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# WATER IMPACT ON CHANGE OF PHYSICAL CHARACTERISTICS OF SINGLE-LAYER WATER-RESISTANT PARTICLEBOARDS

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## ABSTRACT

The paper elaborates water impact on change of physical properties of single-layer water-resistant particleboards. The water impact is analyzed in controlled laboratory conditions through the change of density, volume, thickness swelling and water absorption in the period of 1248 hours (52 days). Experimental panels are made of beech particles. The particles are glued with phenol-formaldehyde resin.

The results from the research showed that the panels are characterized by uniform density, stability in volume, without any deformation of the shape and dimensions of the test specimens. The changes of the properties in the analyzed period are proportional to the change of the treating period of the test specimens. The panels have dimensional stability and meet the requirements of the standards for non-structural use in construction.

**Keywords:** single-layer particleboards, physical properties, changes of physical properties, water-resistant, dimensional stability

## 1. INTRODUCTION

The use of wood-based panels in modern construction determine achieving improved physical and mechanical properties of these materials, their consistency on prolonged water impact, humidity, heat, chemical agents and weathering, as well as achieving dimensional stability. As a result of this, nowadays the researches in the field of wood-based panels are directed to finding methods and technical-technological solutions for production of panels with the mentioned characteristics.

One segment of the researches of wood-based panels is researches of water-resistant particleboards for use in construction, as a sub-group of particleboards. These researches are directed to creating possibilities for production of water-resistant particleboards with improved physical properties that will be resistant to prolonged water impact, humidity, heat, chemical agents etc.

Improving of the physical properties of particleboards can be done by making changes in their structure. This means use of resins with high characteristics, mostly phenol-formaldehyde resins or their modifications.

There are many publications listed in the literature that concern the use of different types of phenol-formaldehyde resins or their modifications for production of water-resistant particleboards. A research of the impact of the content of dry matters of phenol-formaldehyde resin on panels' characteristics was done (Dimeski et al. 1997); thickness swelling and water absorption during prolonged water treatment of single-layer particleboards and combined panels made with phenol-formaldehyde resin were studied (Iliev et al. 2006); thickness swelling and water absorption during prolonged water treatment of combined panels made with phenol-formaldehyde resin were studied

(Mihajlova et al. 2005). There are some researches made for the use of modified phenol-formaldehyde resins in order to determinate the resin impact on panels' properties (Yossifov et al. 1987 and 1996).

The wood type used for particle production has no less significant impact on the particleboard properties. The wood type transfers its positive characteristics on panels, but it should also be noted that its negative characteristics reduce the particleboard properties. This means that it is important to know the quality of the wood raw material that will be used for particle production.

The worldwide deficit of quality wood raw material makes us find methods for production of particleboards from available raw material, mostly with lower quality. The widely spread deciduous trees are largely used for particleboards production, especially beech, which is worldwide dominant forest resource, and different types of pine that are mainly used for production of oriented strand boards (OSB).

In order to give an answer to the question mentioned above, the research presented in the paper is directed to determination of the impact of the phenol-formaldehyde resin on the most important physical characteristics of single-layer particleboards. The oriented strand boards (OSB) were treated in the same way in order to make a comparison of the results.

## 2. METHOD OF THE EXPERIMENTAL WORK

The aim of the researches conducted is studying the water impact on the physical properties of single-layer water-resistant particleboards during prolonged treatment of water. The water impact is analyzed on standard test specimens in controlled laboratory conditions, through change of density, volume, thickness swelling and water absorption.

The research was made on experimental single-layer particleboards made from beech particles. As an adhesive compound, water-soluble phenol-formaldehyde resin (FFS-50) is used with the following characteristics: macroscopic appearance-light red color, content of dry matters - 50,43 %, viscosity by Ford (at 20°C) - 195 s, content of free phenol - 0,30 %, pH 11, water solubility-infinite, gel time - 97 s, density at 20°C - 1,22 g/cm$^3$. As an adhesive for particle bonding, water solution of phenol-formaldehyde resin with content of dry matters of 10 to 13 % was used (depending on the model).

The panel pressing is made according to the following technological parameters: specific pressure of 25 kg/cm$^2$ (≈ 2,5 MN/m$^2$), pressing temperature of 155°C and pressing time of 30 minutes. The panels were made with dimensions of 560×455 mm and thickness of 16 mm.

According to the dry resin content in panels, two basic models were made:

- Model I: panel with resin content of 10 % and density of 677,36 kg/m$^3$, and
- Model II: panel with resin content of 13 % and density of 709,04 kg/m$^3$.

The test specimens for research and analysis were made according to the national standard for wood-based panels MKS D.C8.100. Test specimens with standard dimensions of 100×100 mm were made from the panels. Six test specimens for conducting laboratory research from each model were taken.

Equilibrium moisture of the panels during testing measured by gravimetric method was 7,97 %.

The treatment of the test specimens in water regime was made by their full immersion in distillated water in special bath, continuously for a period of 1248 hours (52 days). The water temperature during the whole treatment was within the limits of 19 to 22°C.

The criterion for evaluation of hygroscopic characteristics and dimensional stability of the panels was the properties that have a direct impact on these characteristics, i.e.: density, volume, thickness swelling and water absorption. Changes in these properties were monitored by control measuring in intervals of: 24, 48, 72, 96, 144, 192, 288, 384, 576, 768, 1008 and 1248 hours.

The researches of the changes of density, humidity, thickness swelling and water absorption were made in accordance with the national standards: MKS D.A8.114/83, MKS D.C8.103/83 and MKS D.C8.104/83. During the research of the two basic models, a research was made on one control model (model III). As a control model, an oriented strand board (OSB) was used. This panel is a product of the company „Kronospan Bulgaria" EOOD from Burgas. The panel is made from pine particles bonded with phenol-formaldehyde resin. The thickness of the panel is 18 mm and density of the panel is 587,12 kg/m$^3$. This panel is declared as type OSB-2 (load-bearing panel for use in dry conditions).

The control model (model III) was tested in the same way as the basics models. The results from the tests of this model were used for comparative analysis with the results of the tests of basics models.

## 3. RESULTS FROM THE EXPERIMENT AND ANALYSIS

The results from the research of the changes of density, volume, thickness swelling and water absorption of tested panels are shown in Tables 1, 2, 3 and 4 and in Figures 1, 2, 3 and 4.

The results from the research of the change of density shows a tendency of increment in mean values in all models for the analyzed period. Increase in the mean arithmetical value was proportional to the increase of the duration of the treatment of the test specimens. The increment in values was intense in the initial period of treatment, whereupon the maximal value was achieved in the final control measuring. This tendency is noticed in all models (Figure 1).

The analysis of the results shows that bigger change of density expressed in absolute units was achieved in basic models compared to the control model. Expressed in relative units, bigger change of density was achieved in control model compared to the basic models (Table 1).

The analysis of the results from the research of volume changes shows a tendency of proportional increasing of the mean values in analyzed period in all models. The increase in volume was intense in the initial period of treatment. After that, the mean values were increasing with lower intensity, whereupon the maximal value of the volume was achieved in the final control measuring (Figure 2).

The change of the volume of the first model was slightly higher than the obtained value of the second model. The change of the volume of the control model was higher compared to the changes of volume of the basic models. This means that this model has higher water absorption resulting in increasing of the volume (Table 2).

The results from the research of increasing of the thickness swelling showed a tendency of increasing of mean values in all models for the analyzed period. The values of thickness swelling as well as the values of other properties were increasing proportionally to the increase of duration of the treatment of test specimens (Figure 3).

According to the standard MKS D.C5.032/83, which for different wood-based panels defines the maximum value of 12 % for relative thickness swelling for treatment of 24 hours, it can be concluded that the basic models meet the requirements of this standard. These models also meet the requirements of this standard after immersion in water for 1248 hours (Table 3). The obtained research results of thickness swelling of these models for the period of 24 hours corresponds to the results of similar researches known in professional literature. Dimeski et al. (1997), for a 24-hour water treatment of single-layer particleboards bonded with different content of phenol-formaldehyde resin, obtained the mean values of 12,18 % for 10 % resin content, 8,64 % for 13 % resin content and 7,38 % for 16 % resin content. Iliev et al. (2006), for single-layer particleboards bonded with phenol-formaldehyde resin (content of dry resin matters-13 % and epoxy resin with 5 % dry matters as modifier) and protected on surface with acid varnish, obtained the following values: 6,87 % after immersion of 2 hours, 11,19 % after 24-hour immersion, 11,94 % after immersion of 48 hours and 12,55 % after immersion in water of 72 hours. Iliev et al. (2006), depending on the model, obtained the following values for combined panels (single-layer particleboard veneered with one and two sheets of constructive beech and pine veneers) protected with acid varnish: from 6,91 % to 8,11 % after immersion of 2 hours, from 9,58 % to 11,46 % after immersion of 24 hours, from 9,66 % to 12,26 % after immersion of 48 hours and from 10,27 % to 12,94 % after immersion of 72 hours. Mihajlova et al. (2005), depending on the model, gave the following values for combined panels (single-layer particleboard veneered with one sheet of constructive beech and pine veneers): from 6,29 % to 7,82 % after immersion of 2 hours, form 10,48 % to 11,00 % after immersion of 24 hours, from 11,35 % to 11,49 % % after immersion of 48 hours, from 11,70 to 11,90 % after immersion of 72 hours and from 16,11 % to17,52 % after immersion in boiling water for 2 hours. Yossifov et al. (1987), for particleboards resistant to weathering made with modified phenol-formaldehyde resin, depending on the modification, gave the values within the limits of 9,50 % to 15,74 % after immersion in water for 24 hours. Yossifov et al. (1996) depending on modification of the resin, gave the values within the limits of 2,43 % to 19,53 % after immersion of 24 hours of water-resistant particleboards made with modified phenol-formaldehyde resin.

According to the European standard EN 300, the maximal value of thickness swelling of OSB-2 after immersion in water for 24 hours (testing method EN 317) was 20 %. The thickness swelling of the control model was above standard value (Table 3). Jakimovska Popovska (2011), for type of panel OSB-2, gave the following values: 22,12 % after immersion of 24 hours, 22,77 % after immersion of

48 hours and 23,88 % after immersion of 72 hours. Taylor et al. (2007) studied the thickness swelling of standard oriented strand boards for use in floorings. The authors determined thickness swelling at the edge of the panels, which was: ≈ 16 % after immersion of 24 hours and ≈ 23 % after 72 hours. Van Houts et al. (2003), for standard oriented strand boards gave the following values: ≈ 15 % after immersion of 2 hours, ≈ 22 % after immersion of 10 hours and ≈ 28,5 % after immersion of 168 hours. Baştürk M. (2007) for standard oriented strand boards give the following values: ≈ 13 % after immersion of 2 hours and 25 % after immersion of 60 hours.

On the basis of the results from the research and literature cited, it can be concluded that the basic models have dimensional stability under water impact, which is one of the requirements for use in high humidity conditions. According to the limitations prescribed by the standard, the control model has higher values of thickness swelling for the period of 24 hours. This model does not meet the requirements of the reference standard, i.e., the panel is not dimensionally stable under water impact.

The results from the research of change of water absorption indicated a tendency of increment of mean values in all models for the analyzed period. The rise in the mean arithmetical value was proportional to the increasing of the duration of the treatment of the test specimens (Figure 4). The results show that water absorption in the analyzed period in basic models was bellow foreseen value of 50 %, while in control model this value was higher for about 6 % compared to the mentioned limit (Table 4).

Dimeski et al. (1997), for 24-hour water treatment of single-layer particleboards bonded with different content of phenol-formaldehyde resin, gave the following values: 82,86 % for 10 % resin content, 61,68 % for 13 % resin content and 54,54 % for resin content of 16 %. Iliev et al. (2006), for single-layer particleboards bonded with phenol-formaldehyde resin (content of dry resin matters-13 % and epoxy resin with 5 % dry matters as modifier) and protected on surface with acid varnish, obtained the following values: 28,44 % after immersion of 2 hours, 41,63 % after 24-hour immersion, 45,95 % after immersion of 48 hours and 47,76 % after immersion in water for 72 hours. Iliev et al. (2006), depending on the model, gave the following values for combined panels (single-layer particleboard veneered with one and two sheets of constructive beech and pine veneers) protected with acid varnish: from 24,48 % to 32,41 % after immersion of 2 hours, from 38,57 % to 44,86 % after immersion of 24 hours, from 43,28 % to 49,45 % after immersion of 48 hours and from 45,82 % to 51,92 % after immersion of 72 hours. Mihajlova et al. (2005), depending on the model, gave the following values for combined panels (single-layer particleboard veneered with one sheets of constructive beech and pine veneers): from 33,02 % to 51,77 % after immersion of 2 hours, from 47,09 % to 65,70 % after immersion of 24 hours, from 50,66 % to 68,93 % % after immersion of 48 hours, from 51,98 to 69,05 % after immersion of 72 hours and from 67,39 % to 93,09 % after immersion in boiling water for 2 hours. Yossifov et al. (1987), for particleboards resistant to weathering made with modified phenol-formaldehyde resin, depending on the modification, gave the values within the limits of 35,75 % to 47,57 % after immersion in water for 24 hours. Yossifov et al. (1996), depending on modification of the resin, gave the values within the limits of 55,68 % to 76,18 % after immersion of 24 hours of water-resistant particleboards made with modified phenol-formaldehyde resin.

Jakimovska Popovska (2011) for water absorption of panel type OSB-2 obtained the following values: 75,35 % after immersion of 24 hours, 86,06 % after immersion of 48 hours and 89,15 % after immersion of 72 hours. Van Houts et al. (2003), for standard oriented strand boards, gave the following values: ≈ 27,5% after immersion of 2 hours, ≈ 33 % after immersion of 10 hours and ≈ 36 % after immersion of 168 hours. Baştürk M. (2007), for standard oriented strand boards, gave the following values: ≈ 47 % after immersion of 2 hours and ≈ 88 % after immersion of 60 hours.

According to the literature cited, it can be concluded that the results from the research of all models were within the limits of the values listed in the literature.

From the conducted researches a general statement can be made, according to which change of physical properties for the analyzed period runs proportionally to the change of the duration of the treatment of the test specimens, i.e. the analyzed property was proportionally increasing with increment in duration of the treatment. The dynamic of change of the mean arithmetical values of the physical properties in the period of 24 to 1248 hours in all models ran according to the logarithmic function $y = aLn(x) + b$. The coefficient of correlation ($R^2$) between the calculated and theoretical values in all models was particularly high, mostly above 0,94 (total correlation according to Roemer-

Orphal scale). For certain model and property, the calculated and theoretical values were almost the same, with the coefficient of correlation above 0,99.

The visual analysis of the form and structure of the test specimens of the basic models after completed treatment showed that there were no structural changes of the test specimens (Figure 5 and 6). The deeper analysis in the panels' structure of these models showed a little expansion of the area between the particles. No other types of deformations of the test specimens were noticed. The test specimens retained their form during the whole experiment.

Beside the fact that in the control model high values of thickness swelling and water absorption were obtained, after completing the treatment no bigger structural changes of the test specimens were evident (Figure 7). A partial ungluing of the particles in panel structure and on panel surfaces was noticed. No other types of deformations were obvious. The test specimens retained their form during the whole experiment. This model showed an agreeable stability under water impact, which results into recommendation for panel general use in interior, dry conditions of exploitation.

***Table 1.*** *Values for increase in density for a period of 0 to 1248 hours*

| Model | Initial value (0 hours) [kg/m$^3$] | Value after 24 hours [kg/m$^3$] | Final value (1248 hours) [kg/m$^3$] | Increase in absolute values [kg/m$^3$] | Increase in relative units [%] |
|---|---|---|---|---|---|
| I | 677,36 | 1021,21 | 1108,10 | 430,74 | 63,59 |
| II | 709,04 | 1009,27 | 1113,21 | 404,17 | 57,00 |
| III | 587,12 | 854,34 | 985,89 | 398,77 | 67,92 |

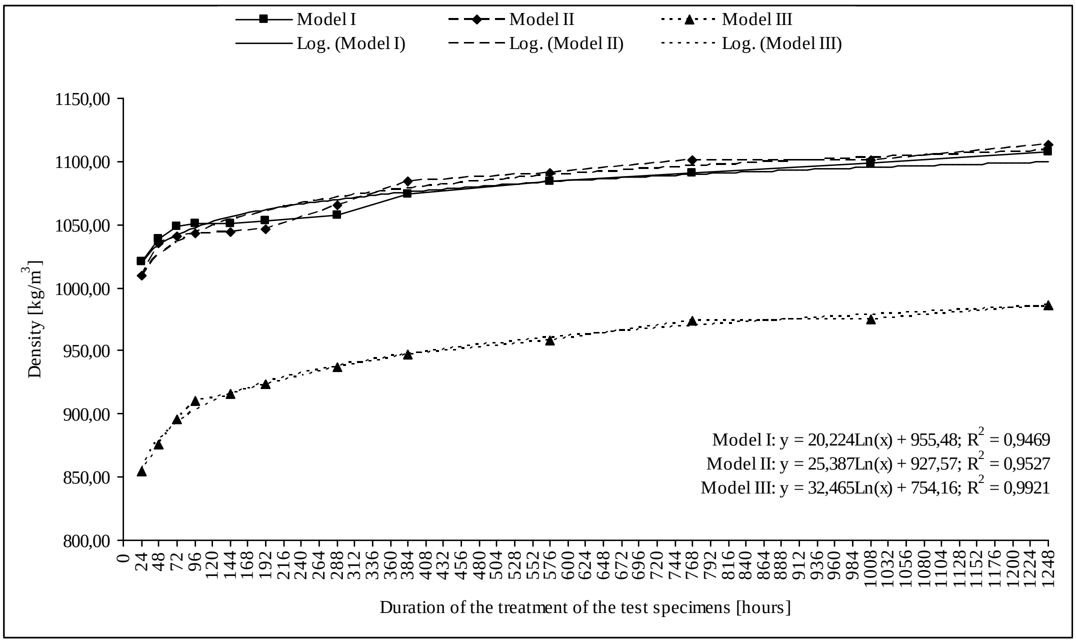


***Figure 1.*** *Increase in mean arithmetical values of density for period of 24 to 1248 hours*

***Table 2.*** *Values for increase in volume for a period of 0 to 1248 hours*

| Model | Initial value (0 hours) [cm$^3$] | Value after 24 hours [cm$^3$] | Final value (1248 hours) [cm$^3$] | Increase in absolute values [cm$^3$] | Increase in relative units [%] |
|---|---|---|---|---|---|
| I | 163,24 | 180,63 | 186,21 | 22,97 | 14,07 |
| II | 164,61 | 181,33 | 187,15 | 22,54 | 13,69 |
| III | 183,27 | 221,82 | 236,94 | 53,67 | 29,28 |

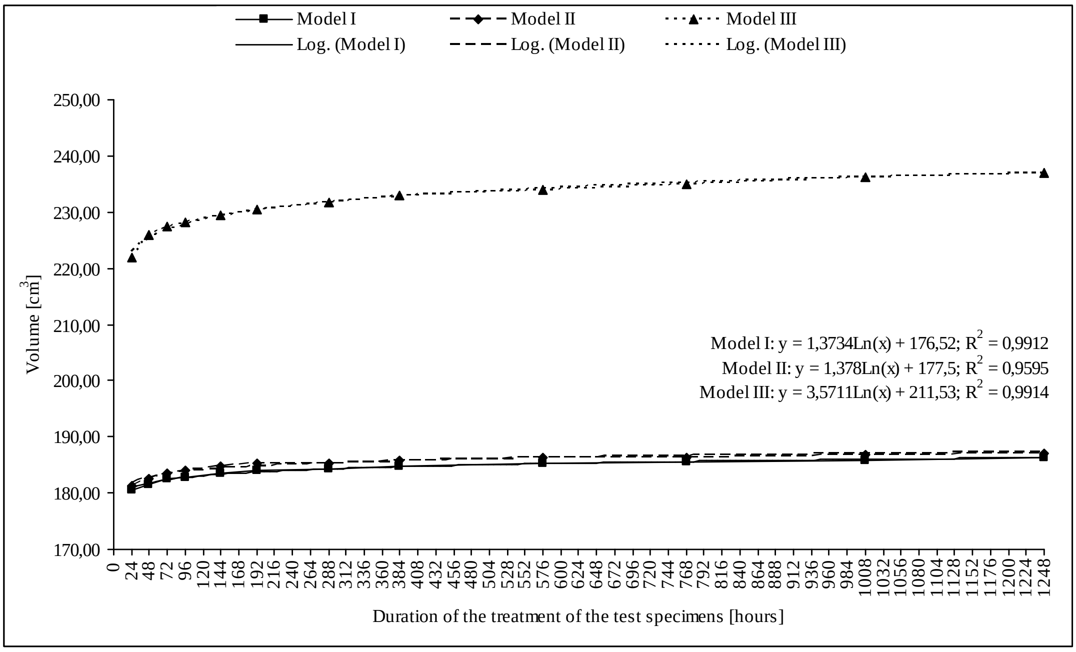


***Figure 2.*** *Increase in mean arithmetical values of volume for period of 24 to 1248 hours*

***Table 3.*** *Values for increase in relative thickness swelling for a period of 0 to 1248 hours*

| Model | Initial value (24 hours) [%] | Final value (1248 hours) [%] | Increase in absolute values [%] | Increase in relative units [%] |
|---|---|---|---|---|
| I | 10,14 | 11,88 | 1,74 | 17,16 |
| II | 9,51 | 11,68 | 2,17 | 22,82 |
| III | 20,49 | 27,15 | 6,66 | 32,50 |

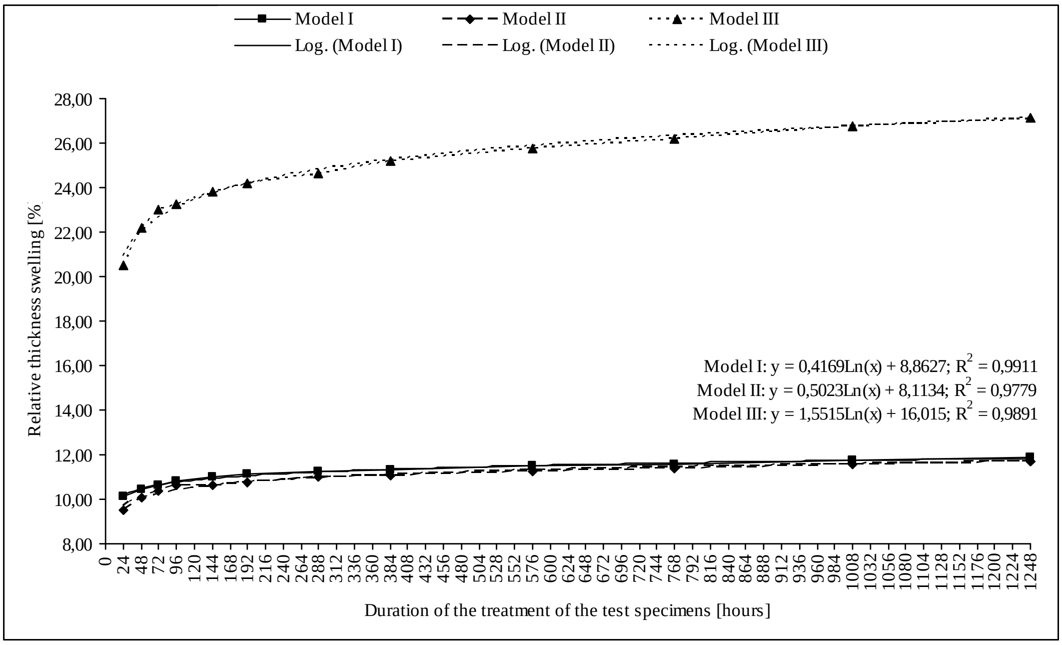


***Figure 3.*** *Increase in mean arithmetical values of relative thickness swelling for period of 24 to 1248 hours*

***Table 4.*** *Values for increase in relative water absorption for the period of 0 to 1248 hours*

| Model | Initial value (24 hours) [%] | Final value (1248 hours) [%] | Increase in absolute values [%] | Increase in relative units [%] |
|---|---|---|---|---|
| I | 66,87 | 86,67 | 19,80 | 29,61 |
| II | 56,93 | 78,65 | 21,72 | 38,15 |
| III | 75,26 | 117,41 | 42,15 | 56,01 |

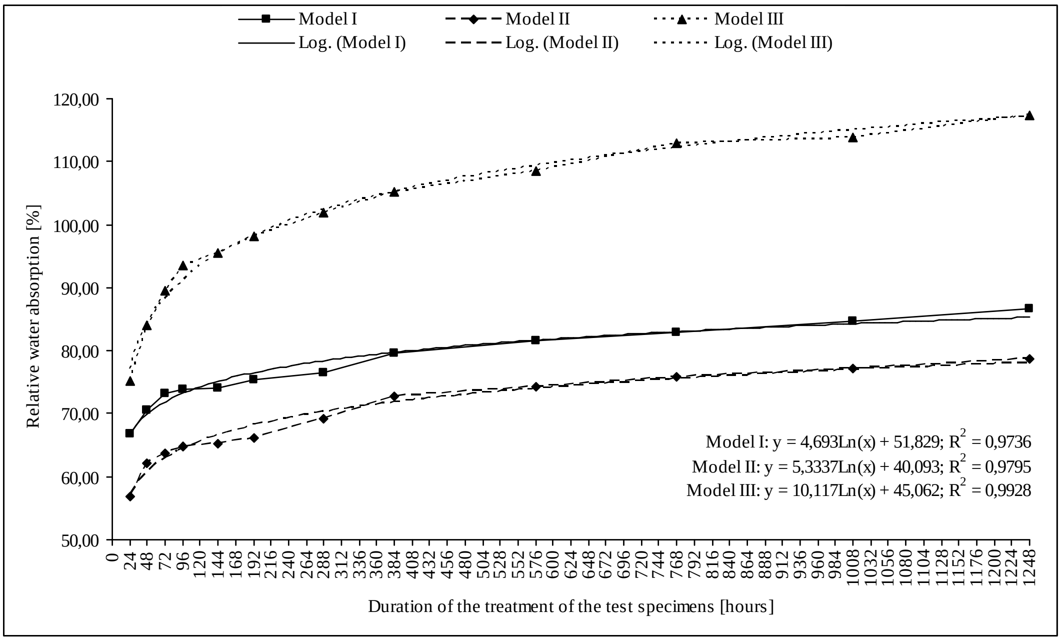


***Figure 4.*** *Increase in mean arithmetical values of relative water absorption for a period of 24 to 1248 hours*

***Figure 5.*** *Cross-section of single-layer particleboard from beech particles made with resin content of 10 % after water treatment of 1248 hours (model I)*

***Figure 6.*** *Cross-section of single-layer particleboard from beech particles made with resin content of 13 % after water treatment of 1248 hours (model II)*

***Figure 7.*** *Cross-section of oriented strand board (OSB) after water treatment of 1248 hours (control model III)*

## 4. CONCLUSIONS

Based on researches conducted, the following major conclusions can be drawn:

1. Researches of change of physical characteristics of water-resistant particleboards showed that stable panels are made, with a stable density and humidity, which is a requirement to perform standard research and analysis. Test models were characterized by uniform density over the entire surface of the panel, stable volume without presence of deformation of the dimensions and form of the test specimens.
2. For all the tested models, a general conclusion was made regarding change of their physical properties during the period analyzed. The change in these properties happened in proportion with the change of time of the treatment of the test specimens, i.e. the value of the analyzed property increased proportionally to the duration of treatment of test specimens.
3. The basic models were dimensionally stable and according to the tested physical properties, they meet the requirements of the national standards for use in wooden structures. The values from research for thickness swelling showed that the connections in the wooden constructions made from these panels exposed on extreme and prolonged water impact will not suffer serious deformations and displacements.
4. The control panel of oriented strand boards (OSB) did not meet the requirements of the standard for using it as load-bearing panel in construction. This model has high values of thickness swelling and therefore it can be used only for general purposes in interior (dry) conditions.
5. Analyzing the results from the research, it can be concluded that in tested models for the analyzed period of treatment, maximum value of the physical properties was not achieved, i.e. the values still had increasing tendency. The maximum value of some physical properties can be defined only by continuing the experiment in the period of time over 1248 hours.
6. These kinds of researches of water-resistant particleboards have scientific and practical meaning. They can help in selection of materials and technological parameters for its production, in order to develop dimensionally stable panels for use in conditions of increased humidity.

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