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Composite Binders on the Basis of Pearlite Raw Material of Transbaikalia

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Abstract: The study deals with the use of natural pearlite to obtain composite binders. It was investigated the influence of mechanical activation process of natural pearlite on its pozzolanic activity and the comprehensive assessment was carried out of ultrafine pearlite as the basis of organomineral additive and part of a multi-component fine cement and low water requirement binder. Concretes with low water requirement binder and pearlite were obtained and investigated.

Key words: Composite binders, pearlite, mechanical activation, multi-componentfine cement, low water requirement binder

INTRODUCTION

The further development of civilization is decelerated by lack of energy resources. This is especially significant for the construction industry. Considerable energy savings can be achieved by using specially prepared raw materials (Lesovik *et al*., 2007, 2009a; Lesovik and Strokova, 2006; Lesovik, 1994; Gridchin *et al*., 2008). Examples of these raw materials are volcanic rocks of the Republic of Buryatia.

Currently, using silicate and aluminosilicate materials which is rich in the Republic of Buryatia (quartzite, pearlite, zeolite, volcanic slags) on existing production facilities can will organize the production of cement-low and cement-less composite binders and construction materials and products based on them: wall blocks and panels of aerated concrete, effective thermal insulation materials and products with using the activation modification of raw material in efficient mills.

To achieve these purposes it is necessary carrying out fundamental and applied research on complex use of pearlite raw materials for the production composite binders, materials and products based on them.

"Mukhor-Tala" pearlite's deposit (Republic of Buryatia) the only one in Russia where in 2001 carried their mining and processing. Investigations of pearlite as an active mineral additive are especially topical due to modernization LLC "Timlyuysky Cement Plant" (Holding Company "Siberian Cement") and commissioning by LLC "Timlyuysky plant" a new production of cement grinding with capacity of 150,000 tons per year. Both companies are located in the immediate vicinity of "Mukhor-Tala" pearlite'sdeposit. Scientists of Belgorod State Technological University named after V.G. Shukhov and East-Siberia State University of Technology and Management carried out investigations to obtain Composite Binders (CB) using pearlite materials: lime-pearlite binder, aluminosilicate composite binders Multi-Component Fine Cement (MCFC), Low Water requirement Binder (LWB), composite binders with ultrafine perlite and Organomineral Additives (OMA) which allow to develop recommendations on the efficient use pearlite raw materials (Urhanova *et al*., 2006; Sulimenko and Urhanova, 2006; Urkhanova *et al*., 2011).

Interest is the production of composite binders with ultrafine perlite and OMA and LWB using pearlite raw materials.

MATERIALS AND METHODS

In current research to obtain composite binders were used Portland cement CEM I 32.5N (LLC "Timlyuysky Cement Plant"), Vitrified (VP) and Crystallized (CP) pearlite of "Mukhor-Tala" deposit (Republic of Buryatia), super plasticizer C-3®. Pearlite applies to magmatic rocks and is one of the volcanic glass. Structural water is 1-6% of pearlite. In vitreous pearlite content of glass phase was 60-80% in the crystallized pearlite -30-50%. The total reserves of pearlites from the Mukhor-Tala volcano are a few tens of millions of cubic meters. The chemical composition of pearlite is shown in Table 1.

Ultrafine pearlite for MCFC and organomineral additive were prepared by a two-stage milling in a ball mill of periodic action "MSF/12" and a centrifugal planetary mill "SAND". LWB was obtained with consistent milling of pearlite rocks (0-70% weight) with OPC and super plasticizer C-3® (1-2% weight). Specific surface area of LWB is 450-480 m^2/kg. From these binders were

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Table 1: Chemical composition of pearlite "Mukhor-Tala" deposit

Oxides	Content percentage by weight
SiO_2	71.40
Al_2O_3	12.10
CaO	0.52
Fe_2O_3	0.77
MgO	0.37
K_2O	3.21
Na_2O	5.20
FeO	0.43
SO_3	-
LOI	2.87

prepared samples with dimensions 20×20×20 mm. Samples were stored in molds at t = 20-22°C, relative humidity of 90-95% and without the molds above the water for a period of 28 days.

Physico-mechanical properties of binders were determined in accordance with Russian national standards GOST 310.2-76, 310.3-76 GOST, GOST 310.4-81.

The combined thermogravimetric and differential thermal analysis was performed on the derivatograph Q1500 D (MOM Paulik-Paulik-Erdey).

Phase composition of materials was determined on X-ray difractometersDRON-3, D8 ADVANCE BRUKER AXS. The structure of LWB was studied using a scanning electron microscope JEOL-JSM-6510LV.

RESULTS AND DISCUSSION

In obtaining of CB at an early stagethe effect of mechanical activation process of natural pearlite on the pozzolanic activity were studied and comprehensive assessment was carried out of ultrafine pearlite as the basis of organomineraladditive and part of CB. For this purpose, the milling of pearlite was performed in two stages: in 12 L ball mill for 6 h to obtain a finely dispersed pearlite; in a planetary mill for 1 h to obtain ultrafine pearlite.

Comparison of thermograms of natural and ultrafine pearlite (Fig. 1) reveals the following differences. Nature perlite DTG curve has two fuzzy effect of mass loss associated with the removal of adsorption (80°C) and hydrate (270°C) water which according to its temperature is crystallized and located in the form of molecules into the structural cavities of the pearlite grid without affecting at its degree of bonding.

On the DTG curve of ultrafine pearlite quite clearly is fixed effect of mass loss at 650°C, typical for the removal of constitutional water. This can be explained by the fact that the process of mechanical activation led to a redistribution of hydrate water in the material according to the following mechanism: bonds Si-O-Si and Si-O-Albreak and form two differently charged unstable "radicals":

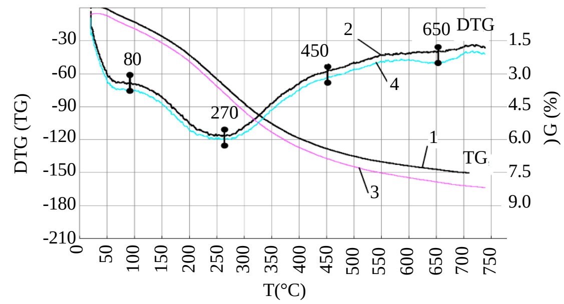

Fig. 1: Thermograms of; 1, 2: natural and 3, 4: ultrafine pearlite

$$\equiv \text{Si-O-Si} \equiv \rightarrow \equiv \text{Si-O-} + \equiv \text{Si+}$$
$$\text{or} \equiv \text{Al-O-Si} \equiv \rightarrow \equiv \text{Al-O-} + \equiv \text{Si+}$$

These "radicals" show large reactivity to the molecules of crystallization water forming OH^- groups in the pearlite structure:

$$\begin{matrix} \equiv \text{Si-O}^- & & \equiv \text{Si-OH} \\ & +H_2O \rightarrow & \\ \equiv \text{Si}^+ & & \equiv \text{Si-OH} \end{matrix}$$

Or:

$$\begin{matrix} \equiv \text{Al-O}^- & & \equiv \text{Al-OH} \\ & +H_2O \rightarrow & \\ \equiv \text{Si}^+ & & \equiv \text{Si-OH} \end{matrix}$$

Thus, the process of mechanical activation leads to depolymerization of structural grid of pearlite and consequently, increases its activity as the pozzolanic additive. Results of determining pozzolanic activity of fine and ultrafinepearlite by the method of absorption CaO are shown in Fig. 2. Pozzolanic reaction with perlite can be represented by the following scheme:

$$\begin{aligned} & mR_2O \cdot pAl_2O_3 \cdot nSiO_2 \cdot gH_2O + xCa(OH)_2 + yH_2O = \\ & CaO \cdot kSiO_2 \cdot tAl_2O_3 \cdot aH_2O + mR_2O \cdot (n\text{-}k)SiO_2 \cdot bH_2O + \\ & (x\text{-}z)CaO \cdot (p\text{-}t)Al_2O_3 \cdot (g+x+y\text{-}a\text{-}b)H_2O \end{aligned}$$

Identification of pozzolanic reaction products is difficult in the first place, due to the impossibility of their complete separation from the amorphous phase (of pearlite) and secondly because of their multicomponent character and low degree of crystallinity. By X-ray analysis (Fig. 3) with a sufficient degree of reliability in the products of the interaction of pearlite with $Ca(OH)_2$ have been identified: calcite $CaCO_3$, aluminum substituted tobermorite, silica SiO_2 and gehlenite.

Thus, fine and ultrafine perlite by the quantity of absorbed CaO (185 and 250 mg g^{-1}, respectively) refer to additives with high pozzolanic activity such as a flask, tripoli, diatomite, ash and some others.

The results of a comprehensive study of pearlites give reason to assume that incorporation into the composite binders of ultrafine and fine-of pearlite lead to the realization of a dense structure and high technical properties of artificial stone (Lesovik *et al*., 2010, 2009b, 2011; Shejchenko *et al*., 2011; Gridchin *et al*., 2005; Prokopetc and Lesovik, 2005; Khozin *et al*., 2011).

All molded from mixtures of "cement-perlite" samples were hardened on equal conditions: the daily exposure in molds at normal temperature and humidity conditions and then samples were demolded and cured in water at a temperature of 22±3°C. The tests of the compressive strength were carried out after 1, 3, 7, 14 and 28 days. (Fig. 4).

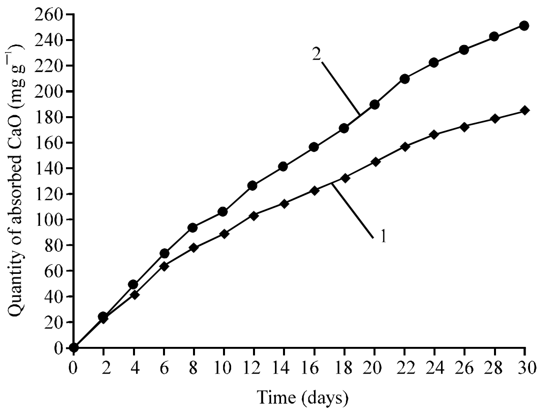

Fig. 2: Kinetic curves of the absorption of calcium oxide with; 1: fine and 2: ultrafine pearlite

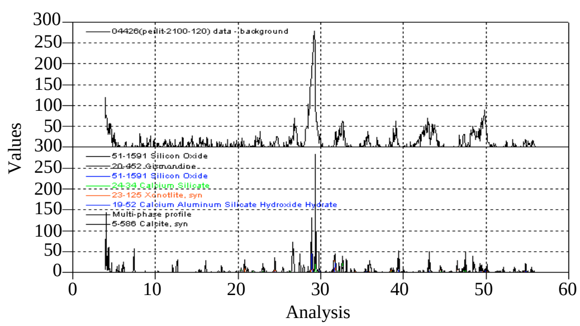

Fig. 3: Identification the products of pozzolanic reaction of pearlite with $Ca(OH)_2$

It was investigated the possibility of using vitrified (glass phase content 60-80%) and crystallized (glass phase content 20-40%) pearlites of Mukhor-Tala depositto obtain LWB (Table 2).

In LWB, it is possible to replace 50-70% of OPC on the vitrified pearlite with the achievement of the compressive strength exceeding the strength of the OPC. Compressive strength of LWB with 30-50% of crystallized pearlite is comparable to the compressive strength of OPC. This is confirmed by the known data: the mineral additive is more active when it has less orderly structure.

As a result of mechanical action on a binary system of "an ionic crystal-a surfactant" irreversible interaction carried out on the donor-acceptor mechanism anion and cationsurfactant with a newly formed surface of the crystals due to the presence on it at the time of the formation of specific electron σ-centers of donor and acceptor type. Furthermore, when a mechanical impact the degradation of the surfactant occurs with appearance of free radicals.

The phase composition of LWB samples, according to XRD and DTA and electron microscopy showed significant content of calcium hydrosilicate type CSH(I).

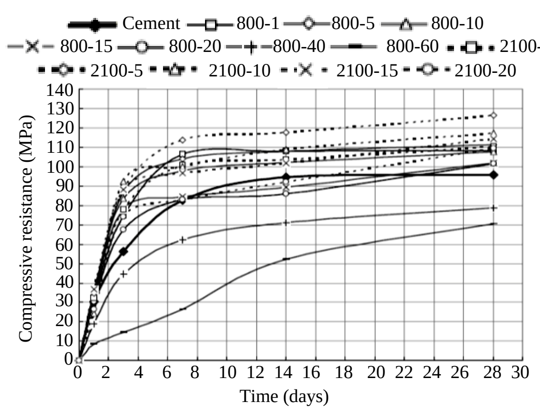

Fig. 4: Kinetics of synthesis composite binders' strength: solid lines a series of binders with the fineperlite, dotted with ultrafine perlite

Table 2: Characteristics of LWB with the use pearlite rocks of Mukhor-Tala deposit

	Vitrified pearlite			Crystallized pearlite			
Indicators	LWB-30	LWB-50	LWB-70	LWB-30	LWB-50	LWB-70	LWB-100
Standardconsistence (%)	27.5	25.8	25	26.6	26.2	25.8	20
Initial setting (min)	170.0	150.0	130	135.0	130.0	120.0	120
Final setting (min)	245.0	220.0	210	270.0	255.0	245.0	205
Compressive strength (MPa)							
3 days	35.0	50.0	58	17.0	29.0	37.0	60
28 days	57.0	73.0	82	28.0	48.0	57.0	90

Table 3: The main properties of concrete on the basis LWB with the use pearlite

Content in concrete mix (kg/m^3)							Compressive strength (MPa)		Water absorption (wt.%)
OPC	LWB-100	LWB-70	LWB-50	Sand	Granitescreenings 2.5-5 mm	Water	3 days	28 days	
550	-	-	-	687	687	209	28	44	5.5
-	550	-	-	687	687	165	44	59	3.8
-	-	550	-	687	687	170	37	49	4.5
-	-	-	550	687	687	175	31	45	5.1

Intensity of the peaks attributed to the lime decreases during hydration cement-low binders in comparison with cement. In the cement stone observed crystalline structure with germinating and fastened together needlelike crystals of tobermorite, ettringite, $C_2SH(A)$ and so on. There are pores of different diameters and inclusions of unreacted amorphous grains of cement and pearlite particles.

Concretes on the basis of LWB have an improved rheological properties of concrete mixes, reduced water consumption through, the use of organic water reduction reagent in the composition of binders, reduction of more expensive component of concrete-portl and cement due to replace up to 30-50% by aluminosilicate effusive rocks. They have increased strength characteristics, including the initial period of hardening, decreased water absorption of concrete (Table 3).

CONCLUSION

Analysis of the results leads to the following conclusions:

- The introduction of fine and ultrafine pearlite to 20% leads to an increase in strength as compared with the strength of the base cement
- Degree of strengthening grows with increasing fineness of pearlite. Most effective is 5% additive of ultrafine pearlite (increased 28 day strength of 32%)
- Introduction of pearlite leads to rapid strength development in the early stages of hardening; so, the strength of 3 daily conglomerates with an additive of ultrafine pearlite from 5-15% in comparison with the base cement higher to 58-64%
- Strength of concrete with LWB is in the range 45-59 MPa after 28 days of normal curing which exceeds the strength of concrete using OPC on average 10-30% and decreases the water absorption of 20-30%
- Increase in strength is related to the reduction consumption of water to obtain concrete mix with the same workability, the acceleration of the pozzolanic reaction and formation CSH(I)

Thus, research has shown promising the use pearlite raw materials of "Mukhor-Tala" deposit for the production of composite binder. This will expand resource base for the production of construction materials and products, increase the range of proposed materials use some capacity of currently idled construction industry enterprises.

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