



AN EXPERIMENTAL RESEARCH REGARDING THE OPTIMUM COMPOSITION FOR WOOD SLAG BOARDS

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Abstract:

Wood slag boards (WSB) belong to the group of composites formed on the basis of mineral binders (cement, gypsum, blast-slag, etc.). They are multi-componential systems consisting of wood particles, slag-alkaline and mineralizator. The physico-mechanical properties of WSB completely answer the standard requirements valid for high-density wood-cement boards and therefore can be used as a competitive building material. The economic relevancy of their production is grounded in providing building industry with high-quality and at the same time cheap materials, as well as in utilizing scrap materials which would otherwise pollute the environment (blast slag and scrap wood).

The optimizing of the mass parts of the components of WSB is a very important problem both from technological and economical point of view. The success in solving the optimizing problem depends to a great degree on the choice of method. This is way a planned experiment is applied, based on the simplex method for multicomponent system with preliminarily determined limits of calculation of the factors. With the help of specialized computer software, the optimum quantity of the components is determined through graphically presented optimum areas.

Keywords: Wood Slag Boards; Composites; Building Material; Multicomponent System; Composition.

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1. Introduction

In recent years the production of different kinds of wood-mineral boards used in the building industry as thermal and acoustic materials (light boards with density of up to 600 kg/m³ or high-density boards, up to 1200 kg/m³, used for construction purposes) has rapidly developed. The basic advantage of these boards compared to the materials produced from wood is that they have higher degree of water-, fire-, and bioresistance, they are more easily processed with cutting instruments, and have smaller bulk mass.

WSB are considered to the type of wood-mineral boards whose production process presupposes not only high economic and ecological effectiveness, but also advanced technological characteristics. Carried out research out (Mihajlova, 1995) shows the following advantages of the production technology of WSB compared to that of wood cement boards: much shorter production

cycle due to the method of hot pressing; lower influence of the type of wood species and of the anisotropic properties of wood on the characteristics of the boards; not so significant dependence of the hardening of the slag-alkaline binder on the content of water-soluble and extractive substances in the composition of wood. The influence of the technological parameters on the properties of WSB has also been examined (Yossifov and collective, 1989; Mihajlova, 1995).

The aim of the present research work is to determine the optimum quantity of the mass parts of WSB components.

WSB consist of four basic components: slag-alkaline binder (X_1), wood particles (X_2), mineralizator (X_3), and water (X_4). Besides, in order to obtain a real product, variations of the components are allowed only within strictly determined boundaries ($0 \leq a_i \leq x_i \leq b_i$) and the following condition has to be followed:

$$X_1 + X_2 + X_3 + X_4 = 1.$$

Further on in the research the quantity of water is accepted to be a constant equal to 0.23, i.e. $X_4=0.23=\text{const}$. In order to simplify the solution of the optimizing problem, it has to be accepted that the sum of the variable components gives a new unit of measurement:

$$X_1 + X_2 + X_3 = 1.$$

The restrictions on the varying of the components a_i and b_i , where $i=1,2$, and 3, have been determined on the basis of preliminary sifting experiments (Mihajlova, 1995). Together with that, the restrictions have been determined to answer the conditions

$$\sum_{i=1}^3 a_i < 1 \text{ and } \sum_{i=1}^3 b_i > 1.$$

Most often in this case the method Mc Lean – Anderson (Vouchkov, 1986) is applied. It presents the factor space as a polyhedron or a polygon whose form depends on the concrete value of the parameters a_i and b_i . A planned experiment is carried out with components changing in a simplex space. The two basic physico-mechanical properties of WSB, bending strength (σ_b) and thickness swelling after 24 h in water (α_δ), form the optimum criterion (Y_j).

2. Materials and Methods

Special laboratory experiments for optimizing the composition of WSB have been carried out following the matrix of planned experiment according to the method of Mc Lean – Anderson (Table 1). The boards are obtained with set density of 1300 kg/m^3 , thickness 18 mm and moisture content $10 \pm 2 \%$. Mixed particles of different broad-leaved hardwood species have been used with a predominant fraction of 2/0,3 mm. A suitable, preliminarily determined (Mihajlova, 1995) composition of the binder has been used: dry component of granulated blast-slag grinded in advance and liquid component of technical caustic-alkali and soluble sodium water glass. Used sodium water glass serves as a mineralizator in order to neutralize the negative influence of simple

sugar contained in wood (Pentosans and Hexans) on the adhesion of the slag-alkaline binder with the wood particles.

Table 1: The Matrix of Planned Experiment

No.	FACTORS			TARGET PARAMETERS	
	X ₁	X ₂	X ₃	Y ₁ ≡ σ _b , MPa	Y ₂ ≡ α _δ , %
1	0.74	0.24	0.02	5.06	3.51
2	0.72	0.24	0.04	4.98	3.89
3	0.68	0.30	0.02	8.95	1.12
4	0.66	0.30	0.04	8.28	1.48
5	0.70	0.27	0.03	6.83	2.42
6	0.69	0.28	0.03	7.47	2.23
7	0.67	0.29	0.04	7.79	2.01
8	0.73	0.25	0.02	5.78	3.04

The preparation of the wood-slag mixture for each board has been carried out in a laboratory mixing device dosing the mass of the components according to the matrix of the plan. The hot pressing followed a three-level diagram with a maximum of the specific pressure 2 MPa, temperature of the pressing plates 120°C and duration of the process 40 min. After pressing comes the conditioning of the boards that goes on for 5 days at temperature of 20 ± 2°C and 60 ± 5 % humidity.

The experiments have been carried out with the following variation limits of the factors (the mass shares of the dry components of WSB):

$$\begin{aligned} 0.66 &\leq X_1 \leq 0.74 \\ 0.24 &\leq X_2 \leq 0.30 \\ 0.02 &\leq X_3 \leq 0.04. \end{aligned}$$

Considering the above variation limits and having in mind the rules for creating a full factor experiment, the apexes of the tetragon have been determined in the simplex space of the factors:

$$\begin{aligned} S_1 &(0.74;0.24; 0.02) \\ S_2 &(0.72;0.24; 0.04) \\ S_3 &(0.68;0.30; 0.02). \end{aligned}$$

The plan of the experiment (Table 1) includes tests at the apexes and in the center of the tetragon, as well as in three additional points.

3. Results and Discussions

Table 1 presents the data from the realization of the planned experiment concerning the target optimizing parameters of WSB: bending strength (Y₁≡ σ_b) and thickness swelling after a 24-h stay in water (Y₂≡ α_δ). On the basis of this information, encoded regressive mathematical models have been devised on a computer for two target parameters:

$$\begin{aligned} Y_1 \equiv \sigma_b &= -12.75X_1 + 49.33X_2 + 24.52X_3 + 19.73X_1X_2 - 40.45X_1X_3 - 156.10X_2X_3; \\ Y_2 \equiv \alpha_\delta &= 15.56X_1 - 24.35X_2 + 4.50X_3 - 15.25X_1X_2 + 12.33X_1X_3 + 83.26X_2X_3. \end{aligned}$$

The statistical analysis of the equations shows that they answer the requirements for precision ($R > 0.91$) and adequacy ($F < F_{\text{TABL}}$).

The solution of the optimizing problem is presented graphically on baricentral coordinates through the diagrams “composition - property” shown in Fig.1 and Fig.2. For this purpose, computer scanning of the target functions Y_1 and Y_2 has been carried out and the equal lines of the tri-component system have been drawing. The best result concerning bending strength coincide with the highest level of Y_1 , i.e. when $Y_1 \rightarrow \max$, while for the other parameter, thickness swelling, it is opposite, i.e. it has its best value when $Y_2 \rightarrow \min$.

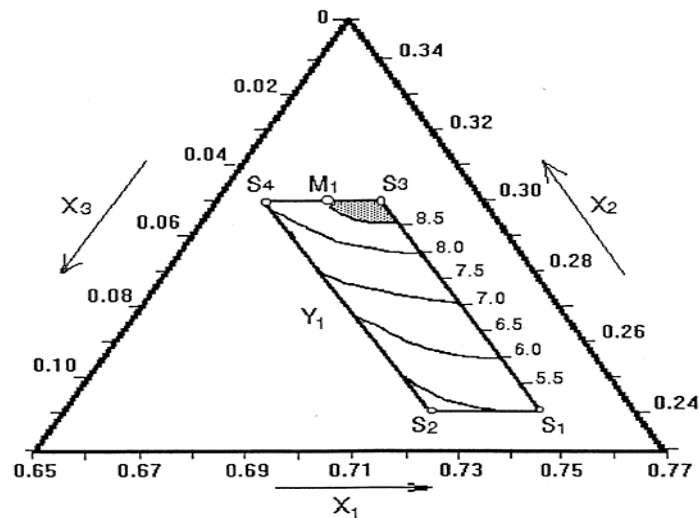


Fig. 1.

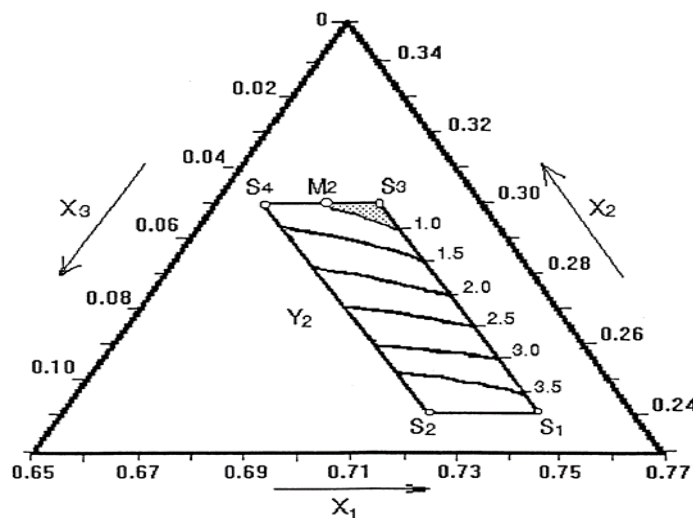


Fig. 2

As it is obvious from the diagrams in Figure 1 and Figure 2 the maximum value of σ_b and the minimum level of α_δ form one and the same point S_3 , lying on the variation boundary of the

components in the upper corner of the diagrams. The points M_1 and M_2 with the coordinates $X_1=0.67$, $X_2=0.30$ and $X_3=0.03$ determine the curves of the equals values for the optimization criterions $Y_1=8.75$ MPa and $Y_2=1.17$ %, which limit the optimal zones about the mass parts of WSB components. It can be pointed out as a general regularity that with one and the same quantity of the mineralizer ($X_3=0.03$), the reducing of the share of slag-alkaline binder ($X_1=0.66$ to 0.74), and the increasing of the wood filler ($X_2=0.24$ to 0.30), leads to an increase in bending strength and a decrease in thickness swelling.

If we consider taken for granted in the methodology, i.e. permanent water content, equal to 23 %, the three investigated components X_1 , X_2 , and X_3 constitute 77 % of the total mass of the boards. Then for the optimum composition of the mixture used for obtaining wood slag boards, the following component share has been calculated & slag-alkaline binder from 0.516 to 0.524] wood particles from 0.223 to 0.231; mineralizator from 0.15 to 0.23] water 0.23.

4. Conclusions and Recommendations

On the basis of the analysis of the results of the experimental research regarding the optimum composition of the mixture used for obtaining wood slag boards, the following conclusion can be drawn: the optimum percentage quantity of the components (wood particles 22-23 %; slag-alkaline binder 51-53 %; mineralizer 1.5-2.5 %; water 23 %), is a good pre-condition for developing a scientifically-grounded technology for producing this building material.

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