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САМОУПЛОТНЯЮЩИЕСЯ МЕЛКОЗЕРНИСТЫЕ БЕТОНЫ НА ОСНОВЕ ВЫСОКОНАПОЛНЕННЫХ ЦЕМЕНТНЫХ ВЯЖУЩИХ

А.С. Балыков, Т.А. Низина, В.В. Володин, Д.И. Коровкин

Артемий Сергеевич Балыков

Кафедра строительных конструкций, Национальный исследовательский Мордовский государственный университет им. Н.П. Огарёва, ул. Большевистская, 68, Саранск, Республика Мордовия, Российская Федерация, 430005

E-mail: artbalrun@yandex.ru

Татьяна Анатольевна Низина

Кафедра строительных конструкций, Национальный исследовательский Мордовский государственный университет им. Н.П. Огарёва, ул. Большевистская, 68, Саранск, Республика Мордовия, Российская Федерация, 430005
E-mail: nizinata@yandex.ru

Владимир Владимирович Володин

Кафедра строительных конструкций, Национальный исследовательский Мордовский государственный университет им. Н.П. Огарёва, ул. Большевистская, 68, Саранск, Республика Мордовия, Российская Федерация, 430005
E-mail: volodinvv1994@gmail.com

Дмитрий Игоревич Коровкин

Кафедра строительных конструкций, Национальный исследовательский Мордовский государственный университет им. Н.П. Огарёва, ул. Большевистская, 68, Саранск, Республика Мордовия, Российская Федерация, 430005
E-mail: asfkorovkin@yandex.ru

Настоящая работа посвящена разработке модифицированных мелкозернистых бетонов классов прочности на сжатие от В20 до В90 из самоуплотняющихся смесей, содержащих микрокальцит, суперпластификатор на основе эфира поликарбоксилата, мелкий кварцевый песок с модулем крупности 1,4, минеральные добавки микрокремнезема, метакаолина и Пенетрон Адмикс (при необходимости). Приведены результаты исследования физико-механических свойств разработанных самоуплотняющихся мелкозернистых бетонов.

Ключевые слова: *мелкозернистый бетон, высоконаполненная самоуплотняющаяся смесь, карбонатный наполнитель, активная минеральная добавка, мелкий песок, физико-механические свойства*

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SELF-COMPACTING FINE-GRAINED CONCRETES BASED ON HIGHLY FILLED CEMENT BINDERS

A.S. Balykov, T.A. Nizina, V.V. Volodin, D.I. Korovkin

Artemy S. Balykov

Department of Building Structures, N. P. Ogarev National Research Mordovian State Uni-versity, 68 ulitsa Bolshevistskaya, Saransk, Republic of Mordovia, 430005, Russia

E-mail: artbalrun@yandex.ru

Tatyana A. Nizina

Department of Building Structures, N. P. Ogarev National Research Mordovian State Uni-versity, 68 ulitsa Bolshevistskaya, Saransk, Republic of Mordovia, 430005, Russia
E-mail: nizinata@yandex.ru

Vladimir V. Volodin

Department of Building Structures, N. P. Ogarev National Research Mordovian State Uni-versity, 68 ulitsa Bolshevistskaya, Saransk, Republic of Mordovia, 430005, Russia
E-mail: volodinvv1994@gmail.com

Dmitry I. Korovkin

Department of Building Structures, N. P. Ogarev National Research Mordovian State Uni-versity, 68 ulitsa Bolshevistskaya, Saransk, Republic of Mordovia, 430005, Russia
E-mail: asfkorovkin@yandex.ru

The paper discusses the development of modified fine-grained concretes of C20 to C90 compressive strength classes from self-compacting mixtures containing microcalcite, polycarboxylate superplasticizer, and fine quartz sand with a fineness modulus of 1.4, mineral additives of microsilica, metakaolin and Penetron Ad-mix (if necessary). The work provides the results of the study of physical and mechanical properties of the de-veloped self-compacting fine-grained concretes.

Key words: *fine-grained concrete, highly filled self-compacting mixture, carbonate filler, active mineral additive, fine sand, physical and mechanical properties*

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Cement-based concrete remains the basic building material. The reliability and durability of building products and structures depend on its performance properties. The modification of cement systems with chemical and mineral additives of different compositions, used both individually and in complex, is one of the main means of controlling structure formation and improvement of physical and mechanical properties of concrete [1, 2].

The range of mineral additives used in the formulation of cement systems nowadays is very extensive and consists of a variety of natural and synthetic materials. At the same time, the following types of mineral modifiers showed the greatest efficiency in compositions of cement concrete: siliceous and aluminosilicate pozzolanic additives (metakaolin, microsilica, etc.); expanding sulphoaluminium type additives; carbonate fillers (limestone, dolomitized limestone, dolomites, etc.) [3, 4].

Application of effective individual chemical and mineral additives as well as complex organic-mineral modifiers promoted the creation of high strength modified concretes, including self-compacting mixtures (SCC) [5, 6], first researched by the Japanese professor H. Okamura [7]. It is known that SCCs are unique due to high technological indicators (standard cone spreading over 550 mm), which have the increased rheological efficiency of the suspension matrix.

It is worth to look into the development of highly mobile concrete mixtures with fine sands. The difficulty in achieving self-compaction of these systems, especially with reduced binder content, is due to the high thickening ability of fine sands, as well as the reduced efficiency of plasticizers in lean concrete mixes [8]. It means that the problem of increasing rheological efficiency of modern plasticizers in cement systems with aggregates from fine and water-demanding sands seems is yet to be solved. In addition, it is necessary to optimize the granulometric composition and dosage of mineral additives in this kind of compositions to ensure their high fluidity at a reduced water content.

The aim of this work was to develop compositions of self-compacting concrete mixtures using fine silica sand. The main components of the cement systems used were: Portland cement CEM I 32.5B (PC); fine quartz sand with particle size modulus 1.4 (FQS); carbonate filler — KM100 grade microcalcite (MCM) in accordance with GOST R 56775-2015; condensed non-compacted microsilica MK-85 (MCN); highly active metakaolin (MTK); additive Penetron Admix (Admix); polycarboxylate ester-based superplasticizer Melflux 5581 F (SP).

Table 1. Compositions and physical-mechanical properties of cement systems under study

Composition number	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Recipe and process parameters							
PC, kg/m^3	*701÷739*				*239÷485*		
FQS/PC	*1.50*				*2.23*	*2.92*	*4.68*
MCM/PC	*0.45*				*1.11*	*1.63*	*3.21*
Modifier (MD), % of mass (PC+MD)	*-*	*10 VMC*	*10 (Admix)*	*10 (MC)*	*10 VMC*	*-*	*-*
SP, % of mass (PC+MCM)	*0.7*						
Water-cement ratio	*0.29*	*0.30*	*0.32*	*0.32*	*0.44*	*0.57*	*0.89*
Flow of Hagerman cone, mm	*295*	*260*	*280*	*280*	*260*	*290*	*300*
Physical and mechanical properties in 28 days							
Density, kg/m^3	*2393*	*2343*	*2320*	*2367*	*2320*	*2323*	*2344*
Flexural strength, MPa	*12.3*	*12.8*	*10.6*	*14.9*	*9.9*	*7.4*	*5.3*
Compressive strength, MPa	*92.5*	*104.2*	*82.7*	*115.8*	*73.8*	*47.5*	*28.3*

Table 1 presents the developed compositions of self-compacting fine-grained concretes. Basic formulation parameters of the obtained cement systems: cement consumption — 239–739 kg/m^3, microcalcite dosage — 45–321% of cement mass, water content and superplasticizer consumption — 20.2–21.8 and 0.7% of Portland cement + microcalcite mixture mass, respectively (Table 1). A distinctive feature of these self-compacting mixtures is an increased degree of microcalcite filling, which determines the high content of rheologically active fine-dispersed components (PC + MCM) (at least 340 l/m^3), as well as the increased volume of rheologically active suspension matrix (PC + MCM + mineral additive + water) (at least 580 l/m^3), which provides necessary separation of fine sand grains and high technological parameters of concrete mixtures (Hagerman cone and standard Abrams cone flow diameter at least 260 and 500 mm respectively).

The testing provided with physical and mechanical properties of self-compacting fine-grained concretes with fine sand FQS in 28 days: density, bending, and compressive strength are 2320–2393 kg/m^3, 5.3–14.9, and 28.3–115.8 MPa, respectively.

The test results confirm that it is possible to obtain self-compacting fine-grained concretes of high strength without active mineral modifiers, as evidenced by the level of strength indicators achieved in the design age for the composition number 1 with Portland cement 739 kg/m^3 — 92.5 and 12.3 MPa in compression and flexure, respectively. At the same time, the replacement of 10 % of Portland cement by metakaolin (composition No. 2) and microsilica (composition No. 4) contributes to increasing the strength *characteristics of cements relative to concrete of control composition No. 1 (up to 21 and 25% in flexure and compression, respectively). On the contrary, the introduction of Admix into composition No. 3 results in 14 and 11% decreases of flexural and compressive strengths of fine-grained concrete, which may be due to a somewhat increased thickening ability of this mineral additive, as well as to the unique aspects of its influence on the structure parameters of the obtained composites.*

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