ABSTRACT

Dimensional stability was studied in Douglas-fir particleboards prepared from a flake-particle mixture. Three levels of resin content and two levels of resin atomization and board density were used, with dimensional stability measured in both relative humidity and water-soak exposures.

Below 80 percent relative humidity, study variables had virtually no effect on amount of movement in either thickness or length. More change occurred between 80 and 90 percent relative humidity but only resin content affected the amount of movement.

In contrast, all variables affected degree of stability in ovendry-vacuum-pressure-soak conditions. Thus, while the soak test is fast and may be related to the relative humidity test, caution should be exercised in interpreting soak test data, especially where interior end uses are concerned.
RESIN EFFICIENCY AND
DIMENSIONAL STABILITY
OF FLAKEBOARDS

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INTRODUCTION

Resin efficiency, or the attainment of desired mechanical and physical properties
with a minimum amount of resin binder, is of prime importance in producing particleboard.
Resin costs remain one of the major manufacturing expenses, and knowledge of resin
amount and application effects on board properties is vital in producing adequate
boards economically.

A previous study discussed effects of resin efficiency on various strength properties
of flakeboards. This study was designed to obtain dimensional stability data using
extra specimens from the previous study.

In the earlier study, particleboards were made of a Douglas-fir flake-particle mixture
using the following factorial design:

- Board density: 0.65 and 0.75 gram per cubic centimeter (based on oven-dry (OD)
  weight and volume at 65 percent relative humidity (RH))
- Resin content: 2, 4, and 8 percent urea-formaldehyde resin solids (based on OD
  wood weight)
- Resin atomization: Coarse and fine

Two panels were made at each combination, resulting in a sample of 24 boards. The
report on the previous study gives details of board manufacture.

PROCEDURE

From the test series reported previously, one extra 3-by-16-inch specimen per panel
remained. These specimens were prepared for measuring linear expansion by drilling
two pairs of small holes on 10-inch centers, 1 inch from each edge of the Specimens,
and inserting metal eyelets into the holes. The duplicate measurements of length
changes on each specimen minimized the chance of experimental error. For thickness
swelling determinations another eight points were marked 1 inch from the edges of
each specimen.

1 Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
2 Lehmann, W. F. Resin Efficiency in Particleboard as Influenced by Density, Atomization,
The specimens were conditioned at 75 ± 5° F. and 12 percent RH until practical
equilibrium was attained. They then were weighed to the nearest 0.01 gram, and length
and thickness measurements taken to the nearest 0.001 inch. Measurements were taken
following conditioning at 30, 42, 72, 80, and 90 percent RH. At the completion of
this series of measurements, one specimen of each pair of replicate panels was ovendried
while the other was vacuum-pressure-soaked. The panels were then weighed and measured
for length and thickness changes.

RESULTS AND DISCUSSION

The data are summarized in table 1 and the more important results of the study
are shown in figures 1 through 7.

Linear Expansion–Moisture Content Relationships

Linear expansion at practical equilibrium in various humidities produces the
normal sigmoid curves shown in figure 1. Only slight differences are apparent between
study variables up to 90 percent RH. At lower RH levels, more linear expansion
occurs with higher resin contents; this generally reverses at 90 percent RH, and
better stability in linear expansion is readily apparent at higher resin contents
in the vacuum-pressure-soak (VPS) exposure. Fine and coarse atomization produce
no difference in linear expansion and only at low resin content is linear expansion
greater at high density.

The same data for linear expansion are compared with moisture content change or
water absorption in figure 2. A linear relationship between linear expansion and
water absorption is also shown in figure 2. This regression, \[ LE = 0.026 + 0.024 \cdot WA, \]
has \( R^2 = 0.939 \) and a standard error of estimate \( (S_{y|x}) = 0.026 \).

In the VPS test data (WA > 100%), the decrease in linear expansion with increasing
resin content is apparent (fig. 2). A decrease in water absorption in VPS with
increasing resin content and density is shown in table 1.

Thickness Swelling–Moisture Content Relationships

No effects of study variables on thickness swelling are evident up to 80 percent
RH (up to 11% MC), and at higher resin levels at 80 percent RH (11–12% MC), decreases
in thickness swelling are only minor (Fig. 3). At 90 percent RH (14–16% MC),
thickness swelling is definitely less at higher resin levels, but no effects of panel
density or atomization are apparent.

In vacuum-pressure-soak, however, better thickness swelling stability is obtained
at higher resin levels, showing minor decreases in swelling with fine atomization
of resin. Less swelling is shown with lower density only at 2 percent resin content.

Effects of Variables in 30 to 90 Percent RH Exposure

In both linear expansion and thickness swelling, much better stability is attained
at 4 and 8 percent resin content than at 2 percent resin content (figs. 4 and 5).

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The general pattern is high instability at 2 percent resin content, followed by a sharp drop at 4 percent resin content, and leveling off toward 8 percent resin content. The total range of linear expansion was from 0.19 to 0.29 percent with fine spray of 8 percent resin at 0.65 specific gravity being best and coarse atomization of 2 percent resin at 0.75 specific gravity being poorest. Panel density and atomization had no effect on thickness swelling and only minor effects on linear expansion at 2 percent resin content.

Another important factor is thickness swelling retention (springback) after ovendrying from 90 percent RH exposure (table 1, fig. 5). In this case, the higher resin contents are definitely beneficial in returning the specimens to near-initial conditions. Also, fine atomization reduces springback levels, particularly at lower resin contents.

Effects of Study Variables in OD-VPS Exposure

The effects of variables on linear expansion and thickness swelling in OD-VPS exposure (figs. 6 and 7) are essentially the same as those evident in previous discussions of dimensional stability–moisture content relationships, but over a wider range of dimensional movement. The combined effects of low resin content, poor atomization, and high density produced the greatest instability in both linear expansion and thickness swelling. At 4 and 8 percent resin content, much improved levels of linear expansion and thickness swelling are obtained as compared with 2 percent resin content. Neither degree of atomization nor panel density has an apparent effect on these two properties at 4 or 8 percent resin content.

Relative Humidity–Water-soak Test Relationships

Perhaps the most important factor concerning relative humidity–water-soak test relationships is the danger of placing too much reliance on a fast soaking test as a measure of stability in various RH conditions. Specimens containing 2 percent resin had much more linear expansion and thickness swelling in VPS than specimens with 4 and 8 percent resin whereas, in exposures of less than 90 percent RH, linear expansion and thickness swelling were roughly equivalent for all resin contents (figs. 1–3).

Another often repeated statement is that high density panels are less stable than low density panels. If only VPS data were available, one might assume this to be true here, especially at low resin content. However, in RH exposures, there were no apparent differences in linear expansion or thickness swelling between the two panel densities at any resin content.

CONCLUSIONS

Based on the data gathered in this study, the following conclusions are presented concerning resin efficiency in flakeboards as affecting dimensional stability in RH and OD–VPS exposures.

1. In both linear expansion and thickness swelling, the study variables (resin content, degree of resin atomization, and panel density) had virtually no effect on panel stability up to 80 percent RH. Range of movement from 0 to 80 percent RH was 0.31 to 0.38 percent in linear expansion and 4.0 to 5.1 percent in thickness swelling.

2. From 80 to 90 percent RH, a large change in thickness swelling occurred, especially at 2 percent resin content; 4 and 8 percent resin contents provided greater stability.
Panel density and resin atomization had no apparent effect on thickness swelling. In linear expansion, none of the variables had an effect in this humidity range and a linear relationship was found between linear expansion and water absorption between 12 and 90 percent RH.

3. On specimens ovendried after 90 percent RH exposure, use of fine atomization of resin produced improved thickness recovery (less springback) than obtained with coarse atomization of resin. This was the only apparent benefit of fine atomization in terms of dimensional stability, but this may be an important consideration in many applications of particleboard, particularly where minimal resin contents are concerned.

4. In contrast with RH exposure, all study variables affected dimensional stability in OD–VPS exposure. Best linear expansion and thickness swelling levels were attained with 8 percent resin content and only slightly less stability was achieved with 4 percent resin content. A large decrease in stability was evident at 2 percent resin content. High density and coarse atomization of resin also resulted in poorer stability at 2 percent resin content. At 4 and 8 percent resin content, density had no effect on linear expansion or thickness swelling, whereas coarse atomization had no effect on expansion, but produced slightly more swelling than fine atomization of resin.

5. The OD–VPS test, while indicating relative stability of a group of specimens in a soaked condition, did not yield a directly representative indication of stability in RH exposures. Thus, there is danger in assuming that a given variable may affect stability in interior environments if the sole basis for the assumption is a water-soak test.
Table 1.--Effect of panel density, resin content, and degree of atomization on dimensional stability of particleboard

<table>
<thead>
<tr>
<th>Panel density</th>
<th>Resin content</th>
<th>30-90 percent RH</th>
<th>90+0</th>
<th>OD-VPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray: Amount</td>
<td>Water</td>
<td>Linear :Thickness</td>
<td>Water : Linear :Thickness</td>
<td></td>
</tr>
<tr>
<td>0.65 :Fine</td>
<td>2</td>
<td>9.99</td>
<td>0.26</td>
<td>10.4</td>
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<tr>
<td>0.65 :Do...</td>
<td>4</td>
<td>9.67</td>
<td>0.21</td>
<td>7.8</td>
</tr>
<tr>
<td>0.65 :Do...</td>
<td>8</td>
<td>9.07</td>
<td>0.19</td>
<td>6.4</td>
</tr>
<tr>
<td>0.65 :Coarse</td>
<td>2</td>
<td>10.19</td>
<td>0.24</td>
<td>11.6</td>
</tr>
<tr>
<td>0.65 :Do...</td>
<td>4</td>
<td>9.73</td>
<td>0.21</td>
<td>8.5</td>
</tr>
<tr>
<td>0.65 :Do...</td>
<td>8</td>
<td>9.38</td>
<td>0.23</td>
<td>7.3</td>
</tr>
<tr>
<td>0.75 :Fine</td>
<td>2</td>
<td>9.50</td>
<td>0.28</td>
<td>10.9</td>
</tr>
<tr>
<td>0.75 :Do...</td>
<td>4</td>
<td>9.23</td>
<td>0.22</td>
<td>7.3</td>
</tr>
<tr>
<td>0.75 :Do...</td>
<td>8</td>
<td>8.75</td>
<td>0.21</td>
<td>6.4</td>
</tr>
<tr>
<td>0.75 :Coarse</td>
<td>2</td>
<td>9.67</td>
<td>0.29</td>
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</tr>
<tr>
<td>0.75 :Do...</td>
<td>4</td>
<td>9.33</td>
<td>0.22</td>
<td>7.9</td>
</tr>
<tr>
<td>0.75 :Do...</td>
<td>8</td>
<td>9.02</td>
<td>0.20</td>
<td>6.8</td>
</tr>
</tbody>
</table>

1-Based on

Figure 1.--Effects of variables on linear expansion of particleboards at various humidities.

(M 140 620)
Figure 2.--Relationship of variables in linear expansion as related to moisture content change.

Figure 3.--Relationship of variables in thickness swelling as related to moisture content change.
Figure 4.—Effects of variables on linear expansion in 30–90 percent relative humidity exposure.  

Figure 5.—Effects of variables on thickness swelling and springback in 30–90 percent relative humidity exposure.
Figure 6.--Effects of variables on linear expansion in oven-vacuum-pressure-soak exposure. (M 140 616)

Figure 7.--Effects of variables on thickness swelling in oven-dry-vacuum-pressure-soak exposure. (M 140 622)