RELATIONSHIP OF BIRCH (BETULA SP.) PLYWOOD BENDING PROPERTIES DETERMINED ACCORDING TO THE EUROPEAN STANDARDS EN 789 AND EN 310

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Abstract

The manufacturers of wood-based panels are interested to get easy and cheap method for determination of characteristic values of panels. The correlation between European standards EN 789 and EN 310 tests results can be used as an alternative procedure for determination of characteristic values of bending properties.

The correlations between two results of bending properties determined by testing methods of European standards EN 789 and EN 310 are studied in this paper. The ratio of EN 789 test results divided with EN 310 test results (ratio of EN 789/EN 310) depending on panel thickness and glue type, was examined. Samples from 846 panels of birch (Betula sp.) plywood with thickness ranging from 6.5 to 30 mm and two glue types – phenol formaldehyde and melamine urea formaldehyde resin – were used for verification of the correlations.

The results show that the panel thickness influences the ratio of EN 789/EN 310 and the highest ratio was found between 12 and 15 mm panels. When the panel thickness is increased or decreased, the ratio of EN 789/EN 310 decreases significantly. The regression equations for each thickness of plywood are presented.

The difference between plywood glued with phenol formaldehyde and melamine urea formaldehyde resin glues was not found.

Keywords: wood-based panels, strength, modulus of elasticity.

Introduction

The wood processing industry has a significant role in the economics of the European Union. The turnover of the European wood processing industry is 226 billion EUR and for wood based panels – more than 20 billion EUR. In 2005, 60.45-million m³ of wood-based panels were produced and 6% of those were plywood (Dóvy, 5th European Wood-Based Panel Symposium, 2006). Plywood has excellent physical-mechanical properties and is widely used in construction.

All construction products should be complying with Construction Product Directive (CPD) of the European Union (Official Journal of the European Communities, 1989). In response to the CPD, European Committee for Standardization (CEN) has been developing ‘harmonized standards’ EN 13086-2004 ‘Wood-based panels for use in construction – Characteristics, evaluation of conformity and marking’, where the requirements for wood-based panels used in construction are defined. The standard EN 13086 is applicable for wood-based panels for use in construction and specifies the relevant characteristics and the appropriate test methods for determination of these characteristics. It also specifies the procedure for the evaluation of conformity and the requirements for wood-based panel marking.

The standard EN 13086 generally divided all wood-based panels in two end-use groups:

1. wood-based panels for use as structural components;
2. wood-based panels for use as non-structural components.

The compliance with EN 13086 requirements should be demonstrated by:

- factory production control;
- initial type test;
- initial factory inspection and continuous surveillance.

In the factory production control, any manufacturer should establish a system for regular inspections, tests and assessment of raw material, production technology process, equipments and product, in order to ensure that product of appropriate quality is offered in the market.

One of the characteristics, which should be determined in the initial type test and regularly tested in the factory production control, is bending properties of the panel.

Bending properties of wood-based panels can be determined according to the following standards:
EN 310:1993 'Wood-based panels – Determination of modulus of elasticity in bending and of bending strength';

EN 789:2004 'Timber structures – Test methods – Determination of mechanical properties of wood based panels'.

The bending properties of wood-based panels for use as structural components should be determined according to the standards EN 310 and EN 789, but for panels that are used as non-structural components the standard EN 789 is not obligatory.

The standard EN 310 specifies a test method for determination of bending properties of wood based panels by testing small test pieces. This standard mostly is used for factory internal quality control and the results can be used for product comparison. These results can't be used in structural design.

The standard EN 789 specifies test methods for determination of some mechanical properties of wood-based panels by testing semi-small test pieces, like bending, compression, tension, panel shear and planar shear properties. EN 789 together with EN 1058:1995 'Wood-based panels – Determination of characteristic values of mechanical properties and density' can be used for determination of structural design values of wood panels. The standard EN 13086 specifies that strength and stiffness for structural use can be determined only once – in the product initial type test.

The panel tests according to the standard EN 789 are quite expensive and they require specific test equipment, which not all manufacturers have. Therefore it is necessary to find alternative test methods for determination of characteristic values of panels.

The standard EN 13086 specified that characteristic values for use in design might be taken from relevant part of the standard EN 12369. These characteristic values are more conservative than the values which can be determined according to the standards EN 789 and EN 1058.

The aim of this paper was to find correlations between EN 310 and EN 789 birch (Betula sp.) plywood bending test results. Such kind of correlations can give more appropriate characteristic values and can be used in the factory production control to insure that the bending properties of wood-based panels still correspond to the values which are determined in the initial type test according to EN 789.

Materials and Methods

The 846 panels of birch (Betula sp.) plywood were selected from regular production of one site. 10 samples according to EN 310 and 2 samples according to EN 789 were cut out from one panel; half of them have surface veneer grain direction parallel to longitude and half – perpendicular to longitude. The thickness of samples was from 6.5 to 30 mm, veneer thickness – 1.4 mm glued together with phenol-formaldehyde (PF) or melamine urea formaldehyde (MUF) resin glue.

<table>
<thead>
<tr>
<th>Nominal thickness, mm</th>
<th>Quantity of panels with PF glue, pcs</th>
<th>Quantity of panels with MUF glue, pcs</th>
<th>Lay-up a</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td>41</td>
<td>-</td>
<td>/ / / /</td>
</tr>
<tr>
<td>9.0</td>
<td>71</td>
<td>-</td>
<td>/ / / /</td>
</tr>
<tr>
<td>12.0</td>
<td>91</td>
<td>52</td>
<td>/ / / - /</td>
</tr>
<tr>
<td>15.0</td>
<td>83</td>
<td>85</td>
<td>/ / - / /</td>
</tr>
<tr>
<td>18.0</td>
<td>123</td>
<td>87</td>
<td>/ / / - /</td>
</tr>
<tr>
<td>21.0</td>
<td>67</td>
<td>-</td>
<td>/ / / / /</td>
</tr>
<tr>
<td>24.0</td>
<td>43</td>
<td>-</td>
<td>/ / / - /</td>
</tr>
<tr>
<td>27.0</td>
<td>50</td>
<td>-</td>
<td>/ / / - /</td>
</tr>
<tr>
<td>30.0</td>
<td>53</td>
<td>-</td>
<td>/ / / - /</td>
</tr>
<tr>
<td>Total</td>
<td>622</td>
<td>224</td>
<td>/ / / / /</td>
</tr>
</tbody>
</table>

aLay-up:
/ – veneer with grain direction parallel to longitude;
-- – veneer with grain direction perpendicular to longitude.

Table 1
The sample division by thickness and lay-up is presented in Table 1.

Standard methods according to EN 310 and EN 789 are used for determination of bending properties. The moisture content of samples was 8 ± 2%.

The principal schema of the test methods is shown in Figure 1.

The ratio of EN 789 test results divided with EN 310 test results was used for determination of ratio, which changed depending on panel thickness. The average ratio value of each nominal plywood thickness was calculated.

The influence of panel thickness and glue type was evaluated by using multiple linear regressions analysis.

![Figure 1. Principal schemas of bending tests, dimensions in mm. (A – EN 310; B – EN 789).](image)

**Results and Discussion**

The correlation between EN 789 and EN 310 bending test results are significant with probability of 99% (Table 2). The better correlate results for samples with surface veneer grain direction parallel to longitude. The results of samples with veneer grain direction parallel to longitude have less variation (approximately 15% instead of 20% for EN 789 tests results).

Regardless of that, the background influence is very high (Figures 2 and 3).

It is necessary to point out that the requirements of sampling procedures according to EN 310 are to pick samples without any visible defects (knots on surface veneer, splits, etc.), but for samples according to EN 789 there are no special requirements.

As shown in Figure 1, the load zones with

| Test method                        | Strength EN 310 || | Modulus of elasticity EN 310 || | Strength EN 310 || | Modulus of elasticity EN 310 || |
|------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Strength EN 789 ||                 | 0.597( ** )     |                 |                 |                 |                 |                 |                 |                 |
| Modulus of elasticity EN 789 ||                 | 0.661( ** )     |                 |                 |                 |                 |                 |                 |                 |
| Strength EN 789 ||                 |                 | 0.419( ** )     |                 |                 |                 |                 |                 |                 |
| Modulus of elasticity EN 789 ||                 |                 |                 | 0.386( ** )     |                 |                 |                 |                 |                 |

\*11 – surface veneer grain direction parallel to longitude;
\*1 – surface veneer grain direction perpendicular to longitude;
** Correlation is significant at the 0.01 level (2-tailed).
maximum load are different. According to EN 789, the maximum load zone is 300 by 300 mm and that means that some defect influence on the results is much higher than in the test method according to EN 310.

These both factors give more variety to the test results.

Figures 4 and 5 clearly show that the ratio of EN 789/EN 310 changes depending on plywood thickness. There are no significant differences between plywood glued with PF and MUF resin glue (Figures 4 and 5). (surface veneer grain direction parallel to longitude; □ - plywood glued with MUF resin glue; ◊ - plywood glued with PF resin glue). (surface veneer grain direction perpendicular to longitude; □ - plywood glued with MUF resin glue; ◊ - plywood glued with PF resin glue).

In Figure 6 the average ratio of EN 789/EN 310 depending on surface veneer grain direction to longitude is shown. Significant differences between the ratios of strength, due to the samples surface grain direction, were found. The ratios of strength for samples with perpendicular grain direction are on average 10% less than ratios of samples with parallel grain direction to longitude.

The regression equations are presented in Table 3.

The regression equations can be used for determination of characteristic values of bending properties for birch plywood, but further investigation is necessary for evaluation of conformity of these characteristic values. Necessary investigation for evaluation other alternative ways for determination of characteristic values of bending properties and to compare it's with reference method (tests results according to EN 789).

Many manufacturers would like to earn alternative way (easy and cheap) for determination of characteristic values, not only bending, but also other mechanical properties.
Figure 3. Relations of EN 789 and EN 310 modulus of elasticity results

(II = surface veneer grain direction parallel to longitude; _I_ = surface veneer grain direction perpendicular to longitude).

Figure 4. Ratio of strength EN 789/EN 310.

(surface veneer grain direction parallel to longitude; □ - plywood glued with MUF resin glue; ◊ - plywood glued with PF resin glue).
Figure 5. Ratio of modulus of elasticity EN 789/EN 310.

(surface veneer grain direction perpendicular to longitude; □ - plywood glued with MUF resin glue; ◊ - plywood glued with PF resin glue).

Figure 6. Ratio of strength and modulus of elasticity EN 789/EN 310

(□ - surface veneer grain direction perpendicular to longitude; ◊ - surface veneer grain direction parallel to longitude).

Regression equations

<table>
<thead>
<tr>
<th>Nominal thickness, mm</th>
<th>Strength II</th>
<th>Modulus of elasticity II</th>
<th>Strength III</th>
<th>Modulus of elasticity III</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td>a = 11.2 + 0.56b</td>
<td>a = 3314 + 1.1b</td>
<td>a = 6.3 + 0.37b</td>
<td>a = 1993 + 0.87b</td>
</tr>
<tr>
<td>9.0</td>
<td>a = 20.0 + 0.56b</td>
<td>a = 3432 + 1.1b</td>
<td>a = 17.7 + 0.37b</td>
<td>a = 3001 + 0.87b</td>
</tr>
<tr>
<td>12.0</td>
<td>a = 25.5 + 0.56b</td>
<td>a = 3253 + 1.1b</td>
<td>a = 27.9 + 0.37b</td>
<td>a = 3340 + 0.87b</td>
</tr>
<tr>
<td>15.0</td>
<td>a = 30.6 + 0.56b</td>
<td>a = 3229 + 1.1b</td>
<td>a = 30.3 + 0.37b</td>
<td>a = 3594 + 0.87b</td>
</tr>
<tr>
<td>18.0</td>
<td>a = 18.7 + 0.56b</td>
<td>a = 838 + 1.1b</td>
<td>a = 23.2 + 0.37b</td>
<td>a = 2156 + 0.87b</td>
</tr>
<tr>
<td>21.0</td>
<td>a = 12.2 + 0.56b</td>
<td>a = -376 + 1.1b</td>
<td>a = 18.5 + 0.37b</td>
<td>a = 1104 + 0.87b</td>
</tr>
<tr>
<td>24.0</td>
<td>a = 2.4 + 0.56b</td>
<td>a = -1901 + 1.1b</td>
<td>a = 11.2 + 0.37b</td>
<td>a = 232 + 0.87b</td>
</tr>
<tr>
<td>27.0</td>
<td>a = 1.2 + 0.56b</td>
<td>a = -1986 + 1.1b</td>
<td>a = 10.8 + 0.37b</td>
<td>a = -64 + 0.87b</td>
</tr>
<tr>
<td>30.0</td>
<td>a = 3.1 + 0.56b</td>
<td>a = -1661 + 1.1b</td>
<td>a = 11.3 + 0.37b</td>
<td>a = 11 + 0.87b</td>
</tr>
</tbody>
</table>

\( ^{\circ} \)II – surface veneer grain direction parallel to longitude; \( ^{\circ} \)III – surface veneer grain direction perpendicular to longitude; b – test result according to EN 310; a – appropriate EN 789 test result.
Conclusions

1. The correlation between EN 789 and EN 310 test results are significant, varying from week to medium.
2. Significant differences between ratios of EN 789/EN 310 due to the plywood thickness were found.
3. Due to the dependency ratio from plywood thickness, the appliance of one equation to calculate bending characteristic values from EN 310 test results for all thickness range is not correct. The conservative equation can be used for the calculation of characteristic values.
4. No significant differences were found between the ratios of EN 789/EN 310 of birch plywood glued with PF and MUF resin glues.
5. Further investigation is necessary for comparison of different alternative methods in order to evaluate the best alternative method for determination of characteristic values of wood-based panels.

References