IMPACT—THE EFFECT OF MOVING LOADS ON RAILWAY BRIDGES*

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MOST engineering structures must be designed to carry more or less moving, or "live" load in addition to a certain amount of immovable, or "dead" load. The calculation of stresses due to any set of immovable loads is a comparatively simple matter: as soon as the loads themselves have been determined, the principles of statics can be applied and the resulting stresses readily obtained. But the calculation of stresses caused by moving loads is not so simple. This is because the rapidity with which the live loads are usually applied produces stresses which are greater than the stresses which would be caused by equal dead loads. The additional stresses due to the effect of the velocity are known as impact stresses.

The usual method of calculating stresses due to live load is to divide them into two parts. One part is obtained by considering the moving loads as a set of fixed loads, and calculating the resulting static stresses. The other part, which represents the effect of the velocity of the moving loads, is determined by increasing the static stresses by a certain percentage, known as the impact percentage, or impact coefficient. Total live load stresses are given by the sum of the static and impact live load stresses.

In any class of structures where the stresses due to impact form any considerable part of the total stresses, it is necessary to know, within reasonable limits, the effect of rapidity of application of the loads, for the final results are uncertain to the extent that the impact stresses are uncertain. Railway bridges are a large and important class of structures which come under this head. This article will deal only with impact in this class of structures.

Unfortunately, no exact method has been devised which will give a general expression for the coefficient to be used in calculating impact stresses. The attempts made to determine the impact coefficient can be classed under three general heads, as follows: First, mathematical methods; second, empirical methods; and third, experimental methods. As a general observation on the results obtained by these methods, it can be said that the first method is not very satisfactory, because the mathematics involved becomes so complex that only the simplest cases can be treated. The second method also is unsatisfactory, as empirical formulas generally are based on the personal opinion of the designer. Probably the most satisfactory method is the third. If tests could be made on all classes of structures under all probable loading conditions, a very close estimate could be made of the maximum impact stresses which would have to be provided for. At present the greatest real progress has been made along this last-named line.

Direct observation on existing bridge structures has shown that the chief factors in causing impact are: (1) Rapidity of application of live load, (2) unbalanced locomotive drivers, (3) eccentric wheels, (4) deflection of beams and stringers, which gives rise to variations in the action of the vertical forces, (5) flat or irregular wheels, and (6) rough and uneven track. Of these causes of impact the last two give impact which is in the nature of a sudden blow upon the structure. The other causes are more in the nature of a varying load, or a series of impulses, acting on the structure.

The efforts of mathematicians to develop an expression for the impact coefficient have been confined largely to the first of the causes of impact mentioned above. A small amount of mathematical work has also been done on causes two, three, and four. As the conditions are complex, no very definite results have been obtained. Causes five and six, when considered to be similar to a suddenly applied load, can be shown to produce a maximum impact stress equal to the static stress. This conclusion holds only for very short spans, or for localized conditions, such as joint details.

In making the mathematical analysis for the first cause of impact given above, it has been necessary to assume very simple initial conditions. The assumptions made are that the track is perfectly smooth, the abutments rigid, and that the moving load is a single load with the rotating parts in perfect balance. If the straight beam AB of Fig. 1 be supposed to carry a rolling load, which moves slowly across the beam, the deflection, greatly exaggerated, will be somewhat as shown by the curved line ACB. The path of the moving load is then along a path ACB. If the load be considered as moving with great velocity, its motion in a curved path will cause a centrifugal force to be set up, which tends still further to increase the deflection. This added deflection is a measure of the impact effect due to the rapidity of application of the moving load. The resulting equations are rather complicated and they will not be given here. For a discussion of this subject the reader is referred to the discussion in "Secondary Stresses in Bridge Trusses," by C. R. Grimm. A similar discussion is given on page 525 of "Modern Framed Structures," Part II., where values for the impact coefficient have been worked out. The values given for a speed of 60 miles per hour are 8.7 per cent. for a 25-foot span, and 3.7 and 1.7 per cent. for spans of 50 and 100 feet respectively.

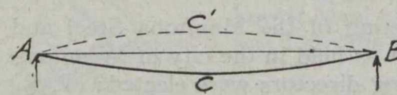

Fig. 1.—Deflection Under Moving Load

The percentages given above are relatively quite small. They are still further reduced by practical considerations, since in most cases bridge structures, when erected, are given a camber, that is, they are bowed upward, as shown by the dotted line AC'B of Fig. 1, to such an extent that under full live load the track is straight. The rolling load then moves along practically a straight line and little or no centrifugal force is set up, even at high speed.

When the impact is in the nature of a series of impulses, as in causes two to four given above, it is possible, in certain simple cases, to obtain some idea of the nature of the impact stresses. So many variables enter, however, even in a simple case, that the resulting expression is qualitative rather than quantitative in nature.

The case of unbalanced locomotive drivers is the most important of the impact-causing loads coming under this head, and the discussion will therefore refer to this cause of impact.

In order to transfer the power from the cylinders to the drive wheels of a locomotive, it is necessary to make use of a combination of rotating and reciprocating parts. It is possible to obtain a perfect balance for the rotating parts by means of properly placed counterweights. But in order to balance the reciprocating parts, it is necessary to add to the counterbalance certain weights over and above what is necessary to balance the rotating parts. This added weight is in the nature of an unbalanced force,

*Abstracted from article in the Wisconsin Engineer.