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Creating Effective Insulation Solutions, Taking into Account the Law of Affinity Structures in Construction Materials

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Abstract: Theoretical approach to the creation of thermal insulation solutions with high thermo-physical and physical-mechanical properties. When you create a material with the desired characteristics used previously suggested by the authors, the law of affinity structures in construction materials , allowing to predict and obtain building composites with desired properties. The results of research on the production of composite binders using waste perlite manufacture for thermal barrier solutions. The microstructure insulation solutions. The method of electron microprobe analysis revealed that between cement and perlite chemical interactions occur. The compositions composite binders for insulating solutions based on local raw materials and plasticizers. The composite binders optimal composition have a compressive strength of 95.2 MPa. It is proved that when using the suggested approaches for creating material may get effective insulating solutions with high heat-shielding properties.

Key words: Law of affinity structures in construction materials % Composite binders % Expanded perlite % insulation solutions on the basis of dry construction mixtures % Microstructure % Microprobe analysis of spectral % Thermal and performance characteristics % Physical and mechanical properties

INTRODUCTION

Construction of housing with high demands on energy saving is one of Russia's most important tasks. Priority for the construction industry need to develop and introduce competitive new high -tech building materials that affect the quality of life and comfort in the "man-material-environment" [1,2]. A modern, efficient insulation materials are solvent-based dry mortar.

The use of heat-shielding materials can not only reduce the energy consumption for heating, but also to accumulate the resulting heat [3, 4, 9]. In developed countries, the most popular were insulating plasters based on aggregate with a porous structure, providing higher thermal insulation solutions.

Such materials include heat-insulating plaster mixtures based on perlite [5,6]. However, the existing solutions have insufficient insulation density to provide the required thermal protection for the lower coating thickness. In this regard, it was necessary to develop formulations for dry mortar insulating solutions with a reduced density of the solution solidified.

In the development of thermal insulation solution with desired performance properties, we used the basic provisions of the law of our proposed affinity structures in construction materials. Implementation of the principles of this law will provide insulation solution with the previously specified physical, mechanical and performance properties.

MATERIALS AND METHODS

Analytical studies of the microstructure of the samples was carried out in a scanning ion-electron microscope Quanta 200 3D with X-ray emission microprobe. Research processes and products of

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hydration mixtures were performed on X-ray diffractometer DRON -3, the thermal conductivity is determined by electronic meter ITP - MG4. Standard Test Methods and binders dry mixes cement binder was conducted in accordance with GOST 310.3-76, 310.4-81 and GOST 31356-2007.

The Main Part: The law of affinity structures in construction materials designed to reflect the existing internal communications and the resulting creation of structures aimed at developing new composite target, which should provide the necessary conditions for reliable function of the building products and construction.

The law of affinity structures in building materials based on cause-and- effect relationships, their interactions with each other, determine the properties of the overall system. Applying the principles of the law to the creation of thermal insulation solution we build a system from its constituent elements: a filler - expanded perlite, a bonding material - composite binding and functional additives. To establish the internal connections between the elements of this system, as well as to give warranted contact layer between the system components necessary to observe the conditions of formation of the material structure as a whole.

The task of developing effective thermal insulation solutions with high thermal performance requires a special approach to the selection of raw materials, preparing them for use, preparation and laying insulation in the design of the solution.

In this paper, we consider the law of affinity structures only at the stage of creating thermal insulation solution without considering it to be used - applying the solution to a variety of reasons. To provide thermal insulation properties of the material, it is necessary to form the internal macro structure taking into account the structural features of the structure of grain filler, binder and then. Since the air in the pores has a smaller thermal conductivity than the surrounding solid material in a condensed state material, a high porosity. Since the solid phase has a high thermal conductivity and therefore, when it is in a continuous structure, the thermal conductivity of the material is 2,5 ... 2 times higher than the continuous pores. In this connection it is necessary to provide a discontinuous solid phase, while maintaining the necessary physical and mechanical characteristics. Perlite filler due to its low density and characteristics of the structure to meet these requirements.

It is known that the thermal conductivity of the material is a function of the thermal conductivity of the material of the skeleton, the thermal conductivity of air and moisture present in the pore space. Substantially lower thermal conductivity can be achieved by the use of skeletal material of amorphous structure, since it conducts much less heat flux than that of the crystalline structure. It is in this amorphous material is expanded perlite. In the process of getting lightweight aggregate perlite rock when heated above 870°C, it swells as bound water evaporates and creates countless tiny bubbles softened glassy particles that provide a much lower density of perlite. This allows for the production of expanded perlite insulation construction materials. The porosity of expanded perlite can reach 88 ... 90% or more, which can provide high thermal performance of building material based on it. Minimum thermal conductivity is dry air, enclosed in small closed pores, in which almost no chance of convective heat transfer. In this case, the thermal conductivity of air is minimal and 0.023 W / (m°C). Consequently, the structure of the insulating material must have a skeleton of an amorphous structure, is extremely rich in small closed-cell or thin air layers. All this is achieved by using expanded perlite as a raw material for the production of thermal insulation mortars.

To create a durable and reliable fusion of elements of the material, it is necessary to create a stable internal communications-contact layer at the interface between the filler and binder, to ensure the strength of the material as a whole, as well as the required properties of the new conglomerate. This contact layer must have affinity for the basic characteristics and (or) a common genetic origin matrix filler.

In accordance with the above, we have developed a series of compositions insulation solution. As part of the heat-insulating solution was used as a placeholder expanded perlite, we developed a composite binder, prepared on the basis of Portland cement [7, 8, 10-12], waste perlite and functional additives. Chemical and genetic affinity aggregate-sand and perlite composite binder, prepared using perlite waste production, led the creation of a reliable and durable contact layer at the interface.

As the raw materials to produce composite binder used Belgorod cement CEM I 42,5 N, corresponding to the requirements of GOST 31108-2003 "Cements. Specifications"; perlite M 75 and M150 production of OAO "Oskolsnab" Stary Oskol, corresponding to requirements of GOST 10832-91 "Sand and rubble perlitic

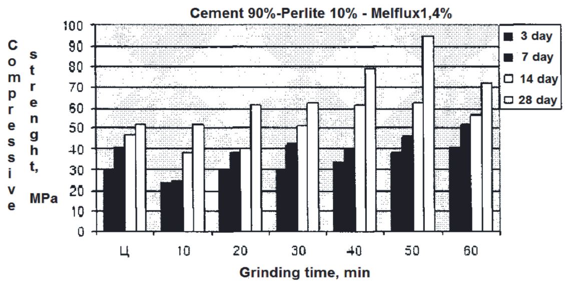

Fig. 1: The influence of the cooking time of the composite binder in a ball mill with a ratio of Cement / Perlite / Melflux = 90/10/1, 4 on the compressive strength of cement

expanded. Specifications"; Melflux additive. The composite binders prepared by grinding together in a ball mill in the following ratio: 90% cement, 10 % perlite and 1.4 % additive. Joint milling of raw materials was performed dosed at different duration of time 10, 20, 30, 40, 50, 60 min.

The main physico-mechanical characteristics of the composite binders prepared in a ball mill shown in picture 1.

From Fig. 1 shows that with increasing cooking time composite binding significantly increases the compressive strength, maximum strength 95.20 MPa composite binding is reached at the time of grinding 50 minutes, which is 82.5% higher than the strength of ordinary cement without additives.

With the further duration of grinding up to 60 minutes of the compressive strength is reduced, which militate against further grinding over 50 minutes.

The presence of expanded perlite in the composite binder creates preconditions for the creation of a reliable firm contact with the major Perlite insulation filler grains due Chemical and genetic affinity and significantly reduces the average density of the composite binder to 1815 kg/m^3 (up 17.5 % less than that of conventional cement), which has a positive impact on density insulation solution. The addition will allow Melflux 6681F significantly reduce the water demand of the composite binding from 28 to 22 %, which is 28.5 % less than the average without additive cement.

Thus, the developed composite binder will greatly reduce the consumption of cement and water in the solution and, therefore, lower density insulating plaster.

The areas of optimal proportions compositional astringent - perlite brands M75 and M150, providing the lowest average density of 437 kg/m^3 insulation solutions (on the M75) and 401 kg/m^3 (for M150) suitable for performing insulating mixtures derived from expanded perlite brands M75 and Ml 50 and developed composite binders prepared based on Portland cement , mineral component of expanded perlite and complex functional additives allowed for thermal insulation solutions for based on perlite M75 with densities ranging from 295 to 315 kg/m^3 and based on the M150 with perlite with densities from 269 to 302 kg/m^3 and indicators of compressive strength within the 1,73 ... 0,87 MPa.

Study of Microstructure [13] of the object allows to obtain considerable information about the formation of a conglomerate structure, concerning the microstructure was investigated by cleaving stone designed insulating solution in 28 plants with the current presented in Fig. 2. For the microstructure of stone chipping insulation solution is characteristic of structural and morphological heterogeneity. Typically, the system consists of spherical particles of perlite surface coated composite binder hydration products are presented in the form of fine fiber or scaly prisms calcium hydrosilicates filling space. Since the grain filler has a "honeycomb" structure, probably comes free migration of Ca^{2+} and OH^- deep perlite particles. In the future, the subtle layer of perlite are active substrate for hydration tumors (fig. 2, x5000, x10000).

The photomicrograph clearly visible and perlite particles are as substrates for germination observed hydration products as prismatic needles (fig. 2) as a volume accumulation. Of particular interest are the processes of formation contact layer of a composite binder to aggregate and structuring in this thin layer, so as to create insulating solution of these components, we posed task-given the affinity of the structures of the components, to create the best conditions for their chemical interaction and the creation of optimal structures for the required physical and thermal engineering mechanical indicators set mortar. In this connection was investigated by a contact layer on the border of the placeholder - a compositional binder with an electron microscope Quanta 200 3D with X-ray emission microprobe analysis of the cleavage surface of the stone insulation solution (Fig. 3).

Number of the distribution of major elements and oxides cleaved surface insulation solution in 28 days is shown in Fig. 4 and in Table 1.

The results are summarized for the three components: cement (1), the contact layer of cement and perlite (2) and grain perlite (3) (Fig. 3).

Table 1: The quantitative distribution of the main elements and oxides in stone insulation solution

	On the basic elements										
Elem	C	O	Na	Mg	Al	Si	S	K	Ca	Fe	E
1)Wt,%	11,03	44,90	0,42	0,22	2,14	10,68	1,00	0,72	27,58	1,29	100
2) Wt, %	9,31	48,38	1,10	0,22	3,36	16,14	1,09	1,23	18,04	1,13	100
3)Wt,%	5,91	47,68	2,21	-	5,16	26,86	0,49	2,20	8,59	0,92	100

On oxides								
Elem	Na_2O	MgO	$A1_2O_3$	Si_2	SO_3	K_2O	Cao	Fe_2O_3	E
1)Wt,%	0,80	0,51	5,66	32,12	3,58	1,20	53,58	2,55	100
2) Wt, %	1,96	0,48	8,49	46,88	3,82	2,01	34,20	2,16	100
3)Wt,%	3,36	-	11,06	65,83	1,43	3,04	13,79	1,49	100

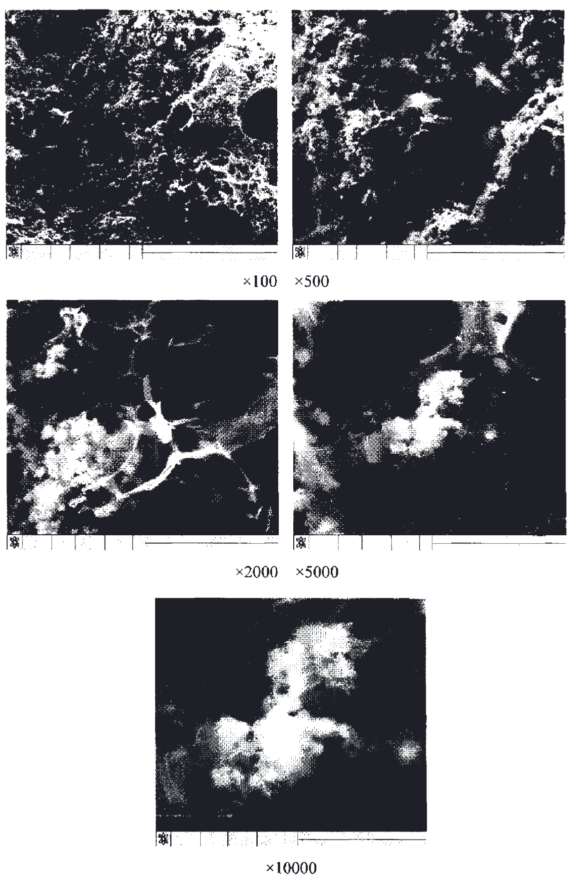

Fig.2. Mikrofotography cleavage surface of the stone insulation solution in 28 days

Spectral analysis (Fig. 3, Table 1) shows the patterns of reducing the content of Ca and at the same time improving the quantitative Si and Al from zone 1 to zone 3. There is penetration of Ca^{2+} deep perlite grains, which is consistent with the results of Table 1. Thus, the chemical reactions are to form additional hydrate phases.

Fig 5. Diffraction pattern is shown hydration products insulation solution. It should be noted that the composition of the products of hydration phase

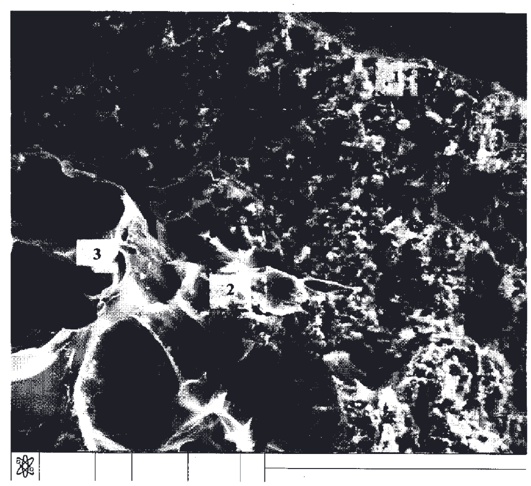

Fig. 3: Micrograph of a cleaved surface of the stone insulation solution in 28 days with the microprobe study (x 600)

insulation solution does not differ from the cement composition. The only difference is in the intensity of the diffraction peaks. Present line alite and belite phases of cement, silicate line low-basic C-S-H (B), CH , tobermorite , xonotlite, there are lines of SiO_2. It can be noted from the increased intensity of lines d = 4,93Å comparison with d = 2,64 Å, indicating that the introduction of calcium hydroxide into the lattice ions Si, Al, Fe.

Thus, studies of the microstructure insulation solutions confirmed the extended position of the creating the conditions for a chemical interaction between the filler and binder elements, resulting in high reactivity perlite aggregate and cement. Microprobe analysis method it is established that between the cement and perlite are chemical interactions, which is consistent with the results of physical and mechanical and performance properties of the insulating fluids.

Analysis showed that the microstructure is determined to a large extent thermally insulating properties of the solution. Perlite in their chemical

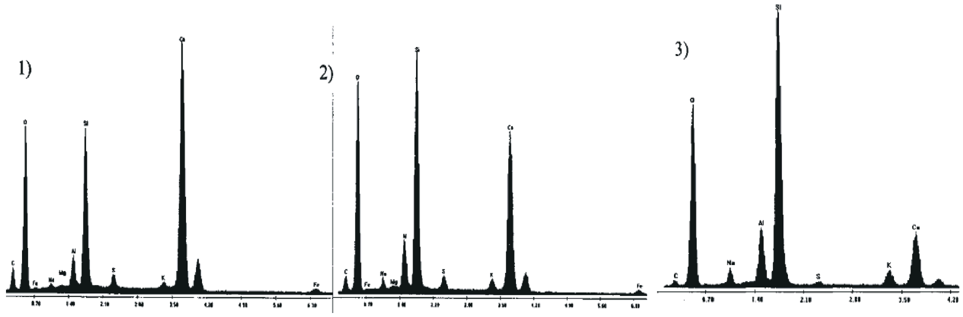

Fig. 4: The results of studies of the cleavage surface of stone insulating solution in 28 days using the microprobe analysis: 1) cement, 2) contact layer of cement and perlite, 3) grain perlite

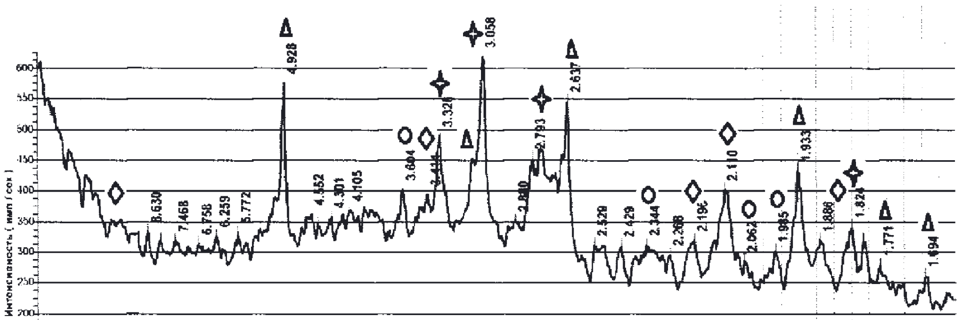

Fig. 5: The XRD pattern of hydration products insulation solution at the age of 28 days:
) Ca (OH) 2; ' Ca-hydrosilicates; N hydroaluminates ' Ca; ettringite

Table 2: The basic performance

Indicator	Normative values	Test data Composition 1	Composition 2	Thermover (Turkey)
Average density insulating solution kg/m^3, more	500	285	305	470
Water-holding capacity,%, not less	90	93,9	91,8	87
Adhesion to base MPa, not less than	0,2	0,26	0,28	o*
Water absorption by capillary leak, kg/m2	-	4,82	4,44	7,3
Water vapor permeability, mg / mh Pa, not less	0,02	0,08	0,06	0,07
Shrinkage of the coating	No cracks			
layer design thickness	No cracks	-		
Compressive strength, MPa, not less than	1,0	1,05	1,22	2
Thermal conductivity, W / (m°C), not more	0,2	0,06	0,07	0,1
Frost cycles least	50	73	75	50

properties can be classified as a pozzolan material that has a high content of amorphous SiO_2, Al_2O_3 and low CaO content. It is established that between the cement paste and perlite are chemical interactions. The primary reaction groups SiO_2; or Al_2O_3-SiO_2 with OH^- ions. In the intergranular liquid phase ions $[SiO_4]^{4-}$ react with Ca^{2+} ions from the slurry and OH^- is attached to form a new phase - hydrate C-S-H. The method of electron microprobe analysis established that between cement test and perlite are chemical interactions with additional formation of calcium silicate and hydrogarnets, besides the subtle layer of perlite grains are active substrates for the formation of the crystalline hydrate tumors. Studies of the structure of the fracture surface of cement on raster ion-electron microscope Quanta 200 3D identified differences in the microstructure without additives and cement with perlite dust. Found that in the hydration process is an active Ca^{2+} ions migrate deep into pearlite grains having a "honeycomb" structure to form on its surface layers acicular calcium silicate and hydrogarnets which due to the volume inside the germination perlite improve their strength between the contact layer grains of cement filler. Revealing that porit cement with additives significantly higher than porit without additive cement stone. The photomicrograph clearly visible and then the configuration in which the formation of neoplasms. There is a clear germination Hydrosilicates across matrix composite.

Prevail prismatic and fibrous crystals which are calcium silicate and hydrogarnets. The microstructure of cement- perlite insulation solution uniform, due to various physical and chemical properties feedstocks. Thus, studies of the microstructure insulating fluids have confirmed the extended position of the high reactivity and perlite composite binder, which is consistent with findings on physical, mechanical and performance properties of plaster solutions based on them.

Of the influence of various factors on the properties of thermal insulation solutions, established in this study will allow increase the effectiveness of further research to create new Effective materials using perlite.

Basic physical and mechanical properties and performance insulation solutions prepared on stamps expanded perlite M75 and M150 are shown in Table 2.

It is established that the properties of plaster on the basis of we have developed dry insulating compounds are not worse than and in some cases superior to the imported mixture *Thermover+ (Turkey). At the same time, they are more economical in the use of local raw materials and waste products of expanded perlite, all of which makes a significant economic and environmental effects.

One of the main indicators of quality insulation solution is the coefficient of thermal conductivity. We have carried out tests to determine the properties of an electronic meter ITP - MG4. The data obtained showed that the rational plasters provide good thermal insulation structures (the thermal conductivity of 0.06 and 0.07 W/(m°C) , respectively, for the compositions 1 and 2 , significantly lower (~ 13 ... 15 times) conductivity traditional cement-sand plaster -0.93 W/(m°C). For mortar important characteristic is the water-holding capacity, it the ability to absorb the mixture to accumulate hold water, followed by its impact on the hydration process of cement. At the request of GOST 28013-98 water-holding capacity must be at least 90 %. The tests developed by dry mixes for thermal insulation solutions for pearlite sand marks M150 and M75 have shown the value of 93.9 % and 91.8 %. Water vapor permeability optimum thermal insulation plaster was 0.08 and 0.06 mg / m*h*Pa for compositions 1 and 2, respectively, higher than the lowest the desired value.

We have carried out tests on the plaster coating compressive strength found that strength of the samples is 1.05 ... 1.22 MPa which corresponds to make mortar - M10. Plasters must have a minimum compressive strength of 1.0 MPa (DIN 18550). Durability and resistance to external influences, as well as high fracture toughness provided when the plaster has a compressive strength in the range of 2 to 5 MPa. Solutions with such strength characteristics able to adapt to small deformations and resist cracking [14].

An important factor for plastering compositions is to check peel strength of the "base-plaster coating". Peel strength plaster should be less than 0.2 MPa. Experiments have shown that the developed plastering composition tested in the laboratory have a peel strength values of 0.28 and 0.26 MPa, respectively, for Formulation 1 and 2, which satisfies the requirements of EN 998, DIN 18550, it must be noted that the gap occurred on the material, it follows that the contact layer " Plaster - base " has a high adhesive strength. The ability to deform elastoplastically perlite provides the stress relaxation at the boundary between the plaster and plaster base, unlike traditional plasters quartz sand prone to cracking and flaking. All these can be recommended for use in the compositions developed as insulation finishing material.

Full-scale testing of the developed compositions on the basis of - of sand-lime brick masonry showed good adhesion of insulation solution for various reasons. Designed plasters are characterized by good workability and plasticity, high adhesion when applied to the substrate.

Insulating plaster solution based on expanded perlite provides ample opportunities for builders thermal protection of buildings from different wall materials, with plaster vapor permeable and allows to provide the required conditions for thermal protection of buildings.

CONCLUSION

Establishing the possibility of establishing effective insulation solutions on the basis of dry construction mixtures, taking into account the affinity of the structures of the components, by optimizing the micro-and macrostructure, through the use of composite binding specific composition. The compositions of composite binders for insulation solutions based on local raw materials and plasticizers. The composite binders optimal composition have a strength greater than the strength of the cement without an additional 82,5% higher and reaches a compressive strength of 95.2 MPa. Analysis showed that the microstructure is determined to a large extent thermally insulating properties of the solution. Perlite its chemical properties may be classified as putstsolan material which has a high content of amorphous SiO_2, Al_2O_3 and low CaO. Found that between cement paste and perlite are chemical interactions. The primary reaction is the interaction of groups of SiO_2 or Al_2O_3-SiO_2 with OH^- ions. In intergranular liquid phase ions $[SiO_4]^{4-}$ come into interaction with Ca^{2+} ions from the slurry and are attached to the OH the formation of a new phase-hydrates C-S-H. Microprobe technique analysis established that between the cement paste and perlite are reacted with an additional form hydrogarnets silicate and calcium, besides the subtle layer of crystalline hydrate form tumors. It was revealed that porit cement with additives significantly higher compared with porit without additivite cement.

Conclusions: When the minds of thermal insulation solutions with specified characteristics used, the authors proposed the law of affinity structures in construction materials, allowing to predict and obtain building composites with desired properties. Practically proved that the use of the proposed approaches for the creation of the material may get effective insulation solutions with high heat-shielding properties.

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