A NOTE ON LOAD DURATION OF DOUGLAS-FIR 2 BY 4S UNDER REPEATED LOADS

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ABSTRACT

Douglas-fir specimens matched to specimens previously tested under sustained constant bending loads were subjected to two different repeated load cycle tests to evaluate the effect of repeated bending loads on load duration of lumber. There was no clear evidence that repeated loading gave different results than sustained constant loading.

Keywords: Repeated loads, sustained constant loads, bending, static strength, time, Douglas-fir, lumber, stress level.

INTRODUCTION

In the typical duration of load experiment with wood (Gerhards 1987), a constant load is applied continuously until the wood member fails. Real wood structures seldom see continuous constant loads, except at very low levels, such as dead loads. Real loads are of a more or less random, repetitive nature. The purpose of this study was to evaluate the effect of repeated loads on load duration of Douglas-fir 2 by 4 beams. The results for repeated bending loads considered in this report only qualitatively simulate real loads and are of slow cycle, rather than the fast cycle used in fatigue testing. The temperature rise caused by fast cyclic fatigue would not occur in slow repeated loading.

Slow cycle repeated loads (repeated 1 week load on, 1 week load off) have been evaluated only on small, clear wood beams (Youngs and Hilbrand 1963). The results for clear wood indicate that for the same load the accumulated time to failure is the same as time to failure for continuous loading.

EXPERIMENTAL

The Douglas-fir 2 by 4s used in this study were of Select Structural quality matched to similar specimens used in a study of sustained constant loads. Matching was done so that each test group of 25 specimens had essentially the same distributions of modulus of elasticity and bending strength ratio (Gerhards 1987). Environmental conditions, test equipment, and test geometry used in the sustained loading study were also used in making the repeated load tests. All tests were done in bending.

Two different repeated load cycles were used in this study (Fig. 1). There were 12 cycles in the first one, each cycle consisting of 666 lb[1] for 6 days followed by 839 lb for 8 days, with the exception that in the first cycle the 666-lb load was on for 7 days. There were 9 cycles in the second one, each cycle consisting of 7

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[1] One pound of bending load = 5.13 psi bending stress.

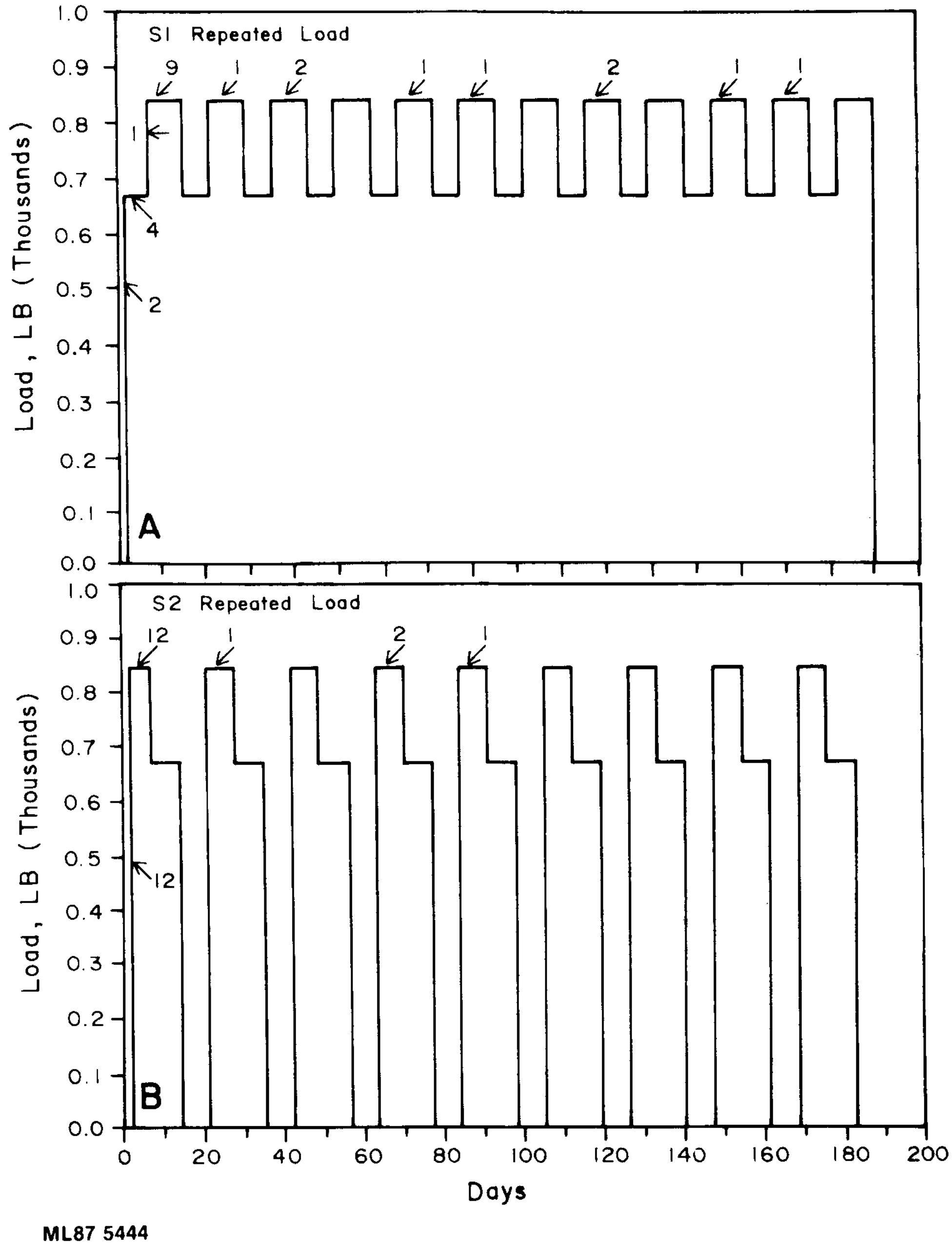

FIG. 1. Repeated load tests. (A) First test cycles. (B) Second test cycles. Numbers in graphs indicate number of failures. (ML87 5444)

days at 838 lb, 7 days at 666 lb, and 7 days at no load. At the end of the repeated load tests, surviving specimens were tested for residual bending strength. All changes in load, including tests of survivors, were at the approximate rate of 5 lb per second, the standard testing rate. Two groups of specimens were tested at each repeated load cycle type, making 50 specimens per type. Constant moisture contents of the test specimens had a 9.6% average and a 0.41% standard deviation. The two load levels of the repeated loads were within 2 lb of two of the four sustained load levels applied on Select Structural specimens in the previous experiment (Gerhards 1987), allowing for comparison of time-to-failure results for those two levels. The 666-lb and 838/839-lb loads represent the approximate fifth and fifteenth percentiles, respectively, of the static strength distribution of the "population" from which the specimens were taken. The static strength distribution was characterized by the lognormal (natural log)

$$\ln ML = 7.123296 + 0.368201R \quad (1)$$

where ML is static strength and R is normal score, a statistic related to distribution percentile (Gerhards 1987). Equation (1) was used to predict the static strengths of the test specimens. Stress level for each specimen was then calculated as the failure load divided by the estimated static strength. Stress level, a normalization of load level, allows direct comparison of time to failure data for different constant load levels.

RESULTS

The number of failures that occurred during the various loading phases are shown in Fig. 1. Additionally, there were 25 survivors from the first repeated load test and 22 from the second. Cumulative times on the constant load at failure are plotted in Fig. 2 as a function of stress level along with the 838-lb sustained loading data and the regression line that was fit to data from the four different sustained load levels from the previous report for comparison (Gerhards 1987). Note that cumulative times in Fig. 2 do not include times of intervening lower or zero loads.

Two points can be made about the repeated load data. First, the "sample" strength distributions for the two sets of 50 specimens used in the repeated load tests appear to represent extremes from the "population" strength distribution. Second, as a consequence of the first point, there is no clear evidence that slow repeated load cycles affect a different cumulative time to failure than a continuously applied load of the same magnitude as the higher repeated load.

My claim about extremes in "sample" static strength distribution is partly objective and partly subjective. It is my contention that the "sample" distribution tended to be high for the first repeated load test and low for the second. On the basis of the "population" distribution, I would expect two or three failures in loading to the fifth strength percentile and seven or eight failures in loading to the fifteenth strength percentile. For the first repeated load test, the number of specimens that failed on first uploading to 666 lb (2), during the first 666-lb sustained level (4) and uploading to 839 lb (1) were very close to expectation; however, the times to failure for the four 666-lb constant load failures were much longer than data from the previous study on sustained loading, suggesting subjectively that those four specimens probably had higher strengths than expected. Moreover, seven of the nine specimens that failed at the first 839-lb duration, and the nine specimens that failed during subsequent cycles at the 839-lb load, had much longer times to failure than comparable specimens from the sustained load study (Fig. 2), again suggesting subjectively that the specimens that failed at

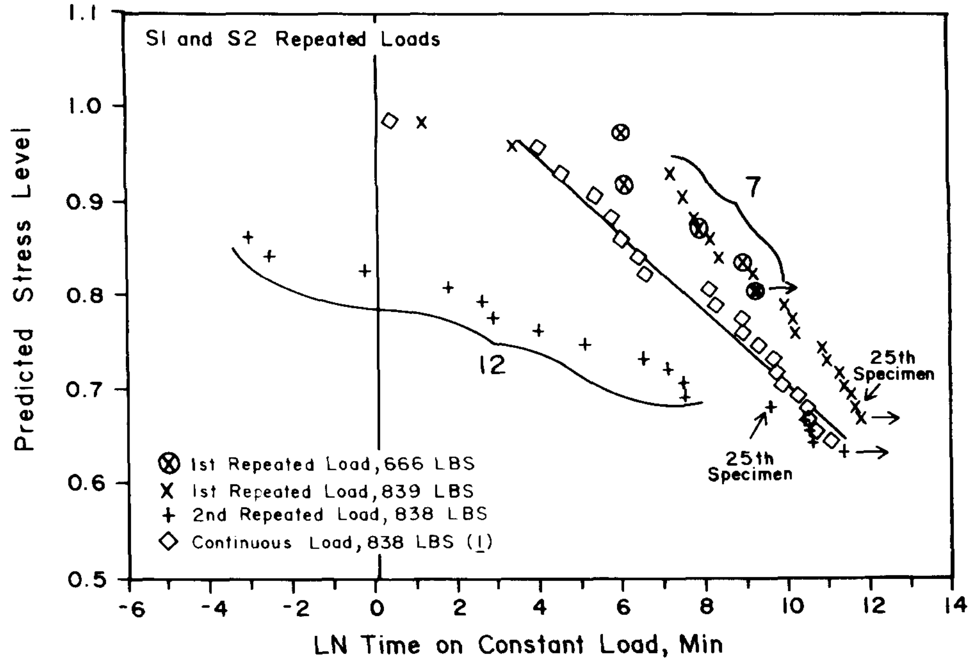

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FIG. 2. Stress level—natural logarithm of cumulative times on load causing failure data from repeated load tests. Sustained loading data and regression line are from Gerhards (1987). Arrows indicate incomplete testing times. (ML87 5443)

the 839-lb level had static strengths higher than expected. Furthermore, the residual strengths of the 25 survivors tended to be about 2 to 5% higher than expected.

In the second repeated load test, 12 specimens failed on uploading to 838 lb versus an expected 7 or 8. Most of the 12 uploading failures had real static strengths below predicted. In fact, the strongest of those 12 failures was 12% weaker than predicted. Additional objective evidence for a weak "sample" static strength distribution exists in the residual strengths of the 22 survivors. Most of the 22 had strengths of 2 to 12% less than predicted. Moreover, the 12 specimens that failed during the first 838-lb phase of the first cycle had sustained times to failure much lower than comparable data from the previous study (Fig. 2), suggesting subjectively that static strengths of those specimens had substantially lower strengths than expected.

Because of the extremes in apparent sample strengths, there were few specimens that actually represent repeated load failures: nine specimens in the first repeated load test and four in the second repeated load test. The 25th specimen to fail in each sample of 50 specimens is highlighted in Fig. 2. While the 25th specimen in the first repeated load test had substantially longer cumulative time under load than the equal-magnitude sustained load, the cumulative times for the 25th and, in particular, the 26th through the 28th, and the survival cumulative time for the 29th specimens in the second repeated load test lie relatively close to the sustained load data. Thus, there is little if any positive evidence that the cumulative time on the repeated load that causes failure is affected by the time at lower or zero load.

CONCLUSION

There is no clear evidence that the cumulative time of repeated loads that cause failure differs from the time to failure caused by an equal-magnitude sustained load.

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