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Design of Concrete Truss Bridges

Discussion of Theoretical and Practical Points Resulting From Designs Proposed For Bridges on the Toronto-Hamilton Highway—Method of Computing Stresses in Arched Chord—Top Lateral Struts Unnecessary — Expansion Plates — Splice of Lower and Arched Chords

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UP to 1915 the concrete truss bridge was something of a novelty in Canada, hardly more than a dozen such bridges then having been built in this country. Of late, however, a wide interest is being taken in them by bridge engineers. This is doubtless due to the fact that the cost of concrete superstructures has not advanced to the same extent as steel bridges. A steel bridge which in 1915 cost erected about five cents a pound, cost in the last season from eleven to thirteen cents a pound. But concrete has advanced in cost only about 50 per cent. in the same time.

I have had several inquiries from engineers in the last year or two regarding various points of design and construction concerning concrete truss bridges and I believe that some of these matters are of some general interest to bridge engineers. Amongst these are the following:—

1—Splice of lower chord with arch chord.
2—Connection of floor beam with hanger.
3—Expansion plates required.
4—Advisability of top lateral struts.
5—Method of computing stresses in arched chord.

It happens that these matters were all discussed at a conference of bridge engineers under the following circumstances:—

The Toronto and Hamilton Highway Commission have let contracts for four concrete truss bridges of 20-ft. roadway, three of them of 120 feet clear span and one of 100 feet. The floor systems were hung from the curved top chords by hangers, no diagonals being used. They were designed by the bridge engineer to the Commission, but as the various counties in which these bridges are situated had to pay the bulk of the cost, the counties had these designs reviewed by bridge engineers retained by them.

Results of Conference

After a discussion of the above points, amongst others, the three engineers retained by the various counties found no difficulty in arriving at conclusions as follows:—

First.—The splice of the lower chord with the arched chord is undoubtedly the most important in the bridge. The maximum stress in the lower chord is the same from end to end, the floor system with its imposed loads being suspended by hangers from parabolic upper chords in a manner similar to the floor system of a suspension bridge suspended from the cables. The function of the lower chord is to tie the opposite toes, i.e., the skewbacks, where in the ordinary arch the earth between the two abutments resists this tension. It was considered necessary for safety that the steel rods of the lower chord should pass through vertical plates at each end to nuts and washers at the back of the plates. The toes of the arch chords press against these plates, the size of which are computed for resisting the total horizontal thrust of the top chord.

Second.—Since the concrete of the lower chord is in tension the hanger rods should pass through a horizontal steel plate at the bottom of each hanger in the same way that the lower chord rods pass through the vertical plates mentioned above. The end of the floor beam then rests upon this plate, which makes a satisfactory bearing for it.

Third.—As to expansion plates, two steel bearing plates, with a brass plate between, was considered to be sufficient and the most satisfactory. The lower bed plate may rest upon a thin sheet of lead so that it shall come to an even bearing after the centres are struck. The expansion due to temperature is less than is ordinarily allowed for. Experiments on the Walnut Lane Bridge, Philadelphia, for instance, show that the concrete of these arch ribs rose in temperature almost evenly from the average temperature of January and February to the average temperature of July and August, 25 degrees C., this being less than half of the actual variation of temperature in air, which was 54 degrees C.

Fourth.—It was considered that top lateral struts were unnecessary for the following reasons:—They are not required to resist wind, since the arch ribs can easily be made to take the wind stresses, and in any event, the toes of the arch must resist nearly all the wind stress.

Not Required to Resist Wind

In one of the designs above referred to which was reviewed, only one-fifth of the wind stress was resisted by hangers, considering the stiffness of hangers and top chords according to their moments of inertia at the bottom section of each.

The hangers were found to be stiffer than the ordinary steel outriggers dividing the top chord of a pony truss into short columns, if the number of hangers compared to the number of outriggers be considered. I quote from the report of one of the engineers above-mentioned as to top lateral struts: "The vertical hangers, along with the fixed ends, would in my opinion constitute as rigid a fixing of this chord as usually obtains in a pony truss. . . . Struts between the chords would not be of value unless along with these diagonals were used as well as portal braces."

Fifth.—There was some discussion as to the readiest method of computing the stresses in the arch chord. The moment of inertia of the lower chords was found to be nearly as great as that of the arch chord at the crown, and as one cannot be strained out of position with carrying the other with it, it was agreed that the moment of inertia of the lower chord should be given as much consideration as that of the upper chord in analyzing it by the theory of elasticity.

Some case could be made out for considering the moment of inertia of the whole floor system, but this was rejected.

Opinions differed as to whether the arch at the skewback could be considered fixed or not, and a compromise was made by taking it half way between the two-hinged chord hinged at the skewbacks and one entirely fixed.

This results in making the arch chord at the skewback considerably thinner than if it is to be computed as having fixed ends.