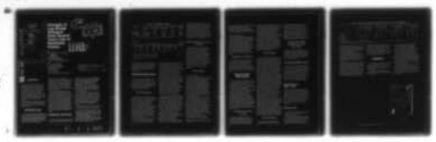
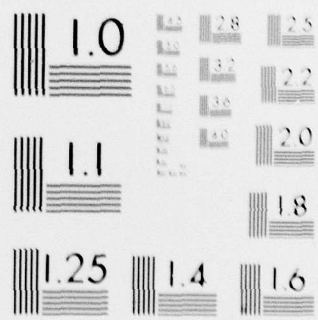
AD-A078 792 FOREST PRODUCTS LAB MADISON WIS F/G 13/13
STRENGTH OF LOG BRIDGE STRINGERS AFTER SEVERAL YEAR'S USE IN SO--ETC(U)
1979 R C MOODY , R L TUOMI , W E ESLYN
UNCLASSIFIED FSRP-FPL-346 NL

1 OF 1
AD
A078792



END
DATE
FILMED
1-80
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

United States Department of Agriculture

9 Forest Service

Forest Products Laboratory

Research Paper FPL 346

11 1979

12 4

6 Strength of Log Bridge Stringers After Several Year's Use in Southeast Alaska[1]

By

10 R. C. MOODY, R. L. TUOMI,
Engineers
W. E. ESLYN,
Plant Pathologist
Forest Products Laboratory[2]

and

F. W. MUCHMORE,
Structural Engineer
Alaska Region
Forest Service,
U.S. Department of Agriculture

14 FSRP-FPL-346

ABSTRACT

Bending tests of 28 untreated log stringers from 12-year-old native timber bridges in southeast Alaska showed significant reductions in strength due to decay. Compared to results on fresh logs, strength reduction was about 25 percent, and could be predicted based on the loss in section modulus due to decay. Log stiffness was not significantly affected.

Results will be helpful to engineers with responsibility of rating the load capacity of bridges having untreated log stringers.

INTRODUCTION

Temporary log stringer bridges constructed of native logs with blast rock surfacing are being extensively used on logging roads throughout southeast Alaska. Meeting the Bridge Inspection and Load Rating requirements directed under the Federal-Aid Highway Act of October 1968 presents a problem—insufficient data have been available to reliably predict the load capacity of this type of bridge. Thus, research was conducted to determine the bending strength of log bridge stringers.[3]

The data developed on bending strength of log bridge stringers was limited to green logs and did not provide any measure of the strength of untreated logs after several years of service. To more accurately assess service life of these temporary log stringer bridges, strength data are needed from bridges which have been in service. Thus, this study was to determine the relative strength and stiffness of stringers after 12 years of service in bridges in southeastern Alaska.

RESEARCH MATERIAL

In the fall of 1975, three log stringer bridges near Thorne Bay on Prince of Wales Island in the Tongass National Forest of southeastern Alaska were scheduled for replacement. These three bridges—Rio Roberts, Rio Beaver, and Thorne River—are described in table 1. Each bridge had carried heavy logging traffic during much of each year from the time they were constructed.

Each bridge consisted of 10 Sitka spruce logs. Eight logs were stringers while the other two, placed on top of the two outside stringers, were called brow logs (fig. 1). During removal and subsequent handling, two logs from the Thorne River Bridge were broken. Thus, 28 logs were available for testing.

The eight stringers from each bridge were numbered from 1 to 8, and the

[1] Conducted in cooperation with the Alaska Region of the USDA, Forest Service, Juneau, Alaska and Louisiana Pacific-Ketchikan Division (formerly Ketchikan Pulp Co.), Ketchikan, Alaska.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Tuomi, R. L., R. W. Wolfe, R. C. Moody, and F. W. Muchmore. 1979. Bending strength of large Alaskan Sitka spruce and western hemlock log bridge stringers. USDA For. Serv. Res. Pap. FPL 341. For. Prod. Lab., Madison, Wis.

Table 1.—Description of bridges

Bridge	Date of installation	Approximate bridge span	Approximate log length	Range of log diameters	
				Tip	Butt
		Ft	Ft	In.	In.
Rio Roberts	Dec. 1964	58-60	66-70	23-33	30-44
Rio Beaver	Sept. 1964	70-72	78-81	26-37	38-49
Thorne River	Late 1963	77-79	[1]85-86	28-39	40-50

[1] Brow logs, which were along the edge of the roadway, were about 100 feet long.

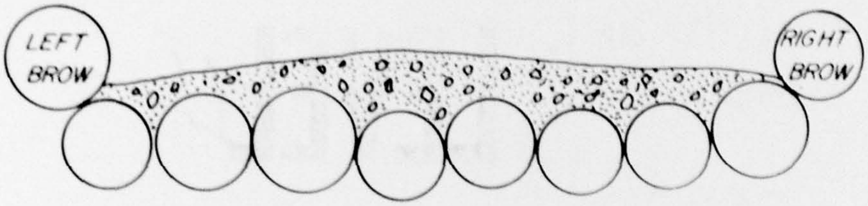


Figure 1.—Cross section of a typical log stringer bridge. Bridge shown consists of 10 logs (8 stringer and 2 brow logs).

upstream and downstream brow logs referred to as BU and BD, respectively. Log identification consisted of the abbreviated bridge name (RR, RB, or TR) and the stringer or brow log designation.

RESEARCH METHODS

The same equipment described in a previous report[3] was used for the stringer evaluations. The structural testing was conducted between June 21 and July 2, 1976, and examination to estimate the extent of decay followed two weeks later.

Test Procedure

The logs, which had been stored in an abandoned rock quarry used as the test site, were all examined prior to test. To the extent possible, knot sizes and areas of decay were recorded. Cables used to hold the stringers together in the bridges had cut several inches into the surfaces of some logs. Also, some logs were damaged by fork lifts during handling. This damage appeared to be most extensive in areas appearing to be partially decayed, i.e., the outer few inches of the diameter.

The circumference at each 10-foot increment, beginning at the log tip, was determined and converted to diameter readings. Nearly all of the bark had either been removed during handling or fell off during service; thus diameter measurements were actually inside bark. The use of inside-bark diameters differs from the previous study of fresh logs which had the bark intact.[3] Surface weathering of the 12-year-old log stringers indicated that most of the bark had been off the logs for some time. Therefore, the diameter without the bark would be the value used for rating the in-place capacity of the bridges and is the appropriate dimension to use in calculating the residual unit strength of the logs. No attempt was made at the time of examination to judge the extent of decay—rather it was an effort to measure the outside diameter.

A test span approximately equal to the bridge span was selected for each of the three bridges and the logs were placed on the test equipment with at least 3 feet of overhang on the butt end. Supports were so positioned that the load could be applied near midlength. For each log tested, the exact location of the supports and load point were referenced to the tip end.

Logs were tested following the general procedure previously described.[3] The load was applied in increments to produce about 0.1-foot increments in log deflection. Following each increment of deflection, the loading was stopped for up to 10 seconds to determine the load by a strain indicator. Then the load was increased to deflect the log an additional 0.1 foot, which required up to another 10 seconds. During loading, the strain indicator was adjusted to closely follow the load so that when logs failed, the maximum load could be determined. Using this procedure, most logs could be tested to failure in 1½ to 5 minutes.

Determination of Extent of Decay

After the log failed, the fractures were examined and characteristics believed to contribute to rupture noted. Within the next 2 weeks, each log was sawn at midlength and the extent of decay determined in this area. The latter determinations were based upon surface appearance of the log and probings into both the peripheral and cross-sectional faces. Peripheral decay was subtracted from the gross area and an equivalent cylindrical sound section was estimated.

Calculations

Modulus of Rupture

Two methods were used to calculate the modulus of rupture (MOR). For both, the dead weight of the test equipment (1,200 lbs) was added to the load determined from the strain indicator. Also, the weight of the log was used to determine the dead load stress by assuming 40 pounds per cubic foot for sound wood and 20 pounds per cubic foot for the decayed portion. These dead load stresses were added to the applied stresses to derive an MOR value.

An MOR value, assuming a tapered section, was calculated according to equations developed for a previous report.[3] The taper and diameter at the *load point used were based on a* regression analysis of the diameters at 10-foot intervals.[4] This modulus of rupture based on full log diameter was referred to as MOR_1. Another value, referred to as MOR_2, was calculated based on a diameter that was reduced by the amount of decay.

The location of the most highly stressed section in center-loaded

[4] For logs containing obvious butt swell, the diameter at the butt was not included in the regression analysis.

tapered members is not necessarily at midspan. The degree of taper determines the point of maximum stress. However, in all these tests, the maximum stress was at the load point.

Modulus of Elasticity

As with MOR, two methods were used to calculate modulus of elasticity values (MOE). MOE_1 and MOE_2 were both calculated assuming a tapered section and using procedures previously developed.[3] The difference was that MOE_1 assumed diameters determined from a linear regression of the diameter measured at 10-foot intervals while MOE_2 assumed a diameter reduced by the amount of decay.

Analysis of Variance

To determine if the results of log tests from the three bridges were different and, if they differed from previous tests of fresh logs, an analysis of variance was conducted. Differences were tested to determine if they were significant at the 95 percent level.

RESULTS AND DISCUSSION

The logs ranged in diameter at the tip from about 24 to 40 inches. All but two had taper of between 0.1 and 0.2 inches per foot, with one 8 percent below the extreme values of this range and the other 2 percent above.

Results of the tests are summarized in table 2. There was no significant difference between strength or stiffness results from the three different bridges; thus, results were combined for subsequent comparisons. Neglecting the reduced section due to decay, the modulus of rupture (MOR_1) for the 28 logs averaged 3,480 lb/in.^{2} and the modulus of elasticity (MOE_1) averaged 1.28 million lb/in.^{2}. The lowest strength log had a MOR of 2,100 lb/in.^{2}.

Logs Broken Prior To Test

There is a question of how to properly consider the two logs from the Thorne River Bridge that broke during removal and subsequent handling. It was difficult to judge whether they were damaged during service and, if not, the level of loading they experienced during handling. The one that was available for visual inspection had extensive decay pockets near midlength. If not previously broken, stresses induced during removal and handling may have approached or exceeded those in several of the tested logs. Without this information, they could not be included in the analysis. However, the fact that they broke during handling suggests that they were likely low in strength and implies that the practical limit for their use may have been reached in the 12 years.

Log Failures

Twenty-two of the 28 logs failed by fracturing on the tension side. Six others did not completely fail. Most of the 22 tension failures occurred near midlength but two were within 10 feet of the tip support. It was necessary to stop the tests on another five logs before complete rupture because the deflection limit of the equipment had been reached. For all of these, the load did not appear to be increasing and it was believed that the maximum load had been reached. The remaining log, RB05, was loaded to over 140,000 pounds before loading was stopped because this significantly exceeded the design load of the test equipment.

The curves of load versus deflection plotted from the data for most of the logs were linear to or beyond 50 percent of the ultimate load. Several curves appeared nearly linear to failure, but most departed from linear behavior by 70 to 80 percent of the ultimate load. The one log that showed no indication of failure had departed from linear load-versus-deflection behavior, and the load likely would not have increased much above the level reached. The resulting MOR_1 of 4,090 lb/in.^{2} was one of the higher values based on the full diameter. When based on net section, its MOR_2 was near the overall average. Although the failure load may have been 5 to 10 percent higher, the actual calculated stress resulting from the over 140,000 pound load was used in the analysis.

Decay Effects

Examination of the failed logs revealed various amounts of decay. The estimated effective reduction in diameter varied between 2 and 8 inches with most logs reduced 4 to 6 inches. Based on the net diameter of sound wood, the modulus of rupture (MOR_2) averaged 4,820 lb/in.^{2} or significantly (39 pct) higher than that based on the full diameter. On this same basis, the modulus of elasticity (MOE_2) averaged 2.09 million lb/in.^{2}.

Comparison With Results Of Fresh Log Tests

Results of previous tests[3] on 25 Sitka spruce logs from southeast (SE) Alaska are included in table 2. Eleven of these 25 were from Prince of Wales Island and their average results are also listed separately.

Full Diameter (MOR_1, MOE_1)

The logs from the three bridges had significantly lower modulus of rupture values than found previously—averaging 23 percent less than all 25 logs from southeast Alaska and 25 percent less than the 11 logs from Prince of Wales Island. The average modulus of elasticity of 28 logs was not significantly different from that of either grouping of previously tested logs.

Sound Diameter (MOR_2, MOE_2)

When strength calculations were based on sound diameters, there was no significant difference between the average modulus of rupture of the 28 logs from the three bridges and the previous results. However, the modulus of the elasticity calculated using this approach resulted in values significantly higher than found for fresh logs.

Notable Points

The comparison with previous tests of Sitka spruce indicated two significant findings:

(1) Log stringer strength is significantly reduced by decay after 12 years in a bridge in southeast Alaska, and the amount of the loss can be accurately determined by measuring the

Table 2.—Strength properties of Sitka spruce log stringers from southeast Alaska[1]

Source	Number of logs	Modulus of rupture						Modulus of elasticity					
		Full diameter (MOR_1)			Sound section (MOR_2)			Full diameter (MOE_1)			Sound section (MOE_2)		
		Mean	Standard deviation	Coefficient of variation	Mean	Standard deviation	Coefficient of variation	Mean	Standard deviation	Coefficient of variation	Mean	Standard deviation	Coefficient of variation
		Lb/in.²	Lb/in.²	Pct	Lb/in.²	Lb/in.²	Pct	Lb/in.² (Million)	Lb/in.² (Million)	Pct	Lb/in.² (Million)	Lb/in.² (Million)	Pct
Logs from 12-year old bridge:													
Rio Roberts	10	3,330	705	21	4,800	762	16	1.22	0.228	19	2.15	0.775	36
Rio Beaver	10	3,380	662	20	4,680	560	12	1.27	.241	19	2.06	.540	26
Thorne River	8	3,780	612	16	5,010	416	8	1.36	.169	12	2.05	.375	18
3 bridges combined	28	3,480	669	19	4,820	600	12	1.28	.217	17	2.09	.580	28
Fresh logs:													
Prince of Wales Island only	11	4,630	1,053	23	—	—	—	1.42	.399	28	—	—	—
Southeast Alaska	25	4,530	797	18	—	—	—	1.23	.344	28	—	—	—

[1] Values calculated assuming log taper determined from diameters at 10-foot intervals.

reduction in the diameter and calculating the reduced section modulus.

(2) Log stiffness is not significantly reduced by the presence of decay under similar conditions.

The inconsistent effect of decay on strength and stiffness might be explained in that strength is controlled by conditions at specific sections, while stiffness is a function of the entire log.

The actual rate of decay is obviously a function of the geographic environment. The bridges on Prince of Wales Island were located in an area of substantial rainfall, 160 to 180 inches per year. This, coupled with the rock wearing surface, probably kept the logs at an extremely high moisture content throughout their service life. Bridges of this design in a different location would undoubtedly have a different rate of deterioration. However, this study suggests that, if a good estimate of the decayed zone can be made, the residual strength can be accurately determined.

SUMMARY

Tests of 28 Sitka spruce logs following over 12 years' service in log stringer bridges on Prince of Wales Island in southeastern Alaska, indicate that:

1. Bending strength was significantly lower than would be estimated for fresh logs.
2. Log stiffness was about the same as estimated for fresh logs.
3. Decay in the 24- to 50-inch-diameter logs reduced the effective diameter between 2 and 8 inches.

A comparison of results with 25 previously tested Sitka spruce logs from the same area suggested that the amount of the bending strength reduction after 12 years was 25 percent, and that this reduction could be accurately predicted by the actual loss in section modulus due to decay.

Considering the amount of strength reduction and the fact that two additional logs broke during handling and could not be tested, it appears that 12 years may be a practical limit for Sitka spruce log stringers in southeast Alaska.

2.0-8-79

☆ U.S. GOVERNMENT PRINTING OFFICE 1979-650-028/14