WOOD RESEARCH
56 (3): 2011
403-412

DYNAMICS OF CHANGES IN THICKNESS OF COMMERCIAL OSB/3 SUBJECTED TO SOAKING

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(Received June 2010)

ABSTRACT

The study analyzed the intensity of changes in thickness of OSB subjected to soaking in water, depending on treatment time. Conducted tests showed that the dynamics of thickness changes in OSB/3 is characterized by at least two rates in the observed period of thickness changes. The first rate covers the period of approx. 150 min and it is dependent both on initial moisture content of board subjected to soaking and on mean density of the boards; whereas, dynamics of changes in thickness for a period over 150 min is characterized by a high dependence of rate II on mean density of boards. As it could have been expected, increment in thickness for all soaked boards is proportional to the amount of absorbed water and in turn this dependence is inversely proportional to nominal thickness of OSB.

KEYWORDS: OSB, thickness swelling, water absorbability.

INTRODUCTION

Wood, absorbing water in the course of soaking, may reach moisture content considerably exceeding 100 %. However, above the fibre saturation point it contains only free water, not causing dimensional changes. This property of wood is transferred to wood-based materials, although during their manufacture it is attempted to reduce this rather disadvantageous phenomenon. Particularly OSB exhibits relatively high dimensional changes as a result of soaking, both in relation to wood and plywood, for which it is a substitute. Water resistance of wood-based materials is determined by the degree of fineness, the type of used adhesive, the application of protecting coats and the addition of hydrophobic compounds, most commonly introduced with the adhesive solution. The dominant binding agents in OSB production worldwide are phenol-formaldehyde resins, making it possible to obtain adhesive-bonded joints with good mechanical properties and high water resistance (Andersen and Troughton 1996, Irle and Bolton 1988). However, due to their colour and relatively low reactivity, four-component melamine-urea-phenol-formaldehyde

(MUPF) resins or polymeric methylene diphenyl diisocyates (PMDI) adhesive are being applied with increasing frequency. Chips used for the production of OSB should facilitate the transfer of positive properties from wood and easy orientation, thus typically chips of 75 - 100 mm in length are used (Keiser 1987, Barnes 2000, 2001). Bigger chips are used for the outer layers, while smaller for the core, which may be, but in industrial production practice is not oriented (Shupe et al. 2001). The use of finer chips by their very nature will hinder orientation.

When analyzing dimensional changes in OSB the non-homogeneous structure at the cross-section (density profile), the degree of chip orientation and chip size need to be considered as well as the relationship of their dimensions with anatomical directions of wood. To date studies have focused on dimensional changes in boards subjected to the action of moist air (Wu 1999, Suchsland 2000, Wu and Lee 2002, Mirski et al. 2007). Most of these studies took into consideration factors mentioned above and attempted to model phenomena occurring as a result of changes in board moisture contents. It needs to be expected that similar changes take place in boards in the course of their soaking in water, except for the fact that these changes are much more marked. The aim of this study was to determine the intensity of changes in thickness of OSB subjected to soaking in water, depending on treatment time.

MATERIAL AND METHODS

Tests were conducted on commercially produced OSB/3 made from chips of pine (*Pinus sylvestris*) with a thickness of 12, 15, 18 and 22 mm, resinated in the core with PMDI, in the outer layers with MUPF resin as well as boards with a thickness of 22 mm resinated with PMDI only. In this study the following testing system was applied (diagram 1):

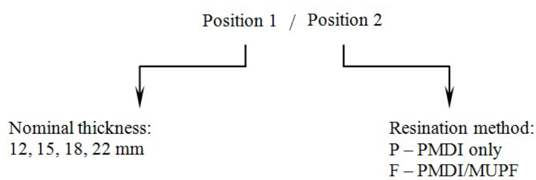

Diagram 1: The testing system used in analyses of OSB/3.

Basic properties investigated in testing of boards are presented in Tab. 1. It results from data given in that table the properties of tested OSB/3 considerably exceed values required by standard EN 300, particularly in terms of bending strength. No significant changes were found in properties for boards of 22 mm in thickness, in which outer layers were resinated with a different bonding agent.

Tests were conducted on samples of boards with a regular thickness, length of 300 mm and width of 50 mm, dimensions required by standard EN 318 to be used in the determination of dimensional changes. From each type of boards 12 samples were cut. On each of the samples three thickness measurement points were established, as presented in Fig. 1. Such prepared samples were subjected to soaking in water at a temperature of 20°C. Thickness was measured accurate to 0.01 mm initially at every 15 min, from 90 min at every 30 min, next gradually increasing the interval between measurements. In the final period of measurements thickness was determined at every 8-12 h. With thickness measurements also weight of each sample was determined accurate to 0.01 g. Since thickness of boards was measured when determining the dynamics of changes in length, the soaking process was completed after constant length was reached by samples (constant length for three successive measurements taken within 8 h). Measurements for the whole range of changes in thickness were conducted only for the board with a thickness of 12 mm. Based on the course of changes in thickness for the same board it may be stated that the period of measurements assumed for the other boards constitutes from 10 to 30 % total period of changes in thickness, thus it was decided to define the observed changes as occurring in the initial period of changes in thickness.

Tab. 1: Characteristics of tested OSB/3.

Property	Testing method	Unit	Board types				
			12 mm /F	15 mm /F	18 mm /F	22 mm /F	22 mm /P
ρ	EN 323	($kg.m^{-3}$)	**625**	**640**	**620**	**615**	**580**
H	EN 322	(%)	**6.53**	**4.85**	**6.22**	**7.88**	**8.40**
G_t	EN 317	(%)	**12** /15*	**7** /15	**9** /15	**14** /15	**11** /15
f_m II	EN 310	($N.mm^{-2}$)	**22** /20	**42** /20	**22** /	**27** /19	**29** /19
$f_m \perp$	EN 310	($N.mm^{-2}$)	**22** /10	**29** /10	**19** /9	**20** /9	**21** /9
E_m II	EN 310	($N.mm^{-2}$)	**4050** /3500	**7350** /3500	**6050** /3500	**5100** /3500	**5050** /3500
E_m	EN 310	($N.mm^{-2}$)	**2990** /1400	**3970** /1400	**3150** /1400	**3160** /1400	**2930** /1400
$f_{t\perp}$	EN 319	($N.mm^{-2}$)	**0.71** /0.32	**0.74** /0.32	**0.42** /0.3	**0.54** /0.3	**0.54** /0.3
V100	EN 1087-1	($N.mm^{-2}$)	**0.18** /0.13	**0.20** /0.13	**0.17** /0.12	**0.15** /0.12	**0.14** /0.12

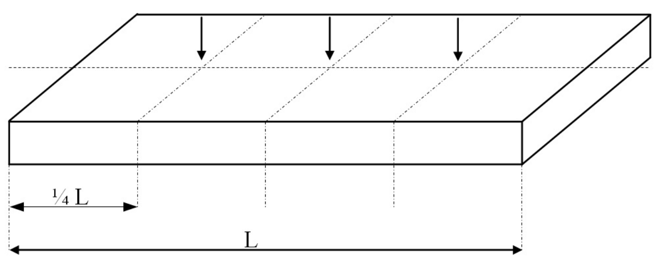

Fig. 1: Positions for measuring thickness.

As it is commonly known, over the entire range of changes the increment in thickness is described by an exponential curve, which general form may be described by formula:

$$\Delta IT=\Delta IT_u[1-\exp(-t/\tau)]$$

where:
ΔIT – increment in thickness,
ΔIT_u – determined (final) value of increment in thickness,
t – time,
τ - time constant.

However, phenomena occurring in nature may rarely be described with the use of a single exponential function and frequently this type of an oversimplification, although in many cases sufficient, may not indicate a more complex process of occurring changes.

RESULTS AND DISCUSSION

Increment in thickness for OSB/3 tested in this study is presented in Figs. 2-6. As it results from data given in these figures, in the period of measurements we may distinguish two areas, in which increments in thickness may be interpolated with a straight line. The first area covers the period of approx. 120 ÷ 150 min, while the other that of 1200 ÷ 3500 min, respectively. The period over which linearity of occurring changes is maintained in the second area is directly proportional to board thickness. In contrast, no effect of the combination of used adhesives may be distinguished.

Determined direction coefficients both for the first (a_1) and the second (a_2) area of increment in thickness define the rate of changes in a given board. These coefficients in the further part of the study will be referred to as rate I (coming from the first area) and rate II (from the second area of measurements).

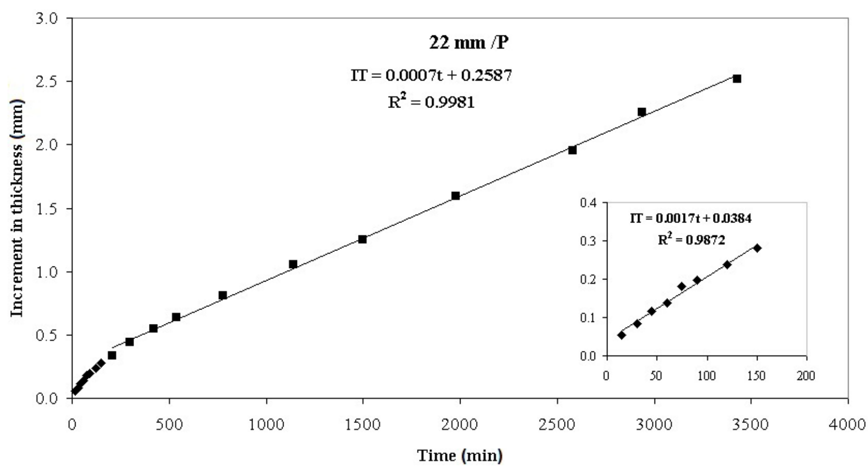

Fig. 2: Increment of thickness OSB/3 - 22 mm, glued with PMDI.

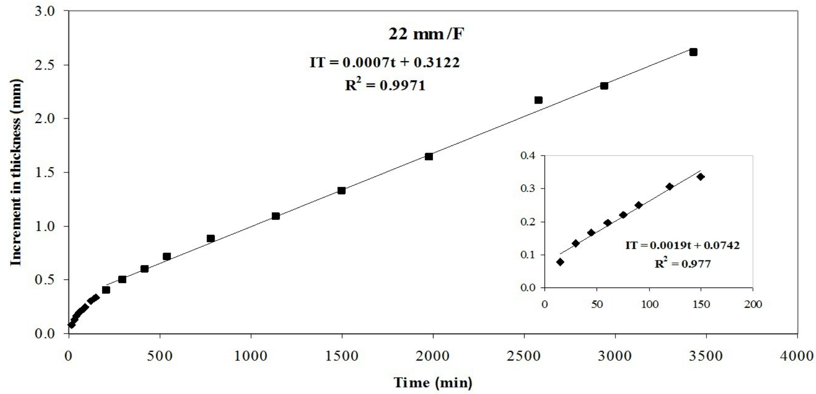

Fig. 3: Increment of thickness OSB/3 - 22 mm, glued with MUPF/PMDI.

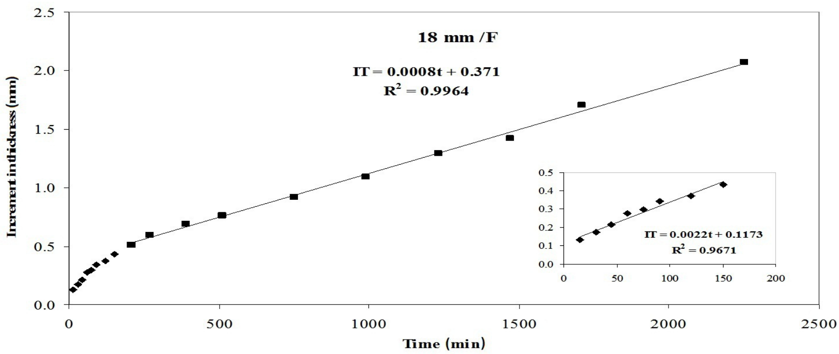

Fig. 4: Increment of thickness OSB/3 - 18 mm, glued with MUPF/PMDI.

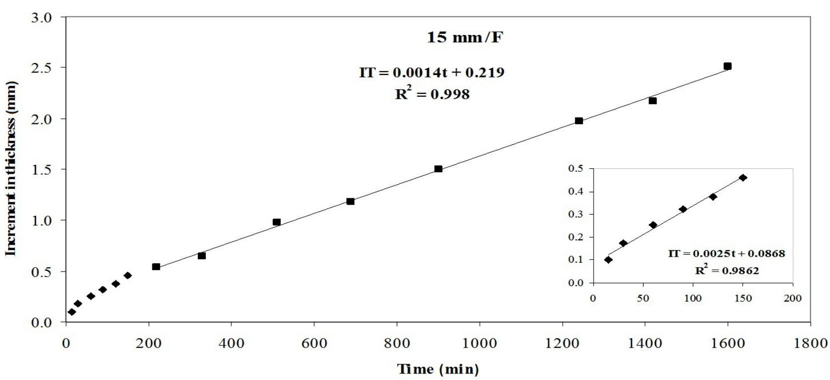

Fig. 5: Increment of thickness OSB/3 - 15 mm, glued with MUPF/PMDI.

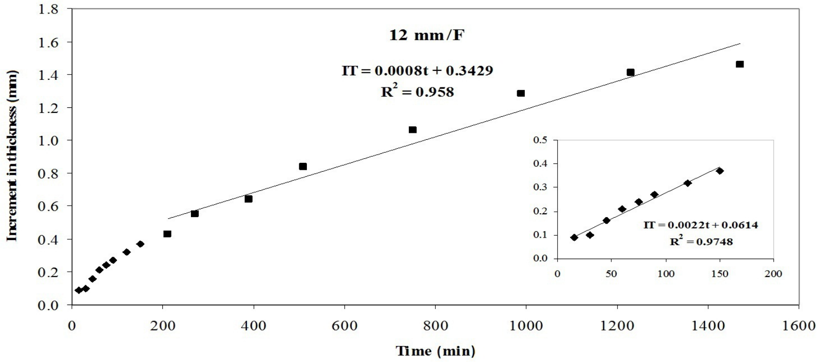

Fig. 6: Increment of thickness OSB/3 - 12 mm, glued with MUPF/PMDI.

Among all the tested boards the slowest increase of thickness in the first period was found for the board of 22 mm in thickness, where outer layers were resinated with PMDI adhesive. Among boards resinated in the outer layers with MUPF resin the slowest increase was recorded for boards with a thickness of 22 mm, while the most rapid increase was observed for the board with a thickness of 15 mm. In the first case this rate was 0.0019 mm.min^{-1}, while in the other it was 0.0025 mm.min^{-1}, respectively. However, as it results from data shown in Fig. 7 we may observe a distinct linear dependence of the first rate on the initial moisture content of boards, irrespective of their thickness or the applied resination method. This dependence is characterized by a high goodness of fit R^2 = 0.9858. It results from the above that increment in thickness is inversely proportional to the initial moisture content of boards. A similar trend was observed by Wu and Lee (2002) when determining changes in length of OSB subjected to gradual soaking (35 ÷ 93 RH). This type of behaviour of tested boards confirms a well-known fact that the drier a material is, the more intensively it absorbs water.

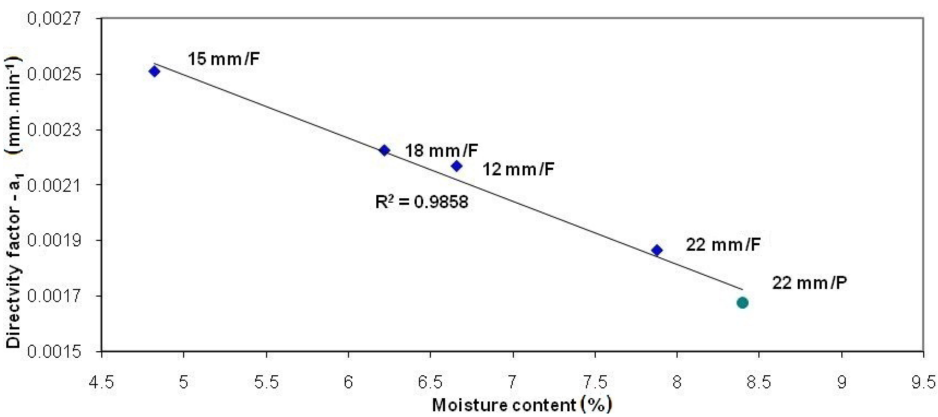

Fig. 7: The effect of initial moisture content of OSB/3 on the rate of changes in thickness in the first soaking period.

Moreover, for this soaking time we may observe that the rate of changes in thickness of boards depends also on their density (Fig. 8). The highest rate I was found for a board with a thickness of 15 mm and mean density 640 kg.m^{-3}, while the lowest for a board of a thickness of 22 mm resinated with PMDI only and mean density 580 kg.m^{-3}. It seems that in the initial soaking period the volume of changes is determined mainly by chips in the outer layer, as they are in direct contact with water.

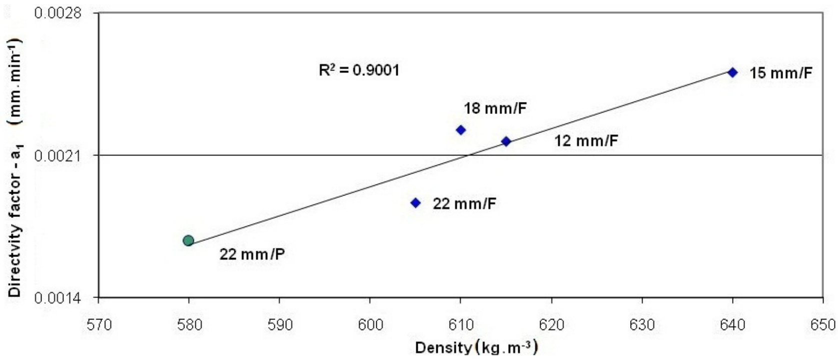

Fig. 8: The effect of the density of OSB/3 on the rate of changes in thickness in the first soaking period.

In the first investigated sample soaking period the increment in thickness is much less significantly affected by the initial thickness of boards or the type of adhesive used in resination of the outer layer. This type of characteristics may become significant after a longer soaking period, i.e. after an increase in moisture content of deeper layers.

It results from the analysis of the second rate that among OSB resinated in the MUPF/PMDI system the most intensive increase in thickness was found for a board with a thickness of 15 mm, while it was slowest for that of 22 mm in thickness. This means that also in that area for this type of boards we may observe a linear effect of density on the rate of swelling in thickness of boards (Fig. 9). The determined value of rate II for a board with a thickness of 22 mm and resinated with PMDI only is the same as for an identical type of board resinated in the MUPF/PMDI system. Assuming that density is the most significant factor affecting changes in thickness in this area of investigated changes, it may be concluded that deformability of chips resinated with PMDI is bigger. However, the process of dimensional changes of boards is also strongly connected with chip orientation and with the distribution of moisture content at the cross-section. Even if as a result of long-term acclimation a uniform level of moisture content was obtained in samples before they were subjected to soaking, the degree of chip orientation will have an effect on the rate of water transport in the board, which undoubtedly is of considerable importance particularly in the first stage of soaking.

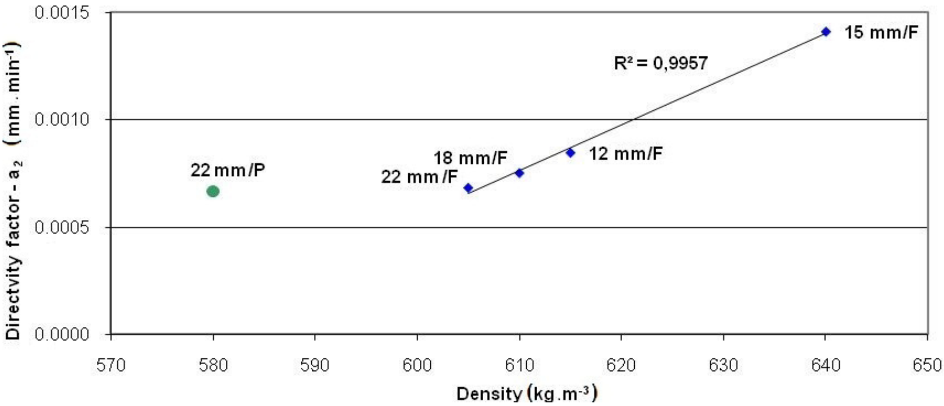

Fig. 9: The effect of the density of OSB/3 on the rate of changes in thickness in the second soaking period.

Tab. 2 presents values of coefficients of linear regression for the dependence of swelling in thickness (TS) on water absorbability (WA). As it could have been expected, a significant correlation may occur between changes in thickness and the amount of water absorbed by a board. A similar dependence was found in their study by Wu and Lee (2002), but not at such a high correlation coefficient as that recorded in this study. The most intensive increase in swelling in thickness was found for board with a thickness of 12 mm, while the smallest for board with a thickness of 22 mm, as a result of absorption of the same amount of water by boards. In turn, among boards with a thickness of 22 mm at this stage of analyses OSB resinated in the outer layer with MUPF turned out to be the most water resistant. However, differences between individual types of boards with a thickness of 22 mm are not big and may be neglected. Moreover, it was found that obtained direction coefficients for this dependence are inversely proportional to board thickness (Fig. 10).

Tab. 2: Regresion results on TS-WA relationship for OSB/3 with a linear model ($TS = a_0 + a_3WA$).

Regresion coefficients	Unit	Numerical value				
		Board type				
		12 mm/F	15 mm/F	18 mm/F	22 mm/F	22 mm/P
a_o	%	- 0.9147	- 1.1524	0.2222	- 0.5976	- 0.3992
Slope, a_3	%/%	0.3831	0.3336	0.3246	0.2808	0.2878
r^2	-	0.9961	0.9804	0.9928	0.9931	0.9961

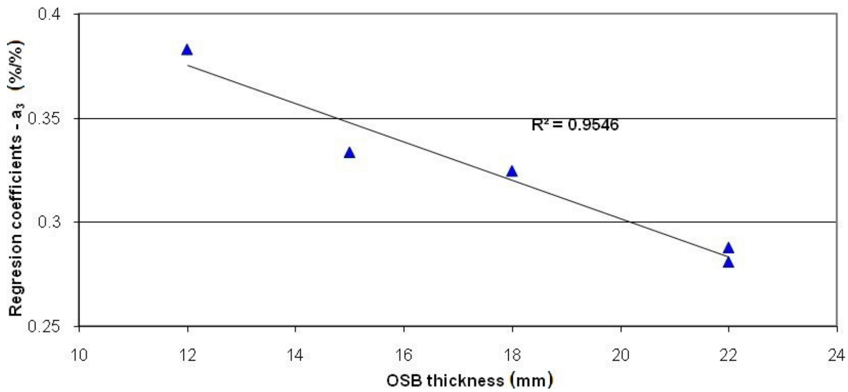

Fig. 10: Relationship factor a3 with nominal thickness of OSB/3.

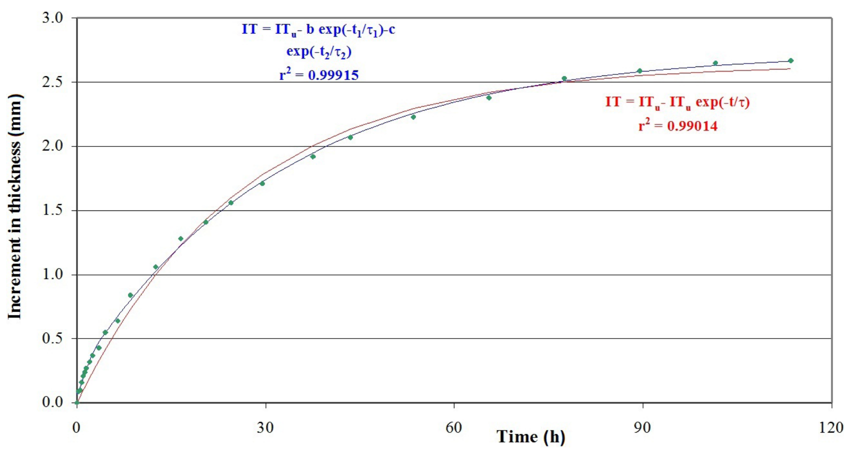

Fig. 11: Interpolations of measurement data for changes in thickness of OSB/3 with the use of the single- and double-exponential curves.

Fig. 11 presents interpolations of measurement data for changes in thickness of a 12 mm board with the use of exponential equations. Both the single- and double-exponential curves with very good approximation reflect the course of changes in board thickness during soaking; however, the latter reflects initial changes in thickness more accurately and probably forecasts a more approximate value of total increment in thickness.

CONCLUSIONS

It results from the conducted investigations that the dynamics of thickness changes in OSB/3 is characterized by at least two rates in the observed period of thickness changes. First rate covers the period of approx. 150 min and it is dependent both on initial moisture content of board subjected to soaking and on mean density of the boards; particularly for initial moisture content of the board a very high value of goodness of fit will be obtained, $r^2 = 0.9858$. Increment in thickness observed for these period results most probably from swelling in thickness of chips in the outer layers; however, no effect of the type of adhesive used to resinate these layers was observed. Dynamics of changes in thickness for a period over 150 min was characterized by a high dependence of rate II on mean density of boards resinated only in the same MUPF/PMDI system. OSB/3 of 22 mm in thickness resinated in its whole mass with PMDI adhesive was characterized by a relatively high dynamics of changes, despite low density of tested samples. As it could have been expected, increment in thickness for all soaked boards is proportional to the amount of absorbed water and in turn this dependence is inversely proportional to nominal thickness of OSB.

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