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BARBER & YOUNG

BRIDGE AND STRUCTURAL ENGINEERS

57 ADELAIDE ST. EAST

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Concrete Truss Bridge on the Middle Road, between the Counties of York and Peel, Ont.

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CANADA'S FIRST CONCRETE TRUSS BRIDGE

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The architect says with truth of the bridge engineer that he aims only at results which are useful and scorns the beautiful. The general form of a steel truss is often decided upon with no thought of æsthetic design, and a few dollars afterwards spent on ornamental railings or other details will never remedy the defect. And yet mathematics and æsthetics go hand-in-hand, and a simple steel truss with the upper panel points lying on the singularly graceful curve, the common parabola, can be designed with more economy of material than the unsightly steel truss with parallel chords. If the cost of the former would be greater under present conditions, then shop practice and facilities are principally to blame. But shop practice is no bugaboo to the designer in concrete, and the form of truss which is the most economical is also the one which is the most natural and the most beautiful. The massive and gracefully arched compression chords are, perhaps, the most notable features of the few concrete truss bridges which have as yet been built.

The seven-panelled parabolic bowstring truss, illustrated above, was built on the Middle Road, between the counties of York and Peel, and officially opened to traffic this month. An examination of it will show that the maximum stress in the lower chord is the same for all its members, consequently the same number of steel rods are used from one end of the chord to the other—a great advantage in construction.

The vertical members of the web system are tension members, and the diagonals are of the nature of counter-braces, carrying no stress for live load covering the entire floor or from the dead load, and acting alternately in compression and in tension for a moving load.

The compression chord, 22 in. by 24 in. at the middle segment, is only slightly reinforced with twelve rods, ¾-in. round, and bonded with smaller rods spaced 6 in. apart, except at the panel points, where somewhat

elaborate detailing is resorted to in order to make the bond perfectly secure between the hangers and the chord. The maximum compressive stress for this chord is 430 pounds per square inch for the concrete and 6,450 pounds for the steel, or about 500 pounds per square inch for concrete and steel acting together.

The maximum tension in the lower chord is 16,000 pounds for the steel, the concrete not being considered to act in tension.

The bridge was designed for a load of ten tons on two axles, two-thirds on the rear axle, and a distributed load of 100 pounds per square foot. A very liberal impact allowance was adopted of one-half the live load.

The length of the bridge is 80 ft. in the clear; roadway, 16 ft. wide; height above water, 14 ft. at one end,

At the time the above view was taken about 70 head of cattle were crowding over the structure—The weight was at least 35 tons, which may be regarded as a satisfactory test.

18 ft. at the other, making a grade of 5 per cent. It contains upwards of thirteen tons of steel, and weighs nearly 200 tons. Provision was made for expansion at one end by brass plates sliding between steel plates. It was tested at the official opening with a concentrated load of ten tons moving across the bridge, and by a herd of seventy cattle, all that could crowd upon the bridge, weighing probably thirty-five tons. The vibration under these loads was very slight.

The reinforcing consisted of plain, round rods except for the floors, which were reinforced with No. 10 standard expanded metal as manufactured by the Expanded Metal and Fireproofing Co., Toronto.

In designing this truss the engineers believed that the joints required the most attention. It is easy to proportion all the members of a concrete truss so that perfect confidence may be placed in it if only the joints may be relied upon. The engineers tried to detail the bridge so that any member would fail in the body rather than at a joint. A description of these details is not here attempted, as it would, perhaps, be too technical to be of much interest to the general reader.

Extraordinary care was taken to avoid poor bonding of successive days' work. For this purpose cracked ice was laid in bags upon the last concrete placed at night, and this was found to be perfectly plastic the

The Middle Road Truss Bridge, showing Forms in position

next morning, as if it had just been poured. This method of keeping concrete from setting by placing ice upon it, and thus securing a perfect bond between concrete placed on successive days, was the invention of Mr. O. L. Hicks, the contractor for this bridge. It is here mentioned by his permission for the benefit of any who may wish to use it.

In order not to cause internal stress in the concrete by some of the rods not being straight at the time the concrete is poured, and in order that hair cracks should not develop under 16,000 pounds tension in the steel the rods were given considerable tension before the concrete was poured by an ingenious device of the contractor.

The mixture used was one of cement to three of aggregate, consisting of sand and crushed stone, so proportioned as to leave a minimum of voids. The bridge was concreted in one week by making special efforts, and the forms and floor were kept wet for another week. The concrete matured without showing any checks or hair cracks. Two inches was chiselled off the caps of the newel posts after the concrete had set as they were thought to be too large, and the mortar was found to be as hard as the stone which was embedded in it, for the stones would crack through quite as readily as the mortar. Owing to a misunderstanding these caps were left rough, but the writer regards this as a mistake. They should have been dressed smooth to harmonize with the rest of the bridge. Whatever may be the life of lean concrete mixtures, which are often used in massive work, the engineers believe that concrete proportioned in the above-mentioned way will endure indefinitely and grow harder and stronger with age.

Considère, the eminent French engineer, was the originator of the concrete truss, and he has built several of them in Europe. The approaches to the Sparkman Street Bridge at Nashville, Tenn., are also of this form. The bridge here described is the first concrete truss to be built in Canada.

The principal differences between Considere's concrete trusses and the Middle Road bridge are in the curved upper chords and in the handrailing and other details. Considere's compression chords are much lighter than those of the bridge here described. The upper chord segments of the former bridges consist of heavily hooped concrete columns, an invention of the designer. This results in high unit stresses and light chords. The designers of the Middle Road bridge considered that a more massive construction would have a better appearance in a concrete bridge, besides being more rigid. Consequently the compression chords in the latter bridge are only slightly reinforced, and the concrete itself takes most of the compression. This construction is no more expensive than light wound columns.

Compared with the ordinary (unhinged) concrete arch, the concrete truss has advantages and disadvantages. In the arch the horizontal thrust is resisted by

the abutments, which are more or less perfectly restrained from spreading by the natural beds of the abutments—clay, rock, or whatever it may be. In the concrete truss the horizontal thrust of the arched compression chord is resisted by the steel rods in the lower chord. The advantage of this for the truss is that the toes of the arched chord are perfectly tied together at all times, and the upper and lower chords expand and contract together with temperature changes, provision for which is made by sliding bearing-plates at one end of the truss. Again, the tendency of the arched chord to deform for different positions of a concentrated load is resisted by the web members of the truss so that the line of resultant pressure in the compression chord does not move from the centre of its section. For this reason the chord segments act as posts, and are proportioned by their area.

In the arch, on the other hand, the abutments often spread somewhat, causing cracks in the spandrel walls. Again, temperature stresses and moving loads cause deformation of the arch-ring, which causes the line of pressures to vary in position. Even in a well-designed arch, where the resultant pressure never leaves the "middle third" of the section, the unit pressure at certain sections of the ring will be zero at the intrados and double the average at the extrados for certain temperatures and loadings, which state will be reversed for other conditions. Thus the section of the arch-ring must be proportioned by its moments of inertia, and will be greater than if the arch could be braced against deformation like a truss. We believe that bracing, where it is possible, is better and more economical than increasing the section.

To recapitulate, the arch has the great advantage, that no lower chord is necessary, or, to put it another way, the natural earth forms the lower chord; but the abutments are often not rigidly held from spreading, temperature stresses are considerable, and deformation must be resisted by making the arch-ring very heavy. In the case of the truss, an expensive lower chord must be supplied, but the toes of the arched chord are more rigidly held together by it than is often the case in arches, there are no temperature stresses, and the tendency to deformation is perfectly resisted by a web system, and a minimum amount of material results.

The Commissioners of York and Peel, for whom the bridge was built, were without exception delighted with

the structure. When tenders were opened the bid for the concrete truss was found to be the second lowest, four tenders for a steel bridge being higher and one lower. Warden George Henry, of York, well supported by Warden Jackson, of Peel, spoke strongly in favor of the concrete bridge as being the most suitable bridge, and the cheapest in the end. Concrete was felt to be especially suitable for a bridge on a grade. Here teams cannot be prevented from trotting over it. The resulting vibration is likely to loosen joints and crystallize the steel, but is almost non-existent in concrete.

The reason that a truss was adopted at the Middle Road rather than an arch was that the truss bridge utilized the old stone abutments and an arch design could not.

The report of the York Commissioners to the County Council contains the following reference to this bridge: "It is a credit to the counties, and all municipal officers requiring bridges should inspect it."

The Commissioners for whom the bridge was built are Warden Henry and Commissioners Annis and Harris, of York, and Warden Jackson and Commissioner Kennedy, of Peel. The contractor was Mr. O. L. Hicks, of Humber Bay.

The bridge was designed by and erected under the supervision of Barber & Young, Bridge and Structural Engineers, Toronto, Ont.