stringers will be spaced at 3 feet centres and each will be assumed to take half of the concentrated wheel load of 10,000 lbs. The Ontario specifications will require a 10-inch I-beam weighing 25 lbs. per foot.

The deflection under dead load will be .1041 inch.

The deflection under the live load of 5,000 lbs. applied gradually at the centre of the span will be .2082 inch.

The maximum allowable deflection by the live load for a stress of 16,000 lbs. per square inch is .2499 inch, which would be produced by a concentrated load of 6,000 lbs. gradually applied. The total resilience of the stringer available for the live load is therefore

$$6{,}000 \times \frac{.2499}{2} = 749.58 \text{ inch-lbs.}$$

This amount of work will be done by the live load of 5,000 lbs. if it is dropped onto the floor from a height of .025 inch, thus

$5{,}000 \times .025 = 125.0$ in.-lbs. kinetic energy

$5{,}000 \times \frac{.2499}{2} = 624.7$ in.-lbs. work in deflecting beam

749.7 total work

In the same way it can be shown that if the live load were dropped more than .15 inch the elastic limit of 32,000 lbs. per square inch would be exceeded.

Fortunately, in actual construction there are many "mitigating circumstances" which greatly modify the theoretical result. The concrete floor slab absorbs work and distributes the load. If the stringer rests on floor beams of a truss span the total drop of the stringer when the live load is applied will be many times its own deflection and the resilience of the truss is thus added to it. This is doubtless one of the reasons why so many shaky old bridges stand up apparently in spite of all theory. Their very flimsiness makes them good shock absorbers. It is not safe, however, to count on this resilience by any means, for if the stringer or floor beam in its vertical vibration is moving upward when the live load strikes it, it is brought to rest and the effect is the same as if it were rigidly supported.

So, while the above illustration must not be taken too seriously, yet it will serve to indicate how little provision is made for rough usage by the average impact formula.

Summing up the preceding discussion, the following conclusions stand out:

1. That these impact formulas are not based on any mechanical law or on practical experiment that would warrant them being accepted as expressing even approximately the true action of live loads on highway bridges. (See *The Canadian Engineer* April 6 for Part I. of this paper.)

2. That the Dominion specifications for the uniform live load with impact added only reduces the stresses to about what the best modern practice demands for static loads.

3. That in practical results there is very little difference which specification is used in spite of the apparent wide difference in unit stress and impact allowance.

4. That by the Ontario specification the impact increment for uniform loads is a very small percentage of the total load and that for spans over 50 feet it soon becomes so small that it might as well be neglected. The uncertainty regarding internal stresses of the materials, secondary stresses, and faulty workmanship, to say nothing of the impact stresses for which it is supposed to provide, are of an order of magnitude greater than the few per cent. added by the elaborate formula. Its use is therefore an unnecessary refinement, even if it gave absolutely accurate results for impact.

5. With reference to the application of these formulas to the concentrated load, no difference is made between it and the uniform distributed load, although their action is very different. The use of s = loaded length, is objectionable in a formula for slow-moving concentrated loads.

6. To provide for the possible impact from the concentrated load and to make an allowance for future increase or an emergency load the percentage of impact increment given by these formulas (the Ontario one in particular) cannot be considered adequate.

Only by an elaborate series of carefully conducted experiments and tests can any final conclusion be reached as to the effects of impact in highway bridges. But the difficulty of getting anything like satisfactory results from even the most carefully conducted experiments would hardly warrant the time and expense required for them. As related above (Part I.) the committee of the American Railway Engineering Association, after making many thousands of measurements and tests, finally recommended the formula for railway bridges that was developed by C. C. Schneider, who had little more than his judgment to guide him. It should be possible for highway bridge engineers to derive from their experience some formula or method which would be accurate enough for all practical purposes and at least be more logical and satisfactory than present methods. It is with this end in view that the following suggestions are made.

In the first place, it is necessary to make certain assumptions regarding unit stresses and loading. The use of high unit stresses make it necessary to provide a more liberal allowance for impact to insure against overstressing the materials. For many reasons it seems desirable to adopt what is now standard for medium steel, namely, 16,000 lbs. per square inch for tensile stresses due to static loads and the corresponding values for bearing, shear, etc.

The choice of loads is more of a matter of judgment and should be carefully considered for each individual bridge. As a large part of the impact increment is expected to provide for uncertainties in the loading and for future increases or emergencies, the choice of a fairly heavy loading will therefore make a large impact increment unnecessary. Fifteen years ago about the heaviest load that the rural highway bridge ever had to carry was the 6-ton traction engine. To-day, road rollers of 15 tons are coming into use all over the country. A new source of trouble is the motor truck which is now made with a capacity up to 20 tons. The chances are that their number will constantly increase and should some substitute be found for the soft rubber tires and roads continue to improve, even heavier loads may be expected. Whereas the traction engine used to make its trip through the country only once or twice a year and could almost be considered as an emergency load for bridges, there is a possibility that the motor truck will become a very important percentage of the traffic along some roads at least. Then, also, the rate of speed of 10 or 12 miles an hour means increased vibration and more wear and tear on the bridges. Some main-road bridges will have to be designed for two motor trucks passing on them, especially if they are long spans with 16-foot roadway or more.

The uniform distributed load, on the contrary, has no tendency to increase. The heaviest concentration of a crowd of people never exceeds 150 lbs. per square foot, while a crowd in motion does not weigh more than 80 lbs. per square foot. True impact from this load need not be considered.