

**NEW APPROACH IN THE CREATION OF ENVIRONMENTALLY FRIENDLY
BUILDING MATERIALS BASED ON THE HIGHLY DISPERSED
MINERAL-REINFORCED WOODEN MATRIX**

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Abstract

The paper presents the formation structure features of the building composite nanomaterial created on the basis of natural environmentally friendly raw materials. Significant improvement of the material properties is achieved by reinforcing microdispersed wooden particles by nanodispersed basalt filler.

Key words: wood, basalt, nanocomposite, building materials, экологичность (environmental properties), dispersion.

1. INTRODUCTION

Modern building industry has a tendency to produce environmentally friendly building materials, which guarantee favourable indoor climate [1]. According to criteria applied to methods of obtaining green building materials, environmentally friendly requirements have to be considered in production.

Wood is the most wide-spread building material in the North of Russia.[2]. Multiple use of wood in construction is explained by optimum combination of the following properties: hardness, durability, strength, stress-strain capacity, elasticity, acoustic resistance, low heat conductivity, high conductivity of electricity, ecological properties, etc. Furthermore, a significant advantage of wood is its high renewability. However, wood has such drawbacks as decay, flammability, hygroscopicity, the dependence of its size on moisture, warping and cracking which significantly reduce performance characteristics of the material especially in severe climatic conditions. Nowadays local research on property improvement of wooden building materials and constructions is linked to treatment and saturation of wood with special substances containing fire-retardants [3]. As a rule, wood preservatives and coatings are multiple-component systems, which have a negative effect on ecological properties of products and do not always improve its performance and appearance properties. Besides, some research is held on modification of wood surface by nanodisperse coatings based on natural minerals, which makes it possible to significantly increase ecological properties of wooden materials. [4-5].

Production of composite materials based on mineral-reinforced wooden matrix is of considerable interest. The principally new approach consists in filling voids in wood grain structure by mineral filler particles. New generation building material can be produced if a nanotechnology approach is used which consists of applying original material in high dispersity state. Moreover, wood-processing and mining wastes can be used to produce nanocomposites. This will make it possible to use natural raw material at best advantage.

Reinforcing components (nanoparticles of rock) will provide the necessary mechanical properties of material while matrix (ultradispersed wood particles) used as bonding material will guarantee their combined action, combining strength properties of both components and will protect them from mechanical damage and aggressive substances.

The reinforcing process of wood matrix by nanoparticles of mineral filler is theoretically based on the fact that wood substance has fiber grain which is able to swell in water. Thus, when geometrical size of wood matrix is changed in water suspension of nanoparticle filler, spontaneous filling of internal cavity (lumen), pore spaces in cell walls and submicroscopic capillars of fibrillar structure of wood fibers by mineral dispersoids can happen due to capillary forces and osmotic pressure.

Nanodispersed particles of basalt are highly resistant to attrition, heat and acoustic resistant, fire-proof, durable and have high strength and low water absorbtion [6], so used as reinforcing mineral filler they will make it possible, as we see it, to significantly improve physical and mechanical, fire-safety, acoustic and thermal insulation properties of composite and to increase resistance of building material to biologically aggressive substances, thus, to increase its performance life.

The objective of this work is to evaluate the possibility to reinforce microdispersed wood by nanodispersed basalt filler.

2. EXPERIMENTAL

Materials

Pine wood from the Arkhangelsk region in form of sawdust (wood wastes of pine timber processing) was chosen as reinforcing matrix. Basalt crumb (wastes of crushed stone production) from Miyanduha deposit of Arkhangelsk region was used as mineral filler.

Methods

Sawdust was being grinded into microdispersed substance on a planetary ball mill Retsch PM100 for 5 min using one-stage dry dispersion method, rotation rate being 420 rpm. Nanostructured samples of basalt were being obtained by wet dispersion on a planetary ball mill **Retsch PM100 for 120 min, rotation rate being 420 rpm.**

To determine the size and charge of fine dispersed wood and basalt particles the method of photon-correlation spectroscopy was applied on Delsa Nano Series Zeta Potential and Submikron Partiele Size Analyzers. Video monitoring of basalt particle shape and size was made on Lasentec S400E with the PVM V819 video microscopy system.

Dispersed substance pH was changed by gradually adding 0,1 M of NaOH solution to basalt suspension. Nanoparticles of basalt were recharged by adding 0,1 M of $MgCl_2$ solution to suspension.

Wood matrix was reinforced by placing microdispersed wood particles into water suspension of nanoparticle basalt filler which later was being intensely mixed for 1 min. After 30 min reinforced wood particles were separated from basalt suspension with the help of 1 mkmm cell size net.

Fine dispersed wood and basalt samples and reinforced wood matrix were examined with a scanning electronic microscopy in science equipment center “Arktika” at Northern arctic federal university named after M.V. Lomonosov. To improve the quality of obtained photographs the surface was photographed by SIGMA VP (ZEISS) microscope, each sample being covered with 5 nm gold and palladium layer with the help of Q150T ES (Quorum) coating installation.

3. RESULTS AND DISCUSSION

The parametres for mineral and wood raw materials dispersion were worked out through tests.

The visual characteristic of form and shape of nanodispersed basalt particles obtained with PVM V819 laser system is represented in Fig. 1.

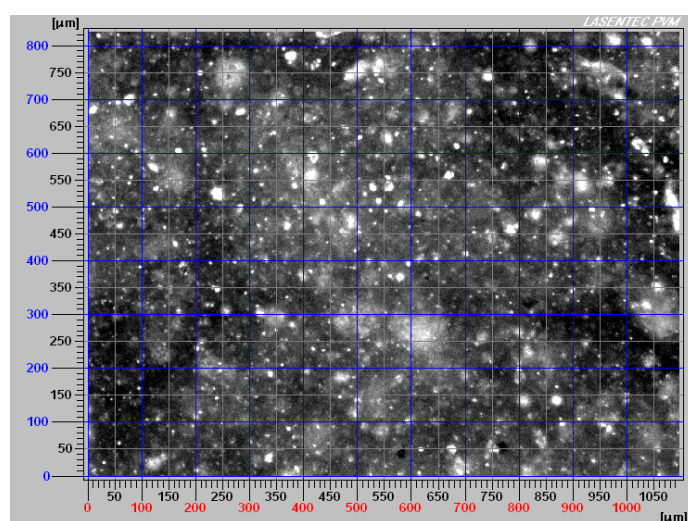


Fig. 1 – Photograph of nanodispersed basalt taken with PVM V819 laser video microscopy system

Fig. 2 shows the distribution of nanodispersed basalt particles according to their size obtained by Delsa Nano Series Zeta Potential and Submikron Partiele Size Analyzers. The average size of finedispersed basalt is 150 ± 40 nm with a satisfactory polydispersity index (0,234).

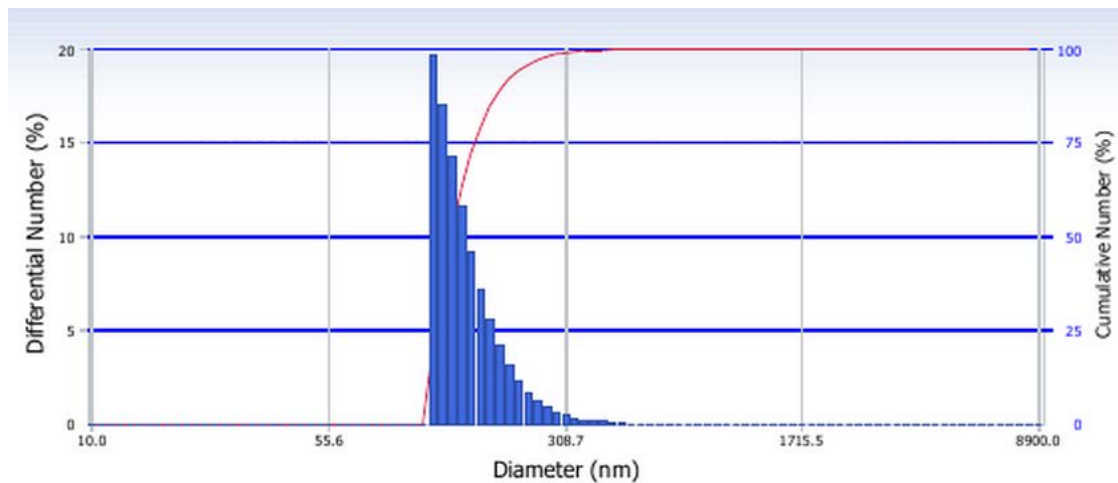


Fig. 2 – Diagramme of basalt particles distribution according to their size

Fig. 3 shows the results of ultradispersed sawdust distribution which prove that an average particle size is $1,3 \pm 0,2$ mkm. Besides there is small quantity of course fraction throughout finedispersed wood particles.

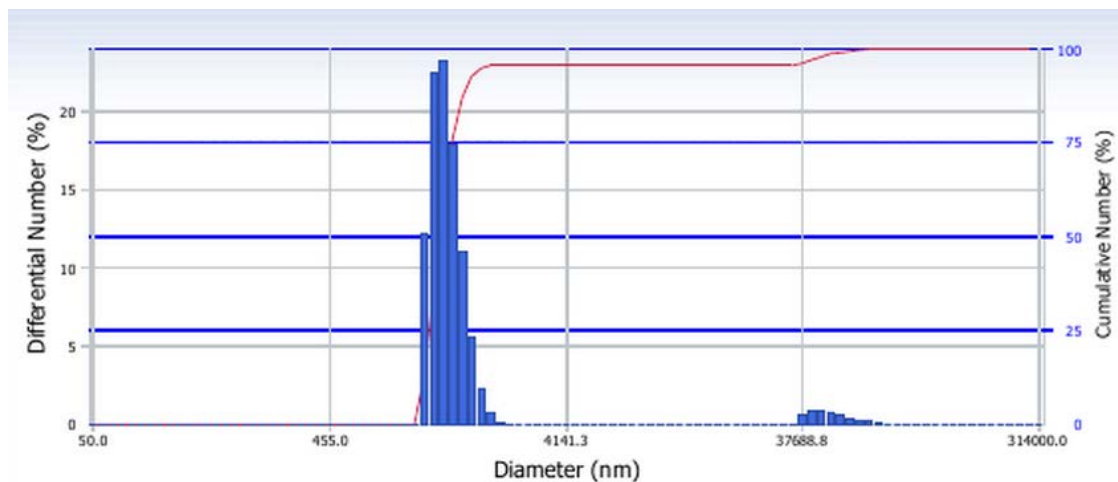


Fig. 3 – Wood particle size distribution

Fig. 4,5 show the surface of wood samples in microdispersed state. As the result of grinding, free effective surface of wood particles increases due to structure destruction and cell walls cleavage thus allowing the passage of nanostructured basalt particles to hardly accessible areas of wood surface.

Charging takes place in water substance on the surface of solid-state fine-dispersed particles (nanodispersed basalt particles and microdispersed wood particles). Table 1 shows data obtained as the result of Zeta (ζ) sizing for fine-dispersed basalt and wood particles in neutral dispersive substance. Fig. 8 shows an example diagram of Zeta sizing for wood microparticles.

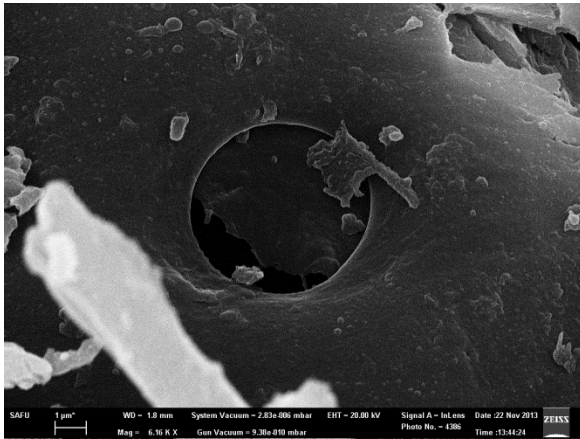


Fig. 4 – Electronic photograph of wood microparticle with open cells in fiber

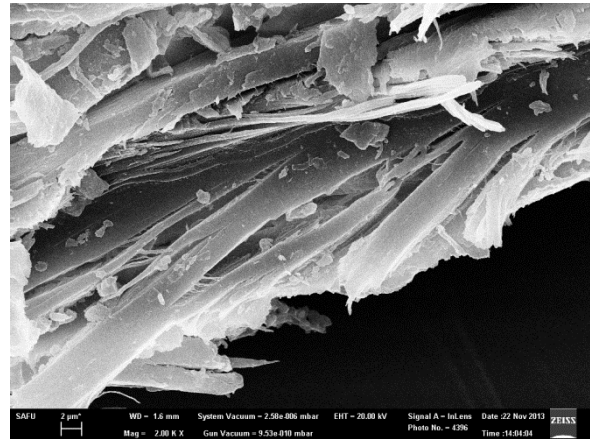


Fig. 5 – Electronic photograph of wood surface microparticles

Fig. 6,7 show particles of reinforced wood matrix. Electronic photographs prove that nanodispersed basalt particles fill fiber cell holes, cells, capillaries, damaged cell walls and cover wood microparticles surface with mineral nanoparticles film. Thus spontaneous reinforcement of wood matrix takes place only due to physical phenomena.

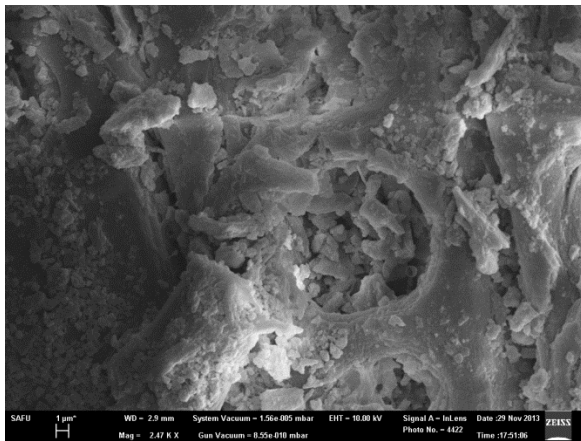


Fig. 6 – Electronic photograph of wood microparticle with cells filled by basalt nanoparticles

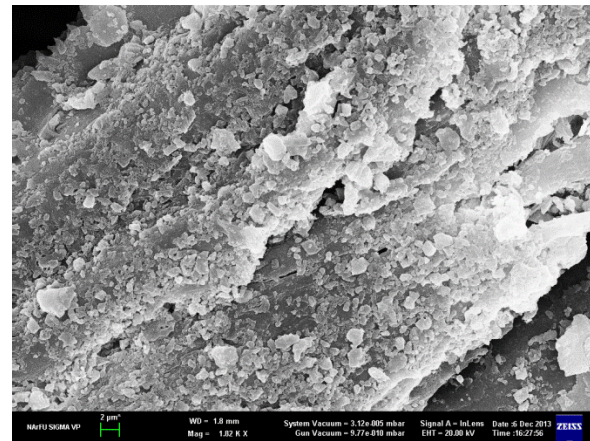


Fig. 7 – Electronic photograph of wood microparticles surface covered with basalt nanoparticles

Table 1. The results of Zeta sizing on Delsa Nano Series Zeta Potential and Submikron Particle Size Analyzers

Dispersion phase	pH of dispersed substance	Zeta ζ -potential, mV
basalt	7	-37.09
wood	7	-15.90

Data in Table 1 prove that the surface of wood and basalt fine-dispersed particles has a negative charge in water suspension. This phenomenon causes electrostatic barrier which blocks intensive reinforcing of wood matrix by basalt nanoparticles.

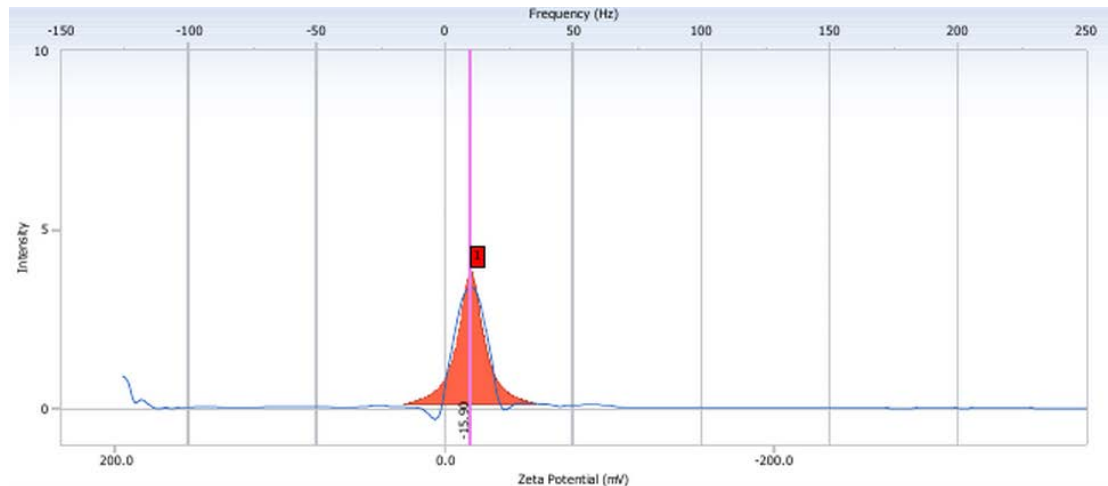


Fig. 8 – Diagram of Zeta sizing for wood microparticles in aqueous environment

One of the experimental methods used to reduce electrostatic barrier and help faster reinforcement of wood matrix is to change dispersion environment pH (Table 2).

Table 2. the results of Zeta sizing with changed environment pH

Dispersion phase	pH of dispersion environment	Zeta ζ -potential, mV
basalt	4	6.17
basalt	9	-63.59
wood	4	-5.66
wood	9	-24.70

Data in Table 2 show that the reinforcement process of wood matrix can be intensified by changing pH of dispersion into acid environment. As the result mineral nanoparticles will fill platelet structure of wood particles and will be attracted to their surface due to electrostatic forces. This will help to intensify filling of wood substance free surface by nanostructured filler.

Another experimental method used to increase the quantity of nano-filler in wood matrix is intentional particle recharge of one of the disperse phase components by adding indifferent electrolyte. Microparticles of wood placed in water have a charge of -15.90 mV, while basalt nanoparticles charge is -37.09 mV. The particles of both components have a negative charge, so to increase their physical and chemical interaction, it is necessary to recharge structure elements of one of the suspension components or to maximum approximate their Zeta potential to zero (isoelectric state). As wood is an organic substance having a great number of active chemical groups it is rather problematic to recharge fine-dispersed particles of wood component, for chemical interaction between wood macromolecules and an electrolyte can take place. Thus, it is more reasonable to recharge basalt fine-dispersed particles.

Bishofite (MgCl_2) was chosen as an electrolyte. Test results are given in Table 3.

Zeta potential (-10.09 mB) for basalt nanoparticles is maximum reduced in comparison to an original suspension sample (-37.09 mB) when 20 ml of indifferent electrolyte is added to dispersion environment. Thus, the given paper shows the possibility to reduce electrostatic barrier, which prevents basalt particles attraction to the surface of wood matrix, by changing the charge on the surface of solid.

Table 3. The results of basalt fine-dispersed particles surface recharge

0.1 M of MgCl_2 additive, ml	Basalt particles Zeta potential, mV
0	-37.09
5	-15.45
10	-11.59
15	-11.35
20	-10.09
25	-15.99
30	-16.68
35	-17.95

4. CONCLUSION

Based on the research the following conclusions were made:

1. The reinforcement of wood matrix by basalt nanodispersed filler happens spontaneously due to physical phenomena which take place in the structure of wood microparticles placed in dispersion environment.
2. The experimental methods were worked out to intensify filling of free cavities and active surface of ultradispersed wood matrix particles by nanodispersed mineral filler.
3. The change of pH dispersion environment into acid environment makes it possible to get the opposite in sign charge of fine-dispersed wood particles and mineral filler surface.
4. The recharge of basalt nanoparticles by adding indifferent electrolyte into suspension helps to reduce electrostatic barrier, which prevents attraction of nanostructured mineral filler to the surface of ultradispersed wood particles.

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