

PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLEBOARD *P4* DEPENDING ON MOISTURE CONTENT

Regino Kask^{1a}, Harri Lille^{1b}, Jaanus Ljahov and Aleksander Rebane

^{1a,b}Institute of Forestry and Rural Engineering, Estonian University of Life Sciences, Tartu,
^aemail: Regino.Kask@emu.ee, ^be-mail: hlille@emu.ee

Keywords: Particleboard, modulus of rupture, modulus of elasticity, static hardness, thickness swelling, linear expansion

Introduction

Strand type composite panels such as particleboard is one of the wood based engineering products, which is most commonly used for cladding of wall and ceiling indoors or outdoors, as a floor decking material and wind barrier. The particleboard panel as a wood-based sheet is a hygroscopic material and its mechanical and physical properties depend on its moisture content and on surrounding temperature. This type of material is also applied for structural purposes in load bearing structures as rigidity material only for use in dry conditions (e.g. *P4* (EVS-EN 312:2010 [1])). Test methods determined by the European Standard (EN) were applied to study changes in modulus of rupture (MOR), modulus of elasticity (MOE) at bending, thickness swelling (TS), linear expansion (LE) and Janka hardness (JH) at different moisture contents. Changes in MOR, MOE, JH, TS and LE for different soaking times were investigated in a Master's thesis [2, 3].

The basic method involves soaking of specimens in water for a controlled period of time (2; 4; 6; 8; 16 and 24 hours), at room temperature (22±1°C), and testing them after pre-treatment in water with the universal test machine INSTRON 3369; drying (48 hours) of specimens in a ventilated drying box at 65±1°C, in order to determine moisture content. These procedures are followed by output of data and analysis of obtained results. The sensitivity of the measured data was studied and the expanded uncertainties of the computed mean values are presented.

A logarithmic function was used for approximation of the change in the physical and mechanical properties of the samples depending on their moisture content.

Experimental procedure and method

Four commercial of 2600×1200×22 mm panels made of particleboard *P4* (EVS-EN 312:2010 [1]). The MOR and MOE at bending were found by three point bending using the test machine INSTRON 3369 (Fig. 1a). Deflection for calculating MOE was measured by an optical gauge (Advanced Video Extensometer 2663-821). The test bending specimens with dimensions (490×50×22 mm) were cut in different directions from the board: one half of them in the longitudinal $\parallel$ direction (lengthwise) and the other half in the transversal $\perp$ direction (crosswise). Experiments were made with 18 series (minimum number of specimens in a series was twelve).

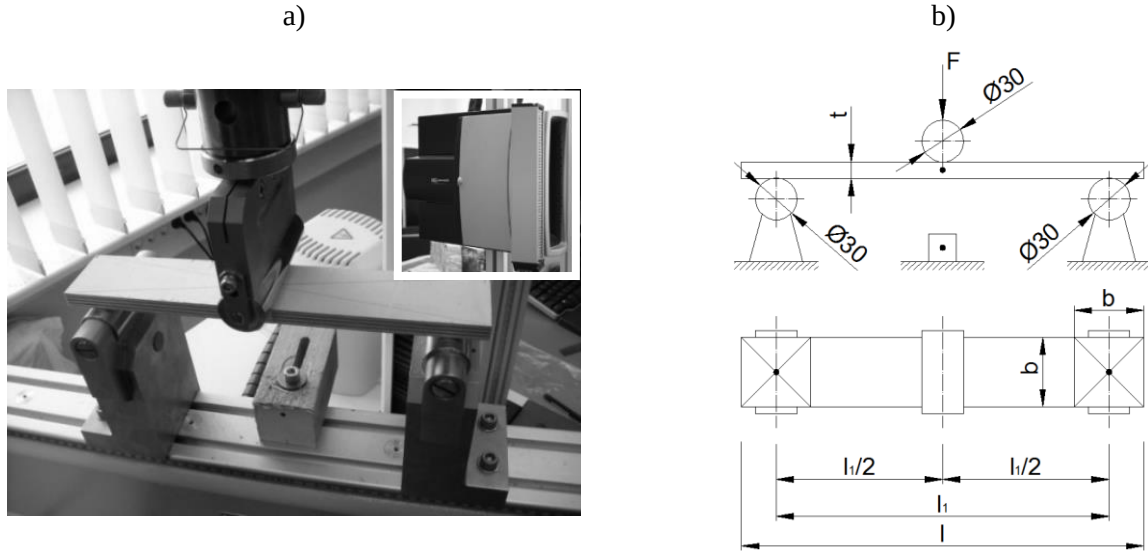


Figure 1. Three point bending and the points of deflection measurement: a) photo, an advanced video extensometer is in the upper right corner, b) scheme, $l_1 = 440$ mm.

The dimensions, length, width and thickness of the specimens extracted from the panels were measured using the calliper Preisser RS-232 with an accuracy of 0.01 mm, and a digital calliper and a micrometer gauge with an accuracy of 0.001 mm; the mass of the samples was measured by the electrical balance Kern EW 220-3NM with an accuracy of 0.01 g. The specimens of the first series were dried (48 hours) in a ventilated drying box at $65 \pm 1^\circ\text{C}$ to a moisture content of 0 %. The test specimens of the second series were tested at a moisture content of 5.1 and 8.7 % (purvey dry). The other remaining test specimens were placed in a tank with cold water ($22 \pm 1^\circ\text{C}$) for 2, 4, 6, 8, 16 and 24 hours. Before testing, the specimens were conditioned in a climatic chamber at a relative humidity of 65 % at 21°C . Moisture content was determined using a weighing method according to the EVS-EN 322:2002 [4] standard and was 20.7, 31.2, 35.4, 40.0, 48.0 and 53.0 %, respectively, depending on soaking time.

All specimens were tested, following three point bending, with the use of the computer-controlled mechanically actuated universal testing machine Instron 3369. Deflection for calculating the modulus of elasticity was measured by an optical gauge (Advanced Video Extensometer 2663-821). A force was applied at constant speed so that failure occurred in 60 ± 30 seconds (700 N/min).

Standard EVS-EN 310:2002 [5] was applied to evaluate MOR and MOE, through bending deflexion, in the longitudinal $\parallel$ direction and transversal $\perp$ direction of the specimens and calculated according to EVS-EN 310:2002. Calculation of the uncertainty of the measurements was done according to EVS-EN 326-1:2002 (at a confidence level of 95 %) [6].

The parameters of dimensional stability were determined before the bending test: TS according to EVS-EN 317:2000 [7] in the middle zone of the specimens (see Fig.1b) and for LE the length of specimen was measured on centreline bilaterally. The JH was determined in the middle of the end area (50×50 mm) of the specimens (see Fig. 1b) before the bending test in accordance with ISO 13061-12 [8]. The following analytical function was used to approximate the obtained experimental data for the investigated properties, depending on the number of the soaking/oven-drying cycles [2, 3].

$$y(x) = y_0 \cdot e^{-(a \cdot x)^2} \quad (1); \quad y(x) = y_f \cdot e^{\left(\frac{-a}{x^2}\right)} \quad (2),$$

where y_0 is the calculated initial values of parameter ($x = 0$), y_f is the final value of parameter ($x \rightarrow 1$); x is moisture content (fibre saturation point + free water), in these formulae a proportionate part of total; and a is a constant. The initial and final values of the properties and the constant should be determined so that the measured experimental data are approximated in the best way by minimizing

the square of error (least squares regression). This problem was solved by using the program *Mathcad 15.0* with the regression function *genfit(vx,vy,vg,F)*. The formulae (1; 2) allowed predict to a certain extent the mechanical and physical properties of the specimens when a limited number of values of their moisture content were known.

Results

The obtained MOR, MOE are presented in Fig. 2 and Fig. 3, respectively. The mean values of the experimental data for one series, approximated by formula 1, are presented.

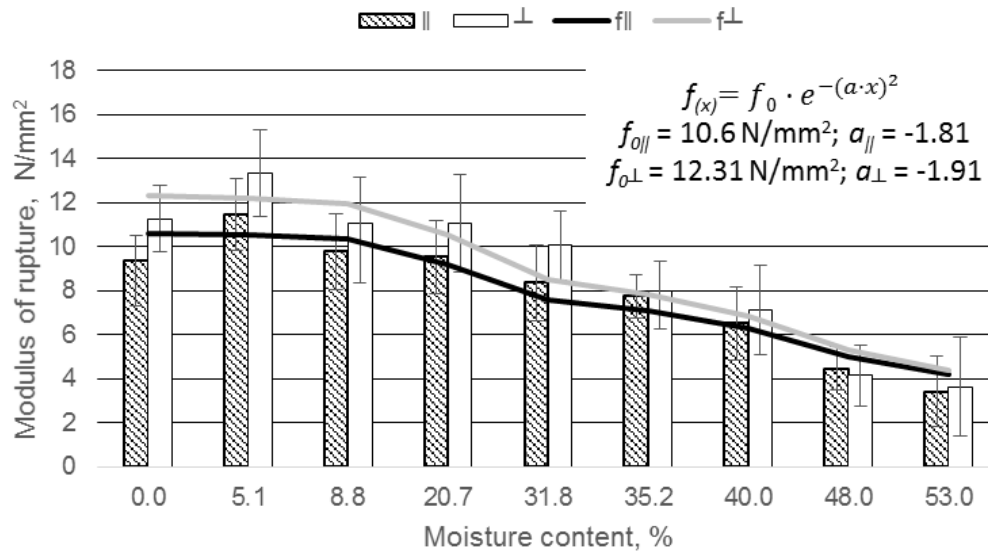


Figure 2. MOR depending on moisture content and the curve of approximation.

Two hours of soaking did not practically reduce the bending strength of the specimens. At a moisture content of 0 %, the strength could be reduced as the volume of timber was decreasing and cavities were forming in the matrix. The properties of the specimens decreased most intensively at soaking between 4 h and 24 h: ||MOR from 7.71 N/mm² to 4.06 N/mm² and ⊥MOR from 8.63 N/mm² to 4.41 N/mm²; ||MOE from 1313 N/mm² to 589 N/mm² and ⊥MOE from 1633 N/mm² to 772 N/mm². MOE decreased significantly even at a slight increase of moisture content. The same was noted for TS and JH see (Fig.4 and Fig. 6).

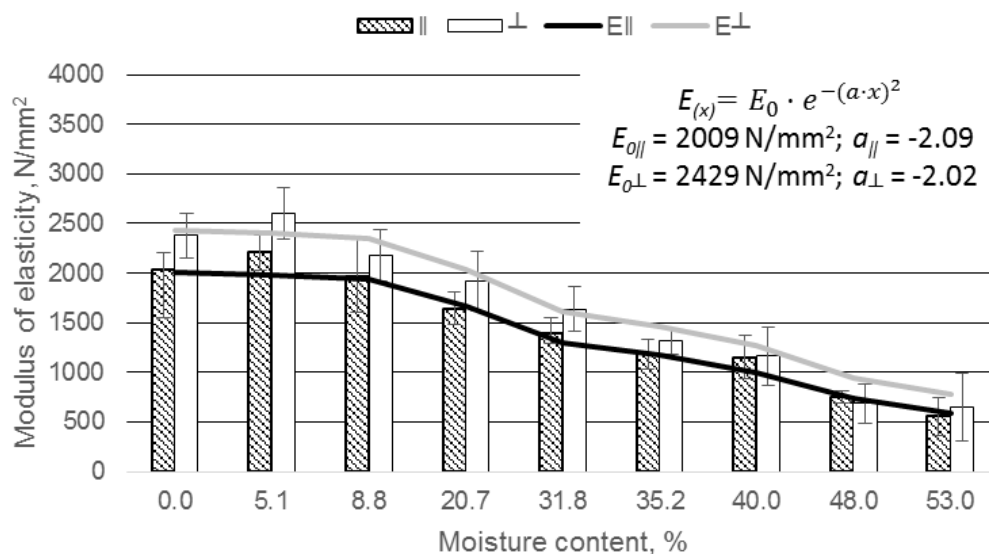


Figure 3. MOE depending on moisture content and the curves of approximation.

There was practically no difference in the results of MOR and MOE in case the specimens were cut from the board in the parallel or in the transversal direction. The values of the other properties were similar.

The mean values of dimensions changes parameters TS and LE are presented in Fig. 4 and Fig. 5, respectively. They parameters are approximated by formula 2.

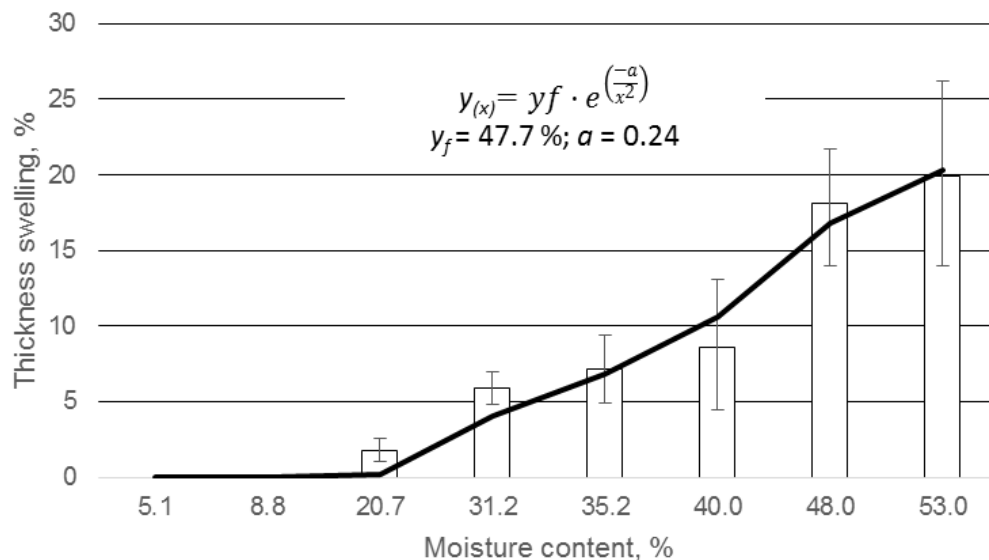


Figure 4. TS, depending on moisture content, in the end zone of the sample and the curve of approximation.

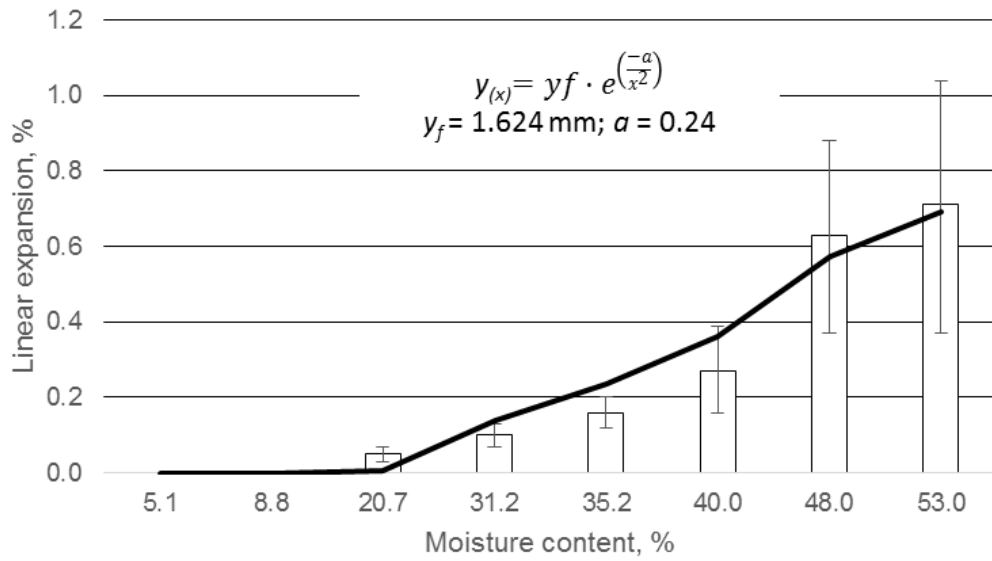


Figure 5. LE, depending on moisture content, measured in the longitudinal direction of the sample and the curve of approximation.

TS of the specimens for the 4 h and 24 h water soaking tests ranged from 4.44 % to 20.3 % and LE ranged from 0.15 % to 0.69 %. The change in dimensions intensified significantly when the samples were soaked longer than 4 h. Then obviously, the fibre saturation point is reached (about 30 % [9]) at which the total amount of water is present within cell wall is exceeded and the moisture content of specimens increases at the expense of free water.

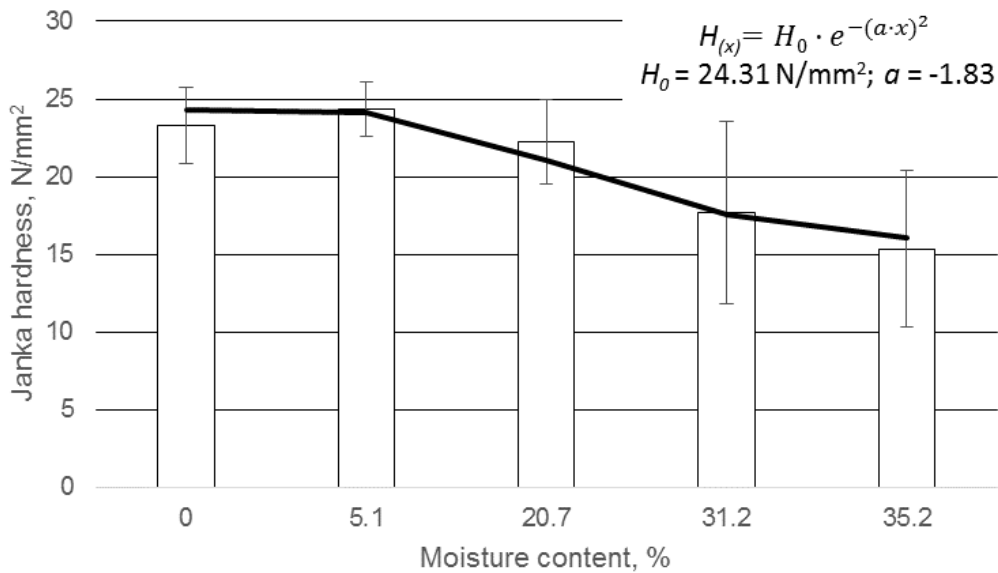


Figure 6. JH, depending on moisture content, measured in the end zone of sample and the curve of approximation.

The values of JH decreased similarly to the values of MOR and after 2 h of soaking u they decreased from 24.3 N/mm² to 21.1 N/mm².

IT is evident that the proposed analytical formulae (1; 2) approximated the experimental data satisfactorily.

Conclusions

The investigated properties were affected by soaking time (2; 4; 6; 8; 16 and 24 hours), at every measured moisture content, their values decreased significantly: MOR and MOE more than three and four times, respectively, irrespective of the fact if the specimens were cut from the test board in the longitudinal or in the transversal direction.

The investigated properties of the test specimens changed significantly starting from 4 h (moisture content 31.2 % up to the fibre saturation point): $\parallel$ MOR from 7.71 N/mm² to 4.06 N/mm²; $\parallel$ MOE from 1313 N/mm² to 589 N/mm² and, in particular TS, from 4.05 % to 20.3 % and LE from 0.14 % to 0.69 %.

An analytical function is proposed for approximation of experimental data, which allows, in the case of limited experimental data, to predict the investigated properties depending on moisture content.

The presented analysis is limited to the data obtained from the above described experiments.

Acknowledgement

We would like to express our gratitude to Ms. Ester Jaigma for linguistic help with this paper.

References

- [1] EVS-EN 312:2010 Puitlaastplaadid. Spetsifikaadid. Particleboards. Specifications. Tallinn: Eesti Standardikeskus. 20 p. (in Estonian).
- [2] Jaanus Ljahov. Particleboard's Physico-Mechanical Properties on Water Content. 2007. Master's Thesis, Estonian University of Life Sciences, Estonia/Tartu. 83 p. (in Estonian).
- [3] Aleksander Rebane. Particleboard's Dependence of Physical and Mechanical Properties on Humidity. 2008. Master's Thesis, Estonian University of Life Sciences, Estonia/Tartu. 87p. (in Estonian).
- [4] EVS-EN 322:2002 Puitplaadid. Niiskussisalduse määramine: Wood-based panels – Determination of moisture content. Tallinn: Eesti Standardikeskus. 9 p. (in Estonian).
- [5] EVS-EN 310:2002 Puitplaadid. Paindeelastsusmooduli ja paindetugevuse määramine: Particleboard. Determination of modulus of elasticity and bending strength. Tallinn: Eesti Standardikeskus. 7p. (in Estonian).
- [6] EVS-EN 326-1:2002. Puitplaadid. Plaatide mõõtmete määramine. Osa 1: Paksuse, laiuse ja pikkuse määramine. Wood-based panels. Sampling, cutting and inspection. Part 1: Sampling and cutting of test pieces and expression of results. Tallinn: Eesti Standardikeskus. 14 p. (in Estonian).
- [7] EVS-EN 317:2000 Puitlaastplaadid ja puitkiudplaadid. Pundumise määramine paksuses pärast leotamist: Particleboards and fibreboards. Determination of swelling in thickness after immersion in water. Tallinn: Eesti Standardikeskus. 10 p. (in Estonian).
- [8] ISO 13061-12 Physical and mechanical properties of wood. Test methods for small clear wood specimens. Part 12: Determination of static hardness (Switzerland: International Organization for Standardization). 10 p.
- [9] Salim Hiziroglu. Dimensional Changes in Wood. Oklahoma Cooperative Extension Service. 4 p. <http://pods.dasn.okstate.edu/docushare/dsweb/Get/Rendition-3624>