Wall materials based on complex binders and organic aggregate

L V Zakrevskaya¹,², Andrei Gavrilenko¹, Ksenia Andreeva¹, Petr Lubin¹, Ilya Kapush¹ and Igor Udin¹

¹Vladimir State University named after Alexander and Nikolay Stoletovs, 600000 Vladimir, Russia
²E-mail: lvzak@mail.ru

Abstract. The technology of hards concrete developed in this study differs primarily by the binders - semi-burnt dolomite, related to magnesia cements. Grouting fluid is bischofite (MgCl₂) or magnesium sulfate (MgSO₄), density 1.2 g/cm³. One of the ways of strengthening and adding new properties to hards concrete, which can significantly expand its application domain, is an introduction of chrysotile to the concrete composition. The best specimen have density 570-585 kg/m³, strength 14.5 - 15.1 MPa and low thermal conductivity (0.065-0.074) W/(m·K), what allow them to serve as structural and thermal insulation material. Sound absorption coefficient is from 0.17 to 0.6 (at audio frequencies of 125-2000 Hz). Frost resistance exceeds 50 cycles, water absorption is 40-50%, shrinkage is less than 0.4%, fire stability is 0.75-1.54. Based on the results obtained, it can be concluded that the material is most applicable in low-rise construction. The developed material will solve the problem of utilizing of industrial hemp waste from textile production and dolomite waste in the form of a magnesian binder, thereby reducing the cost of the material in compare with existing world analogues.

1. Introduction

Wood concrete is a composite material based on organic natural aggregates such as wood chips, sawdust, flax shover, hemp hards, thatch of wheat and rye. Portland cement or lime is traditionally used as a binder. All types of wood concrete have good thermal characteristics [1-2]. The incontestable advantages of the material are:

- high bending strength;
- high sound absorption;
- low fire behavior (G1 according to Russian all-Union State Standard № 12.1.044-89);
- inflame-resistance (V1 according to Russian all-Union State Standard № 30402-96);
- good air permeability. [3]

However, its density and frost resistance often do not satisfy the consumer, in addition, it is rarely accurate in geometric parameters, biological resistance is also low, and the environmental indicators of the finished structure are 1.5 times higher than expected [4-5].

All of the above relates to concrete based on wood chips, which, among other things, has a reinforcing effect on concrete, in the case of using sawdust, the strength characteristics nosedive. Cold bridges in the joints (freezing joints) detract the thermal conditions of the premises [6].
Disadvantages of wood concrete: high moisture absorption requires external decoration, which means that economic indicators worsen [7-10]. All of the listed disadvantages of wood concrete are caused by such aggregate properties as:

- high chemical activity;
- development of pressure during swelling;
- anisotropy;
- low adhesion to the binder;
- elasticity during compaction, which affects the structure formation processes of the composite and its physical and mechanical properties [11].

Hemp hards is another natural organic aggregate for creating wood concrete, but has several advantages over similar materials, as:

- reinforcing filler;
- high strength;
- heat insulating;
- sound absorbing;
- frost resistant;
- fire resistant;
- bioproofness [12].

Hemp hards in its composition contains 40-48% of cellulose, 26% lignin, 22% pentosans.

The properties of wood concrete items like any artificial stone materials depend on the type of binder used in their synthesis. The most common inorganic binders are:

- lime;
- gypsum;
- magnesia cement;
- portland cement [13].

2. Methods

The technology of hards concrete developed in this study differs primarily by the binders – semi-burnt dolomite, related to magnesia cements. Grouting fluid is bischofite (MgCl₂) or magnesium sulphate (MgSO₄), density 1.2 g/cm³. One of the ways of strengthening and adding new properties to hards concrete, which can significantly expand its application domain, is an introduction of chrysotile to the concrete composition. Chrysotile (3MgO • 2SiO₂ • 2H₂O) is a mineral of the serpentine group, its crystal chemical composition is analogous to the magnesian binder obtained from dolomite. The properties of chrysotile fiber are given in table 1.

| Tensile strength, kg/mm² | Mineral density, kg/mm² | Melting temperature, °C | Coefficient of friction (for iron) | Alkali resistance, pH | Thermal conductivity, W/(m·K) |
|--------------------------|-------------------------|--------------------------|-----------------------------------|----------------------|-----------------------------|
| 300                      | 2 400 – 2 600           | 1 450 – 1 500            | 0.8                               | 9.1 – 10.3           | 0.05 – 0.07                 |

Experimental samples were obtained according to the following scheme: hemp hards moistened with water, (the amount of which was calculated by 0.9C - 0.06 K [14]) and mixed with other components until an intimate mass is formed, when adding bischofite and mixing again. Further, the raw material mixture is uniformly compacted with the vibratory plate SMZH-539 for 2 minutes. Next, the mixture was placed in the formwork and was pressed with a force of 3 to 5 kg/mm² with the MS-500 press, and then the resulting building element was dried at room temperature in special box. On the second day, the blocks were dismantled.

Table 2 shows the compositions of synthesized composites.
### Table 2. Compositions of synthesized composites.

| Composite, % mass. | Composition name title | KM-1 | KM-2 | KM-3 | KM-4 | KM-5 | KM-6 | KM-7 | KM-8 |
|-------------------|------------------------|------|------|------|------|------|------|------|------|
| Hemp hards        |                        | 20   | 21   | 22   | 23   | 24   | 25   | 26   | 27   |
| Semi-burnt dolomite |                      | 44   | 46   | 42   | 43   | 45   | 42.5 | 44.5 | 45   |
| Chrysotile        |                        | 4    | 1    | 6    | 1.5  | 2.5  | 3.5  | 3.5  | 2    |
| Bischofite        |                        | 32   | 33   | 30   | 32.5 | 28.5 | 25   | 26   | 26   |

Strength test was carried out with a non-destructive shock pulse testing method. Thermal conductivity was measured with MIT-1 device by the probe technique. Water absorption was measured with a VLAGOMER-MG4B indicator.

### 3. Results and Discussion

The results of studying the operational characteristics of the synthesized composites are presented in Table 3.

### Table 3. Performance characteristics of synthesized composites.

| Composition name title | Rc, MPa | Density, g/cm³ | Thermal conductivity, W/(m·K) | Water absorption, % |
|------------------------|---------|----------------|-----------------------------|---------------------|
| KM-1                   | 13.6    | 681            | 0.091                       | 12.5                |
| KM-2                   | 13.1    | 669            | 0.087                       | 12.8                |
| KM-3                   | 13.8    | 646            | 0.085                       | 13.0                |
| KM-4                   | 13.0    | 621            | 0.08                        | 13.5                |
| KM-5                   | 13.7    | 600            | 0.074                       | 13.8                |
| KM-6                   | 14.5    | 585            | 0.074                       | 13.8                |
| KM-7                   | 15.1    | 580            | 0.07                        | 14.0                |
| KM-8                   | 14.6    | 570            | 0.065                       | 14.0                |

Figure 1 shows correlation between physical and technical characteristics and composition of composites.

![Figure 1. Physical and technical characteristics correlation chart.](image)
thermal insulation material in accordance with Russian all-Union State Standard № 19222-84 "Wood concrete and products from it. General specifications" (table 4).

**Table 4. General properties.**

| Wood concrete type | Compressive Strength Class | Axial compression strength grade | Average density, kg/m³, wood concrete based on Crushed wood | Crushed shover or crushed cotton caulis | Crushed hemp hards | Crushed paddy straw |
|--------------------|---------------------------|---------------------------------|----------------------------------------------------------|----------------------------------------|-------------------|---------------------|
| Heat-insulating    |                           |                                 |                                                          |                                        |                   |                     |
| B0.35              | M5                        | 400-500                         | 400-450                                                  | 400-450                                | 500               |                     |
| B0.75              | M10                       | 450-500                         | 450-500                                                  | 450-500                                | 500               |                     |
| B1.0               | M15                       | 500                             | 500                                                      | 500                                    | 500               |                     |
| Constructional     |                           |                                 |                                                          |                                        |                   |                     |
| B1.5               | -                         | 500-650                         | 550-650                                                  | 550-650                                | 600-700           |                     |
| B2.0               | M25                       | 500-700                         | 600-700                                                  | 600-700                                | -                 |                     |
| B2.5               | M35                       | 600-750                         | 700-800                                                  | -                                      | -                 |                     |
| B3.5               | M50                       | 700-850                         | -                                                        | -                                      | -                 |                     |

Thermal performance meets the requirements (U ≤ 0.23 W/(m·K)) without additional insulation [15].

The explanation of the results lies in the synergistic effect of all components of the composite:
- hards and chrysotile take on the role of fiber;
- semi-burned dolomite, bischofite and chrysotile as magnesial components boost binding properties in the formation of a stone-like structure;
- chrysotile take on the role of the component strengthening the structure as a natural nano particle.

Figure 2 shows samples of hards concrete recommended for in-process testing.

**Figure 2. Samples of hards concrete.**

Primary studies have confirmed previous studies [16-19] that failure under load when the bearing capacity is exceeded (by 70-80%) occurs slowly, and not instantly, due to a hards, which is characterized by reversible plastic deformations.

Hards is a reinforcing filler and the wall of hards concrete does not collapse further with differential settlements. Sound absorption coefficient is from 0.17 to 0.6 (at audio frequencies of 125-
2000 Hz. Frost resistance exceeds ≥ 50 cycles, water absorption is 40-50%, shrinkage is less than 0.4%, and fire stability is 0.75-1.54.

Based on the results obtained, it can be concluded that the material is most applicable in low-rise construction. At the same time, dome can be the most power efficient form of the building. The developed material allows to create dome shape of structures both as cast-in-place so prefabricated using standardized hards concrete blocks for dome forms [20]. Additional saving of thermal energy can be achieved through the use of heating window sills, in the body of which heating elements are introduced. In this case, the cold air from the window is cut off by the warm upward flow from the panel.

4. Conclusions
The designed composite material has improved thermotechnical characteristics compared with the existing wood concrete and cheaper in compare with latter due to the use of industrial waste. Hards concrete can be used in low-rise construction as a structural and heat-insulating material immune to biological destruction. The developed material will solve the problem of utilizing of industrial hemp waste from textile production and dolomite waste in the form of a magnesian binder, thereby reducing the cost of the material in compare with existing world analogues.

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