

leases per mill power. At the above-named places a mill power is equivalent to 65 horse-power on the wheel shaft. The charges for surplus water in the before-mentioned instances amounts to about the same thing at the different places. At Minneapolis, a more modern water-power, the mill power is equivalent to 50 horse-power on the wheel shaft and is charged for at the rate of \$1,200 per mill power. The charges for power at all the above-mentioned places is about the same for new leases, and amounts to nearly \$25.00 per horse-power per year for 24-hour runs. I learn that the Niagara Power Company has leased power in large amounts as low as \$8.00 per horse-power per year in 5,000 horse-power leases. The Eastern powers are based upon ten hours per day run.

The surplus is the accumulation of water in storage pond, enabling the extra running of wheels. With the figures for cost of steam power at hand it is a simple calculation to determine as to the worth of water-power. The original cost of development of the power together with the resulting power, determines its commercial value as compared with steam.

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WOODEN BRIDGE CONSTRUCTION ON THE BOSTON  
AND MAINE RAILROAD.

Read before the Boston Society of Civil Engineers, May 15, 1895.\*

By J. PARKER SNOW, MEMBER OF THE SOCIETY.†

THE subject of iron and steel bridges has been quite extensively written up in our technical literature during recent years, but wooden bridges are seldom discussed, and when mentioned, are generally treated as temporary structures or excuses offered for their use. The building of such bridges is, however, a live business on the Boston and Maine Railroad, although the impression seems to be prevalent in many quarters that such construction is obsolete and out of fashion.

This paper is offered to describe the present practice in wooden bridge construction on the above-named railroad, and if not considered as in line with present approved practice elsewhere, may at least have some interest as a history of one branch of the bridge-building art.

On the system operated by the Boston and Maine there are 1,085 wooden bridges of all kinds in a total of 1,561. This number covers overhead as well as track bridges and includes everything of 6 feet clear opening and upwards, except stone box culverts. The proportion of wooden bridges grows less each year, although more than half of the new structures built to replace old bridges are built of wood.

The types most commonly used for new work are pile trestles, plain stringer bridges, compound stringers made of timbers keyed together to get greater depth than is possible with single sticks, pony trusses of the Queen post and Howe type, and Town lattice bridges. At the present prices of iron bridges Howe trusses of considerable span, if built in first-class shape of Southern pine timber, cost almost exactly the same as iron ones and consequently are practically ruled out. A considerable number of stringers trussed with rods beneath are in existence, but are seldom built at the present time.

Spruce timber is used for all parts of Town lattice bridges, and for caps, stringers and ties in many trestles and plain stringer bridges on Northern lines. On lines south of Central New Hampshire, however, Southern pine is almost invariably used. Spruce is sufficiently durable when roofed in, and on account of its lightness is much better than Southern pine for lattice trusses, but its softness and tendency to warp and the difficulty in getting sticks of sufficient length make it unsuited for Howe truss work of magnitude. For bottom chords of lattice bridges

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of over 100 feet span, recourse must be had to Southern pine also on account of the difficulty in getting spruce of the requisite length. Tamarack, oak and chestnut are used for piles in trestles.

The life of sawed spruce exposed to the weather is but about six or seven years. Southern long-leaf pine of prime quality in similar conditions is reliable for twelve to fourteen years. When covered in and well ventilated and kept free from accumulations of dirt, either timber will last forty to fifty years. Sawed chestnut for ties, stringers, etc., is about intermediate in durability between spruce and hard pine. It has been used for bridge timber on the Southern lines of the system considerably in years past, but is not so used now and is not recommended.

Tamarack piles in dry land trestles will last eight to ten years, chestnut and oak of good quality fifteen to twenty.

The loads used in calculating new wooden bridges are somewhat lighter than the standard used for those of iron. It is thought that wooden bridges are necessarily of a less permanent character than iron ones and that within their natural life the weight of rolling stock will not increase so much above what it is at present as may occur in the life of an iron bridge; again, if wooden bridges are found to be too light for future loads, they can be strengthened, or supported on trestle bents much better than iron ones, and a wooden bridge, like a piece of masonry, will give abundant notice of distress before it will fail entirely. The governing reason for building wooden bridges instead of iron ones altogether is, of course, their less first cost, and if the full standard load for iron bridges was used in designing them this element of advantage would be reduced and they would be no more serviceable or satisfactory for present use than if designed for the lighter load. The load used is a train of consolidation engines weighing, each, with tender, 172,000 pounds, with 24,000 pounds on each driving axle, or 80,000 pounds on two axles, seven feet apart. This is somewhat in excess of engines in use at present on this system, and although considerably lighter than the load used in designing iron bridges, the considerations given above seem sufficient to justify its use.

The usual unit strains used are, for Southern pine 1,000 pounds per square inch direct tension and 800 compression; the latter, of course, reduced for ratio of length to diameter. For spruce this unit is taken at 650 compression and 800 tension. For fiber strain in stringers and beams the unit is 1,200 pounds per square inch for both hard pine and spruce. The reason for adopting this figure for spruce is that in exposed situations, as is the case with stringers, the life of spruce is so short that it is a waste of material to provide for the much talked about increase in engine loads, and while sound, this unit gives a very satisfactory bridge. For combined transverse and longitudinal strain two-thirds of the former is added to the latter and 800 pounds used as the unit. Longitudinal shear-

ing is kept below 80 pounds per inch and transverse crushing on hard pine from 350 to 400 pounds per square inch, depending on whether the whole width of the stick is covered or only a small area.

These unit strains are used for new work; an old bridge will, however, stand up and carry its load when the computed strains in some parts are very high. Of the three classes of bridges built twenty years ago, iron pin, iron riveted and wooden, all of which figure equally near the danger limit, common prudence will select the pin bridge as the first one to be removed, the riveted one next and the wooden one, if sound, last.

The cost of bridges for single track of 120 feet span will compare something as follows:—Iron \$5,300. Howe truss of Southern pine and iron angle blocks \$5,000, and spruce lattice \$3,500. Below this span, the advantage of wooden bridges over iron ones in point of cost will increase and above it the advantage rapidly reduces to nothing.

The standard spacing of bents in pile trestle bridges is 15 feet. Solid caps drift-bolted to the piles and girder caps with riders are used indiscriminately, the former being the cheaper and the latter making the most rigid structure. The stringers used on these trestles are for single track, two 8" x 16" under each rail and one of the same dimensions on each side placed 10 feet apart from outside to outside. The stringer sticks are 30 feet long, laid to break joints; the two sticks under each rail are spaced 2" apart by cast iron spool separators and  $\frac{3}{4}$ " bolts, four at each cap. The stringers are secured to the caps by drift bolts. The floor consists of ties 6" x 8" x 12 feet long, laid 4" apart in the clear. The spacers 6" x 8" are placed flat on the ends of these, notched down one inch and bolted to every fourth tie. These bolts have a round burr washer under the head on top and a Warren nutlock for washer at the lower end. The floor is kept in line by occasional lining spikes or drift bolts through the ties into the side stringer.

The tie floor above described is standard for all wooden bridges; it is shown in cross-section Fig. 1. In designing, the ties are considered as

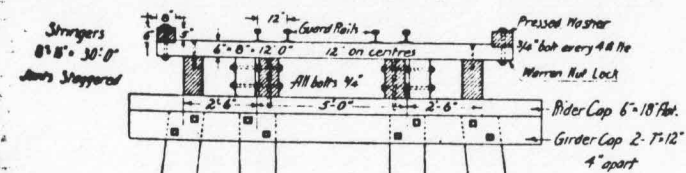


FIG. 1. STANDARD TRESTLE; 15 FT. BENT.

distributing the load so that 80 per cent. is carried by the main stringers and 20 per cent. by the side ones. The continuity of the stringer sticks over two spans is considered as reducing the moment of the load at the centre of span by 10 to 12 per cent.

Plain stringer bridges are built the same as above described for trestles, except as the stringers do not have the advantage of continuity over supports, the sections must be larger for similar spans. The depths of the sticks should not be less than  $\frac{1}{2}$  to  $\frac{1}{4}$  the span.

When the span becomes too great for merchantable depths of timber, or convenient thicknesses, recourse is had to keyed stringers. These are made by placing one stick on top of another and framing cast-iron keys between them, as shown in Fig. 2. A vertical bolt at each key prevents the timbers from separating.

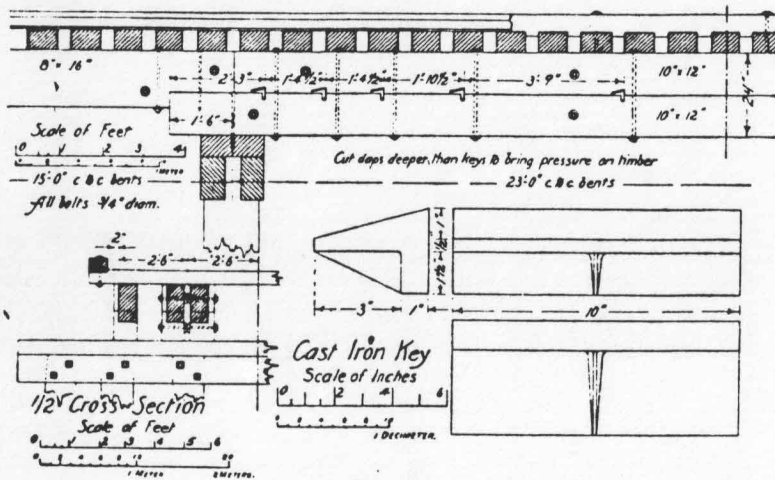


FIG. 2.

These keys are proportioned for the longitudinal shear, and hence the total depth of the compound stick can be used in computing its moment of resistance. The keys are cut  $1\frac{1}{2}$ " into each upper and lower stick, and an attempt is made to distribute them according to the intensity of the shearing strain; but near the ends of the stringer a strict adherence to this requirement would bring them so near together in some cases that the daps might split out. With notches  $1\frac{1}{2}$ " deep, it is desirable that they should be at least 18" apart. The quantity of longitudinal shear at the neutral axis, between any point and the end of a beam, is a function of the fiber strain at that point; being equal to  $\frac{b \cdot d \cdot f}{4}$ : when *b*. is the breadth, *d*. the depth and *f*. the extreme fiber strain.

A convenient way to locate the position of the keys is to draw a line the ordinates of which represent the moment of the load and lay off to some convenient scale,  $\frac{b \cdot d \cdot f}{4}$  as an inclined ordinate at the center of this curve. Now, beginning at the base, space off on this inclined line the value

at each key, and draw horizontals through the points of division; these horizontals will cut the moment curve into spaces showing the proper field for each key. The friction between the two sticks, induced by the load and by the grip of the vertical bolts, helps to resist the longitudinal shear, and a proper proportion can be added to the value of the key when spacing off the inclined ordinate.

These stringers require considerably more material than trusses of equal strength, but the labor on them is small and they can be put in place and prepared for the passage of trains in much less time than trusses. This latter quality is of great importance, and should be given more attention by bridge designers than it generally receives. This style of bridge works in with the ordinary trestle spans very conveniently when it is desired to make a wide opening for a runway for ice or logs, or for a highway underpass. The lower stick of the compound stringer is extended beyond the upper one to furnish a seat for the regular stringers of adjacent bents. In cases, too, where the trestle bents are high and expensive it will lessen the cost of the structure to make alternate spans compound or keyed stringers. This style of bridge is available up to clear spans of 30 feet.

Pony trusses are used for spans between 30 and 60 feet, generally of the Howe type. For overhead highway bridges requiring trusses modified pony Howe trusses are used almost exclusively. For these latter and for track bridges it is altogether better to use floor beams, distributed along the chord about 2½ feet apart, rather than to concentrate the load at panel points by means of stringers carrying the load to large floor beams, as is done in iron bridges, and it is generally best to hang the floor beams below the chord. If the plank floor of highway bridges be laid directly on these cross floor beams it brings the plank parallel to the line of travel; this is considered objectionable, and hence longitudinal spiking joist or stringers, 4 to 6 inches thick, are laid on the cross floor beams and the plank spiked to these. On bridges carrying light traffic a single 3" floor is used, but where the travel is heavy it is economical to use a double floor, generally 2" below and 3" for wearing surface. The under plank lengthens the life of the floor very considerably by keeping it safe for a long time after the corners of the upper plank have worn through.

Railroad bridges of this class should always have the top chords stayed against side motion, as shown in Fig. 3, and it pays to protect the trusses from the weather by sheathing and roofing them in.

For spans greater than is desirable for pony trusses the Town lattice built mostly of spruce is our only resource. As before stated, Howe trusses of Southern pine cost almost as much as iron bridges at present prices. Spruce, the only available timber growing in the region in

which these bridges are used, is not well adapted to Howe truss work, but is excellent for lattice bridges. This style of bridge seems never to have been developed to much extent outside of New England, and it is fre-

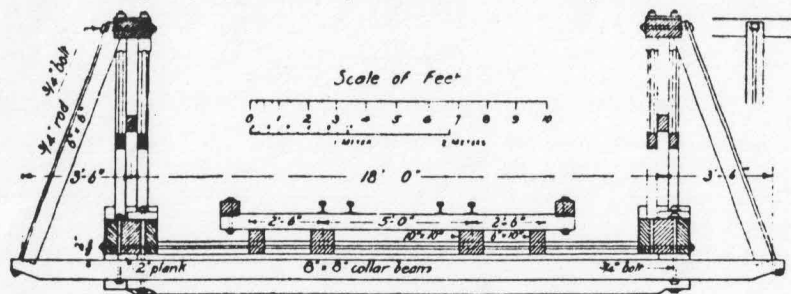


FIG. 3. SWAY BRACING FOR PONY TRUSSES.

quently referred to as peculiarly unscientific and wasteful of timber. It is, however, the best of the purely wooden bridges, and its present survival here and its economy over all other types disproves its wastefulness. These trusses should always be built double, that is, with two webs like a box girder. Single web trusses can be made strong enough up to 80 feet span, but they do not stand so steadily or keep in line so well as those with double webs. The distance between the webs is immaterial, but is generally made equal to the thickness of two chord plank, from 6 to 8 inches. Outside of the webs, it is not deemed advisable to use more than three thicknesses of plank on each side; this confines the chord to 8 planks, and as this is generally not sufficient to give the requisite strength, a second chord is added at the second web intersection. These second chords serve not only to carry chord strain, but also to stiffen the diagonals and to assist the outer chords to distribute the shear between the tension and compression members of the web.

The chord strength of these trusses is computed by assuming the distance between the centers of outer chords as the effective strain depth of the truss, and reducing the section of the inner chords in the ratio of the squares of their distances from the neutral axis. In the case shown on the inset this ratio would be nine-sixteenths. In several bridges of this type now standing on the Boston and Maine road, built in former years, there are three sets of chords, but the third chord has but little theoretical value, and judging by the amount that the joints are pulled they assist but little in carrying the chord strain. The proper arrangement of the breaks in the planks of the lower chord affects the strength of the whole much the same as the arrangement of eyebars affects the strength of pins in an iron bridge.

In bridges of 125 feet span and upwards it becomes necessary to fasten the abutting ends of the chord plank together and the device

shown on the inset is used for this purpose. The gib-bars are wrought iron, varying in section with the thickness and width of plank to be pinned; hexagon nuts are used on the yoke rods so as to necessitate as little cutting of the chord stick as possible. A ribbon is sometimes put between the webs at the middle height of the truss, as shown in the inset, with the idea of stiffening the web and preventing vibration.

The shear is assumed to be uniformly distributed over all the web planks cut in a given section. The members are so thoroughly pinned together that they cannot possibly act as single independent systems to be separately calculated as is advocated in some text-books, but the strain must be equalized throughout a vertical section much as would be the case with a solid web.

A lattice truss should extend well on to the masonry. For reasons connected with the proper construction of the floor this extension on the abutment should be about one and one-half panels; a solid bolster should be placed under the chord for this distance and under this should be the cross wall blocking. The compression diagonals near the end of the truss deliver their shear to very short tension members; the fastenings of these do not seem to be able to carry the load delivered to them, and the bolster is needed to help take the thrust of the compression members direct. Many old bridges built probably without much knowledge where the maximum shear occurs have failed by having the bottom chord split down or literally sheared at the edge of the wall plate by this action. Proper bolsters would have largely prevented this. It is the custom now to put solid posts between the webs at the end and second panel points extending the whole depth of the truss. These cut through the two middle plank of the chords and would endanger shearing the bottom chord if the bolster did not extend beyond the cut-off. These solid posts furnish a substantial support to pin the short ties to and to receive the compression members which do not reach the bottom chord. None of the trusses built in this way have shown indications of weakness in the way explained above. The panels should be between 4 feet and 4½ feet and the web plank should be given inclinations of nearly 60° with the horizontal.

The pins used in these bridges are 2" oak. They should be of well-seasoned timber, and should be carefully turned so as to drive tightly when the bridge is erected. Much depends on the pins. In old and weak bridges the pins are frequently found much distorted. In heavy trusses all plank must be at least 12" wide in order to take four pins at the chord intersections. At the web crosses two only are used. At all chord intersections and some in the web a ¾ bolt is used to hold the plank firmly together. This bolt is deemed of great importance from preventing the plank from opening, which would greatly increase the

leverage on the pins. It is possible that iron pins perhaps of heavy pipe rather than solid bars would mark an advance over the present practice, but they have not yet been tried so far as the writer is aware.

The floor beams in these bridges are at present invariably hung below the chord, two beams per panel. The ends of the web plank projecting below the chord are cut into to allow space for each floor beam. They are hung by bolts passing through the open spaces in the chord and through washer blocks on top of same.

The lateral bracing is the Howe system, that for the lower chord being laid directly on top of the floor beams, and the stringers cut over it; 5" by 8" to 12" is the size generally used. The main stringers under the rail are 10" by 10" and the side stringers 6" by 10".

The load used for floor beams is 5,500 pounds per lineal foot of track, which is assumed to cover both the live and dead loads. Eighty per cent. of this is assumed to be on the main stringers and 20 per cent. on the side ones. The clear width in these bridges is 15 feet. This makes the effective length of floor beams 18 feet or more and calls for sticks so large that it is best to use Southern pine for them. Spruce can be readily obtained of sufficient size, but when so large and in so exposed a situation it twists and checks badly. Southern pine is used also for bottom chord plank for spans greater than 100 feet, and should always be used for bolsters and wall plates. The stone parapets of all through wooden bridges are brought in so as to be flush with the face of the abutment (see inset). This serves to protect the timber floor from the weather, obviates the large amount of blocking needed on the stonework when it is not so done, and shortens the bridge floor.

Lattice bridges are built on the Boston & Maine Railroad as above described up to 150 feet clear span. They are, however, rather unwieldy at this length and it is preferred for spans above 125 feet to build them with an arch inserted between the webs. These arches are built up to the required section with 2" or 3" plank and bolted to the trusses at every lattice cross which comes in contact with the arch. They abut against the stonework below the lower chord on large Southern pine skew-backs scribed to the stone. The skew-backs are mortised out in steps to receive the square ends of the planks. The planks of the arches are well spiked when laid and radial bolts are freely used to bind them well together. The load is brought upon the arch by vertical rods passing through the arch and down through the lower chords and floor beams.

The arch is proportioned to carry its own weight and the whole live load on the bridge. The trusses are made of the same section as those of one half the span which have no arch. These compound bridges are very satisfactory, being rigid under traffic and of more pleasing appearance than when built without arches. They are also much more econo-

mical of timber than simple trusses for the reason that the arch uses timber wholly in compression, in which condition the entire section is available; whereas when timber is called upon to act in tension a large portion of the section must be wasted in making the connection.

In order to secure a satisfactory track surface after several years' use, there must be considerable camber framed into lattice bridges. For trusses without arches, there should be 1" for each 25' of span and for those with arches 1" for about 37½' of span.

The lattice bridge has been described thus at length, partly because it has not been so fully treated as other styles in technical literature, and because it is the only kind that can be built in competition with iron at present prices. On the Boston & Maine system, there are many Howe and Pratt bridges, a few Burr, Briggs and Child's trusses and many of mongrel type; but the Town lattice has a large plurality over any other kind and there seems to be ample and good reasons for its natural survival.

These bridges as built to-day are, in all their important details, direct descendants of, and very near kin to, those built in years past by the bridge carpenters of Northern and Central New England. Those built by David Hazelton and his men furnish the basis of the present practice on this road and although they were built without engineering advice, they bear analysis well, with the possible exception of the bottom chords.

It has come within the observation of the writer many times that when an intelligent master-carpenter has had the care for a term of years of a line of wooden bridges covering any given style of truss, he gradually brings their parts, when building new ones, to almost the exact size called for by scientific analysis when actual loads are used in calculation. He will use iron rods that are too small for they show him no distress unless they break, but the timber parts guide him to right results.

It is this property of a timber bridge, its certainty of giving warning of approaching weakness, that has kept the record of wooden truss bridges so clear from fatal disasters. It is not reasonably safe to use a light iron bridge until it is worn out, but a wooden one may be used till its deterioration is rapidly approaching the end. Neither is it safe to entrust light iron bridges wholly to the care of workmen not technically educated; the timber parts of wooden ones may be.

It is no part of the intention of this paper to advocate building wooden bridges instead of properly designed iron ones, but rather to describe the favorite styles now used on those parts of the Boston & Maine Railroad where wooden bridges prevail, and to show that these styles are not so obsolete as seems to be supposed in some quarters.

## DISCUSSION.

Mr. B. W. GUPPY.—The Town lattice truss was patented in 1820 or 1821. The inventor, Mr. Ithiel Town, published pamphlets in 1821 and 1831, describing the bridge, and the claims that he makes therein as to the economy and durability of this type of bridge have been fully substantiated. Copies of these pamphlets are in the possession of the Boston Public Library.

Some of the advantages that Mr. Town claimed for his bridge are as follows:

"Suitable timber can be easily procured and sawed at common mills, as it requires no large or long timber.

"Defects in timber may be discovered and wet and dry rot prevented much more easily than could be in large timber.

"There is no iron-work required, which at best is not safe, especially in frosty weather."

This last statement is rather amusing, as Mr. Town previously states that the trusses can be built either of wood or iron. Moreover, it is due to a free use of iron that the present development of the bridge has been obtained.

Iron is used principally in the form of bolts and rods, and its use increases the strength of certain parts like the tension chord, and allows of adjustments to take up the shrinkage of the timber.

Wedges at the ends of the pins or treenails were used to keep the sticks in close contact. Bolts at the intersections of chords and lattice are now used for the same purpose, and they also add to the strength of the chord connections.

Iron chord couplings add a large percentage to the strength of the tension chord.

A Howe truss system of lateral bracing is used instead of the Burr system originally adopted, and by means of turnbuckles on the rods placed so as to be easy of access, adjustments can be made to keep the trusses properly in line.

Formerly the floor beams in through bridges rested on top of the bottom chord, bringing most of the load on the inside chord sticks and web system. The present practice is to hang the floor beams below the bottom chord by hanger bolts alternately on opposite sides of the chord, as shown on the drawing accompanying Mr. Snow's paper. This distributes the load equally between the two web systems and adds an amount to the headroom equal to the depth of the chord plus the depth of the floor beam.

Some of these bridges have a very long life. One that was taken down on the Boston and Maine system last year and replaced by a simi-

lar structure was claimed to be over fifty years old, although no exact record could be found. This refers to the trusses. The floor was newer, having been renewed and strengthened. The timber was in fairly good condition, extreme lightness of construction being the principal cause for renewal.

Another bridge taken down the year before was over forty-five years old.

In use these bridges stand a great deal of abuse. A butting collision on the approach to one bridge piled the cars of one train up through the roof. Beyond breaking a hole in the roof, and cutting up a few ties, no damage was done to the bridge. Another collision in which only one train participated, the bridge acting as a buffer, resulted in considerable damage to the end vertical and web; but the bridge is still in use without any repairs and is considered to be perfectly safe. In another case logs at high water broke off the ends of the lattice. Bolts were put in connecting the floor beams with the upper lower chord, relieving the lower joints of all vertical load, and as they are still strong enough to transmit the chord stress, the bridge is used without any apprehension of danger. This bridge has the floor beams resting on top of the bottom chord. If they had been hung below they would have protected the ends of the lattice.

During the recent floods in New Hampshire, a pier was washed out from under a two-span bridge. As the invariable practice is to make these bridges continuous over all intermediate supports, the bridge was saved.

At the same time the abutment was washed out under the end of another bridge, causing one of the trusses to settle several feet. It was blocked up into place and is now in use, the flexibility of the construction preventing any serious damage.

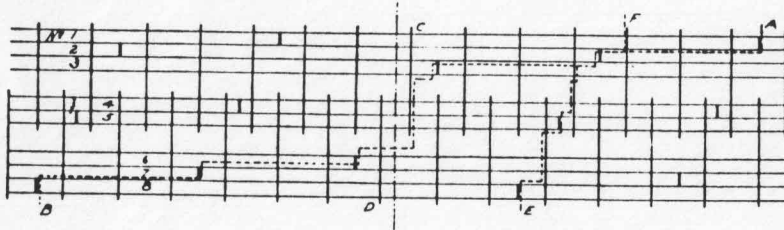
Fire is the principal enemy of these bridges, but the danger has become much less since the introduction of coal burning engines. The fires usually start in the roof and are generally extinguished before they do any damage to the trusses. A good coat of white-wash together with water barrels, buckets and a ladder at each bridge are the means of protection.

The road has these bridges insured, but as fatal fires are so few, and the losses are generally so small, it would seem to be economy to have the road do its own insuring.

In designing this truss, the practice is to use a panel length of from four feet to four feet six inches, the panel length being the distance between the chord pinnings for one of the lattice systems. The pinnings of the second lattice system are half way between those of the first. This brings the distance between two pinnings equal to one half a panel

length. The panel length is taken at such a length within the limits given as will bring the total number of panels equal to  $n + \frac{1}{2}$  where  $n$  is any integer. This arrangement brings the center line of truss half-way between two pinnings, making the chord stick cuts symmetrical, and making the odd length sticks the same at both ends.

The method of arranging the cuts in an eight-chord stick is shown in the accompanying diagram.



In figuring the strength of the tension chord, the following assumptions are made:

(1) When there are four pins and one bolt at a pinning, the net area of the stick is taken as the depth in inches minus five, multiplied by the width.

(2) The value of a pinning to transmit stress between two sticks is taken as 1,100 pounds for each pin and 600 pounds for one bolt, making a total of 5,000 pounds for one pinning of four pins and one bolt.

These values were arrived at by figuring the pin for bearing, shearing and bending; the limiting value being given by the strength of the pin to resist bending. The lever arm was taken a constant of 1.3 inches for the three thicknesses of plank generally used, namely  $2\frac{1}{4}$ ,  $3\frac{1}{4}$ ,  $3\frac{3}{4}$ , as the flexibility of the pin must cause the load to be concentrated near the inner edge of the stick and the examination of pins taken from old bridges seems to justify this assumption.

When wrought iron chord couplings are used, the strength of a coupling is the net value of four  $\frac{1}{2}$ -inch rods at 10,000 pounds per square inch, or 16,920 pounds.

When chord couplings are used, there are two cases to consider: (1) when the strength of one coupling plus three pinnings is less than the net strength of the stick, and (2), when it is greater.

In the second case, the weakest center section is practically straight across the chord on the line *CD*. In the first case, the minimum value of chord is along the line *AB*. There is also a section *EF*,  $1\frac{1}{2}$  panels from the center, the strength of which should be investigated, as in some cases it has a less value than the center section.

In the bridge shown in the drawing, the bottom chord is composed

of six  $14 \times 3\frac{1}{4}$ -inch sticks and two  $14$ -inch  $\times$   $2\frac{1}{8}$  sticks. Net value of one  $14 \times 3\frac{1}{4} = 9 \times 3\frac{1}{4} \times 1000 = 34,875$  pounds.  
 One coupling = 16,920 pounds,  
 Three pinnings = 15,000 "

31,920 " which is less than net stick and the minimum center section will be along the line *AB*.

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	3 "	31,920
" 3	1 "		16,920
" 4	net stick	$14 \times 2\frac{1}{8}$	25,875
" 5	"	"	25,875
" 6	1 coupling	1 pinning	21,920
" 7	1 "	3 pinnings	31,920
" 8	1 "	3 "	31,920

218,270 lbs. net value of center section.

Section  $1\frac{1}{2}$  panels from center

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	1 pinning	21,920
" 3	net stick	$14 \times 3\frac{1}{4}$	34,875
" 4	"	$14 \times 2\frac{1}{4}$	25,875
" 5	1 pinning		5,000
" 6	net stick		34,875
" 7	net stick		34,875
" 8	1 coupling		16,920

206,260 lbs. net strength of chord  $1\frac{1}{2}$  panels from center.

With sticks 16 inches deep and the same widths the center section will have a value of 229,770 pounds, and the other section 235,260 pounds, being the greater in this case. Inspection shows that the strength of the center section is increased only by the increase in sticks 4 and 5.

This span is about the limit of this style of bridge without the use of an arch, although spans have been built up to 150 feet.

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