Structural Analysis and Historical Survey of the Ironto Wayside Footbridge

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History of the bridge

The bridge now known as the Ironto Wayside footbridge was constructed in 1878 in Bedford County as a vehicle crossing of a small stream along Route 637. The bowstring truss design was patented by Z. King in 1859 under the name "Tubular Arch Bridge." The King Iron Bridge and Manufacturing Company of Cleveland, Ohio built 15 steel truss bridges in the state of Virginia around the same time. By the early 1970s the bridge had been bypassed by a pipe culvert and had fallen into disrepair. The Virginia Transportation Research Council (VTRC) recognized the importance of the bridge as a historical landmark as it was the oldest standing steel bridge in the state and worked to preserve by restoring it and putting it into use elsewhere. The bridge is now serving as a pedestrian stream crossing and point of interest for travelers at the Ironto Wayside on I-81N, mile 129.

Figure 1. The bridge in its original location in Bedford, VA being dismantled for relocation to the Ironto Wayside.

Structural Analysis

There was no documentation of a structural analysis from when the bridge was designed and built and one was not deemed necessary when it was relocated. The first step in the analysis process was to create a working computer model. For simplicity, only one truss was modeled. It was noted during an inspection of the bridge that the diagonal cables were lose and would not carry any load. Therefore they were not included. Instead of modeling the vertical bracing system, the restraints were constrained to rotation in the plane of the truss so that only moments perpendicular to the truss were created.

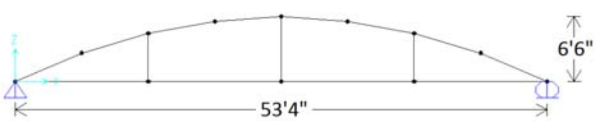

Figure 2. The model used to analyze the bridge's response to typical loading.

Three different loads were applied to the model individually. First was the dead load based on the self-weight of the members. The second came from *Practical Treatise on the Construction of Iron Highway Bridges* (Boller, 1893). This document suggested that a uniform distributed load of 75 psf be applied to ordinary country bridges 60 ft and shorter to represent a typical load. Finally, for a vehicular point load, *De Prontibus* (Waddell, 1898) suggested a 6' by 8' wagon load of 5 tons distributed equally between all four wheels be used. Each of these loads was represented appropriately for the single truss model.

Results

Each load was applied individually to the model and the resulting axial force, moment and deflection in the arch were recorded. From this data, the maximum axial and bending stresses were calculated using Equations 1 and 2 listed below. The results are summarized in Table 1. Negative values represent compression and positive values represent tension.

Eqn. 1: Axial Stress $\sigma_{axial} = \frac{P}{A}$

Eqn. 2: Bending Stress $\sigma_{bending} = \frac{Mc}{I}$

P: axial force, *M*: moment
A: Area, *c*: distance from neutral axis to edge, *I*: moment of inertia
A, I, c are constants found in the AISC Steel Construction Manual

Table 1. Maximum Stresses and Deflection in the Arch of the Bridge

Load	σ_{axial} (ksi)	$\sigma_{bending}$ (ksi)	σ_{top} (ksi)	σ_{bottom} (ksi)	Deflection (in)
Dead	-0.5	0.3	-0.8	-0.2	0.03
Uniform	-6.9	18.0	-24.9	11.0	0.48
Wagon	-2.2	10.8	-13.0	8.6	0.59

Figure 3. The footbridge in its current location at the Ironto Wayside on I-81N, mile 129. A nearby marker notes that it is the oldest steel bridge in the state of Virginia.

What's Next?

The maximum stresses determined by the model analysis are well under the yield stress for wrought iron of 27 ksi. Now a load test is in the works to test the accuracy of the deflections found by the computer model. To measure the deflection of the bridge, a load at least as large as the five ton wagon must be applied to create readable deflections. The deflection will be recorded by a dial gage which will be set up below the middle of the span to record the maximum deflection.

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