

IN-DEPTH TIMBER BRIDGE INSPECTION AND LOAD RATING

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Summary

This paper focuses on field inspection and load rating of timber bridges. The U.S. Department of Agriculture, Forest Service is responsible for more timber bridges than any other U.S. Federal agency. The Forest Service has more than 7,300 timber road and trail bridges located on the National Forest transportation system. This paper discusses cursory and in-depth inspection of timber bridges and load rating timber bridges using two computer programs; Timber Bridge Analysis and Rating (TBAR) and MathCAD.

Keywords: inspection, NDT, timber bridge, moisture meter, resistograph, stress wave, TBAR, MathCAD

1. Introduction

The Forest Service has used timber components in the construction of many of its road bridges for more than 100 hundred years. There are approximately 6,200 road bridges currently in-service on the National Forest transportation network. Bridges constructed of timber make up over half these bridges. There are more than 3,450 timber bridges on Forest Service roads with one or more of the primary structural components constructed of timber (i.e., decks, girders, slabs). Forest Service timber bridges (Figure 1) have been built for more than 100 hundred years with most existing bridges being built 30 or more years ago. Due to the age of these structures, a good inspection and load rating process is required to maintain them and to ensure that they are safe for general public use.



Fig. 1 Typical Forest Service timber road bridge

2. Why Do We Inspect and Load Rate Bridges in The United States?

We inspect road bridges in the United States because it is the law, covered by the Code of Federal Regulations, Title 23, Part 650 (23 CFR 650) – Bridges, Structures, and Hydraulics. 23 CFR 650.311(a)(1) requires that routine inspections be conducted on each bridge at intervals not to exceed twenty-four months. In addition, 23 CFR 650.313(a) outlines the inspection procedures and 23 CFR 650.313(c) requires that each bridge be rated for a safe load-carrying capacity in accordance with American Association of State Highway and Transportation Official's *The Manual for Bridge Evaluation* [1].

3. Bridge Inspection Types

Types of inspections can be classified as visual or in-depth inspections. Visual inspections are the most common method of inspection and use the human senses (vision, touch, hearing, and smell) and non-specialized equipment as the means for inspecting a structure. In-depth inspections typically use specific equipment that has been specially design for testing a certain type of material.

Visual inspections can be further broken down into two categories; cursory and hands-on. Cursory inspections involve looking at the bridge as a whole and identifying possible defects or problems. Examples of things that you would be looking for during a cursory inspection are sagging beams, water ponding, uneven surfaces, or any other things that do not look visually correct. The hands-on inspection involves getting within an arm's reach of the feature being inspected and looking for potential problems.

Typical tools used for hands-on inspection for timber members are a hammer, awl, level, and ruler. The hammer is used for sounding the timber beams and decks and listening for unusual sounds. Sounding works best for members less than 2 inches thick. Most timber bridges are pressure-treated and have a 1½ to 2-inch thick protective shell around the outside of the member, making it hard for the inspector to hear any difference. The awl is used to perform a pick test to find out if the wood fibers are starting to decay and also to probe the member to see how much decay is occurring on the outside of the member.

In-depth inspections can be either non-destructive testing (NDT) or destructive testing. This paper focuses only on non-destructive testing [2] while the inspector is trying to reduce any effect that the

testing will have on the timber member. There are three main types of specialized testing equipment we use for timber bridges: the moisture meter [3], the stress wave tester [4], and the resistograph drill [5].

Moisture meters are used to measure the percentage of water in the wood member. When the moisture content exceeds 25 percent, the chance of the wood rotting is greater. The stress wave tester is used to determine the velocity at which a stress wave travels through the wood. It can be used to determine the chance of decay being present in the wood. The resistograph drill is an electronic, high-resolution needle drill that is used to measure the resistance of the wood based on the power consumption of the drill.

4. Bridge Inspection Procedures

The procedure for inspecting a bridge should follow a consistent sequence. Following a constant procedure reduces the chances of overlooking a problem with the structure. A typical bridge inspection follows these basic steps:

- 1) Conduct a cursory inspection of the bridge looking for any sagging members, ponding water, uneven surfaces, and any other unusual observations.
- 2) Conduct a hands-on inspection of the bridge, making sure to investigate any problems that were observed during the cursory inspection.

A hands-on inspection includes measuring the bridge components (beams, decks, sills, etc.) and beam spacing, determining wood species, looking for moist areas, decay and fruit bodies, and looking for defects, crushing areas, and hollow sections (Figure 2). Tools that are normally used for this is inspection are a hammer, awl, level, stringline, and tape measure.



Fig. 2 Hollow section caused by advanced decay

- 3) Conduct an in-depth inspection of any problems found during the hands-on inspection. The Forest Service uses a moisture meter, stress wave tester, and resistograph drill to conduct in-depth NDT. The in-depth process used includes:
 - a. Looking for areas of moisture, crushing, or any other signs of distress and taking a moisture reading at these locations
 - b. Using the stress wave tester to take readings along the entire length of the beam and marking high reading locations with chalk

- c. Using the resistograph to drill the high stress wave reading locations to investigate them
- d. Drawing up a diagram of all problem locations

A common problem with solid sawn timber beam bridges with plank decking and no asphalt wearing surface is that the decking has been replaced and the old nail holes never sealed up. This allows water to infiltrate into the top of the beam and causes the beam to decay from the inside out. One way to check for this is to use the resistograph and drill down through the decking and top of the beam to assess the top of the beam.

- 4) Collect data required for load rating:
 - a. Total deck width and clear travel width
 - b. Species and grade of beams and decking
 - c. Beam type, size, and spacing
 - d. Span length and bracing locations
 - e. Deck type and size
 - f. Moisture content of beams and decking
 - g. Section loss of beams and decking

5. Load Rating

The Forest Service uses two main programs for load rating timber bridges: Timber Bridge Analysis and Rating Program (TBAR) [6] and Mathcad. TBAR (Figure 3) was developed for the Forest Service by HDR Engineering, Inc. It is a standalone program for load rating various types of timber bridges.

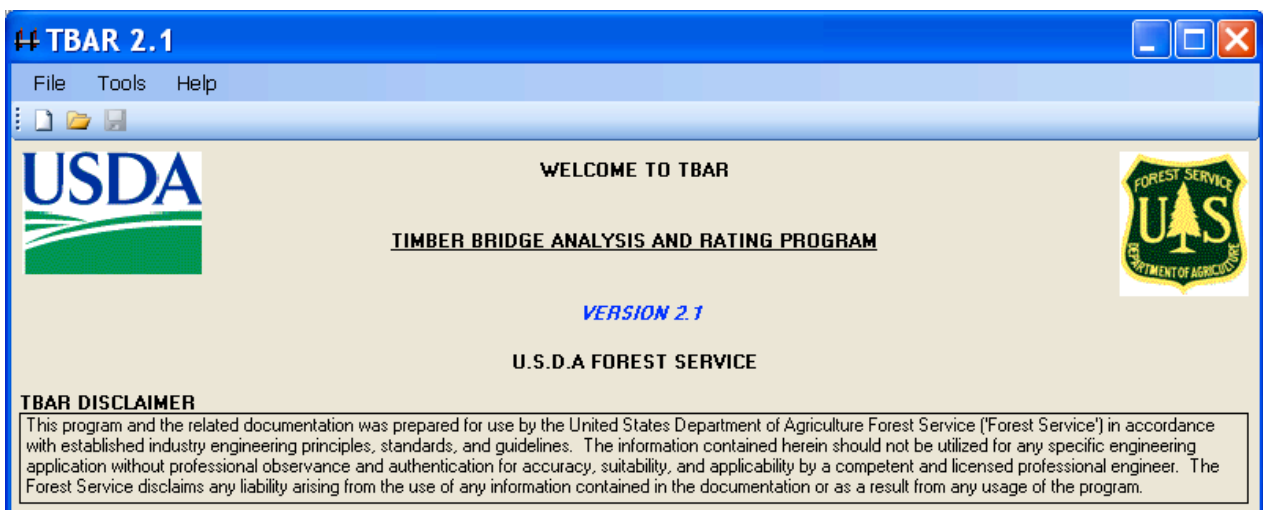


Fig. 3 Start-up screen for Timber Bridge Analysis and Rating program

The following bridge and deck types can be load rated in TBAR using load resistance factor design (LRFD) or allowable stress design (ASD):

Beam Type Bridges:

- Solid sawn
- Glued-laminated
- Native Log
- Steel girders with timber decks

Slab Type Bridges:

- Longitudinal glued-laminated deck
- Longitudinal nail-laminated deck
- Longitudinal spike- (or dowel-) laminated deck

Bridge deck types:

- Solid sawn planks
- Non-interconnected and interconnected glued-laminated panels
- Nail-laminated decks

TBAR works well for typical bridges that are in fair or good condition. For timber bridges that are in poor condition or were not constructed using a standard design, the Forest Service has developed numerous Mathcad worksheets (Figure 4) for these special circumstances.

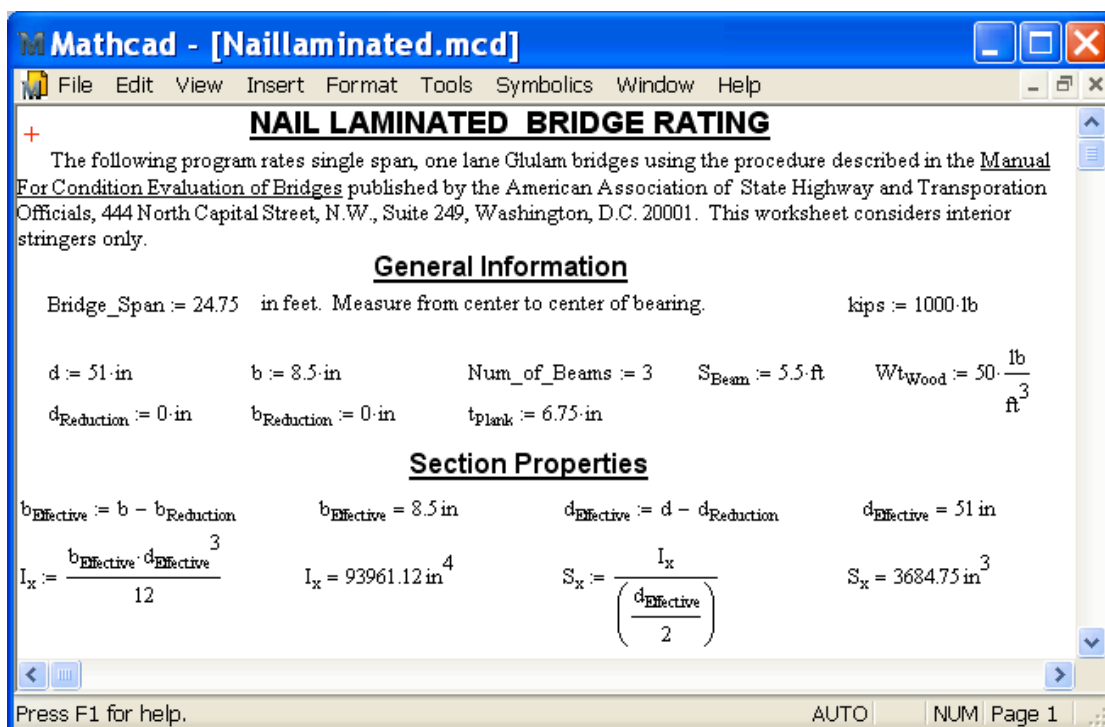


Fig. 4 Typical Mathcad worksheet for load rating

6. Conclusion

The Forest Service has been building timber bridges for more than 100 hundred years with most existing bridges being built 30 or more years ago. Due to the age of these structures, a good inspection and load rating process is required to maintain these structures and to ensure that they are safe for general public use. The Forest Service has accomplished this task by using the moisture meter, stress wave tester, and resistograph drill for in-depth inspections and Timber Bridge Analysis and Rating (TBAR) and Mathcad worksheets for load ratings.

7. References

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