

## "TIMBER STRINGER ULTIMATE STRENGTH TESTING"

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### Summary

The Association of American Railroads (AAR) research staff (now employees of Transportation Technology Center, Inc., a subsidiary of the AAR), and University of Illinois Urbana-Champaign, conducted static bending tests on various timber stringers as part of the AAR's Timber Bridge Life Extension Program. Ultimate strength tests were conducted in 1995 and 1996 on 100 specimens of Douglas fir and southern pine stringers donated by member railroads Norfolk Southern, Union Pacific, and the former Southern Pacific lines. Current design standards are based on values derived from small (2"x2") clear specimens which may not be applicable to large size timber bridge members. The following observations are based on initial results:

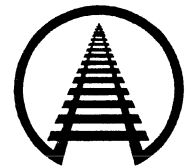
- Average shear stress values at failure were about 270 pounds per square inch (psi) on 75 Douglas fir stringers and 300 psi on 7 southern pine stringers.
- Average bending stress values at failure measured 3500 psi for the Douglas fir and 4000 psi for southern pine stringers.
- Douglas fir stringers displayed considerable reserve strength, even after an estimated 1400 million gross tons (MGT) of accumulated traffic.
- Load positioning affects the ultimate shear and bending stress values. The load position of 3d, as recommended by AREA Chapter 7 for design was used in these tests as it is considered to provide the lowest failure load.
- In addition to shear and tension failures, almost every 12-foot stringer exhibited compression wrinkles in the form of buckling of fibers prior to failure.
- Stringers exhibiting end checks tended to develop shear failures, while those with knotted sections failed in tension and developed fiber slippage.

The main objective of testing was to assess the potential for improving timber rating accuracy through evaluation of shear and bending stress results from Douglas fir and southern pine stringers. Stringer shear and bending stresses govern the rating for many timber bridges. Increasing timber rating could result in longer service life and/or increased load carrying capacity for existing timber bridges. According to a 1995 industry survey, timber bridges accounted for more than 28 percent of the bridge footage in service on Class I railroads in the United States and Canada. However, now they are becoming a predominant part of bridge inventory of the short and regional railroads.

Test results are being shared with the AREA Timber Structures Committee #7 for consideration in the updating of the AREA manual.

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#### Suggested Distribution:

- Maintenance of Way
- Planning & Analysis
- Track Maintenance
- Safety

## INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR) research staff (now employees of Transportation Technology Center, Inc., a subsidiary of AAR) and the University of Illinois, Urbana-Champaign (UIUC) conducted static bending tests on used timber stringers as part of the AAR's Timber Bridge Life Extension program. During 1995 and 1996, ultimate strength tests were conducted on 100 used Douglas fir and southern pine stringers donated by member railroads Norfolk Southern (NS), Union Pacific (UP), and the former Southern Pacific (SP). Current design allowable shear stresses and bending stresses were derived from small (2" x 2") clear specimens; this data may not be applicable to large size timbers. The goal of the AAR/UIUC study is to use laboratory results to improve bridge rating accuracy, which could possibly extend the service life of existing timber bridges and increase the load carrying capacity.

Preliminary analyses show that the Douglas fir stringers still contained considerable residual strength even after an estimated 1,400 million gross tons (MGT) of traffic. Average shear and bending stress values of about 270 psi and 3,500 psi, respectively, were measured at failure. The southern pine stringers had slightly higher values at failure with 300 psi shear stress and 4,000 psi bending stress. The accumulated tonnage on the southern pine specimens is not known; typically they were installed as replacement stringers some time after the Douglas fir stringers were installed.

## TEST PROCEDURES

Each stringer was tested at UIUC in a load frame. The study focused on measuring shear and bending stresses at failure. In addition, maximum load, maximum deflection, and failure mode were recorded.

Two hydraulic actuators were used to apply loads on the top surface of a stringer (8" x 16" nominal size). Steel loading blocks (6" x 12") were placed underneath each actuator. Displacement transducers were used to measure bending deflections and data was recorded with a computer-based data

acquisition system. The stringers were loaded at a rate of 0.4 to 0.5 inch/minute until they reached failure. Load and deflection measurements were recorded for each stringer. Maximum horizontal shear and maximum bending stresses were derived from the data collected.

## LOAD POSITIONING

Different load positions of the actuators were used when the test was initiated in 1995. From the left support, the first actuator was placed at 2.25d, 3.0d, and approximately 3.5d; where d is the nominal depth of the stringer or 16 inches. The second actuator was then placed at L/3 from the first position, where L is the nominal length of the stringer. The load positions were based on AAR's laboratory investigations of static and repeated load testing of Douglas fir and southern pine stringers from the 1960's (Reports ER-70 and ER-76). These previous tests were conducted at 1.5d, 2.25d, and 3d, where 3d was determined to be the worst-case scenario.

After analysis of 1995 data, it was determined that load positioning had an effect on shear stress at failure. Twelve stringers are represented in Exhibit 1, including eight Douglas fir and four southern pine. Four stringers were tested at each load position.

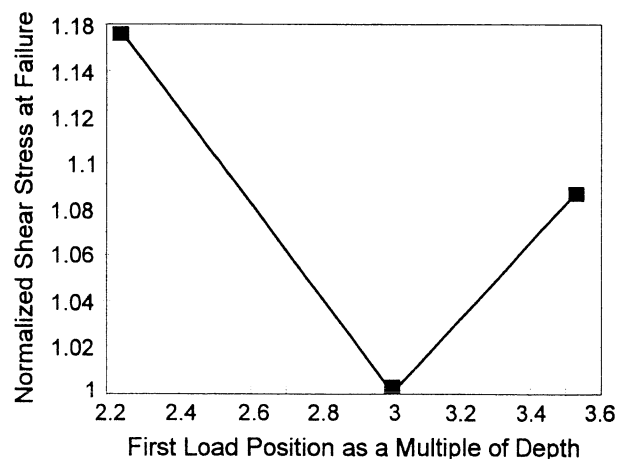


Exhibit 1. Effect of Load Position on Shear Stress at Failure



Based on these results, it was decided to continue testing at 3d (with the second actuator again at L/3), since it proved to be the most critical position for typical railroad timber bridge applications. Exhibit 2 shows loading schemes used for the 12-through 15-foot stringers in the remainder of the study.

**Exhibit 2. Loading Schemes: 12-foot through 15-foot Stringers**

Nominal Length (feet)	Loading Scheme
12	$\begin{array}{c} \text{3d} \quad \text{L/3} \\ \downarrow \quad \downarrow \\ \hline 4'0'' \quad 3'10'' \quad 3'8'' \end{array}$
13	$\begin{array}{c} \downarrow \quad \downarrow \\ \hline 4'0'' \quad 4'2'' \quad 4'4'' \end{array}$
14	$\begin{array}{c} \downarrow \quad \downarrow \\ \hline 4'0'' \quad 4'6'' \quad 5'0'' \end{array}$
15	$\begin{array}{c} \downarrow \quad \downarrow \\ \hline 4'0'' \quad 4'10'' \quad 5'8'' \end{array}$

**STRINGER DESCRIPTION**

Exhibit 3 summarizes the quantities and service conditions of the donated stringers.

**RESULTS AND ANALYSIS**

Exhibit 4 shows results from the Douglas fir and southern pine stringers tested at the 3d load position. The predominant mode of failure in all lengths of stringers was in shear or in a combination of shear and tension.

Exhibit 5 lists the physical properties for the Douglas fir stringers.

**Exhibit 5. Physical Properties for all Douglas Fir Stringers**

Railroad	Rings/Inch	Summer Wood (percent)	Moisture Content (percent)	Density (lbs/ft <sup>3</sup> )
NS	7.4	34.7	21.7	41.3
UP	10.2	31.8	15.4	39.9
SP	13.2	29.3	11.8	35.8

**Exhibit 3. Description of Stringers**

Railroad	Douglas Fir	Southern Pine	Bridge Site	Approximate Accumulated Tonnage on Douglas Fir Stringers
NS	17	7	Louisiana	600 MGT
UP	29	1	Illinois	1000 MGT
SP	44	2	W. Texas	1300-1400 MGT

**Exhibit 4. Test Results at 3d Load Position**

	Douglas Fir		Southern Pine	
	Shear Stress (psi)	Bending Stress (psi)	Shear Stress (psi)	Bending Stress (psi)
Maximum	483	6127	547	6963
Average	272	3466	301	3976
Minimum	109	1273	228	2905
Standard Deviation	88	1146	107	1378
Number of Stringers	75	75	7	7



Other findings are as follows:

The average shear stress values at failure were about 270 pounds per square inch (psi) on 75 Douglas fir stringers and 300 psi on 7 southern pine stringers. The average bending stress values measured at failure were 3,500 psi for the Douglas fir and 4,000 psi for southern pine. At 95 percent exceeding the value of bending stress range between 2,100-2,600 psi and of shear stress range between 120-140 psi. Douglas fir stringers displayed considerable reserve strength, even after an estimated 1,400 million gross tons (MGT) of accumulated traffic. Load positioning affects the ultimate shear and bending stress values. The load position of 3d, as recommended by AREA Chapter 7 for design, was used in these tests as it is considered to provide the lowest failure load. In addition to shear and tension failures, almost every 12-foot stringer exhibited compression wrinkles in the form of buckling of fibers prior to failure. Stringers exhibiting end checks tended to develop shear failures, while those with knotted sections failed in tension and developed fiber slippage.

Tests results are being shared with the AREA Timber Structures Committee for consideration in the updating of AREA's manual.

#### ACKNOWLEDGMENT

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