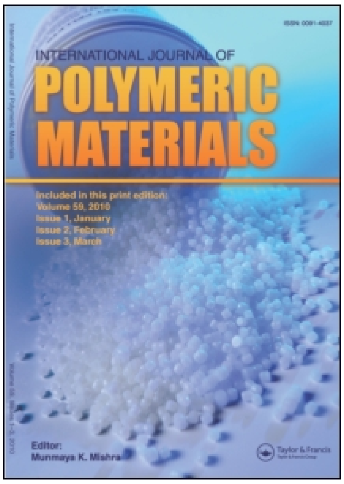

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A. Perevozchikov[a]; G. Yakovlev[a]; V. Kodolov[a]
[a] Educational-Academical Department of Physico-Chemistry and Mechanics of Polymers, Udmurt Scientific Centre, Ural Branch, Russian Academy of Sciences, Izhevsk, Udmurt Republic, Russia

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Polyethylene Foam Waste Utilization for Light-weight Concrete Production

A. PEREVOZCHIKOV, G. YAKOVLEV and V. KODOLOV*

Educational-Academical Department of Physico-Chemistry and Mechanics of Polymers, Udmurt Scientific Centre, Ural Branch, Russian Academy of Sciences, 7 Studencheskaya Str., Izhevsk, 426069, Udmurt Republic, Russia

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The utilization of construction materials based on polymers is considerably limited by their low fire-safety and insignificant durability. In this paper the investigations results of construction on composite including up to 30% of the volume of foam polyethylene waste are discussed. Its destruction during the fire action and also utilization is limited by a cement concrete matrix which has a traditional composition. The composition optimization to thermal conductivity value is carried out. The aggregate of amorphous structure in the form of ash-slag waste is used to decrease concrete thermal conductivity.

Keywords: Polyethylene; foam; waste; concrete

INTRODUCTION

The structure modeling of artificial construction conglamerates used for work in protective constructions of buildings is bound with the solution of two mutually exclusive properties of construction materials: when the products strength is high it is necessary to have ultimately low values of material thermal conductivity. The last parameter is obtained by maximum material polarization which decreases sharply the bearing strength of constructions. To solve this problem a skeleton – panel method for the erection of buildings with a heat-insulating core from porous organic polymers is used. This leads to the decrease of

*Corresponding author.

buildings overhauling and their durability. The second problem is connected with the increased combustibility of products based on synthetic resins, this leads to the considerable application limitation of porous minerals in constructional production due to National rules and norms for building ⟨⟨Fire Safety of buildings and structures⟩⟩..... Besides, the production technology of the majority of polymer heat-insulating materials allow the production of articles in the form of plates or blocks which exclude the possibility of air- and steam-exchange of a protecting construction.

It is also known that heat-engineering characteristics of the majority of existing heat-insulating structural material do not conform to National rules and norms for building by constructional heat engineering, in which the requirements to the values of thermal resistance of protecting constructions increase in 3, 5 times in comparison with the average, combining the improved heat-insulating properties and sufficient bearing strength, fire safety, and air steam-impermeability can be solved by development of compositions which include high-efficient porous organic heat-insulating components of artificial origin together with mineral matrix.

Taking into account low thermal- and sound conductivity, the absence of water absorption, high chemical resistance, low combustibility, low average density of foam polyethylene it is decided to determine the conduct of foam polyethylene in cement concrete to solve the above problems and set the characteristics of the composite obtained.

EXPERIMENTAL

The structure of the ideal construction material is wood structure in which many of the parameters mentioned are combined, and first of all high bearing strength at considerable porosity. As applied to artificial mineral conglomerates, cement stone has high strength but high heat conductivity limits its use only as a structural material. Porous and gas concretes, based on cement stone, have low durability due to low frost-resistance which is connected with the structure of communicating pores, prevailing in these materials structure. Thus, in order to model the material structure not subject to destruction due to inner stresses occurring when water transforms from liquid into solid phase, it is necessary to limit water access into material with its high porosity simultaneously. This task, as well as the improvement of heat-insulating composition properties, are solved while creating pores inside cement stone by introducing fine foam polyethylene waste into concrete mixture composition.

The raw material for foam polyethylene production is the polyethylene of high pressure of 15803-020 and 16204-020 brands. The raw material is powdered to the mass where the powdery porofor is added to and depending on intumescence ratio, zinc stearate, zinc oxide, titanium dioxide, phenozane are added in definite amounts. After mixing the mass is transferred to extrusion the obtained material is subject to radiation treatment in electron accelerator where the lacing of polyethylene molecules is achieved. After lacing the material is carried to a foam furnace at 220°C where the porofor decomposition and polyethylene intumescence take place. The production of articles from sheet polyethylene is accompanied by waste production (Fig. 1a) which have been subject to grinding. The grinding of polyethylene waste is carried out in two-step grinding unit in order to obtain oblong crumbs with particles sizes up to 5 mm long and up to 1,5 mm across. Special attention is paid to the roughness of the particles surface, provide better adhesion of foam polyethylene with cement stone (Fig. 1b) and provide the elastic work of concrete when achieving ultimate stress in the stone under load.

It is necessary to note that the production technology predetermines the obtaining of micropores in foam polyethylene with closed, inaccessible for water structure.

As mineral aggregate forming a mineral matrix and cement slurry when hardening, ash slag mix of Izhevsk Thermal Electric Station 2 with compactness 1450 kg/m^3 produced from Khuznetsk basin coal when burning and removed hydraulically into the settling basin pond is used.

The activity modulus of ash slag mix is $M_a = 0{,}37$ that is why we can refer it to super acid, being excited as a result of joined basic activization.

The studying of ash slag mix samples using an optic microscope MIM-6 and the data of X-ray structural analysis using diffractometer ⟨⟨DRON-2⟩⟩ (Fig. 2) show that a glass phase in the form of rounded yellow, brown, black and colourless glass particles prevails in the ash

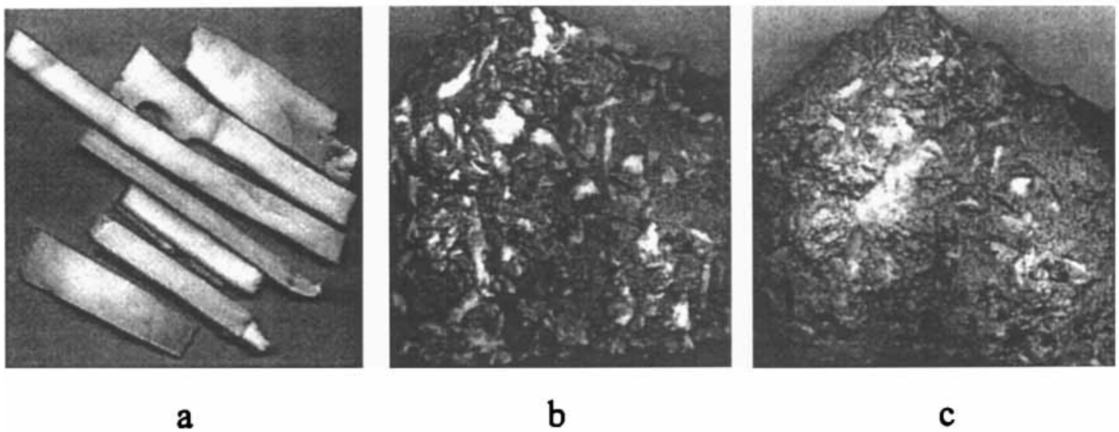

FIGURE 1 External appearance of: a – foam polyethylene waste; b – concrete spall with ground foam polyethylene; c – concrete spall after fire action.

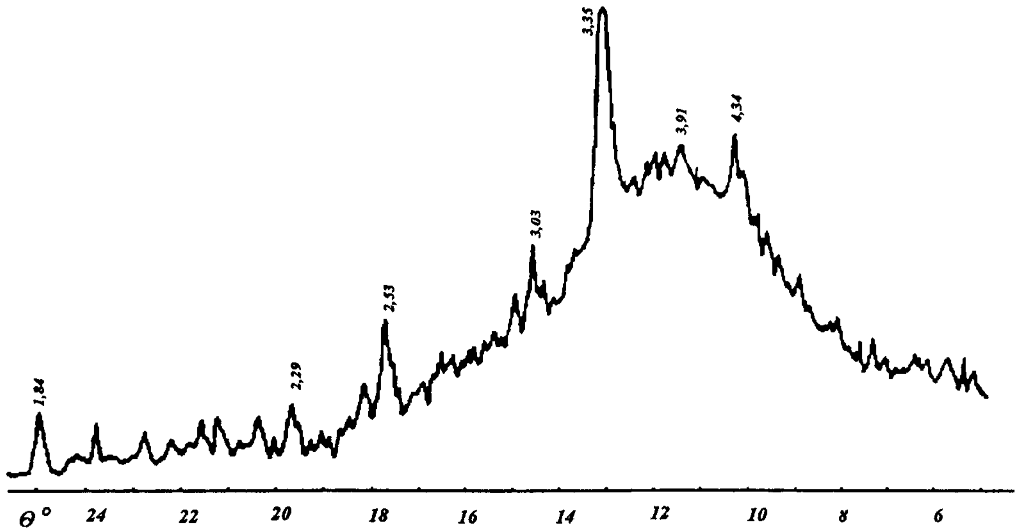

FIGURE 2 X-ray photograf of ash slag after hydraulic removal.

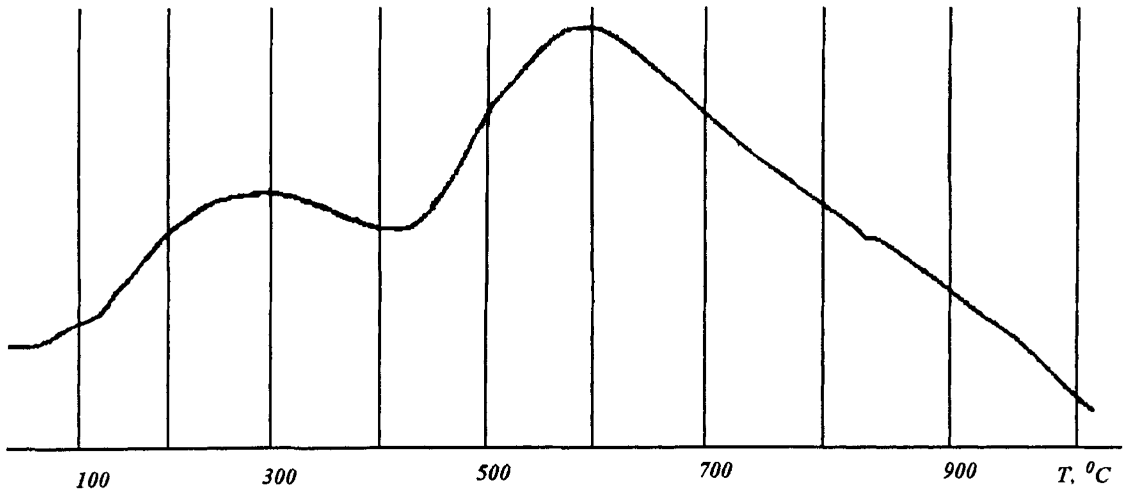

FIGURE 3 Derivatogram of ash slag mixture.

slag. In the ash there are small quantities of crystal quartz β-SiO_2 (d_α = 3,35; 2,47; 2,29; 1,82) and calcite $CaCO_3$ (d_α = 3,03), as well as a mullitizated clayey substance.

Ash thermograph made on derivatograph of MOM firm shows two exothermic effects on differential-thermal curve (Fig. 3) at temperatures 290°C and 600°C, connected with the burning down of powdered coal particles and carbon.

At temperature 840°C endothermic effect connected with the decarbonization of calcite formed as a result of secondary processes from free calcium oxide, is known. Mass losses during calcination based on the result of thermogravimetric curve treatment are 3,07%.

IR spectroscopy of ash slag mix is carried out at spectrometer UR-20 in range of frequencies 440–3800 cm^{-1}..... Absorption spectra of ash slag are characterized by a wide stripe in the area of valent vibrations Si—O—Si (Fig. 4). The absorption maximum of deformative vibrations stripe Si—O—Si is in the area 470 cm^{-1}..... According to [1] there is a linear dependence between the position of the given maximum of absorption stripe and hydraulic activity of ash slag mix in the composition used.

Gorhozavodsk portland cement 400 is used as a binder in the composition.

INVESTIGATION METHODS

Strength characteristics of the concrete are defined by testing box-specimens of $100 \times 100 \times 100$ mm side size in the age of 14 days of normal storage. Concrete frost-resistance is defined by the method of alternative freezing at temperature −18°C and thawing in water with temperature +20°C. Taking into account wall material specifications concerning frost resistance (not less that 15 cycles), the tests are stopped after the composition has with stood 25 cycles of frost-resistance testing.

Samples heat conductivity is determined measuring the stationary heat flow passing through the flat sample being tested by low-inertia heat flow meter on the unit produced according to the requirements of the National Standard 7076-87 ⟨⟨Constructional materials and products. The method of heat conductivity determination⟩⟩.

Samples with sizes $(300 \times 300 \times 50)$ mm are used.

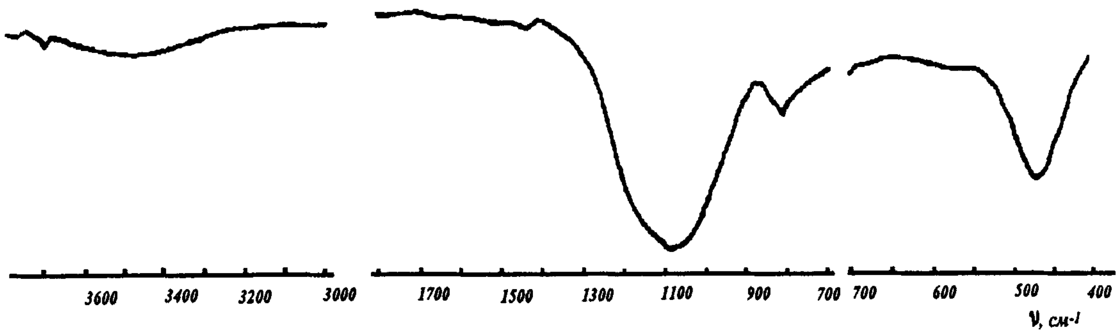

FIGURE 4 IR-spectra of ash slag mixture.

RESULTS AND DISCUSSION

The optimal consumption of the foam polyethylene is defined experimentally by forming as small cube-shaped block of 100 mm side size [2]. The consumption of concrete is constant, mineral aggregate, foam polyethylene crumbs and water content being varied. The consumption of foam polyethylene in the compound composition (300 l of crums per 1 m^3 of concrete mixture) is defined by the maximum strength of the concrete.

Further, during the constant consumption of ash slag mixture and foam polyethylene crumbs 6 compounds of concrete are produced. The composition per 1 m^3 of concrete and its properties are given in Table.

The table shows that the compositions of the concrete mixture of satisfactory strength ensure considerably better thermal insulation properties in comparison with conventional compositions of light concretes.

The discrepancy between the heat conductivity values and conventional relationship between material average density and its thermal conductivity values is also connected with ash slag mixture where an amorphous component prevails. It is know [3] that that in such case the heat conduction is lower than the heat conductivity of materials with a crystal structure.

The frost-resistance of the samples is one of the main material properties defining its durability as the calculative negative temperatures are at −25°C level. At such strict effect of environment conditions it is very important to have in the material structure damper components which can perceive the pressure of redundant water

TABLE Compositions of concretes with foam polyethylene aggregate

Composition	*Cement, kg/m^3*	*Ash slag, kg/m^3*	*Water, l/m^3*	*Foam polyethylene, l/m^3*	*Average density, kg/m^3*	*Compressive strength, R, MPa*	*Thermal conductivity coeff.,*
1	150	1450	165	300	1592	2.31	–
2	200	1450	180	300	1638	3.73	0.37
3	250	1450	195	300	1690	4.22	–
4	300	1450	210	300	1736	5.93	–
5	350	1450	225	300	1793	7.16	–
6	400	1450	240	300	1840	8.44	–

volume being formed during its transformation into ice. The role of such a damper foam polyethylene accepts. It allows considerable elastic deformation due to the air jammed in pores. Besides, frost – resistance is increased considerably due to the composition low water adsorption, the value of which is limited by the presence of pores closed structure in foam polyethylene.

Concrete testing in the conditions of the dynamic effect (to define the possibility of splits formation) is carried out with the help of high-rate identors ensuring an impulse local load. In his case the concrete product can be considered rigid formed under the impact process [4]. The comparison analysis of an outlet opening diameter when the material is split for the samples of heavy cement concrete and the sample being tested give the relationship of 2,7 which proves the assumption of the viscosity improvement of the concrete destruction due to the deceleration of cracks development by elastic particles in the foam polyethylene.

The concrete mixture is prepared by conventially used concrete mixing equipment followed by mixing dry proportions in a fixed-drum mixing. When the uniformity is achieved the required quantity of water is added into the dry mixture. The mobility of fresh concrete should correspond to 4 cm of the standard cone settling. From the produced concrete stone wall units of $190 \times 190 \times 390$ mm size pressing 3 blind hollows are formed by the vibrocompression method.

The produced units are imploded to erect buildings of a small number of stories if according to operatiry conditions of the building the dynamic loads of the working equipment affect on it.

It is particularly important for small enterprises producing building materials since those enterprises are rich in vibration equipment and at the same time, especially in winter time, the wall material is undergone repeated freezing and thawing due to the operating conditions of the productions.

Considering low thermal conductivity and comparatively low cost, the produced units have a market in the individual housing construction.

Thanks to their effective behavior at service, the compositions may have prospects to be used in seismic regions.

The Russian patent N 2083523 concerning the structure of a concrete mixture of obtained [5].

CONCLUSIONS

The application of the composites investigated allows:

- to raise fire safety of the materials and goods produced;
- to eliminate the collapse of the material in structures under simultaneous plastic deformations of the structure under the dynamic effect of the buildings;
- to decrease thermal conductivity of the concrete due to the presence of the amorphous structure aggregate and the thermal insulation additive as foam polyethylene crumbs with the size of the particle up to 5 mm;
- to reduce water absorption of the concrete due to application of foam polyethylene with the closed pore structure;
- to increase frost resistance of the concrete due to the presence of the elastic component in the form of foam polyethylene particles;
- to improve the economic index of the products made of the compound due to the application of two wastes in the concrete simultaneously: of the ash slag mixture of Thermal Electric Station and foam polyethylene clippings.

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