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# Pennsylvania Hardwood Timber Bridges: Field Performance after 10 Years

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## Abstract

Several hardwood demonstration timber bridges were built by the Pennsylvania Department of Transportation in the early nineteen nineties. These bridge superstructures are of the recently developed stress-laminated deck design-type using Red Oak lumber laminations that were pressure-treated with creosote preservatives. This paper will describe the data acquisition system used to monitor seven of these bridge superstructures between 1997 and 2002 and to characterize any effects of cold (winter) temperatures on their structural performance. Prestressing bar forces, a key performance parameter for stress-laminated bridges, have stabilized after more than ten years in-service and remained above minimum design threshold levels at six of the seven bridges.

## Introduction

The technique of stress-laminating timber bridge superstructures was initially developed during the mid-1970s to rehabilitate longitudinally nail-laminated timber bridge decks in Ontario, Canada. Initially, the stress-laminated system was externally retrofitted to longitudinally nail-laminated timber slab decks by attaching high-strength steel bars in a transverse orientation (top and bottom of deck) at intervals along the bridge length and anchoring them with steel channels and plates to maintain compressive forces. Subsequent load testing revealed the superior load distribution characteristics of the stress-laminating technology. This led to the adoption of stress-laminated methods for the design and construction of new timber bridges, with the first U.S. demonstration structures being built in Pennsylvania and Colorado during 1987.

In 1989, the Pennsylvania Department of Transportation (PennDOT) established the Pennsylvania Demonstration Hardwood Timber Bridge program to increase the utilization of timber as a bridge material. This program paralleled the National Wood In Transportation efforts by the U.S. Forest Service and it designated 18 timber bridges to be built throughout Pennsylvania using locally available and underutilized hardwood species, including Red Oak, Red Maple, Beech, and Yellow Poplar.

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PennDOT officials desired additional field performance data on their new stress-laminated bridges to ensure they are performing at a satisfactory level. In 1997, after most bridges had been in-service for approximately 5 years, PennDOT contacted the USDA Forest Service, Forest Products Laboratory (FPL) for technical assistance with bridge field monitoring activities. A 5-year field monitoring study plan was mutually developed by FPL and PennDOT to evaluate the long-term structural performance of seven hardwood stress-laminated bridges in Pennsylvania. The project scope included data collection and analysis related to deck moisture content, stressing bar force, static load test behavior, and general bridge condition. In addition, thermal and relative humidity conditions in the vicinity of the bridge were monitored. Data collection techniques were previously developed as part of a National Bridge Monitoring Program conducted by FPL to gather performance data for stress-laminated timber bridges **(Ritter and others 1991).**

This paper will describe the data acquisition system employed to monitor the key performance parameters for stress-laminated bridges and will summarize bridge performance after 10 years in-service. A more comprehensive report of field data results collected between 1997 and 2002 is available **(Wacker and Others 2004).**

## Bridge Descriptions

**Table 1** provides summary information for the seven stress-laminated hardwood timber bridges included in this bridge monitoring study. They include both single- and double-lane bridges located in six different counties throughout Pennsylvania. The single span bridges range from 23–46 ft long and from 20-32 ft wide. Six of the bridges are constructed with creosote-treated Red Oak lumber, while one uses the Beech–Birch–Hickory lumber species group. Five bridges are located along unpaved, rural roadways with less than 50 vehicles per day. The Dutch Hill Road and Millcross Road Bridges are located along paved, suburban roadways with over 500 vehicles per day.

**Table 1 – Summary of seven hardwood timber bridges evaluated in this study.**

| | | Superstructure Dimensions | | | |
|---|---|---|---|---|---|
| Bridge Name | Bridge Location | Length (ft) | Width (ft) | Depth (In.) | Wood Species |
| Dutch Hill Road | City of Titusville | 24 | 32 | 15 | Red oak |
| Brookston Road | Howe Township | 35 | 20 | 14 | Red oak |
| Laurel Run | Jackson Township | 40 | 24 | 16 | Red oak |
| Jacobs | Todd Township | 46 | 26 | 16 | Red oak |
| Millcross Road | East Lampeter Twp | 23 | 30 | 15 | Red oak |
| Dogwood Lane | West Brunswick Twp | 36 | 26 | 15 | Red oak |
| Birch Creek | Cherry Township | 25 | 26 | 16 | Beech / Birch /Hickory |

All of the bridges were designed to carry AASHTO HS25-44 live loading in accordance with the American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges **(AASHTO 1989).** In addition,

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predicted deflections under design live load conditions were limited to L/500. Stress-laminated deck features were designed in accordance with U.S. Forest Service recommendations **(Ritter 1992)** and the AASHTO Guide Specifications **(AASHTO 1991).** All wood bridge components were pressure-treated with creosote preservatives in accordance with AWPA C1/C13 **(AWPA 2000).**

## Data Acquisition System

A remote data acquisition system (DAS) was installed at each bridge site to monitor key performance parameters for stress-laminated decks that included temperatures, relative humidity, and stress-laminating compression forces. The DAS consisted of the datalogger and several sensors installed on the bridges as depicted in **Figure 1.**

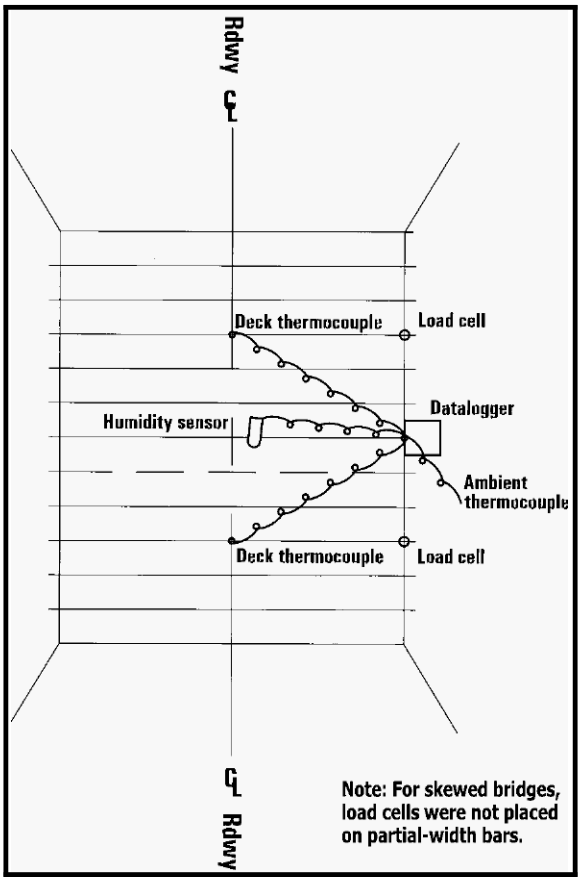


**Figure 1—Plan-view drawing showing typical data-acquisition system setup and sensor locations.**

The datalogger was typically installed at the outer face of the wood bridge rail near the bridge midspan. Laboratory-calibrated load cells were installed at two prestressing bar locations. Deck thermocouple sensors were installed in bored (and plugged) holes at locations on the deck underside corresponding with prestressing bars with the load cells.

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The relative humidity sensor was suspended from deck underside to shelter from direct sunlight exposure.

A Campbell-Scientific™ CR-10X datalogger **(Figure 2)** was attached to each bridge and powered by 12-volt alkaline battery power supply. Field data was collected at 2-hour intervals throughout the monitoring period. Data was periodically downloaded from solid-state storage modules with a notebook computer at the bridge site.

**Figure 2 – Campbell-Scientific™ CR10X datalogger, mounted inside a weatherproof fiberglass enclosure, used to automatically collect and store data.**

**Figure 3 – Various sensors used in conjunction with datalogger at field bridges.**

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A summary of the sensors used with the DAS is provided in **Figure 3.** Air temperature and relative humidity data was collected with probe sensors manufactured by Vaisala™ to a precision of ±3 percent. Wood temperature data was collected with copper-constantan thermocouple wire manufactured by Omega Engineering, Inc. The accuracy of temperature data was periodically verified by independent measurements using hand-held devices. Stress-laminating compressive force data was collected with hollow-core, steel load cells custom-manufactured by FPL personnel to a precision of ±300 lbs. The accuracy of the compressive force data was independently verified by hydraulic cylinder gauge pressure measurements on several occasions.

## Field Monitoring Results

Typical 5-year field data plots from the Dutch Hill Road Bridge are presented in **Figure 4.** These results show the typical data pattern for most bridges. Seasonal temperature variations in the wood bridge deck ranged from 20°F to 80°F with relatively small "temperature-induced' bar force losses during winter seasons. Bar forces were generally stable throughout the monitoring period with a gradual decreasing trend. The bar forces dropped below the threshold of 40 lb/in$^2$ interlaminar stress at the Millcross Road Bridge and required re-tensioning of the stressing bars to the full design level.

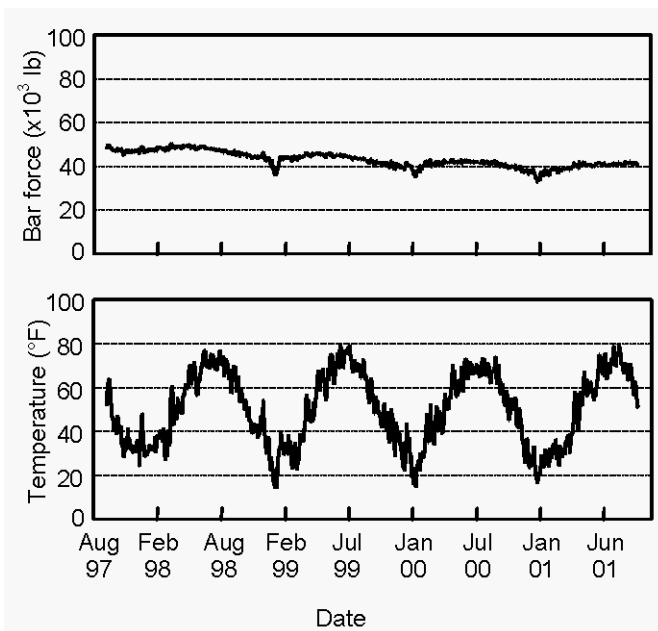


**Figure 4 – Typical bar force and wood bridge deck temperature data collected over 4 years at the Dutch Hill Road Bridge.**

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Typical winter-season data plots from the Laurel Run Bridge are presented in **Figure 5.** Temperature-induced bar force losses were observed during those periods when the bridge deck temperatures dropped below 32°F. These temperature-induced bar force losses were generally less than 10 percent and are related to the elevated (greater than 20 percent) moisture content of the bridge deck lumber laminations. After the cold weather season, the prestressing bar forces returned to their pre-winter levels, as observed in laboratory bridge studies **(Wacker 2003).** Even though bridges experienced significant cold weather periods, their severity and duration was not sufficient to significantly affect the prestressing bar forces. Relative humidity field data proved unreliable and new sensors are being considered for future field projects.

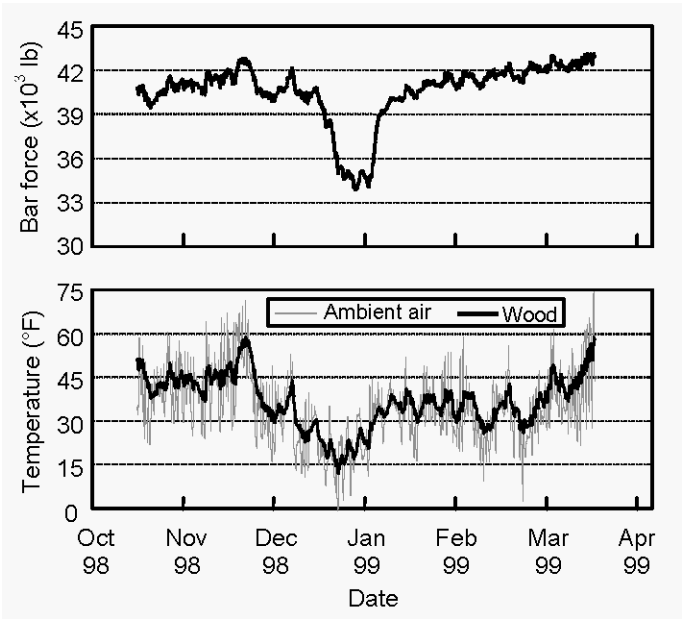


**Figure 5 – Typical bar force and temperature data collected during winter months at the Laurel Run Bridge.**

These results indicate that bar forces measured during the monitoring period remained stable and were sufficient for satisfactory structural performance at all bridges. However, since the bridges remain at elevated moisture content levels, they remain susceptible to significant "thermally-induced' bar force losses during severely cold winter periods.

## Summary

A remote data acquisition system (DAS), which includes a weather-proof datalogger and various sensors, was successfully employed to monitor the long-term structural performance of seven hardwood timber bridges. Prestressing bar force and temperature data were collected with the DAS to characterize the effects of cold (winter) temperatures on stress-laminated deck bridges in-service. Prestressing bar forces, a key performance

parameter for stress-laminated bridges, have stabilized after more than ten years in-service and remained above minimum design threshold levels at six of the seven bridges.

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## References

**AASHTO.** 1989. Standard specifications for highway bridges, 14th ed. Washington, DC: American Association of State Highway and Transportation Officials.

**AASHTO.** 1991. Guide specifications for the design of stress-laminated deck wood bridges. Washington, DC: American Association of State Highway and Transportation Officials.

**AWPA.** 2000. Standards. AWPA C1/C13. Creosote coal tar treatment specifications. Granbury, TX: American Wood Preservers' Association.

**Ritter, M.A.** 1992. Timber bridges: design, construction, inspection, and maintenance EM7700–8. Washington, DC: U.S. Department of Agriculture, Forest Service, Engineering Staff. 944 p.

**Ritter, M.A.; Geske, E.A.; McCutcheon, W.J. [and others].** 1991. Methods for assessing the field performance of stress-laminated timber bridges. In: Marcroft, Julian, comp. Proceedings, 1991 international timber engineering conference; 1991 September 2–5;London, United Kingdom. London, United Kingdom: TRADA: 3: 319-326.

**Wacker, J.P.** 2003. Cold temperature effects on stress-laminated timber bridges—A laboratory study. Res. Pap. FPL–RP–605. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 22 p.

**Wacker, James P.; Calil, Carlito, Jr.; Hislop, Lola E.; Hilbrich Lee, Paula D.; Kainz, James A.** 2004. Long-term performance monitoring of hardwood timber bridges in Pennsylvania Res. Pap. FPL-RP-612. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 56 p.