Production Engineering and Properties of Low-Energy Masonry Cement

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Abstract – Relation between sustainability and cement manufacture that can be obtained by replacement of clinker with zeolie and limestone additives which decreases the use of energy resources and reduce CO_2 emissions in cement production is shown. It is shown that a synergistic combination of mineral additives of different groups with substantial reduction of high energy-consumption clinker component in the low-energy masonry cement allows to improve rheological properties and provides acceleration of strength increase, to improve quality parameters of mortar mixes and building mortars.

Key words – low-energy masonry cement, multicomponent cement, mineral additives, strength, building mortar, reducing CO_2 emissions.

I. Introduction

Low-energy and multicomponent cement for building mortar and low-strength concrete is actual for further development of energy and resource saving technologies in the building industry and providing high performance of building works. Multicomponent composition of cement allows to manage the processes of cement matrix of mortar structure formation and to obtain it with predetermined properties [1, 2]. Thus, mineral additives, among them widely used technogenic waste (domain granulated slag, fly-ash, etc.) plays the key role for building mortars. Simultaneously, the significant reduction of energy intensity of cement and mortar is also achieved by natural additives [3]. Adding some active mineral additives and fillers to cement significantly influnces on technological factors of mortar mixture and the strength of mortars.

II. Requirements to materials for production of masonry cement

Portland cement clinker with normalized mineralogical composition by JSC "Ivano-Frankivskcement" (mass.%: C_3S – 59,72; C_2S – 14,46; C_3A – 7,4; C_4AF – 11,89) with activity 50 MPa was used for production of low-energy masonry cement. Furnace granulated slag (in the total CaO, SiO_2, Al_2O_3, Fe_2O_3 are 92-96 mass.%), zeolites from Sokyrnytsky field (extent of active SiO_2 – 75,34 %). The limestone with content of $CaCO_3$ 95 mass.% were used as active mineral additives.

Mortar prisms (40×40×160 mm) with cement–sand–water ratio (1/3/0.5) were prepared. The compressive and flexural strength were determined on two mortar prisms for each testing age according to EN 196-1. Physical and mechanical tests of cements and cement-sand mortars were carried out according to usual procedures. Sulphate resistance of cements was determined by the accelerated method.

Study of fractional composition and grinding fineness of cements were carried out by sieve analysis and by determination of the specific surface area by Blaine. Physical and mechanical properties of the cements were carried out according to current standards and generally accepted methods [4]. The study of the phase composition of cement's hydration products was made using complex of modern physical and chemical methods of analysis: X-ray diffractometry (DRON-2.0), chemical composition of cements and mineral additives was defined using X-ray spectrometer ARL OPTIM'X. The chemical composition of mineral additives is presented on Fig.1.

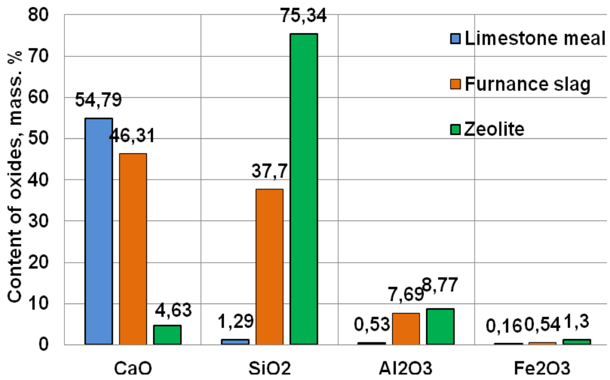


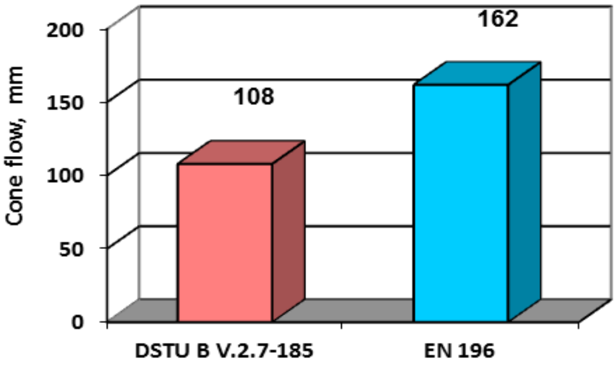
Fig. 1. The chemical composition of additives

III. Experimental part

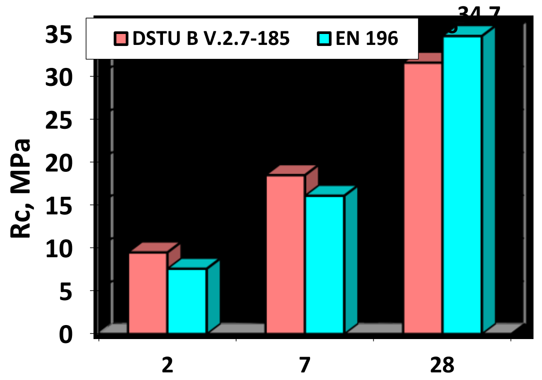
Multicomponent cement was received by milling of Portland cement clinker, mineral additives of hydraulic and pozzolanic action and gypsum dihydrate into ball mills which works in a closed loop milling on JSC "Ivano-Frankivskcement" factory. Water demand of multicomponent cement (SSA=7600 cm^2/g) is 30,8%, initial setting time – 160 min, final – 210 min, volume coefficient of water separation is 4,8%. Standard cone flow for multicomponent cement according to DSTU B V.2.7-185 and EN 196 is 108 and 162 mm (Fig. 2, a).

Masonry cement complies to class MC 22,5 X DSTU B EN 413-1:2015 according to EN 196. Compressive strength after 7 and 28 days of hardening is 16.1 and 34.7 MPa respectively (Fig. 2, b).

Lines of calcite (d/n=0,303; 0,249 nm) and crystalline hydrate phases: calcium hydroxide (d/n=0,490; 0,263; 0,192 nm), ettringite (d/n=0,973; 0,561 nm) and a certain amount of calcium hydroaluminate C_4AH_{13} (d/n = 0,81 nm) are observed on diffractograms of cement stone based on MC 22,5 X (W/C=0.45) after 1 day and 28 days of hydratation by the method of X-ray analysis. After 28 days of hydration it is observed a decrease of calcite lines $CaCO_3$ and observed presence of intensive libes of hydrocarboaluminate $C_3A{\cdot}CaCO_3{\cdot}H_2O$ (d/n=0,76; 0,380 nm), which indicates partial transformation of hexagonal hydroaluminate into hydrocarboaluminate.



a



b

Fig. 2. Standard cone flow (a) and compressive strength (b) of masonry cement

The addition of highly active mineral additives to cement MC 22,5 X allows to reduce the calcium hydroxide in 2.2 times compared with a stone based on CEM I after 28 days of hydration. The dense structure of the hydrated solid phase is provided by AF_m- i AF_t-phases into gel-like CSH phase (Fig. 3). Active forms of SiO_2 and Al_2O_3 in the composition of aluminum-containing pozzolana promote better binding of calcium hydroxide into low-basic calcium hydrosilicates, which indicates that the acceleration of puzzolanic reaction. Fine limestone stabilizes hydration products of tricalcium aluminate with the formation of hexagonal hydrocarboaluminate $C_4A{\cdot}CO_2{\cdot}12H_2O$ during hydration of clinker component [1, 5].

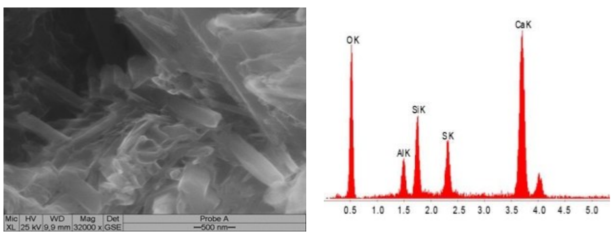


Fig. 3. The SEM images and the EDX spectrum of paste based on masonry cement after 28 days of hardening

The use of aluminum-containing pozzolanic additives promotes fuller binding of calcium hydroxide in calcium hydrosilicates which indicate acceleration of the pozzolanic reaction. Carbonate additives in multicomponent cements act as a microfiller and active components relatively to aluminate aluminoferrite phases.

Synergistic combination of mineral additives of different groups with substantial reduce of high-energy-consumption clinker component content in multicomponent cement MC 22,5 X allows to improve the technological characteristics of mortar mixes and quality of buildings mortars. This cement is characterized by high processability, plasticity and adhesion, which significantly accelerates the speed of construction and reduces production costs for materials in the preparation of masonry and finishing mortars. Cement is used for finishings and plaster works, construction of couplers, laying of walls of cellars, as a basis for laying pavers, dry mixes, special works in construction and others. Low-energy-consumption multicomponent cements with addition of granulated slag, natural pozzolane and carbonate microfiller are characterized by a decreased production costs and increased environmental friendliness. Reduction of clinker component in cement for masonry MC 22,5 X provides lower emissions of CO_2 in 2,14-2,37 times, that refers it to ecocement type.

Conclusion

The development of low-energy-consumption cement with partial replacement of Portland cement clinker with additional cementing materials together with synergetic combination of pozzolanic additives of hydraulic action and microfiller, which are characterized by reduced energy consumption and meet the requirements of modern construction industry, and protection of the environment (reduction emissions of CO_2) - is one of the main aspects of balanced development in construction.

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