Modern concretes based on the Rapid-Hardening Portland cement compositions

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In the paper results of testing of building and technical properties of High Performance Concretes (HPC) based on the Rapid-Hardening Portland cement compositions with complex chemical admixtures are shown.

It was observed, that strength of developed concretes after 2; 7 and 28 days of hardening is respectively 54.4; 60.1 and 80.9 MPa, what gives the reason to determine these materials to Rapid-Hardening and High Strength Concretes. The modern concretes based on the Rapid-Hardening Portland cement compositions are characterized by better construction and technical properties, which provide durability of constructions in different conditions.

Key words – Complex chemical admixtures, Rapid-Hardening Portland cement compositions, High Performance Concrete (HPC), Self-Compacting Concrete (SCC), building and technical properties.

I. Introduction

Modern concretes with high flowability such as High Performance (HPC) and Self-Compacting Concrete (SCC) were developed in Japan about 20 years ago in order to reach durability of concrete constructions. Some investigations have been carried out to achieve a rational mix design for a modern concretes, which is comparable to ordinary concrete. Self-Compacting Concrete is defined so that no additional vibration is necessary for the compaction. The development and use of modern high flowable concretes in many countries have shown that it can successfully be produced from a wide range of materials, especially cement replacement materials (supplementary cementitious materials) and superplasticizers. It is difficult, and often impossible, to predict the properties of the concrete. The task of choosing materials and their relative proportions should be done in complex [1, 2].

The compositions of the mixtures for the modern concretes differ from the compositions of other, traditional concretes. The main difference consists in the higher ratio of the fine fractions ≤ 0.125 mm. The fine fractions, the optimum water content and complex chemical admixtures can provide a stable suspension with high viscosity. This suspension flows spontaneously keeping the aggregate grains without segregation [3, 4].

The modern concrete is a material of polystructural composition, which is based on multistage organization (structure of any lower level is the component of structural heterogeneities of higher level on principle „compo in a compo"). In this case mesostructure (Portland cement compositions and fine aggregate) of concretes has the major role in flowability and homogeneity of mixtures concrete resistance to mechanical loading [3, 5].

Considering the economy and durability of modern concretes compaction of the mixture are the main parameters. As a result of the mix design, some properties of the hardened concrete can be different for modern high flowability concretes in comparison to normal vibrated concrete. Therefore, it is important to verify the mechanical properties of modern concrete before using it for practical applications, especially if design rules are applicable or if they need some modificators [6].

Rapid-Hardening Portland cement compositions with complex chemical admixtures are already used in the modern concrete technology. The increasing of the complex chemical admixtures content in the Portland cement compositions and concrete mixture provides better workability, stability of the mixture without segregation, high strength development and freeze-thaw resistance. These admixtures provide increasing of durability parameters of hardened materials, such as strength, porosity and shrinkage, corrosion resistance, freeze-thaw resistance and the other properties [7, 8].

The designing of the Rapid-Hardening Portland cement compositions with complex chemical admixtures and building and technical properties of High Performance Concretes properties of their basis require further investigations.

II. Results and discussion

In the investigations ordinary Portland cement CEM I-42.5 was used Complex chemical admixtures were included in Portland cement compositions as modifiers. Two kinds of sands (sand 1 – 0-0.315 mm, sand 2 – 0-1.25 mm) and coarse aggregate were applied for concrete mixes. The improving of concrete properties achieved by using the polyfractional aggregates and their optimal packing in composite structure. The fine aggregates optimization in mesostructure of concrete was conducted. To provide the maximum packing density of fine aggregates particles 30 mass % of sand 1 (0-0.315 mm) and 70 mass % of sand 2 (0-1.25 mm) were used.

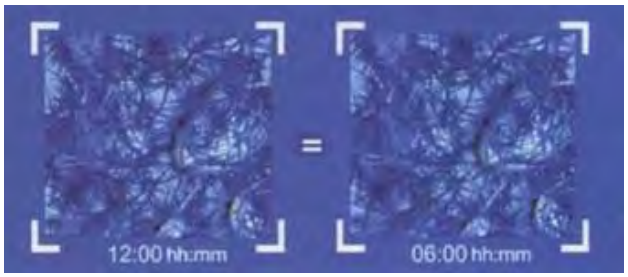
The fluidity of concrete mixtures was determined as the average of slump flowability. Physical and mechanical tests of cements and concretes based on Portland cement compositions were carried out according to usual procedures. The evaluation of the properties of Portland cement compositions was carried out through a flowing and compressive strength tests.

Modifying of Portland cement compositions by complex chemical admixture of polyfunctional action for obtaining binders materials with high exploitative properties has significant practical interest. Complex admixtures increase plasticity of cement composition with reduced water content and provide high strength due to formation of homogenous micropore structure.

The optimal content of complex chemical admixtures was determined by methods of mathematic modeling according to the criteria of flowability and strength of Portland cement compositions. The flowability (F) of optimal modifying mortars increased from 115 to 170 mm according to DSTU B V.2.7-187:2009 (technological effect).

The cement systems plasticized by superplasticizers provide reological effectiveness and hydration activity, which determine strength of binder materials at early and later age of hardening. At the same time water demand of superplasticized cementitious systems decreases on 23.1% due to significant effect of water reducing. The early strength (after 2 days) of mortars based on Portland cement compositions was 49.8 MPa (W/C=0.30). The results of investigations show that using of Portland cement compositions with complex chemical admixtures allow to increase compressive strength of mortars after 28 days of hardening in 1.4 time (F=110-115 mm). The strength of mortars based on Portland cement compositions with complex admixtures of plasticizing and accelerating action was 72.5 MPa at the age of 28 days. The using of complex modifiers in optimal contents allow to obtain Portland cements with high 28 days strength and Rapid-Hardening Portland cement compositions at W/C=0.40.

One of the innovative approaches of designing modern concretes is nanoscience and nanotechnology, which gives the possibility to control the structure formation of hydrated phases and Portland cement matrix with improved properties in the context of sustainable development. Using liquid admixtures X-SEED 100 (BASF) with synthetic crystalline calcium silicate (seed nanocrystals – Crystal Speed Hardening), which initiate crystal growth on the surface of the cement grains and also between them – in saturated solution (Fig. 1). This determines the acceleration of the binder hydration at low and high temperatures with reducing shrinkage and increasing durability of composites [11].



a b

Fig. 1. SEM pictures of Rapid-Hardening Portland cement compositions without (a) and with (b) X-seed

During the hydration process in the Rapid-Hardening Portland cement compositions with complex chemical admixtures there is a reaction in the unclinker part with formation of ettringite by a topo-chemical reaction, which provides the compaction of cement matrix and increasing strength of modern concretes.

Rapid-Hardening Portland cement compositions with complex chemical admixtures accelerate the increasing of strength, compact of concrete matrix and have a significant structure formatting role due to the creating of possibility of hydrate phase formation. Strength of modern concrete based on Rapid-Hardening Portland cement compositions (F=660-725 mm; W/C=0.35) after 2; 7 and 28 days of hardening is respectively 58.8; 66.5 and 67.9 MPa, which can be classified as Rapid-Hardening High Strength Concretes.

The modern concrete based on Rapid-Hardening Portland cement compositions are characterized by dense structure and high technical properties. Thus, high density causes the increasing of SCC waterproof to the class W20. The corrosion resistance of concrete test samples after 6 months of hardening in an aggressive environment increase compared to the specimens, which were stored in water.

Conclusion

The regulation and control of structure formation and properties of Rapid-Hardening Portland cement compositions with complex chemical admixtures give the possibility of producing modern Rapid-Hardening concrete. The using of complex chemical admixtures in Rapid-Hardening Portland cement compositions provides creation high flowability, viscosity, homogeneity and prevents segregation of modern concrete mixtures. High physical and mechanical properties of modern concrete based on Rapid-Hardening Portland cement compositions allows increasing durability and reliability of constructions in different exploitative conditions.

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