Plasters with wood processing waste additives

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Abstract. The paper assesses the influence of additives based on wood processing industry waste on the physical and mechanical properties of plasters. As additives to the plaster, the bark and sawdust of Scots pine were used, previously crushed and purified from extractive and easily hydrolysable substances. Extraction of extractive substances from wood processing waste was performed by hot water extraction. The content of additives was in the range from 1.5 to 6 \% by weight of cement. The average density, compressive strength, flexural tensile strength, water absorption, and thermal conductivity were monitored for the obtained samples of plasters. As a result of the carried out experiments, it was found that the quantitative increase of the additive in the mixture reduces the density of the mortar, water absorption increases slightly, the coefficient of thermal conductivity and the tensile strength during bending decreases. The compressive strength increases with the addition of sawdust 1.5 \%, in other cases it decreases with the increase in the amount of the additive. It is shown that mortars with the addition of fine wood processing waste can be used as plasters with reduced thermal conductivity for interior work.

1. Introduction

Construction is a large-scale industry, the development of which moves on. Mass construction of residential and non-residential buildings creates the need to re-evaluate the material and raw material base of the construction industry in order to rationalize its use and reduce net cost.

When building objects, major repair or refurbishing finishing works are necessary, in the production of which dry plaster mixtures are used. Cement plaster mixtures are common because they provide high strength, good adhesion to the surface, wear resistance, low thermal conductivity and water resistance.

The task of choosing raw materials for plaster mixtures that provide high quality and low cost of the solution becomes urgent, so currently there is an active search for effective additives that help reduce the cost and improve the strength and thermal insulation properties of plaster mixtures [1, 2].

One of the leading areas of production in the Arkhangelsk region is the woodworking industry. In this regard, a large amount of waste is generated, which includes wood bark, sawdust, wood chips, wood flour, and others that can be used as a replacement for part of the cement in mortars, including plasters ones. The use of such woodworking waste in composite materials [3-6] will reduce the consumption of cement, the production of which has a negative impact on the environment. In
addition, replacing part of the cement with wood processing waste will reduce the cost of the final product and improve its quality characteristics.

However, when adding wood processing waste to plasters, it is necessary to take into account the fact that wood and Portland cement have a complex composition, and mixing them with water causes a significant number of competing chemical reactions [7, 8]. Organic matter (wood) and inorganic hydraulic binder (cement) are antagonistic in nature. Under the action of the highly alkaline liquid phase of cement (pH=12 ... 14), lignocarbon bonds are destroyed, thus violating the integrity of the material structure. The effect of water-soluble substances of wood on hardening cement is shown in the stabilizing effect [9]. “Cement poisons”, i.e. extractive and easily hydrolysable substances, consist mainly of carbohydrate groups [10-12]. These substances are deposited on the surface of the cement mineral particles 3CaO·SiO$_2$ (tricalcium silicate) and 3CaO·Al$_2$O$_3$ (tricalcium aluminate) and form the thinnest shells that hinder the course of cement hydration processes. But monomeric sugars (glucose, xylose, derivatives of glucuronic and ascorbic acid) in a small amount (up to 0.125 wt. %) accelerate the setting processes and promote structure formation, and at a concentration of more than 0.25 wt. %, on the contrary, slow down the setting and hardening of cement, which completely eliminates the possibility of obtaining strong compositions. One of the easiest ways to reduce the negative impact of water-soluble extractive and easily hydrolysable substances on the strength of wood-cement compositions is pre-extractive wood processing [13, 14].

Based on the above, the aim of this study is to assess the impact of additives based on pre-prepared wood processing industry waste on the physical and mechanical properties of plasters.

2. Materials and methods

As an additive to the plaster mixture, the bark and sawdust of Scots pine were used, pre-extracted with hot water to extract the water-soluble components of the wood, and then dried to a constant mass at a temperature of 80 °C. The efficiency of the extraction process was controlled by reducing the optical density of the water extract taken from the reaction system at specified time intervals. The optical density was determined by recording the electron absorption spectra of experimental liquid samples on a SF-2000 spectrophotometer in the wavelength range of 270-480 nm. Extraction was stopped when the absorption spectrum of the water extract stabilized. The wavelength range was chosen based on the literature data, according to which the maximum absorption for most water-soluble extractives of wood (water-soluble phenolic compounds, monosaccharides, etc.) is located in this range. Then the bark and sawdust were ground by mechanical dry dispersion lasting 15 minutes at a rotor speed of 420 rpm with large grinding bodies made of stainless steel with a diameter of 20 mm in the amount of 18 pieces at the Retsch RM100 planetary ball mill. The grinding time was taken based on pre-conducted experiments. To obtain a uniform plaster mixture, to mix the dry components well, and to evaluate the effect of additives on the properties of mortars, the size of the bark and sawdust particles must correspond to the size of the cement particles. In order to meet this condition, it is necessary that the remaining 0.09 mm of crushed bark and sawdust on the screen does not exceed 0.8 %, which is achieved with a grinding time of 15 minutes.

As a binder, we used Portland cement of type CEM I normal hardening strength class 42.5 MPa. According to the quality certificate, this cement has a residue on the sieve of 0.09 mm-0.8 %, so it is not necessary to grind sawdust and bark to a size smaller than the cement particles, i.e. more than 15 minutes, and carries extra energy costs.

For the production of experimental samples of plasters, fine river polymineral sand of the Krasnoflotsky-Zapad Deposit was used, pre-ground and sifted through a sieve with round holes with a diameter of 2.5 mm. Production of prototypes began with the calculation of the ratio of components in the mortar. The ratio of cement and sand was assumed to be 1:4. For samples with additives, part of the cement was replaced with crushed sawdust or bark. These samples had sawdust or bark in the amount of 1.5 %, 3 %, 4.5 % and 6 % by weight of cement. Then the dry components of the mixture were mixed, after which the required amount of water was gradually added. Plaster mixtures were thoroughly mixed and stacked in layers in metal molds, tamping each layer. The samples were
decomposed after 24 hours. At the same time, during the production of prototypes, the mobility, density, and water-holding capacity of the mixture were monitored using standard methods. The average density, compressive strength, flexural tensile strength, water absorption, and thermal conductivity were determined for the obtained samples of plaster mortars using standard methods.

3. Results and discussion
Thus, samples of plaster mortars were made with the addition of sawdust and bark, the consumption of the mixture components for which is shown in table 1. This table also provides data on the density and water retention capacity of mixtures.

Table 1. The consumption of the plaster mixture components.

| Additive | Amount of sand, g | Amount of cement, g | Amount of water on calculation, g | Actual amount of water, g | Amount of additive, g | Mixture density, g/cm³ | Water retention capacity of the mixture, % |
|----------|-------------------|--------------------|----------------------------------|---------------------------|----------------------|------------------------|------------------------------------------|
| Without additive | 2000.0 | 500.0 | 250.0 | 407.0 | 0 | 1.89 | 95.55 |
| Sawdust 1.5% | 2000.0 | 492.5 | 246.3 | 414.5 | 7.5 | 1.89 | 95.65 |
| Sawdust 3% | 2000.0 | 485.0 | 242.5 | 419.5 | 15.0 | 1.86 | 95.69 |
| Sawdust 4.5% | 2000.0 | 477.5 | 238.8 | 424.5 | 22.5 | 1.82 | 95.72 |
| Sawdust 6% | 2000.0 | 470.0 | 235.0 | 428.5 | 30.0 | 1.79 | 96.14 |
| Bark 1.5% | 2000.0 | 492.5 | 246.3 | 410.5 | 7.5 | 1.90 | 95.87 |
| Bark 3% | 2000.0 | 485.0 | 242.5 | 415.5 | 15.0 | 1.90 | 95.97 |
| Bark 4.5% | 2000.0 | 477.5 | 238.8 | 420.5 | 22.5 | 1.88 | 96.80 |
| Bark 6% | 2000.0 | 470.0 | 235.0 | 425.5 | 30.0 | 1.87 | 97.07 |

From the obtained data, it can be seen that, as expected, the greater the amount of additive, the lower the density of the mixture. This is due to the fact that sawdust and bark are much lighter than cement, so the mass of the mixture is reduced. In accordance with clause 4.5.3 of GOST 33083-2014, the water-holding capacity of mixtures ready for use must be at least 95%. This requirement for prepared mixtures is met. As it can be seen from the data presented in table 1, the water retention capacity increases with the increase of the additive. But with the addition of bark, the increase is more intense than with the addition of sawdust.

Figures 1 and 2 show the testing results on compression and flexural strength of samples of mortars after their 28-day of exposure.
Figure 1. Change in the compressive strength of mortar samples with different additive content.

Figure 2. Change in the flexural strength of mortar samples with different additive content.

From the data presented in figure 1, it can be seen that the greatest strength of the samples was achieved with the addition of sawdust in the amount of 1.5%. In our opinion, this is due to the residual amount of extractive substances contained in the sawdust. When extracted with water, tannins and sugary substances, organic acids, mineral salts and acids are extracted from wood, but other extractive substances – fats, resins, waxes, essential oils and others can only be isolated by organic solvents, so they are present in sawdust. It is known that extractive substances negatively affect the adhesion of cement to wood. But with a small amount of them, namely 0.02-0.04 % of the mass of the mortar, its strength increases. This is due to the fact that with small amounts of extractive substances, i.e. with a low degree of saturation with adsorption layers (these layers are formed around the cement grains due to the hydrophilicity of their surface), the dispersion effect prevails. The predominance of the dispersion effect (distribution of active fine particles in the bulk phase) over the stabilization effect (shielding of the surface of these particles) causes a marked increase in strength.
Also, the decrease in the strength of the plaster mixture, observed with an increase in the amount of the additive, can be explained by the properties of the additive itself, namely: significant volumetric humidity deformations and the development of swelling pressure; expressed anisotropy of properties and structure; high permeability; low adhesion to cement stone. It should also be noted that the strength of samples with the addition of bark is less than with the addition of sawdust. The bark is a dead layer of cells, has a low density and low strength. Sawdust has a much higher density and strength than bark, so the mortar with the addition of sawdust has better strength indicators than samples with bark.

The results given in figure 2 show that the flexural strength of the samples with plant additives is reduced compared to the control sample. For samples with added bark, the flexural strength is higher than for samples with added sawdust. However, mixtures with the addition of sawdust 1.5 % and with the addition of bark 3 % and 4.5 % have indicators close to the strength of the control. Crushed sawdust and bark are fibers that reinforce the hardened mixture. Also, sawdust and bark have a rough surface, so as the amount of additive increases, the adhesion of the wood additive to the cement matrix increases.

The results of measuring the coefficient of thermal conductivity of samples of plaster mortars are shown in figure 3.

![Figure 3. Change in the value of the thermal conductivity coefficient of experimental samples from the number of additives.](image)

From the data presented in figure 3, it follows that with an increase in the amount of plant additives, the coefficient of thermal conductivity decreases. With the addition of 6 % bark, the coefficient of thermal conductivity is almost 2 times lower than that of a mortar without additives. Wood has a low coefficient of thermal conductivity due to its low density, so samples with an additive have a lower coefficient compared to the control sample without additives.

Table 2 shows the results of determining the average density and water absorption by weight and volume of samples of plasters.
The data given in table 2 show that as the additive content in the mixture increases, the density of the mortar, as well as the density of the mixture, decreases. As the amount of additive increases, water absorption increases by both weight and volume. This is due to the microporous structure of the wood matrix, which can be filled with water. But the increase in water absorption is insignificant, even with the addition of sawdust or bark 6%.

### 4. Summary

It is shown that the waste of mechanical processing of plant raw materials (sawdust, bark) after preliminary preparation, consisting in the removal of extractive substances, can be used as an additive that replaces part of the cement in plasters.

It is experimentally established that the replacement of 1.5 % (by weight) of cement with sawdust allows to obtain plasters with improved thermal insulation characteristics, while not inferior in their physical and mechanical characteristics (compressive strength, flexural strength, water absorption) to mortars without additives used in this work. Mortars with the addition of fine wood processing waste can be used as plasters with reduced thermal conductivity for interior work.

### 5. References

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