CHELSEA CENTER FOR RECYCLING AND ECONOMIC DEVELOPMENT

UNIVERSITY OF MASSACHUSETTS

# Technical Report # 29

## MATERIAL TESTING OF RECYCLED PLASTIC LANDSCAPING TIMBERS

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# MATERIAL TESTING OF RECYCLED PLASTIC LANDSCAPING TIMBERS

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## CHELSEA CENTER FOR RECYCLING AND ECONOMIC DEVELOPMENT TECHNICAL RESEARCH PROGRAM

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The Chelsea Center for Recycling and Economic Development, a part of the University of Massachusetts' Center for Environmentally Appropriate Materials, was created by the Commonwealth of Massachusetts in 1995 to create jobs, support recycling efforts, and help the economy and the environment by increasing the use of recyclables by manufacturers. The mission of the Chelsea Center is to develop an infrastructure for a sustainable materials economy in Massachusetts, where businesses will thrive that rely on locally discarded goods as their feedstock and that minimize pressure on the environment by reducing waste, pollution, dependence on virgin materials, and dependence on disposal facilities. Further information can be obtained by writing the Chelsea Center for Recycling and Economic Development, 180 Second Street, Chelsea, MA 02150.

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## 1. Abstract

A research project was conducted to test the material properties of recycled plastic landscape timbers manufactured by SelecTech, Inc. of Taunton, MA for the purpose of evaluating the suitability of the timbers for retaining wall construction. Four-point flexural tests were used to evaluate the moment resistance characteristics of the timbers. The performance of the timbers was compared with theoretical performance of traditional wood timbers. As expected, the timbers were more flexible and had a lower moment resistance capacity, but the performance more than exceeded any expected loads when used in typical residential and commercial landscape retaining walls not exceeding eight feet in height.

## 2. Background

As part of the *Chelsea Center for Recycling and Economic Development's* mission, researchers at the University of Massachusetts were approached to investigate the feasibility of using recycled plastic landscape timbers (RPLT) manufactured by SelecTech, Inc. of Taunton, MA. The purpose of the testing was to determine the strength of the timbers as compared to conventional wood landscape timbers, and to establish the feasibility of using such timbers in the construction of typical landscape retaining walls.

The expected market for the RPLTs would be for professional and homeowner installation. These walls would typically not exceed eight feet in height. Therefore, the testing was designed to evaluate performance of the loading associated with walls of this height. The RPLTs are injection molded with an open interior baffle structure. Although the cross-section isn't uniform, the overall performance was compared with the performance of solid cross-section wood timbers.

## 3. Description of Approach to Work and Work Completed

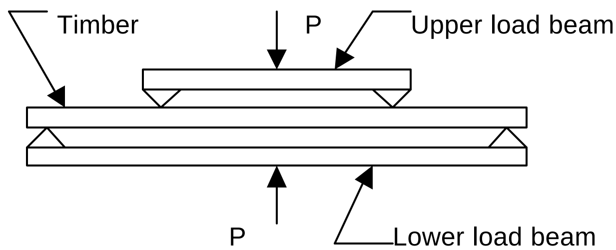
To evaluate the comparative strength, four-point flexural tests in the vertical and transverse horizontal direction were be done on the RPLTs. Thirty-three RPLT's were tested. The test program was done at the University of Massachusetts Amherst in the Geotechnical Engineering Laboratories of the Department of Civil and Environmental Engineering. Descriptions of the RPLTs used in the laboratory tests and the test procedure is described in the following sections.

### 3.1 Recycle Plastic Landscape Timbers

The RPLTs provided by Selectech came from two different batches. The batches could be best characterized by color. There were twelve timbers of a light brown color, identified as batch A. Twenty-one timbers of a medium brown color were identified as batch B. All of the timbers were otherwise constructed identically. The timbers each measured 96 in (244 cm) in length and nominally 5.5 x 5.5 $in^2$ (14.0 x 14.0 $cm^2$) in cross-section. These dimensions are typical of commercially available wood landscape timbers. The timbers were all manufactured with dowel holes so that they could be connected using reinforcing bars (rebars). The largest span between two adjacent holes is 18.75 in (47.6 cm). This structure allows for a typical configuration of 24 in (61.0 cm) spacing. This spacing is important, because the narrower the span, the lower the bending moment that would result from the lateral earth pressure of the earth behind the wall. The bottom of the RPLT is open, and therefore, one would expect a difference between vertical and horizontal capacity. This was addressed in the test program.

### 3.2 Test Apparatus, Setup, and Procedure

The recycled plastic timbers were all tested on an Instron 4468 load frame. The load frame was equipped with a fixture to allow for four-point loading to develop pure bending failure in the mid-span of the timber. A schematic of the fixture is shown in Figure 1. The fixture was set to provide a constant maximum bending moment across the central portion of the beam. Therefore, if the beam were to fail, it would fail somewhere in that mid-span. The distance between loading points was arbitrarily set so that the span between the lower supports was 54 in (137 cm) and the span between the upper load points was 25 in (73.7 cm).




Schematic not to scale

**Figure 1**
**Rough Schematic of the Four-Point Loading Fixture for the Instron Load Frame**

All of the timbers were first tested in the vertical direction. The intention was to deflect the RPLT at least 2.0 in (5.1 cm).

### 4. Results

All of the beams were tested with loading in the vertical direction first. This is the most flexible direction of bending as there is no membrane on the bottom of the RPLT. The results of the vertical loading tests are shown in Table 1 in the Appendix. The load deformation curves are shown in Figures 2 and 3. Analysis of the data indicates that the timbers had sufficient strength for use in a landscape retaining wall. The maximum bending moment across the mid-span of the RPLT exceeded 575 ft-lb in every test and averaged 1030 ft-lbs. If rebars are placed at 24 inch centers, the maximum bending moment resulting from a distributed load based on active pressure for an eight foot wall with typical soil and poor drainage conditions would be one-tenth that of the lowest test results. To calculate the lateral pressure (active pressure and hydrostatic pressure) the following equation is used,

$$\sigma_h = \gamma h \times \tan^2(45° - \frac{\phi}{2}) + \gamma_w h_w$$

where $\sigma_h$ is the horizontal pressure, $\gamma$ is the unit weight of the soil, $h$ is the height of the wall, $\phi$ is the friction angle of the soil, $\gamma_w$ is the unit weight of water and $h_w$ is the height of the water table as measured from the bottom of the retaining wall. If the wall is eight feet tall and the water table is at the top of the wall (worst case, saturated condition), $\sigma_h$ would equal 831 psf (39.8 kPa). Considering that the RPLT is 5.5 inches in height, the distributed load would be equivalent to 381 lb/ft (5.56 kN/m). The RPLT should behave like a continuous beam with multiple simple supports. A worse case analysis could be done by modeling the 24 inch span as a single, simply supported beam with a distributed load. The maximum bending moment will then be,

$$M_{\max} = \frac{wL^2}{8}$$

where $w$ is the distributed load and $L$ is the distance between simple supports. It should be noted that a continuous beam would have $M_{max}$ values about half that of this case. Even with this worst case calculation, $M_{max}$ for the eight foot retaining wall would be one order of magnitude less than the lowest bending moment developed during the tests. In addition, the expected deflection would be less than 0.25 in (6 mm).

Comparison of the allowable load for the wooden timbers and the maximum loads for the RPLTs are shown in Table 2 of the Appendix. When the RPLTs were compared with wooden timbers, the wooden timbers were an order of magnitude stiffer and stronger. The secant spring constant for the RPLT timbers loaded vertically, were in the range of 713-1478 lbs/in with a mean value of 1162 lbs/in. The transverse load tests (shown in Tables 3 and 4) resulted in lower secant spring constant values (700-830 lbs/in with a median value of 752 lbs/in) most likely because the timbers may have been softened by the initial vertical tests. The wooden timbers would have a secant spring constant of 28,837 lbs/in. But when compared with the types of loads one would expect under typical usage, the RPLTs were more than adequate for the application.

The two batches of timbers behaved differently. The lighter colored batch (batch A) was more brittle and fractured along the mid-span joint in 4 of 12 tests. The darker colored batch (batch B) only fractured in 4 of 21 tests. It is also important to note that the RPLTs all sustained some minor plastic deformation that resulted in the inability of some RPLTs not being able to be tested in the transverse direction. This was considered not significant for the following reasons: first, the direction in which the timber was loaded was the more flexible direction; second, the results of the tests that were conducted indicated that the transverse load yielded stiffer and stronger results. The transverse test data are shown in Figures 4 and 5. Note that only two timbers from Batch A and six timbers from Batch B were tested with transverse loading. Only timbers that showed no indication of the initiation of cracks were tested. Still, there was most likely softening and weakening of the RPLT timbers from the vertically loaded tests. The maximum load versus deflection for the vertically loaded timbers is shown in Figures 6 and 7. There is a clear trend that indicates a relatively consistent stiffness (linear distribution of points). This corresponds to a consistent value of the secant spring constant.

## 5. Recommendations for Future Work

Since the findings of this preliminary report indicate that the RPLTs are sufficiently strong and stiff to be used in a typical landscape retaining wall, it is recommended that the next phase of the project be initiated. This phase includes the construction of retaining walls using the RPLTs in various configurations and loads.

## 6. Conclusions

The testing presented in this report constitutes initial testing to determine strength and stiffness of the RPLTs. The strength and stiffness requirements are based on the proposed usage. Typical landscape usage will produce loading conditions that will not approach failure conditions. It is reasonable to expect that timbers used in such applications will perform properly and will not fail.

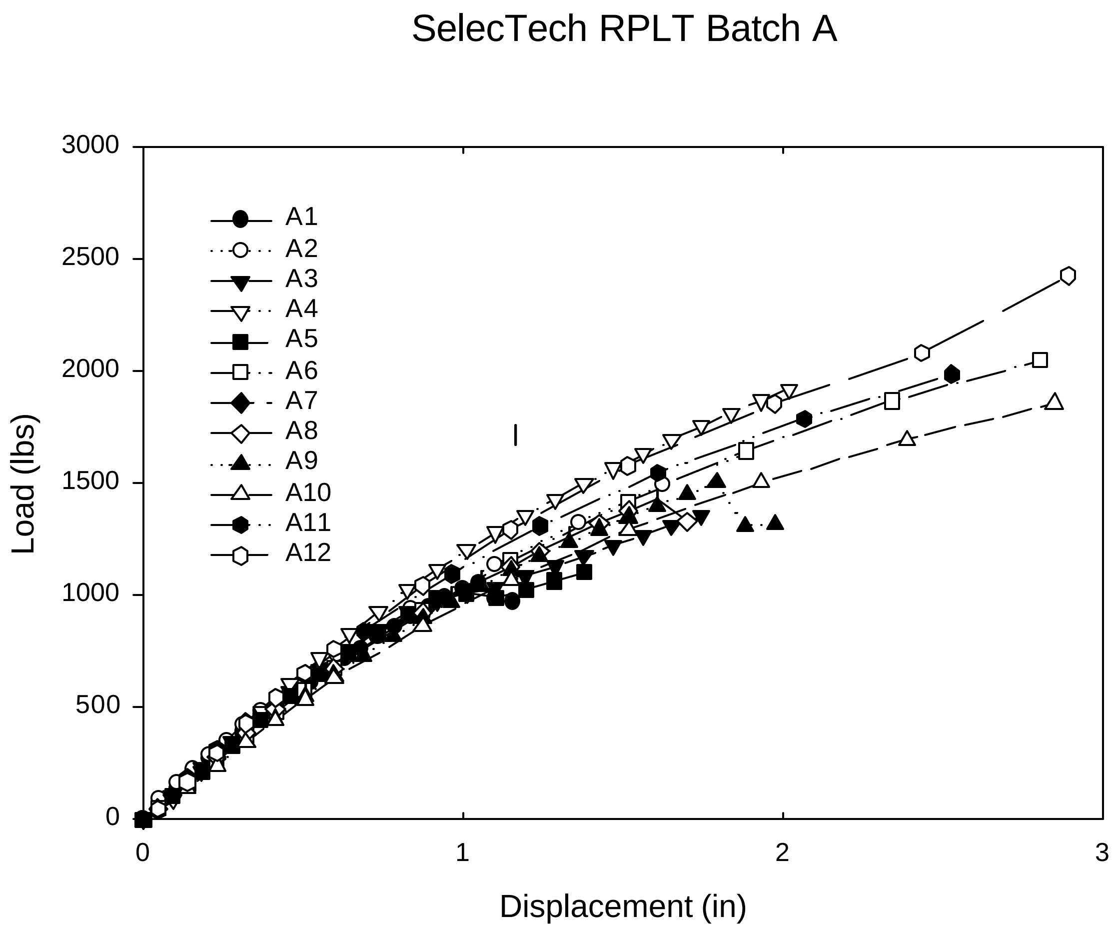



**Figure 2**

**Results of Batch A Vertical Loading Tests for Four-Point Bending**

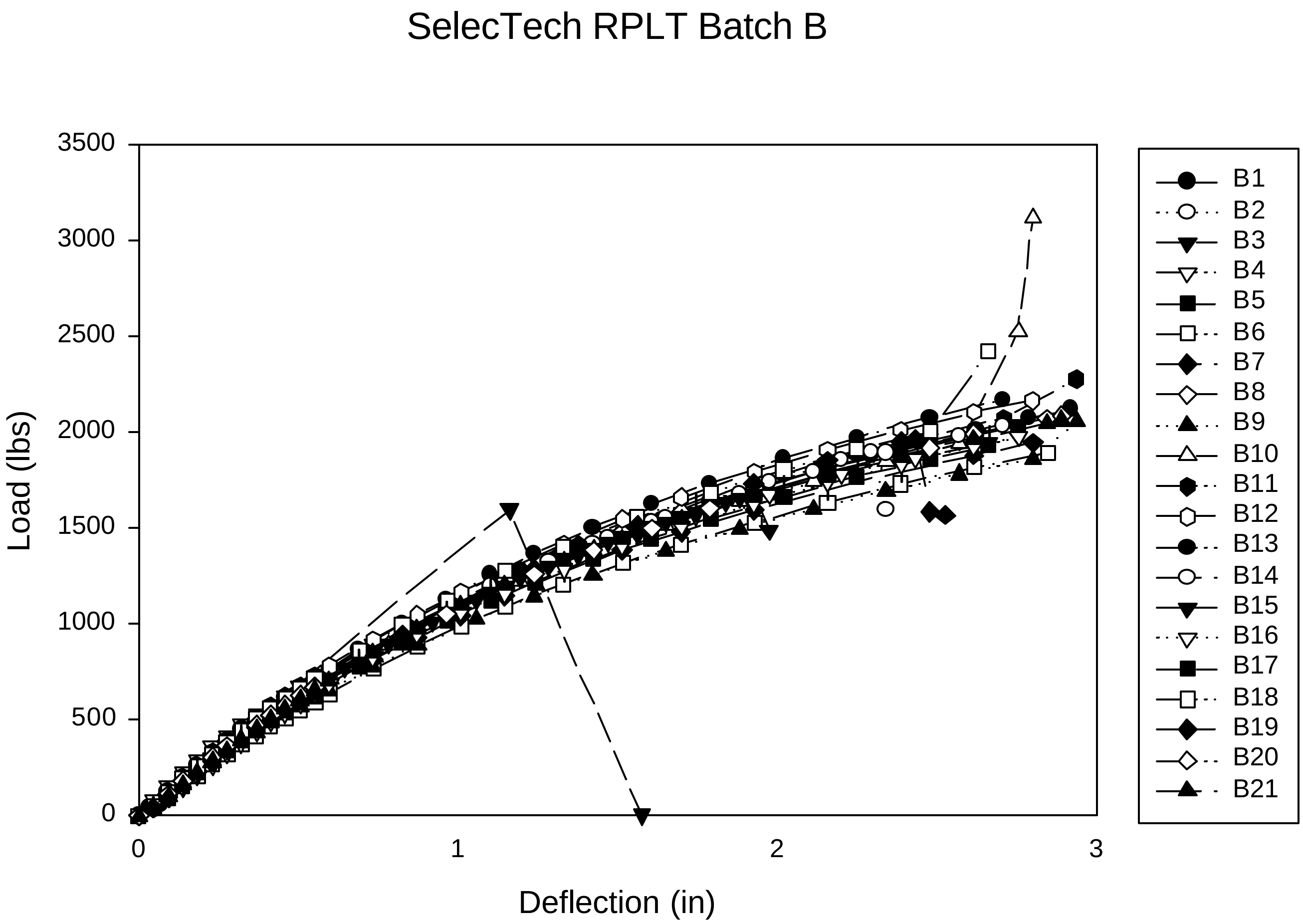



**Figure 3**

**Results of Batch B Vertical Loading Tests for Four-Point Bending**

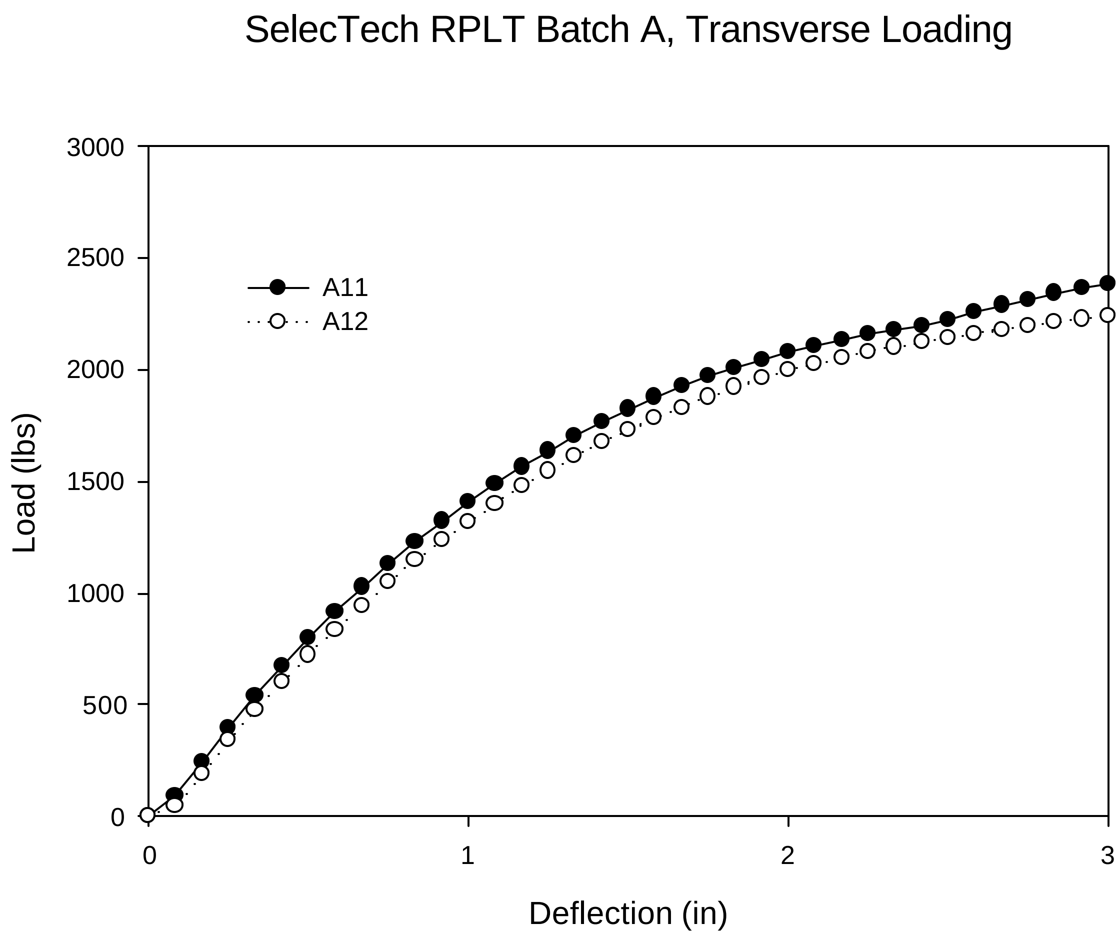



**Figure 4**

**Results of Batch A Transverse Loading Tests for Four-Point Bending**

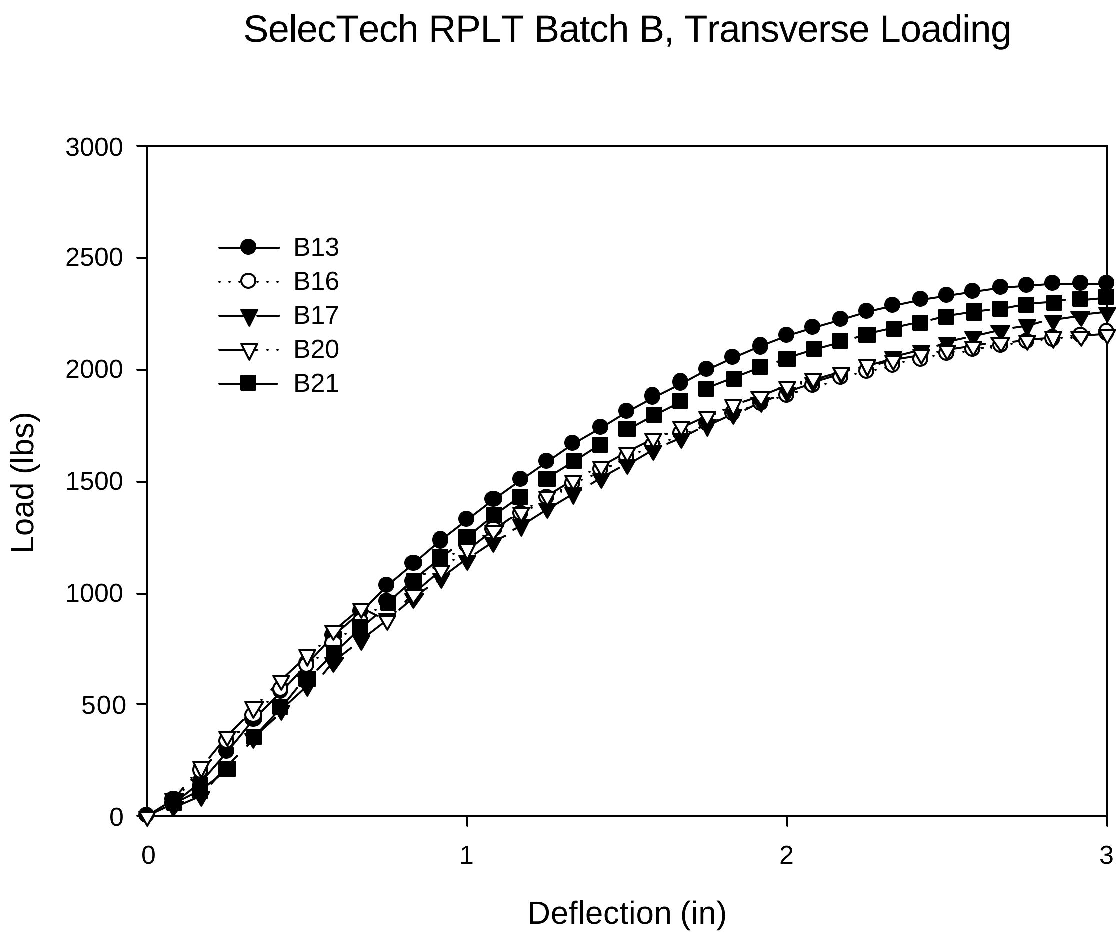



**Figure 5**

**Results of Batch B Transverse Loading Tests for Four-Point Bending**

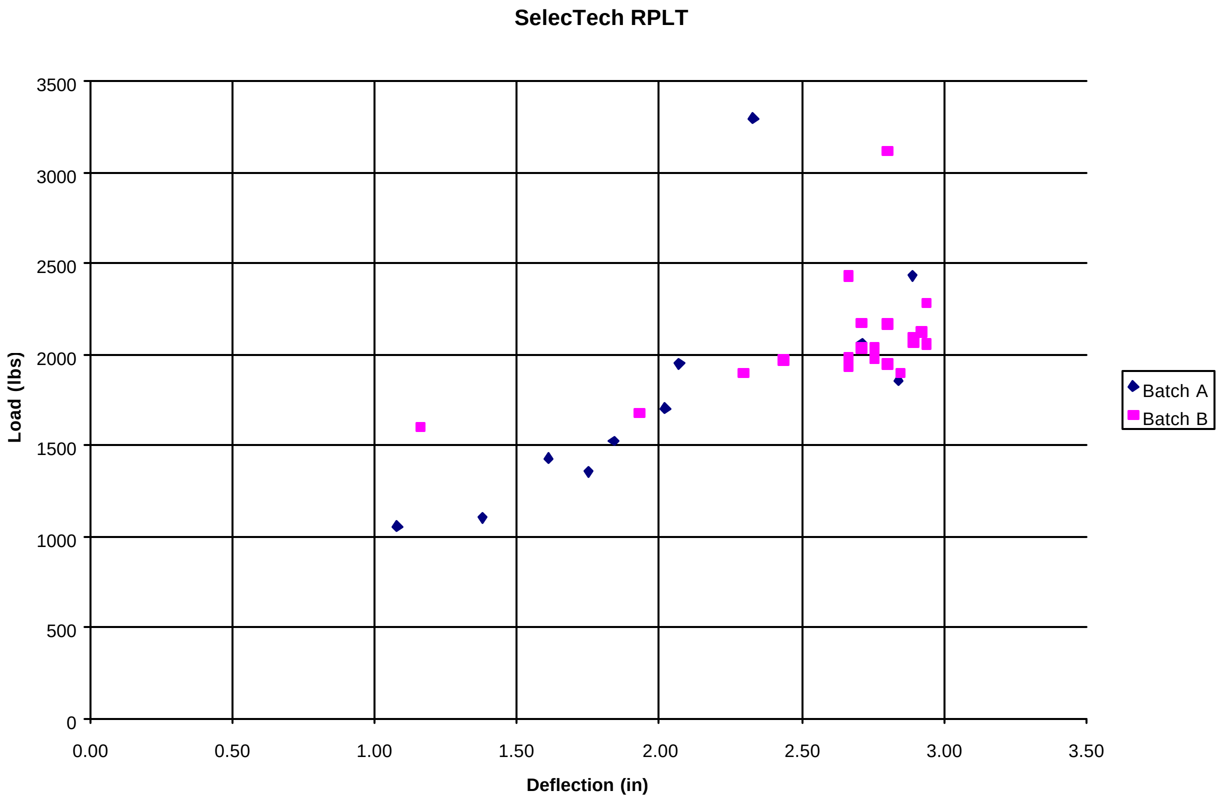



**Figure 6**

**Maximum Vertical Load and Deflection of Batch A Tests**

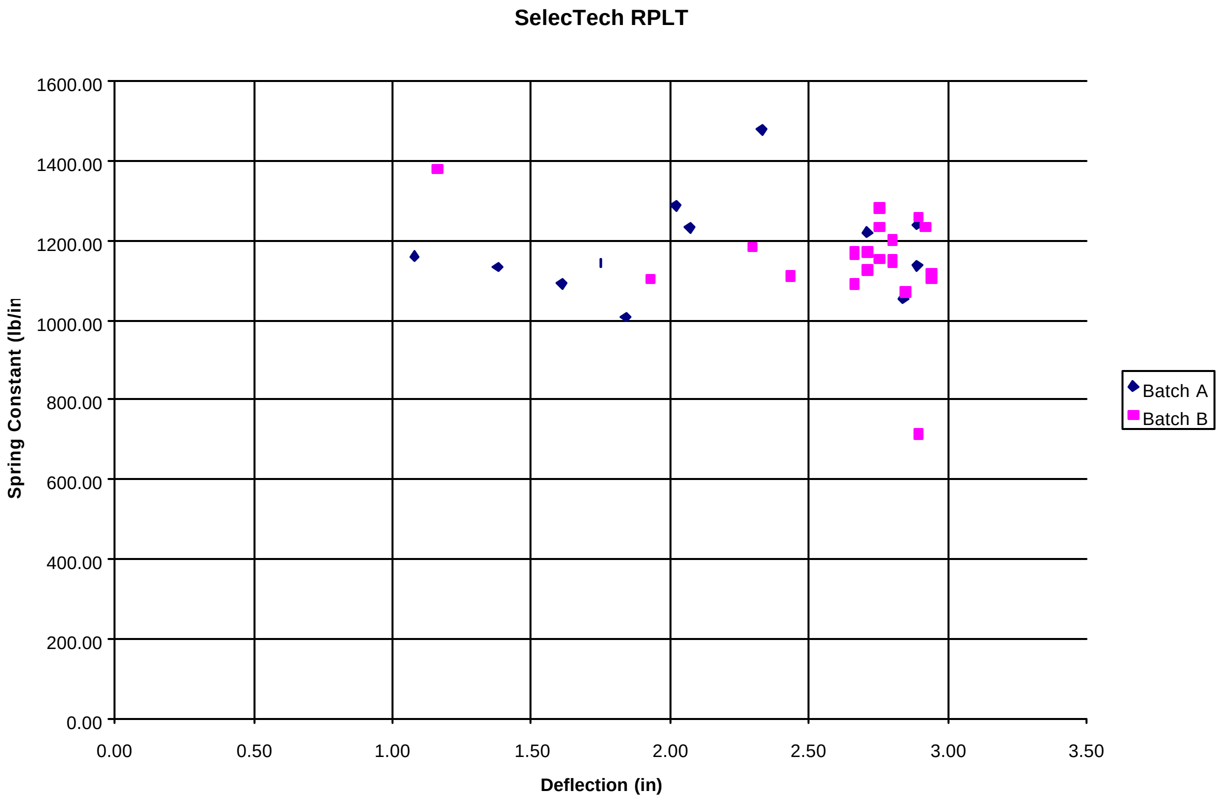



**Figure 7**

**Maximum Vertical Load and Deflection of Batch A Tests**

**Table 1**

**Summary of Vertical Load Test Results**

$P_{max}$ is the maximum load applied by the load frame; δ is the deflection of the midspan of the timber; $\sigma_{eq}$ and $\tau_{eq}$ are the equivalent allowable stresses if the section were solid; $K_t$ is the tangent spring constant for the RPLT.

| BEAM ID | $P_{max}$ (lbs) | δ (in) | Fracture? | $\sigma_{eq}$ in bending (psi) | $\tau_{eq}$ in shear (psi) | $K_t = P_{max}/\delta$ (lbs/in) |
|---|---|---|---|---|---|---|
| A1 | 1054 | 1.08 | Yes | 475 | 52 | 1160 |
| A2 | 1702 | 2.02 | No | 767 | 84 | 1287 |
| A3 | 1354 | 1.75 | No | 610 | 67 | 1144 |
| A4 | 1947 | 2.07 | No | 878 | 97 | 1231 |
| A5 | 1104 | 1.38 | No | 498 | 55 | 1133 |
| A6 | 2080 | 2.89 | No | 938 | 103 | 1136 |
| A7 | 3295 | 2.33 | Yes | 1485 | 163 | 1478 |
| A8 | 1430 | 1.61 | Yes | 645 | 71 | 1092 |
| A9 | 1525 | 1.84 | Yes | 687 | 76 | 1008 |
| A10 | 1858 | 2.84 | No | 838 | 92 | 1054 |
| A11 | 2060 | 2.71 | No | 929 | 102 | 1220 |
| A12 | 2430 | 2.89 | No | 1095 | 121 | 1239 |
| B1 | 2123 | 2.92 | No | 957 | 105 | 1234 |
| B2 | 1897 | 2.30 | Yes | 855 | 94 | 1183 |
| B3 | 1601 | 1.16 | Yes | 722 | 79 | 1380 |
| B4 | 1978 | 2.76 | No | 892 | 98 | 1280 |
| B5 | 2033 | 2.76 | No | 916 | 101 | 1233 |
| B6 | 1897 | 2.85 | No | 855 | 94 | 1070 |
| B7 | 1948 | 2.80 | No | 878 | 97 | 1154 |
| B8 | 2088 | 2.89 | No | 941 | 104 | 1259 |
| B9 | 2060 | 2.94 | No | 928 | 102 | 1103 |
| B10 | 3119 | 2.80 | No | 1406 | 155 | 1145 |
| B11 | 2280 | 2.94 | No | 1028 | 113 | 1118 |
| B12 | 2168 | 2.80 | No | 977 | 107 | 1200 |
| B13 | 2174 | 2.71 | No | 980 | 108 | 1173 |
| B14 | 2037 | 2.71 | No | 918 | 101 | 1127 |
| B15 | 1677 | 1.93 | Yes | 756 | 83 | 1104 |
| B16 | 1978 | 2.76 | No | 892 | 98 | 1153 |
| B17 | 1935 | 2.66 | No | 872 | 96 | 1092 |
| B18 | 2431 | 2.66 | No | 1096 | 121 | 1165 |
| B19 | 1965 | 2.43 | Yes | 886 | 97 | 1112 |
| B20 | 1986 | 2.66 | No | 895 | 98 | 1171 |
| B21 | 2064 | 2.89 | No | 930 | 102 | 713 |

**Table 2**

**Comparison of Recycled Plastic Landscape Timber Test Results and Douglas Fir Timbers of Equivalent Nominal Dimensions Loaded Vertically**

$P_{max}$ is the maximum applied load during the flexural test; $\delta_{all}$ is the deflection of an equivalent douglas fir timber loaded to $P_{max}$; $\delta$ is the deflection at maximum load (note that this was the maximum deflection of the test aparatus); $P_{all}$ is the load needed for the douglas fir timber to deflect the same amount that the RPLT deflected ($\delta$); $K_{wood}$ is the secant spring constant of the douglas fir timber.

| BEAM ID. | $P_{max}$ (lbs) | $\delta_{all}$ (in) | $\delta$ (in) | $P_{all}$ (lbs) | $K_{wood}$ (lbs/in) |
|---|---|---|---|---|---|
| A1 | 1054 | 0.04 | 1.08 | 31144 | 28837 |
| A2 | 1702 | 0.06 | 2.02 | 58250 | 28837 |
| A3 | 1354 | 0.05 | 1.75 | 50464 | 28837 |
| A4 | 1947 | 0.07 | 2.07 | 59692 | 28837 |
| A5 | 1104 | 0.04 | 1.38 | 39795 | 28837 |
| A6 | 2080 | 0.07 | 2.89 | 83338 | 28837 |
| A7 | 3295 | 0.11 | 2.33 | 67189 | 28837 |
| A8 | 1430 | 0.05 | 1.61 | 46427 | 28837 |
| A9 | 1525 | 0.05 | 1.84 | 53059 | 28837 |
| A10 | 1858 | 0.06 | 2.84 | 81896 | 28837 |
| A11 | 2060 | 0.07 | 2.71 | 78147 | 28837 |
| A12 | 2430 | 0.08 | 2.89 | 83338 | 28837 |
| B1 | 2123 | 0.07 | 2.92 | 84201 | 28837 |
| B2 | 1897 | 0.07 | 2.30 | 66223 | 28837 |
| B3 | 1601 | 0.06 | 1.16 | 33494 | 28837 |
| B4 | 1978 | 0.07 | 2.76 | 79470 | 28837 |
| B5 | 2033 | 0.07 | 2.76 | 79469 | 28837 |
| B6 | 1897 | 0.07 | 2.85 | 82119 | 28837 |
| B7 | 1948 | 0.07 | 2.80 | 80794 | 28837 |
| B8 | 2088 | 0.07 | 2.89 | 83443 | 28837 |
| B9 | 2060 | 0.07 | 2.94 | 84767 | 28837 |
| B10 | 3119 | 0.11 | 2.80 | 80796 | 28837 |
| B11 | 2280 | 0.08 | 2.94 | 84769 | 28837 |
| B12 | 2168 | 0.08 | 2.80 | 80794 | 28837 |
| B13 | 2174 | 0.08 | 2.71 | 78144 | 28837 |
| B14 | 2037 | 0.07 | 2.71 | 78144 | 28837 |
| B15 | 1677 | 0.06 | 1.93 | 55625 | 28837 |
| B16 | 1978 | 0.07 | 2.76 | 79470 | 28837 |
| B17 | 1935 | 0.07 | 2.66 | 76821 | 28837 |
| B18 | 2431 | 0.08 | 2.66 | 76820 | 28837 |
| B19 | 1965 | 0.07 | 2.43 | 70195 | 28837 |
| B20 | 1986 | 0.07 | 2.66 | 76821 | 28837 |
| B21 | 2064 | 0.07 | 2.89 | 83443 | 28837 |

**Table 3**

**Summary of Transverse Load Test Results**

$P_{max}$ is the maximum load applied by the load frame; $\delta$ is the deflection of the midspan of the timber; $\sigma_{eq}$ and $\tau_{eq}$ are the equivalent allowable stresses if the section were solid; $K_t$ is the secant spring constant for the RPLT.

| BEAM ID. | $P_{max}$ (lbs) | $\delta$ (in) | Fracture? | $\sigma_{eq}$ in bending (psi) | $\tau_{eq}$ in shear (psi) | $K_t = P_{max}/\delta$ (lbs/in) |
|---|---|---|---|---|---|---|
| A11 | 2404 | 3.08 | No | 1084 | 119 | 781 |
| A12 | 2254 | 3.08 | No | 1016 | 112 | 732 |
| B13 | 2557 | 3.08 | No | 1153 | 127 | 830 |
| B16 | 2174 | 3.08 | No | 981 | 108 | 706 |
| B17 | 2336 | 3.08 | No | 1054 | 116 | 758 |
| B20 | 2157 | 3.08 | No | 923 | 107 | 700 |
| B21 | 2334 | 3.08 | No | 1053 | 116 | 758 |

**Table 4**

**Comparison of Recycled Plastic Landscape Timber Test Results And Douglas Fir Timbers of Equivalent Nominal Dimensions Loaded Transversely**

$P_{max}$ is the maximum applied load during the flexural test; $\delta_{all}$ is the deflection of an equivalent douglas fir timber loaded to $P_{max}$; $\delta$ is the deflection at maximum load (note that this was the maximum deflection of the test aparatus); $P_{all}$ is the load needed for the douglas fir timber to deflect the same amount that the RPLT deflected ($\delta$); $K_{wood}$ is the secant spring constant of the douglas fir timber.

| BEAM ID. | $P_{max}$ (lbs) | $\delta_{all}$ (in) | $\delta$ (in) | $P_{all}$ (lbs) | $K_{wood}$ (lbs/in) |
|---|---|---|---|---|---|
| A11 | 2404 | 0.08 | 3.08 | 88818 | 28837 |
| A12 | 2254 | 0.08 | 3.08 | 88818 | 28837 |
| B13 | 2557 | 0.09 | 3.08 | 88818 | 28837 |
| B16 | 2174 | 0.08 | 3.08 | 88818 | 28837 |
| B17 | 2336 | 0.08 | 3.08 | 88818 | 28837 |
| B20 | 2157 | 0.07 | 3.08 | 88818 | 28837 |
| B21 | 2334 | 0.08 | 3.08 | 88818 | 28837 |