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SELF-COMPACTING CONCRETES, HARDENING AT DIFFERENT TEMPERATURE CONDITIONS

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In the article the features of reinforced concrete hardening at different temperature conditions and the current issues of preparation technology of Self-Compacting Concretes (SCC) on the basis of superplasticized cementitious systems, combining knowledge of structure and modifying Portland cement compositions "Portland cement – active mineral additives – microfiller – superplasticizer – accelerator of hardening" to search for rational making provision of technical and building properties of concrete in the changing factors of its composition, technology and exploitation are shown.

The physico-chemical peculiarities of hydration and hardening processes of superplasticized cementitious systems were established. The problem of obtaining Self-Compacting mixtures and Rapid-Hardening Concretes on their basis by the direct structure formation of cementitious matrix was solves. The optimization of Self-Compacting Concretes composition on the base of superplasticized cementitious systems with high early strength was carried out. The quality parameters of developed concretes were investigated and the effectiveness of their using in different temperature conditions was shown.

The results of the studies found that the use of the superplasticized cementitious systems allows to influence on technological properties and kinetics of structure formation and create concrete structure with improved construction and technical properties at a different temperature conditions. Technological solutions designing of superplasticized cementitious systems that solves the problem of obtaining the Self-Compacting Concretes (SCC) on their basis with using non-vibration technology are established. This creates an opportunity allows to solve the problem of obtaining for enabling early loading, reducing the production cycle, increasing turnover and formwork acceleration of monolithic buildings and structures at different temperature conditions.

Key words: polycarboxylate, fly ash, limestone microfiller, metakaolin, superplasticized cementitious systems, non-vibration technology, Self-Compacting Concretes, temperature conditions.

Introduction

Self-Compacting Concrete (SCC) was developed in Japan 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 SCC in many countries have shown that it can successfully be produced from a wide range of component materials, notably cement replacement materials (mineral additives) and superplasticizers (Urban, 2018).

The compositions of the mixtures for the SCC differ from the compositions of the other, traditional concretes. The main difference consists in the higher ratio of the fine fraction ≤ 0.125 mm. The fine fractions, the optimum water content and superplasticizer produce a stable suspension with high viscosity. This suspension flows spontaneously keeping the aggregate grains without segregation. The microfillers, such as fly ash, finely ground limestone, metakaolin and the other fine mineral additives are the components of fine fraction. The properties of concrete mixture and hardened concrete are significantly affected by the type of microfiller in cementitious system. In this case mesostructure (cementitious matrix and fine aggregate) of concretes has the major role in flowability and homogeneity of SCC mixtures concrete resistance to mechanical loading (Rakesh, 2015).

Considering the economy and durability of SCC the quality and the density of the concrete cover, as well as the compaction of the concrete are main parameters. As a result of the mix design, some properties of the hardened concrete can be different for SCC in comparison to normal vibrated concrete. Therefore, it is important to verify the mechanical properties of SCC before using it for practical applications, especially if the present design rules are applicable or if they need some modificators (Aggarwal, Siddique, Aggarwal & Gupta, 2008).

Fly ash, limestone microfiller and metakaolin is readily used in the SCC technology. The increase of the fly ash and metakaolin content in the mixture results in better workability at fairly high strength development and freeze-thaw resistance. In the presence of the limestone microfiller the stability of the mixture is affected and the segregation is not observed; however this additive is not used on such a large scale in SCC technology as the fly ash. These additives provide increasing of durability parameters of hardened materials, such as strength, porosity and shrinkage, corrosion resistance, freeze-thaw resistance and the other properties (Collepardi, 2010).

Self-Compacting Concrete (SCC) was developed in order to reach durability of concrete constructions. Self-Compacting Concrete is defined so that no additional vibration is necessary for the compaction. The development and use of SCC in many countries have shown that it can successfully be produced from a wide range of component materials, notably cement replacement materials (mineral additives) and superplasticizers. The task of choosing materials and selecting of their relative proportions should be done in complex. Therefore, the technology of modern construction in reinforced concrete urgent problem is to obtain Self-Compacting Concrete with high rheological properties that determine their durability at different temperature conditions with using non-vibration technology which improves productivity and increase the turnover of formwork (Runova, Gots, Rudenko, Petropavlovskyi, Konstantynovskyi & Lastivka, 2018).

Target of this article

The purpose of the work is the optimal design of technology of Self-Compacting Concrete based on superplasticized Portland cement compositions, which proved the rational solutions for concrete performance, technology and exploitation. Superplasticized cementitious systems allow to solve the problem of obtaining the Self-Compacting Concretes (SCC) hardening at different temperature conditions are established.

Techniques used

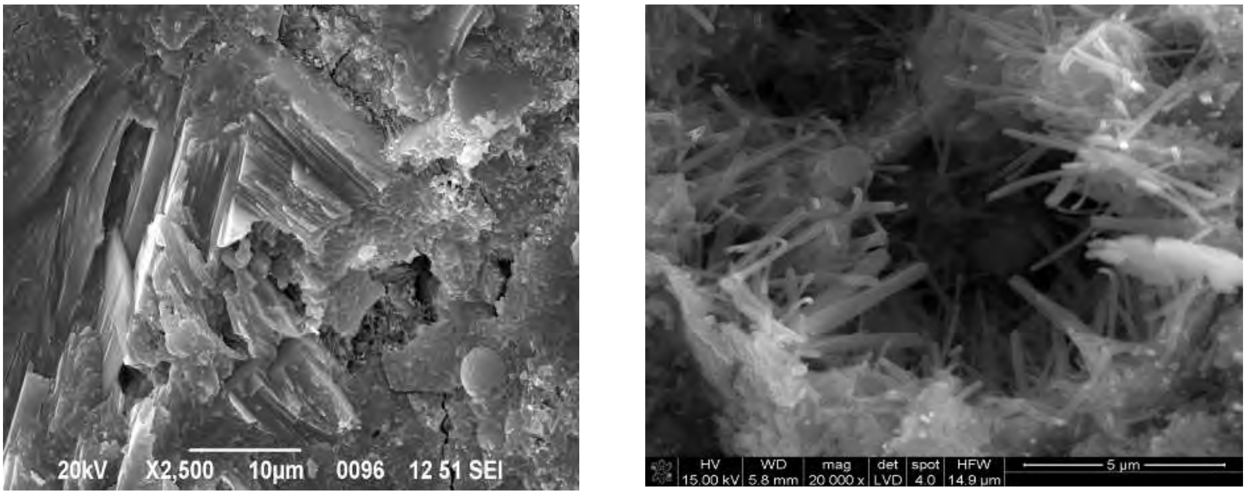
The fluidity of concrete mixtures was determined by FFB (Flieβmaβ –Flieβzeit – Bloker – Test), as the average of slump flowability and the viscosity as the time of flowability of concrete mix to get the slump flow T500 test. Physical and mechanical tests of concretes were carried out according to usual procedures. The electron microscopy analysis was used for investigation of superplasticized cementitious systems hydration processes (Vasim Nye, 2020).

The optimal content of mineral and complex chemical admixtures was determined by methods of mathematic modeling according to the criteria of flowability and strength of superplasticized cementitious systems and SCC on their basis (Shi, Krivenko & Roy, 2006). The using polycarboxylate and mineral additives provide the increasing of slump flow of concrete mixture up to 660–725 mm. This effect is observed due to the optimal distribution of particles in the system. At the same time the water is located between the grains of material playing the role of lubricant, which creates the great conditions for particle slipping, minimization of internal friction and increasing the flowability with the same W/C ratio

(W/C=0.35). It should be admitted that high flowable concrete mixture with fly ash is characterized by the mixture flowing time from slump to get the slump flow of 500 mm t_{500}=5 s, with limestone microfiller and metakaolin – respectively 6 and 12 s.

Fine mineral additives and limestone microfiller accelerate the increasing of strength, compact of concrete matrix due to the effect of “fine powders” and plays active structure formatting role due to the creating of possibility of hydrate phase formation. These hydrate phases, in particular hydrosilicates of type CSH (B), structure active AF_m-phases – calcium hydrocarbonates and AF_t-phases – ettringite, are characterized binder properties in mineral unclinker part of composition (Stark & Möser, 2002).

The microstructure of superplasticized cement paste hydration products (W/C=0.30) after 28 days are shown in Fig. 1. The morphology, crystal structure and composition of these products can be very different. Cement stone based on the superplasticized cementitious systems after 28 days of hydration is characterized by a dense microstructure with the presence of hexagonal crystals of portlandite size of 10–20 μm (Fig. 1, *a*). If sufficient gypsum is present (as component of complex mineral additive), in favourable conditions ettringite is the main hydration product in unclinker part (Szwabowski & Golaszewski, 2010). The crystals of ettringite were small, because the ettringite was generated in confined space by topo-chemical reaction only after the cement matrix had formed (Fig. 1, *b*). The ettringite precipitates as a thin layer, which provides the compaction of cement matrix of SCC. This is one of the major causes of increasing of the early strength of SCC based on superplasticized cementitious systems (Sanytsky, Kropyvnytska, Rusyn & Geviuk, 2014).



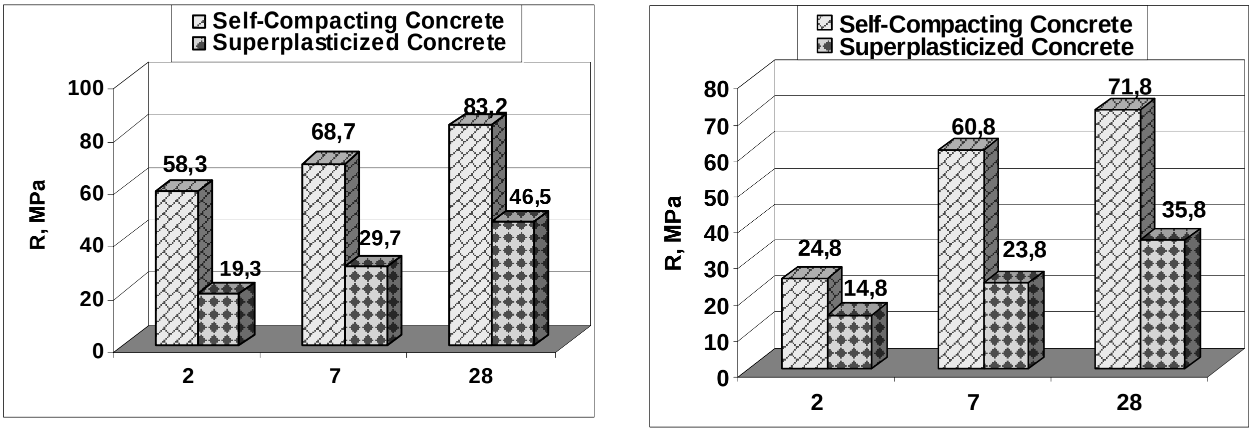
a *b*

Fig. 1. Microstructure of superplasticized cement stone after 28 days: crystals of portlandite (a) and dispersive crystals of ettringite (b)

Upon reaching the critical concrete (minimum required) strength 5 MPa creates an opportunity to counteract the negative impact of negative temperatures (Kurdowski, 2014). Conducted research found that the compressive strength of superplasticized concrete (C:S:G = 1:1.38:2.29, C=480 kg/m^3) after 2 and 28 days in normal conditions is 19.3 and 46.5 MPa (Fig. 2, *a*), and at alternating temperatures – 14.8 and 35.8 MPa respectively (Fig. 2, *b*). During the hardening in normal strength of Self-Compacting Concretes (C:S:G=1:1.52:2.04, C=480 kg/m^3) after 2 and 28 days is 58.3 and 83.2 MPa, and at -2 ... +5 °C – up to 35–85 % of the value of strength in normal conditions and after 7 and 28 days is 60.8 and 71.8 MPa respectively (Kirakevych, Sanytsky & Chaykovska, 2015).

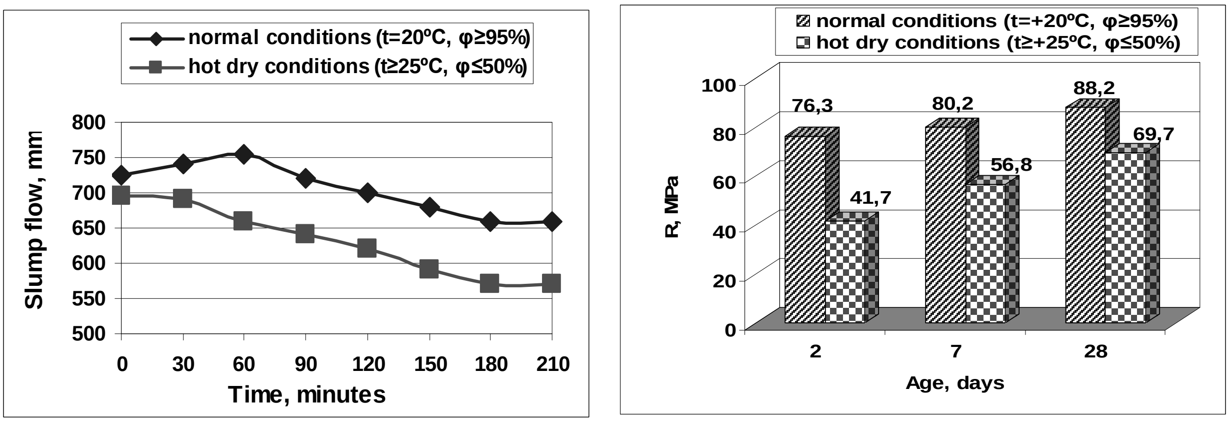
In order to study the possibility of construction in the summer investigated the rheological and physical and mechanical properties of concrete based on superplasticized cementitious systems in hot dry conditions ($t \geq 25$ ℃, $\varphi \leq 50$ %). Slump flow of Self-Compacting concrete mix in the dry hot conditions lasts 3 hours and 1.5 hours for the first loss of mobility mix up only 8 % (Fig. 3, *a*). The early strength of Self-

Compacting concrete at 30 °C is reduced by 20–30 % compared with the strength in normal conditions and after 2 and 7 days is 41.7 and 56.8 MPa respectively with branded strength is 69.7 MPa (Fig. 3, *b*).



a *b*

Fig. 2. Compressive strength of Self-Compacting and superplasticized concretes at normal conditions (a) and at temperature -2…+5 ºC (b)



a *b*

Fig. 3. The slump flow (a) and compressive strength (b) of SCC based on superplasticized cementitious systems

The regulation and control of properties of cementitious systems with fine ground mineral additives give the possibility of producing concrete of new generation, in particular SCC. High physico-mechanical properties of SCC based on superplasticized cementitious systems allows increasing durability and reliability of structures at different exploitative conditions (Kirakevych, Marushchak, Kirichenko & Sanytsky, 2011). High density causes the increasing of SCC waterproof to the class W20. The corrosion resistance of concrete obtained after the strength test samples (6 months of hardening) in an aggressive medium comparatively to strength of specimens stored in water increased. Frost resistance of concrete was in range of 400 freezing-thawing cycles.

Conclusions

Technological solutions designing of superplasticized cementitious systems that solves the problem of obtaining the Self-Compacting Concretes on their basis was established. This creates an opportunity allows to solve the problem of obtaining for enabling early loading, reducing the production cycle, increasing turnover and formwork acceleration of monolithic buildings and structures in different temperature conditions.

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САМОУЩІЛЬНЮВАЛЬНІ БЕТОНИ, ЩО ТВЕРДНУТЬ У РІЗНИХ ТЕМПЕРАТУРНИХ УМОВАХ

У статті наведено особливості монолітного бетонування в різних температурних умовах та розглянуті актуальні питання технології приготування самоущільнювальних бетонів на основі суперпластифікованих цементуючих систем, що поєднує знання закономірностей структуроутворення і модифікування портландцементних композицій “портландцемент – активні мінеральні добавки – мікронаповнювачі – суперпластифікатор – прискорювачі тверднення” для пошуку раціональних рішень забезпеченості технологічних та експлуатаційних властивостей бетону в умовах зміни факторів його складу, технології й експлуатації.

Встановлено фізико-хімічні особливості процесів гідратації і тверднення суперпластифікованих цементуючих систем, які завдяки направленому формуванню структури дозволяють вирішувати проблему одержання самоущільнювальних сумішей та бетонів з швидким наростанням міцності на їх основі. Проведено оптимізацію складів самоущільнювальних бетонів на основі суперпластифікованих цементуючих систем з високою ранньою міцністю, досліджено їхні показники якості та встановлено ефективність використання в різних температурних умовах.

Результатами досліджень встановлено, що використання суперпластифікованих цементуючих систем дозволяє направлено керувати технологічними властивостями і кінетикою структуроутворення та створити міцну структуру бетону з покращеними будівельно-технічними властивостями при твердненні в різних температурних умовах. Розроблено технологічні рішення приготування суперпластифікованих цементуючих систем, які дозволяють вирішувати проблему одержання самоущільнювальних бетонів на їх основі з використанням безвібраційної технології бетонування. При цьому створюється можливість раннього навантаження конструкцій, скорочення виробничого циклу, збільшення оборотності опалубки та прискорення зведення монолітних будівель і споруд у різних температурних умовах.

Ключові слова: полікарбоксилат, зола винесення, вапняковий мікронаповнювач, метакаолін, суперпластифіковані цементуючі системи, технологія безвібраційного бетонування, самоущільнювальні бетони, температурні умови.