POINTS REQUIRING SPECIAL OBSERVATION AND INVESTIGATION IN BRIDGE INSPECTION*

By Herbert C. Keith

THE old proverb that a chain is no stronger than its weakest link seems sometimes to be contradicted by a bridge truss, which may be stronger than its weakest member appears to be, as judged by the ordinary methods. Professor Vose used to say that there are many bridges that are kept from falling "only by the grace of God and the force of habit." There are certainly many which depend upon some means of transmission of loads to the abutments that no self-respecting engineer would rely upon in designing, though recognizing and taking advantage of it sometimes in a critical investigation of an existing bridge. For instance, a rapidly moving electric car may skate safely across a short span or a single panel which would be unsafe for the same car even to stand on. Another example is found in the fact that a bridge may be safe for a car electrically driven when it would be unsafe for a steam locomotive of the same weight, on account of the difference in the mode of transmission of the power to the driving wheels, rotary in the one case and reciprocal in the other. These are cases which show a reduction of strain on stringers often greater than would be the increase of strain due to the sudden application of a load. Track rails (and jack stringers when used) add materially to the carrying power of stringers of short spans, especially if the rails are heavy. Guard rails and even guard timbers and the stiffness of the car itself give some help; also the continuity of the stringers of a truss bridge when the stringers are framed into the floorbeams and riveted to them. The stiffness of truss chords may make the strength decidedly greater than would be determined by considering each intersection as if it were a joint with a fractionless pin, instead of a continuous riveted box girder, as may be the case.

Rivets and Pins

A very marked instance of greater strength than is assumed in the ordinary methods of calculation is the case of rivets and pins. A large factor (indeed probably the main factor) in the real strength of a riveted joint is the friction of the members upon each other under the pressure of the gripping of the rivet. W. J. Watson, in a paper presented to the American Society of Civil Engineers in 1906, assigns to this friction a value of 14,000 lbs. per sq. in. of cross section of rivet for one plane of contact (or when acting in single shear) and 18,000 lbs. per sq. in. for two planes of contact (or in double shear). The present author would hesitate to give definite mathematical value to this friction, since probably no two rivets exert the same pressure. But it is axiomatic that this friction is great only while the rivet is tight; as soon as the rivet becomes loose it is an entirely different story. This value of a riveted joint is so great and so evident that account of it is taken in the author's modifications of the specifications of the Massachusetts Public Service Commission. In calculating pins it is customary to assume that the pressure of each member upon the pin is concentrated at the centre line of its bearing surface, whereas the fact is that, before a pin would fail by bending, the pressure of each member would become concentrated at that edge of the member which would give the minimum bending moment. This makes the real bending moment on most pins only a small fraction of that obtained by using the ordinary assumptions. An examination made by sawing through the line of flange rivets of an iron floorbeam removed nearly 30 years ago showed the rivets in exceptionally good condition, though by the accepted method of calculation they had been subject to 80,000 lbs. per sq. in. in shear and 130,000 lbs. per sq. in. in bending. In the same bridge, pins which were figured to have a moment of 300,000 lbs. per sq. in. bending, were found to show no slightest sign of overstrain.

*From a paper presented before the Brooklyn Engineers' Club.

Another matter, the importance of which is often greatly overestimated, is the secondary stresses due to large gusset plates at joints of riveted trusses. In most cases where youthful engineers speak with awe of the "terrible secondary stresses," they overlook the added value given to the members by stiffening them through the length of these gussets, thereby reducing the unsupported length of the members, and also giving them "fixed ends." This remark should not be understood to give approval to eccentric connections, for these should always be avoided if practicable, and the eccentricity reduced to a minimum when it cannot be altogether avoided; it is simply intended to call attention to a side of the question which is sometimes overlooked. If one were to judge by the school of specialists on the "secondary stress" bugaboo, pin-connected trusses would be the ideal construction for all bridges, long or short; whereas the greater rigidity or stiffness of riveted trusses makes them far more durable, especially for moderate and short spans; while plate girders, for a similar reason, are still better for lengths for which their use is practicable.

Reduction of Vibration

The importance of rigidity and reduction of vibration, not only in prolonging the life of a bridge but also in increasing its strength when new, can hardly be overestimated. Its advantage in increasing the confidence of the public is also real and important. Time was when some engineers delighted in pointing out the "spidery" structures of their designing, with pride that they could perform such marvels. The cost, or amount of material used in such cases may have exceeded what would have sufficed for a structure that would appear, and really be, much more substantial.

Effect of Track Position

The capacity of a bridge for track loads is far more affected by the position of the track than is generally appreciated. It is frequently found that a track which, according to the plans, should be centered with the bridge is considerably off centre. As an illustration of the effect of this "eccentricity," take the case of stringers 5 ft. on centres, and the centre of the track 1 in. to one side of the centre of stringers; this causes a strain on the nearer stringer 3⅓ per cent. greater than if the track were on centre. The eccentricity of a track is likely to change from time to time, especially on a curve and particularly near its ends. Because of possible changes in the eccentricity, it is the practice of the author, in making up the figures for moment and shear, for inspection reports, to make them first as if the track were on centre and to make a separate item for the excess due to eccentricity of more than about ½ in.

Shear Due to Sidewalks

An overhanging sidewalk, similarly, adds more than its weight and that of its load to the strain in the nearer truss. Reduction of moments in floorbeams by such overhanging sidewalks is disregarded in the author's calculations, on account of the possible temporary removal of the sidewalk. But the increase in shear due to such sidewalk is given its due importance.

Roadway and Sidewalk Loads

Sometimes engineers are known to argue that no impact allowance need be made with roadway and sidewalk loads, though it seems strange that anyone should hold this opinion. The specified 100 lbs. per square foot is no doubt sufficient to provide for as large a crowd on a sidewalk as can move with such speed and harmony as to exert the additional force ordinarily included in the term "impact," unless the gathered crowd is expected to "cheer with its feet." But even for sidewalk loads there is a possibility of a greater weight than the sum of the specified weight and the specified impact. Prof. L. J. Johnson, in experiments made in 1904, obtained a weight of 181 lbs. per square foot. In reporting the experiments to the Boston Society of Civil Engineers, Prof. Johnson says: "Though 181 lbs. per square foot must be conceded to be an extreme, it is believed that something very close to that figure is reached, over the whole drawbridge on the way from Soldiers' Field to Harvard Square