EFFECT OF A SINGLE REVERSAL OF STRESS ON THE STATIC AND IMPACT BENDING STRENGTH OF SITKA SPRUCE AND DOUGLAS-FIR

~~Information Reviewed and Reaffirmed~~

~~October 1955~~

INFORMATION REVIEWED
AND REAFFIRMED
1962

**This Report is One of a Series
Issued in Cooperation with the
ARMY-NAVY-CIVIL COMMITTEE
on
AIRCRAFT DESIGN CRITERIA
Under the Supervision of the
AERONAUTICAL BOARD**

No. 1325

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison 5, Wisconsin
In Cooperation with the University of Wisconsin

EFFECT OF A SINGLE REVERSAL OF STRESS ON THE STATIC AND IMPACT BENDING STRENGTH OF SITKA SPRUCE AND DOUGLAS-FIR[1,2]

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Summary

Specimens, 1 by 1 by 16 inches and 3/4 by 3/4 by 12-1/2 inches, of seasoned Douglas-fir and Sitka spruce were loaded in bending to stress values ranging from 85 to 100 percent of the average modulus of rupture of control specimens from the same planks. Following this the 1- by 1-inch specimens were broken in static bending, and the 3/4- by 3/4-inch specimens in a toughness machine; in each instance the bending was in the reverse direction. Individual values of modulus of rupture and values of toughness obtained in this manner were compared to average values for specimens that were taken from the same planks but were not previously stressed. The modulus of elasticity in bending was measured during the prestressing and was again measured on the same specimens during loading to failure in the reverse direction.

The modulus of rupture showed a reduction of 10 percent for Sitka spruce and 2 percent for Douglas-fir, when specimens stressed in bending at 85 to 100 percent of the ultimate strength, as established by control specimens, were reversed and tested to failure by stressing in the opposite direction. The corresponding average decrease in modulus of elasticity was 20 percent for Sitka spruce and 4 percent for Douglas-fir. In toughness, the average reduction was 22 percent for Sitka spruce and 33 percent for Douglas-fir. The effect of prestressing by bending is more severe in toughness than in static bending. The indications are that some loss in toughness results from prestressing in bending to a value considerably less than 85 percent of the modulus of rupture. In general,

[1]Original report published in 1943.

[2]This is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft. Results here reported are preliminary and may be revised as additional data become available.

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

the tests were not extensive enough to establish definite relationships between intensity of prestressing and reversed static strength for the properties studied, but the results, nevertheless, indicate a substantial strength in the reversed direction even when marked compression failures are present from initial prestressing far above the proportional limit.

Introduction

This report is concerned with part of the program of tests in progress at the Forest Products Laboratory to determine the effect of reversed and repeated stress on the strength properties of wood and plywood. It is desirable to know, for purposes of design, the stress to which a material may be subjected an infinite number of times without failure, the effect of only a few repetitions of stress on the ultimate strength properties, and the effect of a single reversal of stress.

The purpose of this report is to present the results of tests in which an initial loading of bending specimens of Sitka spruce and Douglas-fir to within a few percent of the ultimate bending strength was followed by bending and toughness tests with stress in the opposite direction.

Material Tested

The specimens were cut from air-dried Sitka spruce and Douglas-fir conditioned at 75° F. and 65 percent relative humidity. The Sitka spruce specimens were cut from two planks having specific gravities of 0.375 and 0.368 based on the weight when oven dry and the volume at test. The Douglas-fir specimens were also cut from two planks of average specific gravities of 0.524 and 0.520. The first plank of each species was cut into specimens having finished nominal dimensions of 1 by 1 by 16 inches, with the grain parallel to the length and the annual rings approximately parallel to one face. The specimens from each of these planks were divided into two equal groups; the first group for the determination of control values from static bending tests, and the second group for tests under reversed stress.

The second plank of each species was cut into specimens having finished nominal dimensions of 0.75 by 0.75 by 12.5 inches, with the grain and annual rings oriented as previously mentioned. Specimens were divided into three groups; the first group for the determination of the control static bending strength, the second for the determination of the control toughness value, and the third for the reversed stress-impact tests.

Methods of Test

Control Bending Tests

The static bending tests, for the determination of average modulus of rupture values of specimens of the control groups, were made in a 1,000-pound capacity mechanical-testing machine using rates of descent of the loading head to produce the standard rate of fiber strain of 0.0015 inch per inch per minute. The specimens were simply supported 1 inch from each end and loaded at the center. The span-depth ratio was 14 to 1 for both the 1-inch and 0.75-inch cross-section specimens. The specimens were placed in the machine so as to be loaded on a tangential face. Deflections were recorded for equal increments of load for the determination of the modulus of elasticity.

Control Toughness Tests

The toughness tests, to establish values for specimens from one Sitka spruce and one Douglas-fir plank, were made in the Forest Products Laboratory toughness testing machine as described in Mimeograph No. 1308. This machine is of the pendulum type. Its operation permits only the energy absorbed in breaking the specimen to be determined. Results are stated in terms of the number of inch-pounds of work or energy absorbed by the specimen.

Reversed Stress Tests

The tests to determine the effect of one reversal of stress on the static bending strength of Sitka spruce and Douglas-fir consisted of loading the specimens as simple beams to an initial predetermined stress above the proportional limit, followed by final loading to failure with the specimen turned as to be stressed in the opposite direction; that is, the face of the specimen subjected to compression in the initial test was subjected to tension during the final test.

The rate of descent of the loading head during the initial stressing corresponded to a rate of fiber strain of 0.0053 inch per inch per minute which caused the predetermined load to be reached in approximately 2 minutes. This rate of loading was used, as the 2-minute loading time approximates the dead-weight strength tests of aircraft assemblies. The rate of fiber strain during the final test was 0.0015 inch per inch per minute as in the control tests.

The specimens used for the determination of the effect of one reversal of stress on the toughness values of Sitka spruce and Douglas-fir were subjected to initial loading in bending as described above, immediately following which toughness tests were made with the specimens so oriented that tension was applied to the face that was previously stressed in compression.

Explanation of Charts

Figure 1 is a chart of the results of the reversed stress tests in static bending of Sitka spruce and Douglas-fir. In this figure the initial stress in percent of the average modulus of rupture of the control specimens is plotted against the final or reversed strength also in percent of the same average. Since both percentages are to the same base the pattern of plotted points is for each species exactly the same as if the modulus of rupture in the final test had been plotted against the stress applied in the initial test. The initial stresses applied to the specimens ranged from approximately 91 to 101 percent of the average control modulus of rupture.

Figure 2 is a chart of the results of reversed toughness tests. The initial stress in percent of the average of the static modulus of rupture of the control bending specimens is plotted against the toughness values for reversed specimens expressed as a percentage of the average toughness of control specimens. The initial stresses ranged from approximately 85 to 100 percent of the control modulus of rupture.

Figure 3 shows typical load-deflection curves for the initial and reversed loadings of a Sitka spruce bending specimen.

Discussion of Results

Effect of Prestressing on Bending Strength

In figure 1 points below line A-B represent specimens that failed at the reverse direction in stress values lower than had been previously applied. A large majority (17 out of 23) of the spruce specimens are in this category and this might be taken as definite evidence of damage from the first tests. However, use of a slower rate of deflection in the final tests presumably caused the loads to be less than would have resulted had the same rates been used as in the initial loading. Three percent is the best available estimate of the effect of this change in the rate of deflection. Raising the points by this 3 percent amount would still leave the majority of them below line A-B.

Modulus of rupture values for spruce specimens as determined by test are:

	34 control specimens	24 specimens tested in reversed position
Average...........	10,190	9,225
Maximum...........	11,440	10,380
Minimum...........	9,150	8,000

These figures, and relations shown in figure 1, show that the modulus of rupture of the reversed specimens was reduced somewhat by the initial loading. The difference in averages is approximately 10 percent.

As indicated by figure 1 the majority (11 out of 17) of Douglas-fir specimens developed higher stress under the reversed loading than had been applied initially (allowance for effect of the change in the rate of deflection would increase the stress difference).

Modulus of rupture values for Douglas-fir specimens as determined by test are:

	21 control specimens	17 specimens tested in reversed position
Average..............	14,250	14,038
Maximum..............	15,780	15,400
Minimum..............	13,020	11,840

Effect of Prestressing on Stiffness

Comparisons of average values of modulus of elasticity for Sitka spruce and Douglas-fir, indicate that stressing to some 90 percent of the ultimate strength reduced the modulus of elasticity for reversed flexure by about 20 percent and 5 percent for these species, respectively.

Effect of Prestressing on Toughness

Figure 2 shows a large majority of the plotted points below the horizontal line representing 100 percent. The few points that are above this line no doubt represent specimens that were originally better than the average of the controls. Also some of the greater deficiencies shown are no doubt due in part to original lack of toughness and not solely to the effect of the initial stressing. Within the limits of figure 2 a general tendency for the toughness to decrease with the increase in the value of the initial stress is discernible. The conclusion is that loading to within 15 percent of the ultimate bending strength results in a definite decrease in resistance to shock or impact in the reversed direction. The trend of the data suggests the effect on the toughness may begin at a percentage considerably smaller than 85. For the range of prestressing investigated the average loss of toughness was 22 percent for spruce and 33 percent for fir.

Conclusions

The modulus of rupture showed a reduction of 10 percent for Sitka spruce and 2 percent for Douglas-fir, when specimens stressed in bending to from 85 to 100 percent ultimate were tested to failure by stressing in the opposite direction. The corresponding average decrease in modulus of elasticity was 20 percent for Sitka spruce and 4 percent for Douglas-fir. In toughness, the average reduction was 22 percent for Sitka spruce and 33 percent for Douglas-fir. The effect is more severe in toughness than in the static properties. Indications are that some loss in toughness may result from prestressing in bending to a value considerably less than 85 percent of the modulus of rupture.

In general, the tests were not extensive enough to establish definite relationships between intensity of prestressing and reversed static strength for any of the properties studied, but the results, nevertheless, indicate a substantial strength in the reversed direction even when marked compression failures are present from the initial prestressing far above the proportional limit.

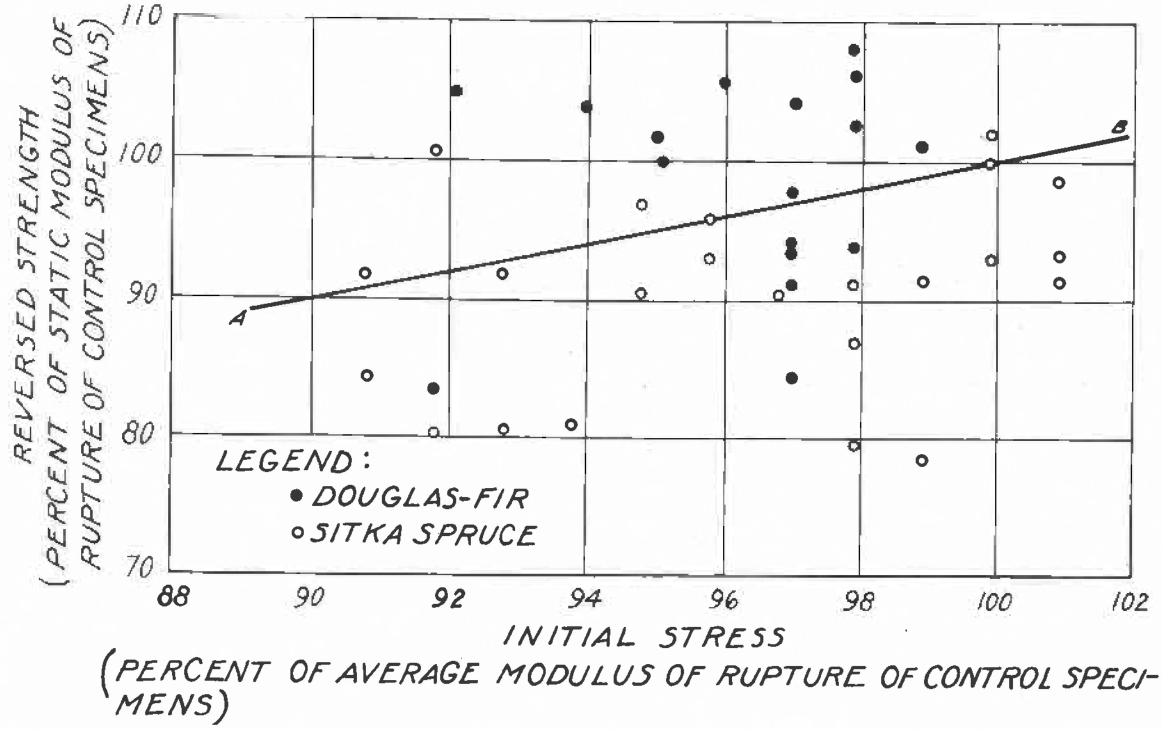

Figure 1.--Relation of breaking stress in bending to stress previously applied in the opposite direction.

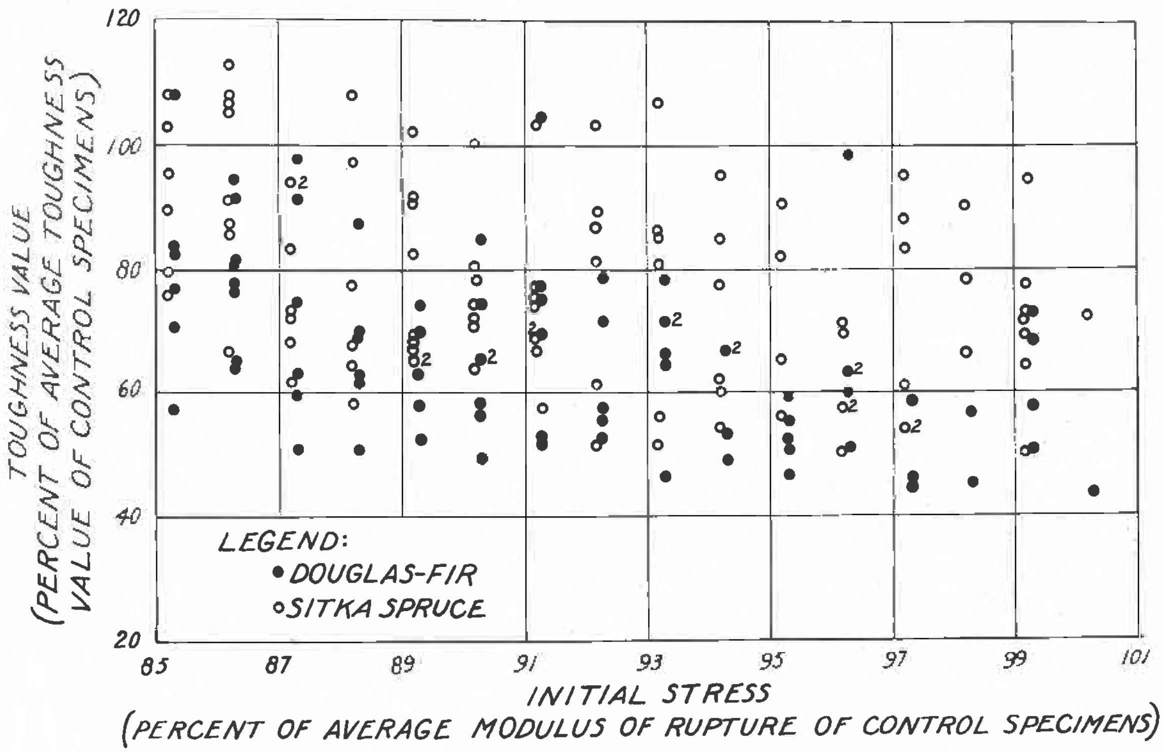

Figure 2.--Relation of toughness value to bending stress previously applied in the opposite direction.

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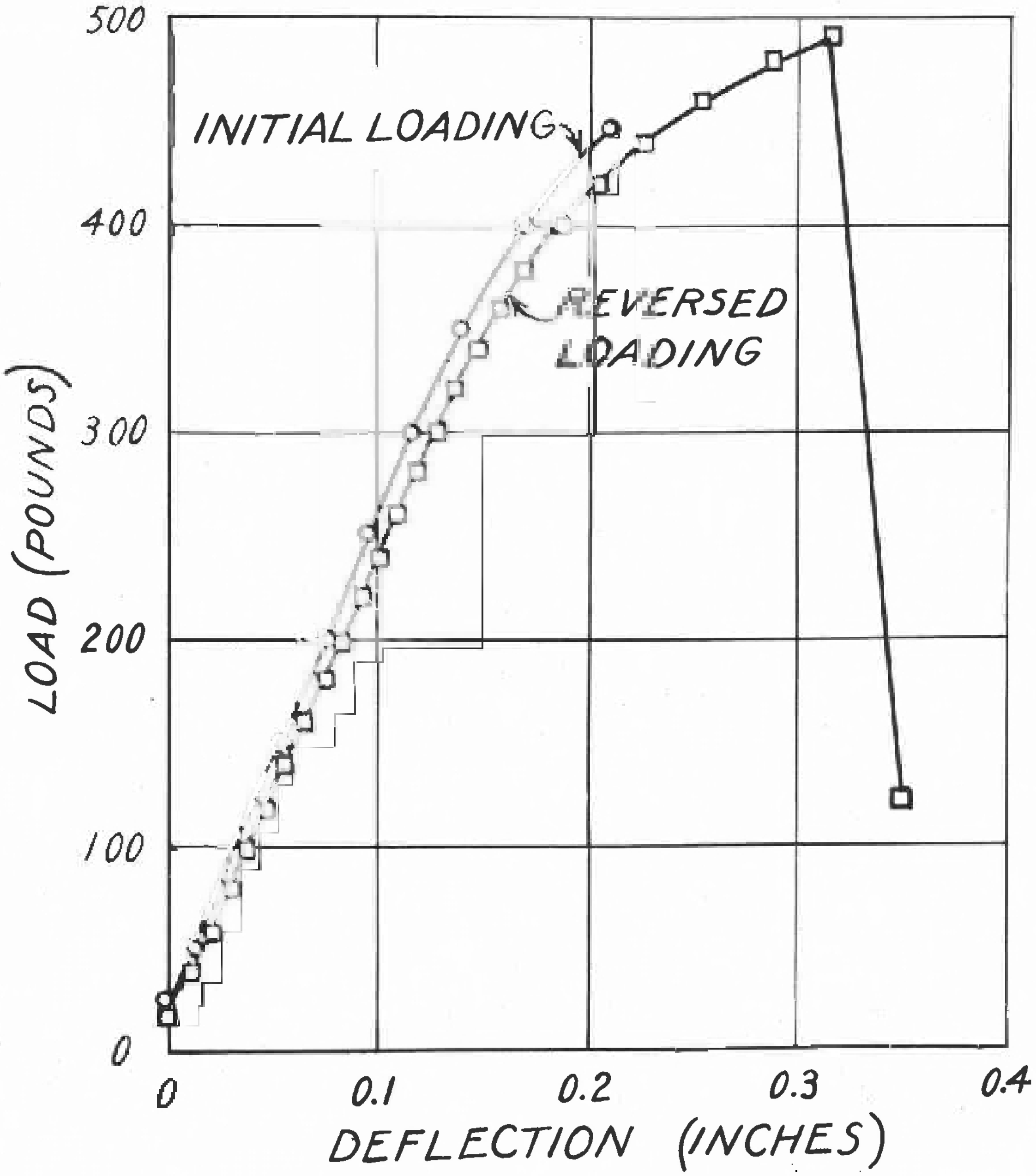

Figure 3.--Load-deflection curve for initial and reversed bending tests on a Sitka spruce specimen.

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