PRACTICE OF RESTORING A DAMAGED HISTORICAL TRUSS BRIDGE

by Chung C. Fu[1], Member, ASCE, and Ken Harwood [2]

Abstract: Keysville Road Bridge is an 1880 wrought iron truss bridge listed on the U.S. National Register. The bridge is across Tom's Creek located in Frederick County, MD. This 31.4 m (103 ft)-long structure has an overall width of 4.57 m (15 ft-0 in.) c/c of the trusses and 3.66 m (12 ft-0 in.) clear roadway between timber curbs. The trusses are wrought iron Warren trusses with eight about equally spaced panels. This historical bridge was damaged by previous year's flooding. During the flood, the bridge, which was then covered with canvas for painting, was uprooted by the high water and displaced for several yards downstream.

The bridge was recently rehabilitated and repainted. Several bent and damaged truss members including all the deck were restored. All the replaced truss members are A36 steel and the deck panels are treated glue-laminated woods. Some of the truss members were recovered from damage and the integrity of the whole truss structure was the concern of the county officials. A field test by using strain gauges was conducted by the Bridge Engineering Software and Technology (BEST) Center, Department of Civil Engineering, University of Maryland. While the bridge was undergoing testing, rehabilitation was nearly completed, except for the railing. The complete test was done and with the load-proofing, bridge was opened to traffic.

Keywords: bridge, steel; bridges, truss; testing; rehabilitation; retrofitting; instrumentation; ratings; bridge tests

INTRODUCTION

Keysville Road Bridge is a single-span steel truss bridge in Frederick County, MD. The span of the structure is 31.4 m (103 ft) between centerline of the end pins, and the clear waterway is 4.45 m (14 ft-7 in). The

---

[1] Director and affiliate Associate Professor, the Bridge Engineering Software and Technology (BEST) Center, Department Civil Engineering, University of Maryland, College Park, MD 20742

[2] County Project Manager, Department of Public Work, Frederick County, MD 21701

structure has an overall width of 4.57 m (15 ft-0 in.) center to center of the trusses and 3.66 m (12 ft-0 in.) clear roadway between timber curbs. The two trusses are steel Warren trusses with eight about equally spaced panels. The bridge was built before 1885 with an “Illustrated Pamphlet of Wrought Iron Bridges” printed by the Wrought Iron Bridge Co. In this pamphlet they included an illustration of this bridge and listed it as a completed project that could be inspected by prospective customers (Figure 1). Because of it’s historical significance and because it is listed on the National Register of Historical Places, the rehabilitation was funded through federal historical bridge rehabilitation program, which required a lot of additional coordination during the design and bidding process with Maryland State Highway Administration (MDSHA) and the Federal Highway Administration (FHWA).

The Keysville Road bridge was closed due to structural deterioration of its stringer beams, abutments and vehicle damage to various truss members. The contractor started this project in the previous summer but was not able to move ahead much due to heavy rains and flooding. The painting sub-contractor installed the containment system and had just started blasting when hurricane Fran came up the coast. The resulting flood water caught debris in the containment system and dragged the bridge off its abutment, leaving it resting against the trees on the east bank of Tom’s Creek (Figure 2).

This historical bridge was recently restored from the damage caused by the previous year’s flooding. Before the opening, a bridge testing was conducted by the University of Maryland research team. When the bridge was undergoing testing, rehabilitation was nearly completed, except for the railing and the pavement. Rehabilitation was completed and the bridge was opened to the public.

APPROACH AND MATERIAL TESTING

The “Illustrated Pamphlet of Wrought Iron Bridges” printed by the Wrought Iron Bridge Co in 1885, says, *”We have testing machinery for ascertaining the actual strength and character of material used in construction. Our iron is specially manufactured for us under rigid specifications and every car load is carefully tested”.*

“We offer every facility for testing the material or finished work at our shops before shipment, to parties purchasing our bridges, and give their engineers personal supervision of the manufacturer, when asked”.

In order to prove the quality of materials and the method of repair, the Owner, Frederick County, proceeded with the following:

1) County tested all structural castings with die penetrant. Six bottom chord bars were also tested die penetrant and no crack was found.

2) To verify strength and chemical makeup County had four (4) samples (one from each corner of the bottom chord members) tested by Herron Labs, Ohio.The results were good and roughly what County expected. All four (4) samples had a higher percentage of elongation than the minimum for A-36. This means that the Keysville material is very ductile and can be straightened cold.

3) Three (3) bars, 28.6 mm x 28.6 mm (1-1/8 in. x 1-1/8 in.) that had been bent in the flood, were taken to Wilton Corporation, MD to get them straightened. Then, die penetrant tests for cracks on all three (3) bars were ran by the first author and no cracks were found.

4) Two (2) of the above cold straightened bars were sent to Herron for tension tests to verify strength after strengthening.

The above work were part of the work outlined in the county research and procedure document. The tensile test results were listed in Table 1. In Table 1, the first set was done as samples of wrought iron in tension members on the bridge. The second set was samples that were taken from the most severely bent members on the bridge. These bent members were cold straightened on a hydraulic press, dye penetrant tested for cracks (none found) and then sent to be tensile tested. These results indicated that the material is a very ductile and easy material to work.

BRIDGE REPAIRING

The County plans to repair the bridge in accordance with the original contract documents set before the damage done by the flood. As a result of the work for the material testing, the County determined what additional repairs need to be made above those original planned.

Based on the coupon testing results, all the original truss members are considered yield stress of 30 ksi. Replaced members include U1L1 & U7L7, both sides; L0L2 & L6L8, both sides; U3L4 & L4U5 (upper part above turnbuckle), upstream only; U3L4 (lower part inside bar of the pair), downstream only. All the replaced members are A36 steel.

All of the cast iron connection parts are determined to be reusable. Dye penetrant tests were done on them to verify that they are not cracked. Approximately 2 to 4 of the 101.6 mm (4 inch) wide connection plates on the ends of the upper cross beams were straightened or replaced. Several connection plates around bottom chord pins were damaged and replaced. The diagonal small cross section bars, which were in compression, were straightened when they are put back in tension. The end posts and verticals were straightened as provided in the original documents (Figure 3).

The floorbeams, stringers, bearings, deck and railings were either replaced and/or repaired as shown in the original contract documents. The cleaning and painting of the remaining original metal and the painting of new steel were also performed.

BRIDGE TESTING

In order to be sure that the finished bridge worked correctly, County contacted the University of Maryland to work with County to do strain gauge testing of the truss bridge. The tested bridge was completing rehabilitated and repainted (Figure 4). Some of the truss members were recovered from damage and the integrity of the whole truss structure is the concern of the county officials. A field test by using strain gauges was conducted by the Bridge Engineering and Technology (BEST) Center, University of Maryland. The strain gauges were installed and the complete test was done within three days

A bridge Inspection truck was used as the testing vehicle. The truck front axle weighed 2,900 pounds and the rear axle weighed 4,360. The distance between axles is 3.35 m (11 ft-0 in).. The truck was weighed before testing and the axle distance was measured on site.

With this known axle spacing and weights, the bridge structure was loaded by running the truck back and forth with a series of testing and recording. Two series of truck loadings were done, one by running the truck at the center and the other along the side curb.

INSTRUMENTATION AND DATA COLLECTION

A mainframe unit for the data acquisition system is named MAGADAC 2200C, and is manufactured by OPTIM Electronics, located at Germantown, Maryland. The MAGADAC 2200C is a modular system which makes it a versatile unit in data acquisition from a wide range of active and passive transducers in different applications. The system is a self-contained unit, which in addition to providing the excitation current (and voltage) for the transducers, also includes signal conditioning modules, differential amplifiers, ADCs, and other important electrical hardware for signal generating and controlling, processing and saving.

Even though the MAGADAC 2200C alone can be considered a computer, it is easier to use the control system OPUS2000 provided by OPTIM Electronics for signal generating, controlling, monitoring and saving. In this case, an IBM personal computer with IEEE-4888 interface was used to communicate between the computer and the data acquisition system.

Adhesive-type strain gauges CEA-06-250UW-350 produced by Micro-Measurements were used in this test. The strain gauges were instrumented on the truss steel members to capture the strain data for the bridge response to the moving test truck on the bridge. The gauges were bonded to the truss members by keeping the major axis along the longitudinal direction.

The bridge was intend to be instrumented with sixteen strain gauges on the first day and was tested on the second day. Due to time constraints, only one balance procedure was done with the strain gauge calibration. If the strain gauges were not balanced, they have to be abandoned to save time. Even though nine out of the sixteen strain gauges were not able to be balanced and calibrated due to various reasons (connection, splicing, bonding, bad wiring, ... etc.), there are still seven strain data records which were reliable and were able to be used.

Once the gauges were instrumented, they were connected to the data acquisition system through lead wires, screw terminal block (STB), and shield ribbon cables. Gauges were monitored through the computer, which was connected to the data acquisition system.

Data were collected by test case. Separate data files were created with a unique file name for each vehicle test and they were stored as digital signals and ready to be processed.

TESTING RESULTS AND COMPARISON

BEST Center software TRAP (Truss Rating and Analysis Program) was used to generate the live load forces for all the members. Since the test truck was moving slowly on the bridge, impact was ignored. Table 2 lists the stresses for those members which has testing strain records.

Several strain data records based on the test truck T1 were collected and sorted out. The maximum strain for L3L4 was 45.6. This strain from testing corresponds to 1.32 ksi in stress, compared to 1.396 ksi with impact by computer analysis.

The second set of data was for L6U7 which produced maximum strain of 50.9. This stress converted from testing strain was 1.48, compared to 1.47 ksi with impact by computer analysis.

The test results of these sample strain records are very close to the computer output. We then had the confidence to use the computer results to obtain all the other live load forces and stresses for rating purposes. Both AASHTO truck H-15 and test truck T1 are used for bridge rating. Rating based on T1 was used only for calibration. H-15 truck gives the following rating results.

1) Inventory Rating Factor: 1.07, which corresponds to 1.07 x 30/2 = 16 tons
2) Operating Rating Factor: 1.54, which corresponds to 1.54 x 30/2 = 23.1 tons
3) Most Critical Members: U3L4 & L4U5 (computer model U4L5 & L5U6).

CONCLUSION

Rehabilitation of historical truss bridges is needed for the structural elements that have been deteriorating over the years. Detail plans has to be made to retain the historical appearance of the structure. Due to damage from flood, special consideration has to be made to the structural integrity of the re-constructed structure. Bridge testing is the most reliable method to ensure the integrity and functionality of the bridge. By comparing the testing results with the computer analysis results, conclusions can be inferred from the comparison. It is found that the test yielded valuable information about the behavior of the structure. Based on the collected information, we may have more confidence on the computer results, which will give more detailed and comprehensive results. With other types of loading the bridge rating can be decided.

ACKNOWLEDGE

The bridge rehabilitation and testing work described here was planned and implemented under the supervision of the Frederick County Department of Public Work, Maryland. The authors wish to thank for their insight, advice and contribution of this project and this paper.

Sample #	Yield Stress (psi)	Ultimate Strength (psi)	% Elongation	% Reduction in Area
1 of 4	34,400	50,500	18	31
2 of 4	38,000	52,500	29	44
3 of 4	29,700	48,000	32	44
4 of 4	31,900	51,000	30	41
1 of 2	35,600	49,800	27	40
2 of 2	36,200	50,400	25	44

Member Number	Area mm^2 ($inch^2$)	Stress from testing Mpa (ksi)	Computed Stress w/impact MPa (ksi)	Computed Stress w/o impact MPa (ksi)
L3L4	3226 (5.0)	9.101 (1.32)	9.625 (1.396)	7.998 (1.16)
U4L5	387 (0.6)	N/A	10.205 (1.48)	8.067 (1.17)
L4U5	774 (1.2)	N/A	21.10 (3.06)	16.824 (2.44)
L6U7	2016 (3.125)	10.205 (1.48)	10.136 (1.47)	8.343 (1.21)