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Dynamics examination of selected properties for wood materials varying their humidity

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Abstract: *Dynamics examination of selected properties for wood materials varying their humidity.* The work concerns the dynamics of changes of selected properties of wood and wood-based materials that change their moisture. The aim of the study was to compare the selected properties and humidity Scots pine wood, plywood, chipboard and MDF board. The samples behave differently during soaking and depending on the time of soaking adopt different characteristics. Solid wood achieves the fastest highest water capacity. Among the composite wood samples with low density can get much water at the same time wetting.

Keywords: wood, wood materials, humidity, water absorption, swelling

INTRODUCTION

Wood in its natural form is absorptive and hygroscopic. Absorption of humidity from air results in its swelling. However, noticeable decrease in its humidity is followed by its shrinkage. Both these phenomena cause changes of mechanical properties. Resulting from permanent or partial hygroscopic humidification, or due to water flooding, some wood materials are deformed irreversibly, dissection occurs, which is one of many factors to determine the scope and application methods in numerous fields, an example being civil engineering. Therefore knowledge on humidity-related properties of timber materials and adequate selection depending on their purpose and usage location is an important aspect. Consequently, reasonable selection of wood materials not only should take into account a competitive price, but most of all mechanical and humidity-related characteristics. The purpose of this paper is to present differences occurring in examined wood materials when they are soaked in water. Specific aims realized in this paper are: identifying humidity levels for scots pine sapwood, plywood, chipboard and MDF board with the application of the oven-dry method; maximum water capacity identification for pine sapwood, plywood, chipboard and MDF board; absorptivity testing for pine sapwood, plywood, chipboard and MDF board.

IDENTIFICATION METHODOLOGY OF MAXIMUM WATER CAPACITY FOR WOOD AND WOOD-BASE MATERIALS

Maximum water capacity is the highest amount of water which can be absorbed by wood, it is expressed in % of dry wood mass. When wood which is submerged in water reaches its constant mass, it can be assumed that it has absorbed the maximum amount of water. This parameter is dependent, most of all, on the wood species, additional substances, wood structure and hardwoods number. Wood absorptivity is its ability to absorb water and other fluids it is soaked in (***Kokociński 2004***). The tests were carried out in accordance to norms (***PN-D-04119: 1959, PN-D-04227: 1977. PN-EN 325: 1999, PN-EN 322: 1999***), in a laboratory with the following conditions: air temperature 20°C, distilled water temperature 20°C and relative air humidity 50-60%. 20 moisture sections were set up of the following dimensions: 30x30x10±1 mm (the latter dimension relate to wood along its fibers), with 5 moisture sections from each material. Moisture sections were dried in order to reach constant mass and were weighed with 0,001 g precision. They were then subjected to soaking in distilled water of 20°C temperature. So as to mark their humidity, maximum water capacity and absorptivity, the following weighing time regime was applied, after 1,5,10,20,30,40,50,60,120 minutes and then after 1,2,5,8 and 11 days. The changing absorptivity values were calculated from the following equation (***PN-D-04119: 1959***):

$$W_t = \frac{m_{w(t)} - m_0}{m_0} \times 100\ [\%] \tag{1}$$

Next parameter, which was determined was absorption velocity V_n, calculated from the equation with 0,1%/h precision (***PN-D-04119: 1959***):

$$V_n = \frac{W_t}{t}\ [\frac{\%}{h}] \tag{2}$$

Maximum water capacity of materials was calculated from the equation (***Kokociński 2004***) :

$$W_{max} = \frac{m_{Wmax} - m_0}{m_0} \times 100\ [\%] \tag{3}$$

Saturation ratio S_n was calculated from the equation equation (***Kokociński 2004***):

$$S_n = \frac{W_t}{W_{max}}\ [\%] \tag{4}$$

In the above equations the symbols denote:
W_t – absolute humidity in time t
t- humidification time
W_{max}- maximum water capacity [%]
m_{Wmax}- mass of a moisture section with maximum water saturation [g]
m_{Wt} – mass of a moisture section after humidification time t [g]
m_0 - mass of a completely dry moisture section [g]
The results were presented in the form of tables and graphics.

THE RESEARCH RESULTS

From the recorded moisture sections masses, which changed according to their soaking time in water and with the application of equations: (1), (2), (4), W_t, V_n, S_n values were calculated, which were averaged out for each moisture section type, in every time interval, from the equation (5):

$$\bar{x} = \frac{x_1 + x_2 + \dots + x_N}{N} = \frac{\sum_{i=1}^{N} x_i}{N} \tag{5}$$

Maximum water capacity calculated from equation (3) was presented in the last line of tables, and the mass applied in order to find W_{max} should not differ from the mass in the preceding time interval by more than 0,1 g. The averaged out research results are gathered in tables 1-4 and their analysis is presented in figures 1-3.

Tab. 1 The research results for scots pine sapwood

SCOTS PINE				
m_0(g)= 3,96				
ρ_0 (kg/m^3)= 502				
t	m_w	W_t	V_n	S_n
min	g	%	%/min	%
1	4,66	17,54	17,54	10,12
5	5,40	36,37	7,27	20,93
10	5,69	43,62	4,36	25,11
20	5,98	51,05	2,55	29,37
30	6,10	54,09	1,80	31,12
40	6,14	55,11	1,38	31,71
50	6,19	56,38	1,13	32,44
60	6,22	57,19	0,95	32,90
120	6,29	59,07	0,49	33,98
1440(24h)	6,87	73,38	0,05	42,24
2880(2days)	7,62	92,48	0,03	53,27
7200(5 days)	8,63	117,91	0,02	67,85
11520(8 days)	10,76	171,77	0,01	98,91
15840(11days)	10,84	173,65	0,01	100,00
MAXIMUM WATER CAPACITY W_{max} [%]			173,65	

Tab. 2 The research results for plywood

PLYWOOD				
m_0(g)= 3,45				
ρ_0 (kg/m^3)= 660				
t	m_w	W_t	V_n	S_n
Min	g	%	%/min	%
1	3,58	3,84	3,47	4,08
5	3,74	8,27	1,80	8,74
10	3,79	9,86	1,36	10,46
20	3,88	12,47	1,21	13,21
30	3,93	13,86	1,19	14,66
40	3,98	15,23	1,18	16,12
50	4,02	16,54	1,24	17,46
60	4,08	18,27	1,27	19,29
120	4,24	22,76	1,42	24,08
1440(24h)	5,02	45,59	2,50	48,16
2880(2days)	5,25	52,11	2,72	55,03
7200(5 days)	5,77	67,26	3,22	71,13
11520(8 days)	6,66	93,18	3,74	98,91
15840(11days)	6,70	94,26	3,75	100,00
MAXIMUM WATER CAPACITY W_{max}[%]			94,26	

Tab. 3 The research results for chipboard

CHIPBOARD				
m_0(g)= 3,55				
ρ_0 (kg/m^3)= 610				
t	m_w	W_t	V_n	S_n
Min	g	%	%/min	%
1	3,72	4,82	4,82	5,44
5	4,01	12,89	2,58	14,49
10	4,07	14,59	1,46	16,46
20	4,19	17,98	0,90	20,30
30	4,32	21,59	0,72	24,40
40	4,44	25,07	0,63	28,29
50	4,49	26,39	0,53	29,87
60	4,56	28,59	0,48	32,34
120	4,74	33,40	0,28	38,06
1440(24h)	5,89	65,83	0,05	75,23
2880(2days)	6,11	72,22	0,03	82,59
7200(5 days)	6,48	82,50	0,01	94,46
11520(8 days)	6,64	87,08	0,01	99,69
15840(11days)	6,65	87,36	0,01	100,01
MAXIMUM WATER CAPACITY W_{max}[%]			87,36	

Tab. 4 The research results for MDF board

MDF BOARD				
m_0(g)= 4,54				
ρ_0 (kg/m^3)= 390				
t	m_w	W_t	V_n	S_n
Min	g	%	%/min	%
1	4,67	2,76	2,76	1,93
5	4,88	7,42	1,48	5,21
10	4,94	8,82	0,88	6,18
20	5,07	11,73	0,59	8,31
30	5,17	13,78	0,46	9,73
40	5,23	15,16	0,38	10,71
50	5,26	15,79	0,32	11,15
60	5,28	16,28	0,27	11,49
120	5,57	22,64	0,19	15,98
1440(24h)	7,29	60,45	0,04	42,43
2880(2days)	8,84	94,53	0,03	66,56
7200(5 days)	9,34	105,67	0,01	74,48
11520(8 days)	10,90	139,85	0,01	98,66
15840(11days)	10,98	141,73	0,01	100,00
MAXIMUM WATER CAPACITY W_{max} [%]			141,73	

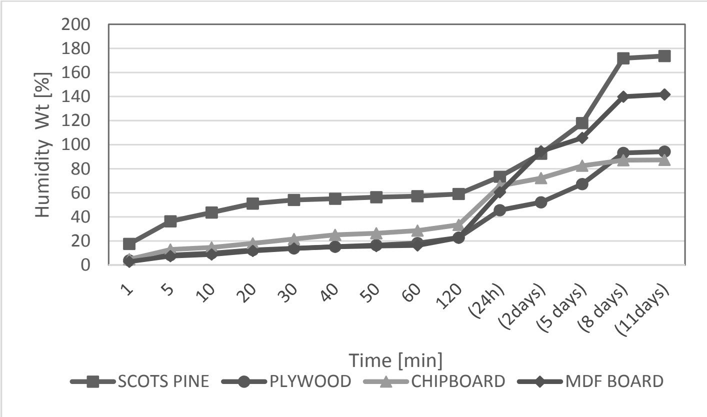

Fig. 1 Moisture sections soaking time dependency on their humidity changes

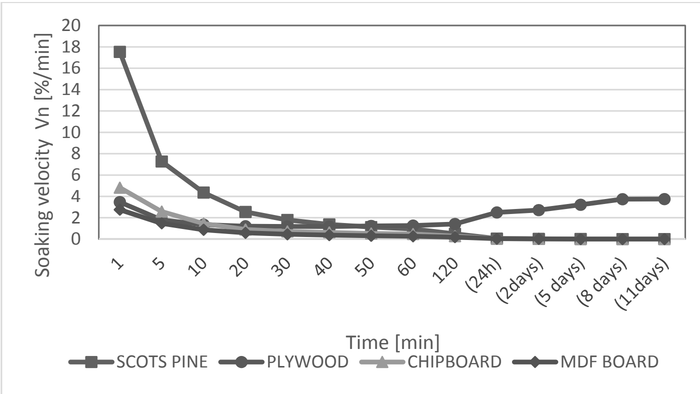

Fig. 2 Soaking velocity changes for moisture sections in time

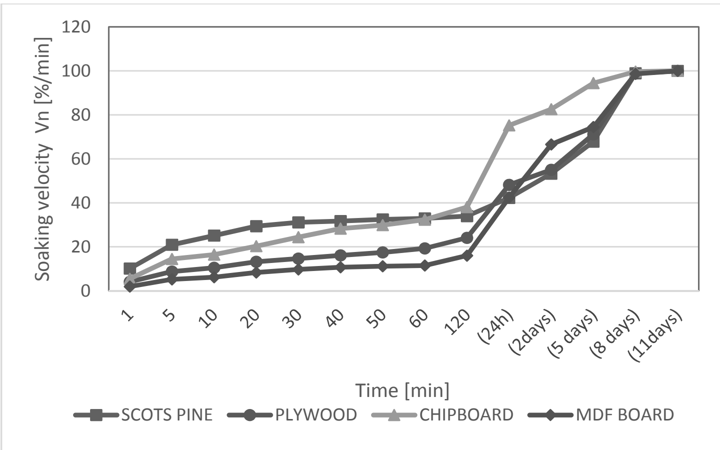

Fig. 3 Saturation degree changes for moisture sections in time

Analysis of dependencies between moisture sections humidity change and soaking time (Fig.1) shows that during the first 2 hours of the subjects soaking, humidity of wood-base materials is similar, values changes are minor and close to 20%. At the same time scots pine sapwood humidity differs substantially from that of wood-base materials. Its humidity increases more rapidly and within one hour it reaches the value close to 60%. From the second hour to twenty fourth hour, plywood humidity increased twice, chipboard and MDF board three times, and pure stand wood by only 10%. Wood-base materials were only just starting to absorb more water whereas pure stand wood has already filled its outer layers with it. After 2 days scots pine wood humidity increase becomes linear, which may support the thesis that water started penetrating through the pores located in the deep inside of the moisture section and fill them. Wood-base materials continued to increase their humidity, with MDF board standing out in this respect, after 5 days its humidity was close to that of scots pine wood and was higher than 100%. Chipboard humidity after 5 days was a little above 80%, and after 3 more days the increase was only by 5%. Plywood on the fifth day of soaking indicated the lowest humidity level of all the samples, because it was only 67%. However this tendency changed in the next subsequent days. Plywood was now close to its maximum water capacity and its humidity was set at approximately 93%, while it outperformed chipboard, which was nearing to its maximum water capacity since the fifth day. Humidity level for both moisture sections was approximately 95%. MDF board absorbed the highest amount of water among all wood-base materials and ended its soaking with the result above 140% humidity. Scots pine took the first place with its humidity over 170%. One may infer that in case of wood-base materials maximum water capacity is not necessarily dependent on the material type rather than on its density. MDF board is classified as a wood-base material which is most resistant to outdoors conditions, however, after a longer period of time (longer than 24 hours) it absorbs the highest amount of water, it is the MDF board which features the lowest density. MDF board is light, so chips it is made of are not very much collided, which enables water to penetrate through, and fill the space. Chipboard and plywood have similar density in their dry state, and their maximum water capacity is almost alike. Wood absorbs the highest amount of water. Until the fiber saturation point, water fills cavities of some cells, such as vessels, tracheids, and subsequently penetrates intercellular space, pores. Wood is capable to absorb the highest amount of water, yet, even after a long soaking time its appearance does not differ much from that of the dry state, which is not the case for wood-base materials.

Absorption velocity analysis (Fig.2) indicates that scots pine wood featured much higher velocity than wood-base materials in the first hour. After the first hour scots pine and plywood have similar absorption velocity which is more than 1%/min, and MDF board and chipboard approximately 0,3%/min. after 2 hours of soaking scots pine wood, chipboard and MDF board absorb water very slowly, and their absorption velocity consequently decreases until the end of the process and takes the value of approximately 0,03%/min. Only for plywood absorption of water accelerates after 48 hours, and after 8 days its absorption velocity stabilizes and amounts to almost 4%/min. It is then justified to claim that wood-base materials, with the exception of plywood, in the initial phase of the process allow water to penetrate into their inside faster, after that it constantly fills empty space. However, plywood, after 2 days, shows some symptoms of dissection and absorbs water faster, which does not mean it absorbs more of it, as after 48 hours its humidity is the lowest of all moisture sections.

The amount of water the samples can absorb also differs (Fig.3). However, half of its maximum water capacity is reached by chipboard (after 5 hours), other moisture sections reach such value after approximately 24h since the beginning of soaking.

SUMMARY

During soaking, behavior of moisture sections is diversified and, depending on soaking time, they take different characteristics. Pure stand wood reaches its maximum water capacity most rapidly. Among wood-base materials moisture sections with little density can absorb most water in the same time of soaking. Within 2 days their humidity is 2-3 times lower than that of pure stand wood, whereas in time it is nearing to reach it.

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Streszczenie: *Badanie dynamiki zmian wybranych właściwości materiałów drzewnych zmieniających swoją wilgotność*. Praca dotyczy dynamiki zmian wybranych właściwości drewna i materiałów drewnopochodnych, które zmieniają swoją wilgotność. Celem pracy jest porównanie wybranych właściwości wilgotnościowych drewna sosny zwyczajnej, sklejki, płyty wiórowej i płyty MDF. Próbki zachowują się różnie podczas moczenia i w zależności od czasu moczenia przyjmują odmienne charakterystyki. Drewno lite osiąga najszybciej największą pojemność wodną. Wśród tworzyw drzewnych próbki o małej gęstości potrafią pobrać najwięcej wody w takim samym czasie moczenia.

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