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STONE ARCH BRIDGES RECENTLY CONSTRUCTED ON THE FITCHBURG RAILROAD.

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DURING the fifteen months just past, five stone arch bridges have been constructed on the Fitchburg Railroad. The construction of these arches, instead of steel bridges, was primarily due to the high prices of structural steel which prevailed during the year 1899, and to the difficulty of getting quick delivery after orders were placed. The bridges were located as follows:

(*a*) One double track railroad bridge, having two spans of 140 feet each, carrying the Cheshire Branch over the Connecticut River at Bellows Falls, Vt.

(*b*) One highway bridge, having two spans of 38 feet each and two spans of 14 feet each, carrying New Street, in Fitchburg, Mass., over the Nashua River.

(*c*) One highway bridge, having two spans of 40 feet each, carrying Putnam Street, in Fitchburg, Mass., over the Nashua River.

(*d*) One double-track railroad bridge, having two spans of 100 feet each, carrying the tracks of the Fitchburg Railroad over the Hoosick River at Hoosick Junction, N. Y.

(*e*) One double-track railroad bridge, having one span of 58 feet, carrying the tracks of the Fitchburg Railroad over the Tomhannock River near Schaghticoke, N. Y.

The largest and most interesting of these structures is the bridge at Bellows Falls. In the latter part of August, 1899, it be-

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came evident that the old wooden bridge which had carried trains ever since the construction of the Cheshire Railroad, was in such condition that immediate renewal was necessary. The old bridge (Fig. 1) was a double-track bridge of the trussed-arch type, the arches consisting of four members of white pine, each 10 x 16 inches in section, the lower chord being hung by rods from the arch when the latter was above the chord, and supported on the arch when the arch was below the lower chord. The old bridge was 38 feet wide over all. For twenty years only one track has been used, it having been thought unsafe to load the middle truss, which was apparently the same as the outside trusses, with trains on both

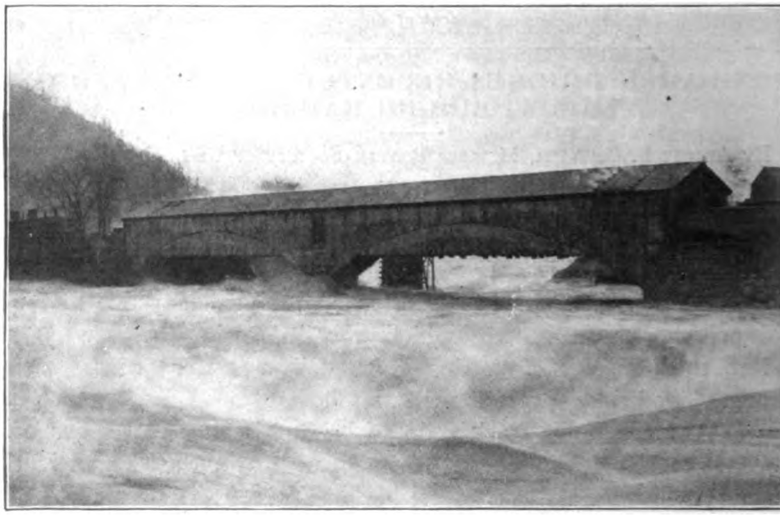

Fig. 1. Old Bridge at Bellows Falls.

tracks at the same time. At the time named, the price of steel was very high and it was impossible to get delivery of bridges until the middle of winter.

Owing to the impossibility of erecting and maintaining false work in the river at that point during the winter and spring, it was probable that if a steel bridge had been ordered at once, it would not have been safe to begin erection earlier than about the middle of May. It was also found that stone arches for a double-track bridge could be built for a little more than a single-track steel bridge, and for considerably less than a double-track steel bridge would cost, and that there would be time to build the arches before cold weather set in. The water in the river was then very low, and there was not much probability of a material rise unless heavy rains should occur during the fall. For these reasons it was deemed best to build arches, and contractors were found who were willing and ready to take the risk of starting at once. Work was begun on September 12th, on November 19th trains were running over a trestle built on the arches, and on December 7th the masonry was completed. The site of the bridge, which is almost directly over the falls, is particularly well adapted for arches, as the bed and banks of the river are of solid ledge, and there is a natural pier of rock in the middle of the river, dividing the stream into two channels. The

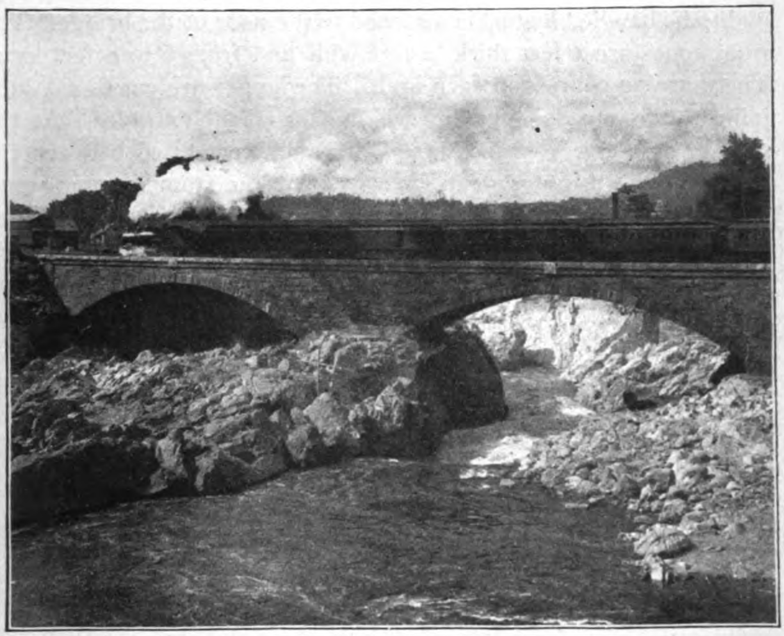

FIG. 2. NEW BRIDGE AT BELLOWS FALLS.

westerly channel is much deeper than the other, and in dry weather carries all the water. At low water the larger part of the water in the river is held up by the dam about a quarter of a mile above the site of the bridge, and is carried around through the canal and the mills, and is discharged into the river channel a short distance below the bridge. During all the time of construction only a small amount of water was passing under the bridge, so that it was possible to place all the posts carrying the false work directly on the ledge, the width of the channel to be spanned being only 40 feet. Nature having already supplied the abutments, it was only necessary to bed the skewback stones in Portland concrete enough to fill up the holes in the rock, and give a smooth and even bearing. The span of the arches was fixed by the natural conditions, and the rise was limited by the old bridge which had to be kept in place for the operation of trains. The arch ring was carried as close as it was possible to lay stone under the bottom chord of the bridge, and, in order to work with all possible rapiditv, the outside trusses and one track of the bridge, which was a three-truss double-track bridge, were removed. This left only 12 feet of the width of the arches under the bridge, and made it possible to lay the ring stones without difficulty, except a few at the crown of the arches, which had to be handled by tackle attached to the floor of the bridge. The ring stones are 4 feet thick, 2 feet wide and from 6 to 8 feet long. There are 72 courses in each arch. The stones are cut to a ½-inch joint on the intrados, opening to 2 inches on the extrados. As the stones were laid, V-shaped strips of wood were fitted between the joints on the intrados, to prevent the mortar from dropping out. The joints were then filled with Portland cement mortar, mixed one part of cement to two of sand, and they were thoroughly tamped with strips of 3 x ½-inch iron about 4 feet long, so that every crevice was completely filled. After this was done, as many pinners of stone as could be put in were forced into the joints. The arch first built was turned in six days, the second in four days. Considerable discussion arose as to the probable amount of settlement which would occur, and, to provide for it, the centers were made 3 inches high. Before the rings were closed the weight of the stone settled the centers 1 inch, but after the centers were removed no settlement whatever could be measured in either of the arches. After the arches were turned, it was an easy matter to build the rubble masonry of the side walls, and this was rapidly done. Trains were transferred to a single-track trestle built on the arches and the remaining part of the old bridge was thrown into the river bed and burned. The centers were removed in the latter part of December, so that they were in place only about a month after the second arch was turned. The completed bridge is shown in Fig. 2 and in Plate I. The dimensions and quantities of the work are as follows:

Span of arches	140 feet.
Rise of arches	20 "
Thickness of rings	4 "
Width of arch sheeting	27 "
Width of bridge at track level	29 "
Length of coping over all	414 "
First-class masonry	1,443 cu. yards.
Third-class masonry	2,467 " "
Timber in centers	232 M feet.

At the same time that the Bellows Falls arch was started, the work of abolishing the grade crossings at Water and Putnam Streets at Fitchburg was going on. The plan provided for two steel bridges with plank floors for carrying highways over the Nashua River. As there was a strong desire among the citizens of Fitchburg to have solid floors with granite paving, it was finally arranged to substitute arches for the steel highway bridges. The high price of steel brought the cost of a bridge, heavy enough to carry a floor of I-beams and concrete arches, to about that of a stone arch bridge. The angle of the crossing of New Street (Plate II) and the river is 45°, and if the skew arches had been built, the cost would have been

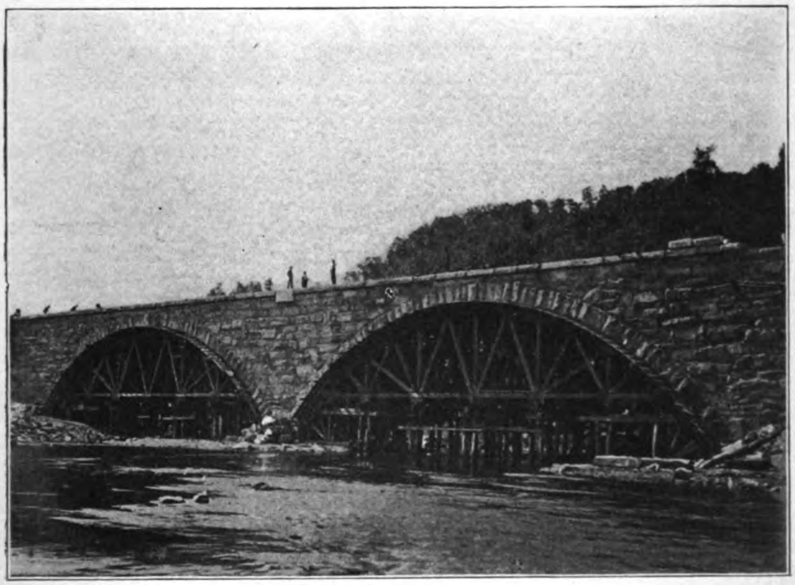

Fig. 3. Bridge at Hoosick Junction.

prohibitive. It seemed at first rather startling, and opposed to the usual practice, to build skew arches with the joints parallel to their axes, and to cut off the ends on so great an angle, especially as there was only 30 feet of the total length of 70 feet of the abutments squarely opposite. Arches had been built in a similar manner, but no case came to notice where the ends had been cut at so great an angle. Faith in the efficacy of Massachusetts granite and Portland cement finally prevailed, and the arches were built with joints made in the same manner as at Bellows Falls. As this work caused considerable comment among observers, the contractors, as soon as the first river arch was turned, before any of the backing and side walls had been built and after centers had been drawn, placed a hoisting engine on the keystone at one end of the arch and a derrick on the other end, using them to handle the larger part of the stone laid in the second arch and in the side walls. This was a good object lesson, and thoroughly proved the stability of the arch. When the centers were removed there was no settlement, and no cracks have appeared. The span of these arches is 38 feet, the rise 19 feet. The ring stones are $2\frac{1}{2}$ feet thick.

The bridge carrying Putnam Street over the river was similar to that at New Street, except that the angle of skew was much smaller, only 25°. The span of these is 40 feet, the rise $12\frac{1}{2}$ feet.

FIG. 4. CENTERING AT HOOSICK JUNCTION.

The arch bridge built at Hoosick Junction (Fig. 3 and Plate III) was constructed to replace a two-span iron bridge which was too light for the increased weight of the engines now in use. In order to bring the cost of a masonry bridge down to the cost of a new steel bridge, it was necessary to build the cheapest kind of work that would be sufficient. Cut ring stones could not be used, on account of the expense, and such good success had resulted from the use of open joints tamped full of Portland cement mortar that it seemed perfectly safe and proper to build a rubble arch in the same way, using large sheet stones just as they were taken from the quarry. The railroad company is fortunate in having, on its line, a quarry in which the seams are regular and parallel, and so even that the natural beds of the stones are almost good enough for ashlar work without any cutting. All the stone used in the bridge was from this quarry. The end ring stones alone were cut, all the rest of the arch sheeting being made of rough stone. The centers were covered tightly with plank (Fig. 4) and the sheeting was set on the centers as closely as possible, all openings being thoroughly filled and tamped with Portland cement mortar, in the same way as was done at Bellows Falls. The result, after removing the centers, was even better than was expected, no settlement occurring and not a single crack appearing in any of the masonry. The foundations for

FIG. 5. BRIDGE OVER TOMHANNOCK RIVER AT SCHAGHTICOKE.

this structure deserve some mention. Samples of material from borings, to a depth of 30 feet below the bed of the river, indicated that piles should be driven, but this question of pile foundations was most thoroughly settled when the temporary pile bents were driven, to carry the iron bridge, which was moved to one side to carry trains around the work. The driving of these piles showed the difficulty of penetrating the bed of the river, and that the borings did not give a proper idea of the material. This was still further proved by the time one of the foundation pits was excavated to the point where the masonry was to start. The bottom was of hard compacted gravel, and it became evident that piles were unnecessary and they were omitted. The iron bridge was moved to one side to allow room to construct the arches. The bridge was on a 45° skew, and consisted of three quadruple lattice trusses continuous over the pier, placed 9 feet apart center to center. The bridge was 250 feet long, about 16 feet deep, and, with the track ties, which were not removed, weighed about 225 tons. Previous to moving the bridge and without any disturbance of traffic, it was jacked up enough to remove the bed plates on rollers, so as to pass rails under the ends on the centers. Three lines of heavy pile trestle were built, extending from the masonry to the new position of the bridge, each of them being capped with 14 x 14-inch hard pine timbers carrying three lines of rails. Hitches were made to timbers buried in the ground, and to the ledge on the other side of the river opposite the ends and the center, and lines were carried from the bridge through two sets of double blocks back to three hoisting engines. The first pull moved the bridge about 5 feet, and, as the lines were so arranged that no overhauling of the falls was necessary, the bridge could have been moved over in ten minutes had it not been for the trouble caused by rivet heads in the bottom chord binding against the nuts in the joints of the rails. It was not possible for the hoisting engines to pull equally, and the bridge could be moved only a few feet at a time. It was then stopped by one end getting a little ahead of the other, and this caused the rivet heads to bind against the bolts of the rail joints. Considerable time was used up in finding and cutting out the rivets which were holding the bridge. This was, of course, greatly increased by the large angle of skew; but, notwithstanding the trouble caused by the rivet heads, the bridge was in its new position in one hour and twenty minutes after the first pull was made.

The arch over the Tomhannock River at Schaghticoke (Fig. 5 and Plate IV) was built under the middle span of a three-span plate girder bridge and the other two spans were filled up, after removing the old iron bridge. This arch was built in the same way as that at Hoosick Junction, and was comparatively a small affair, the interesting point about it being that it enabled a bridge 200 feet long to be removed and a solid roadbed to be carried over the river, and that it cost no more than it would have cost to renew the superstructure of the bridge with new plate girders for double track.