Biostability of composite material based on wood waste processing industry

O Selzneva¹, V Orlov¹ and P Shustov²,³

¹Industrial University of Tyumen, 625000, Ural Federal district, Tyumen region, Tyumen, str. Volodarsky, 38
²Angarsk State Technical University, 665835, Irkutsk region, Angarsk, Tchaikovsky str., 60, Russia
³Irkutsk National Research Technical University, 664074, Irkutsk, Lermontov str., 83

E-mail: sel__olga@mail.ru

Abstract. The actual task of the construction industry is to increase the durability of building materials. The use of wood and materials based on waste from the woodworking industry puts forward requirements for increasing biostability and fireproof properties. The article presents wood composite materials based on opal rocks on unfired and fired diatomite with the use of water glass in the form of a binder, sawdust and chips in the form of filler. The biostability of both types of composite has been studied. Studies of the qualitative phase composition were carried out using X-ray phase analysis. The dependence of the biostability of the composite material on the content of the filler has been established. The possibility of using liquid glass in the form of a binder to protect the aggregate from biological damage to wood in composite materials based on opal rocks has been proven.

1. Introduction
The use of wood in construction is associated with the need to carry out work to protect structures from biological damage, destruction under the influence of weather factors and operational loads [1, 2, 3]. It is possible to ensure the service life of the structure by constructive measures and by processing the material with various compositions (antiseptics, fire retardants, varnishes, paints). An effective way to protect wood from decay and fire is the use of liquid glass in the form of a suspension. Application technology includes preparation of a suspension by diluting liquid glass with water to a given viscosity, layer-by-layer application of the composition to the surface of the structure [4, 5]. Each subsequent layer is applied after complete drying (curing) of the previous one. Treated wooden structures acquire refractory properties and their hygroscopicity decreases, which contributes to the creation of protection against dampness, mold and mildew [6, 7, 8].

Liquid glass this is a solution of alkaline silicates, mainly sodium and potassium. Liquid glass is widely used in various industries. It is used as a binder in the manufacture of acid-resistant concretes, for strengthening the soil base, for making casting molds, for coating welding electrodes, as an adhesive. In addition, it is used for impregnation of concrete products in order to increase water resistance, in the technology of preparing paper, cardboard, various types of soaps, for the preparation of drilling fluids.
and flushing fluids. A huge amount of liquid glass is used to manufacture the most common adsorbent for silica gel of various brands and purposes [9].

In the last twenty years, another vast area of using liquid glass has opened up, associated with the manufacture of fireproof sound and heat insulation materials.

The traditional method of producing liquid glass, where quartz sands are used as raw materials, is an energy-intensive operation. Melting of silicate glass for construction purposes is carried out in glass-making furnaces according to a special temperature regime for each composition and type of products at temperatures up to 1500 °C.

To date, the existing deposits of pure quartz sands are no longer able to meet the increased demand for liquid glass. Therefore, of particular interest in this respect is the silica raw material of sedimentary rocks (diatomites, opokas, tripoli, etc.), which are widespread in the European part and east of the Urals up to the Ob river.

To obtain water glass, diatomite is mixed with sodium alkali and water to obtain a liquid mass and kept at a temperature of 90 °C for 4 hours, while dissolution of amorphous silica in alkali occurs to form sodium silicates. Used as untreated diatomite, and fired at a temperature of 700 °C for 4 hours. During heat treatment, organic substances burn out and additional activation of silica occurs. The resulting silicate modulus is 2.7 on average [10]. The characteristics of liquid glass are determined in accordance with GOST 13078-91 [11].

Further, sodium fluorosilicate, which is a hardener, is additionally introduced into the liquid glass solution. Waste from woodworking enterprises in the form of sawdust is used as a filler. In the investigated compositions, the size of the fine fraction is 2.5-5mm, the coarse fraction is 10-20mm.

The main construction purpose of this material is the laying of the walls of the building. External walls are exposed to various physical and natural influences, while performing the main functions: heat-insulating, sound-insulating, load-bearing. In addition, the material must meet the requirements for durability, fire resistance, protection of premises from adverse external influences.

The durability of a composite material is the ability to resist all types of factors affecting it during operation. Such factors can be: changes in temperature and humidity, exposure to various gases in the atmosphere, sunlight, etc.

Biological damage includes rotting wood as a result of the vital activity of fungi. The greatest danger is represented by house fungi, which destroy cellulose and lignin in wood and cause destructive rot. For the development of house mushrooms, the following conditions are necessary: wood moisture content of at least 18-20%, air oxygen access, positive (from 5 to 45 °C) temperature and increased (90-100%) air humidity, lack of sunlight, the presence of a slightly acidic environment. The biostability of the aggregate in the composite determines the durability of the wall material [12, 13, 14].

2. Results and Comments
To research a composite material based on opal rocks for biostability were used samples of 70.7x70.7x70.7 mm made on unannealed, anneal diatomite, as well as with the introduction of microsilica. After curing, the molded cubes were placed in a Votsch VC7018 climatic chamber, where they were kept for two months and subjected to cyclic heat treatment.

The cycle of operation of the climatic chamber consisted of raising the temperature to + 45 °C, for 8 hours, cooling to a temperature of +20 °C with an exposure of 16 hours, while controlling and maintaining the humidity at 100%. The specified temperature regime, combined with the lack of sunlight, provide conditions for wood decay.

Photos of the research process is shown in Figure 1.
Figure 1. Test of samples for biostability (1.1-1.6).
After 60 cycles, the cubes of the composite material were destroyed on the press, and the state of the aggregate was visually examined. The research results are presented in table 1.

### Table 1. Biostability test results.

| Base binder                  | Aggregates fraction, mm | Aggregates for 1 m³, % | Changes in the condition of samples after a certain number of test cycles in the climate chamber. |
|------------------------------|--------------------------|------------------------|---------------------------------------------------------------------------------------------------|
|                              |                          | 70                     | 20 cycles: Discoloration and biodamage not diagnosed  /
|                              |                          | 100 (basic)            | 40 cycles: Discoloration and biodamage not diagnosed  /
|                              |                          | 130                    | 60 cycles: Discoloration and biodamage not diagnosed  |
| Raw diatomite                |                          | 70                     |                                                                                                    |
|                              |                          | 100 (basic)            |                                                                                                    |
|                              |                          | 130                    |                                                                                                    |
| Heat Treated Diatomite       |                          | 70                     |                                                                                                    |
|                              |                          | 100 (basic)            |                                                                                                    |
|                              |                          | 130                    |                                                                                                    |

Also, research of the qualitative phase composition were carried out. In the X-ray phase analysis of the fabricated samples, the powder method was used, based on obtaining a diffraction pattern of X-rays scattered on a flat polycrystalline powder sample [15, 16, 17].

The survey was carried out on a DRON-7 diffractometer from CuKα - radiation λ=1,54184 Å, Ni filter. The results were processed using the software package PDWin 4.0, diffractometric database PDF 4.0.
For the X-ray phase analysis samples were taken on unbaked and thermally treated diatomite. The samples were 1 month and 1 year old for each composition.

X-ray diffraction patterns of samples on unfired diatomite are shown in Fig. 2 and 3.

**Figure 2.** X-ray of a sample at 1 month of age.

**Figure 3.** X-ray of a sample at 1 year of age.

Comparison of the X-ray diffraction patterns of samples on unfired diatomite shows the following:

1. A 1 month old sample contains silicon dioxide SiO₂ in various forms (quartz, tridymite). A large amount of the compound dehydrated potassium pentafluoroaluminate K₂AlF₅ and sodium fluoride NaF are observed, obtained by reaction with sodium silicofluoride Na₂SiF₆.

2. In a sample aged 1 year, the main lines on the X-ray diffraction pattern are represented by silica in the form of quartz; modifications in the form of cristobalite and tridymite are practically absent. Dehydrated potassium pentafluoroaluminate K₂AlF₅ is also absent on the X-ray diffraction pattern.

X-ray diffraction patterns of samples on calcined diatomite are shown in Fig. 4 and 5.
Comparison of the X-ray diffraction patterns of samples on thermally treated diatomite shows the following:

1. 1 month old sample, silicon dioxide SiO$_2$ is observed in the forms of quartz and tridymite. Compounds are observed: dehydrated potassium pentafluoroaluminate $\text{K}_2\text{AlF}_5$, and sodium fluoride NaF, obtained by reaction with sodium silicofluoride Na$_2$SiF$_6$.

2. In a sample aged 1 year, the main lines on the X-ray diffraction pattern are represented by silica in the form of quartz; modifications in the form of cristobalite and tridymite are practically absent. Dehydrated potassium pentafluoroaluminate $\text{K}_2\text{AlF}_5$ is also absent on the X-ray diffraction pattern.

In samples on fired diatomite at the age of 1 year, the content of sodium fluoride NaF is higher than in unbaked one. This can have a positive effect on the biostability of the material, since this compound is used as an antiseptic in wood processing. Also, the content of silicon dioxide SiO$_2$ in the form of quartz and tridymite is higher in sample using fired diatomite, which indicates its denser structure and increased strength.
Based on the results of a research of a composite material with opal rocks and woodworking waste for biostability, the following conclusions can be drawn: the use of liquid glass as a binder for the manufacture composite material can reliably protect the aggregate from biological damage to wood.

References
[1] Allsopp D, Seal K and Gaylarde C 2004 Introduction to Biodeterioration (Cambridge University Press) p 237
[2] Solomatov V I, Erofeev V T and Smirnov V F 2001 Biological Resistance of Materials (Publishing house Mordv.) p 196
[3] Zavalishin E V, Erofeev V T and Smirnov V F 2004 Biological resistance of composites based on liquid glass J. Sci. Biological damage and biocorrosion in const. pp 156-159
[4] Heveran C M, Williams S L, Qiu J, Artier J, Hubler M H, Cook S M, Cameron J C and Srubar W B 2020 Biominalerization and Successive Regeneration of Engineered Living Building Materials Matter doi: 10.1016/j.matt.2019.11.016
[5] Iwanczuk A, Kozlowski M, Lukaszewicz M and Jabłonski S 2015 Anaerobic Biodegradation of polymer composites filled with natural fibers J. Polym. Environ. 23 (2) pp 277–282
[6] Levinskait L 2018 Biodegradation potential of fungi penicillium isolated from synthetic polymeric materials JoEE 144 (7) pp 51–58
[7] Nanazashvili I Kh 1990 Building Materials from Wood-Cement Composition (Stroyizdat) p 415
[8] Ilichev V D 1987 Biodeteriorations (Moscow: Vyshaya shkola) p 352
[9] Radayev S, Seleznjova O, Ilyukhin K, Forosevich N and Ivanov K 2016 The problem of structurization of liquid glass Solid State Phenomena 871 pp 90-95
[10] Seleznjova O, Radayev S and Baranova A 2019 The influence of heat treatment on the granulometric and chemical composition of diatomite of the kamyshlovsky deposit in the preparation of a liquid glass binder IVIB 3 pp 550-555
[11] GOST 13078-91 Liquid sodium glass. Technical conditions (in Russian)
[12] GOST 9.049-91. Unified system of corrosion and ageing protection. Polymer materials and their components. Methods of laboratory tests for mould resistance (in Russian)
[13] Stroganov V F, Boychuk V A and Sagadeev E V 2014 Biodamage of wood materials and structures Izvestiya KGASU 2 pp185-193
[14] Erofeev V, Dergunova A, Piksaikina A, Bogatov A, Kablov E, Startsev O and Matvievskiy A 2016 The Effectiveness of Materials Different with Regard to Increasing the Durability, MATEC Web of Conf. 73 doi: 10.1051/matecconf/20167304021
[15] Pushcharovsky D Y 2000 Radiography of Minerals (Moscow: Geoinformmark) p 296
[16] Mikheev V I 1965 X-ray Detector of Minerals (Leningrad: Nedra) p 868
[17] Kovba L M and Trunov V K 1969 X-ray Phase Analysis (Moscow: Moscow State University Press) p 104