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Influence of nanosized silica component on physical and mechanical properties of a composite gypsum binder

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Abstract: The work presents the results of development of the composite gypsum binder (GB) with nanostructured binder on the basis of silica component (NBC). Introduction of NBC changes the kinetics of hardening, as well as improves physical and mechanical properties of gypsum system. Analysis of the microstructure of the GB has demonstrated in the presence of the NB the size and morphology of crystals are changed, promoting the formation of fine-crystalline structure and increase the contact area between new formations, compared to NBC – free gypsum system.

Experimental studies have shown that the mechanical properties of the composite gypsum application of NBC increased, reduced water absorption, density increases, and increases the setting time.

Introduction

Due to the constantly increasing requirements to ecological safety of construction materials and their production as well as to energy saving, the reorientation of the construction industry basis to more efficient composite binders. Among of analogue materials meeting the above requirements [1, 2] it is should be noted a gypsum composites, due to the new complex of properties, which are unusual for raw components. However, the introduction of mineral components in any binder system associated with the change in the kinetics of hardening, as well as physical and mechanical properties [3] that is very important in gypsum materials.

Thus, in the paper the possibility of creating a free of cement composite gypsum binders using silica component (NBC).

Experimental part

2.1 Materials and equipment

In the paper semi-aquatic gypsum as well as nanostructured silicate binder (NB) [3] as silica component were used. The NB is an inorganic multi-mineral polydisperse system containing 5–10% of nano-component. NB is obtained by wet grinding of quartz sand in a ball mill. Microstructural studies of experimental samples were carried out on the scanning electron microscope (SEM) with a high resolution Supra 50 VP (LEO, Germany, 2003. Determination of

compressive and flexural strength tests are carried out on a hydraulic testing machine PGM 100, at an average loading rate of 1 MPa/s.

Normal consistency is characterized by a diameter of gypsum paste flowing, arising from the cylinder when it is pulled up. Cylinder is made from stainless steel with brushed inner surface with height of 100±0.1 mm and inner diameter of 50±01 mm.

2.2 Preparation of samples

In this work the preliminary investigations was carried out to establish the optimal range of NBC concentration in gypsum system where the output parameters were mechanical characteristics. When synthesis of composite gypsum binder, the NBC was administered in content of 10–30 % (by wt.). Water requirement per 1 m^3 of moulding mixture was controlled by normal density value of the gypsum paste. As a reference binder composition was zero-admixture one. «Water-gypsum» ratio for reference and other samples and was 0.5, taking into account the humidity NBC [4].

In this study the most rational method of obtaining the HC, which consists in the preliminary introduction of the NBC in the water, to obtain water suspension and further introduction of gypsum system. This method allows obtaining a homogeneous mixture for 30 seconds of mixing after the introduction of gypsum binder. It should be noted the NBC is a mineral suspensions with humidity of 14–20 %. Therefore it is suggested the introduction of NCC in dry state.

Obtained HC was moulded into the open forms of 160 × 40 × 40 mm. Curing process was in ambient conditions (at temperature of 22±2 ^{o}C) during 2 hours. After that samples were dried at a 35 ^{o}C, for a day.

Results and discussion

3.1. Analysis of physical and mechanical characteristics

Results of physical and mechanical characteristics are presented in table 1.

Table 1

Characteristics of GB

№	The binder composition, [%]		Flow, [cm]	Curing time, [s]		Density, [kg/m^3]	Compressive strength, [MPa]		Tensile strength, [MPa]	
	NBC	GB		Initial period	Final period		after 2 h	after 24 h*	after 2 h	after 24 h*
1	-	100	18,0	535	985	1201,1	5,04	10,19	2,69	3,7
2	10	90	18,2	566	1082	1263,2	4,91	11,88	2,62	4,0
3	15	85	18,6	777	1239	1285,4	4,68	14,13	2,56	5,1
4	20	80	19,2	805	1330	1307,5	4,42	13,97	2,49	5,0
5	25	75	18,3	948	1549	1318,9	4,29	11,61	2,40	4,3
6	30	70	17,8	1025	1634	1330,2	4,05	9,46	2,34	3,5

*———————————————

Isotermal period at 35 ˚C

When studying of the influence of the NBC on the rheological characteristics of binder system the flow of experimental compositions was determined.

Introduction of the NBC up to 25 %, the plasticizing effect. At the same increasing the concentration up to 30 % leads to flow ability decreasing of binder system.

Analyzing the results of the obtained samples with content of NBC, cured at ambient conditions for 2 hours after moulding demonstrate reducing of the strength.

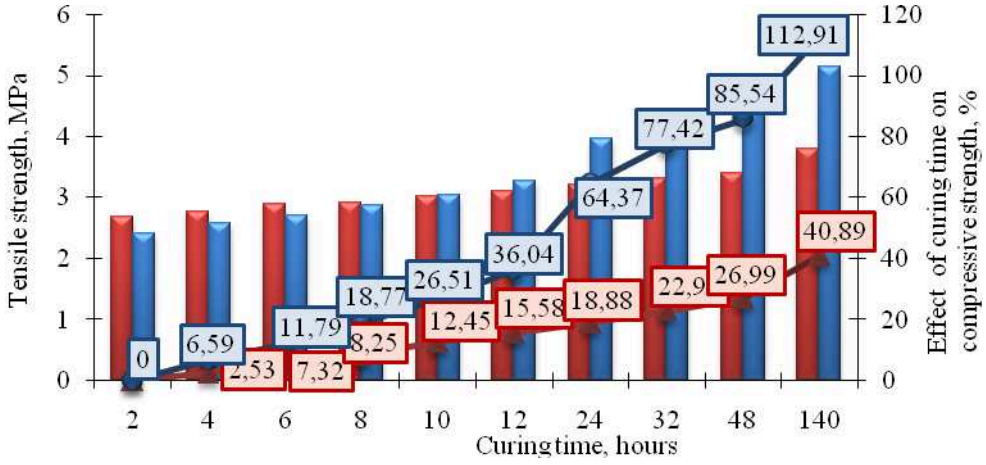
On the other hands, the content composites with NBC content from 15 to 20 % after the isothermal exposure during the day, give the largest values of the compressive and flexural strength that higher to 40 % in comparison with reference one. While the density of samples containing NBC is not increases with increase of NBC with increase of NBC content.

Also, analysis of experimental samples after isothermal curing that were exposure in water medium for 4 hours has shown, the NBC reduces the water absorption.

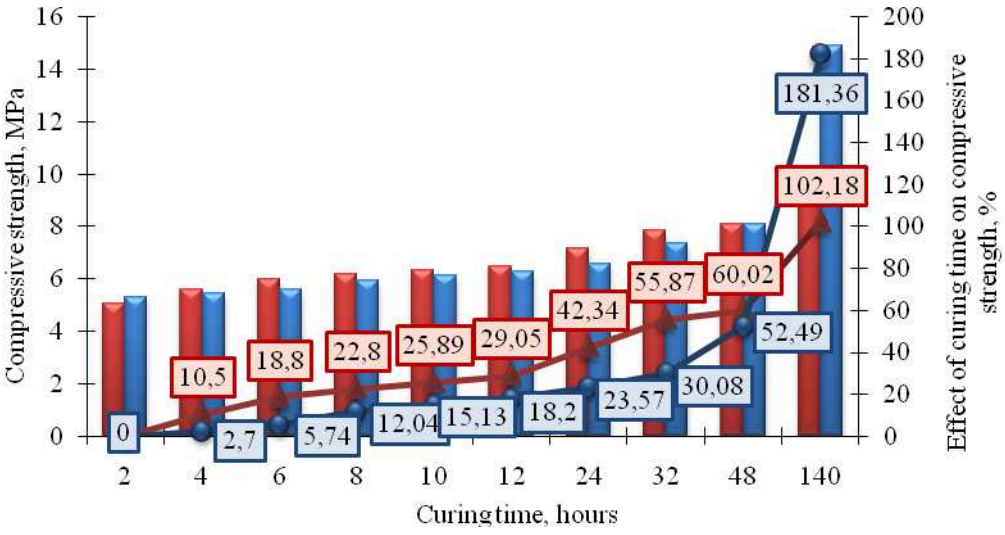
Basing on the experiment data the optimum range of NBC content in gypsum system is 15 %. The process of formation of gypsum paste structure is carried out during a few hours after mixing with water gypsum binder, and further hardening process takes place due to desiccation. On the basis of the data obtained the study of kinetics of hardening for samples containing 15% of NBC vs. the reference sample was performed. Measurement was held at 2, 4, 6, 8, 10, 12, 24, 36, 48, 140 hours.

To analyze the rate of change of physical and mechanical characteristics (yield compressive and flexural strength, as well as desiccation) were calculated deviations (in %) depending on curing time period (Fig. 1).

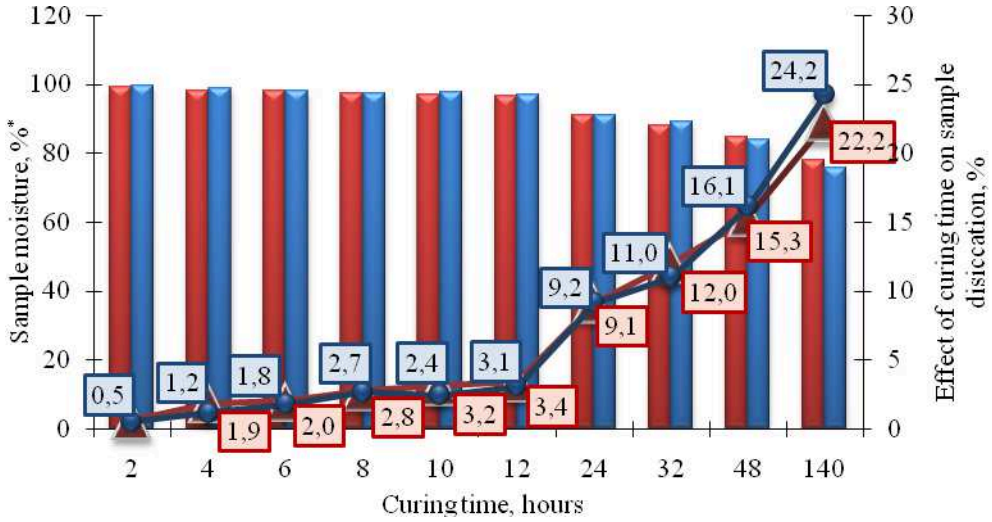
When processing the experimental data, statistical methods were used.



a



b



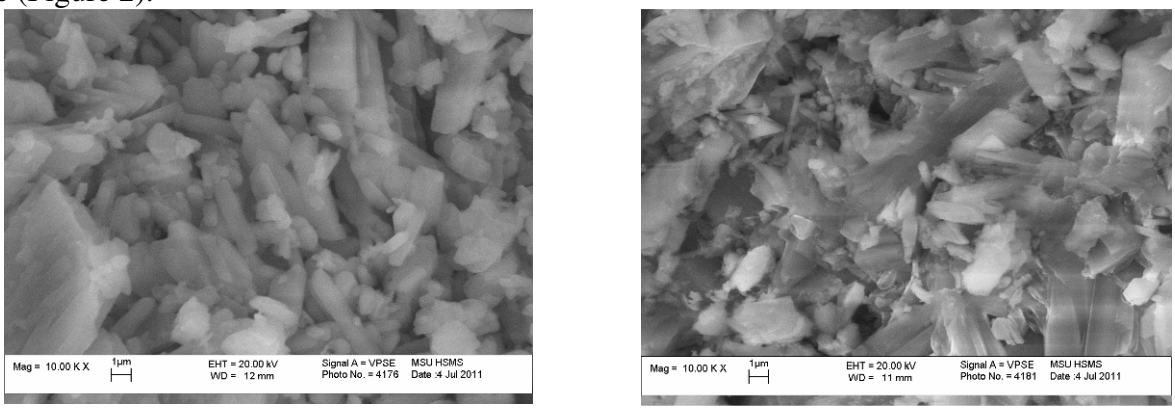
c

Fig. 1. Effect of curing time and composition on physical and mechanical properties
-GB; -CGB (NSC 15%)
a – tensile strength;
b – compressive strength;
c – moisture of samples;
* as 100% was accepted moisture of 1 hour- samples

Analysis of the obtained data allows make a conclusion the introduction of the NBC into gypsum system affects the kinetics of hardening process. Increase the compressive and flexural strength (as a reference was used the strength of specimens at the age of 2 hours) for reference samples takes place regularly, that is attributed to desiccation, whereas the introduction of the NBC in the gypsum system changes the structure formation. Tensile strength of GB samples higher than the reference ones during all time of the experiment. The main growth of the compressive strength is observed after 48 hours of curing. Such a change in the strength characteristics, over time, in NC system can be explained by the formation of new phases [5] those are responsible for the increase in tensile strength characteristics.

3.2. Analysis of the structure of composite gypsum binders.

To study the morphology the SEM images of the control and experimental composition were made (Figure 2).



a *b*

Fig. 2 Microstructire of gypsum binders:
a – reference sample; b – GB (15 % of NBC)

Analysis of the microstructure obtained with scanning electron microscopy has shown the GB has xenomorphic grain structure with high content of low-dimensional mineral components (Fig. 6, b) in contrast to the control sample, which is characterized by a coarse-grained structure with

significantly manifested idiomorphism of gypsum crystals (Fig. 6, a). This is the reason of increasing the density and strength properties of the GB, in comparison with the reference sample.

Conclusion

In the work the nature of the exposure concentration NBC on physical-mechanical properties of a composite gypsum binder was done.

The results of the experiment showed that the optimal content of the NBC in the gypsum system is 15–20 % that provides increase of durability up to 40 %. Further increase of NBC content of is not reasonable due to decrease in the strength properties that can be explained with overload system by solids and the lack of dispersion medium participating in the hydration process.

It is experimentally established the introduction of optimum content of NBC provides with plasticizing effect that allows reducing the «water –gypsum» ratio.

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