons of extremely low water in the Mississippi River are making necessary an amount of channel maintenance work that is putting to test the dredging-equipment resources of the government engineers responsible for maintaining navigation. Even old dredges which had supposedly been retired from active service have been called back into the fighting line and forced to wage battle with the "rising bottom." Dredging for channel maintenance is primarily a task of cutting through shoals which form mostly at reverse bends where the channel crosses the river. It calls for a type of organization mobility and of planning and operating technique quite different from ordinary channel-deepening and land-filling operation. These characteristics are notably well presented in the article that follows.
—Editor.

The general course of a river through an alluvial valley is a succession of reverse curves (see Fig. 1) called bends, which are of widely varying lengths and degree of curvature. In the upper part of the river the bends are short and sharp, but as the lower limits are approached there is a gradual increase in length and decrease in degree of curvature. The thalweg of the river is parallel to and from 200 to 600 ft. from the outside bank of the bends. Where two reverse bends join, the thread of the channel leaves the upper bend a short distance above its lower end or foot and joins the lower bend a short distance below its head. This place is called a crossing, as the channel crosses from one bank to the other, and, except in extraordinary cases, all shoals are found at these places.

From New Madrid to Helena is the most difficult section of the Mississippi River in which to maintain a navigable channel. Owing to greater slope there is a stronger current, resulting in excessive bank erosion. There are also many islands, with a possible channel on either side. The increased width of river also increases the possibility of more than one channel through the bars. In this section the most troublesome part is above Memphis, which comprises only 66 per cent of the distance but contains 80 per cent of the shoals. The accompanying table indicates the conditions.

LOCATION OF MAXIMUM SHOAL FORMATION AND DREDGING OPERATIONS

Districts	Miles in District	Slope Per Mile-Ft	No. of Shoals Dredged	Per Cent of Shoals
Cairo to New Madrid..	71	0.25	4	2
New Madrid to Helena	236	0.49	159	83
Helena to Vicksburg...	295	0.32	11	6
Vicksburg to mouth Red River.........	171	0.25	17	9
Mouth Red River to New Orleans.......	192	0.25	0	0

Below Helena a gradual change takes place in the character of the river, the decreased slope resulting in fewer caving banks and the width being more uniform. The first large tributary enters 12 miles above Helena and between there and the mouth of Red River three other rivers enter to increase the discharge. This increased volume is taken care of by greater depths. Except in extremely low water, dredging operations below Helena have been confined to a few crossings. Dredging to maintain channel is not found necessary below Red River.

When the gage at Cairo registers 22

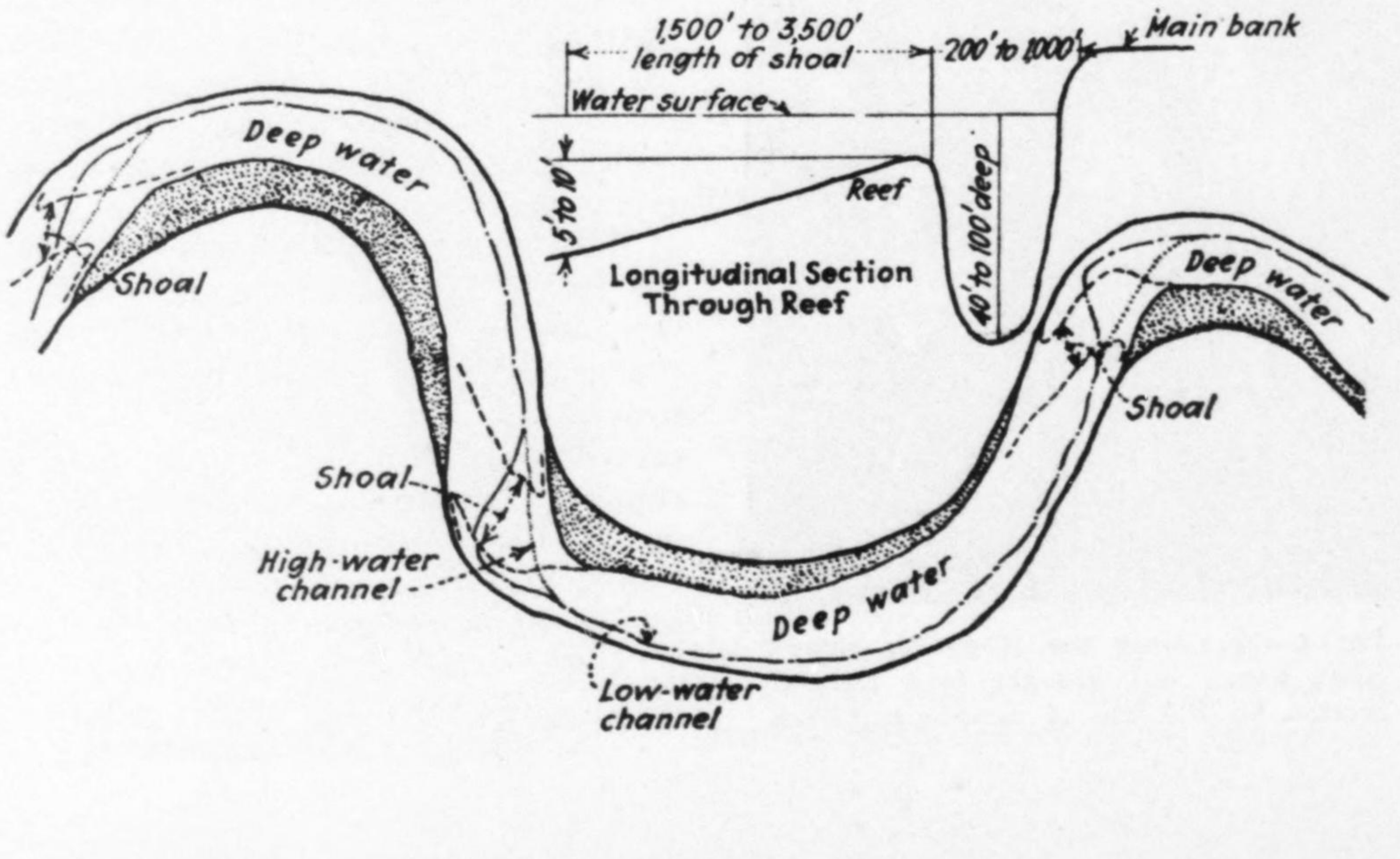

Fig. 1—Typical section of river showing shoals at crossovers of channel.