

Replacement or Repair of Old Truss Bridges

Conrad P. Heins, University of Maryland
William S. Fout and Raymond Y. Wilkison, Frederick County Roads Board,
Frederick, Maryland

Throughout Frederick County, Maryland, and possibly many other counties in Maryland, there are many steel truss bridges that were built in the late nineteenth century. Most of these truss bridges are on secondary roads and carry a single lane of local traffic. Their importance, however, cannot be minimized, for they supply a great need to the local community.

All of these bridges have been inspected and rated. In many instances the ratings are so low that only passenger cars are permitted to cross the bridge. School buses, farm equipment, and trucks must find an alternate route, or the bridge must be replaced or repaired to upgrade its capacity. Because the cost of replacing these bridges is prohibitive, the solution is to repair and strengthen the bridges. The actual strength of the bridges can only be determined if the bridge is examined under a typical truck loading.

This paper presents the results of tests on six such steel truss bridges and the effects that strengthening of the deck had on the floor system. Also presented are the results of laboratory tests on stringer beams when the beams are stiffened with nailers and planking. The results yield a distribution factor that is less conservative than that of AASHTO.

PROBLEM

The useful carrying capacity of bridge elements can be determined by analytical methods or experimental tests. When the structural system is highly indeterminant, simplified analytical methods can greatly underestimate the load-carrying capacity. In the instance of bridge structures, which are highly indeterminant systems, the ultimate load capacity may be 15 times the elastic capacity.

Six truss bridges throughout Frederick County, Maryland, were examined, and the allowable load capacity was determined by simplified analytical techniques.

These results recommend a severe lowering of the carrying capacity of the bridges. These results may be reasonable at face value. However, from field observations it has been noted that the bridges have supported much greater loads without any noticeable detrimental effects to the structure. Therefore, there is some disagreement between the analysis results and what is actually occurring in the structure under load.

This discrepancy was overcome by testing six selected bridges and certain components in the laboratory under a known load and proper instrumentation. The results of the testing and the rating of the bridges are presented.

PROGRAM DETAILS

The objectives of the study were to

1. Select six bridges that had been inventoried, inspected, and rated for test purposes;
2. Examine and study the bridge inspection and rating reports for each bridge, and locate critical members;
3. Determine the location of strain gauges for each bridge;
4. Determine the field truck loading position;
5. Instrument the bridge with strain gauges;
6. Test the bridge, i.e., position a loaded truck at various locations on the bridge and read gauges;
7. Reduce data, and develop rating;
8. Test in the laboratory typical floor beams with and without nailers;
9. Compare field and laboratory test results with analytical data; and
10. Prepare recommendations for the rating of the bridges.

BRIDGE FIELD TEST STUDY

Bridge Description and Gauge Locations

The six truss bridges that were field tested consist of single-lane steel pinned, jointed truss structures approximately 4.6 m (15.0 ft) wide with spans 18 to 27 m (60 to 90 ft) long. With the exception of the Gapland Road bridge, the other five bridges have wooden decks. These

Table 1. Rating of Long Mills Road bridge over Owens Creek.

Member	Gauge	Dead Load Stress (MPa)	Live Load Stress (MPa)	Allowable Stress (MPa)	Rating
Floor beam	1	20.7	82.8	69.0*	H8.8
Diagonal	2	0	32.4	86.3	H40
Diagonal	3	0	-33.8	86.3	H12.8
Stringer	4, 5	—	68.3	86.3	H18.9
Bottom horizontal	6	33.1	18.6	86.3	H42.8
Bottom horizontal	7	33.1	22.8	86.3	H35

Note: 1 MPa = 145 lbf/in².

*Corrosion of member.

Table 2. Rating of Daysville Road bridge over Israel Creek.

Member	Gauge	Dead Load Stress (MPa)	Live Load Stress (MPa)	Allowable Stress (MPa)	Rating
Stringer	1	6.9	72.5	86.3	H16.4
Bottom horizontal	2	27.6	20.7	86.3	H42.5
Top horizontal	3	-19.3	-43.5	32.4	H4.5
Top horizontal	4	-19.3	-35.2	32.4	H5.6
Floor beam	5	24.2	147.0	82.8	H6
Vertical	6	0	12.4	86.3	H104

Note: 1 MPa = 145 lbf/in².

Table 3. Rating of Water Street bridge over Israel Creek.

Member	Gauge	Dead Load Stress (MPa)	Live Load Stress (MPa)	Allowable Stress (MPa)	Rating
Diagonal	1	23.5	60.0	75.9	H13
Bottom horizontal	2	37.3	33.1	86.3	H22
Stringer	3	8.3	51.8	86.3	H22.6
Diagonal	4	58.0	49.7	—	—
Floor beam	5	14.5	18.6	43.1	H23
Top horizontal	6	-24.8	-31.1	58.7	H16

Note: 1 MPa = 145 lbf/in².

Table 4. Rating of Gapland Road bridge over Broad Run.

Member	Gauge	Dead Load Stress (MPa)	Live Load Stress (MPa)	Allowable Stress (MPa)	Rating
Stringer	1	5.7	45.5	86.3	H26.7
Floor beam	2	20.0	66.2	86.3	H11.5
U-bolt	3	—	70.4	—	—
Vertical*	4	12.4	33.1	43.1	H14
Vertical*	5	12.4	2.1	43.1	H225
Bottom horizontal	6	31.1	24.8	86.3	H33
Diagonal	7	33.8	66.2	69.0	H8

Note: 1 MPa = 145 lbf/in².

*Corrosion of member.

Table 5. Rating of Old Hagerstown Road bridge over Little Catocin Creek.

Member	Gauge	Dead Load Stress (MPa)	Live Load Stress (MPa)	Allowable Stress (MPa)	Rating
Bottom horizontal	1	35.9	10.4	86.3	H73
Diagonal	2	26.9	51.8	86.3	H17
Stringer	3	13.1	134.6*	86.3	H8
Stringer	4	13.1	117.3*	86.3	H9.4
Stringer	5	13.1	183.5*	86.3	H6.5
Floor beam	6	29.0	86.9	86.3	H9.9

Note: 1 MPa = 145 lbf/in².

*Without lateral support. With lateral support through new nailers, the live load stress would be 69 MPa and the ratings would be H15.9.

decks are nailed to nailing strips attached to the steel stringers. The deck members are generally wooden (7.6 by 25.4 cm or 3 by 10 in) and the nailers are wooden (7.6 by 25.4 cm or 3 by 10 in), either of pine or oak. The Gapland Road bridge deck consists of steel grating.

Each of the six bridges was instrumented with SR-4 strain gauges at various positions.

Loading

The truck load that was applied to each bridge consisted of a gravel loaded 2D truck. The rear axle weight of 10.2 Mg (22.5 kips) was positioned along the bridge at various locations, as dictated by the influence lines, to institute maximum effects. These trucks are similar to the design H15 vehicle, which has a rear axle weight of 10.8 Mg (24 kips) and front axle weight of 2.7 Mg (6 kips). This type of vehicle represents the worst possible load a bridge can be subjected to.

Test Results

The test truck was placed on each bridge at various positions, and the induced strains on the various members were recorded. In some instances, the strain gauges were monitored for both static and dynamic loading.

The resulting induced stresses are given in Tables 1 through 6 for each of the six bridges. The gauge numbers refer to the gauge locations on the bridge. The tabulated stresses were obtained by converting the strain readings from an assumed elastic modulus of 2.07 GPa (30 million lbf/in²).

BRIDGE DESIGN STUDY

As mentioned previously, each of the six bridges was rated based on a complete analytical study. The ratings were obtained after computing the probable induced dead and live load stresses and the allowable stresses. The allowable stresses were selected from the AASHTO specification in the Manual for Maintenance Inspection of Bridges and field observations; the design value of certain members was reduced if the member was noted to be distorted or corroded. With these criteria and field observations of the various members, the rating of each bridge was computed. The ratings correspond to H15 truck with an appropriate reduction.

Those members of each bridge that govern the rating are as follows:

Bridge	Member	Gauge	Rating
Longs Mill Road	Stringers	4, 5	H0
Crum Road	Floor beam	2	H2
Water Street	Diagonal	1	H1.2
Daysville Road	Stringer, floor beam	1, 5	H3
Old Hagerstown Road	Stringer	3, 4, 5	H1
Gapland Road	Diagonal	7	H5

If the dead load stresses computed are accurate, it remains to establish the accuracy of the live load stresses. Such stresses were obtained through tests (Tables 1 through 6). These field live load stresses, in conjunction with the computed dead load stresses, were used to reevaluate the bridge ratings.

LABORATORY STUDY

As described, the ratings of three of the six bridges are governed by the strength of the stringers. In most instances, these low ratings are due to the fact that no lateral bracing of the compression flange is assumed. To rectify this condition, the county engineer devised a

Table 6. Rating of Crum Road bridge over Israel Creek.

Member	Gauge	Dead Load Stress (MPa)	Live Load Stress (MPa)	Allowable Stress (MPa)	Rating
Top chord	1	-22.1	-39.3	86.3	H9.9
Floor beam	2	42.8	107.6	86.3	H6
Stringer	3	6.2	58.0	86.3	H20.7
Vertical	4	10.4	26.9	86.3	H42
Bottom horizontal	5	35.2	43.5	86.3	H17.6
Bottom horizontal	6	31.0	39.3	86.3	H21
Top chord	7	26.2	20.7	86.3	H44

Note: 1 MPa = 145 lbf/in².

method of providing continuous lateral bracing by attaching wooden (7.6 by 20.3-cm or 3 by 8-in) nailing strips to each stringer. The top deck is then nailed to the nailing strips to provide continuous lateral support.

To determine the effectiveness of this type of bracing, a series of laboratory tests was conducted to accurately evaluate the strength of the stringer members and thus provide an alternate rating.

Model Descriptions

Two models were constructed for test purposes. One model consisted of three 6I12.7, 3.1-m-long (10.0 ft) steel girders spaced 0.9 m (3.0 ft). The three girders were welded at each end to 7.6 by 7.6-cm (3 by 3-in) steel angles. The other model consisted of the same members but had nailing strips bolted to the side of each stringer. Attached to each strip were 7.6 by 25.4-cm (3 by 10-in) wooden planks.

Each model was instrumented with SR-4 strain gauges attached on the top and bottom flanges at midspan. Vertical deformation at midspan of the models was also measured during each test.

The models were subjected to two loads applied on the top flange of the center girder. The model without the nailing strips had similar planking laid across the model width.

Results

The resulting stress data indicate that the average distribution is 14, 72, 14 percent for the model without nailers and 22, 56, 22 percent for the model with nailers for the exterior, center, exterior girders. Based on this information, the load distribution factors are $S/4.2$ and $S/5.2$ for the decks without and with nailers respectively.

BRIDGE RATING

Each of the six bridges had been rated previously; however, these ratings were revised by using the observed field live load stresses and computed dead load stresses. A summary of these results (Tables 1 through 6) yielded the following new bridge rating:

Bridge	Rating	Bridge	Rating
Longs Mill Road	H10	Gapland Road	H8
Daysville Road	H5	Old Hagerstown Road	H10
Water Street	H10	Crum Road	H6

For the Water Street and Old Hagerstown Road bridges new floor systems are required. The Daysville and Gapland Road bridges, which have ratings less than H10, are governed by the truss elements. The Crum Road bridge rating is governed by the floor beam. A comparison of these new ratings and the analytical ratings, as listed

previously, shows a substantial increase in the load capacities of the six bridges.