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EFFECT OF MUPF LOADING ON PROPERTIES OF ORIENTED STRANDBOARD

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ABSTRACT

The purpose of this paper was to assess the effect of loading wood strands with melamine -urea-phenol formaldehyde (MUPF) on the changes in thickness and internal bond perpendicular to the plane in oriented strand boards (OSB) exposed to air with a relative humidity of 30, 65 and 85 %. The study showed that the degree of the resulting deformations was inversely proportional to loading, and independent of the direction of moisture content changes. Much greater, nearly 3-fold, decrease in strength was observed in the boards initially exposed to air of high (85 %) than low humidity (30 %).

KEYWORDS: OSB, MUPF, humid conditions, dimensional stability.

INTRODUCTION

One of the basic characteristics of wood materials is the change in their linear dimensions triggered by the change in moisture content. The range of these changes is so great that failure to follow the established principles of creating structures and sheathings/roofing results in the damage of the entire construction or its elements. Dimensional changes in wood materials are associated with the presence of considerable forces, which can cause internal damage not only to the material itself, but also to its related components. Despite the fact that limiting these alterations was one of the basic assumptions in the manufacture of wood-based materials, this problem still persists.

The degree of moisture-related deformations of wood-based materials is affected by many factors, and some of them can be modified by using different technologies. The most important factors include hydrophobization degree, the type of adhesive and the geometry of glued components, and their arrangement in relation to each other. Another crucial property of the wood-based materials is their density, as it determines the dynamics of the changes (Kelly 1977, Suzuki and Miyamoto 1998). Gatchell showed that compressed wood materials absorb moisture from the air and increase their thickness not only as a result of wood swelling, but also by "loosening their structure", compacted during pressing (Gatchell et al. 1966). While in the first case, the effect tended to dwindle as the stimulus disappeared, in the second the increase in thickness was permanent. It can not be excluded that the increased thickness is a result of damage to the material structure, triggered by wood swelling. Hallligan (1970) defined this growth as non-recoverable thickness swelling (*NTS*). As concluded by Wu and Suchsland (1997) and Mirski et al. (2012), there was a linear dependence between the internal bond and *NTS* in boards subjected to wetting or soaking.

Moreover, the direction of moisture content changes did not affect the degree of resulting linear distortions. The works by Mirski (2009, 2010), Mirski and Dziurka (2013) revealed slightly bigger permanent linear deformations in OSBs exposed to cyclic changes in moisture content with the prevalence of wetting process. It is well known that wood achieves lower moisture content during gradual growth of relative air humidity than in the process of its gradual reduction. The same relationships were observed for the wood-based materials, but the course of the sorption curves was slightly different than in wood. Kelly (1977), citing Halligan and Schniewind (1972), reported that equilibrium moisture content in particleboards was lower than in solid wood. Suchsland (1972) suggested that different course of sorption curves may be due to exposing the strands to high temperatures during drying. Wu and Ren (2000) determined the effect of strand density and orientation on the sorption isotherms in oriented strand boards, by making detailed references to the previous studies. Most studies investigating the moisture content related deformations of OSBs concern either industrially manufactured OSBs or laboratory boards glued with PF or polymeric methylene diphenyl diisocyate (pMDI) (Wu and Suchsland 1996).

In our earlier work we presented discussed of the effects of loading the strands with MUPF and wax emulsion on the course of their sorption isotherms (Derkowski et al. 2014). The purpose of this study was to determine the degree of thickness deformation in OSBs loaded with MUPF, and to find possible relationships between the deformation range and the strand equilibrium moisture content.

MATERIAL AND METHODS

The study involved industrial pine wood strands loaded with MUPF. The strands, of moisture content 6.3 %, were loaded with green coloured adhesive containing wax emulsion in an amount of 1.8 %, and the resin in an amount of 5, 10 or 15 % of the strand dry weight. In the next step the strand-adhesive mass was used to form a three-layer OSB with a nominal thickness (t) of 15 mm and a density of 650 $kg.m^{-3}$. The prepared sheets were pressed for 300 seconds at 200°C. Pressed boards were exposed to air at 20°C and 65 % relative humidity (RH), and then their basic physical and mechanical properties were determined, according to EN 300 (2000) standard for OSB/3.

In order to determine the effect of loading on the degree of thickness deformations and changes in internal bond perpendicular to the planes, triggered by the variations in relative air humidity, 45 samples, 50 x 50 mm in dimensions, of each type of board were prepared and exposed to air. Following the conditioning period, the samples from all boards were divided into three groups. One of them was subjected to evaluation of internal bond perpendicular to the board plane, and the other two were conditioned as described in Tab. 1.

Tab. 1: The course of the conditioning process.

Set No. 1		Set No. 2	
Degree	**Air parameters**	**Degree**	**Air parameters**
0	20°C, 65 % RH	0	20°C, 65 % RH
1	20°C, 30 % RH	1’	20°C, 85 % RH
2	20°C, 85 % RH	2’	20°C, 30 % RH
3	20°C, 65 % RH	3’	20°C, 65 % RH

After each conditioning stage the weight and thickness of each sample were measured, and following the third stage all the samples were torn, and thus the internal bond perpendicular to the planes was evaluated. Relative changes in thickness were calculated using the Eq. 1:

$$\delta t = \frac{t_{2(3)} - t_{1(0)}}{t_{1(0)}} \times 100 \qquad (\%) \tag{1}$$

where: t - board thickness after specific conditioning stage.

Since the studied OSBs differed in loading, the relative changes in thickness were presented with respect to the change in board moisture content (Eq. 2):

$$\delta t_{CM} = \frac{\delta t}{MC_{2(3)} - MC_{1(0)}} \qquad (\%/\%) \tag{2}$$

where: MC - board moisture content after specific conditioning stage.

The changes between the first and second stage were called adsorption, when they were evaluated for set No. 1, and desorption with a prime symbol (') for the set No. 2. The changes between the third and zero stage were determined as total changes for a given set.

Relative changes in the internal bond perpendicular to the planes were calculated by the Eq. 3:

$$\Delta IB = \frac{IB_0 - IB_3}{IB_0} 100\% \tag{3}$$

where: IB_0 – board strength for degree 0,
IB_3 – board strength for degree 3.

RESULTS

Properties of oriented strand boards

Physical and mechanical properties of the boards were shown in Tab. 2. The data contained therein show that increased loading resulted in better mechanical properties of the OSBs. Improvement was also observed for swelling, but while rising the loading from 5 to 10 % enhanced water resistance by about 47 %, the growth from 10 to 15 % brought about only 19 % improvement. Mechanical properties of the studied boards, except for board A (5 % loading) greatly exceeded the requirements of EN 300 (2000) standard for OSB/3.

Tab. 2: Properties of the tested boards.

Property	EN 300	Resin content (%) – board symbol		
	OSB/3	5 - A	10 - B	15 - C
Density [a] ρ (kg.m^{-3})	-	650[e] (20)	650 (30)	645 (30)
Swelling [b] G_t (%)	15	34.2 (2.4)	18.2 (1.2)	14.8 (1.3)
Modulus of rupture [c] MOR ⊥ (N.m^{-2})	10	15.9 (1.0)	20.0 (1.5)	23.0 (1.7)
Modulus of elasticity [c] MOE ⊥ (N.mm^{-2})	1400	1660 (120)	2420 (120)	2720 (150)
Internal bond [d] IB (N.mm^{-2})	0.32	0.30 (0.03)	0.54 (0.06)	0.64 (0.07)

[a] according to EN 323; [b] according to EN 317; [c] according to EN 310; [d] according to EN 319;

[e] – mean value, standard deviation in parentheses

The properties of the board A were only slightly worse than recommended for the internal bond perpendicular to the planes. However, significantly poorer results were obtained for swelling parameters, following 24 h soaking in water. Relevant requirements were met only by the board C (15 % loading), and swelling for the board A was over 2 times higher than required. None of the boards met the V100 test requirements, but this is normal for this type of adhesive.

Changes in OSB thickness

Relative changes in OSB thickness for different MUPF loading options were shown in Fig. 1. According to the data presented therein, the greatest changes in thickness were observed during adsorption process (Set No. 1) in the board A (5 % loading), and the smallest for the desorption process (Set No. 2) in the board E (15 % loading). A more general analysis of the obtained data revealed that, irrespective of loading, the changes in thickness perceived for the adsorption process were much larger than those reported for the desorption process. Thickness variations for these processes amounted to approximately 50 % and were statistically significant (ANOVA - F(1.72)=221.76, p=0.0001). However, the higher the loading, the smaller the differences were in the relative change in thickness between the desorptive and adsorptive direction of the moisture content changes. The effect of loading on the range of thickness variability was also well visible. The extent of the changes in thickness was inversely proportional to the loading degree. Mean relative changes in thickness (for both directions of moisture content changes) were 0.9933, 0.7194 and 0.4928 % /% for the loading of 5, 10 and 15 %.

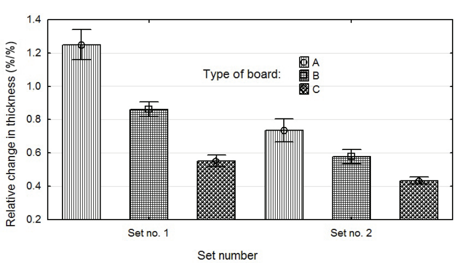

Fig. 1: Relative change in thickness as measured between 2→1 degree of conditioning.

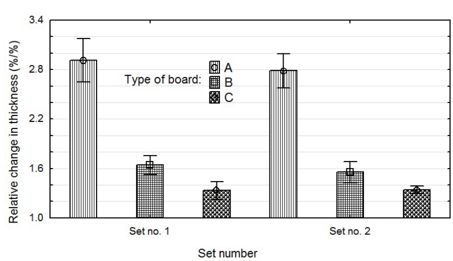

Fig. 2: Relative change in thickness as measured between 3→0 degree of conditioning.

Relative changes in thickness, determined after the conditioning process (so-called total changes) were shown in Fig. 2. The observed deformations seemed to be too large in relation to those registered between the 2 and 1 degree of conditioning.

However, this is due to the fact that re-conditioning of the samples in air with relative humidity of 65 % resulted in 2.07 to 3.21 % greater moisture content of the boards than after pre-conditioning (stage 0), and adsorptive and desorptive changes altered the board moisture content by 7-8 %. The data presented in Fig. 2 indicated that the changes in thicknesses were inversely proportional to the strand loading. For 5 % loading the gain in the board thickness was almost 80 % bigger than for 10 % loading, while the gain in thickness for 10 % loading was only about 25 % greater than for 15 % loading. Therefore, the increase in loading above 10 % did not cause such huge changes in the behavior of the boards exposed to air of varying humidity. Moreover, the direction of board conditioning did not affect the range of the observed thickness deformations. The observed changes in thickness for both sets were very similar, irrespective of the loading (ANOVA: $F(1.72)=1.2353$, $p=0.27008$).

Internal bond

Relative changes in the board resistance, triggered by the conditioning process carried out in various relative air humidity were shown in Fig. 3. According to the presented data, increased loading improved the board resistance to changes in relative air humidity, as measured by this parameter. However, regardless of the loading, the reduction in internal bond perpendicular to the planes was significantly greater for the boards moistened at the first stage of conditioning (set No. 2).

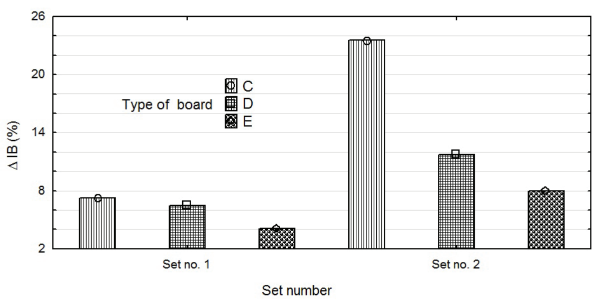

Fig. 3: The effect MUPF loading on changes in the internal bond perpendicular to the planes caused by changes in relative air humidity Δ IB.

Detailed analysis of the obtained results of the internal bond perpendicular to the planes revealed that these changes can be considered statistically significant (Tukey's test: 0.0001 - board A; 0.0111 - board B; 0.0029 - board C), in contrast to the resistance values determined for the set No. 1 and compared to the initial values (Tukey's test: 0.1184 - board A, 0.2326 - board B, 0.1376 - board C).

DISCUSSION

Physical and mechanical properties of the laboratory boards with 10 and 15 % loading were similar to those of industrial OSB/3, and the boards with 15 % loading met the requirements for

OSB/4 of the same thickness. Assuming linear relationship between OSB thickness and moisture content changes advocated by Wu and Suchsland (1997), it may be expected that for similar humidity conditions (2→1) the relative change in thickness for an industrial OSB/3 would be about 0.6 % /% (Mirski et al. 2007), and for OSB/4 about 0.45 % /% (Mirski and Dziurka 2013). Thus, the changes in thickness in the laboratory board C were similar to those in the industrial OSB/4, and the board B matched OSB/3. However, in both industrial boards only the outer layers were loaded with MUPF resin, and the core layer was glued with pMDI. As demonstrated by Wang and Winistorfer (2003) and Wang et al. (2003) in the case of OSB the swelling concerned mainly the outer layers. Therefore, the range of thickness changes in B and C boards, even at full loading with MUPF resin, perfectly matched the nature of the industrial boards. This was probably due to a significantly higher loading than normally used in the industrial conditions. The effect of loading degree was clearly manifested through IB changes. In this case, the changes in B and C boards were considerably smaller than in the industrial boards (Mirski et al. 2012).

CONCLUSIONS

The study proved that all tested MUPF loaded OSBs had very good mechanical parameters that were close to or exceeding the requirements of EN 300 (2000) standard for OSB/3. However, satisfactory level of swelling was not achieved for lower loading degree, and this was reflected in the performance of boards exposed to air with high and low relative moisture content. This was clearly visible while analyzing the deformations perceived throughout the cycle of moisture content variations. Changes in thickness in the boards with 5 % loading were almost two times greater than in the boards with 10 % loading, while the increase in thickness of the latter boards was only about 25 % greater than in those with 15 % loading. The study also showed that the range of deformations for partial changes (between 2 and 1 stage) was inversely proportional to loading. The changes in thickness were from 30 to 70 % greater in the set No. 1. No significant changes in the internal bond perpendicular to the board planes were found for this set. It seems, therefore, that moistening was a crucial factor determining the mechanical properties, as the samples from set No. 2 were subjected to two moistening cycles, and those from set No. 1 to only one.

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