

**FLEXURAL RESPONSE OF  
SEATIMBER<sup>TM</sup> AND SEAPILE<sup>TM</sup> COMPONENTS  
REINFORCED WITH E-GLASS BARS**

**Submitted by**

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# Flexural Response of Seatimber™ and Seapile™ Components Reinforced with E-Glass Bars

## INTRODUCTION

This report presents the results of an experimental investigation aimed at determining the flexural properties of 49 Seatimber and Seapile composite marine timber components manufactured by Seaward International, Inc., Clearbrook, Virginia. Test components had rectangular, square, and circular cross sections and were made of recycled plastic materials with and without internal E-glass reinforcement bars. In addition, three wood components and one recycled plastic component not manufactured by Seaward International were also tested.

## TEST COMPONENTS

Test components had three different cross sections: rectangular, square, and circular. The designation, nominal dimensions and reinforcing scheme for each component are shown in Figure 1 and listed in Tables 1, 2, and 3. In these tables, test components are designated by a combination of letters and numbers in the form  $MA-a \times b-pFmn-L$ . The  $MA$  represents a specific type of material,  $a \times b$  are the nominal width and depth of the section,  $p$  is the number of reinforcing bars,  $Fmn$  represent the size of the bar (e.g. F08 indicates number 8 bar, having a nominal diameter of 8/8 inches), and  $L$  is the test span.

## TEST PROCEDURE

A screw-type testing machine equipped with a load cell was used for all tests. A typical test setup is shown schematically in Figure 2 with a photograph in Figure 3. Test components rested on end bearing plates with a knife-edge type support (Figure 4) at one end and a steel rod free to roll (Figure 5) as the component was loaded at the other end. The bearing plates were provided to avoid premature end failures during the duration of the test. One linear variable differential transformer (LVDT) was placed at midspan to measure the deflection. The load was applied at midspan by means of 6-inch diameter cylinders connected to the load cell of the testing machine at the rate of 0.2 in./minute until the ultimate load was reached. Load and deflection data were collected using an Optim Megadac data acquisition system.

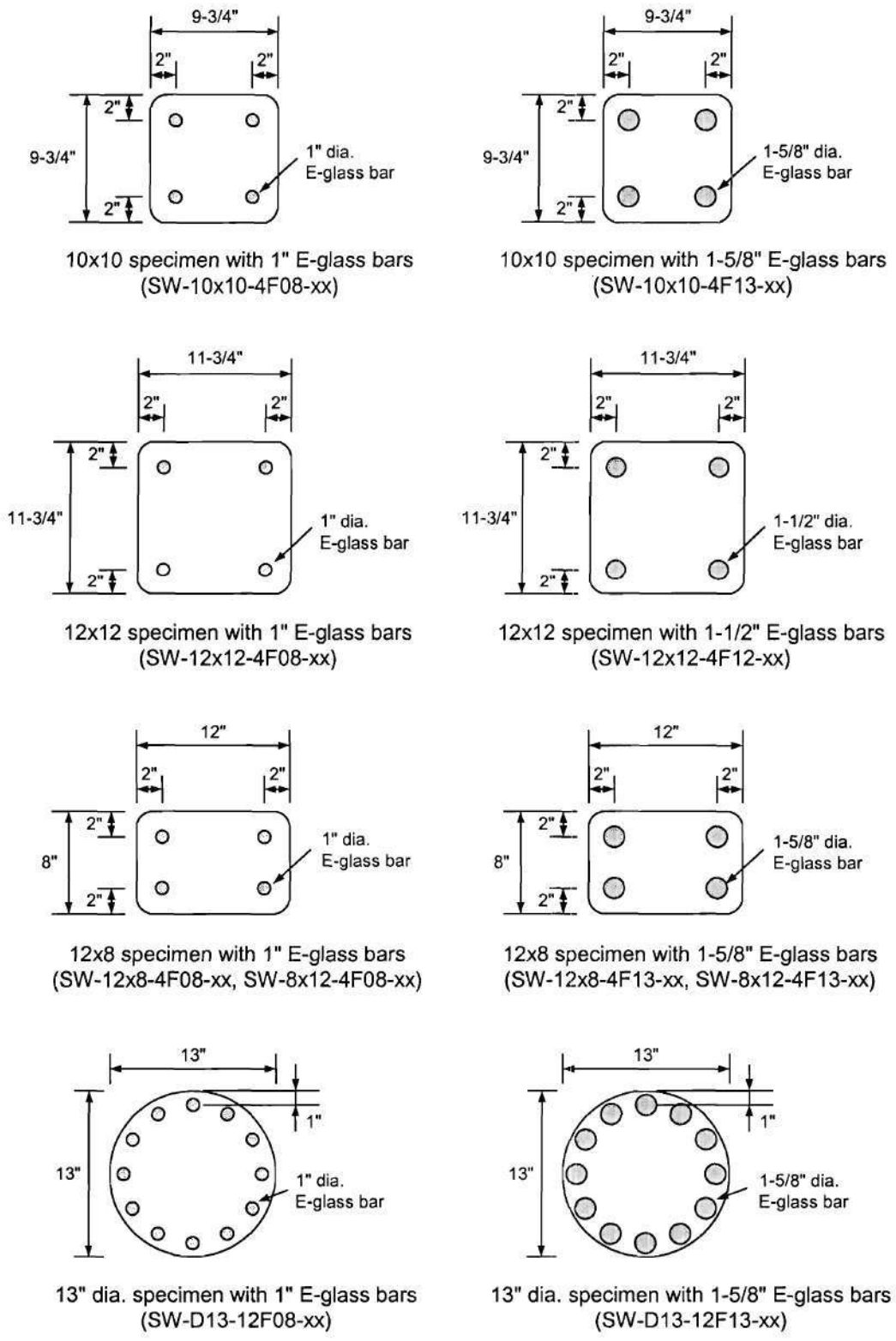


Figure 1. Nominal dimensions of test components

Table 1. Nominal dimensions of “as received” Seatimber™ components

Specimen	Width (in)	Height (in)	Length (ft)	Span Length (ft)	E-Glass Bar Diameter (in)
SW-10x10-0F0-5.5	9.75	9.75	7.5	5.5	N/A
SW-10x10-0F0-6.5	9.75	9.75	8.5	6.5	N/A
SW-10x10-0F0-8.5	9.75	9.75	10.5	8.5	N/A
SW-10x10-0F0-14	9.75	9.75	17	14	N/A
SW-10x10-4F08-5.5	9.75	9.75	7.5	5.5	1.0
SW-10x10-4F08-6.5	9.75	9.75	8.5	6.5	1.0
SW-10x10-4F08-8.5	9.75	9.75	10.5	8.5	1.0
SW-10x10-4F08-14	9.75	9.75	17	14	1.0
SW-10x10-4F13-5.5	9.75	9.75	7.5	5.5	1.625
SW-10x10-4F13-6.5	9.75	9.75	8.5	6.5	1.625
SW-10x10-4F13-8.5	9.75	9.75	10.5	8.5	1.625
SW-10x10-4F13-14	9.75	9.75	17	14	1.625
SW-12x12-4F08-5.5	11.75	11.75	7.5	5.5	1.0
SW-12x12-4F08-6.5	11.75	11.75	8.5	6.5	1.0
SW-12x12-4F08-8.5	11.75	11.75	10.5	8.5	1.0
SW-12x12-4F08-14	11.75	11.75	17	14	1.0
SW-12x12-4F12-5.5	11.75	11.75	7.5	5.5	1.5
SW-12x12-4F12-6.5	11.75	11.75	8.5	6.5	1.5
SW-12x12-4F12-8.5	11.75	11.75	10.5	8.5	1.5
SW-12x12-4F12-14	11.75	11.75	17	14	1.5
SW-12x8-4F08-3.5	12	8	5.0	3.5	1.0
SW-12x8-4F08-4.5	12	8	6.0	4.5	1.0
SW-12x8-4F08-5.5	12	8	7.5	5.5	1.0
SW-12x8-4F08-9.5	12	8	11.5	9.5	1.0
SW-8x12-4F08-5.5	8	12	7.5	5.5	1.0
SW-8x12-4F08-6.5	8	12	8.5	6.5	1.0
SW-8x12-4F08-8.5	8	12	10.5	8.5	1.0
SW-8x12-4F08-14	8	12	17	14	1.0
SW-12x8-4F13-3.5	12	8	5.0	3.5	1.625
SW-12x8-4F13-4.5	12	8	6.0	4.5	1.625
SW-12x8-4F13-5.5	12	8	7.5	5.5	1.625
SW-12x8-4F13-9.5	12	8	11.5	9.5	1.625
SW-8x12-4F13-5.5	8	12	7.5	5.5	1.625
SW-8x12-4F13-6.5	8	12	8.5	6.5	1.625
SW-8x12-4F13-8.5	8	12	10.5	8.5	1.625
SW-8x12-4F13-14	8	12	17	14	1.625

Table 2. Nominal dimensions of “as received” Seapile™ components

Specimen	Diameter (in)	Length (ft)	Span Length (ft)	E-Glass Bar Diameter (in)
SW-D13-12F08-6	13	8.0	6	1.0
SW-D13-12F08-7	13	9.0	7	1.0
SW-D13-12F08-9.5	13	11.5	9.5	1.0
SW-D13-12F08-15	13	18.0	15	1.0
SW-D13-12F08-	13	25.5	21.5	1.0
SW-D13-12F13-6	13	8.0	6	1.625
SW-D13-12F13-	13	25.5	21.5	1.625

Table 3. Nominal dimensions of “as received” Wood and Type-P components

Specimen	Width (in)	Height (in)	Length (ft)	Span Length (ft)	E-Glass Bar Diameter (in)
Wood-10x10-5.5	9.75	9.75	7.5	5.5	N/A
Wood-10x10-6.5	9.75	9.75	10.5	6.5	N/A
Wood-10x10-14	9.75	9.75	17	14	N/A
P-9x9-6.5	8.75	8.75	8.5	6.5	N/A

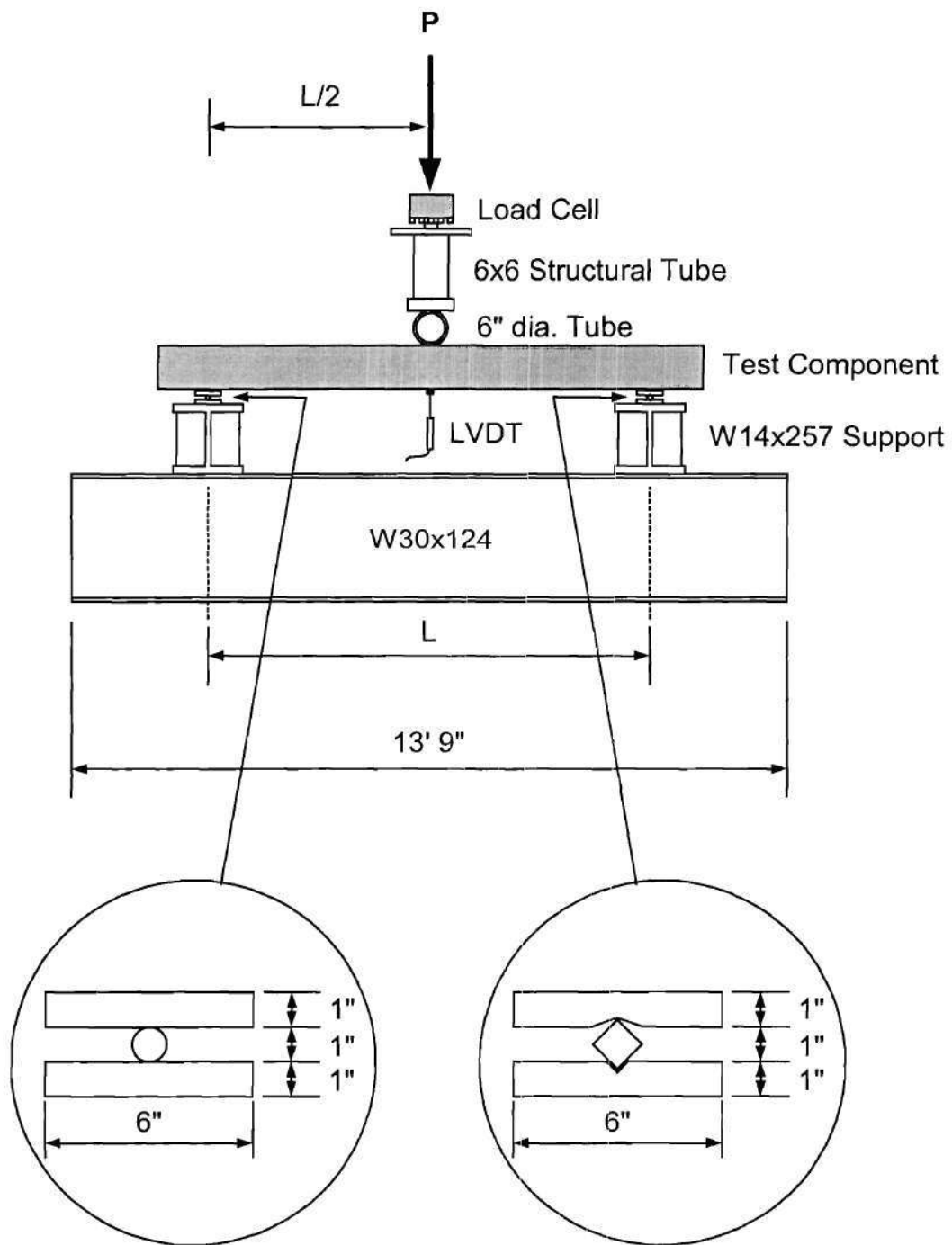


Figure 2. Typical test setup

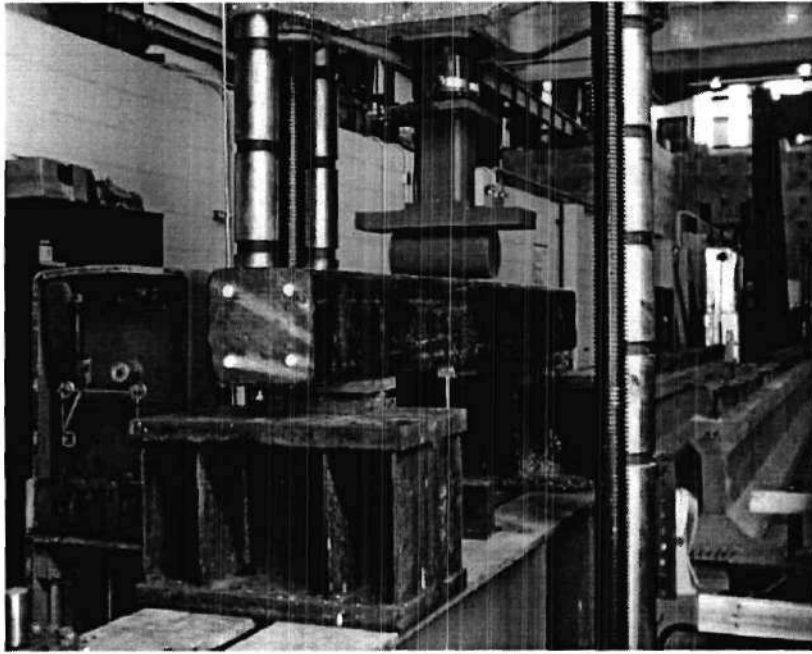


Figure 3. Photograph of a typical test set-up

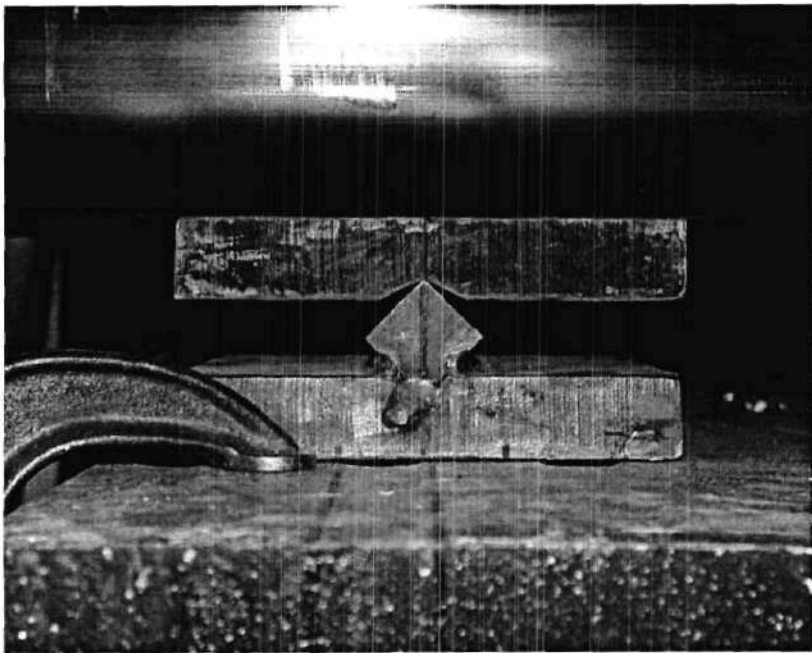


Figure 4. Knife-edge support

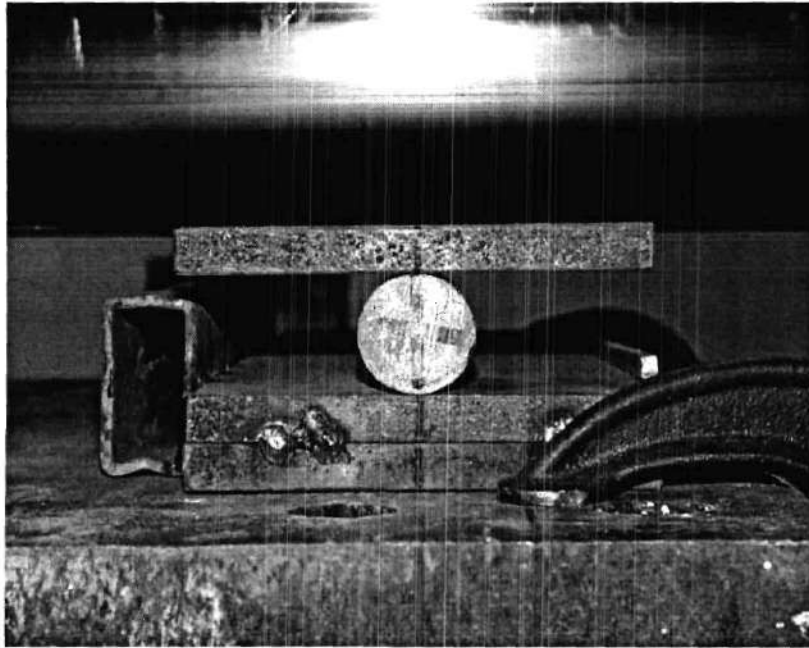


Figure 5. Roller support

## TEST RESULTS

Table 4, 5, and 6 presents the ultimate load and the maximum deflection for the test components. The load-deflection curves for all test components are presented in Figure A-9 through Figure A-20 in Appendix.

Table 4. Test results for Seatimber™ components

Test Number	Test Component	Maximum Load (kips)	Deflection at Maximum Load (in)
1	SW-10x10-0F0-5.5	39.9	4.7
2	SW-10x10-0F0-6.5	23.1	3.4
3	SW-10x10-0F0-8.5	22.1	9.54
4	SW-10x10-0F0-14	10.1	16.1
5	SW-10x10-4F08-5.5	55.2	2.0
6	SW-10x10-4F08-6.5	55.5	3.0
7	SW-10x10-4F08-8.5	51.0	5.2
8	SW-10x10-4F08-14	32.1	12.1
9	SW-10x10-4F13-5.5	56.8	2.5
10	SW-10x10-4F13-6.5	47.6	1.7
11	SW-10x10-4F13-8.5	48.7	2.6
12	SW-10x10-4F13-14	42.4	10.5
13	SW-12x12-4F08-5.5	83.8	1.6
14	SW-12x12-4F08-6.5	60.3	2.0
15	SW-12x12-4F08-8.5	69.7	5.6
16	SW-12x12-4F08-14	45.0	10.5
17	SW-12x12-4F12-5.5	132.9	2.15
18	SW-12x12-4F12-6.5	75.3	1.5
19	SW-12x12-4F12-8.5	89.2	3.2
20	SW-12x12-4F12-14	71.5	8.5
21	SW-12x8-4F08-3.5	48.1	3.8
22	SW-12x8-4F08-4.5	38.7	1.9
23	SW-12x8-4F08-5.5	26.1	3.5
24	SW-12x8-4F08-9.5	21.4	8.0
25	SW-8x12-4F08-5.5	52.5	1.9
26	SW-8x12-4F08-6.5	40.2	2.3
27	SW-8x12-4F08-8.5	30.8	7.8
28	SW-8x12-4F08-14	18.1	9.3
29	SW-12x8-4F13-3.5	47.9	3.0
30	SW-12x8-4F13-4.5	31.4	2.0
31	SW-12x8-4F13-5.5	32.3	1.9
32	SW-12x8-4F13-9.5	23.0	4.5
33	SW-8x12-4F13-5.5	36.3	1.7
34	SW-8x12-4F13-6.5	35.7	2.4
35	SW-8x12-4F13-8.5	34.7	3.1
36	SW-8x12-4F13-14	23.4	5.8

Table 5. Test results for Seapile™ components

Test Number	Test Component	Maximum Load (kips)	Deflection at Maximim Load (in)
37	SW-D13-12F08-6	66.5	3.7
38	SW-D13-12F08-7	60.6	4.4
39	SW-D13-12F08-9.5	48.9	5.0
40	SW-D13-12F08-15	27.4	7.3
41	SW-D13-12F08-21.5	25.7	17.2
42	SW-D13-12F13-6	88.3	3.1
43	SW-D13-12F13-21.5	50.5	12.0

Table 6. Test results for Ecoboard and S.Y. Pine wood components

Test Number	Test Component	Maximum Load (kips)	Deflection at Maximim Load (in)
44	SY-10x10-5.5	34.0	0.4
45	SY-10x10-8.5	26.9	1.0
46	SY-10x10-14	13.5	1.8
47	Ecoboard-9x9-6.5	9.9	3.3

Table 7. Additional test results for 8x12 Seatimber™ components with 8.5-foot span

Test Number	Test Component	Maximum Load (kips)	Deflection at Maximim Load (in)
48	SW-8x12-4F08-8.5_C1	19.9	4.0
49	SW-8x12-4F08-8.5_C2	11.4	2.6
50	SW-8x12-4F08-8.5_C3	16.1	5.4
51	SW-8x12-4F08-8.5_C4	14.3	3.1
52	SW-8x12-4F08-8.5_C5	19.3	4.9
53	SW-8x12-4F08-8.5_C6	18.6	3.9

Flexural stiffness and shear stiffness properties for Seatimber™ and Seapile™ were investigated from test results. Deflection at the midspan of a simply supported beam subjected to a center load  $P$  can be expressed in the form:

$$\delta = \frac{PL^3}{48D} + \frac{PL}{4Q} \quad (1)$$

This is rearranged as:

$$\frac{\delta}{PL} = \frac{1}{48D}L^2 + \frac{1}{4Q} \quad (2)$$

When a straight line is then fitted to the experimental data, the slope and the intercept of such a line represent  $1/(48D)$  and  $1/(4Q)$ , respectively, and thus the flexural and shear stiffnesses  $D$  and  $Q$  can be determined readily. For all test components except those which were not reinforced with E-glass bars, the values of  $D$  and  $Q$  were computed at the deflection level corresponding to 1% pure bending strain estimated from:

$$\delta = \frac{\epsilon L^2}{6h} = \frac{(0.01)L^2}{6h} \quad (3)$$

Computed stiffness values for Seatimber™ and Seapile™ components are summarized in Table 8. All the experimental data and regression curves used in the calculation are presented in Figures 6, 7, and 8.

Table 8. Computed flexural stiffness and shear stiffness

Test Component	Flexural Stiffness, $D$ (kips-in <sup>2</sup> )	Shear Stiffness, $Q$ (kips)
SW-10x10-4F08	333,000	1,616
SW-10x10-4F13	676,500	1,730
SW-12x12-4F08	551,700	4,162
SW-12x12-4F12	1,094,900	3,209
SW-12x8-4F08	112,100	1,530
SW-8x12-4F08	248,600	3,572
SW-12x8-4F13	211,800	958
SW-8x12-4F13	536,600	965
SW-D13-12F08	618,700	1,332
SW-D13-12F13	1,961,000	1,550

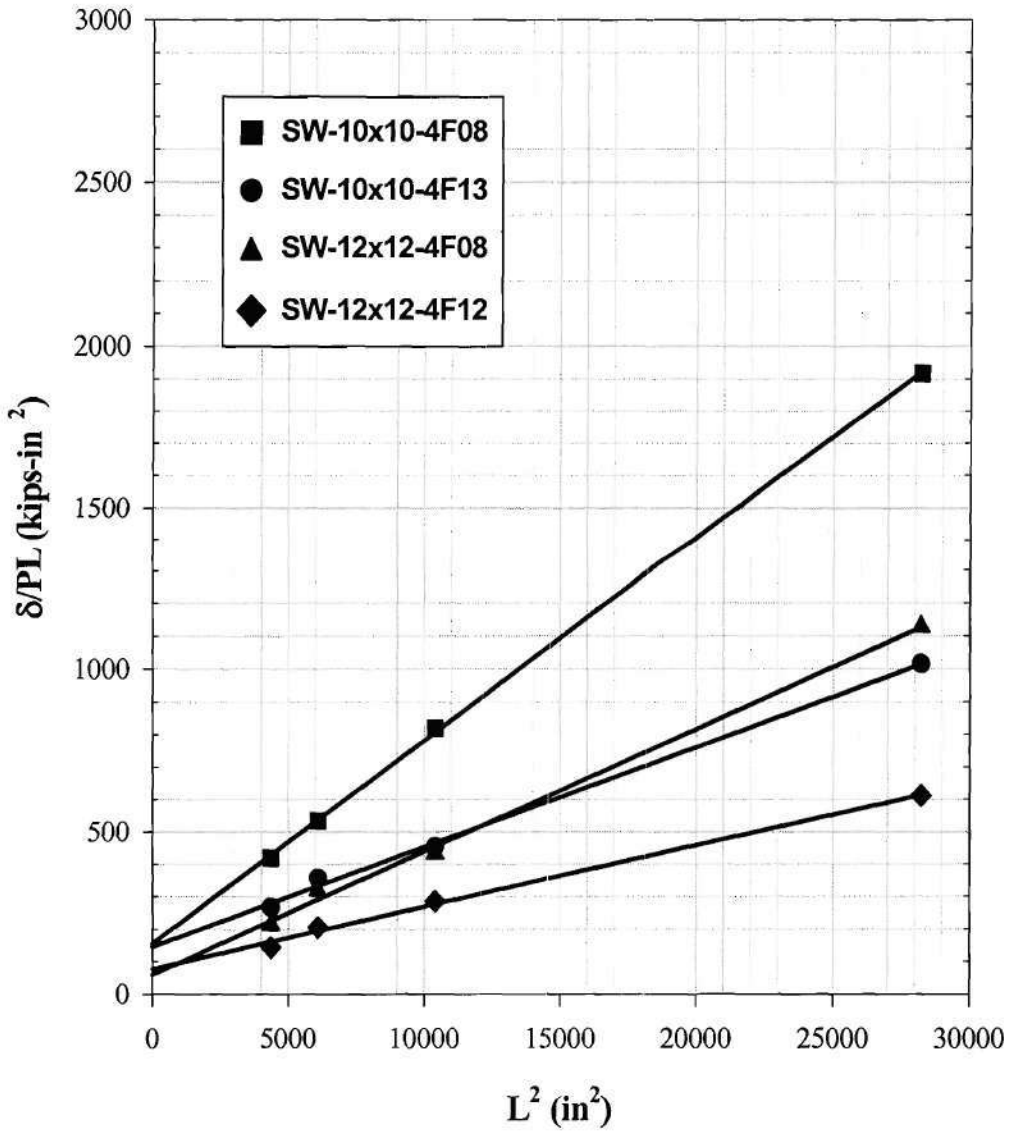


Figure 6. Experimental data and linear regression curves in a  $L^2$  and  $\delta/PL$  plane for square Seatimber<sup>TM</sup> components

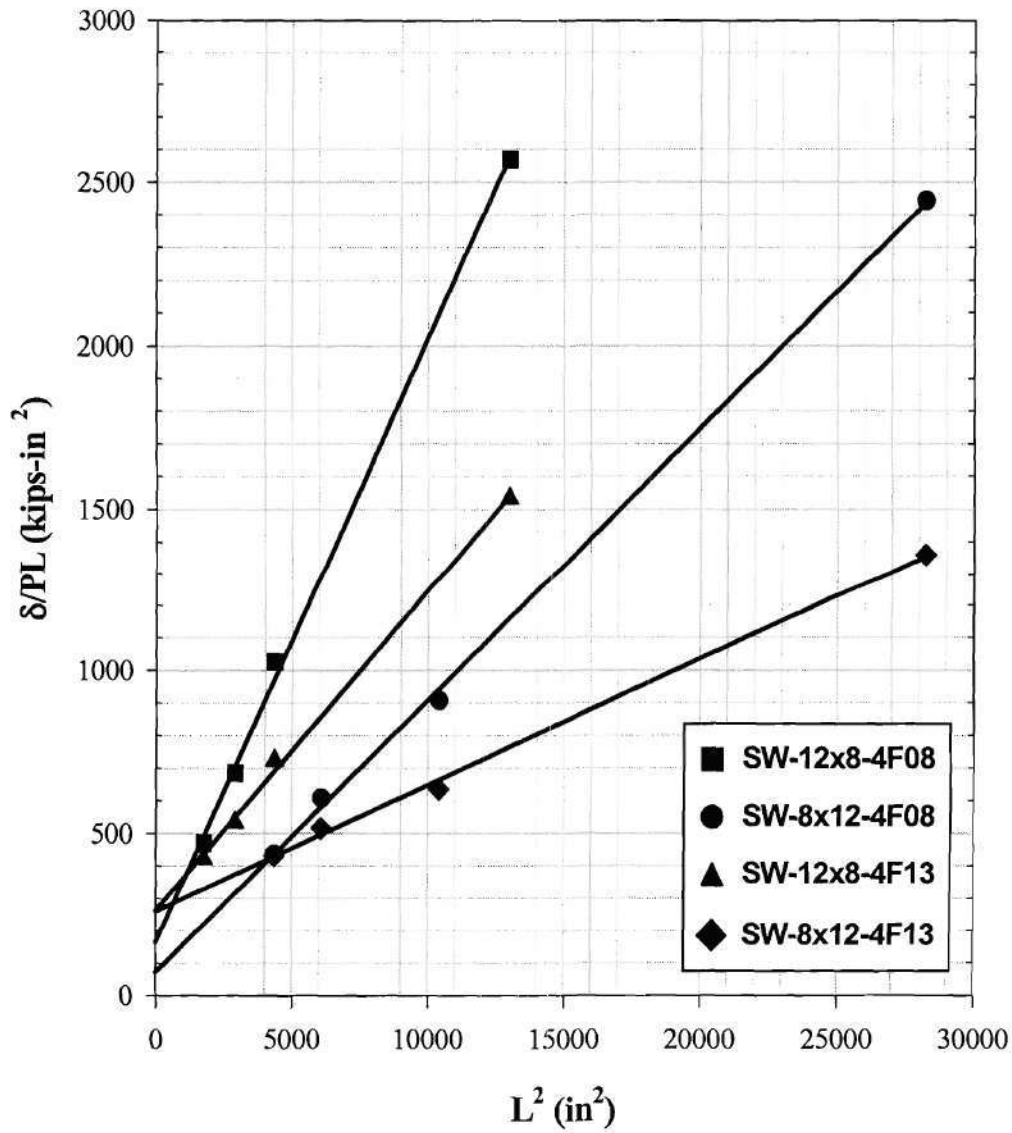


Figure 7. Experimental data and linear regression curves in a  $L^2$  and  $\delta/PL$  plane for rectangular Seatimber<sup>TM</sup> components

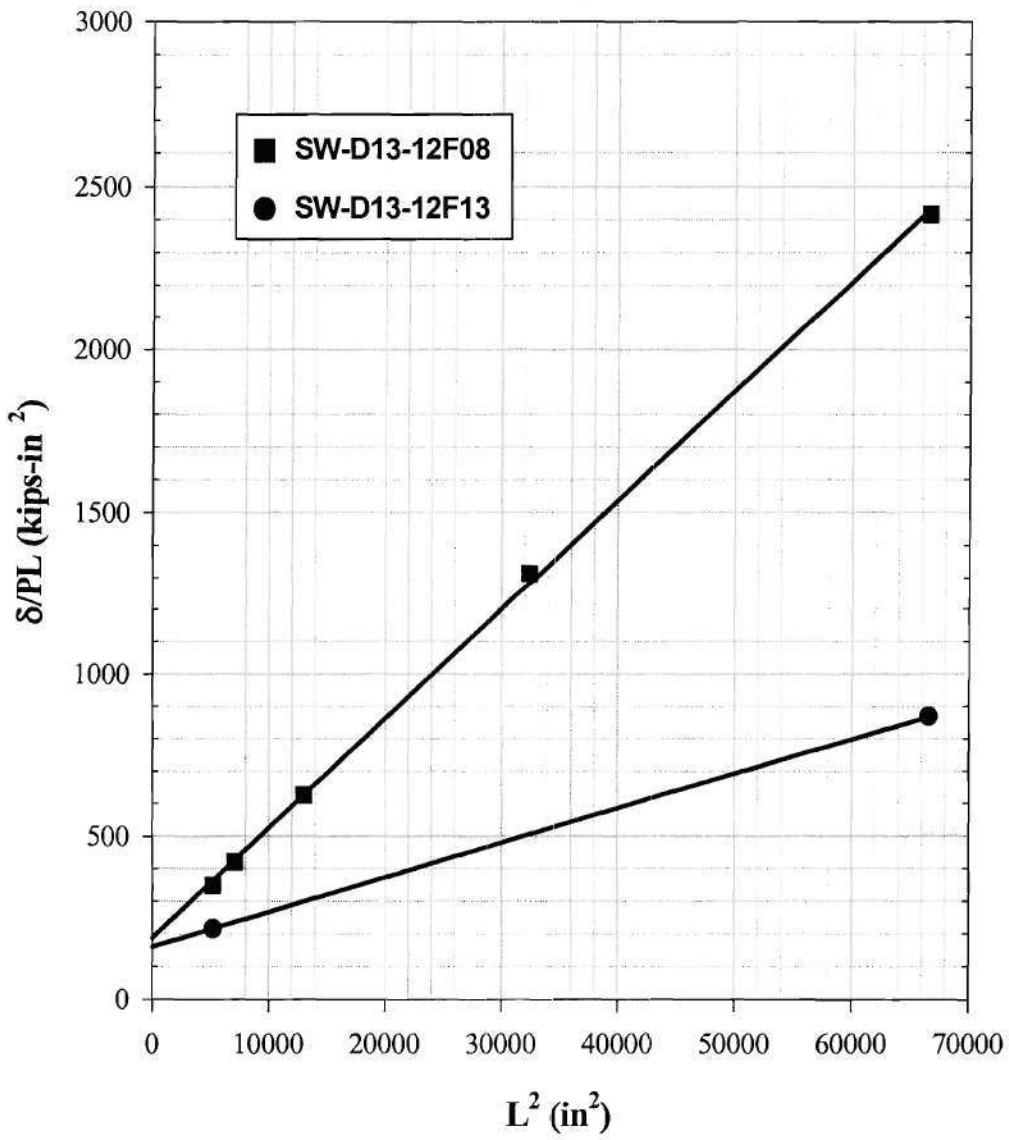


Figure 8. Experimental data and linear regression curves in a  $L^2$  and  $\delta/PL$  plane for Seapile<sup>TM</sup> components

APPENIDIX

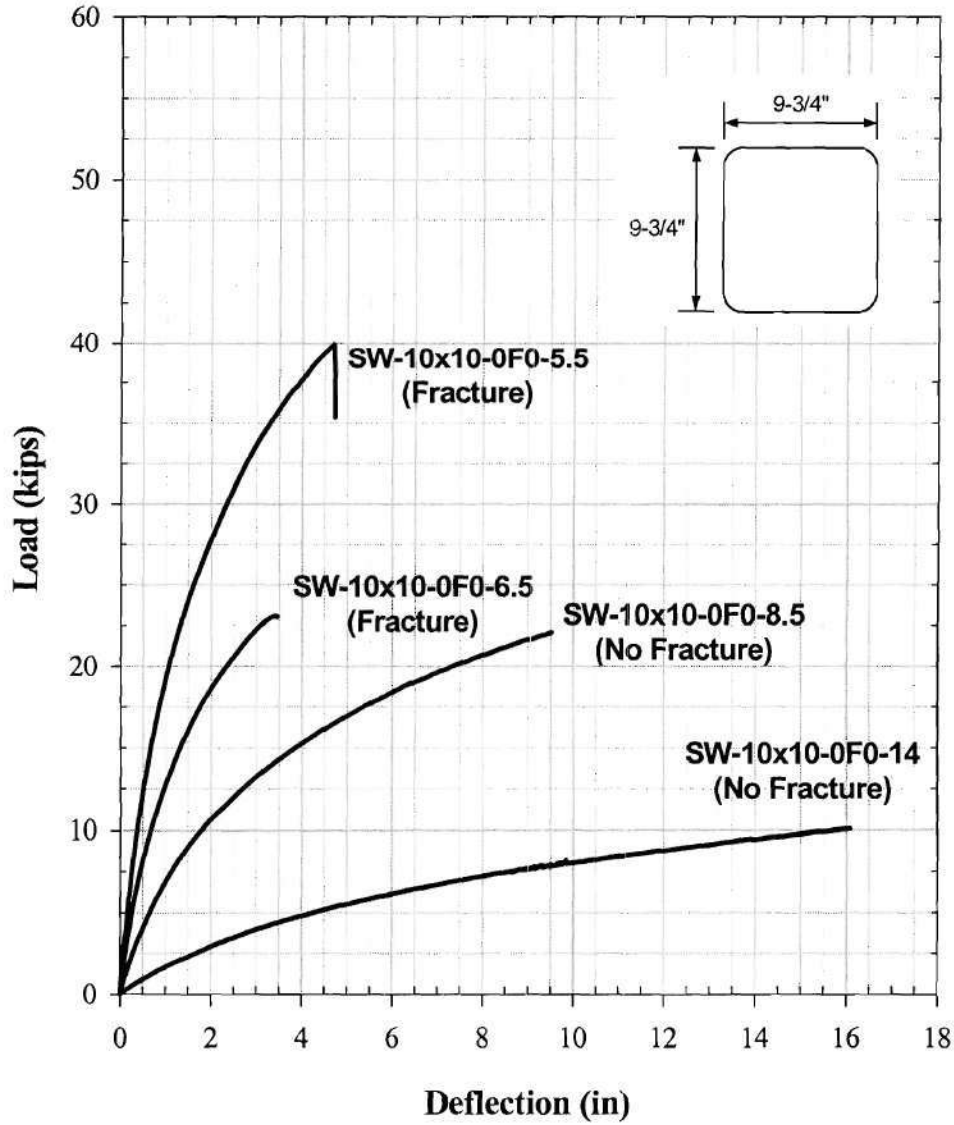


Figure A-9. Load-deflection curves of 10x10 unreinforced Seatimber™ components

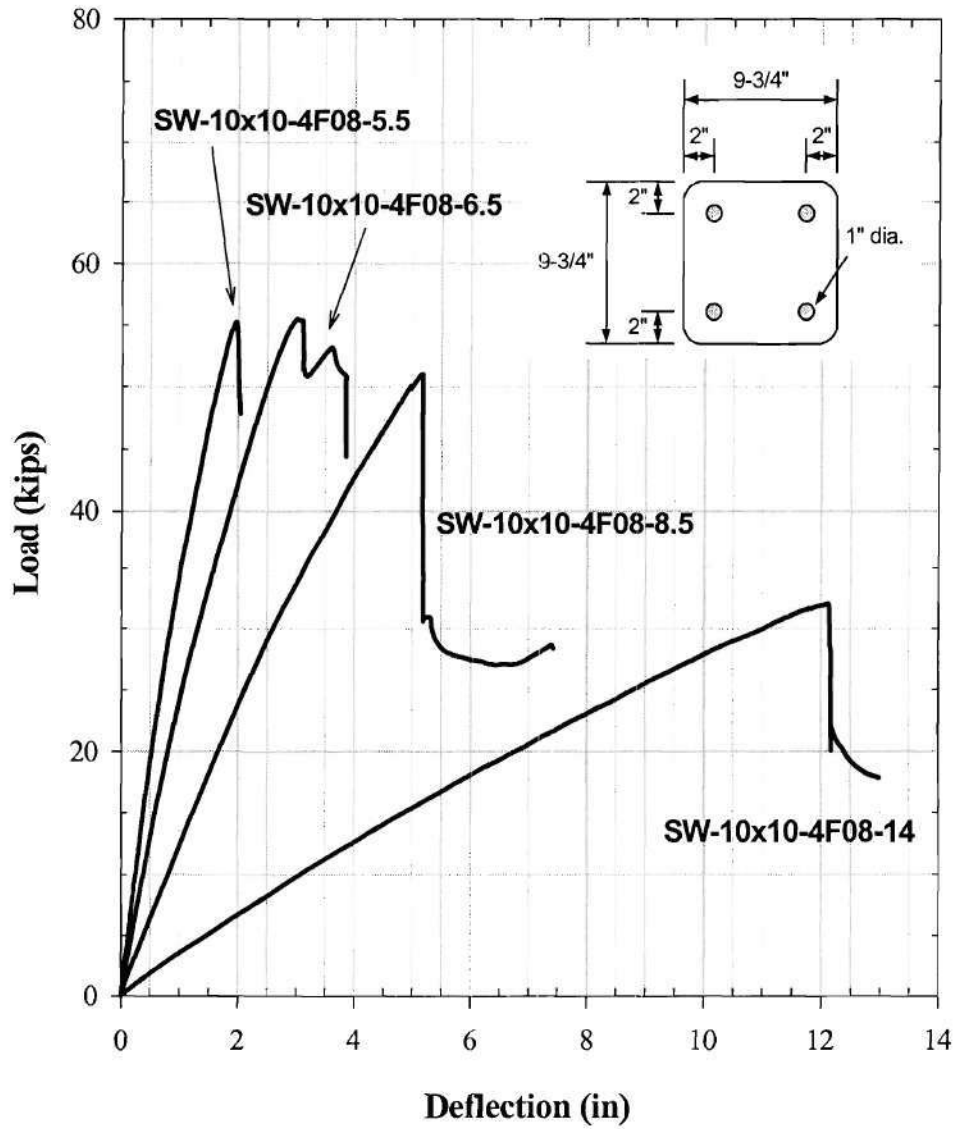


Figure A-10. Load-deflection curves of 10x10 Seatimber<sup>TM</sup> components reinforced with four 1-inch diameter E-glass bars

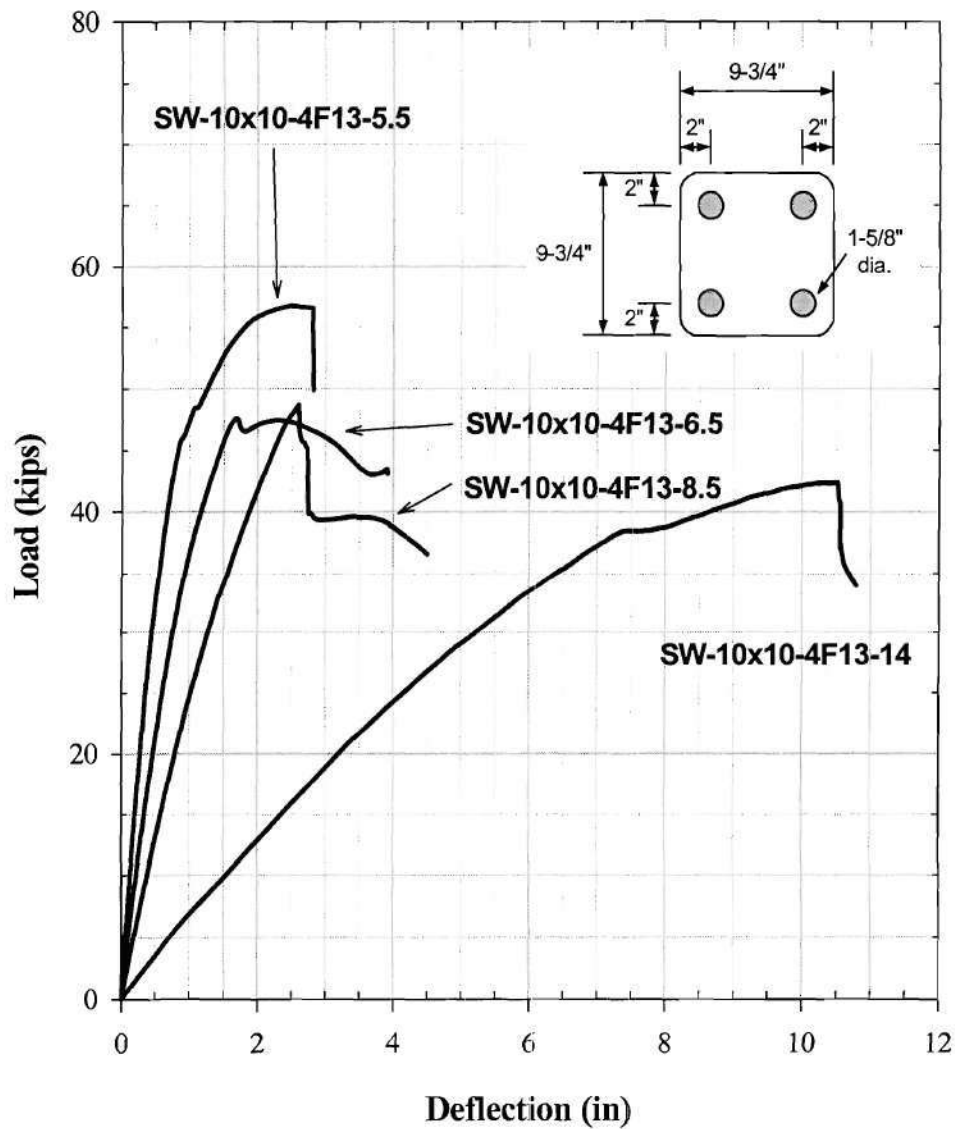


Figure A-11. Load-deflection curves of 10x10 Seatimber<sup>TM</sup> components reinforced with four 1-5/8-inch diameter E-glass bars

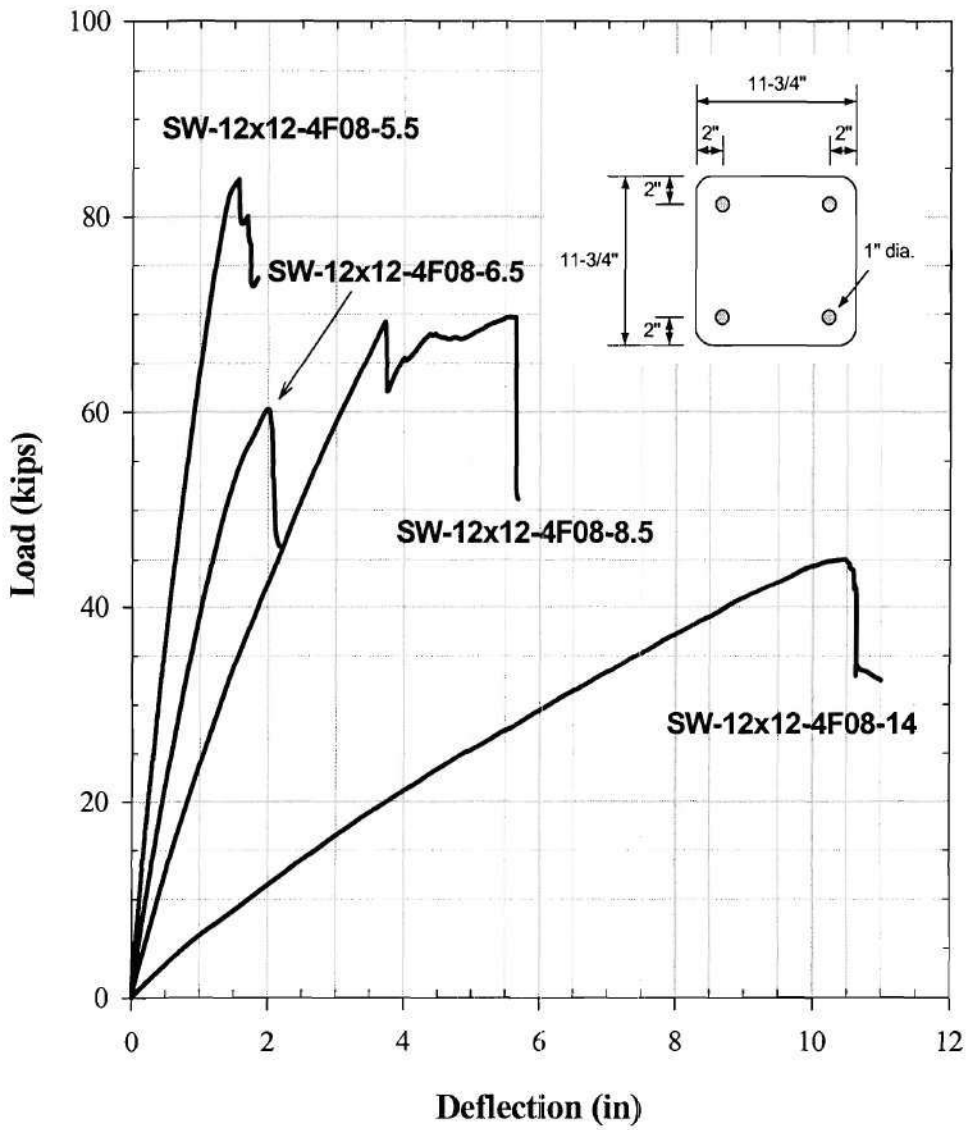


Figure A-12. Load-deflection curves of 12x12 Seatimber™ components reinforced with four 1-inch diameter E-glass bars

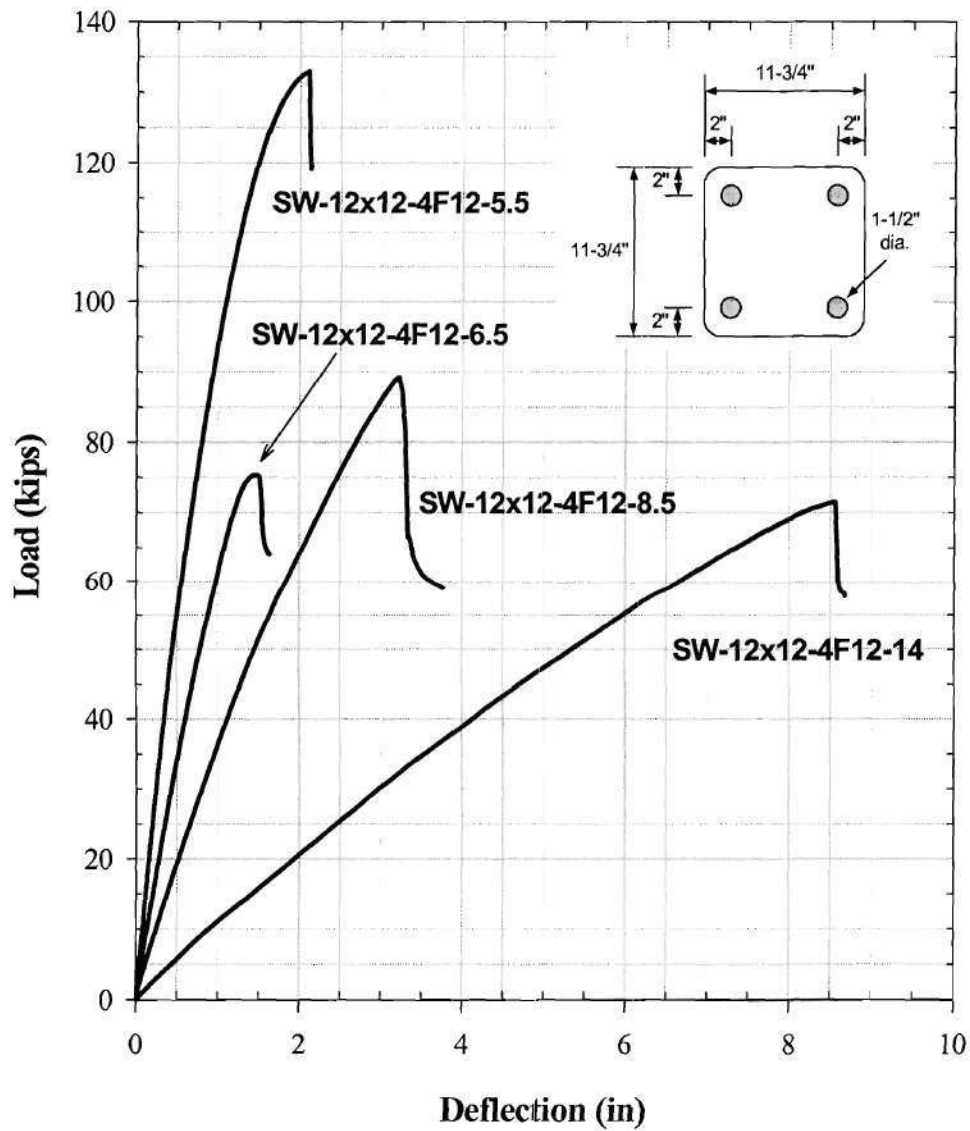


Figure A-13. Load-deflection curves of 12x12 Seatimber™ components reinforced with four 1-1/2-inch diameter E-glass bars

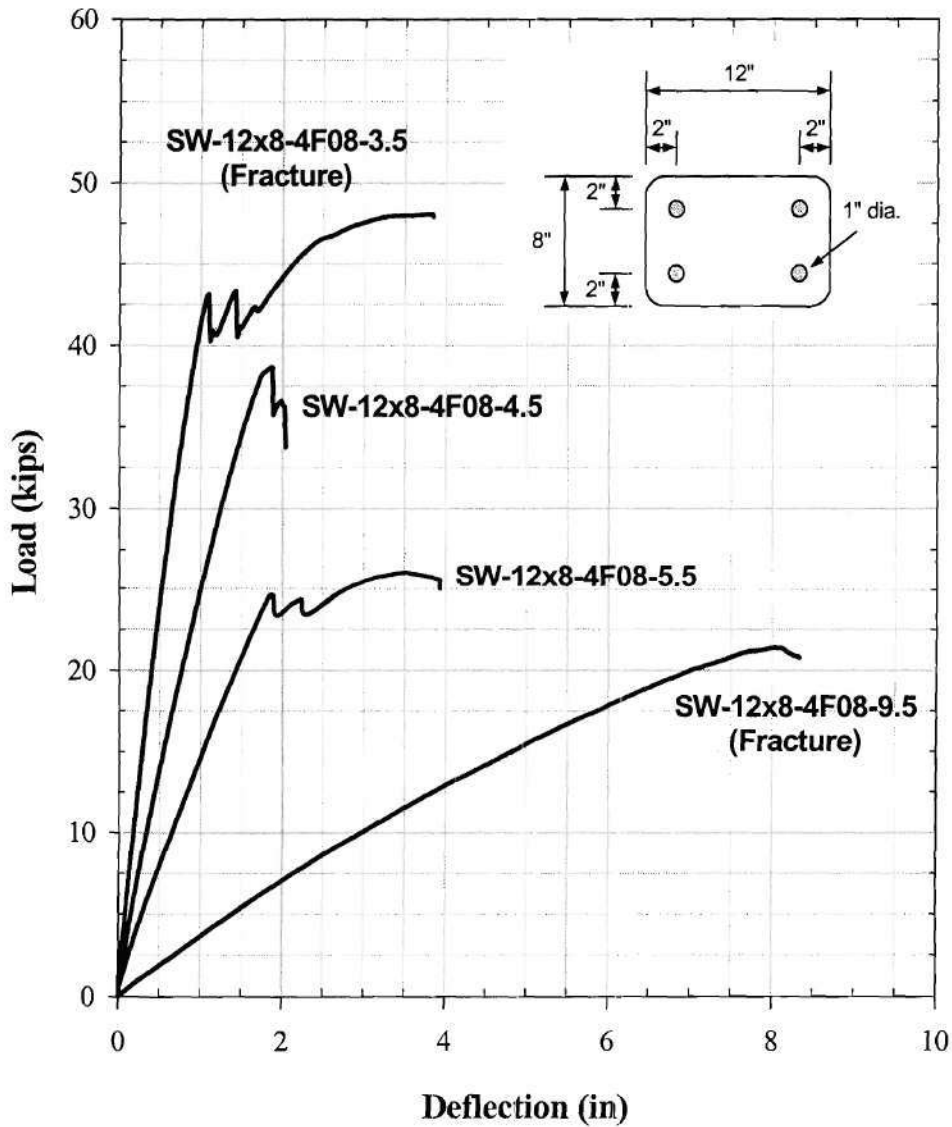


Figure A-14. Load-deflection curves of 12x8 Seatimber™ components (weak axis) reinforced with four 1-inch diameter E-glass bars

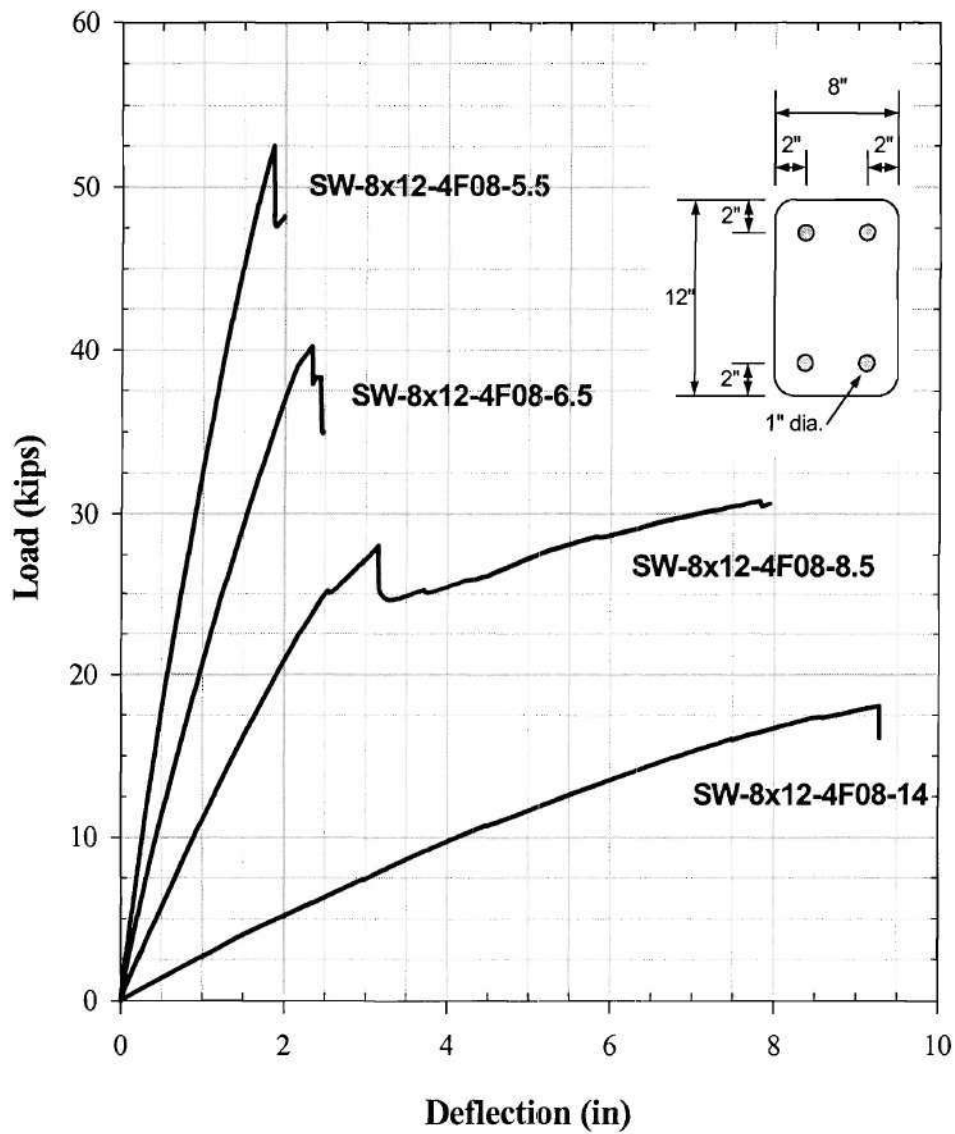


Figure A-15. Load-deflection curves of 8x12 Seatimber<sup>TM</sup> components (strong axis) reinforced with four 1-inch diameter E-glass bars

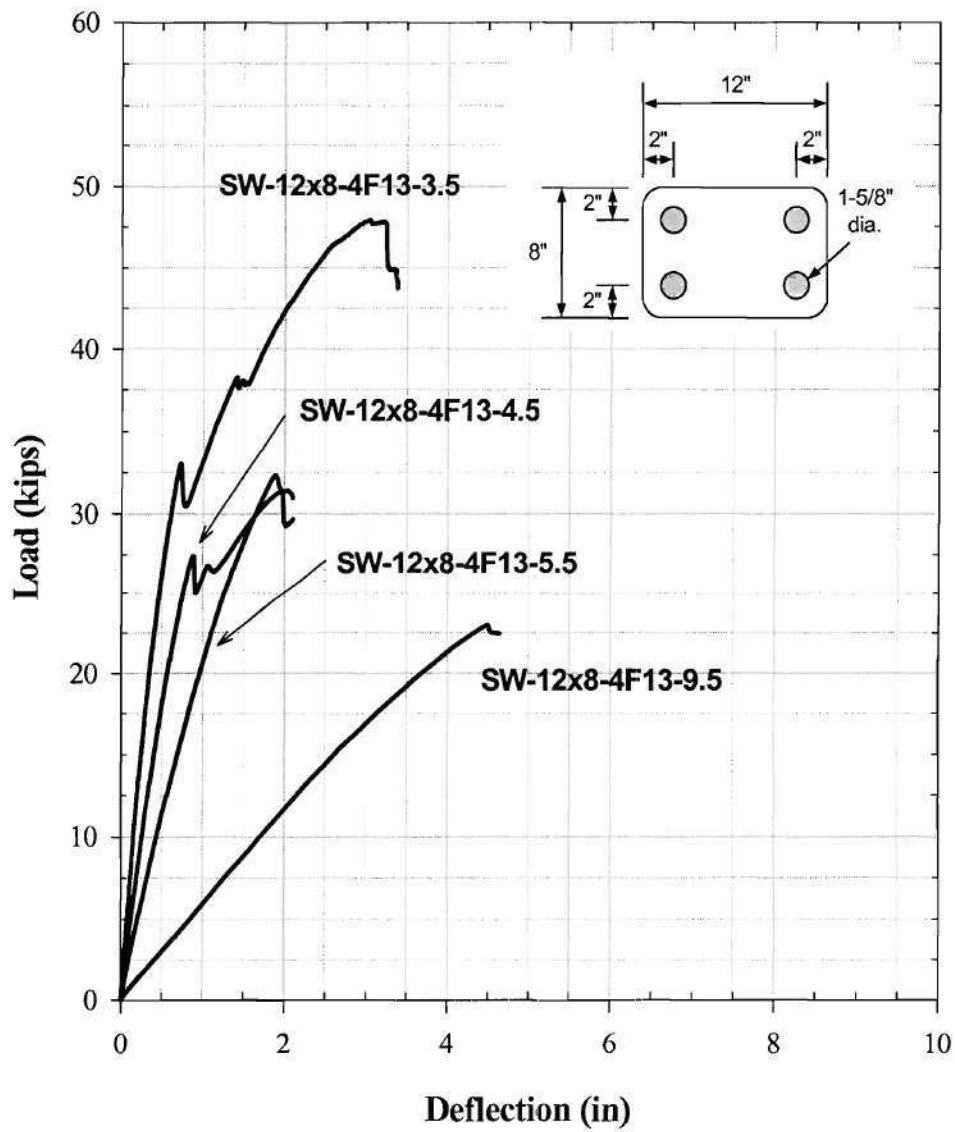


Figure A-16. Load-deflection curves of 12x8 Seatimber™ components (weak axis) reinforced with four 1-5/8-inch diameter E-glass bars

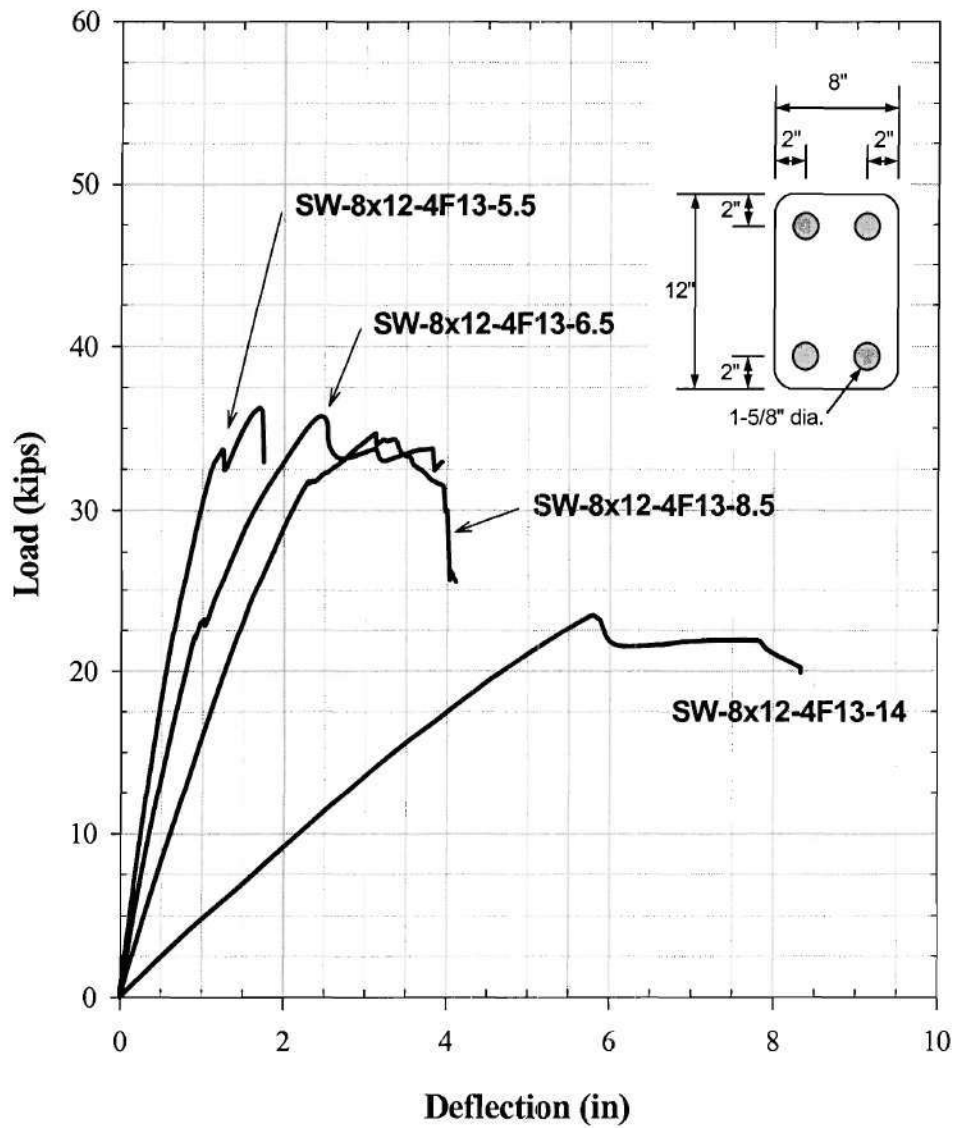


Figure A-17. Load-deflection curves of 8x12 Seatimber™ components (strong axis) reinforced with four 1-5/8-inch diameter E-glass bars

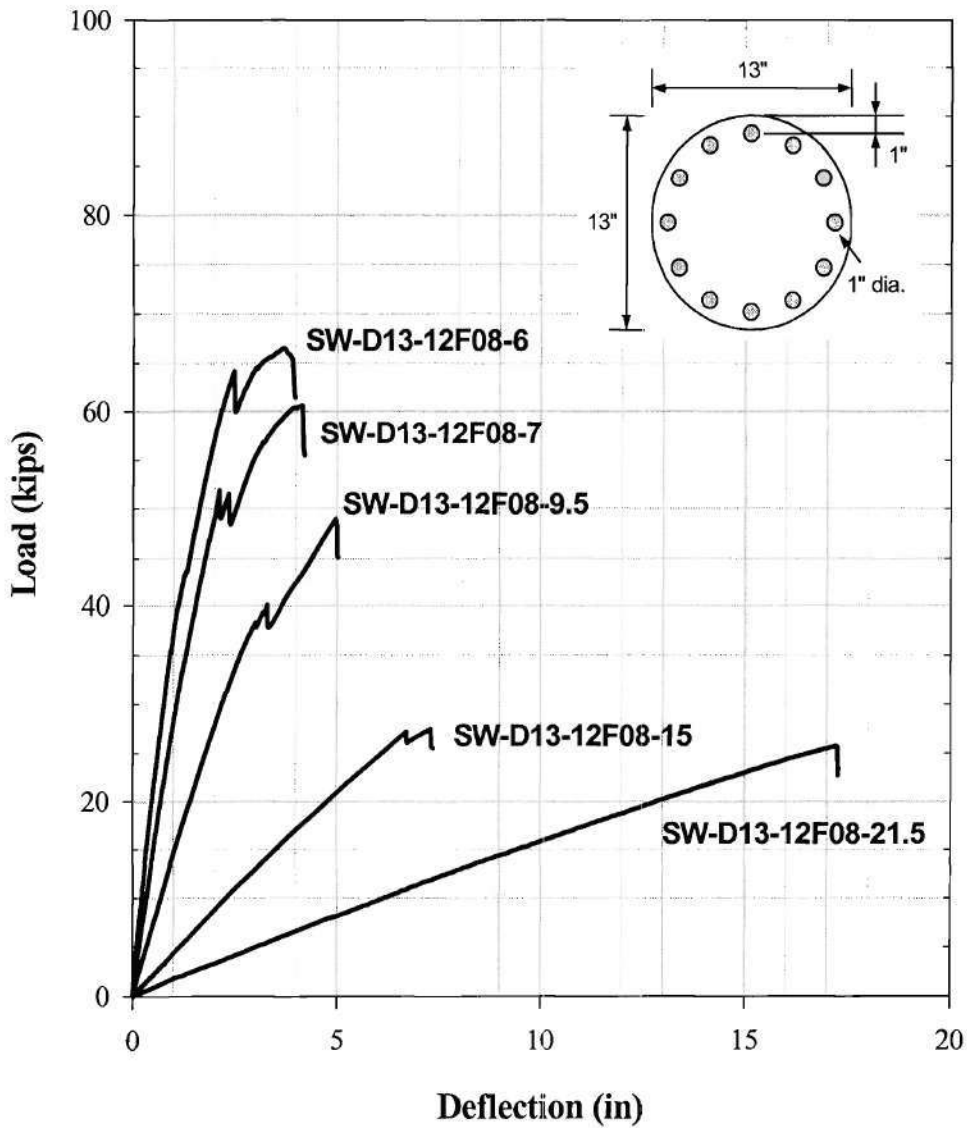


Figure A-18. Load-deflection curves of 13-inch diameter Seapile™ components reinforced with twelve 1-inch E-glass bars

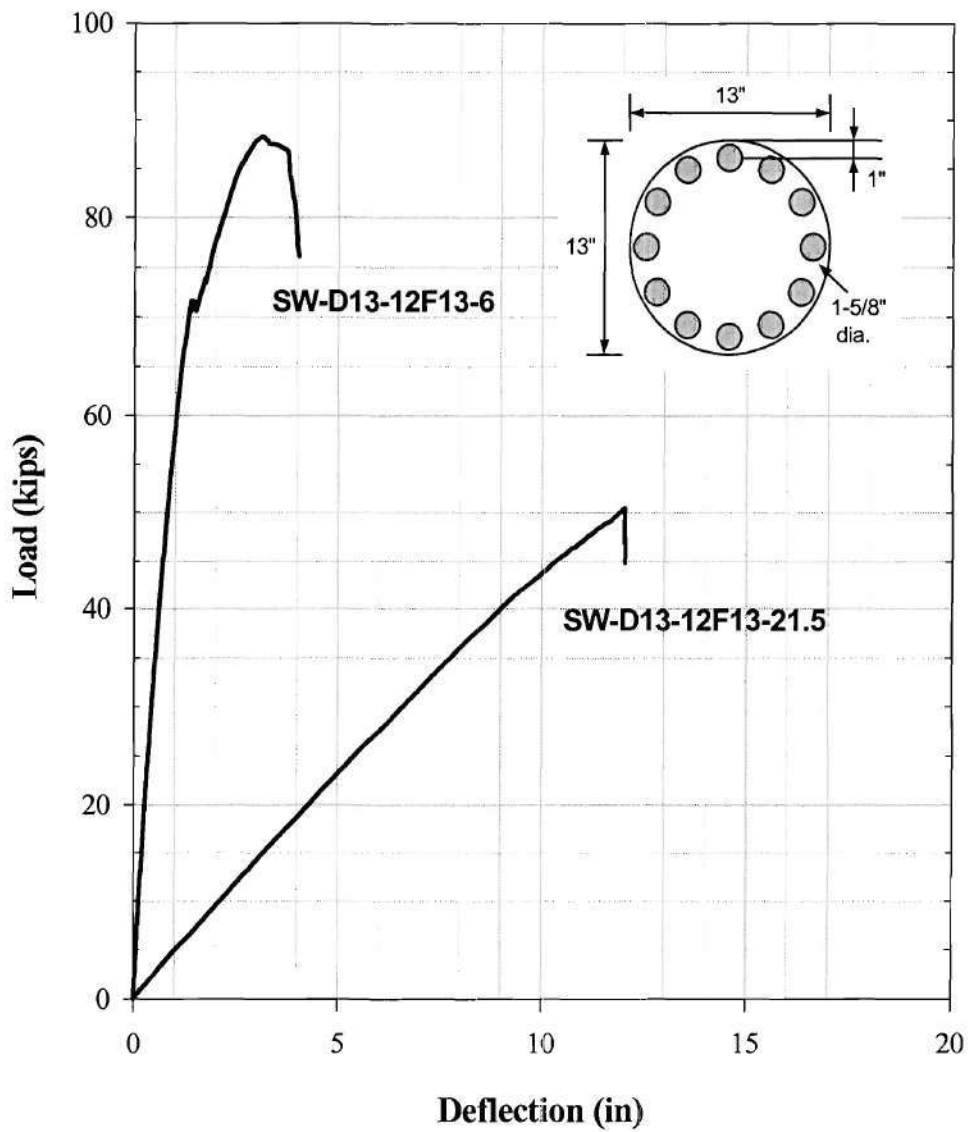


Figure A-19. Load-deflection curves of 13-inch diameter Seapile™ components reinforced with twelve 1-5/8-inch E-glass bars

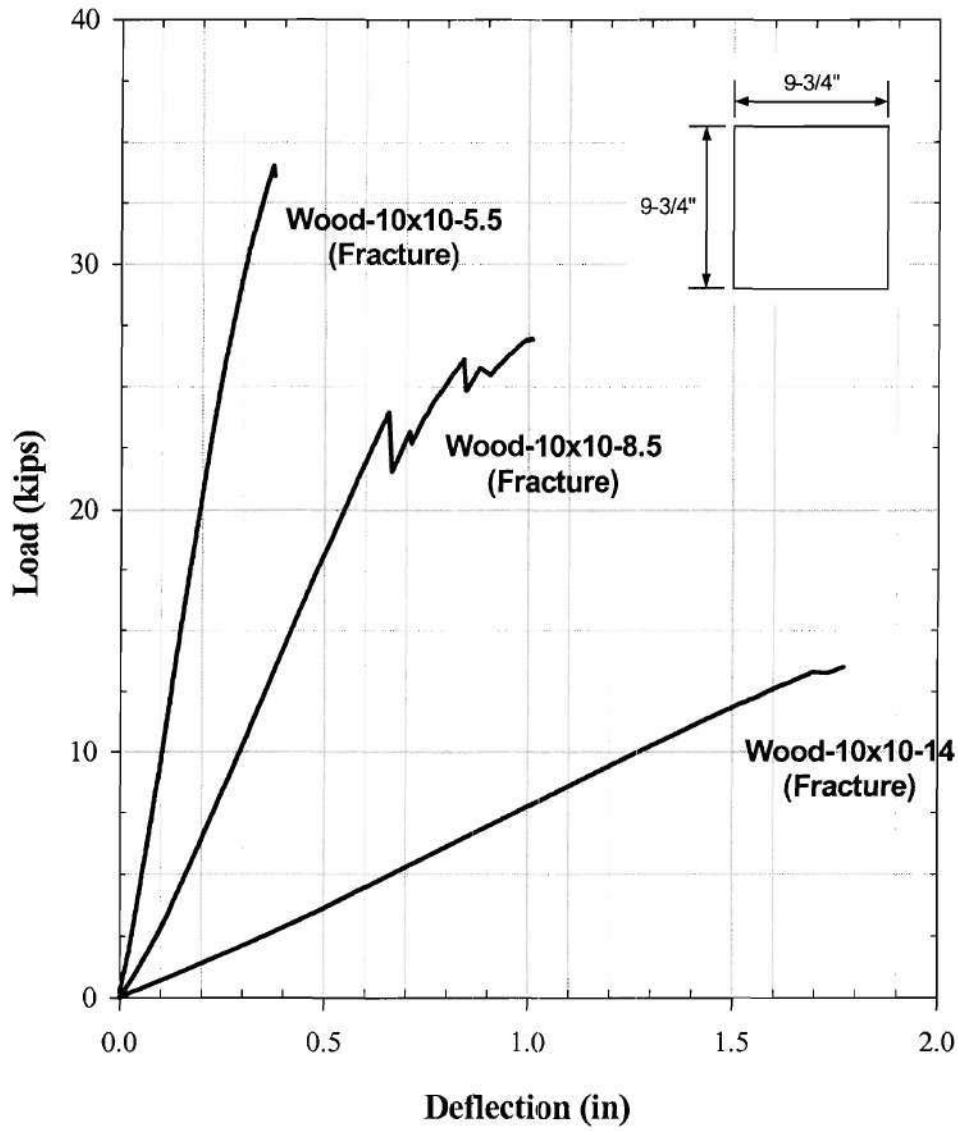


Figure A-20. Load-deflection curves of 10x10 Wood Components

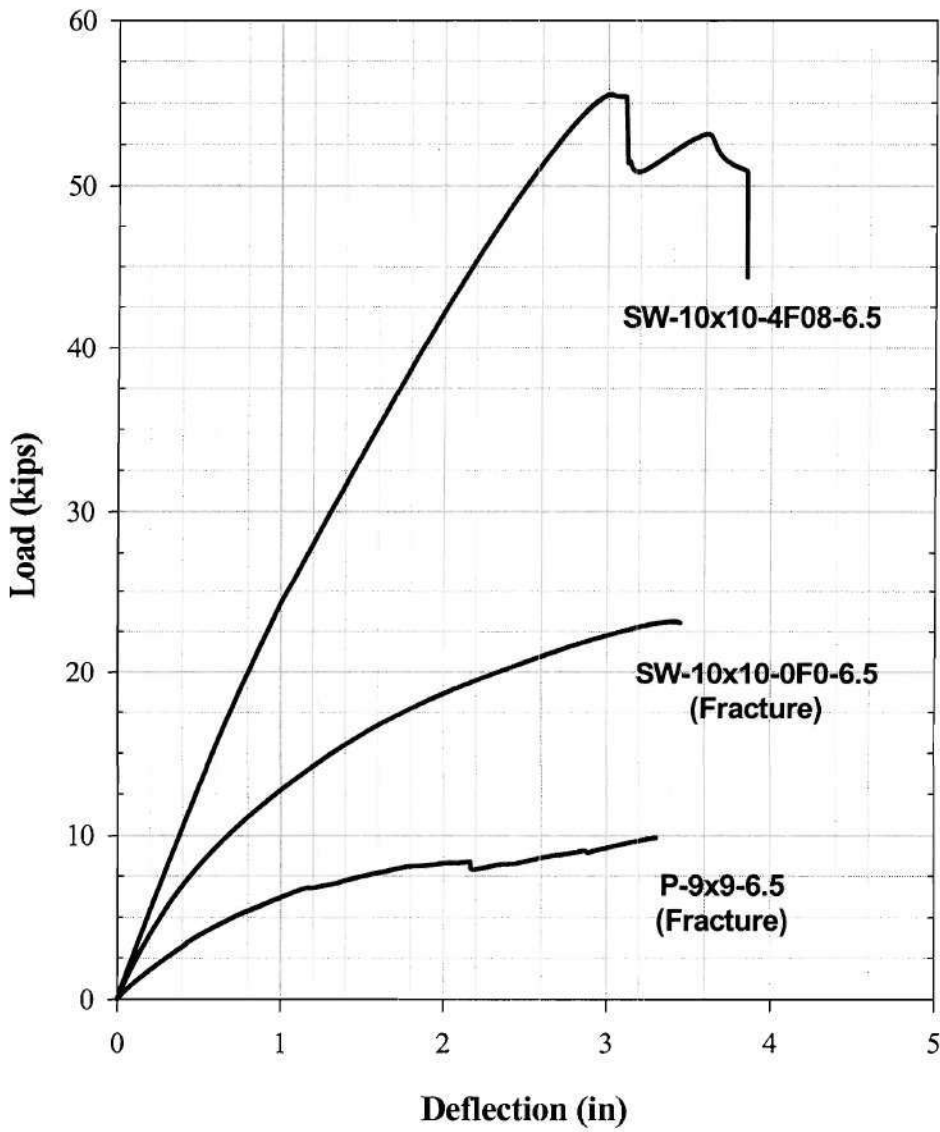


Figure A-21. Comparison of load-deflection curves of Seatimber™ components ant Type-P component

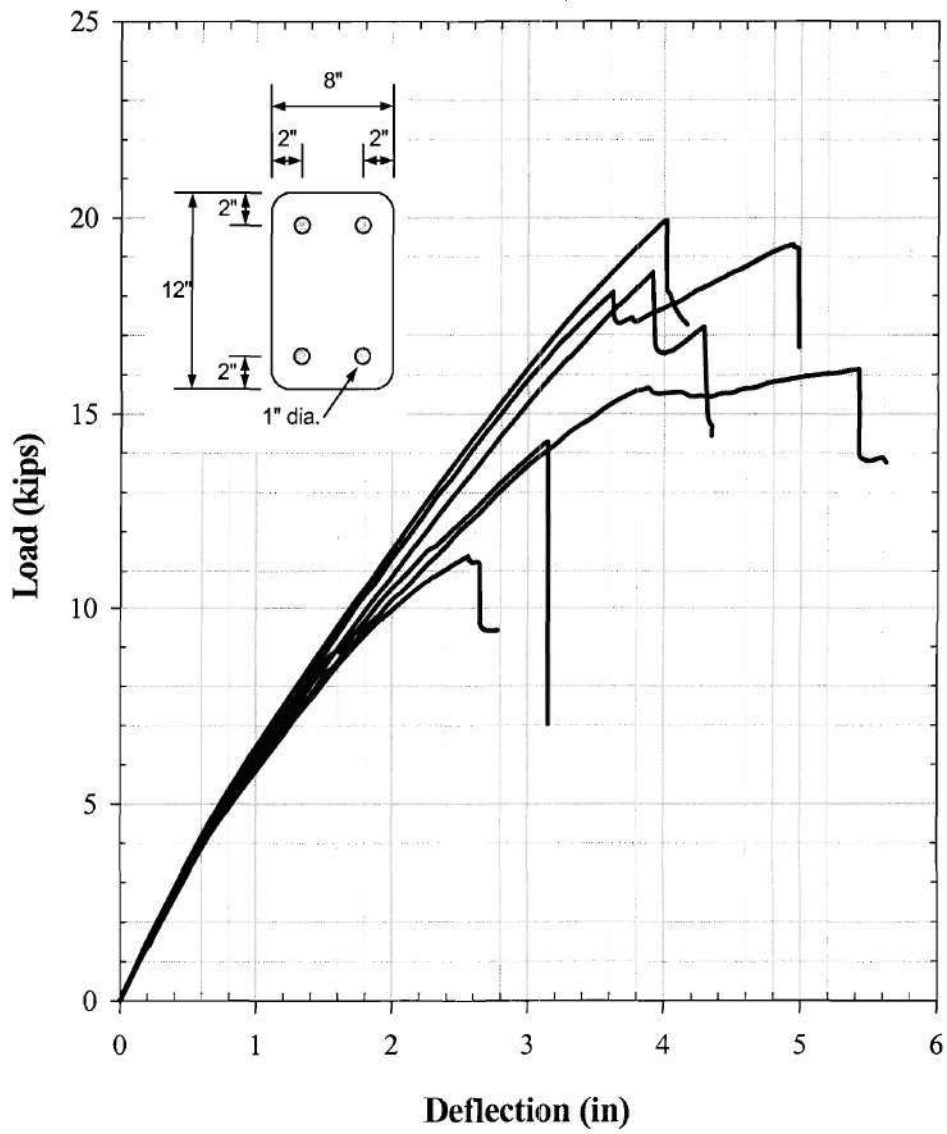


Figure A-22. Comparison of load-deflection curves of 8x12 Seatimber<sup>TM</sup> components (strong axis) with 8.5-foot span

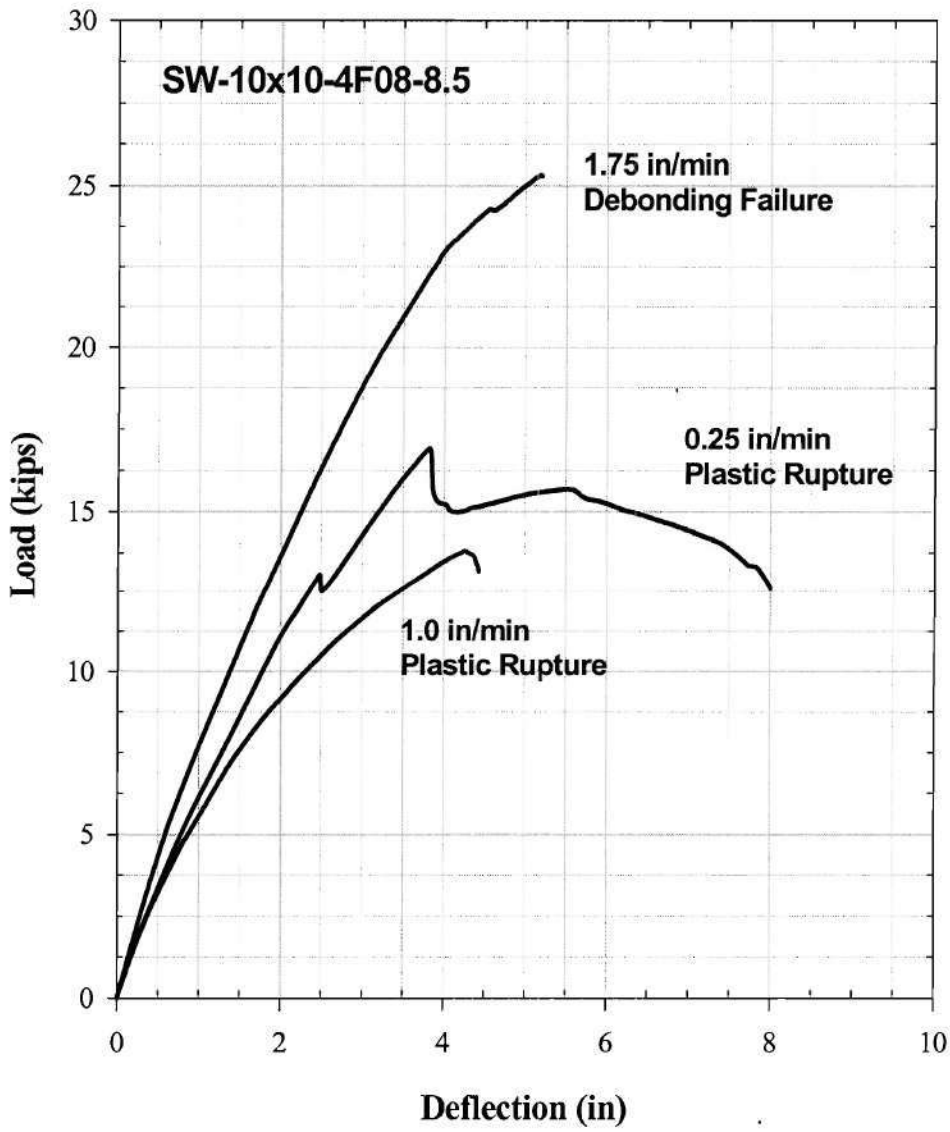


Figure A-23. Load-deflection curves of 10x10 Seatimber™ components with various loading rates