AN EXAMINATION OF DEFECTIVE OREGON
(*PSEUDOTSUGA TAXIFOLIA*).

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With Plates XXI-XXIII.

(Read before the Royal Society of New South Wales, 5th Dec., 1928.)

Oregon or Douglas Fir, *Pseudotsuga taxifolia* (Lam.) Britton (*P. Douglasii* Carr), is usually regarded as a strong tough wood and is used extensively in building construction for scantlings, scaffoldings, etc. Recently an Oregon back stay of an electric derrick crane, which was being used in demolition work, broke suddenly and without warning, whilst under load, resulting in a very serious accident. The defective timber was submitted by the Scaffolding and Lifts Branch of the Department of Labour and Industry of New South Wales for examination. Since Oregon is used so largely for purposes in which it is subjected to heavy loads, it was thought advisable to examine the wood fairly thoroughly in order to determine, if possible, the cause of failure. The wood appeared to be quite normal and its external appearance gave no indication of its brittleness.

The broken wood showed a typically brash failure which was almost without splinters and unlike the "long-fibre break" usually obtained for Oregon. Brashness or brittleness is a most serious defect in timber, since under load the wood is liable to fail suddenly and the absence of warning often results in serious consequences; the wood is especially liable to rupture under sudden or impact loads.
Additional static bending tests were made subsequently, on 2" x 2" x 28" span*. It will be noted that the moisture content has decreased.

The following static bending tests were made on 3" x 3" x 36" span, centre load. The test pieces were cut to this size to include as much as possible of the cross section of the beam, which measured 7.6" x 6.6". Four test pieces were therefore obtained.

<table>
<thead>
<tr>
<th>f</th>
<th>E</th>
<th>D</th>
<th>r.p.i</th>
<th>L.W.</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7000</td>
<td>1,700,000</td>
<td>32.4</td>
<td>6.3</td>
<td>24</td>
</tr>
<tr>
<td>2</td>
<td>9000</td>
<td>1,660,000</td>
<td>33.0</td>
<td>8.5</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>8600</td>
<td>1,730,000</td>
<td>33.1</td>
<td>8.0</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>8000</td>
<td>1,720,000</td>
<td>34.4</td>
<td>9.3</td>
<td>26</td>
</tr>
<tr>
<td>Mean</td>
<td>8150</td>
<td>1,703,000</td>
<td>33.2</td>
<td>8.0</td>
<td>25</td>
</tr>
</tbody>
</table>

\( f \) = Modulus of Rupture in lbs. per sq. in.
\( E \) = Modulus of Elasticity in lbs. per sq. in.
\( D \) = Weight per cubic foot at time of testing; air dry volume and weight.
\( r.p.i. \) = Average number of growth rings per inch.
\( L.W. \) = Percentage of late or summer wood in the growth ring.
\( M \) = Moisture percentage on the dry weight.

The proportional limit was not clearly defined in tests. The failures were carotty and the wood failed in tension without warning.

Two static bending tests were made on the full-sized timber with a span of six feet, centre loading.

<table>
<thead>
<tr>
<th>f</th>
<th>E</th>
<th>r.p.i</th>
<th>L.W.</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4890</td>
<td>1,570,000</td>
<td>Max. 10</td>
<td>26.2</td>
</tr>
<tr>
<td>2</td>
<td>7680</td>
<td>1,570,000</td>
<td>Min. 5</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>6285</td>
<td>1,570,000</td>
<td>8.5</td>
<td></td>
</tr>
</tbody>
</table>

The proportional limit was not defined. The failures were sudden, partially in tension and horizontal shear, and definitely indicated the brashness of the wood.
Additional static bending tests were made subsequently, on 2' x 2' x 28" span* It will be noted that the moisture content has decreased.

<table>
<thead>
<tr>
<th>f1</th>
<th>f</th>
<th>E</th>
<th>W. to W.</th>
<th>D.</th>
<th>r.p.i.</th>
<th>L.W.</th>
<th>M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7350</td>
<td>7930</td>
<td>1,870,000</td>
<td>1.58</td>
<td>2.08</td>
<td>32.0</td>
<td>8.0</td>
<td>24.3</td>
</tr>
<tr>
<td>7980</td>
<td>8820</td>
<td>1,890,000</td>
<td>1.87</td>
<td>2.58</td>
<td>32.2</td>
<td>9.0</td>
<td>28.4</td>
</tr>
<tr>
<td>7350</td>
<td>7480</td>
<td>1,810,000</td>
<td>1.63</td>
<td>1.94</td>
<td>32.3</td>
<td>8.0</td>
<td>28.0</td>
</tr>
<tr>
<td>7140</td>
<td>7715</td>
<td>1,580,000</td>
<td>1.79</td>
<td>2.40</td>
<td>31.3</td>
<td>6.5</td>
<td>24.8</td>
</tr>
<tr>
<td>7455</td>
<td>7990</td>
<td>1,790,000</td>
<td>1.72</td>
<td>2.25</td>
<td>31.9</td>
<td>7.4</td>
<td>26.4</td>
</tr>
</tbody>
</table>

f1 = Fibre stress at proportional limit in lbs. per square inch.

W. to P.L. = Work to proportional limit in inch lbs. per cubic inch.

W. to M.L. = Work to maximum load in inch lbs. per cubic inch.

For comparison the results of the following static bending tests are given, made on small clear specimens from the Technological Museum.

3" x 3" x 36" span centre load.

<table>
<thead>
<tr>
<th>f</th>
<th>E</th>
<th>D.</th>
<th>r.p.i.</th>
<th>L.W.</th>
<th>M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11,620</td>
<td>2,260,000</td>
<td>34.7</td>
<td>16.0</td>
<td>39.6</td>
</tr>
<tr>
<td>2</td>
<td>12,660</td>
<td>2,330,000</td>
<td>35.2</td>
<td>20.5</td>
<td>36.9</td>
</tr>
<tr>
<td>3</td>
<td>13,580</td>
<td>1,670,000</td>
<td>34.2</td>
<td>12.0</td>
<td>34.5</td>
</tr>
<tr>
<td>4</td>
<td>13,060</td>
<td>2,010,000</td>
<td>32.7</td>
<td>12.5</td>
<td>28.6</td>
</tr>
<tr>
<td>5</td>
<td>10,520</td>
<td>1,800,000</td>
<td>36.5</td>
<td>6.5</td>
<td>38.4</td>
</tr>
<tr>
<td>6</td>
<td>8,400</td>
<td>1,770,000</td>
<td>33.2</td>
<td>4.0</td>
<td>35.8</td>
</tr>
<tr>
<td>7</td>
<td>7,660</td>
<td>1,330,000</td>
<td>26.4</td>
<td>4.0</td>
<td>25.2</td>
</tr>
</tbody>
</table>

Mean 11,070 | 1,800,000 | 33.3 | 11.0 | 31.4 | 11.9 |

The following static bending tests were made on 2" x 2" x 28" span clear specimens.

* Tests marked * have been made in conformity with the specification adopted for testing small clear specimens of timber and described in U.S.D.A. Forest Service Bull. 108, and subsequently in Projects I. of the Canadian Forest Product Laboratory and also of the Department of Scientific and Industrial Research, Forest Products Research, of Great Britain, 1928.
Compression parallel to grain.

\[
\begin{array}{cccccc}
\text{CI} & \text{C} & \text{B} & \text{r.p.i.} & \text{M} \\
\text{Maximum} & . & . & 5,500 & 7430 & 1,250,000 & 9 & — \\
\text{Minimum} & . & . & 3,875 & 6230 & 833,000 & 6.5 & — \\
\text{Mean 12 tests} & 11,520 & 1,790,000 & 31.9 & 22.3 & 12.3 \\
\end{array}
\]

Canada \(^{(1)}\) and American \(^{(2)}\) mean tests for static bending tests on 2" x 2" x 28" span air dry clear specimens are as follows:

\[
\begin{array}{cccccccc}
\text{f1} & \text{f} & \text{E} & \text{P.L.} & \text{M.L.} & \text{D+} & \text{r.p.i.} & \text{L.W.} & \text{M} \\
\text{Mountain (1)} & 8,460 & 13,340 & 1,664,000 & 2.44 & 8.40 & 31.4 & 26.2 & 25.0 & 9.5 \\
\text{Mountain (1)} & 9,540 & 13,620 & 1,806,000 & 2.86 & 11.80 & 33.2 & 17.4 & 32.0 & 10.7 \\
\text{Coast (1)} & 8,990 & 14,050 & 2,142,000 & 2.20 & 9.90 & 33.4 & 13.3 & 38.0 & 11.1 \\
\text{Wyoming (2)} & 6,900 & 10,300 & 1,460,000 & 1.83 & 6.5 & 33.6 & 22.0 & 27.0 & 9.4 \\
\text{Oregon (2)} & 10,600 & 14,000 & 2,210,000 & 2.94 & 8.4 & 38.1 & 13.0 & 35.0 & 6.2 \\
\text{U.S.A. (3)} & 5,065 & 6,777 & 1,853,000 & — & — & 31.0 & 12.2 & 41.0 & 14.9 \\
\end{array}
\]

\(^{(1)}\) Some Commercial Softwoods of Canada. Forest Service Bulletin No. 78, Dept. of Interior, Canada, 1927.


+ Corrected to 12% moisture.

Impact Tests.

Izod impact tests were made in conformity with the British Engineering Standard Association Specification for Aircraft Material.

Energy absorbed in foot lbs. r.p.i. M

\[
\begin{array}{cccc}
\text{Maximum} & . & . & 15 & — \\
\text{Minimum} & . & . & 2 & — \\
\text{Mean 6 tests} & . & . & 8.3 & 15% \\
\end{array}
\]

Tests made on Oregon in stock gave the following results:

r.p.i. M D

\[
\begin{array}{cccc}
\text{Maximum} & . & . & 28 \text{ ft. lbs.} & 35 & 11.3% & 34.2 \text{lbs.} \\
\text{Minimum} & . & . & 17.5 \text{ } & 12 & 9.8% & 25.4 \text{ } \\
\text{Mean (12 tests)} & . & . & 23.0 \text{ } & 22 & 10.6% & 31.2 \text{ } \\
\end{array}
\]
*Compression parallel to grain.

<table>
<thead>
<tr>
<th></th>
<th>Cl</th>
<th>C</th>
<th>E</th>
<th>r.p.i.</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>.</td>
<td>5,500</td>
<td>7430</td>
<td>1,250,000</td>
<td>9</td>
</tr>
<tr>
<td>Minimum</td>
<td>.</td>
<td>3,875</td>
<td>6230</td>
<td>833,000</td>
<td>6.5</td>
</tr>
<tr>
<td>Mean (6 tests)</td>
<td>.</td>
<td>4,685</td>
<td>6695</td>
<td>999,000</td>
<td>8.5</td>
</tr>
</tbody>
</table>

C1 = Fibre stress at limit of proportionality in lbs. per square inch.
C = Maximum crushing strength in lbs. per square inch.

Canada (l.e.) .. | 4220 | 7600 | 2,229,000 | 19 | 10.4 |
U.S.A. (l.e.) .. | 7290 | 8885 | — | — | — |

*Compression perpendicular to grain.

Fibre stress at limit of proportionality in lbs. per sq. in.: 

<table>
<thead>
<tr>
<th></th>
<th>(a)</th>
<th>(b)</th>
<th>r.p.i.</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>.</td>
<td>..</td>
<td>1440</td>
<td>8.5</td>
</tr>
<tr>
<td>Minimum</td>
<td>.</td>
<td>..</td>
<td>1325</td>
<td>6.0</td>
</tr>
<tr>
<td>Mean (5 tests)</td>
<td>.</td>
<td>..</td>
<td>1370</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Canada (l.e.) .. | .. | 997 | 19 | 10.4 |
U.S.A. (l.e.) .. | .. | 860 | 17.5 | 7.8 |

Tension parallel to grain.

<table>
<thead>
<tr>
<th>Area in sq. in.</th>
<th>Breaking Load in lbs. per sq. in.</th>
<th>r.p.i.</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.7651</td>
<td>3850</td>
<td>9.0</td>
</tr>
<tr>
<td>2</td>
<td>0.7543</td>
<td>6995</td>
<td>9.0</td>
</tr>
<tr>
<td>3</td>
<td>0.7466</td>
<td>7640</td>
<td>7.0</td>
</tr>
<tr>
<td>4</td>
<td>0.7698</td>
<td>8060</td>
<td>10.5</td>
</tr>
<tr>
<td>Mean</td>
<td>6636</td>
<td>9.0</td>
<td>13.5</td>
</tr>
</tbody>
</table>

Koehler† gives the following mean figures for tension parallel to grain.

1. 16,200 lbs. sq. in.  
   \[ M = 24.1\% \]  
   \[ D = 33 \text{ lbs.} \]
2. 13,300 lbs.  
   \[ M = 23.0\% \]  
   \[ D = 30 \text{ lbs.} \]

† Koehler Properties and Uses of Woods, 1924.
One of the most important requirements in a timber which is subject to loads is toughness. The term is applied to a number of different properties of wood, but can be regarded as the reverse of brittleness; it is indicated by (a) the ability of the wood to absorb energy in impact tests, (b) the work to maximum load in static bending tests.

An examination of the results of the static bending tests shows that the modulus of rupture is small in comparison with the other tests on small clear specimens, but the figure is not abnormally low. The most striking result is the small interval between the proportional limit and the ultimate load, which is a definite indication of brittleness.

Further, although the resilience of the wood is normal, the work to maximum load is very low, indicating again a brittle timber. Similarly, the impact tests, with an

Den Berger, Mechanical Properties of Dutch East Indian Timbers, No. 12. Proefstation v/h. Boschwezen, 1926, refers to a tough wood as "one that will not rupture until it has deformed considerably under loads at or near its maximum strength or one which still hangs together after it has been ruptured and may be bent back and forth without breaking apart, and which gives way only gradually and gives warning of rupture. It is able to store a considerable amount of energy and has a remarkable shock resisting ability."

*Shearing Strength parallel to grain.*

<table>
<thead>
<tr>
<th></th>
<th>(a)</th>
<th>(b)</th>
<th>(a)</th>
<th>(b)</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>1490</td>
<td>1420 lbs. per sq. in.</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>812</td>
<td>1030</td>
<td>6.5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Mean (6 tests)</td>
<td>1190</td>
<td>1266</td>
<td>7.3</td>
<td>8.1</td>
<td>12.7%</td>
</tr>
</tbody>
</table>

(a) Plane of failure radial.
(b) Plane of failure tangential.
<p>*Cleavage.</p>

<table>
<thead>
<tr>
<th></th>
<th>S(a)</th>
<th>S(b)</th>
<th>(a)</th>
<th>(b)</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>190</td>
<td>140</td>
<td>9.0</td>
<td>8.0</td>
<td>12.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>120</td>
<td>160</td>
<td>6.5</td>
<td>6.5</td>
<td>12.7</td>
</tr>
<tr>
<td>Mean (6 tests)</td>
<td>141</td>
<td>152</td>
<td>7.4</td>
<td>7.3</td>
<td>12.7</td>
</tr>
</tbody>
</table>

S = Splitting Strength in lbs. per in. of width.
(a) = Plane of failure radial.
(b) = Plane of failure tangential.

Canada (1.c.) .. (a) & (b) 265 19 10.4
U.S.A. (1.c.) .. Cleavage tests for air dry wood not given.

One of the most important requirements in a timber which is subject to loads is toughness†. The term is applied to a number of different properties of wood, but can be regarded as the reverse of brittleness; it is indicated by (a) the ability of the wood to absorb energy in impact tests, (b) the work to maximum load in static bending tests.

An examination of the results of the static bending tests shows that the modulus of rupture is small in comparison with the other tests on small clear specimens, but the figure is not abnormally low. The most striking result is the small interval between the proportional limit and the ultimate load, which is a definite indication of brittleness. Further, although the resilience of the wood is normal, the "work to maximum load" is very low, indicating again a brittle timber. Similarly, the impact tests, with an

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† Den Berger, Mechanical Properties of Dutch East Indian Timbers, No. 12. Proefstation v/h. Boschwezen, 1926, refers to a tough wood as "one that will not rupture until it has deformed considerably under loads at or near its maximum strength or one which still hangs together after it has been ruptured and may be bent back and forth without breaking apart, and which gives way only gradually and gives warning of rupture. It is able to store a considerable amount of energy and has a remarkable shock resisting ability."

P—December 5, 1928.
energy absorption of 8.3 foot lbs. in comparison with 23.0 foot lbs. for normal Oregon, clearly show the brashness of the wood.

Except that the wood failed, almost without warning and with no defined limit of proportionality, the large beam tests did not reveal any serious lack of strength, in comparison with large beam tests made in U.S.A.

The stiffness of the wood, indicated by the modulus of elasticity, was not low in comparison with many other of the test results.

Tests made in compression parallel to the grain showed that the wood was not particularly weak in this regard, and that there is a very appreciable difference between the limit of proportionality and the ultimate load, although less than that given for the Canadian tests.

The strength in compression perpendicular to the grain was higher than the means given by other authorities and seems to indicate that the ability of the tracheids to withstand lateral crushing is not weakened, however brittle the wood might be.

As Record\* states, the tensile strength, parallel to the grain, of a wood is about three times its strength in compression, but the results of the tests show that there is practically no difference in the figures for tension and compression obtained for the defective Oregon, whilst the results given by Koehler (l.e.) clearly show the very great superiority in tensile strength of normal Oregon. It is easy to understand, therefore, that whilst with normal wood it is possible to bend it considerably before failure takes place on the tension side, in wood which has the tensile strength approximately equal to the compressive strength, very slight bending is sufficient for the wood to fail on the tension side and the wood is therefore brittle.

\*Record, Mechanical Properties of Wood, 1914.
The results of the tension perpendicular to the grain, with a radial plane of failure are low and indicate a small degree of lateral cohesion between the tracheids or that the cell walls are easily split when subjected to a transverse pull. The greater strength in tension in a radial direction, i.e., with a tangential plane of failure, is apparently due to the action of the medullary rays.

The hardness tests, whilst lower than the Canadian tests, are close to those for the U.S.A. wood, for the side, and higher for the end, and show that the wood was not soft or spongy. As pointed out by Record (l.c.) resistance to indentation is largely dependent on density.

The results of the shearing tests parallel to grain are quite normal and do not indicate any weakness in this respect.

Strength to resist splitting, as indicated by the cleavage tests, is comparable with tension perpendicular to the grain. The results of this series of tests (i.e., cleavage) are also low in comparison with the Canadian figures.

Weight.

One of the most important factors influencing the strength of timber is weight. In practice, weakness in timber is usually associated with a low density and relationships have been established between the various mechanical properties of wood and specific gravity* †.

The density of the defective wood, about 33 lbs. per cubic foot, is not low and compares closely with the average figures given for the material tested in Canada and U.S.A., and it also approximates to the mean of the specimens

† Den Berger (l.c.) outlines the various theories in reference to the mechanical properties—density relationship.
tested for comparison. There was no evidence of compression wood, which is comparatively weak. Den Berger (i.e.) has pointed out that specific gravity does not give any clue to the pliability or toughness of the wood and this is borne out by the result of the impact tests.

**Rate of Growth.**

From a large series of tests on structural sizes made in U.S.A.† the optimum rate of growth for Oregon was found to be 24 rings per inch, but considerable variation in strength was found, and the conclusion was reached that "rings per inch are not a reliable index to the mechanical properties of timber, especially structural timbers containing knots and other defects." Further, in particular reference to Oregon, the following conclusion was made that, "in general, rapidly grown wood (less than eight rings per inch) is relatively weak. A study of individual tests upon which the average is based shows, however, that when it is not associated with light weight and a small proportion of summer wood, rapid growth is not indicative of weak wood".*

In the crane backstay the maximum number of rings per inch is 10, and the minimum 5, the mean being 8.5, which, though showing comparatively rapid growth, is not exceptionally fast. The American Society for Testing Materials has adopted as a standard for the best grade, known as Dense Douglas Fir, that it shall have an average of not less than 6 rings per inch and at least \( \frac{3}{4} \) summer or late wood, or if the rings are wide the summer wood must constitute at least \( \frac{1}{2} \) of the ring†. Tests (5), (6) and (7)

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made on 3” x 3” x 36” clear specimens were selected from rapidly grown material; (6) and (7) with 4 r.p.i. are comparable in strength with the results for the small clear specimens from the defective wood. Both (6) and (7) were cut from near the heart, and showed brittle failures. Although the position of the heart is not regarded as affecting the strength in structural sizes, provided the weight is normal, it is commonly found that wood near the heart, either due to very rapid growth or incipient decay is liable to be brittle. The inner side of the crane section was cut approximately 3 inches from the heart.

Slow growth also frequently results in a weak timber, one of the Museum test pieces with 35 r.p.i. had a density of only 25.4 lbs. and gave a modulus of rupture of 8,800 lbs. per square inch.

**Late Wood.**

The percentage of late or summer wood in the growth ring has an important bearing on strength since a low percentage usually indicates brashness. The average figure of 26% obtained is rather lower than the specification for “dense” Oregon of 33%, but is not low enough to account for the brittleness of the wood. Forsaith,* in his investigation of brashness, found that it was increased by a decrease in the amount of late wood, by a decrease in the thickness of the tracheid wall, and by an increase in the number and size of the bordered pits. He found also that fibre or tracheid length was unimportant in determining brashness. Since obviously increased cell wall thickness must result in increased weight, if the weight is normal one would not expect to find thin tracheid walls. Observations made on the radial thickness of the tracheid wall are as follows:—

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From the photomicrographs of sections from the compression side of the failure it is apparent that there is no sign of buckling of the tracheids. Although aniline chloride, followed by aniline blue, indicates minute lines on the cell wall, apparently corresponding to the slip planes described by Robinson, these appear just as numerous in wood which, as far as is known, had not been subjected to any severe strains. Chlor-zinc-iodine and iodine and sulphuric acid gave no appreciable darkening of the tissues in the vicinity of the zone of failure.

Nothing unusual was observed in the number or distribution of the bordered pits.

The failure appeared to be almost transverse in the late wood, the tracheids being broken almost at right angles. In places the fracture followed the rays; in others it occurred along the grain in the middle of the late wood. Many of the tracheids showed a break inclined at an angle of about 45°, the plane of maximum shear, whilst others were inclined at greater or lesser angles to the longitudinal direction.

The extreme weakness of the wood in tension, which approximates that in compression, evidently accounts for the lack of buckling of the fibres in compression, since the failure apparently occurred first on the tension side.

In the position in which the wood was used it was subjected to variable eccentric loading and the compressive and tensile stresses alternated from side to side, with the alteration of the position of the jib. The wood was apparently subjected to loads approaching, if not exceeding, the elastic limit and the continuous reversal of stresses suggests the possibility of fatigue.

Moisture.

Although wood dried to a very low moisture content is liable to become brittle, the moisture content of the crane material is normal for air-seasoned material and cannot have had any effect in bringing about the extreme brashness of the wood.

A microscopical examination showed no evidence of fungal attack nor was the wood discoloured in any way. Although wood may become brittle in areas adjacent to those in which the hyphae are actually present, the fact that test pieces from all parts of the beam showed similar brashness does not suggest the possibility of a fungal origin of the trouble.

Robinson†, who has made a very careful microscopical study of the initial causes of failure in timber, found definite indications of minute slip planes, in the cell walls, especially in compression. These gave cellulose reactions with various reagents. He further concluded that the formation of these slip planes preceded the buckling or crinkling of the tracheids.

Although fatigue is not usually regarded as seriously affecting timber, Siminski, according to an abstract1, has proved that wood previously subjected to compression is rendered weaker in tension and that reversal of stresses materially lowers the resistance of the wood to rupture. On the other hand, repeated impact tests were made on wood at the Forest Product Laboratory, Madison**, in which the specimens were stressed to a little above the elastic limit; the wood was then subjected to a static bending test and the results in comparison with similar specimens which had not been subjected to impact showed no significant change in the properties of the wood.

There seems to be no reason why modification of the tissues of the wood should not occur as the result of severe stresses, ultimately resulting in weakness or brashness. The subject appears to be worthy of further investigation.

I am indebted to Prof. H. P. Brown, of the New York State College of Forestry, Syracuse University, for the above references.

Summary. Tests showed that the wood was extremely brittle and failed without warning. Whilst the strength in compression is normal it is extremely weak in tension parallel to the grain. The ability of the wood to absorb energy is very small, rendering it unfit for the purpose for which it was used. Although the rate of growth is faster than the optimum for Oregon and the percentage of late wood is rather less than is permitted in first-grade timber for structural purposes, the density of the wood is normal. It is suggested, if Siminski I Vestnik Ingenirow, No. 4, April, 1927. Abstract seen in Mechanical Engineering, Vol. 49, 802, 1927. Original not available.


From the photomicrographs of sections from the compression side of the failure it is apparent that there is no sign of buckling of the tracheids. Although aniline chloride, followed by aniline blue, indicates minute lines on the cell wall, apparently corresponding to the slip planes described by Robinson, these appear just as numerous in wood which, as far as is known, had not been subjected to any severe strains. Chlor-zinc-iodine and iodine and sulphuric acid gave no appreciable darkening of the tissues in the vicinity of the zone of failure.

Nothing unusual was observed in the number or distribution of the bordered pits.

The failure appeared to be almost transverse in the late wood, the tracheids being broken almost at right angles. In places the fracture followed the rays; in others it occurred along the grain in the middle of the late wood. Many of the tracheids showed a break inclined at an angle of about $45^\circ$, the plane of maximum shear, whilst others were inclined at greater or lesser angles to the longitudinal direction.

The extreme weakness of the wood in tension, which approximates that in compression, evidently accounts for the lack of buckling of the fibres in compression, since the failure apparently occurred first on the tension side.

In the position in which the wood was used it was subjected to variable eccentric loading and the compressive and tensile stresses alternated from side to side, with the alteration of the position of the jib. The wood was apparently subjected to loads approaching, if not exceeding, the elastic limit and the continuous reversal of stresses suggests the possibility of fatigue.
Although fatigue is not usually regarded as seriously affecting timber, Siminski, according to an abstract†, has proved that wood previously subjected to compression is rendered weaker in tension and that reversal of stresses materially lowers the resistance of the wood to rupture. On the other hand, repeated impact tests were made on wood at the Forest Product Laboratory, Madison**, in which the specimens were stressed to a little above the elastic limit; the wood was then subjected to a static bending test and the results in comparison with similar specimens which had not been subjected to impact showed no significant change in the properties of the wood.

There seems to be no reason why modification of the tissues of the wood should not occur as the result of severe stresses, ultimately resulting in weakness or brashness. The subject appears to be worthy of further investigation.

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Summary.

Tests showed that the wood was extremely brittle and failed without warning. Whilst the strength in compression is normal it is extremely weak in tension parallel to the grain.

The ability of the wood to absorb energy is very small, rendering it unfit for the purpose for which it was used. Although the rate of growth is faster than the optimum for Oregon and the percentage of late wood is rather less than is permitted in first-grade timber for structural purposes, the density of the wood is normal. It is suggested,


however, that wood of rather slower growth and cut further from the heart should be used for purposes where it is known that the member will be subjected to severe stresses.

Microscopically, there appears to be no reason to account for the brashness, which is apparently due to some inherent quality of the wood or possibly to a state of fatigue brought about by continual reversal of stresses near the elastic limit.

In conclusion, I am indebted to the Mechanical Engineering Department of the Sydney Technical College for making the large beam tests; to this Department and to Wing-Commander Wackett, R.A.A.F., Experimental Station, Randwick, for the use of the necessary machines; and to Mr. F. B. Shambler, of the Museum Staff, for his assistance in the making of the tests and for the two photographs illustrating the fracture and cross section of the wood.
Fig. 1. Transverse section of timber, showing nature of wood and distribution of growth rings.

Fig. 2. Original failure of the crane backstay. The right is the compression side of the member. The brittleness of the wood is indicated by the "short-fibred" break.

Fig. 3. Radial longitudinal section, showing break on compression side; the fracture is frequently transverse in the late wood. $\times 11\frac{1}{2}$.

Fig. 4. Tangential longitudinal section, showing break on compression side. $\times 11\frac{1}{2}$.

Fig. 5. Radial longitudinal section of break on compression side, showing inclination of fracture of the tracheid walls. The spiral bands are normal in Oregon. Note absence of buckling of the tracheids. $\times 125$.

Fig. 6. Similar section to above at junction of early and late wood. The transverse fracture of many of the late wood tracheids is apparent. In the spring or early wood the failure frequently but not always follows the line of the bordered pit. Fine markings can be observed on the walls of some of the late wood tracheids. $\times 125$.

Fig. 7. Tangential longitudinal section of break on compression side in early wood, showing irregular fracture of the tracheids; these commonly occur at the same inclination as the spiral tracheid thickenings. $\times 125$. 

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