The strength of sawdust concrete, produced without mineral aggregates

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Abstract. The construction industry widely uses concrete for various purposes. The addition of lightweight fillers to the compounding of concrete allows to obtain lightweight concrete with high heat-insulating indicators and a smaller mass. Various materials can be used as fillers, including industrial waste. The paper is devoted to the study of the properties of lightweight concrete with the addition of sawdust. As a result of experimental studies, the strength properties of sawdust concrete produced without the use of mineral fillers (sand) were determined. The positive effect of tempering the mixture with latex emulsion on the strength properties of sawdust concrete has been established. The strength characteristics of samples made with the addition of a latex emulsion were 3.65 MPa at a density of 1080 kg/m³. Such indicators allow using the material as a structural thermal insulation during construction.

The experience of the modern forestry complex of the leading foreign countries shows the trend of the integrated and full utilization of the forest resources obtained during logging. The task of rational use of sawmill waste retains its relevance for a long time. The volume of sawmill waste is directly dependent on the volume of processing of timber for sawn timber. The volume of lumber production on a global scale is more than 400 million m³ per year [1]. Russia accounts for about 20 million m³. With the existing methods of processing wood raw materials in Russia as a whole, about half is used, and in the Siberian region only a third of the biomass of the tree is used.

The need to recycle waste from the timber industry is one of the most important environmental issues. Nowadays, many technological schemes have been developed for the processing of various types of recycled wood raw materials. However, their implementation requires large capital and operating costs, skilled personnel, and sophisticated equipment although it implies a significant economic effect. For example, chemical processing of wood waste can recycle only 25–30% of their total amount [2]. Most of the waste is located in landfills, which occupy large areas. This leads to fire hazardous situations, since all wood waste can ignite spontaneously [3]. Studies have shown that the proportion of organic waste reaches 50%, but about 40% of them are not included in the recycling program, but end up in landfills [4].

Currently, the industry mainly uses stem wood. The share of low-quality wood, logging residues and lumbering is, respectively, 15–40, 30–40 and 19–20% [5]. For Russia, in volumetric terms, this is a very impressive figure. It counts up to more than 90 million m³ of wood waste, 12.7 million m³ of sawmill waste, of which over a million m³ [6] is sawdust. One of the directions of utilization of wood waste in the form of sawdust is the production of structural thermal insulation materials in the form of wood
compositions based on various astringent-adhesive substances. These materials can be used as structural insulation in the form of blocks, slabs, etc. Interest in such materials will inevitably increase due to an increase in the volume of construction work in the spheres of the construction of new buildings, the renovation and repair of existing housing stock, and also because the price of high-quality stem wood is constantly increasing.

Sawdust concrete is a type of lightweight concrete, obtained on a mineral binder and organic cellulose filler (sawdust). Fundamentally, the technology of sawdust concrete production is similar to the technology of wood concrete. In principle, wood concrete is a better-studied material. But many of the provisions and principles with some stretch apply to sawdust concrete [7]. In addition to traditional adhesives, suspensions and cement, crushed plastic waste, suitable for the production of wood-plastic composites (WPC), can also act as binding materials [8]. The mechanical properties of sawdust concrete largely depend on the shape and size of the particles used as a filler, the percentage of binders, mineral additives and organic aggregate [9]. The effect of the fractional composition of sawdust on the strength of sawdust concrete was studied in some researches [10]. When using calcium hydraulically closed binders, there is a decrease in the strength of sawn concrete due to the presence of sugars in the wood composition, which slow down the hydration process. The percentage of sugars in the wood depends on the breed and growing conditions and ranges from 0.5 ... 2% (tropical species) to 18% (larch) [7]. To combat this phenomenon, materials are used - neutralizers of sugars, accelerators of hardening and setting of cement (aluminium chloride, magnesium chloride, iron chloride, barium chloride, sodium sulphate, calcium chloride, hydrochloric acid) and by adding waterproofing-enveloping mineral substances (liquid glass, PVA emulsions, varnish) [11,7,12]. However, any additional processing of raw wood inevitably leads to higher prices for the final product, which is highly undesirable.

For the preparation of compositions based on sawdust and concrete, various formulations are used that determine the brand of the material obtained. For M15 type in terms of 1 m³ of the mixture, 210 kg of M400 concrete, 600 kg of sand, 210 kg of sawdust are required. Such a significant amount of mineral filler (sand) causes a relatively low rate of thermal efficiency of the material obtained. At the same time, the possibility of minimizing the proportion of high-heat conducting mineral fillers in the manufacture of sawdust concrete is promising.

The purpose of the paper is to determine mechanical parameters of sawdust concrete using formulations without the introduction of mineral fillers. To achieve the purpose, the following tasks were solved:

- To investigate the properties of sawdust concrete produced without mineral fillers;
- To assess the prospects for mixing the mixture of components with an emulsion of latex and the effect on the strength of the resulting materials;
- To carry out an experiment and to investigate the strength of the obtained samples of sawdust concrete, depending on changes in various factors with compression as an orthotropic material.

The subject of research: the effect of the absence in the formulation of sawdust concrete mineral components (aggregates) on the strength properties of wood-concrete material, made on the basis of these sawdust, including the use of latex additives.

To determine the strength of sawdust without mineral additives, experimental studies were conducted. Samples of cubic sawdust concrete were prepared with dimensions of 50 × 50 × 50 mm. The dosage of the components was carried out by weight, with an accuracy of 1 gram. The combination was prepared by mixing sawdust and Portland cement, followed by mixing with water. When tempering a mixture with latex additives, a latex emulsion was first prepared, then sawdust was added and then the concrete was added. In all cases, the water-concrete ratio was equal to 1. The components were mixed manually. The mixture was compacted in the form during vibration. Drying of the samples was carried out at a temperature of + 240 °C. Samples were removed from the forms after 7 days. Next, the samples were stored for 28 days at room temperature for the final set of strength. To eliminate the influence of random factors, 20 samples of each formulation were made. Typical M15 type of concrete was used,
but no sand was added to the mixture. The proportion of PC400 Portland cement in a mixture from 100 to 500 kg (in terms of 1 m$^3$) changed. P PC 400-D20 Portland cement was used (Portland cement with slag (W) from 6% to 20%, strength class 32.5 fast-hardening, GOST 31108-2003 Binder manufacturer - Krasnoyarsk Cement LLC. Sawdust obtained from sawing pine was used to mix the mixture on a sawmill installation. Fractional composition particle size of sawdust from 2 to 5 mm. Sawdust was sifted through a sieve with a cell size of 5 mm. Humidity of sawdust was not measured and matched the humidity of raw growing wood. emulsion (mixture 2). Latex emulsion was prepared by mixing Latexcol-M latex additive and water in a ratio of 1 part Latexcol-M to 1 part of water. The obtained samples were measured in three planes and weighed. The results were recorded in a log of observations (figure 1). Further, the samples were tested for compressive strength on a hydraulic testing machine. The compressive strength of the samples was determined. Statistical processing of the experimental data was conducted.

The results of studies of compressive strength are presented in figure 2. The graph shows that an increase in the percentage of the binder significantly improves the mechanical strength characteristics of the samples. The compressive strength of the resulting samples increases to 3.65 MPa (for mixture 2). The mechanical properties of the samples obtained using pure water for tempering the mixture do not meet the requirements for structural heat-insulating materials; the maximum compressive strength of these samples does not exceed 0.64 MPa.

![Figure 1. Sample density, kg/m$^3$, depending on the content of PC400.](image1)

![Figure 2. Tensile strength, MPa at compression depending on the content of PC400 Portland cement.](image2)

Sawdust concrete on the basis of sawdust and Portland cement allow to obtain a composite wood-concrete material of relatively low density and low thermal conductivity. However, the interaction of organic material and mineral binder has a negative effect of the wood filler properties. This is a significant water absorption of wood and chemical aggressiveness of individual compounds contained in the wood cage [7,12] in relation to the concrete stone in the stage of its hardening. When mixing the mixture with water (mixture 1) due to the intensive absorption of water by sawdust, the mixture is dehydrated, while the hydration of the concrete stone occurs without close adhesion to the wood particles. In addition, water-soluble chemical components contained in the cells of wood, actively interact with the concrete stone, reducing its strength properties. As a result, the maximum tensile strength of the samples is only 0.64 MPa. The density of the material with such strength is 1080 kg/m$^3$. Thus, it turns out that the material is too dense as a heat-insulating material, and extremely weak when working in the form of heat-insulating - structural. With an increase in the content of PC400 to 500-600 kg/m$^3$, the practical sense of the insulating material is lost, since the density of the samples exceeds 1000 kg/m$^3$ and the thermal conductivity approaches the parameters of light blocks without organic additives.

Sawdust concrete on the basis of the latex emulsion prepared on a latex additive (Latexcol-M) and
water, has significantly greater strength compared to the material made on water. In this case, there is practically no increase in the density and, accordingly, the thermal conductivity of the material. When pre-processing sawdust, latex emulsion, enveloping wood particles, eliminates the intensive dissolution of the chemical elements contained in the wood. In addition, latex additionally glues the particles of cement stone. Indirectly, this indicates the nature of the destruction of the samples. Samples made on the latex emulsion (mixture 2) were more plastic and collapsed when the magnitude of linear deformations were 25–30% more compared to samples from mixture 1. The positive effect on the strength characteristics when modifying cement compositions with polymers was substantiated and proved by many studies [13].

The strength characteristics of sawdust concrete made with mixing a mixture of latex emulsion (mixture 2) generally correspond to those for D600 aerated concrete [14] which is characterized by compressive strength of 3.2 MPa (according to GOST 31360-2007). The strength of sawdust concrete, depending on the ratio of components (figure 2), reaches 3.65 MPa. Thus, according to the strength criteria, the material is not inferior to aerated concrete and can be effectively used, for example, in “low-rise construction”.

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