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Basalt fiber insulating material with a mineral binding agent for industrial use

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Abstract. The paper considers a possibility of using mining industry waste as a binding agent for heat insulating material on the basis of basalt fiber. The main objective of the research is to produce a heat-insulating material to be applied in machine building in high-temperature environments. After synthetic binder having been replaced by a mineral one, an environmentally sound thermal insulating material having desirable heat-protecting ability and not failing when exposed to high temperatures was obtained.

1. Introduction

Basalt fiber insulation is commonly used [1]. In mechanical engineering such kind of thermal covering is applied for heat and acoustic isolation of heat-treatment machinery, heating and hardening furnaces, heat pipelines, and etcetera. In addition, more than 55% of insulating materials perform under temperatures below 200 °C, about 25 % – at 180...400 °C, 5 % – in the range of 401...600 °C, and only 0.1 % of them is fitted on sites where temperature values exceed 600 °C.

The most part of its drawbacks is caused by the application of such synthetic organic binding agent as phenol-formaldehyde resin having a narrow temperature operational range (max 250 °C). In this case, such toxic compounds as phenol, formaldehyde, methyl isocyanate, etc. are emitted to the environment due to the binding agent oxidative decomposition, so the mineral wool item loses its structure rigidity [2].

In this regard, producing light noncombustible environmentally sound and cost effective heat insulating materials operating at temperatures above 600 °C is very important.

High-plasticity bentonite clay should be used as a binding agent to eliminate the disadvantages of phenol-formaldehyde mineral wool insulation. This method of clay application is implemented into manufacturing at the ‘Zavod izolatsii’ (‘Insulation plant’, Irpen, Ukraine).

The saponite containing material (SCM) is a typical example of bentonite clays. SCM is a clay mineral, layer silicate (montmorillonite group), its solid mineral particles in suspension including 63 % of saponite, 10 % of quartz, 10 % of dolomite, other minerals (chlorite, hematite, calcite, apatite, etc.) not exceeding 2...3 % [3]. The SCM chemical composition determination by X-ray fluorescence spectroscopy [4] revealed harmful impurities being absent. However, the fact of such chemical compounds (expressed as oxides) as SiO₂ (52 %), MgO (19 %), Al₂O₃ (10 %), CaO (4 %) present in the pilot samples implies that hydrosilicates out of mechanically pre-activated saponite, containing raw material, are to be formed while hydrating, after SCM having been mechanically dispersed in a ball mill to an ultrafine state [5-6]. Binding properties of SCM were evaluated by calorimetric method of hydration heating value measuring [6].



The aim of the proposed research is to evaluate the ability of SCM to be applied as a binding agent in mineral wool industrial insulating.

2. Method

The initial SCM sample was pre-dried to constant weight at 105 °C, and then grinded with a planetary ball mill (PM 100, RetschGmbH) using a dry mechanical dispersion method. The grinding machine operating parameters are the following: there were 25 tungsten carbide grinding bodies ($\phi = 20$ mm), rotation velocity was 420 rpm, grinding periods were 15, 30, 45, and 60 min.

The granulometric composition of superfine SCM samples was determined with Delsa Nano (a sub-micron particle size analyzer) by photon correlation spectroscopy based on the dynamic light diffusion principle.

The average basalt fiber diameter was estimated by Lasentec D600 (a laser particle size analyzer) provided with PVM V819 (a laser and video microscopical investigation system) using a technology based on the focused beam reflection method (FBRM).

To measure hydration enthalpy changes in the SCM samples the Expert-001K-2 installation was used, calorimetric method being applied. While pretesting, the calorimetric system constant (k) was estimated by introducing a specified portion (2.5040 g) of potassium chloride salt ($k = 580$ J/K). To determine the sample hydration specific heat, SCM dry weight (4...5 g) measured by counterbalance was used, data being read up to hundredth values. The distilled water volume in the calorimeter inner chamber was 100 ml. Calorimetric measuring (final stage) was being carried out for two hours, the system temperature premeasuring periods vary between 10 and 15 minutes, tested mixture temperature changes being recorded up to 0.01 °.

Test samples of insulating material were procured by layer-by-layer deposition of SCM aqueous suspension (10 %) sprayed onto mineral wool. Then, the sample was processed in the drying oven (200 °C) until moisture was removed completely. Drying oven soaking temperature was selected on the basis of an ordinary production cycle of thermal insulation material manufacturing, the synthetic binding agent polymerization chamber maintaining max 240 °C.

To specify density, thermal conductivity, combustibility, and destruction temperature characteristics of the binding agent, sample testing was carried out on the basis of standard procedures.

3. Result and discussion

After having analyzed fiber ultra-photos (Figure 1) the fiber diameter range was found to be 3...7 μm .

The dimensional characteristics of the SCM samples obtained after different grinding periods are shown in Table 1.

Table 1. Characteristics of saponite containing material fraction after dry planetary ball mill grinding

Grinding time, t, min	Fraction size, nm / Content, %							Average size, nm
	№ 1	№ 2	№ 3	№ 4	№ 5	№ 6	№ 7	
15	1270/16	1375/22	1489/21	1613/15	53774/2	58235/2	63066 /1	5259
30	1111/8	2809/35	4134/6	36018/8	57274/4	66850/1	78028/1	8898
45	900/9	968/13	1041/15	1119/14	1245/22	1390/8	1502/9	1269
60	964 /20	1061/14	1142/14	1228/13	1321/11	1421/8	1528/6	1230

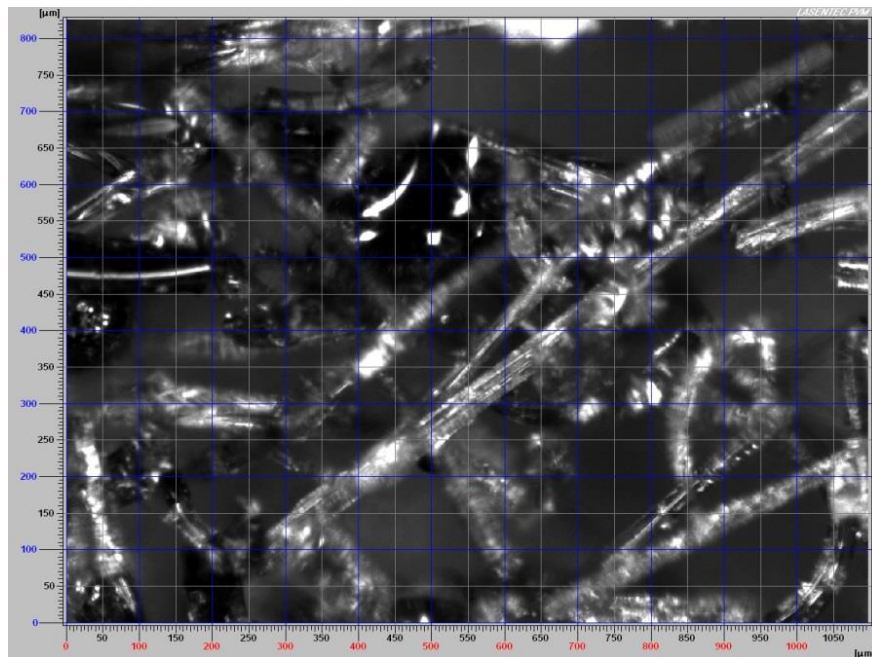


Figure 1. Fiber insulating material (ultra-photo).

The above-mentioned data (Table 1) proved that the SCM samples milled for 15 and 30 min to include coarse fraction, which can possibly cause uneven distribution of the binding agent along insulation fibers, thus increasing SCM hydration period. SCM samples milled for 45 and 60 min demonstrated more even degree of dispersion proportionate to the fiber insulation average diameter.

To specify an optimal SCM dispersion mode the experiments determining the hydration enthalpy values (ΔH) for highly dispersed saponite, containing material samples milled for 45 (SCM1) and 60 min (SCM2), were carried out. The results of the experiment are included in Table 2.

Table 2. SCM hydration specific enthalpy calorimetric measuring results.

Sample	m , g	k , kJ	Temperature, °C		Δt , °	$-\Delta H$, kJ/kg
			Input	2 h after experiment start		
SCM1	5.06	0.58	23.50	25.50	2.00	230
SCM2	5.02	0.58	23.50	25.50	2.00	230

Specific hydration heating (for 2 h) for SCM samples is 230 kJ/kg and is proportionate to hydration heat values of the main clinker mineral (belit β – $2\text{CaO} \cdot \text{SiO}_2$) equal to 260 kJ/kg, thus proving the saponite containing material binding properties.

The experiments, measuring the SCM samples specific hydration enthalpy, proved the optimal grinding period for a planetary ball mill to be 45 min while dry grinding.

Figure 2 demonstrates a prototype of the thermal insulating material on the basis of the mineral binder.

The main quality characteristics of the specimen, produced under laboratory conditions, and those of the mineral wool mat (P35) are illustrated in Table 3.

The data of Table 3 demonstrate that the thermal conductivity value of the thermal mineral binder insulating material sample is 0.0379 W/(m·K). It is 4 % higher than that of the similar synthetic binder insulating material, but it does not exceed the standard values for this insulation grade.

Table 3. Test results

Sample	Density, kg/m^3	Humidity, %	Thermal conductivity, $W/(m \cdot K)$	Combustibility group	Binding agent destruction temperature, °C
Mineral binder thermal insulating material sample	36.80 ± 0.20	1.2 ± 0.1	0.0379 ± 0.0020	noncombustible	over 1000
P35, mineral wool mat	34.49 ± 0.20	1.0 ± 0.1	0.0365 ± 0.0020	noncombustible	300...350

**Figure 2.** Mineral binder insulating material.

Moreover, the mineral binding agent can withstand minimum 1000 °C making it possible to operate with mineral binder insulating materials in high-temperature environments without emitting carcinogenic substances.

4. Conclusion

Summarizing the above-mentioned data and results it is possible to state the following: while using SCM as a binding agent it is possible to produce thermal insulating material in industrial scale without changing a mineral wool insulation production mode. In addition, such type of thermal insulation should be completely ecologically sound and should not fail by heating.

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