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DISPOSAL OF USED FORMING MIXTURES FROM FOUNDRIES OF MACHINE-BUILDING PLANTS IN THE PRODUCTION OF PERFORATED MATERIAL

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Abstract. The waste of foundries of machine-building plants - spent moulding mixtures was studied. The expediency of using spent mixtures of foundry production as a siliceous component of foam concrete mixtures has been proven. The spent mixtures were studied for their foaming ability. The foam properties are determined. The effect of concrete mixture components on the pore-forming ability of foam agents was investigated. Of the six foaming agents studied in the work, saponified tree resin was found to be the most effective. The technological parameters for the preparation of aerated concrete mixture have been developed. The average density of foam concrete in the dry state and its limit of compressive strength were used as criteria for resource evaluation of used moulding mixtures of foundry production. Foam concrete products of non-autoclave hardening with an average density of not less than 900 kg/ m^3 and a compressive strength of not less than 4.5 MPa were obtained.

Keywords: molding mixtures, foaming agent, foam concrete, average density, compressive strength.

1. Introduction

Used mixture – moulding (rod) mixture, which after punching out the form used for the production of castings in foundries of machine-building plants, cannot be used a second time and is taken to landfills.

Foundries are ecologically the dirtiest in the structure of enterprises in the machine-building industry 90 % of all solid foundry production waste consists of spent moulding and core mixtures. For example, for the production of 1 ton of cast iron castings, about 6 tons of moulding materials are consumed (0.7–1.2 tons of spent mixtures are taken to the dump) (Prokopovych, 1999). This waste occupies large areas of the land fund in Ukraine and disturbs the natural landscape. Every year, thousands of rail cars are needed to transport spent mixtures.

Spent moulding mixtures are waste of the 4th hazard class and in terms of the specific activity of natural radionuclides, they belong to the 1st class (that is, they can be used in construction without restrictions) (Prokopovych, 1999).

Forming mixtures are used for the production of cement, construction mortars, fine-grained cement, and asphalt concrete. Unfortunately, only about 1% of spent mixtures undergo regeneration (Prokopovych, 1999).

The purpose of the work is to develop an environmental protection technology for the production of perforated material using spent moulding mixtures of foundry production.

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2. Materials and Methods

The following materials were used for the preparation of aerated concrete mixture:

• spent moulding mixtures of foundry production – as a siliceous component (production of Korum Druzhkivskyi Machine Building Plant LLC, Donetsk region) (Fig. 1). According to the State Waste Classifier DK-005-96, the qualification grouping "Spent moulding mixtures based on furan resins" belongs to the waste of production of basic metals (group 27, code 2741.2.9.05).

Fig. 1. Conditioned used molding mixture

• quartz sand – Chasiv-Yarske field (Chasiv Yar, Donetsk region) (DSTU B V.2.7-232:2010);

• Portland cement brand 400 PrJSC “Kramatorsk cement plant-Pushka”, Donetsk region (DSTU B V.2.7- 46:2010);

• calcium quicklime of the Collective Enterprise “Firm “Azovbudmateriali” (Mariupol, Donetsk region) (DSTU B V.2.7-90:2011);

• foaming agents of domestic production:

1) PSC – protein-soap concentrate (producer – PP “Segnetel”, Kyiv);

2) PBK – an aqueous solution of a mixture of surface-active substances with stabilizing and functional additives (producer – TDV “Lysychansk gelatin factory”, Lysychansk, Luhansk region);

3) Alpen-PB – based on the hydrolysis of animal protein with the addition of rosin (manufacturer – Althim LLC, Vyshneve, Kyiv region);

4) Sofir-PB – triethanolamine salts of primary alkyl sulfates of fractions C_8–C_{10} (producer – Firma “Soyuz LTD” LLC (Kharkov);

5) SWR – saponified wood resin, a product of alkali saponification of wood resin (sodium salt of abietic acid) (producer – Termo-Pantser LLC, Cherkasy) (Fig. 2);

Fig. 2. Saponified wood resin (SWR)

6) WPD – waste from the production of detergents (producer – OJSC “Firma SV” (Kharkiv region, Dergachivskyi district, village of Ruska Lozova);

• the water met the requirements (DSTU B V.2.7-273:2015).

Metal particles in the spent mixture were removed using a magnetic separator. The grinding of baked lumps took place in a jaw crusher. Then the mixture was sieved.

The foam multiplicity was calculated according to the known method as the ratio of the volume of the foam to the volume of the working solution of the foaming agent, from which it was formed according to the formula (DSTU 3789:2015):

$$К = \frac{V_п}{V_p}, \qquad (2.1)$$

where $V_п$ is the volume of foam, m^3; V_p is the volume of the working solution of the foaming agent, m^3;

The volume of the working solution of the foaming agent was 50–100 ml.

Technologically, the maximum duration of the existence of the foam before its collision with other components of the foam concrete mixture is two minutes necessary to obtain a perforated material.

The stability of the foam (the ability to store its structure for a certain time) was determined by the following method:

– 200 ml of foam was taken into a measuring cylinder. If the volume has not decreased within two minutes, the suitability of the foam is "good" ("+" sign);

– if the volume is reduced by no more than 25 % (no less than 150 ml remained in the cylinder), then the suitability is "satisfactory" (mark "±");

– if there is less than 150 ml left in the cylinder, then the suitability is "unsatisfactory" ("-" mark).

The temperature of the foaming agents during the tests was 22 ± 2 °C.

The average density of foam concrete (DSTU B V.2.7-170:2008) and its compressive strength (DSTU B V.2.7-214:2009) were adopted as criteria for the resource value of used moulding mixtures. Before the test, cube samples 0.07x0.07x0.07 m were dried in an electric cabinet at a temperature of (105±10) °C to a constant mass (item 3.1.13 (DSTU B V.2.7-214:2009).

The average density of concrete ρ_m determined by the formula (DSTU B V.2.7-170:2008):

$$\rho_m = \frac{m}{V}, \qquad (2.2)$$

where *m* is the mass of the sample, kg; *V* is the sample volume, m^3.

The compressive strength of aerated concrete (MPa, kgf/cm^2) was calculated with an accuracy of 0.1 MPa (1 kgf/cm^2) according to the formula (DSTU B V.2.7-214:2009):

$$\sigma_{\text{ст}.cube} = \frac{\alpha \cdot F \cdot K_w}{A}, \qquad (2.3)$$

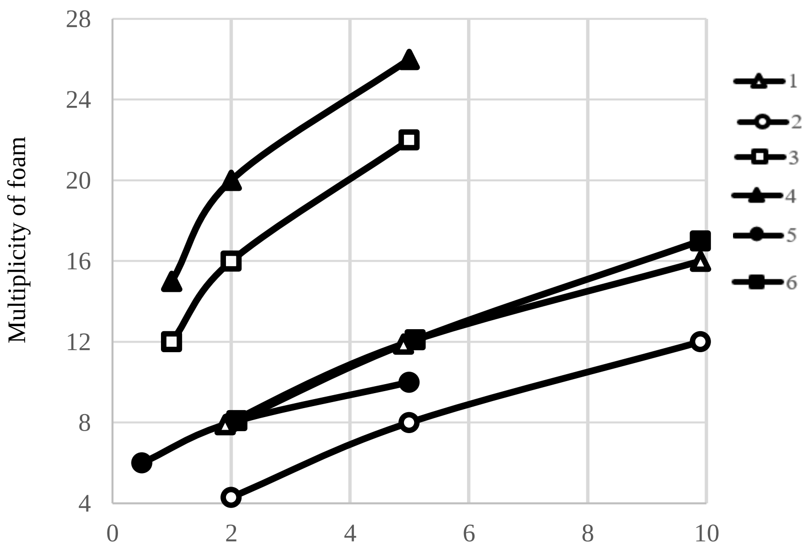
where *F* is the destructive load, H, (kgf); *A* is the working cross-sectional area of the sample, mm^2 (cm^2); α - scale factor for reducing the strength of concrete to the strength of concrete in samples of the basic size and shape (for cube samples with an edge length of 70 mm α = 0.9, note 2 of Table 5 (DSTU B V.2.7-214:2009); K_w - correction factor for aerated concrete, which takes into account moisture at the time of testing (for moisture 0 % - samples dried to constant weight K_w = 0.8, Table 6 (DSTU B V.2.7-214:2009).

3. Results and Discussion

3.1. Research of foundry waste for foam-forming ability. Definition of foam properties

The foam was obtained by the dispersion method by whipping the foam in a laboratory mixer for two minutes.

At the same concentration of the foaming agent (for example, 5 %), the foaming agent Alpen-PB has the highest pore-forming capacity – an aqueous solution of a mixture of surface-active substances with stabilizing and functional additives (manufacturer – LLC "Alchem" (Vyshneve, Kyiv region) (multiplicity of foam is more 20 – curve 3 in Fig. 3).



Concentration of wood saponified resin
Foaming agents: 1 – PSC; 2 – PBK; 3 – Alpen-PB; 4 – Sofir-PB; 5 – SWR; 6 – WPD

Fig. 3. Concentration dependences of foam multiplicity

The smallest multiplicity of foam, equal to 8, corresponds to the foaming agent PBC based on the hydrolysis of animal protein with the addition of rosin (producer – TDV "Lysychansk Gelatin Plant" (curve 2 in Fig. 3).

Saponified wood resin has an average value of the multiplicity of foam (10) – a product of alkali saponification of wood resin (manufacturer – Termo-Pantser LLC (Cherkasy) (curve 5 in Fig. 3).

For studying the properties of foam, the concentration of the foaming agent is of great importance (it is desirable to obtain the optimal characteristics of the foam with the *minimum* concentration of the foaming agent). At any concentration of the foaming agent in the working solution, the stability of the foam is "good" (+) only on saponified wood resin. The final selection of the optimal foaming agent was made during the preparation of the foam concrete mixture (Table 1).

Table 1

Stability of foam

No	Foaming agent	Manufacturer of foaming agent	Concentration foaming agent in the working solution, %	Stability foam
1	PSC (protein-soap concentrate)	PE "Segnetel" (Kyiv)	2.0 5.0	± +
2	PBK TU U 15.6-00418030-001:2007 (based on hydrolysis of animal protein)	TDV "Lysychansk gelati-new factory" (Lysychansk, Luhansk region)	2.0 5.0 10.0	- + +
3	Alpen-PB (aqueous solution of a mixture of surfactants with stabilizing and functional additives)	LLC "Alchem" (Vyshneve of Kyiv region)	1.0 2.0 5.0	- - ±
4	Sofir-PB (triethanolamine salts of primary alkyl sulfates of C_8 - $C_{10\ fractions}$)	LLC "Firm "Soyuz LTD" (Kharkov city)	1.0 2.0 5.0	- - ±
5	SWR (wood saponified resin, a product of alkali saponification of wood resin (sodium salt of abietic acid)	LLC "Thermo-Pantzer" (Cherkasy)	0.5 2.0 5.0	+ + +
6	WPD (detergent production waste, environmental management system ISO 14001)	OJSC "Firma SV" (Kharkiv region, Dergachivskyi district, with. Ruska Lozova)	2 5	± ±

3.2. Study of the effect of concrete mixture components on the pore-forming ability of foaming agents

The mixture porous with foam obtained from foaming agents Alpen-PB and PSC had a great settling because the foam was unstable even during its preparation and partially collapsed during mixing. When working with the PBK foaming agent, the foam-concrete samples were characterized by a high average density (over1000 kg/m^3) and with an average density below 900 kg/m^3, the mixture heterogeneity and a slight settling were observed. A non-shrinking, homogeneous porous aerated concrete mixture was obtained using saponified wood resin (SWR) with an average sample density of 700–1000 kg/m^3. Foam stabilizer – CaO.

When using SWR with a concentration of 1.5–5.0 %, the duration of the setting of the foam concrete mixture was significantly extended. At a concentration of SWR less than 1 %, the porous mixture had a little settling. The foam concrete mixture had optimal properties at a concentration of SWR of 1 %.

So, of the six foaming agents studied in the work, the saponified wood resin was found to be the most effective, using which the technological parameters for the preparation of the foam concrete mixture were developed.

3.3. Development of technological parameters for the preparation of foam concrete mixture

In laboratory conditions, the siliceous component was supplied in the form of a dry powder with a specific surface area of 270 m^2/kg. For the foam concrete mixture, Portland cement brand 400, calcium quicklime with an activity of 72 % were used, and saponified wood resin was used as a foaming agent.

For comparison, traditional (quartz sand) and spent molding mixtures of foundry production were used as a siliceous component.

Grinding of the siliceous component was carried out in a laboratory ball mill. Compositions of foam concrete mixtures were selected (DSTU-N B V.2.7-308:2015) based on the calculation of components per 1 kg of dry components (0.3 kg of cement + 0.7 kg of siliceous component; 0.4 kg of cement + 0.6 kg of siliceous component; 0.5 kg of cement + 0, 5 kg of siliceous component) (Table 2). Foam concrete samples-cubes were subjected to thermal and moisture treatment according to the regime of 0.5+7+1 hours (temperature rise + isothermal exposure + cooling).

Table 2

Compositions of foam concrete mixtures

No. of the sample series	No. composition of the mixture	Amount of cement, Ts, kg	Amount of siliceous component (sand – P, molding mixture – FS, kg)	Amount of foaming agent, saponified wood resin, SWR, kg	Amount of water, V, l	Mark on the graph
1	2	3	4	5	6	7
I	1	0.3	0.7	0.08	0.330	
	2	0.3	0.7	0.09	0.320	
	3	0.3	0.7	0.10	0.310	
II	4	0.4	0.6	0.08	0.335	
	5	0.4	0.6	0.09	0.325	
	6	0.4	0.6	0.10	0.310	
III	7	0.5	0.5	0.08	0.340	
	8	0.5	0.5	0.09	0.330	
	9	0.5	0.5	0.10	0.320	
IV	19	0.3	0.7	0.08	0.355	
	20	0.3	0.7	0.09	0.355	
	21	0.3	0.7	0.10	0.345	
V	22	0.4	0.6	0.08	0.360	
	23	0.4	0.6	0.09	0.359	
	24	0.4	0.6	0.10	0.345	
V I	25	0.5	0.5	0.08	0.365	
	26	0.5	0.5	0.09	0.355	
	27	0.5	0.5	0.10	0.340	

With an increase in the saponified wood resin content in the aerated concrete mixture, the average density of foam concrete naturally decreases (Fig. 4).

A slight decrease in the average density (in all cases less than 5 %) is caused by the replacement of a larger component (specific surface area of a siliceous component of 270 m^2/kg) with a smaller component (specific surface area of cement, as a rule, 400 m^2/kg). In this case, the thickness and, accordingly, the mass of the shell of each foam bubble decreases, which leads to a decrease in the density of concrete.

The average density of foam concrete on sand is 1.0–1.2 % higher than on used molding mixtures.

The average density values are 901–968 kg/m^3, which according to (DSTU B V.2.7.-45:2010) the studied foam concrete belongs to the D900 and D1000 brands.

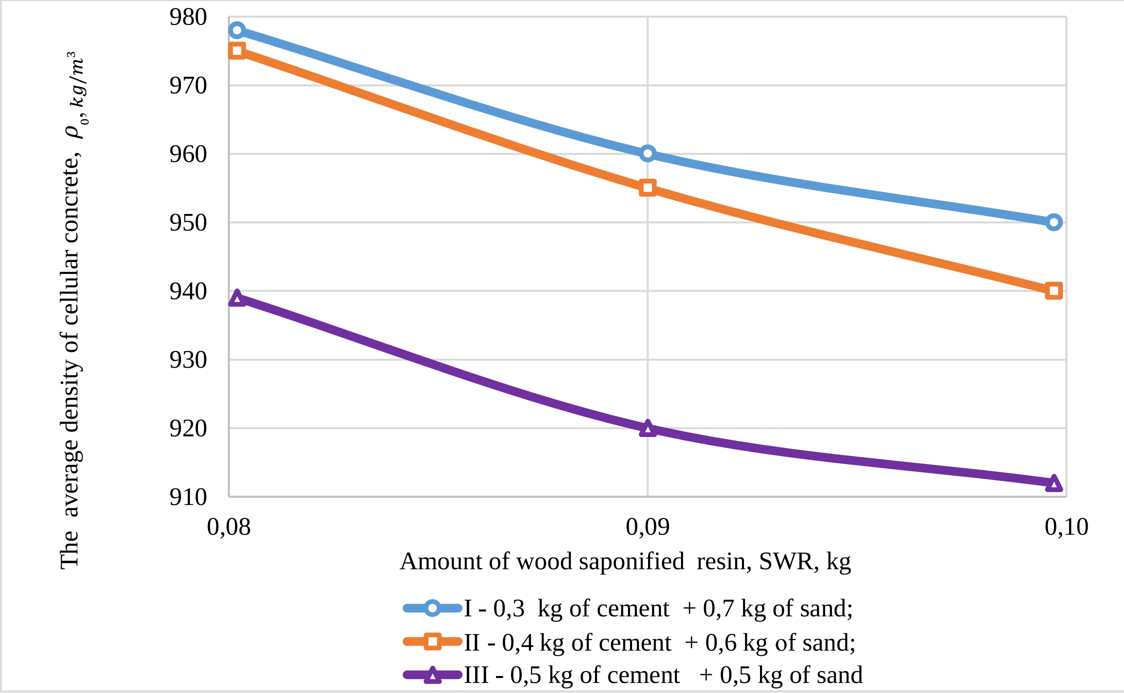
With an increase in the content of saponified wood resin in the aerated concrete mixture, the compressive strength of foam concrete also naturally decreases (Fig. 5).

When replacing part of the siliceous component with cement, the strength of the material increases under all constant conditions. With a constant average density of foam concrete, the strength would increase to a greater extent than shown in Fig. 5.

The compressive strength of foam concrete on sand is, on average, 7 % higher than on used molding mixtures, which is due to the inhomogeneity of the granulometric composition of the latter, and the presence on the surface of their grains of the dust-like fraction and films of hardened binding components.

The values of compressive strength are 4.3–5.7 MPa, which according to Change 2 (DSTU B V.2.7.-45:2010), the studied foam concrete belongs to class C3.5 and C5.

Foam concrete of the D900 grade and class C3.5 belongs to the structural and heat-insulating type, and foam concrete of the D1000 grade and class C5 belongs to the structural type.



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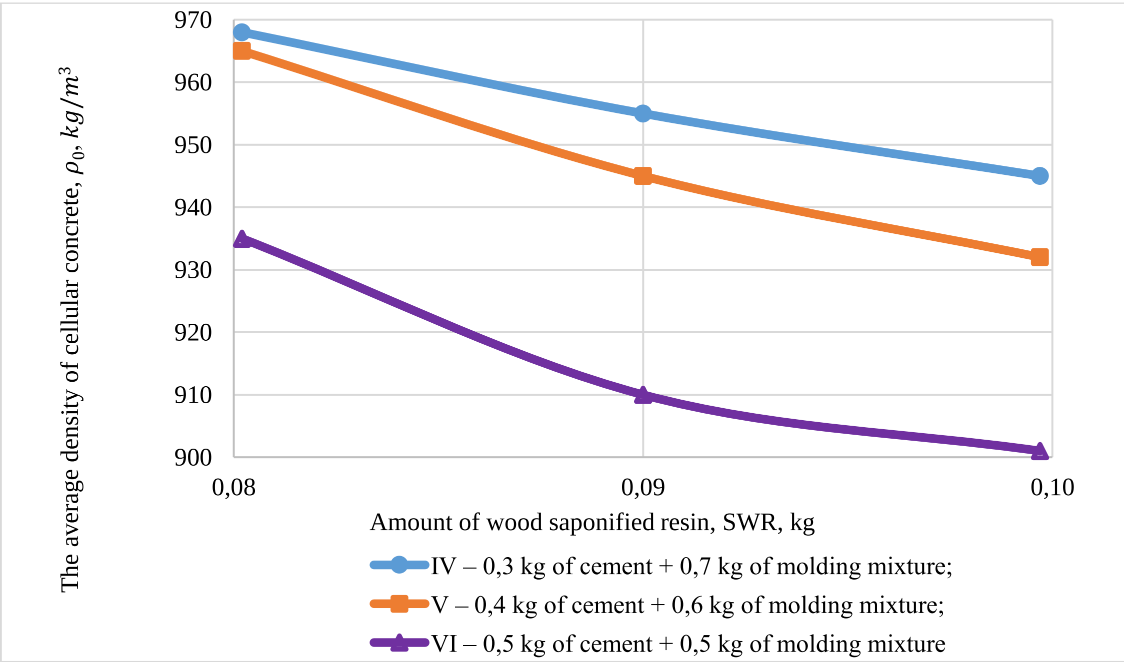

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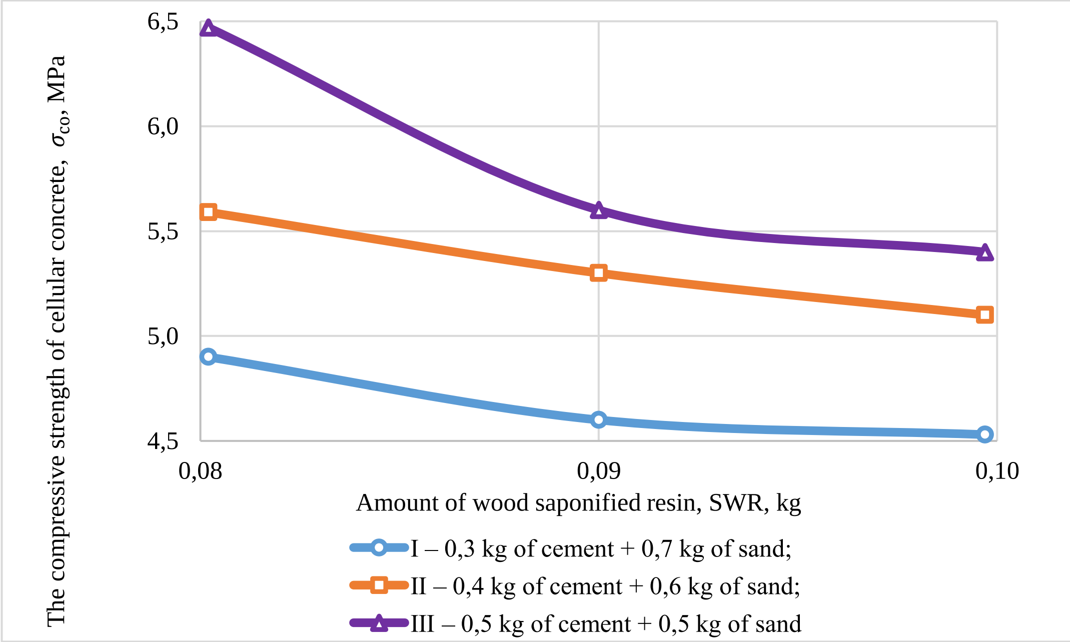
Fig. 4. Dependence of the average density of foam concrete on the amount of wood saponified resin



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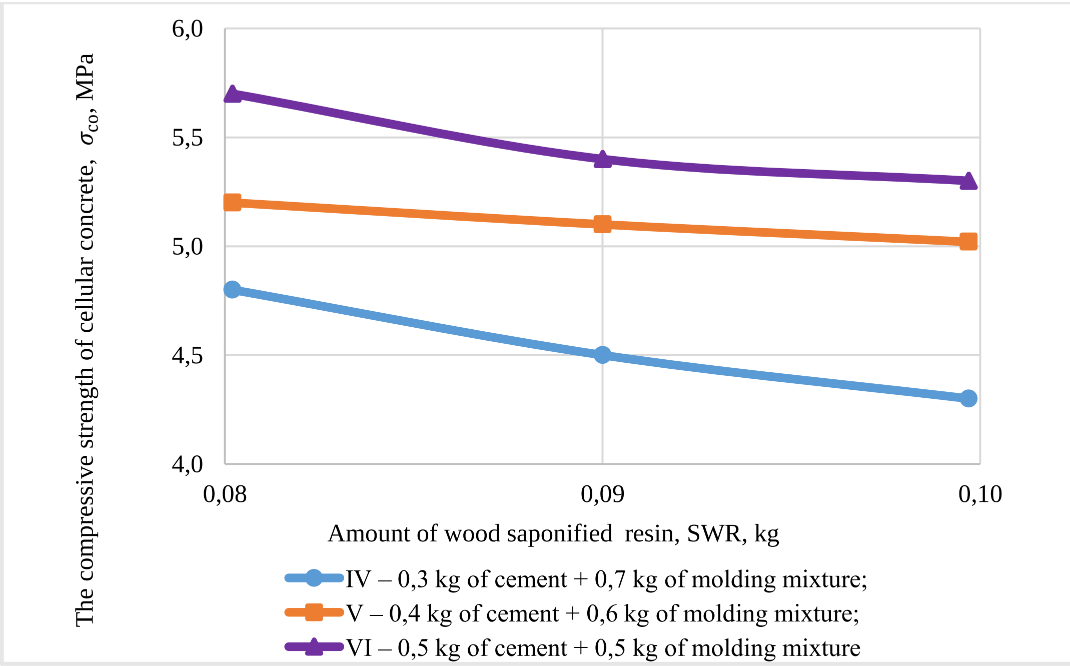

b

Fig. 5. Dependence of the compressive strength of foam concrete on the amount of wood saponified resin

4. Conclusions

- Of the six studied foaming agents, the most effective was found to be saponified tree resin.
- The technological parameters for the preparation of foam concrete mixture based on spent molding mixtures of foundry production have been developed.
- Foam concrete products of non-autoclave hardening were obtained with an average density of not less than 900 kg/m^3 and compressive strength not less than 4.5 MPa (DSTU B V.2.7-137:2008).

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