Building a Rib-Arch Concrete Bridge in Arkansas

Fourteen 146-ft. and Two 212-ft. Arches with Girder Span Approaches, Form Concrete Structure 3,173 ft. Long—First Highway Crossing of the Arkansas River—At Fort Smith, Ark.

BY C. A. PROKES
Resident Engineer, Missouri Valley Bridge & Iron Co., Fort Smith, Ark.

ARCH centers were special features in constructing the nearly completed Arkansas River bridge at Ft. Smith, Ark. Methods of erection and the way of building out 146 ft. steel centers to carry a 212-ft. arch, were uncommon. The pier work was unusual in plan and in some of the construction methods. Incidentally the bridge is one of the largest concrete structures of the southwest, being 3,173 ft. long and containing over 20,000 cu.yd. of concrete reinforced with 784 tons of steel.

A view, Fig. 1, of the nearly completed bridge, looking from Oklahoma toward Arkansas, indicates the principal structural features. Besides an earth fill approach 2,000 ft. long on the Oklahoma shore, there are 3,173 ft. of concrete structure as follows: Arkansas retaining wall approach, 203½ ft.; twelve girder spans, 498½ ft; fourteen 146¼-ft. arch spans, 2,047½ ft., and two 212¼-ft. spans, 424½ ft. The overall width is 41 ft., comprising a 28-ft. roadway and two 6½-ft. sidewalks. The highest point of the roadway is 76 ft. above mean low water.

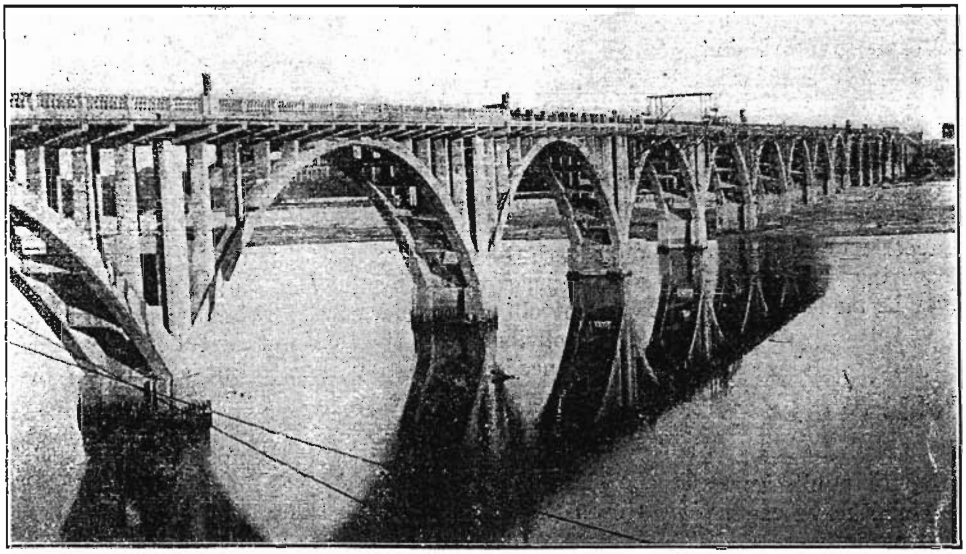


FIG. 1. ARKANSAS RIVER HIGHWAY BRIDGE NEARING COMPLETION AT FT. SMITH

A 1:2½:5 concrete mixture was used in the bases of all piers, the railing concrete was a 1:1½:3 mixture, and all the remaining work was of 1:2:4 concrete. The arch ribs were designed for a live-load of two 49-ton street cars on a single track; 100 lb. per square foot on the remainder of the roadway; 80 lb. per square foot on the sidewalks, and 25 per cent impact. The floor slab and girders were designed for the live-load of a 15-ton road roller, or 150 lb. per square foot; 100 lb. per square foot on sidewalks, and 25 per cent impact. The maximum allowable stresses used in the slabs and girders were 600 lb. per square inch concrete compression, and 16,000 lb. per square inch tension in steel. The allowable compression in concrete in the arch ribs, including dead and live loads, rib shortening and temperature stresses for a range of 40 deg. F. was 800 lb. per square inch.

All the piers, including the abutment piers, have solid rectangular concrete footings, varying in height from 14 to 16 ft., and resting on a hard shale river bottom. From this rectangular footing the two abutment piers rise vertically in front, and on an incline in the rear, to take the thrust from the arch ribs. There are no wing walls on the abutment piers. The other fifteen piers above the footing, have a section like capital H, Fig. 2. The sides of the H which take the thrust are at the spring line, 8 x 14 ft. for the two longer spans, and 6 x 9 ft. for all the others. The web section is 48 in. wide. The two side sections are battered 1¼ in. per foot in height, from pier base to spring line.

The arch ribs for each of the fourteen 146-ft. 3-in. arches are 4 ft. 6 in. wide, varying in height from 3 ft. at the crown to 5 ft. 6 in. at the haunch. On the two 212-ft. 3-in. arch spans the arch ribs are 6 ft. 6 in. wide, with a height 3 ft. 6 in. at the crown and 7 ft. at the haunch. The small arch ribs are braced laterally by four rectangular concrete beam struts to each half span, and the large arch ribs have three beam struts per half span, (Fig. 1.) The spandrel columns are rectangular, 11 ft. 3 in. apart horizontally, and support the cross beams, or floor beams, 15 in. wide, which carry the roadway slab. The sides of the spandrel columns are battered ⅛ in. per foot, downward from the floor beam, in the width only. At each pier a T-shaped column 43 ft. 3 in. high, Fig. 2, connects the top of the pier with the deck. The floorbeams are 48 x 15 in. in section, between the columns, and are cantilevered from the column to the sidewalk edge to carry the sidewalk. The roadway and sidewalk are divided longitudinally into panels 11 ft. 3 in. long by these floorbeams, thirteen per small span and eighteen per long span. Each small span has four transverse expansion joints of ½ in. elastite, which cut the deck work into sections averaging 38 ft. long. The long spans also have four expansion joints, averaging 51 ft. apart. The sidewalk slab is 4 in. thick, the roadway slab is 8½ in. thick, and two track girders at the center, and one railing girder on each side are the only longitudinal beams under the roadway.

Four river piers and one abutment pier on the Arkansas shore, were built in open cofferdams of light steel sheetpiling by M. M. Elkan, contractor, Macon.

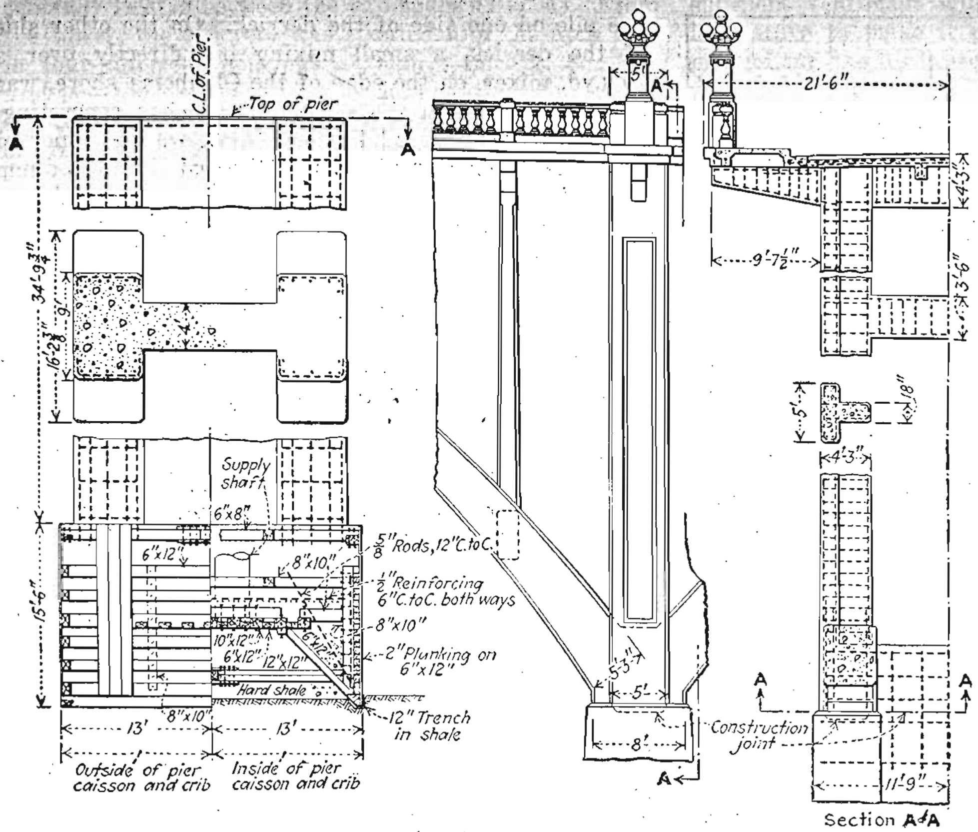


FIG. 2. TYPICAL PIER AND CAISSON DETAILS

Ga., who suspended work in April, 1920. In July, 1920, a new contract to complete the 75 per cent of unfinished work was awarded to the Missouri Valley Bridge & Iron Co., of Leavenworth, Kan. The remaining twelve river piers were then sunk by the pneumatic process, six piers through 32 ft. of sand and gravel on the sand bar, and the other six piers through water for one-third of the sinking depth. The twelve piers were sunk in 4½ months, averaging 7½ actual working days for sinking one pier, working three 8-hour shifts. An air compressor on the Oklahoma shore furnished air through a 4-in. iron pipe, carried across the river on a pile and timber tram trestle, and the maximum distance for piping was 2,000 ft.

The side walls of the caisson cribs were 6 x 12 in. timbers laid horizontally, and held together with ¾-in. iron drifts, 30 in. on centers, and covered on the outside with 2-in. friction planks, placed vertically, (Fig. 2). The cutting edge timber was covered with a 6 x 6 x ½-in. iron angle on the bottom, to act as the cutting edge of the pier. On the sand bar, the caissons were built directly on the ground, while in the river, they were built on a platform, supported by wood piling, and when built, were lowered to the river bed with six 2-in. screw jacks.

The most difficult pier work was where one of the steel pile cofferdams, that had to be abandoned on account of high water, was discovered almost full of sand and leaning downstream, distorted and at an angle, and partly in the site where the new pneumatic pier was to be sunk. Several 1-in. cable slings were passed through holes in the tops of the steel piling under water, by a diver. These cable slings were attached to wire rope rigging of double and triple blocks, fastened to the adjacent finished pier and the combined effect of several heavy dynamite blasts under water, and pulling on the piling, swung it aside so as to clear the pier site.

The steel falsework for each of the fourteen 146-ft. 3-in. arch spans consisted of one steel truss under each of the two arch ribs, with a pin connection at the center. These two trusses, when in place, were diagonally and laterally braced with rods, have a span of 136 ft. from back to back of shoes and are 46 ft. high. There was 7½ in. of oak blocking between the back of the truss shoe and the face of the concrete pier. The shoes rested on a 12 x 12 in. oak cap, supported by four 12 x 12 in. posts, on the top of the pier footing, and held to the side of the pier with bolts. The top chord of the trusses, on a radius 10 in. smaller than the intrados of the arch ribs were parallel to the arch rib bottom, thus requiring only 6 x 8-in. joists on edge, with 2-in. lagging on top of the joists, for the bottom form of the arch rib. The 6 x 8-in. joists were set perpendicular to the axis of the bridge, spaced 30 in. apart and held in place with ½ x 4-in. lag screws through the top chords of the trusses.

On the two 212-ft. 3-in. arch spans the clear distance between the face of piers, is 198 ft. The same steel centering was set in the center of the span, with each shoe resting on a cluster of nine wooden piles. With this set up, there was a clear space from the face of the concrete pier to the back of the truss shoe, of 31 ft. The falsework, therefore, consisted of the three steel trusses, braced diagonally and laterally, with the space between the top chord of the trusses and the intrados of the arch ribs built up of timber posts, caps and stringers, Fig. 4.

A layout was made on the floor of a barn hay loft, near the site of the work, of the arch ribs, the steel trusses, etc., on a scale of 1½ in. per foot, then the proper size stringers, posts, caps and sills for the design, were located on the layout. From the layout, full sized templets were made with the proper lengths, bevels and daps in the posts, sills and caps, and also the intrados curve on the joists for the arch rib. From these templets, all the timber was framed on the ground, properly marked, then erected in place and fitted together. This framing of all the timber before erection was a great saving in carpenter work.

The three steel trusses for the two long spans were erected in half sections. Three half trusses were assembled on pile bents on a level with the truss shoes, laterally and diagonally braced, then raised as one piece, by using two sets of four triple 14-in. iron blocks, Fig. 5. From each set of four triple blocks, there was one lead cable ⅝ in. in diameter leading to a two-drum hoist, which raised the three half trusses as one piece, by winding both engine drums simultaneously. The triple iron blocks were lashed to four 1-in. cable slings, rest-

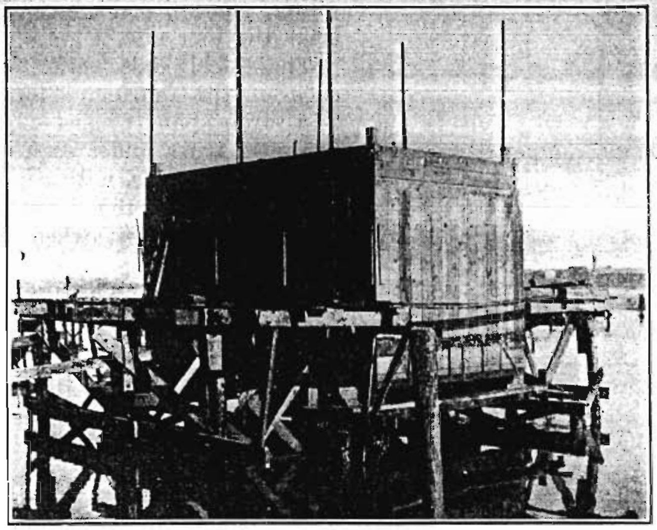


FIG. 3. CAISSON ON PLATFORM READY TO BE LOWERED

ing on a heavy timber bent, about 35 ft. above the truss shoes, this giving the necessary purchase to start the load of 25 tons, upward. After one half of the three steel trusses was raised and the cables clamped, the other half was similarly raised, and then the pin connection at the center was made. For the twelve shorter spans of 146 ft. 3 in. where the steel falsework consisted of only two complete trusses, the two half trusses were similarly raised in one piece, but the rigging consisted of four sets of one double and one triple blocks.

Plant for Concrete Work

A timber-trestle service railway was maintained across the two channels of the Arkansas River, respectively 570 ft. and 900 ft., during the construction of the piers. This tram track was 6 ft. above mean low water and was washed out by flood waters four times within six months, during the construction of the piers, but each time the piling and timber were salvaged by being held by wire rope. The tram track carried a 4-in. air pipe line from the compressor plant on the Oklahoma shore to the sand bar, which could be tapped at any pier site during the pneumatic sinking.

All sand and gravel for concreting was pumped out of the Arkansas River within a mile of the bridge site, delivered in barges to the Oklahoma shore and tested for the proper proportion of sand and gravel and then unloaded with a stiff-leg clamshell derrick, into a storage pile on one side of the derrick. On the other side of the derrick, a small mixing bin directly over a 1-cu.yd. mixer, on the edge of the Oklahoma shore, was kept supplied from the storage pile, when concreting.

The concrete for all the pier work was transported over the timber tram in two 1-cu.yd. bottom dump buckets, mounted on two 36-in. gage trucks and drawn by a 10-ton dinky steam locomotive, with a maximum hauling distance of 2,000 ft. For the river piers, a barge derrick lifted the bottom-dump concrete buckets from the cars, delivered on the tram, and deposited the concrete into the piers, directly. On the sand bar, an A-frame portable derrick, on one side of the track, lifted the buckets of concrete from the tram and deposited the concrete into the piers. After the pier work was complete, the arch ribs for the two long spans, near the Arkansas shore, were poured. The dinky locomotive hauled cars of concrete from the Oklahoma mixing plant, over the two river trams, and deposited the concrete into a hopper at the bottom of a 200-ft. tower,

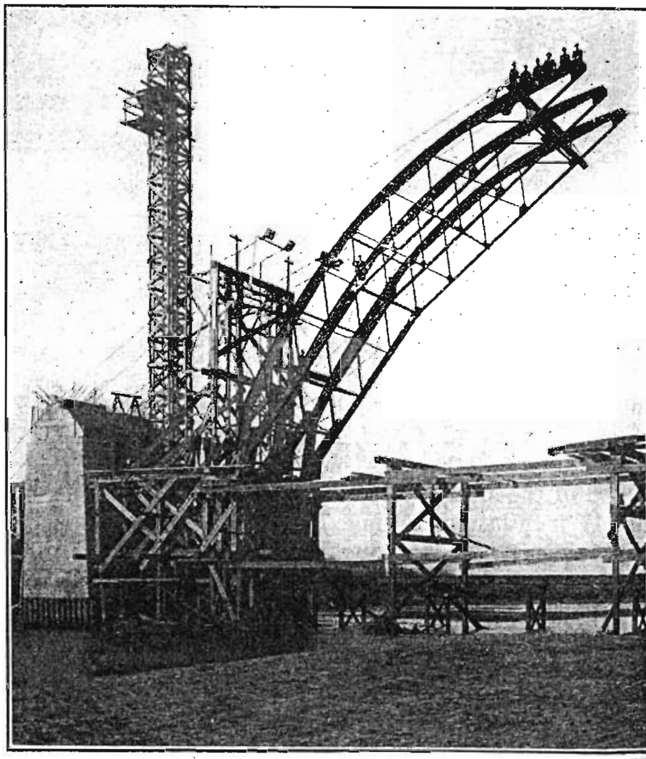


FIG. 5. RAISING STEEL CENTERS FOR 212-FT. SPAN

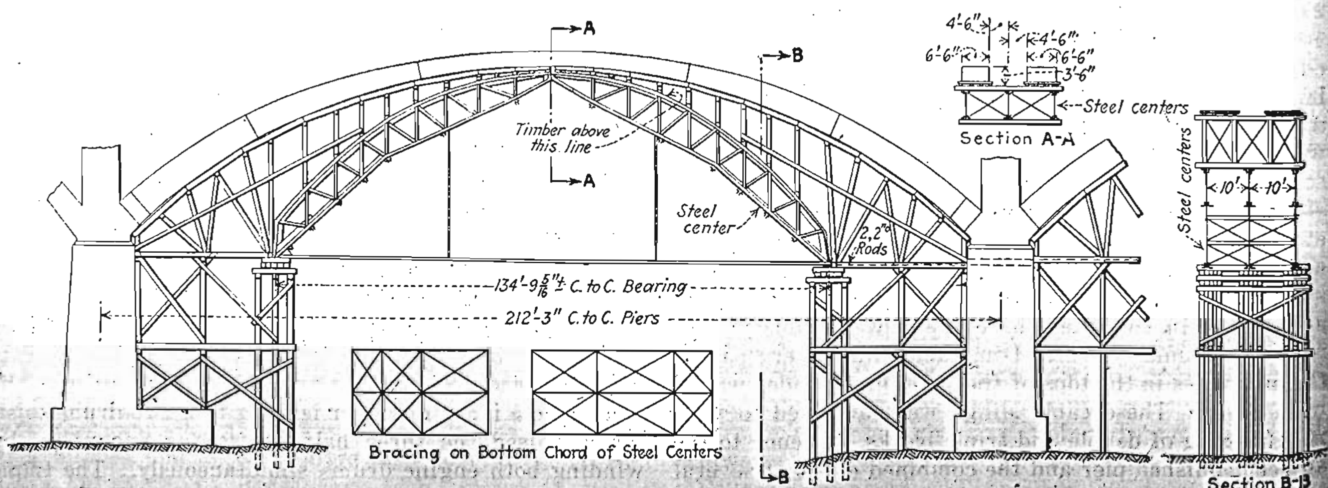


FIG. 4. STANDARD ARCH CENTER BUILT OUT FOR LONGER SPAN

centrally located between the two spans (Fig. 4). From the tower, the concrete was spouted into the arch ribs in four different pourings as shown in Fig. 3. The first pouring being adjacent to the haunches, the second adjacent to the crown, the third pouring covering the crown, and the last pouring being made at the haunches.

After the long arch ribs were poured, the river tram was abandoned and removed, and all the superstructure concrete above the tops of piers, was transported over an overhead tramway, resting on the forms for the arch ribs, and erected over the center line of the bridge, with its track 52 ft. above and parallel to the tops of the piers. The concrete in the 14 small arch ribs was poured in two operations only, of 215 cu.yd. and 16 cu.yd. respectively. The first pouring each time of 215 cu.yd., extended from a bulkhead 4 ft. from the haunch at the spring line, to the opposite bulkhead, similarly placed. This allowed the necessary settlement and shrinkage of about 97 per cent of the concrete in the full arch ribs, and 48 hours later, when the timber bulkheads were removed, the remaining 4 ft. of arch rib at the four haunches was poured.

The superstructure concrete was elevated in a 100-ft. tower at the Oklahoma shore, spouted 100 ft. to the center line of the bridge into two 1-cu.yd. cars, drawn by a gasoline tractor on a single 36-in. gage track. The tram track for the superstructure work was 4 ft. above the finished concrete roadway of the bridge, was maintained until all the superstructure concrete was in place, and after dismantling, the 8 x 8-in. holes in the 8-in. floor slab, through which the tram posts passed, were filled with concrete.

The original contract was awarded to M. M. Elkan of Macon, Ga., in February, 1919, for $537,000, for the entire work, but in April, 1920, work was suspended and the contract breached. In July, 1920, the contract to complete the unfinished work was awarded on a percentage fee basis. The structure will be ready for traffic about March 1, 1922, and the total cost will be approximately $850,000. The bridge was designed by Messrs. Hedrick & Hedrick, consulting engineers, of Kansas City, Mo., with J. M. Robinson, resident engineer. M. L. Wagner was superintendent and C. A. Prokes, resident engineer for the Missouri Valley Bridge & Iron Co., contractors.

Ban on Highway Advertising Signs

Advertising signs of all kinds are prohibited on state highways in California, according to the ruling of the California Highway Commission, and when found thereon are immediately removed by maintenance forces. While this policy keeps the right-of-way of the state highways free from obstructions, it does not prevent construction of billboards on adjacent private property.

Recently Kings County passed an ordinance prohibiting the erection of advertising signs on the county highways of that county and traffic officers have been instructed to remove all signs that remain on roads after a certain date. This action probably will be followed by other counties, as there is a growing sentiment against the disfiguring of highways with advertising contraptions.

The Farm Bureau centers in Butte County and in other sections of California are taking up the subject and it is quite possible, the commission believes, that sufficient sentiment will be aroused before the next legislature to make it possible to pass a general law prohibiting the disfigurement of the landscape by commercial appeals.

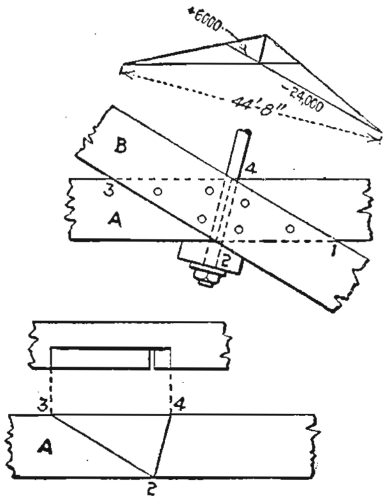
Hook Joint for Timber Chord of Scissors Truss

By David C. Coyle
Gunvald Aus Co., Consulting Engineers, New York

Ordinarily a wooden scissors truss is used only for short spans, and the stresses occurring at the intersection of the bottom chords, being small, are easily carried by bolts. The special detail shown herewith was made necessary by the unusual size of the truss, which has a span of 44 ft. 8 in., and by the fact that it is exposed, and must have no unsightly connections.

The stresses in the bottom chord are 24,000 lb. tension below the point of crossing, and 6,000 lb. above, making a total force at the joint of 30,000 lb. in each chord timber. If a pair of steel splice-plates had been used they would have required about thirty $\frac{7}{8}$-in. bolts; whether so many bolts would work together satisfactorily is more than doubtful. Splicing with 2-in. plank was rejected as unsightly.

Finally a form of hook splice was adopted which combines neatness with positive action and sufficient strength. The total thickness of the joint, for two 6 x 8-in. chord timbers, is 9 in., so that each timber is $1\frac{1}{2}$ in. off center. The top and bottom chords are framed flush at the end connection, and above the crossing the bottom chord is tapered to the point where it enters a mortise in the top chord. By cutting this taper from one side only, the required bend is obtained to bring the tapered end on center. To make the joint the chord-timber *A* is cut on its inner or near face on the lines 2-3 and 2-4, removing a triangular block $2\frac{1}{2}$ in. thick. Piece *B* is cut exactly the same (*not* opposite hand). When assembled, the two pieces hook together on the surface 2-4, which is very nearly perpendicular to the grain and to the line of stress. Surface 2-3 need not be accurate. The compressive stress on surface 2-4, which is about 8 x $2\frac{1}{2}$ in., amounts to 1,500 per sq.in. Part of this surface is cut by a hole for the $1\frac{1}{8}$-in. rod, but as this area is enclosed in 3 in. of wood and firmly bolted against splitting, it seems fair to count the whole projected area as bearing load. The net tensile section of $3\frac{1}{4}$ x $5\frac{3}{4}$ in. (2 bolts out), carrying 23,000 lb. (1,000 lb. deducted as load carried by first bolt), is under a unit stress of 1,240 lb. per sq.in.



TIMBER SCISSORS TRUSS, AND SPECIAL JOINT OF BOTTOM CHORD