



UTILIZATION OF BOON AND CHAFF FOR MANUFACTURING LIGHTWEIGHT WALLING MATERIALS

Algimantas Kazragis¹, Aušra Juknevičiūtė², Albinas Gailius³, Elena Zalieckienė⁴

^{1, 2, 4} Dept of Chemistry and Bioengineering, Vilnius Gediminas Technical University,
Saulėtekio al. 11, LT-10223 Vilnius-40, Lithuania

³ Dept of Building Materials, Vilnius Gediminas Technical University,
Saulėtekio al. 11, LT-10223 Vilnius-40, Lithuania

E-mail: ¹ chemkat@fm.vtu.lt; ² aujuk@fm.vtu.lt; ³ albinas@st.vtu.lt, ⁴ elenaz@fm.vtu.lt

Received 20 May 2003; accepted 17 Oct 2003

Abstract. Lightweight composites for walls and thermal insulation, containing anhydrite (An) or aluminate cement (Al), vinyl acetate (VA) or cellulose (Cl) polymeric binders and cellulose fiber fillers (boon, chaff) were produced. The best results were obtained for transportation and construction of items containing: An \geq 30–45 %, Al \geq 30–50 %, VA \geq 1–5 %, Cl \geq 0,5–5,0 %, boon or chaff \geq 40–47 %. Polymeric binder VA for both kinds of cement is better than Cl. An is better for boon than for chaff. Aluminate cement is a good binder for both types of fiber fillers. Density r of a composite containing cements 50–60 % is less than 400 kg/m³. According to density such composite materials are light-weight heat-insulating materials. Density ($\rho \leq$ kg/m³) depends on the amount of cement content. Bending strength for samples with $\rho \leq$ 400 kg/m³, containing CMC is 0,6–1,3 MPa. Coefficient of thermal conductivity for samples, density with 400 kg/m³ is 0,06 W/m·K.

Keywords: utilization, lightweight walling materials, thermal insulation, boon, chaff, inorganic binders and polymeric binders.

1. Introduction

One of the major environmental problems facing the world today is reduction of the greenhouse effect. Lithuania signed the Vienna Convention pledging the countries to take all possible actions against the depletion of the ozone layer surrounding the Earth which is caused by the greenhouse effect. One of possible ways to achieve this is to utilize organic waste in the manufacture of various materials instead of burning or rotting them.

Two large groups of materials-construction and lightweight wall materials are among the great variety of known building materials.

Lightweight wall materials are also thermal insulating materials. These are composites heat insulating properties of which are determined by their macro structure which includes bubbles of air. The most effective materials of this type are fibrous composites and foam plastics.

The costs of most wall materials are rather high due to large energy expenditures and significant custom duties in Lithuania. On the other hand, wall materials

based on local materials are practically absent. That is why it is expedient to start to manufacture lightweight wall and thermal insulating materials which require small amounts of energy and use of local agricultural production waste materials. These materials could be manufactured directly at a building or renovation site what is very important when such a work is undertaken in rural areas. Also, such a production could reduce CO₂ and CH₄ emissions, if agricultural production waste is not burnt or decayed. This could contribute, maybe at a less extent, to lowering the world greenhouse effect.

The present investigation is based on the experience gained by the authors in using agricultural waste, such as cellulose fibres and particular kinds of plants in the production of heat- and sound-insulating materials from straw and PVA [1–4], straw and CMC, straw, cane and various polymer fillers [5–7] as well as on the experiments conducted. In addition, use was made of the data published by the researchers from various countries on using cellulose-containing waste to increase the strength of sewer pipes [8] as well as investigation of the effect of cellulose fibres on wood fibre-cement com-

posites [9], the properties of mortars with straw and wheat [10], the temperature effect on wood fibre cement composites [11], the effect of admixtures on cellulose-cement articles [12], the use of rice processing waste in the manufacture of building products [13,14], Brazil fibres effect on cement composites [15], lignosulphonate admixture effect on cement hydration [16,17] and the addition of bamboo fibres to cement paste [18].

2. Investigation object

In agricultural production considerable amounts of cellulose-containing waste – boon and chaff can be found.

Boon is a hardened part of a flax stem remaining in flax processing when fibres are separated from the sticks. It makes about 65–75 % of the flax stem mass. Boon also contains 50–64 % cellulose and 21–29 % lignine.

In some areas, for example, in Dotnuva, where a house is built with walls made of 75 % of clay, 20 % of boon and 2–5 % of sand, boon is used to produce cellulose, paper and building panels. The Institute of Thermal Insulation recommends to manufacture non-fired fibre bricks of clay (even with admixture of limestone) with addition of 40–60 % boon, sawdust and chopped straw [19].

In the present tests boon obtained from AB „Ukmergės linai“ (Ukmergė Flax) was used.

Chaff consists of wheat waste containing grains, chopped leaves of cereals and straw, weed seeds, etc. Chaff may be used as an organic filler of heat-insulating materials.

Chaff for testing was obtained from Vilnius Granary.

3. Testing materials

In manufacturing lightweight materials with boon or chaff for wall panels, the following materials were used as binders.

Inorganic binders

- Anhydrite cement – made by „Palemonas ceramics“, Co, volume (25,6–33,5) % CaO and (27,4–41,0) % SO₃; initial setting time (0,5–2,5) h, final setting time (2–4) h, strength gained in 28 days: flexural strength (2,6–3,0) MPa, compression strength (16–18) MPa. X-ray phase analysis has shown that CaSO₄ prevails in the material.

- Aluminate cements Gorkal 40 (G-40) and Gorkal 70 (G-70) – from „Gorkal“ Co (Trzebinia, Poland), containing (69–72) % Al₂O₃ and (28–29) % CaO; initial setting time ≥ 40 min, final setting time ≤ 8 h; strength gained after 24 h: flexural – (6–8) MPa, compression – (30–40) MPa. X-ray analysis has shown that the material mainly consists of CaO · Al₂O₃, CaO · 2Al₂O₃, 12CaO · 7Al₂O₃ and α-Al₂O₃.

Polymer binders

- Polyvinylacetate (PVA)–HW1 trademark commercial dispersion (Finland) containing 50 % dry solids; it is an aqueous dispersion 1:1.

- PVA powder–Vinnap RS55Z trademarks commercial product; 4 % dispersion.

- Carboximethylcellulose (CMC) powder–commercial product (Finland); 4 % dispersion.

- Walocell–commercial CMC product MK 3000 supplied in the form of powder; 4 % dispersion.

- Methylcellulose (MC) – „Metylan normal“ produced in Germany; 2 % dispersion.

Antiseptic additives used were sodium hexafluorosilicate Na₂[SiF₆] as well as fire retardant – sodium tetraborate Na₂B₄O₇ · 10H₂O.

4. Testing methods

The work was carried out according to the following scheme: product composition design – manufacture of specimens – determination of specimen properties: durability – density – strength, specific thermal conductivity – thermal resistance – economic calculations – conclusions, recommendations.

Shape holding (steadfastness) of specimens was assessed in the following way: a specimen cured for 3 days in the laboratory at 20 °C is laid on the table and a steel plate of 160 × 40 × 3 mm is placed over it. Then, a load is applied to the plate and the initial time of specimen failure is fixed: 1) an applied load is 200 g – if the failure of the specimen occurs, 0 points are scored; 2) if the failure does not occur, the load is increased up to 500 g – if the failure occurs, 1 point is scored; 3) a load of 200 g is added to 500 g load – if the specimen fails, 2 points are scored, if not – 3 points are given.

The density, flexural and compression strength, specific thermal conductivity and pH of specimens were found by standard procedures. Using a derivatograph Q-1500 for analysing 5 specimens at a time performed thermographic testing. X-ray photographs were obtained by a diffractometer DRON-2 (Russia) (Co anode, Fe filter, slits – 1:2:0,5 mm); diffractometer tube's operating mode: $U = 3$ kV, $I = 10$ mA.

5. Results and discussion

5.1. The effect of inorganic filler composition on the properties of composites

- Composites containing anhydrite cement

A thermographic analysis of a hardened and cured specimen containing 50 % of anhydrite cement, 45 % of boon and 5 % of CMC (dry solids) was made with the main part of fibre filler removed by screening it through a 0,2 mm sieve.

Analysing the temperature curve presented in a thermograph (Fig 1), which demonstrates the specimen's

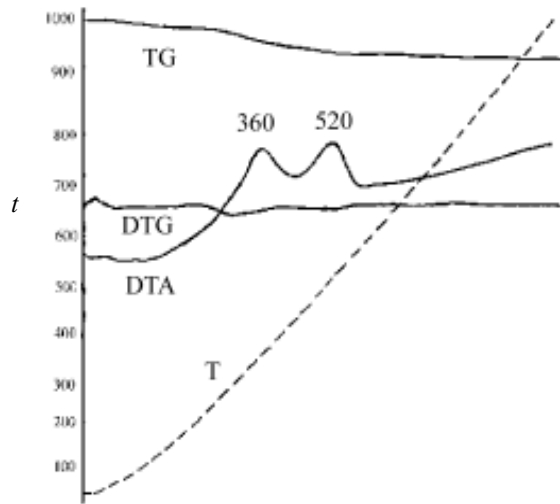


Fig 1. Derivatogram of mineral particles present in a specimen containing anhydrite cement, boon and CMC during heating. Temperature curve (T) – 10 °/min, mass change curve (TG) – 200 mg, heat change curve (DTA) – 250 μ m, mass change rate curve (DTG) – 500 μ m

thermal behavior (DTA) at heating, one can observe a considerable exothermic effect reaching the maximum at a temperature of 360 °C and 520 °C. It is associated with the splitting of CMC which softens at 170 °C and splits and burns at a higher temperature; the boon also burns up when heated. The fact that the process is completed at a temperature exceeding 520 °C is evident from the curves representing mass transformation (TG) and the rate of mass transformation (DTG).

X-ray analysis of a hardened and cured specimen,

containing the above-mentioned amounts of anhydrite cement and other components and from which the main part of fibre filler was removed, was made.

As can be seen from the roentgenogram (Fig 2), major components of a mineral composition of the specimen are anhydrite and quartz (to a much lower degree). Other admixtures are represented in small quantities not allowing for their identification.

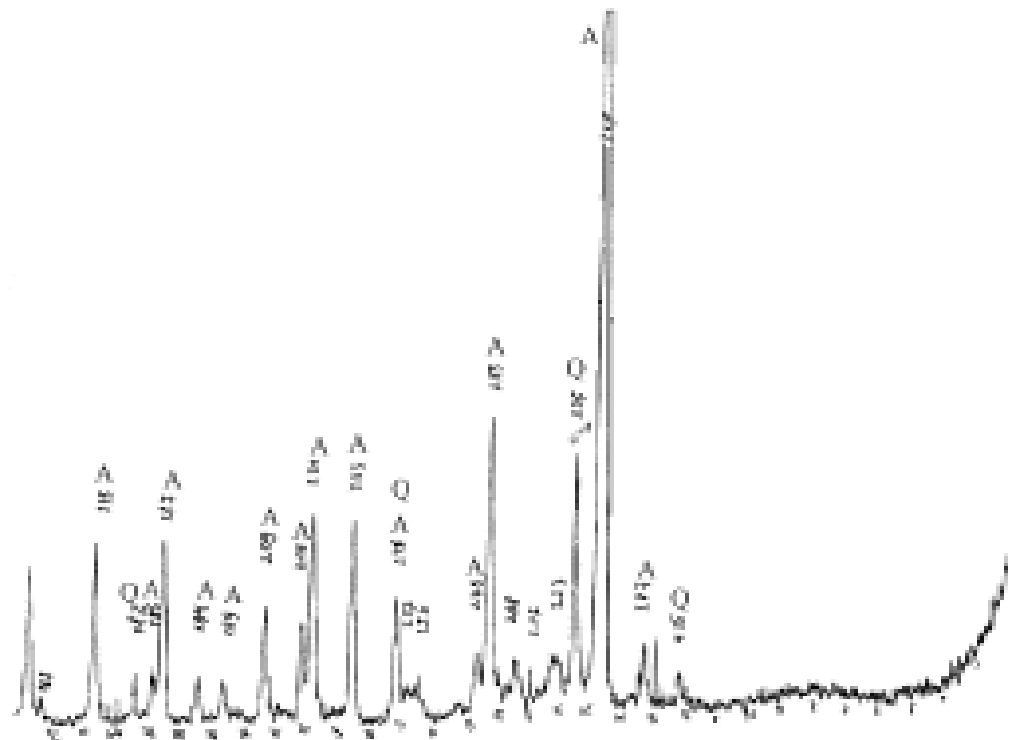
The fact that thermodynamically feasible compounds ($\text{CaSO}_4 \cdot 0,5\text{H}_2\text{O}$, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) are not formed in large amounts may be accounted for low hydration degree of CaSO_4 found in anhydrite cement and a short-time interaction of CaSO_4 of the specimen with water during its preparation, which prevented CaSO_4 hydration in a heterogenic system – CaSO_4 and H_2O .

• Compositions with aluminate cement

A thermographic analysis of a hardened and cured specimen containing 61 % of aluminate cement G-70, 18 % of chaff and 21 % of PVA (dry solids) with a portion of fibre filler removed by screening through 0,2 mm sieve, was made.

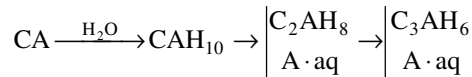
The curves of the thermogram (Fig 3) show that absorption water evaporates at about 120 °C, while at 170 °C destruction of PVA takes place and at 300 °C, 340 °C and 380 °C dehydration (endothermic effects and mass decrease) of the products may be observed. However, in the temperature interval of 300 °C–700 °C the burning up of organic materials takes place, reaching the maximum at 460 °C (as can be seen on the DTA curve representing exothermic effect). At a temperature of about 600 °C smoldering rather than burning can be observed.

Fig 2. X-ray-gram of mineral materials present in a specimen containing anhydrite cement, boon and CMC. Type of X-ray apparatus-DRON-2, anode-Co, filter-Fe, A-anhydrite, Q-quartz



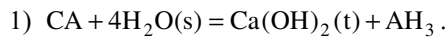
At 860 °C carbonates decompose (DTG curve), while at 960 °C – CA crystallization takes place. X-ray phase analysis was made of a hardened and cured specimen containing aluminate cement and other composites in the considered amounts and from which the main portion of the fibre filler was removed. One can see on the roentgenogram (Fig 4) that major mineral components of the specimen are CAH₁₀, AH₃ (gibbsite), α-Al₂O₃ (corundum) as well as calcite and vaterite (both – CaCO₃).

The CA hydration takes place as follows:

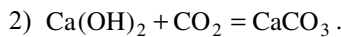


The absence of C₂AH₈ as well as C₃AH₆ hydrates in the investigated specimens can be explained by the fact that the CMC polymer forms a colloidal solution in the system the particles of which surround the CA and initially CAH₁₀ formed particles, thus eliminating further hydration. This process is assisted by the presence of a limited amount of water in the mixture and sufficiently fast aluminate cement hardening and curing.

The presence of CaCO₃ (calcite also vaterite) in the samples can be explained in our opinion by the following processes:



Our calculations show that the hydrolysis process Gibbs energy value ΔG₂₉₈⁰ = -0,184 kcal; this means that the reaction is possible, although on a small scale,



Ca(OH)₂ solution pH calculations were performed to verify that the CaCO₃ present in the specimen was formed from Ca(OH)₂ according to the latter equation which is thermodynamically very close to chemical equilibrium.

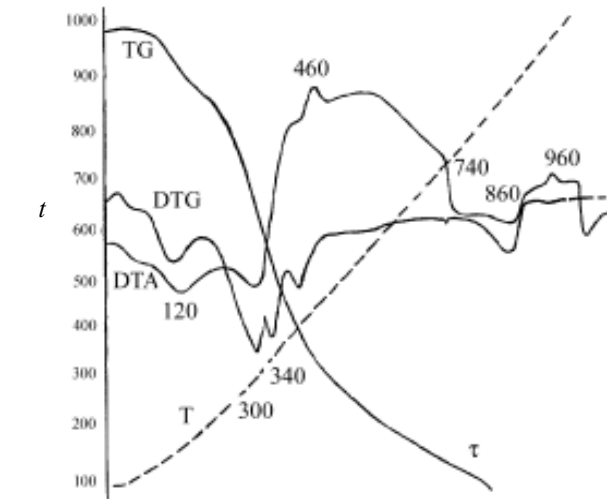
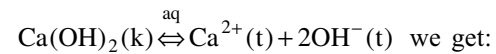


Fig 3. Derivatogram of mineral particles present in a specimen containing aluminate cement G-70, boon and PVA. Temperature curve (T) – 10 °/min, mass change curve (TG) – 200 mg, heat change curve (DTA) – 250 ηm, mass change rate curve (DTG) – 500 ηm

The following Ca(OH)₂ solubility multiple given in the handbook was used for calculations.

$$L = [Ca^{2+}][OH^-]^2 = 3,1 \cdot 10^{-5} .$$

In the case of the equation



$$L = [Ca^{2+}][OH^-]^2 = 3,1 \cdot 10^{-5}; [OH^-] = 0,5[Ca^{2+}];$$

$$L = 0,25[Ca^{2+}]^3 = 3,1 \cdot 10^{-5}; [Ca^{2+}] = 0,05;$$

$$[OH^-] = 0,025M ;$$

$$pOH = 1,6; pH = 12,4 .$$

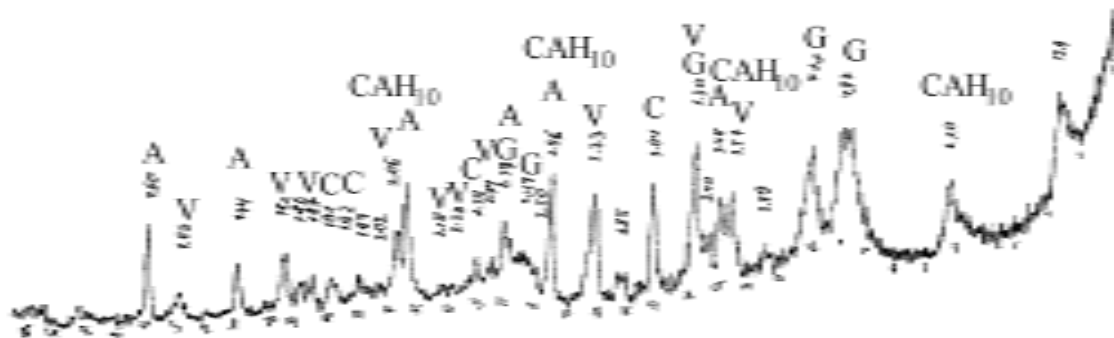


Fig 4. X-ray-gram of mineral particles present in a specimen containing aluminate cement, boon and PVA. Type of X-ray apparatus–DRON-2, anode–Co, filter–Fe. CAH₁₀ – CaO·Al₂O₃·10H₂O; G – gibbsite Al₂O₃·3H₂O; A – corundum α-Al₂O₃; C – calcite CaCO₃; V – vaterite γ-CaCO₃

pH-metric experiments were conducted with all the cements used. The following pH values were obtained for cement dispersion: in the case of aluminate cement 40 pH = 11,18, for aluminate cement 70 – pH = 10,58 and for anhydrite cement – pH = 9,49.

This means that the described CaCO₃ formation mechanism in the specimens is reliable.

The presence of α-Al₂O₃ in the investigated samples can be explained in two ways: 1) AH₃ formed during insignificant CA hydrolysis decomposes to Al₂O₃ and water during sample drying, 2) the presence of corundum admixtures in the aluminate cement.

5.2. Retention of specimen form

Experiments show that the form retention of hardened and dried samples in ambient air of a typical composition (50 % of cement, 45 % filler and 5 % of polymer binder-based on dry solids) depends on its composition (Figs 5, 6):

- Anhydrite cement binds boon better than chaff, while aluminate cement binds both evenly well.
- Vinyl acetate binders (PVA, Vinnap), irrespective of the type of cement used, binds cellulose fiber fillers better than cellulose binders (CMC, Walocel, MC).

The composition of steadfast samples is shown in the diagram (Fig 7 – a combination of aluminate cement 70 – polymer binders-chaff).

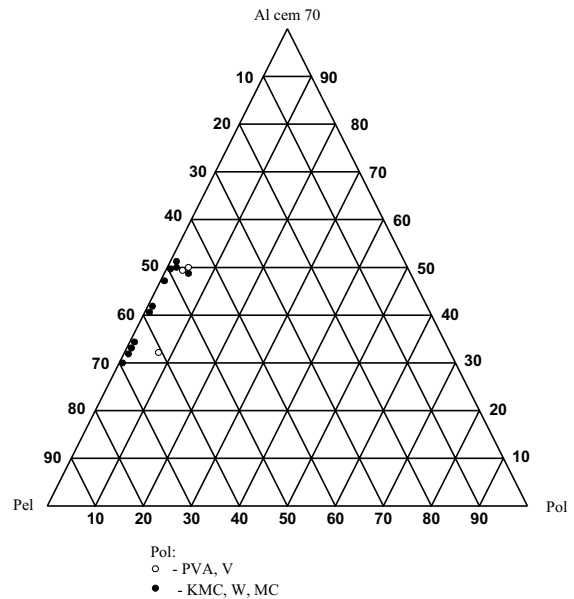


Fig 7. Triangular diagram for the composition of heat insulation composites made from aluminate cement 70, polymeric binder and chaff

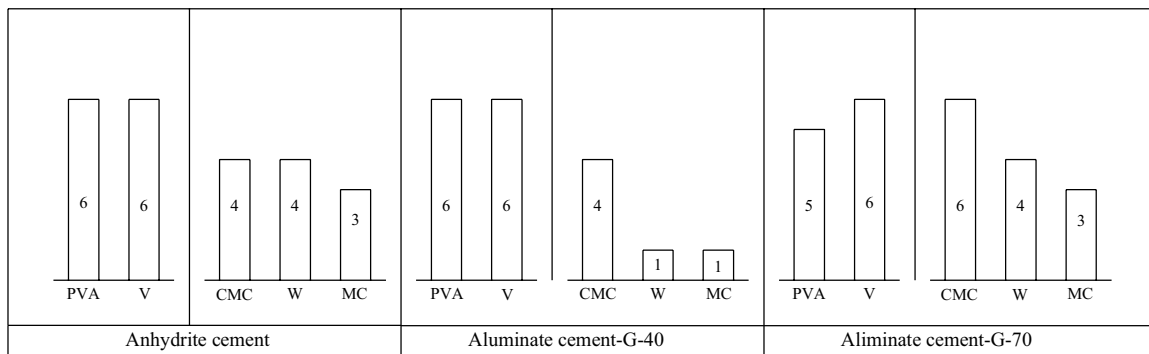


Fig 5. Influence of inorganic and polymer binder composition on the form steadfastness of a freshly formed and conditioned for 7 days specimen with standard composition (figures show the number of steadfast samples)

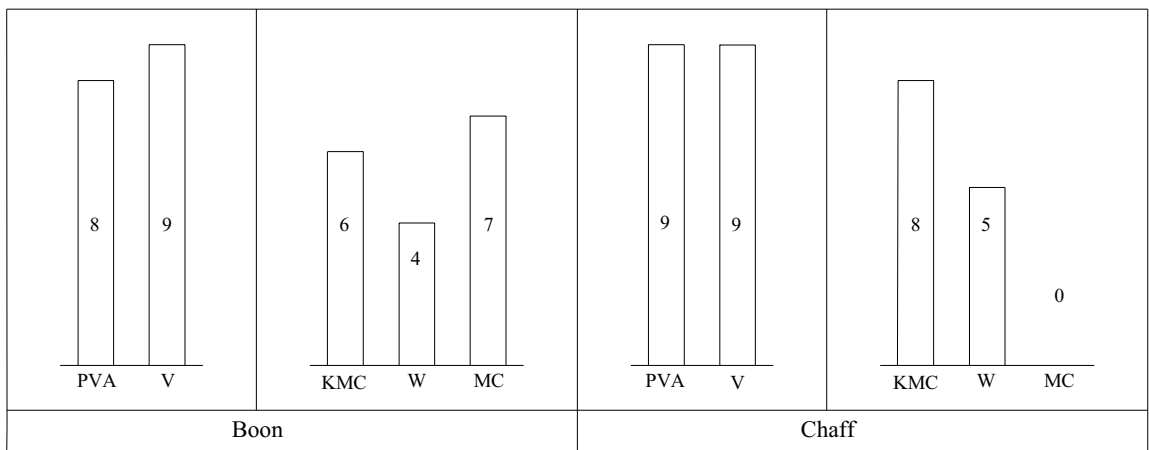


Fig 6. Influence of polymer binder and cellulose fiber filler composition on the form steadfastness of a freshly formed and conditioned for 7 days specimen with standard composition (figures show the number of steadfast samples)

5.3. Optimal compositions

The most efficient compositions obtained in the investigation are given below (Table).

The tests have shown that the relationship between the mass of all the three inorganic binders and fillers is about one. Thus, in making mixes to produce heat insulating materials with the use of anhydrite or aluminate cement 70, equal amounts (by weight) of inorganic binder and cellulose fibre filler may be taken to facilitate the process. It is particularly suitable for manufacture in rural localities. In the case of aluminate cement 40 the amount of the latter should be 1,1–1,3 times the quantity of cellulose fibre filler.

5.4. Composite density

The composite density ρ , (kg/m^3) depends on the amount of cement present in it according to a parabolic relationship (the case of Fig 8 with anhydrite cement and boon bound with CMC 4 % dispersion).

According to the classification currently used in the EU states, the compositions obtained may be referred to as structural heat insulating materials ($\rho = (< 500 - 600) \text{ kg/m}^3$, $\lambda > 0,2 \text{ W/m}\cdot\text{K}$).

The relationship – “density – cement quantity” in a composition containing anhydrite cement may be expressed in the following way:

$$\rho = \rho_{\min} + \Delta\rho(\text{An} - \text{An}_{\min})^2, \text{ kg/m}^3,$$

where: ρ_{\min} – minimal ρ value determined from the diagram; $\Delta\rho$ – empirical ρ increase ratio, kg/m^3 ; An – anhydrite cement part, %, in a composite; An_{\min} – cement part, %, in a composite, at minimal ρ value.

The minimum referring to the dependence of the composite density on the amount of cement (about 30 %) in it found on the curves may be accounted for the following fact. When a composition is cement-free or having a small proportion of it, the polymer binder takes over the cement function, closely connecting the par-

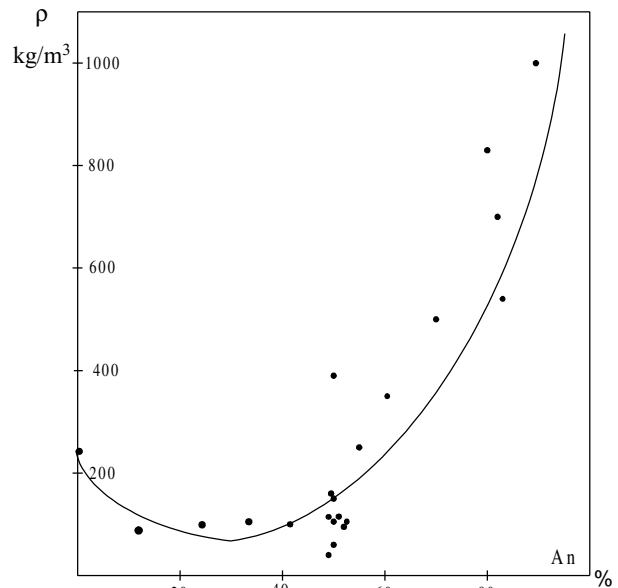


Fig 8. Dependence of the density ($\rho, \text{kg/m}^3$) of heat-insulating composites containing anhydrite cement (An) and boon binder with 4 % of CMC dispersion on the amount of cement present, An, %

ticles of the filler. It results in a composite with a density higher than that of a material containing about 30 % of cement. If the amount of cement is increased, the influence of its mass on composite density also increases, according to a parabolic relationship.

5.5. Composite mechanical strength

The composite flexural strength for 400 kg/m^3 and less density specimens with polymeric binder–CMC is in the (0,6–1,3) MPa range which is sufficient for hardening, transportation and assembly.

During compressive deformation samples with a density less than 400 kg/m^3 act not like brittle materials but are compressed. This composite property is very important during transportation and assembly work. This

Article composition percentage intervals (density not more than 400 kg/m^3) of inorganic binders, polymeric binders (dry state) and cellulose fiber fillers. Note: An – anhydrite cement, A 40 – aluminate cement 40, A 70 – aluminate cement 70, S – boon, P – chaff, PVA – polyvinyl acetate, V – Vinnap, CMC – carboxymethylcellulose, W – Walocel, MC – methylcellulose

Composition	Inorganic binders	Polymeric binders	Cellulose fiber filler
An-S-PVA, V	45–55	1–5	47–55
An-S-KMC, W, MC	42–60	1–5	40–55
An-P-PVA, V	35–55	2–8	45–60
An-P-KMC, W, MC	30–55	0,2–0,5	45–65
A 40-S-PVA, V	absent	absent	absent
A 40-S-KMC, W, MC	50–60	~5	40–45
A 40-P-PVA, V	45–55	~5	40–50
A 40-P-KMC, W, MC	50–60	5–6	40–45
A 70-S-PVA, V	35–50	~5	45–60
A 70-S-KMC, W, MC	35–55	1–5	45–65
A 70-P-PVA, V	30–50	5–8	45–60
A 70-P-KMC, W, MC	30–55	0,5–1	45–70

feature can be explained by a isotropic composite structure in which the cellulose fiber filler is connected by polymeric patches which preform the function of a framework (Fig 9).



Fig 9. Fractured composite specimen containing 70 % of aluminate cement 40, 20 % of boon and 10 % of CMC (dry solids)

5.6. Composite thermal conductivity

To assess the heat insulating properties of anhydrite and aluminate containing lightweight walling materials, their λ values had to be found. The samples of the composition found in the central areas of triangular diagrams were chosen for testing. These are the following composites:

1) A composite containing 50 % of anhydrite cement, 45 % of boon and 5 % of CMC (dry solids) with $\rho = 225 \text{ kg/m}^3$.

2) A composite containing 50 % of aluminate cement – 70,45 % of boon and 5 % of PVA (dry solids) with $\rho = 119 \text{ kg/m}^3$.

As a result, the following λ values were obtained:

1) for anhydrite composite –

$$\lambda = 0,063 \pm 0,01 \text{ W/m} \cdot \text{K}, (\rho = 225 \text{ kg/m}^3);$$

2) for aluminate composite –

$$\lambda = 0,12 \pm 0,01 \text{ W/m} \cdot \text{K}, (\rho = 119 \text{ kg/m}^3).$$

Thus, the anhydrite and aluminate compositions investigated may be used in manufacturing lightweight walling and heat-insulating materials. The compositions may be obtained by using the triangular diagrams presented in this work.

5.7. Composite heat resistance and costs calculations

The obtained thermal insulation calculations were compared with heat losses Q which arise when a typical building with a two-silicate-brick wide wall and a 2 cm plaster layer is heated from October to April at a mean outdoor and inside temperature of 0,7 °C and 20 °C, respectively. The following results were obtained:

- for a non-insulated wall – $Q = 18152 \text{ kWh}$;

- for walls of the same building insulated for warmth keeping with an 8 cm-thick composite ($\lambda = 0,08 \text{ W/m} \cdot \text{K}$) layer covered with gypsum-cardboard – $Q = 14135 \text{ kWh}$;
- for the same case with a 10 cm-thick composite layer – $Q = 10645 \text{ kWh}$.

The relationship between the heat loss value Q_2 (for a wall after insulating materials were applied) and heat loss value Q_1 (for a wall before to insulation was installed) was as follows, %:

$$(Q_2 / Q_1) 100 = (10645 / 18152) 100 = 58,6 \%$$

In fact, the above value is slightly higher than the efficiency factor of the boiler $\eta = 0,7$ used for heating a building, while the heat losses of the heating system N reach 13 %, ie $N = 13$. Taking into account the above considerations, we find that the insulation of walls of a building for warmth-keeping can save the following amount of heat:

$$\Delta Q_{\text{fakt}} = \Delta Q / \eta (1 - 0,01N) = 7507 / 0,7 (1 - 0,01 \cdot 13) = 12327 \text{ kWh or } 44,4 \text{ GJ}.$$

In rural localities fuel oil is burned in heating boilers, while coal or wood are used for firing furnaces. When fuel oil is used in urban boiler rooms, its cost is by about 30 % higher. Since the average cost of fuel oil in the world is about 73 \$ per ton (recalculated as equivalent fuel), 1,5 ton of fuel oil will cost 526 Lt.

Thus, by winter-proofing a house of 100 m² with its walls insulated only with the suggested thermal insulating materials, more than 520 Lt a year may be saved (in the period of heating including October–April, ie for 7 months or 219 days).

Assuming an average cost of 1 m² of insulating materials to be 10 Lt, the insulation of 170 m² wall area will cost 1700 Lt.

Therefore, than average repay time of building winter-proofing with insulating materials will make 1700 : 526 = 3,23, ie the renovation of building walls will repay less than in 4 years

Calculations show that the composite's role is especially revealed when a wall is insulated according to the following scheme (ρ – layer density, kg/m³; δ – layer thickness, m; λ – specific thermal conduction coefficient, W/m·K):

- decorative brick masonry ($\rho = 1600$; $\delta = 0,12$; $\lambda = 0,64$)
- composite ($\rho = 750$; $\delta = 0,125$; $\lambda = 0,11$)
- holey clay brick masonry ($\rho = 1600$; $\delta = 0,12$; $\lambda = 0,64$)
- stucco ($\rho = 1700$; $\delta = 0,02$; $\lambda = 0,87$)

In this case the composite thermal resistance makes up for 65,5 % of the total wall thermal resistance.

5.8. Principled technological scheme for producing lightweight walling and heat-insulating materials

Fig 10 shows a principal anhydrite and aluminate lightweight wall and heat-insulating material production principled scheme is proposed.

Raw material hoppers are filled with an inorganic binder (1), a cellulose fiber filler (2) and a dry polymeric binder (3). Water is held in the tank (4). All the reservoirs are equipped with batchmeters (10).

The polymeric binder dispersion is prepared by mixing it in a separate reservoir (5) equipped with a mixing device (6). The required amount of dispersion is then dispensed through a batch meter (10).

After that the required amount of cement and filler material is transported to a mixing reactor (7). All the dry raw materials are mixed in the mixer (6). After that the required amount of polymer dispersion is introduced into the reactor. All the components are well mixed in the mixer (6).

Then the prepared raw material mixture is transported to pressforms where they are formed by a press (8). After the required hardening time the obtained pre-fabricated articles are forwarded to a warehouse (9).

6. Conclusions

1. Lightweight walling and heat-insulating composites were developed based on inorganic binders (anhydrite cement, aluminate 40 and aluminate 70 cements); polymeric binders–vinyl acetate (PVA, *Vinnap*); cellulose binders (CMC, *Walocel*, MC); cellulose fiber fillers (chaff, boon) and special additives (antiseptics, flame-retarders, water-prooferers, etc).

2. The article steadfastness during assembly is dependant on the following indices: a minimal amount of anhydrite cement in various compositions should be $\geq 30\text{--}45\%$; a minimal amount of aluminate cement–40 $\geq 45\text{--}50\%$; a minimal amount of aluminate cement–70 $\geq 30\text{--}35\%$; a minimal amount of vinyl acetate polymer binder in various compositions – $\geq 0,5\text{--}5,0\%$; minimal cellulose fiber filler amount in various compositions – $\geq 40\text{--}47\%$.

3. Vinyl acetate binders in combination with all cements bind cellulose fiber fillers (chaff and boon) better than cellulose binders; anhydrite cement binds boon better than chaff, while aluminate cement binds both with equal success.

4. When the amount of cement used in composi-

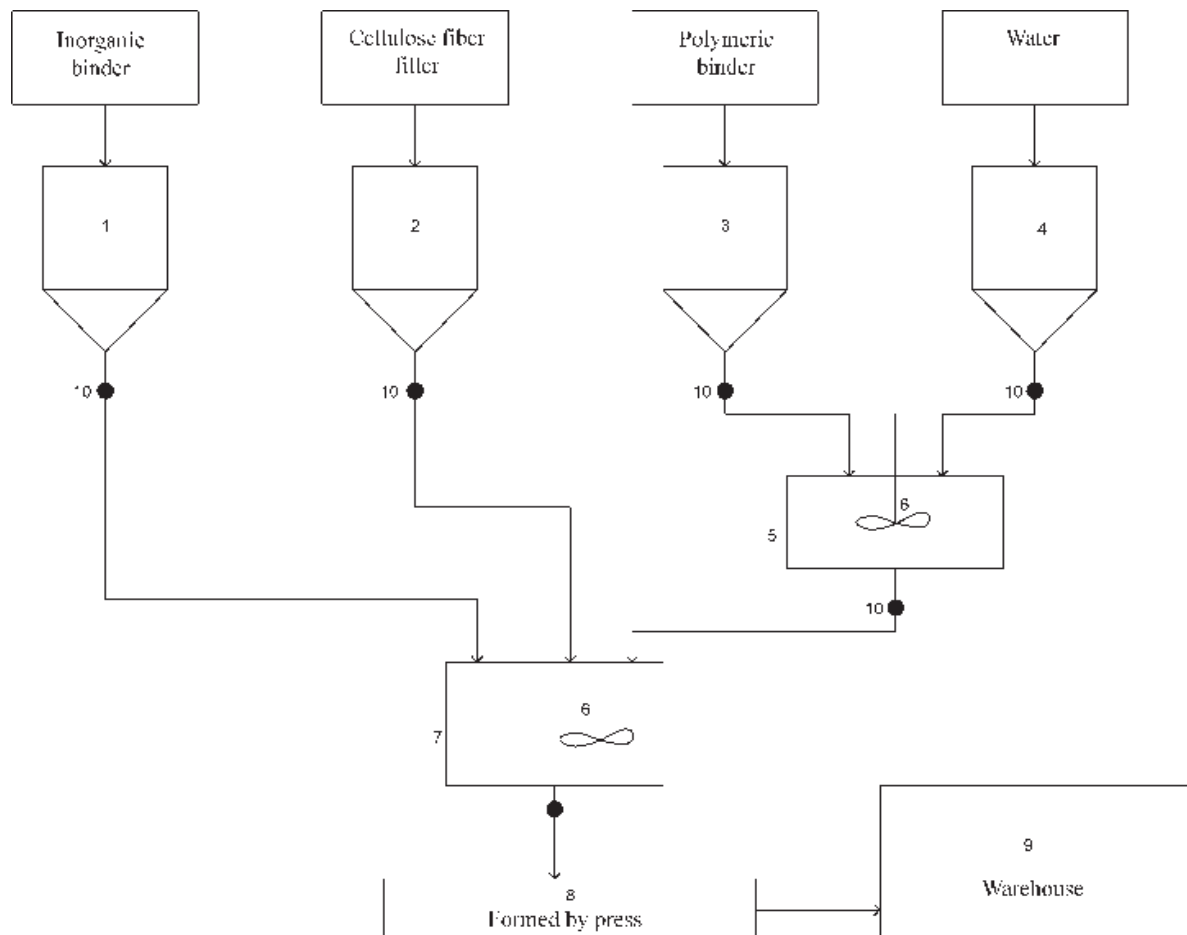


Fig 10. Principled technological scheme for manufacturing lightweight walling and heat-insulating materials containing anhydrite and aluminate. 1–3 – raw material hoppers; 4 – a water reservoir; 5 – a reservoir for polymeric binder dispersion; 6 – a dispersion mixer; 7 – a mixing reactor; 8 – a press; 9 – a warehouse; 10 – a material dispenser

tions does not exceed 50–60 % the specimen density is lower than 400 kg/m³ which is correlatively inversely proportional to the specific thermal conductivity coefficient. According to this index, the developed compositions belong to the lightweight heat-insulating material class. The specimen density ρ for all cements depends on the amount of cement present in a sample, % according to the approximate parabolic dependence.

5. The specimen flexural strength is in the range of 0,6–1,3 MPa when the specimen density is lower than 400 kg/m³ and CMC is used as a polymeric binder. This is enough for article transportation and assembly. Such specimens deform under pressure in a different way than fragile materials – they are compressed. This property of the material is of special importance in transportation and assembly.

6. The composite article thermal conductivity coefficient is about 0,06 W/m·K for specimens with a density lower than 400 kg/m³. The use of the developed heat-insulating slabs for insulating buildings can substantially increase the wall thermal resistance. For example, a 170 m² building built by using a two-silicate-brick wall and a 2 cm plaster layer could have heat losses of about 18 thousand kWh during a 7-month cold season, and if 8 cm thick composite slabs were used, the heat losses could be lowered to 14 thousand kWh, if 10 cm – 10,6 kWh. That is why the use of developed composite slabs for insulation of buildings (6 variations are possible) can save as much as 1,5 tons of conventional fuel. It follows that the building wall insulation costs could be paid off in less than 4 years.

7. The use of agricultural by-products for heat-insulating material production would not allow them to decay and form CH₄ and CO₂ gases which could take part in lowering the atmospheres greenhouse effect.

References

- Kazragis, A.; Nickus, I.; Gailius, A. Construction Material Production Technology Using Organic Fillers. In: Proceedings of 4th International conference „Modern Building Materials, Structures and Techniques“. Vilnius, Technika, 1995, p. 234–238 (in Lithuanian).
- Kazragis, A.; Gailius, A.; Nickus, I. Heat Insulating Materials Made from Local Raw Materials. *Construction and Architecture (Statyba ir architektūra)*, No 4, 1996, p. 15–16 (in Lithuanian).
- Kazragis, A.; Milčiūnienė V.; Kulinič, H.; Gailius, A.; Nickus, I. Use of Organic Production Waste for Manufacturing Construction Materials Investigation. *Environmental Engineering (Aplinkos inžinerija)*, No 2(6), 1996, p. 18–24 (in Lithuanian).
- Kazragis, A.; Kulinič, H.; Gailius, A.; Nickus, I. Straw bricks Containing Carboxymethylcellulose in its Compositions. In: Proceedings of International Conference Lithuanian Science and Industry “Silicate technology”. Kaunas: Technologija, 1999, p. 142–147 (in Lithuanian).
- Kazragis, A.; Gailius, A.; Kulinič, H. Influence of composition structure on the properties of building products with agricultural elements. Investigation. *Environmental Engineering (Aplinkos inžinerija)*, No 4, 2000, p. 223–227 (in Lithuanian).
- Kazragis, A.; Gailius, A.; Juknevičiūtė, A. Thermal and Acoustical Insulating Materials Containing Mineral and Polymeric Binders with Celluloses Fillers. *Materials Science (Medžiagotyra)*, Vol 8, No 2, Kaunas, 2002, p. 193–195 (in Lithuanian).
- Kazragis, A.; Gailius, A.; Tamulaitienė, B.; Kulinič, H. Utilization of straw and reed in building product fabrication. Investigation. *Environmental Engineering (Aplinkos inžinerija)*, Vol 10, No 2, 1996, p. 77–83 (in Lithuanian).
- Fischer, A. K.; Bullen, F.; Beal, D. The durability of cellulose fibre reinforced concrete pipes in sewage application. *Cement and Concrete Research*, Vol 31(4), 2001, p. 543–553.
- Blankenhorn, P. R.; Blankenhorn, B. D.; Silsbee, M. R.; DiCola, M. Effects of fiber surface treatments on mechanical properties of wood fiber–cement composites. *Cement and Concrete Research*, Vol 31(7), 2001, p. 1049–1055.
- Biricik, H.; Akoz, F.; Turker, F. and Berktaş, I. Resistance to magnesium sulfate and sodium sulfate attack of mortars containing wheat straw ash. *Cement and Concrete Research*, Vol 30(8), 2000, p. 1189–1197.
- Blankenhorn, P. R.; Silsbee, M. R.; Blankenhorn, B. D.; DiCola, M. and Kessler, K. Temperature and moisture effects on selected properties of wood fiber–cement composites. *Cement and Concrete Research*, Vol 29(5) 1999, p. 737–741.
- Savastano, H.; Warden, Jr.; P. G and Coutts, R. S. P. Ground iron blast furnace slag as a matrix for cellulose–cement materials. *Cement and Concrete Composites*, Vol 23(4–5), 2001, p. 389–397.
- Qijun, Yu; Sawayama, K.; Sugita, S.; Shoya, M. and Isojima, Y. The reaction between rice huck ash and Ca(OH)₂ solution and the nature of its product. *Cement and Concrete Research*, Vol 29 (1), 1999, p. 37–43.
- Cisse, I. K. and Laquerbe, M. Mechanical characterisation of filler sandcretes with rice huck ash additions. *Cement and Concrete Research*, Vol 30(1), 2000, p. 13–18.
- Savastano, H.; Warden, Jr.; P. G. and Coutts, R. S. P. Brazilian waste as fibres as reinforcement for cement–based composites. *Cement and Concrete Composites*, Vol 22(5), 2000, p. 379–384.
- Singh, N. B.; Singh, V. D.; Rai Sarita and Chaturvedi Shivani. Effect of lignosulfonate, calcium chloride and their mixture on the hydration of RHA–blended portland cement. *Cement and Concrete Research*, Vol 32(3), 2002, p. 387–392.
- Sebok, T. Relationships between the properties of ligninsulphonates and parameters of modified samples with cement binders. *Cement and Concrete Research*, Vol 30(4), 2000, p. 511–515.
- Coutts, R. S. P. and Ni, Y. Autoclaved Bamboo Pulp Fibre Reinforced cement. *Cement and Concrete Composites*, Vol 17(2), 1995, p. 99–106.
- Bložė, V. Non-fired bricks made of local raw materials. *Construction and Architecture*, No 9, 1994, p. 20 (in Lithuanian).

SPALIŲ IR PELŲ UTILIZAVIMAS GAMINANT LENGVAS SIENINES MEDŽIAGAS

A. Kazragis, A. Juknevičiūtė, A. Gailius, E. Zalieckienė

Santrauka

Gauti lengvi sieniniai bei šilumos izoliaciniai kompozitai, kuriuos sudaro neorganiniai rišikliai (anhidritinis cementas, aluminatinis cementas-40 ir aluminatinis cementas-70), polimeriniai rišikliai (vinilacetatiniai – PVA, *Vinnap*); celiulioziniai (KMC, *Walogcell*, MC), celiulioziniai plaušiniai užpildai (pelai, spaliai).

Dirbinių patvarumą transportuojant bei montuojant lemia tam tikri rodikliai. Minimalus įvairių medžiagų kiekis kompozicijose turi būti: anhidritinio cemento – $\geq (30-45) \%$; aluminatinio cemento-40 – $\geq (45-50) \%$; aluminatinio cemento-70 – $\geq (30-35) \%$; vinilacetatinių polimerinių rišiklių – $\geq (1-5) \%$; celiuliozinių rišiklių – $\geq (0,5-5,0) \%$; celiuliozinių plaušinių užpildų – $\geq (40-47) \%$.

Bandinių tankis, kai naudotų cementų kiekis kompozicijose neviršija $(50-60) \%$, yra mažesnis negu 400 kg/m^3 . Pagal šį rodiklį sukurti kompozitai priskiriami lengvųjų šilumos izoliacinių medžiagų klasei. Bandinių tankis, esant skirtingiems cementams, priklauso nuo cemento kiekio bandinyje.

Bandinių lenkiamasis stipris, kai nustatant naudojami bandiniai, kurių tankis neviršija 400 kg/m^3 , o kaip polimerinis rišiklis – KMC, yra $0,6-1,3 \text{ MPa}$.

Bandinių, kurių tankis mažesnis nei 400 kg/m^3 , savitasis šilumos laidžio koeficientas esti apie $0,06 \text{ W/m}\cdot\text{K}$.

Raktažodžiai: utilizavimas, lengvos sieninės medžiagos, šilumos izoliacija, spaliai, pelai, neorganiniai rišikliai, polimeriniai rišikliai.

УТИЛИЗОВАНИЕ КОСТРЫ И МЯКИНЫ В ПРОИЗВОДСТВЕ ЛЕГКИХ СТЕНОВЫХ МАТЕРИАЛОВ

А. Казрагис, А. Юкнявичюте, А. Гайлюс, Е. Залецкене

Резюме

Получены легкие стеновые и теплоизоляционные композиты, состоящие из ангидридного (АН) или алюминатного (АЛ) цемента, винилацетатных (ВА) или целлюлозных (ЦЛ) полимерных вяжущих и волокнистых целлюлозных заполнителей (костры, мякены).

Устойчивость изделий при транспортировке и монтаже обуславливается следующими показателями: содержание АН $\geq (30-45) \%$, АЛ $\geq (30-50) \%$, ВА $\geq (1-5) \%$, ЦЛ $\geq (0,5-5,0) \%$, костры или мякены $\geq (40-47) \%$. Вяжущие типа ВА в случае обоих видов цемента связывают заполнители лучше, чем вяжущие типа ЦЛ; АН связывает костру лучше, чем мякены; АЛ одинаково успешно связывает оба заполнителя.

Плотность композита ρ при содержании цемента в композите $< (50-60) \%$ не превышает 400 kg/m^3 . По данному показателю полученные композиты относятся к классу легких теплоизоляционных материалов. Значение ρ зависит от содержания цемента в композите по параболической закономерности.

Прочность композитов при изгибе для образцов $\rho \leq 400 \text{ kg/m}^3$ в случае применения КМС составляет $(0,6-1,3) \text{ МПа}$. Такие образцы при сжатии деформируются как эластичные материалы и подвергаются прессованию, что особенно важно при их транспортировке и монтаже.

Коэффициент теплопроводности образцов, обладающих плотностью менее чем 400 kg/m^3 , составляет около $0,06 \text{ Вт/м}\cdot\text{К}$. При использовании для отопления стен дома площадью в 170 м^2 плит из таких композитов толщиной в 10 см потери тепла за сезон уменьшаются на $10,6 \text{ тыс. кВт}\cdot\text{час}$.

Ключевые слова: утилизация, легкие стеновые материалы, теплоизоляция, костра, мякина, неорганические вяжущие, полимерные вяжущие.