LOAD CAPACITY OF OLD BRIDGES AND METHODS OF MAKING REPAIRS

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The state and the various counties have on their highway systems a great many old bridges. These bridges have been built at various times and according to various ideas of design and construction. Naturally, very few of the older ones were ever adequate for the heavy loads of today, which are beyond the wildest dreams of only a few years ago.

Also, these bridges have been exposed for years to the ravages of time, wind and weather, floods and fire, decay and rust, freezing and thawing, and, above all, the hammering and battering of traffic. Very few have wholly escaped some damage from one or more of these agencies of destruction. Considering these things, we find that the problem of determining the load capacity of old bridges and making repairs to restore or improve them presents an almost infinite variety of questions in detail.

The early replacement of all our weak and crippled bridges would overtax our resources under the most favorable conditions. Under the present economic situation, it is even more necessary that we patch up our old bridges and make them serve as well as we can until funds become available for replacing them.

This problem of figuring strength and working out repairs is very hard to discuss in a general way. It is largely a question of ingenuity and judgment, and often the mechanic and handy man is better in these respects than the engineer or technician. Some people are naturally ingenious and resourceful in a mechanical way, while others are not, and never will be.

For this reason, it is vital that the foreman selected to handle bridge repairs in general or in any specific case should be very carefully chosen with these things in mind. I can think of no place where more time and material can be saved or wasted than in making repairs of this character.

However, even the best qualified foreman may fail utterly through lack of appreciation of fundamental engineering principles, and this is where careful supervision by the county engineer or highway superintendent is very important. And I want to warn you that unless you have kept your mathematics and mechanics fresher in your mind than most of us, you are likely to slip up once in a while if you are not very, very careful.

LOAD CAPACITY

I shall attempt in a rambling way to point out some of the more common pitfalls and errors, and a few of the more common defects in bridges and some methods which have been used in repairing them, but first I will pass over very briefly the question of load capacity.

The methods for figuring load capacity are covered in the standard textbooks and I shall not attempt to go into the details of the calculations here. Mr. R. B. Yule, Engineer of Bridge Location for the Bridge Department of the Indiana State Highway Commission, has worked out instructions in detail for making surveys and calculations to determine the maximum load capacity of bridges, which instructions are being followed in determining the load limits to be recommended to the Commission under the 1931 truck law. For this purpose, we are using unit stresses approximately twice as high as those used in design. Since such heavy penalties are fixed by the law, it appears to us that we should do this, thus reducing our factor of safety so that we prohibit only loads which are very likely to damage the structure.

Of course, it should be understood that in many cases there are unknown elements of strength which enable a structure to carry even higher loads. I have personal knowledge of many cases, and authentic reports of others, where bridges have temporarily stood and carried traffic with some essential part broken or missing. But, of course, it is utterly unsafe to depend upon these factors, because most of them will fail to help under certain conditions and this may happen at the worst possible time with serious consequences.

The changes in traffic in recent years have resulted in much heavier concentrations of load with much smaller increases in the total load for which trusses are designed. Consequently, we have found that in old steel truss bridges, the stringers are almost invariably the weakest part of the bridge. Occasionally the floor beams or floor beam hangers or connections are the limiting point and more rarely some member or connection of the truss. Of course, this may be changed by rust or other damage to other parts of the bridge.

Because of these facts, we have for some years used a simple formula for roughly calculating the probable safe load capacity of steel bridges. This formula is as follows:

$$L = \frac{267\,S}{ls}$$

L is the gross truck load in tons—40 per cent on each rear wheel,

S is the section modulus of the steel stringer in inches^3,

l is the stringer span in feet, and

s is the stringer spacing in inches.

This formula is based on a stress of 16,000 pounds per square inch for steel. The result should be doubled if the maximum load which will not cause permanent damage is desired. This formula disregards the weight of the floor and floor system, which makes very little difference in stringers under normal conditions. For heavy floors and long stringer spans, the dead load should be figured.

REPLACING FLOORS

For the reasons set out above, one of the most common bridge repairs is the replacing of the floor or floor system. If the stringers are to be replaced with stronger ones, the other elements of strength of the bridge should be carefully studied and no money wasted in making the stringers stronger than the rest of the bridge. Also, the floor should not be greatly increased in weight unless it is certain that the floor system and trusses are sufficient to carry it. I have known a number of bridges to be overstressed or even broken down by the weight of a concrete floor, when the bridge would have been quite satisfactory if a lighter floor had been used.

One very important matter to consider in a bridge floor is impact and its closely related companion, vibration. I recall very vividly one case where a very serious condition was found just in time to avoid a serious accident. In the White River bridge west of Martinsville, an experimental section of laminated floor was installed. This floor was four inches thick, while the old double plank floor was six inches thick, leaving a two-inch offset at the point where the two types joined. One panel of stringers next to this offset was bent down from two to six inches by the impact resulting from this condition, while the other stringers in the bridge were in excellent condition.

In another case, a bridge with a single plank floor was so loose that its rattling could be heard a mile away when a car crossed it at high speed, and it was locally regarded as a very weak and dangerous bridge. When a smooth longitudinal floor was placed on top, the vibration was almost entirely stopped. There were no further complaints about this bridge.

DAMAGED TRUSS MEMBERS

If one of the truss members of a bridge is damaged, the repair or replacement of the member is largely a matter which any good mechanic can work out. Care should be taken to see that bolt or rivet holes are not so located as to weaken the repaired member and that the repair does not throw the stress badly off the line of the member. *The big problem is to keep the bridge from falling down while the repair is being made.* Usually the safest, simplest, and cheapest way is to put a bent under each floor beam to support the bridge while the truss member is out of service. Sometimes one or two such bents will do, but this is a risky plan unless the distribution of stresses in the truss under these conditions is carefully investigated, and the overstressed members strengthened. In the reconstruction of the Wabash River bridge on State Road 34 at Covington, traffic was carried on a truss span which was strengthened and supported at the first panel point while an abutment was torn out and a pier built in its place.

In many cases, if live loads are kept off the bridge, a temporary member may be used to permit the removal and replacement or the repair of the member without removing it. This was done in repairing a damaged hanger in the Broad Ripple bridge over White River on State Road 31. In the double intersection truss bridge over the Wabash River on State Road 1 at Bluffton, several compression verticals were buckled. The cost of falsework in this case would have been excessive. These members were straightened in place all at once by specially designed clamps and beams and without the use of falsework. The clamps and straightening beams were left in place, resulting in members stronger than when they were built, though rather clumsy in appearance.

A discussion of this subject would not be complete without reference to one rather common mistake. When a bridge as a whole shows signs of weakness, it is only natural to think of putting an additional support in the middle of the span. In the case of slab, beam, or girder bridges, this is a very effective device for strengthening the structure, but in the case of truss bridges, it may even have the opposite effect. A rather simple stress analysis will show that unless certain members are reinforced or new ones added, under certain conditions a simple Pratt truss with an extra support at the center of the span may actually fail under a concentrated load which it would safely carry without the center pier.

NEW DEVELOPMENTS IN THE MATERIALS FIELD

By H. F. Clemmer, Engineer of Materials,
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Professor Ben H. Petty, in his splendid discussion entitled "Highway Demand Is Turning from Main to Local Roads," as published in the recent highway number of the Engineering News-Record, stated: "The peak has been reached in improvement programs concentrated on main state highways. We are now entering an era of unprecedented low-cost improvement of secondary roads." This fact is very evident. During the past ten years, a network of high-type pavements has become a reality. With this development has come an

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