The technology for concrete production using an activated mixture of wood processing waste and sand

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Abstract. The article presents a technology for producing concrete using the waste of wood processing plants as the concrete filler. The waste was activated by mechanical, hydromechanical and hydromechanochemical technologies in a centrifugal disk installation. The established optimal ratio of sand to the waste (activated mixture) is 70:30%. The accepted fraction of the activated mixture is 10 wt% (of the mass of cement). The tests confirmed the reduction in the average density of the cement stone, while preserving its strength; the thermophysical properties of the stone increase.

1. Introduction

The concrete based on the waste of wood processing plants is a structural and heat insulating material. Novel technologies and methods that increase the characteristics of binders due to admixture of nanofunctional additives in combination with nanotechnologies enable production of concretes with predefined properties intended for specific operation conditions.

The implemented waste has different moist content: dry (below 15%) and semi-dry (from 16 to 30%). In terms of their structure, shavings and wood dust (as an ultrafine filler) are classified as bulk materials. The surface-active properties of wood increase with its fineness. The average wood density largely ranges from 380 to 1100 kg/m³ in a completely dry state. The bulk density of a dry hogged chips of pine is 675 kg/m³, that of aspen is 554 kg/m³, that of birch is 247.2 kg/m³. The thermal conductivity along the tree wool is 0.2–0.3 W/(m·°C). Across the wool, it is considerably smaller: 0.11–0.17 W/(m·°C). For ready wooden-concrete product with an average density of 830 kg/m³, the thermal conductivity coefficient is 0.32 W/(m·°C).

A specific feature of the technologies of building materials on the basis of dispersed system is constant presence of a solid phase in the system, regardless of the presence of liquids and gases. The solid phase is the carrier of strength — the basic property of construction materials; it takes part in the formation of all the three structures mentioned above. The solid phase particles are elementary “blocks” that form various structures which strength is predetermined, primarily, by their dispersity and granulometric composition. The smaller the particles, the fewer internal defects they contain. The presence of such particles in base dispersed systems is mandatory. The structure of the base dispersed systems (cement paste and mortars, plaster paste, molding compounds and mixtures, various suspensions, etc.) should distinguish two components: structural matrix formed by coarse particles and pore substance composed of fine particles and liquid phase inside the porous volume of the coarse matrix. Colloid-chemical properties of the pore substance and its content in the system have the decisive impact on the strength formation of different structures. [1]
The study was also aimed at optimizing the activated composition of the mixture of sand (as abrasive material) and wood processing waste and its mass content in the concrete to reveal the effect of the activated mixture (sand : wood processing waste) on the physicomechanical properties of concrete. The results were used to propose a technology of concrete production using the wood processing waste. [2, 5-7]

2. Experimental
The centrifugal disk installation was used to activate the waste by mechanical action (dry milling) allowed obtaining ultrafine materials; hydromechanic activation (wet milling) of the material in the installation enabled hydrodynamic, acoustic and turbulent cavitation treatment of the mixture; hydromechanochemical activation (wet milling and chemical reagent), chemical reagent: plasticizing additive “Megalit S-3 ML”, powder density $\rho = 1.15 \text{ kg} / \text{ m}^3$.

The mechanical and hydromechanical activation yielded ultrafine materials with the size as small as 0.001 nm.

The weight distribution of the particle dimensions (figure 1) was determined on a MicroSizer–201 laser analyzer (VA INSTALT, Russia): 70% of sand and 30% of wood processing waste.

![Figure 1. Weight particle distribution of the activated mixture: 1 - Designed values (no activation); 2 - Mechanical activation; 3 - Hydromechanical activation; 4- Hydromechanochemical activation.](image)

The production of concrete with wood processing waste includes the following technological stages:

1. Optimization of the disk mill-activated mixture: 70% of sand with 30% of wood processing waste.
2. The filler (sand with ultrafine filler) and cement (TsEM II/A-Sh 42.5N) are dosed and mixed for 5–6 minutes.
3. The concrete is poured into molds with preliminary holding of the concrete mixture over 3–4 hours at a temperature of 20 °C.
4. Thermal-moist treatment in an autoclave at 12 atm. in the following mode: increase of the temperature up to 80 °C for 4 hours, isothermal heatup at 80 °C for 6 hours; temperature reduction down to 20 °C for 4 hours.
Based on the results of activation of the concrete mixture, the optimal mass ratio of sand to the wood processing waste was accepted as 30:70%, based on the acceptable variation of the strength of the control specimens (4–5%), while their thermophysical properties improved.

The physicomechanical properties of the cement stone specimens made from cement-sand-waste mixture are presented in Table 1.

| Physicomechanical indicators of activated mixture (70% of sand/30% of wood processing waste) | Specific surface $S_{sp}$ [cm$^2$/g] | Powder density $\rho$ [g/cm$^3$] | Average particle size $D$ [$\mu$m] | Bending strength $R_{bend}$ [MPa] | Compression strength $R_{compr}$ [MPa] | Thermal conductivity coefficient $\lambda$ [W/(m∙°C)] |
|---|---|---|---|---|---|---|
| Designed values (no activation) | 3450 | 218 | 47.0 | 16.7 | 42.0 | 0.46 |
| Mechanical activation | 6980 | 318 | 5.3 | 17.8 | 45.5 | 0.42 |
| Hydromechanical activation | 7445 | 350 | 4.2 | 18.5 | 46.2 | 0.40 |
| Hydromechanochemical activation | 8017 | 355 | 4.0 | 18.7 | 46.5 | 0.39 |

The strength indicators of the cement stone specimens from the activated mixture (sand:waste = 70%/30%) with 10 wt% of cement are presented in Table 2.

| Physicomechanical indicators of activated mixture (70% of sand/30% of wood processing waste) with 10 wt% of cement | Bending strength $R_{bend}$ [MPa] | Compression strength $R_{compr}$ [MPa] |
|---|---|---|
| Mechanical activation | 17.4 | 45.8 |
| Hydromechanical activation | 18.2 | 46.5 |
| Hydromechanochemical activation | 18.4 | 46.7 |

The structure of the specimens was determined using a REM-100U scanning electron microscope (Russia). Figure 2 illustrate the microstructure of pore space and pore walls of the specimens, respectively.

![Figure 2. Microstructure of pore space and pore walls of foam concrete.](image-url)
Evidently from the figures, needle-like ettringite crystals penetrate calcium hydrosilicate particles, which contributes to the strengthening of the microstructure and augments the characteristics of the foam concrete specimens as a whole.

The mineral composition of the specimens was analyzed on a D8 ADVANCE XRD analyzer (Bruker, USA). The analysis has shown that the cement stone specimens of cement TsEM II/A-Sh 42.5N contain the following minerals: calcium carbonate CaCO$_3$, calcium hydroxide Ca(OH)$_2$, calcium hydrosilicate Ca$_2$SiO$_4$ and calcium aluminosilicate Ca$_3$Al$_2$Si$_3$O$_{12}$. The thermal conductivity of the specimens based on the same cement without addition of wood processing waste was 0.46 W/(m·°C). [3, 4, 6]

3. Conclusion
The article presents a technology for producing concrete using the waste of wood processing plants as the concrete filler. The waste was activated by mechanical, hydromechanical and hydromechanochemical technologies in a centrifugal disk installation.

The introduction of different fraction of shavings and wood dust decreased the thermal conductivity coefficient of the cement stone specimens (Table 2). With larger fraction of shavings and wood dust in the specimens, the strength decreases by 5–7% for each 4–5% of filler; the thermal conductivity coefficient reduces by 7–9%.

The established optimal ratio of sand to the waste (activated mixture) is 70:30 %. The accepted fraction of the activated mixture is 10 wt% (of the mass of cement). The decrease of sand-to-waste ratio is unreasonable because this reduces the strength of the cement stone by 2.5% and more.

The application of ultradispersed wood processing waste in concrete as an activated mixture (70% of sand + 30% of waste) allows reducing the average density by 10% without deterioration of strength and increasing the thermophysical characteristics of the cement stone.

The tests confirmed the reduction in the average density of the cement stone, while preserving its strength. The thermophysical properties of the stone increase.

The use of the suggested innovative construction material from easily available waste of wood processing plants for civil and industrial building may facilitate the attraction of considerable amount of investment, which will be economically and socially beneficial for the country.

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