LOOK ACADEMIC PUBLISHERS
OPEN ACCESS

INTERNATIONAL JOURNAL OF ENVIRONMENTAL & SCIENCE EDUCATION
2016, VOL. 11, NO. 18, 12779- 12786

High-Performance SCC-Concrete at Earthquake Resistant Construction

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ABSTRACT

The article introduces the survey on either national or international practice in obtaining and applying of self-compacting concrete (SCC). There has been analyzed either natural or anthropogenic raw material base of the Chechen Republic, along with other regions of the country. There have been obtained mixtures of SCC-grades as to compression capacity B80 and above, including integrated use of natural or anthropogenic raw material; there have been analyzed beton (concrete) recipe and its rheological and physic-mechanical properties.

KEYWORDS
High-performance concretes; selfcompacting mixtures; fillers; microfillers; rheology; polycarboxylic ether; compositional cementing.

ARTICLE HISTORY
Received 29 May 2016
Revised 3 September 2016
Accepted 28 September 2016

Introduction

Today within different types of construction along with standard ordinary heavy concretes of strength quality B7,5-B40 new-made functional beton is being applied: extra-strong selfcompacting concretes, extra lifetime concretes, non-shrink concretes, expansive cement concrete and self-stressing concrete, concretes made of flow concrete mixture, special concretes, including those ones made of modern compositional cementing, modern types of light-weight concrete and several other (Bazhenov, 2009; Bazhenov et al., 2006; 2011; Monolithic Construction within the Territory of Russia, 2015; Murtazaev et al., 2009; Boldyrew, 1993; Abel, 1993; Middendorf, 2005).

Among the above said high-performance modified concretes the most advanced one appears to be a compound selfcompacting concrete, the production technology and properties of which essentially differ from composition and properties of ordinary concrete mixtures.

Selfcompacting concrete (SCC) – is concrete, which apart from any outer compacting effect, due to effect of its own weight, singly flows, releases from air containing in it, and fully fills space between steel bars and formwork. SCC can contain hold-up volume of pores exactly as vibrated concrete (DAfStb-Richtlinie, 2013;

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Bazhenov et al., 2008; Murtazaev et al., 2009; Lermit, 2007; Lesovik et al., 2012; Fokina et al., 2004; Aitkin, 2000; Chung, 2004; Hui et al., 2004).

The shortened name for selfcompacting concrete in German is 'SVB' (selbstverdichtenderBeton), in English it is 'SCC' (selfcompactingconcrete), in French – 'BAP' (Betonautoplacant) (Hillemeier et al., 2006; Fedosov et al., 2010). It is possible, that due to spreading of selfcompacting concrete it will also acquire the acronyme 'СУБ' (SCC) in Russian.

Materials and Methods

The composition of self-compacting concrete mixture most essentially differs from the ordinary concrete mixture (Table 1). The main distinction lies in the essentially new approach to ratio and aggregate grading (approximate equal proportion of fine and coarse aggregates, balanced by adding it into grain size composition of the aggregate). Another distinction constitutes an essential filling agent into mixture (primarily, chalky dust) including the increased cement consumption.

One more distinctive feature lies in type and gauging of plasticizer (normally, it is superplasticizer, gauging of which is much superior in normal consumption of the ordinary concrete) (Kaprielov, 2008; Kudryavtsev, 2006; Batrakov, 2001; Murtazaev et al., 2015; Kaprielov et al., 2006; 2010; Komokhov & Shangina, 2002).

High cost of selfcompacting concrete mixtures, on one hand, suggests applying them only in obtaining of high performance concretes with high or ultra-high performance properties, but on the other hand, it induces to develop actions on reducing production cost on them to effect upon the area of potential application.

While implementing self-compacting mixtures, work methods become essentially practical, considering noisiness factor, labour cost reduce, and rapid development of construction. Thus, in disregard of significantly higher cost of these mixtures the general building costs are even getting lower.

The use of popular low cost, often non-demanded, local raw material, that, apart from being a natural resource, refer also to industrial wastes, would cheapen production of SCC (СУБ).

Table 1. Concrete composition for SCC (СУБ) applied worldwide (Kaprielov, 2008)

Item No.	SCC (СУБ) components	1 m^3 of self-compacting concrete mixture consumption, applied worldwide			
		Japan	EU	USA	India
1	Water, kg	175	190	180	163
2	Block Fill, kg	530	280	357	330
3	Filler, kg	70 (flyash aggregate)	245 (building chalk stone)	119 (slag sand)	150 (high-lime ash)
4	Fine aggregate, kg	751	865	936	917
5	Coarse aggregate, kg	789	750	684	764
6	Superplasticizer admix, kg	9	4,2	2,5	2,4

Results and Discussions

With the aim of development of SCC (СУБ) recipe of SCC nature as to compression capacity with the use of raw materials of Chechen Republic, there have been carried out joint survey on technology of obtaining of SCC (СУБ), their composition and performance.

In capacity of chemical admixture there was taken polycarboxylate addition in series Sika produced by international manufacturer of admixture SIKA. We basically used 2 types of such admixture, namely:

-SIKA® VISCOCRETE® 5 NEW – liquid superplasticizer based on polycarboxylic ether for production of high tech concretes of long-term flow (up to 90 min.) including high rate water reducing capacity (up to 40%);

-SIKA® VISCOCRETE® 5-600 SK – liquid superplasticizer based on polycarboxylic ether for production of high tech concretes of long-term flow (up to 240 min), including the high rate water reducing capacity (до 40%) and intense strength gain.

During the first stage of analysis the local raw materials of natural and anthropogenic origin were used. As a cementing agent there was taken Block Fill (ЦЕМ I 42,5 Н) from Chiri-Yurt Cement Plant of normal consistency 25 %, with the initial and final set 2 hours 15 minutes and 3 hours 40 minutes accordingly, as well as mineralogical composition: C3S – 59 %; C2S – 16 %; C3A – 8 %; C4AF – 13 %. In capacity of coarse filler there was taken gravel from Deposits of Argun of Chechen Republic (Table 2).

Table 2. Local Gravel Performance of Argun fr. 5-20 mm of boulder-gravel mixtures

Item No	Line Item					Figures
1	Specification for Grain Size Composition:					According to GOST 8269.0-97 (2004) fr. 5-20 mm
	Sizing screen, mm	20	10	5	< 5	
	part. rem., %	15,4	68,2	38,6	0,4	
	complete rem., %	15,4	83,6	99,6	-	
2	Aggregate strength: brand of gravel					М600-800
3	Bulk density, kg/m3					1366
4	Real density, g/cm3					2,64
5	Crushed grain content, %					96,2
6	Plate-like (flaky) and needle shaped grain, %					9,3
7	Soft ground grain, %					4,8
8	Gritty and clayish, %					1,8
9	Clay fisheye, %					no
10	Mass specific gravity, g/cm3					2,59
11	Hollowness of gravel, %					42,0

As the fine filler the natural sand from Chervlenskiy deposit of Chechen Republic was used (Table 3).

Within the analysis the flyash aggregate from CHP of Grozny, and the limestone meal from Yarysh-Mardynskiy deposit of Chechen Republic with specific surface area 700-800 m2/kg was used.

The obtained tailored composition of SCC (СУБ), and their performance are given in the table 4.

The analysis of the survey carried on SCC local raw materials (see table 4) gives the following arguments:

1) obtained SCC mixtures are marked by intense strength gain of a concrete during first day of its hardening: when 7 days' RCL: of the concrete gains up to 90 % from the design strength. The flow of the inverted cone (WPC) of obtained self-compacting concrete mixtures comprised 65-70 cm;

Table 3. Sand of Chervlenskiy Deposit

Item No.	Line Item		Figures					
1	Sand Grain Size	Sizing Screen, mm	2,5	1,25	0,63	0,315	0,16	< 0,16
		Partial Remainders, %	2	4	14	44	34	2
		Complete Remainders, %	2	6	20	64	98	
2	Fineness Modulus		1,9					
3	Gritt and Clay particles, %		2,4					
4	True specific gravity, kg/m^3		2620					
5	Bulk density, kg/m^3		1560					
6	Hollowness of sand, %		40,5					

Table 4. Composition and Performance of SCC (СУБ)

Composition	Amount of addition	W/C	Consumption, kg, for 1 m^3 of concrete					ρB, kg/m^3	RCL mature, day, mPas			PK, cm
			C	W	G	S	F		7	14	28	
Grade of Concrete B 25												
1	SikaVis-coCrete 5-600 SK, 0,5 %	0,55	380	210	930	825	70	2330	24,9	30,6	34,2	65
2	SikaVisco Crete 5NEW, 2,0 %	0,54	380	205	930	845	70	2360	23,6	29,9	33,7	68
Grade of Concrete B 35												
3	SikaVis-coCrete 5-600 SK, 0,5 %	0,41	480	195	860	865	80	2442	42,5	47,0	49,3	67
4	SikaViscoCrete 5-600 SK, 0,6 %	0,44	440	195	920	850	80	2428	41,5	46,9	48,7	70
Grade of Concrete B 40												
5	SikaViscoCrete 5NEW, 2,0 %	0,36	480	175	685	1035	80	2455	51,0	53,6	55,6	70
6	SikaVis-coCrete5-600 SK, 0,7 %	0,41	520	195	860	820	80	2475	48,8	54,8	57,2	65

Note: W/C - water and cement ratio; C - cement; W - water; G - gravel; S - sand; F - filler; RCL - compression capacity; WPC - Water Pollution Class; ρB - beton density

2) gravel localized at the Argun bank provides obtaining of concrete up to B 40 (M500), concretes of the higher grades undergo destruction due to the given filler, being evaluated in terms of the lower structural strength effected by chalky particles with crushing capacity rate M600-M800;

3) sand from Chervlen deposit comes to be suitable for obtaining of concretes with compression capacity up to B 40 (M500). In the higher grade of concretes, for example, from B 45 (M600) up to B 50 (M700), the sand from Chervlen can be added into composition only after beneficiation with coarser sand of Fineness Modulus = 2,8 (sand of Alagir from the Republic of North Ossetia-Alania) in ratio close upon 4:1 (Coarse sand: Fine sand).

The use of sand from Chervlen without beneficiation of the higher grade concretes leads to excessive consumption of cement due to moderate Fineness Modulus that is equal 1,8, and what is more, rheotechnology of concrete mixture caused by misbalance in grain size composition;

4) cement taken from local Chiri-Yurt Cement Plant provides obtaining of compositions of SCC's compression capacity up to B 65 (M900), however, rheological properties (WPC, water segregation, etc.) of the given concretes are not fully compatible with the criteria as to SCC;

5) flyash aggregate from CHP of Grozny being used in concrete composition of grade higher than B 40 (M500) does not provide obtaining of the required of waterholding capacity, persistency to sedimentation of concrete mixture;

6) limestone meal from Yarysh-Mardynskiy deposit comes usable for production of concretes with compression capacity up to B 50 (M700). In the higher grades' concretes the given filler is not consistent with waterholding capacity of concrete mixture, persistency to sedimentation and obtaining of concrete of high strength.

With the aim to develop SCC mixtures of higher grades as to compression capacity, up to B80 and above, of more advanced physic-mechanical properties, during the second stage of the analysis the following imported high-performance materials were used:

- Cement of Tula Plant CEM I 42,5 H of normal consistency 27 %, with the initial and final set 2 hours 20 minutes and 3 hours 30 minutes accordingly, as well as mineralogical composition: C3S – 62 %; C2S – 18 %; C3A – 5 %; C4AF – 15 %;
- crush stone fraction of 5-20 mm, 2,5-10 mm from the bank "PavlovskGranit" and LLC Progress (Table 5);
- coarse sand of МК = 2,8 from CJSC Bagayevskiy bank, Alagirskiy bank (Table 6);
- microsilicasuspension from Novokuznetsk Integrated Plant with BET surface area 1279 m^2/kg;
- mineral fines МП-1 unactivated the city of Kaluga;
- flyash from Nevynomysskaya GRES Power Plant with BET surface area 980 m^2/kg.

Table 5. Gravel of granite-diabasic solids fr. 5-10 (Progress LLC, North Osetia)

Line Item		Figures				
Grain size of Gravel	Sizing Scree, mm	12,5	10	7,5	5	< 5
	Partial remainders, %	0,0	9,2	38,6	42,9	9,3
	Complete remainders, %	0,0	9,2	47,8	90,7	100
	acc. to GOST 8267-93	Up to 0,5	Up to 10	30-60	90-100	-
Strength capacity of gravel (brand)		1200-1400				
Bulk density, kg/m3		1450				
Real density , kg/m3		2700				
Average density, kg/m3		2630				
Crushed Grain, %		85,2				
Plate-like (flaky) and needle shaped grain, %		12,2				
Soft ground grain, %		2,6				
Gritty and clayish, %		0,8				
Clay fisheye, %		no				
Hollowness of gravel, %		44,9				

Table 6. Sand of Alagir deposit

Line Item		Figures						
Grain size of Sand	Sizing Scree, mm	5	2,5	1,25	0,63	0,315	0,16	< 0,16
	Partial rem., %	0,9	17,4	12,3	25,8	30,5	10,5	2,6
	Complete rem., %	0,9	18,3	30,6	56,4	86,9	97,4	
Fineness Modulus		2,87						
Gritty and clayish, %		0,9						
Real density of grains, kg/m^3		2690						
Bulk density, kg/m^3		1457						
Water content, %		2,1						
Grade of sand grain		1						
Hollowness of sand, %		45,8						

As to chemical admixture there were also used polycarboxylate additive agents SIKA® VISCOCRETE® 5 NEW.

The SCC' compositions were obtained from the above said raw materials, as well as analyzed their properties and performance (Table. 7).

The survey of the analysis carried out with the use of high performance imported materials (Table 7), reflected the fact that SCCs are distinguished by strong physic-mechanical performance. SCC compositions (see Table 7, compositions 4 and 5), referred to powder like substance, excluding coarse aggregate and ultradisperse filler, and are of grade class with compression capacity B100. Therewith, it is important to note, that for these compositions there were applied cements of different production (CEM I 42,5 H the city of Tula, and CEM I 42,5 H the city of Grozny), however, their strength capacity did not much differ. Besides, the excess amount of cement in both compositions would require additional analysis as to reduce of its consumption.

Table 7. Composition and Performance of SCC

Compositions	Amount of Addition	W/C	Consumption of Concrete, kg on 1 m^3 of concrete							ρB, kg/m^3	RCL mature, days, mPas		WPC, cm
			C	W	G	G	S	MSS	3		7	28	
Grade of Concrete B 60													
1*	SikaVisco Crete 5NEW, 1,9 %	0,34	450	152	620	267	802	85	-	2372	63,6	84,8	69
Grade of Concrete B 80													
2	SikaVisco Crete 5NEW, 1,9 %	0,32	500	158	620	242	777	85	-	2497	89,8	100,9	75
3*	SikaVisco Crete 5NEW, 1,9 %	0,31	500	154	620	242	777	85	-	2400	70,9	95,4	72,5
Grade of Concrete B 100													
4	SikaVisco Crete 5NEW, 2,2 %	0,29	900	260	-	-	870	180	180	2240	95,7	112,9	85
5*	SikaVisco Crete 5NEW, 2,2 %	0,267	900	240	-	-	870	180	180	2244	91,5	109,2	78

Note: compositions 1*, 3*, 5*- were made on the basis of cement of Chiri-Yurt ЦЕМ I 42,5 Н. W/C – water and cement ratio; C – cement; W – water; G – gravel; S – sand; F – filler; MSS (МКУ)- microsilicasuspension of Novokuznetsk Integrated Plant; FA- flyash of Nevynomyskaya GRES; RCL – compression capacity; WPC – Water Pollution Class; ρ_B – beton density.

Conclusion

Therefore, it has been carried out the analysis of recipe of SCC applied within different countries in modern monolithic construction.

There have been obtained tailored recipes of SCC of grade class with compression capacity up to B100, based on the use of local natural and anthropogenic raw materials of Chechen Republic, including the imported ones. There have been analyzed rheological and physic-mechanical properties of obtained SCC, considering intention to use them in high-rise monolithic construction, among other in earthquake resistant regions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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