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RESEARCH ON THE PROPERTIES OF LIGHT BOARDS FROM LIGNO-CELLULOSE MATERIALS AND CEMENT

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ABSTRACT

The aim of this research is production in laboratory conditions of light weight boards from different types of ligno-cellulosic materials and Portland cement as inorganic binder. Wood particles from recycled coniferous wood (white pine) and recycled deciduous wood species are used as ligno-cellulosic materials, as well as particles from grape vine rods, flax and hemp. Gel made from aluminum sulphate and sodium silicate solution (water glass) is used for mineralization of the particles.

Boards with thickness of 50 mm and dimensions of 400×400 mm are made in laboratory conditions. Test specimens for determination of the most important physical and mechanical properties re made from the boards. Some test specimens are used for determination of the coefficients of sound absorption and thermal conductivity.

The results from the research show that light-weight boards from ligno-cellulosic materials and cement with density bellow 0,630 g/cm^3 can be classified as structural-insulation materials. Insulation properties and strength properties of investigated boards indicate that the latter meet the requirements for application in construction as a material for components of wall panels, permanent formwork, roof panels, partition walls etc.

The obtained light-weight boards made of ligno-cellulosic materials and cement are a good option for sustainable material management, with a view to protecting, preserving and improving the quality of the environment, protecting human health, ensuring prudent, efficient and rational utilization of natural resources.

Key words: light wood-cement boards, recycled wood, ligno-cellulosic residues, mineral binding agents, utilization of natural resources

1. INTRODUCTION

In recent decades, as a promising construction material, many countries in the world have produced wood-mineral boards. They proved to be inexpensive and effective material in terms of quality properties, which is successfully used in construction of dwellings in rural and suburban areas, and also in construction of tourism buildings and commercial construction. Their basic composition includes the following components: mineral cement agent (cement, gypsum, magnesite, alkali-slag bonding agent, etc.), ligno-cellulosic residues filler (recycled chipped wood or woody stems of annual and perennial crops, etc.), mineralizer ($CaCl_2$, $Ca(OH)_2$, $Al_2(SO_4)_3$, water glass, etc.) and water. According to density and application, they are classified into three classes: lightweight (low-density board), with density of 0,350 to 0,650 g/cm^3; medium heavy (medium density board), with density of

0,650 to 1000 to g/cm^3, for insulation and structural application, and heavy (high density board), with density of 1,000 to 1,400 g/cm^3, for structural application.

Special interest for quick application in practice are lightweight boards made of different types of ligno-cellulosic materials and cement, due to their advantages over other building materials, which are used in construction. The technological process for production of these boards is comparatively easier to implement, especially that it does not require large investments for technological equipment and construction site. The raw material for the ligno-cellulosic filler is cheap and widely available - mainly recycled wood and agricultural ligno-cellulosic materials are used. The boards are characterized by good sound and thermal insulation properties, good bio and fire resistance and easy processing. In practice, lightweight panels of ligno-cellulosic materials and cement have found a wide application such as permanent formwork, partition walls, acoustic ceilings and underlayment in roofs, constituent elements, walls, panels etc. All of this predetermines the reasons for rapid development of production of this kind of boards in different parts of the world. Unfortunately, it should be noted that despite the positive results of long-term researches in Bulgaria and Macedonia (University of Forestry - Sofia and Faculty of Design and Technologies of Furniture and Interior - Skopje), this production has not found practical realization yet.

The issue of using recycled wood raw material or replacing it with agricultural ligno-cellulosic residues is important and up-to-date, especially in view of the adopted Directive (EU) 2018/851 of the European Parliament and of the Council dated 30 May 2018 amending Directive 2008/98/EC on waste.

Improving the efficiency of resource use and ensuring that waste is valued as resource can contribute to reducing the Union’s dependence on the import of raw materials and facilitate the transition to more sustainable material management and to a circular economy model. That transition should contribute to the smart, sustainable and inclusive growth goals set out in the Europe 2020 strategy and create important opportunities for local economies and stakeholders, while helping to increase synergies between the circular economy and energy, climate, agriculture, industry and research policies, as well as bringing benefits to the environment in terms of greenhouse gas emission savings and to the economy.

Waste management in the Union should be improved and transformed into sustainable material management, with a view to protecting, preserving and improving the quality of the environment, protecting human health, ensuring prudent, efficient and rational utilization of natural resources.

2. MATERIALS AND METHODS

Laboratory lightweight panels of various types of ligno-cellulosic materials and cement were made in the Laboratory for pressing at the Department of mechanical wood technology, University of Forestry in Sofia. The following raw materials were used:

- lime Portland cement CEM II/B-L 32.5R in accordance with BDS EN 197-1:2011;
- wood particles from recycled conifers (white pine) and recycled hard deciduous wood (beech);
- particles from chipped vine rods;
- hemp and flax residues;
- aluminum sulphate $Al_2(SO_4)_3$ in accordance with BDS 1841:1978;
- water glass (sodium silicate solution) in accordance with BDS 2284:1974.

From the aluminum sulphate and the water glass, a particle mineralization gel is prepared, which has density of 1100 g/cm^3.

Ligno-cellulosic particles from different types of raw material are first processed in a laboratory mixer with the prepared mineralization gel, at ratio of gel to wood particles, expressed in weight units, of an average 12:100, whereas regarding the components of mineralization gel, the ratio of aluminum sulphate to water glass is 1,4:1.

Mixing of the processed (with a mineralizing gel) ligno-cellulosic filler with cement was carried out in a laboratory mixer at a weight ratio of the cement to the filler of an average of 160:100. From the prepared moist mixture, by means of forming frames mounted on a metal base (sheet), particleboard mats are formed for different types of boards, which are subjected to vibration for several minutes. By cold pressing at a pressure of approximately 3 MPa over a period of 24 hours, calibration of the formed mats was achieved up to the predetermined thickness of the boards. The

semi-finished boards are released from the frames after 24 hours and together with the tin sheets are placed on the shelves in order to continuously lie off for 28 days, i.e. to complete hydration of the cement.

The finished boards, with thickness of 50 mm and format of 400 × 400 mm, are cut on test specimens for determination of the physical and mechanical properties, as follows: density, on test specimens 100×100×50 mm; moisture content, on test specimens 50×50×50 mm; water absorption and thickness swelling for 24 hours, on test specimens 100×100×50 mm; bending strength, on test specimens 400×50×50 mm and compressive strength, on test specimens 50×50×50 mm. The coefficients of sound absorption and thermal conductivity are determined on single test specimens.

3. RESULTS FROM THE EXPERIMENTAL RESEARCH

Results from the conducted researches on physical and mechanical properties of laboratory-scale light-weight boards from ligno-cellulosic materials and cement are shown in Table 1 and Figure 1.

Table1. *Average statistical values of physical and mechanical properties of light-weight boards made from ligno-cellulosic materials and cement*

No.	Board type according to the ligno-cellulosic filler	Properties				
		Density, g/cm^3	Water absorption, %	Thickness swelling, %	Bending strength, N/mm^2	Compressive strength, N/mm^2
1.	Recycled coniferous tree – white pine	0,420	102	2,2	0,62	0,58
		0,550	90	2,4	0,87	1,19
		0,570	72	3,1	1,22	1,75
2.	Recycled hardwood deciduous – beech	0,620	77	3,0	1,02	1,34
3.	Vine rods	0,630	68	2,5	1,09	1,38
4.	Hemp residuals	0,450	86	2,6	0,98	1,43
5.	Flax residuals	0,510	74	2,9	1,05	1,56

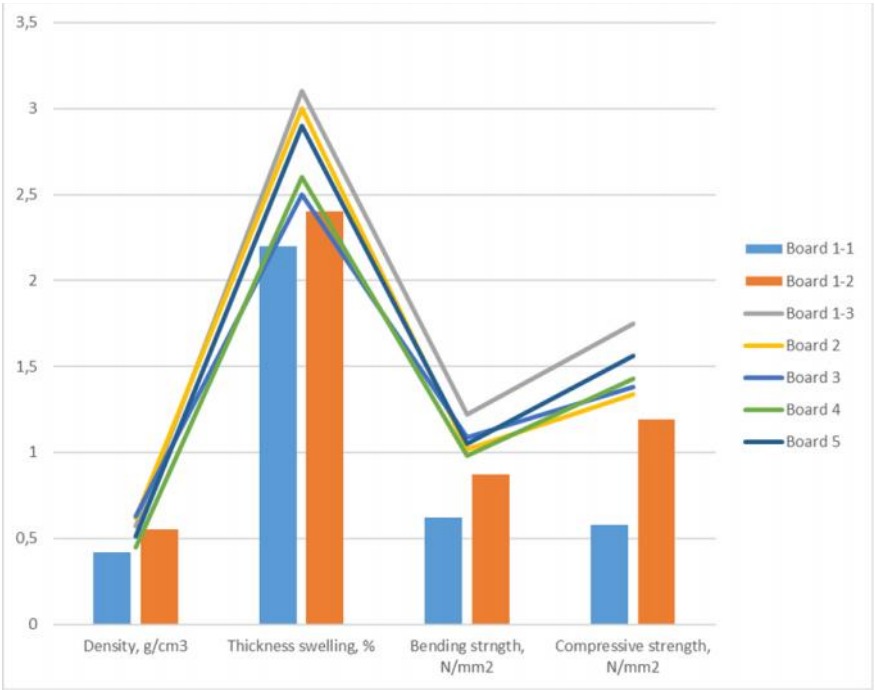

Figure 1. *Physico-mechanical indicators of light-weight boards from ligno-cellulosic materials and cement*

The data presented in Tab. 1 and Fig. 1 shows that the density of the tested light boards from ligno-cellulosic materials and cement is in the limits of 0,420 to 0,630 g/cm^3, i.e. the lower density of the raw material (white pine, hemp and flax residuals) corresponds with the lower density of the boards. Increment in the density of the boards made from the same raw material (in this case white pine) leads to significant increment of the strength properties.

Thickness swelling of the boards is comparably lower – from 2,2 to 3,1 %, while water absorption is significant – from 68 to 102 %, which is due to the porous structure of the boards.
Moisture content of the tested boards is in the limits of 8,2 to 10,9 %.

The obtained values of the coefficients of thermal conductivity and sound absorption at frequency of 500 Hz for the boards made from coniferous wood raw material with density of 0,545 g/cm^3 are 0,12 W/(mK) and 0,49, respectively. Based on these values it can be concluded that these boards are characterized by very good insulation properties.

The results from the conducted research in order to optimize the composition of light-weight wood-cement boards are given in Table 2.

Table 2. *Physical and mechanical properties of wood-cement boards from white pine with different composition*

Light weight wood-cement boards with different ratio of the components	Density, g/cm^3	Bending strength, N/mm^2	Compressive strength, N/mm^2
1. Ratio cement : wood			
C:W=120:100	0,410	0,33	0,28
C:W=200:100	0,620	1,46	2,09
2. Ratio mineralizator : wood			
M:W=8:100	0,550	0,64	0,91
M:W=16:100	0,540	0,93	1,27

As it is apparent from the results given in Table. 2, and taking into account the data from Table. 1 and Fig.1 for light weight wood-cement boards from pine wood with density of 0,550 g/cm^3 (C:W=160:100 and M:W=12:100), one can deduce that the increase in the amount of cement and mineralizer leads to an increase in the strength characteristics of the boards. It is necessary to note that it leads simultaneously to weakening of the economic indicators of the finished production. Therefore, as compromise, optimal values of these ratios should be taken C:W=160:100 and M:W=120:100.

4. CONCLUSION

Based on the results of the conducted laboratory researches for defining the physical and mechanical parameters of light-weight boards of various ligno-cellulosic materials and cement, the following important conclusions and recommendations can be made:

1. The obtained light-weight boards made of ligno-cellulosic materials and cement are of density below 0,630 g/cm^3 and belong to the group of insulation-structural building materials;
2. The insulating properties and strength characteristics of the tested boards meet the requirements for use in the construction as a material for component elements of wall panels for single-family dwellings and light constructions, permanent formwork, underlay panels in roof constructions, partition walls, etc.;
3. From a technical and economic point of view, a compromise optimum composition of light-weight wood-cement boards is defined at the following weight ratios: cement: wood =160:100 and mineralizer: wood=12:100;
4. The obtained light-weight boards made of ligno-cellulosic materials and cement are a good option for sustainable material management, with a view to protecting, preserving and improving the quality of the environment, protecting human health, ensuring prudent, efficient and rational utilization of natural resources.

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