ACTA SCIENTIARUM POLONORUM Architectura 7 (4) 2008, 3–14

CEMENT TYPE AND PROPERTIES OF SELF--COMPACTING CONCRETE

Anna M. Grabiec[1], Robert Chutek[2]
[1] Poznań University of Life Sciences
[2] MC Bauchemie, Środa Wielkopolska

Abstract. Self-compacting concrete (SCC) is undoubtedly a promising ecological cement matrix composite of new generation. However, it is not easy to achieve the required combination of properties in fresh SCC mixes. SCC is also particularly sensitive to any changes in the laboratory and at the job site. Choice of constituents for SCC, especially cement and superplasticiser which are able to collaborate in the correct way, has a significant effect on SCC performance. In this investigation considered in qualitative way, four cements, varying in physical and chemical properties and phase composition were used to check their compatibility with a new generation superplasticiser, taking into account the properties of fresh and hardened self-compacting concretes. Results revealed some differences although it is impossible to answer definitely which cement performs with the superplasticiser in the best way.

Key words: self-compacting concrete, cement, superplasticiser, compatibility

INTRODUCTION

Self-compacting concrete (SCC) is a result of research on enhanced durability concrete carried out by Japanese scientists [Okamura and Ouchi 1999].

Special advantages of SCC – including its ability to self-level without any external compaction, which makes it possible to consider this composite as an ecological material, and its enhanced durability, which determines the concrete quality in the modern technology rather than its strength – allow us to qualify this material as a structural material of the future. It is, however, a composite difficult to handle at the current state of civil engineering knowledge and practice, due to its sensitivity to small variations in its composition as well as to changes in environmental conditions – especially temperature and work quality [Okamura and Ouchi 2003, Kaszyńska 2003, Domone 2006, Schwartzen-

Corresponding author – Adres do korespondencji: Anna M. Grabiec, Uniwersytet Przyrodniczy w Poznaniu, Katedra Mechaniki Budowli i Budownictwa Rolniczego, ul. Piątkowska 94 E, Poznań, e-mail: agra@up.poznan.pl

truber et al. 2006]. Its properties depend on the quality of its constituents, i.e. microfiller and cement among others [Okamura and Ouchi 1999, Giergiczny et al. 2002, Kaszyńska 2003].

The SCC technology allows using various types of cements, not just the best known Portland cement CEM I. It has been confirmed by the Japanese practice, which admits both blast furnace slag cement and type A Portland blended fly ash cement, as well as by extensive Polish research, which exhibits satisfactory results of the application of the cements CEM II/B-S, CEM II/B-V and also the blast furnace slag cement CEM III/A [Giergiczny et al. 2002]. The choice of cement depends on working conditions of SCC structure and on the rheological compatibility with a superplasticiser in the presence of a given microfiller [Felekođlu et al. 2006].

The microfiller in SCC concrete increases the viscosity of cement paste and thus stabilises the concrete mix. Without increasing the cement content over the required minimum, the microfiller increases the volume of the paste and effectively compacts the structure of the hardened paste [Giergiczny et al. 2002, Kaszyńska 2003]. Chemically inert additives, like limestone powder [Takada et al. 1999, Kaszyńska 2003, Zhu and Gibbs 2005] or active ones like: fly ash, blast furnace slag and, in special cases of high quality concrete – silica fume [Takada et al. 1999, Kaszyńska 2003, Termkhajornkit et al. 2005, Felekoglu et al. 2006], are used.

Superplasticiser is a necessary constituent of SCC which allows us to achieve and retain a required flowability of concrete mix with a low value of water to binder ratio. Highly effective superplasticisers of the new generation, mostly of the polycarboxylate type, are used in the SCC technology [Hamada et al. 2000, Kinoshita et al. 2000, Tseng et al. 2000, Okamura and Ouchi 2003, Kaszyńska 2003, Papayianni et al. 2005, Domone 2006]. Superiority of the new generation of superplasticisers over the conventional water reducing admixtures is manifested in the higher level of the concrete mix fluidity and its retention [Tseng et al. 2000, Okamura and Ouchi 2003, Papayianni et al. 2005]. It results from a different chemical structure, leading to a different mode of action [Hamada et al. 2000, Kinoshita et al. 2000, Tseng et al. 2000]. Superplasicisers of the new generation are characterised by the steric effect, i.e. long polymer chains prevent the cement grains from approaching each other and evoke repulsive forces. Concrete mix is plasticised and stabilised to a higher extent, what prevents the segregation of its constituents [Giergiczny et al. 2002, Li et al. 2005].

EXPERIMENTAL

Scope, materials and mix proportions

The investigation was intended to assess the effect of the type of cement used on the physical properties of fresh self-compacting concretes such as slump-flow and its loss with time, air-content, unit weight, segregation resistance, temperature change, initial setting time as well as on physical (water tightness, water absorption) and mechanical (compressive strength) characteristics of hardened SCC. Four concretes made from four different cements were subjected to this study.

Four Polish commercialised cements were used: CEM I 42.5R (rapid early strength Portland cement), CEM I 42.5N HSR NA (high sulphate resistant Portland cement), CEM II/A-V 42.5N (type A Portland blended fly ash cement) and CEM III A 42.5 N (type A blast furnace slag cement), according to Polish standard PN-EN 197-1:2002. Some characteristics of the cements, according to the information provided by the manufactures, are given in Table 1. Pit sand (0/2 mm) and coarse gravel aggregate (2/8 mm and 8/16 mm) were used. Fly ash (ignition loss – 4.44%, Cl^- – 0.01%, free lime – 0.06%, SO_3 – 0.45%, SiO_2 – 28.7%) was a pozzolanic filler in this investigation. A polycarboxylated superplasticiser (pH 6, specific gravity – 1.07 kg/l, solid content – 30%) was chosen for the performance with cements in self-compacting concretes.

Table 1. Composition, physical and mechanical properties of cement used
Tabela.1. Skład, fizyczne i mechaniczne właściwości zastosowanych cementów

Characteristic Charakterystyka	CEM I 42.5R	CEM I 42.5N HSR NA	CEM II/A-V 42.5N	CEM III/A 42.5N
Chemical compounds [%] Skład chemiczny				
SO_3	3.13	2.00	2.95	3.05
Cl^-	0.019	0.003	0.031	0.04
Na_2O eq	0.61	0.50	0.30	0.77
Insoluble residue [%] Części nierozpuszczalne	0.52	0.30	11.98	0.30
Ignition loss [%] Straty prażenia	2.90	0.70	1.69	0.50
Potential compounds [%] Składniki mineralne				
C_3S	52.6	56.6	58.5	28.3
C_3A	7.0	1.5	9.2	3.7
Blaine's specific surface [$m^2 \cdot kg^{-1}$] Powierzchnia właściwa według Blaine'a	387	308	413	470
Initial setting time [min] Początek wiązania	180	230	148	230
Compressive strength [MPa] Wytrzymałość na ściskanie				
2 days	29.6	15.0	24.5	14.4
28 days	56.8	50.0	46.4	52.7

The proportions of concrete mixes designed to obtain a diameter of slump-flow of 600–750 mm, (corresponding to that of self-compacting concrete) are summarised in Table 2. In concrete mixes, the water content varied with the type of cement. As a result values of water/cement ratio were different for the same cement content.

Procedure

Mixing. The constituents of SCC were mixed using a paddle-type 0.05 m^3 mixer. Firstly, all dry materials were mixed for 1 minute. Then three-quarters of the total amount of

Table 2. Mix proportions of self-compacting concretes
Tabela 2. Skład betonów samozagęszczalnych

Constituent [kg·m^{-3}] Składnik						
Cement Cement	Fly ash Popiół lotny	Sand Piasek	Gravel Żwir 2/8 mm	Gravel Żwir 8/16 mm	Superplasticiser Superplastyfikator	Water Woda (w/c)
350	150	702	501	501	5.25 (1.5)[a]	
CEM I 42.5R						130 (0.37)
CEM I 42.5N HSR NA						123 (0.35)
CEM II/A-V 42.5N						135 (0.39)
CEM III/A 42.5N						145 (0.41)

[a]In % by cement mass.
W % masy cementu.

water was introduced and mixed for 0.5 minute. Finally, the materials with the superplasticiser and the rest of the water were gradually added and mixed for 2 minutes.

Slump-flow and its loss with time. The fluidity of fresh concrete was indicated by the measured flow spread diameter in the turned upside down Abrams' cone (Fig. 1a). The flowability was also evaluated in confined conditions. In this case, measurements were taken using a J-ring with the turned upside down Abrams' cone (Fig. 1b). In order to examine the changes in the flow value over time, the flow value was measured at 0, 30, 60 and 90 minutes after mixing.

a b

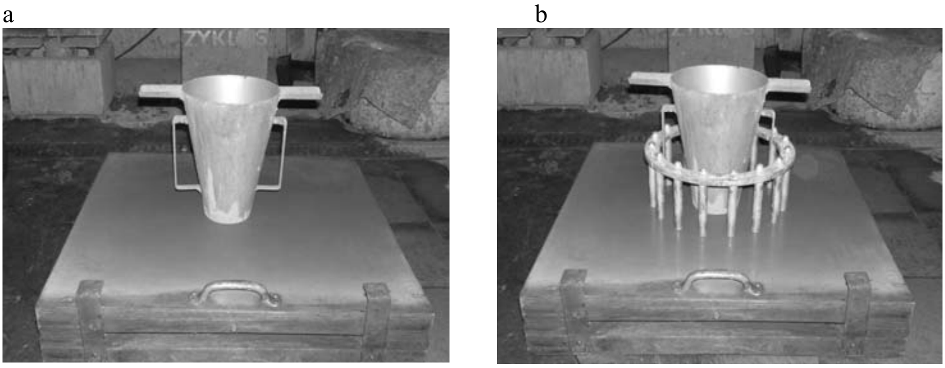

Fig. 1. Flow table Abram's cone and J-ring for measurement of flowability of SCC in: a – unconfined, b – confined conditions
Rys. 1. Stożek rozpływowy, odwrócony stożek Abramsa i pierścień J do pomiaru ciekłości mieszanek samozagęszczalnych w wariancie: a – bez prętów zbrojeniowych, b – z prętami zbrojeniowymi

Air content. Air content of fresh concrete was tested by a method specified in Polish standard PN-EN 12350-7:2001, with a 3-minute break for self–deaereating of the concrete sample instead of using vibration. Measurements were made at 0 and 90 minutes after self-deaerating.

Unit weight. The unit weight of fresh concrete was measured according to the method specified in Polish standard PN-EN 12350-6:2001, with a 3-minute break for self-deaerating of the concrete sample instead of using vibration. Measurements were taken immediately after self-deaerating.

Segregation resistance. In order to evaluate the resistance of self-compacting concrete to the vertical segregation, fresh concrete was poured into a plastic vessel (ϕ 150 mm, h = 495 mm). The vessel had two thin cuts for putting metal partitions and dividing the concrete sample into three parts (Fig. 2). After 20 minutes needed for vertical moving the aggregate in the vessel, partitions were fixed in the cuts. The concrete of the upper, middle and bottom parts were put through an 8 mm sieve, and the aggregate pieces coarser than 8 mm were washed out from the sample. The coarse aggregates of three parts were dried and weighted. MC Bauchemie has developed the method and claims that, when the differences between the upper, middle and bottom sections are lower than 20%, there is no segregation in self-compacting concrete in the vertical direction.

Fig. 2. Set evaluating resistance of SCC to vertical segregation
Rys. 2. Zestaw do oceny odporności mieszanek samozagęszczalnych na segregację w kierunku pionowym

Evolution of the temperature of fresh concretes with time and initial setting time. Measurements of the temperature of fresh self-compacting concretes were begun after mixing of the constituents and were conducted for 20 hours in a thermically insulated device, equipped with thermocouples immersed in the concrete samples and connected with a special recorder monitoring results graphically. The initial setting time, according to the method which MC Bauchemie has developed, is the time when the temperature of concrete mix is two degrees centigrade higher from the initial one.

Water penetration and water absorption. The water tightness and water absorption tests were conducted on 150 mm concrete cubes. The samples (6 for each examined series of concrete in the case of water tightness and 3 in the case of water absorption) were taken out of the moulds at the age of 24 hours and subjected to testing after being cured for 28 days at 20°C and 98% RH. The water penetration tests were conducted according to Polish standard PN-EN 12390-8:2001. The water pressure was 0.5 MPa within 72 hours.

The water absorption was evaluated as the ratio of maximum water mass absorbed by concrete samples to the mass of samples in their dry state.

Compressive strength. The compressive strength was evaluated using 150 mm concrete cubes. After demoulding, the samples were cured in water at 20°C until the time of testing at 1, 2, 7, 28, 90 and 180 days. The number of samples for each examined series of concrete was 3.

RESULTS AND DISCUSSION

The mean diameter of the spread of fresh concretes both in unconfined and confined conditions (J-ring test) and its variation in time is given in Table 3. Table 4 compares air content and unit weight of self-compacting mixes (mean values). Data regarding the resistance of fresh concretes to vertical segregation are presented in Table 5. Changes of temperature of fresh concretes in time are shown in Table 6. Mean values of the water penetration depth and water absorption of self-compacting concretes are given in Table 7. Figure 3 illustrates the mean compressive strength values of SCC after various periods of hardening.

Table 3. Slump-flow and slump-flow retention of fresh concretes
Tabela 3. Rozpływ mieszanek betonowych

Type of cement Rodzaj cementu	Test option Wariant badania	Slump-flow [mm] Rozpływ			
		initial początkowy	after po 30 min	after po 60 min	after po 90 min
CEM I 42.5R	without J-ring bez pierścienia J	730	710	680	580
	with J-ring z pierścieniem J	730	700	630	500
CEM I 42.5N HSR NA	without J-ring bez pierścienia J	730	720	700	680
	with J-ring z pierścieniem J	710	700	670	630
CEM II/A-V 42.5N	without J-ring bez pierścienia J	730	730	680	660
	with J-ring z pierścieniem J	730	710	640	610
CEM III/A 42.5N	without J-ring bez pierścienia J	730	730	710	700
	with J-ring z pierścieniem J	730	710	690	680

Table 4. Air content and unit weight of fresh concretes
Tabela 4. Zawartość powietrza i gęstość objętościowa mieszanek betonowych

Type of cement Rodzaj cementu	Air content [%] Zawartośc powietrza		Unit weight [kg·m^{-3}] Gęstość objętościowa
	initial początkowa	after 90 min po 90 min	
CEM I 42.5R	0.8	2.4	2490
CEM I 42.5N HSR NA	1.1	1.4	2500
CEM II/A–V 42.5N	0.9	2.4	2360
CEM III/A 42.5N	1.0	1.1	2400

Table 5. Segregation resistance of fresh concretes to vertical direction
Tabela 5. Odporność mieszanek betonowych na segregację w kierunku pionowym

Type of cement Rodzaj cementu	Residue of gravel aggregate above 8 mm in diameter in each particular part of vessel [g] Pozostałość żwiru o wielkości ziaren > 8 mm w poszczególnych częściach naczynia pomiarowego		
	upper part górna część	medium part środkowa część	bottom part dolna część
CEM I 42.5R	1636	1674	1637
CEM I 42.5N HSR NA	1701	1857	1798
CEM II/A-V 42.5N	1642	1694	1703
CEM III/A 42.5N	1548	1620	1670

Table 6. Initial setting and the maximum temperature of concrete mixes
Tabela 6. Początek wiązania cementu i maksymalna temperatura uzyskiwana przez mieszankę betonową

Type of cement Rodzaj cementu	Initial setting time [hours] Początek wiązania cementu w mieszance betonowej [h]	Maximum temperature of concrete mix [°C] Maksymalna temperatura osiągnięta przez mieszankę betonową
CEM I 42,5 R Kujawy	4,0	40,0
CEM I 42,5 N HSR NA Rejowiec	8,0	33,0
CEM II/A-V 42,5 N Chełm	4,5	37,0
CEM III/A 42,5 N Górażdże	10,5	27,0

Table 7. Physical properties of hardened SCC
Tabela 7. Właściwości fizyczne betonu samozagęszczalnego

Type of cement Rodzaj cementu	Water penetration depth [mm] Głębokość przesiąkania wody	Water absorption [%] Nasiąkliwość
CEM I 42.5R	15.0	2.94
CEM I 42.5N HSR NA	19.8	3.04
CEM II/A–V 42.5N	16.3	3.13
CEM III/A 42.5N	27.0	3.57

Four types of cement of the same class but with different chemical and mineral composition, as well as physical properties, were used in experiments. It was expected that properties of fresh concretes and a hardened concretes made using these cements would be different.

One of the main assumptions of the research was to prepare all the concrete mixes using the same composition. The mixes had to contain different type of cement but the same quantity of the other constituents. However, it was found during the experiments, that each mix required a different amount of water, what resulted in different values of the water/cement ratio. The analysis of results given in Table 2 yielded the highest demand of water (w/c = 0.41) for the cement CEM III. It was probably due to its highest specific surface among the selected cements (Table 1). The higher the specific surface of concrete, the higher the water demand is. The lowest w/c (0.35) among the compared mixes was

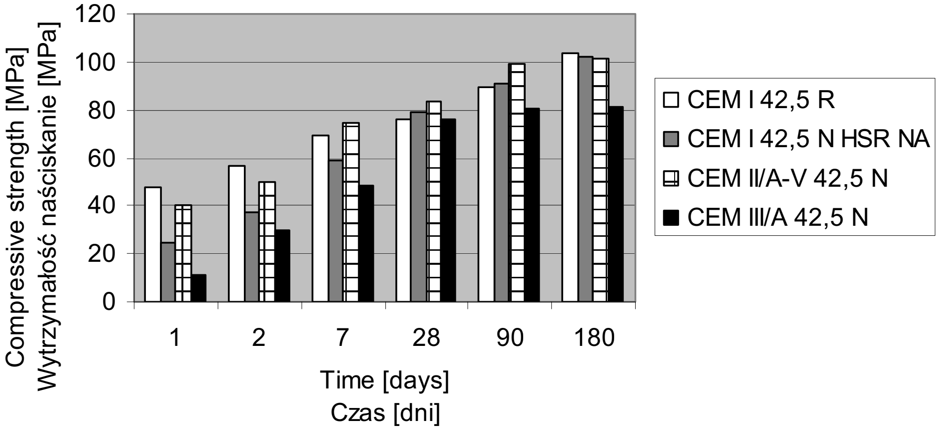

Fig. 3. SCC compressive strength
Rys. 3. Wytrzymałość betonów samozagęszczalnych na ściskanie

found for the cement CEM I 42.5N HSR, which according to the data in Table 1, was characterised by the lowest specific surface. Comparing the values of the w/c ratio determined in the experiments with the content of the tricalcium aluminate (C_3A) in cement (Table 1) led to the conclusion that the higher the C_3A content was, the higher the water demand and the w/c ratio were.

One of the essential characteristics of a self-compacting mix is the longest possible retention of its initial slump-flow. In this research the slump-flow was examined within the period of 90 minutes. From the results given in Table 3 it can be concluded that all the fresh concretes fulfilled the slump-flow criterion of 600–750 mm for SCC during the period of 60 minutes. The initial slump values, directly after mixing of constituents for all the mixes were similar, both without the blocking ring "J" and with the ring. All the mixes lost the flowability in time thus leading to the decrease of the diameter of the spread. This concerned the mix with the cement CEM III/A 42.5N the least. For this fresh concrete the differences of slump-flow immediately after mixing and after 90 minutes were 30 mm and 50 mm for the case without the J-ring and with the ring, respectively. This property of the fresh concrete with the blast furnace slag cement resulted from the w/c ratio, which was the highest (0.41) among all the compared mixes, as well as from the latest initial setting time (as shown in Table 6 – after 10.5 hours). The worst performance was observed when the Portland cement CEM I 42.5R was used. The concrete mix lost the flowability between 60 and 90 minutes in the quickest way and the diameter of spread after 90 minutes fell below the admissible value (600 mm). This might be the result of relatively high content of the tricalcium aluminate (C_3A) in the cement CEM I 42.5R, reaching 7%. According to some data [Ramachandran 1995, Rixom and Mailvaganam 1999], the effectiveness of superplasticisers gets lower the higher the content of the tricalcium aluminate in the cement. However, carboxylated polymers appear less sensitive towards variation in the composition of cement than sulphonated polymers [Spiratos et al. 2006]. Loss of flowability might also be a result of the earliest setting time – after 4 hours (Table 6).

The air content in fresh concretes was controlled immediately after their self-deaerating and after 90 minutes. The results presented in Table 4 prove that the air content is closely related to the slump-flow of the mix. The air content of the mixes instantly after self-deaerating was 0.8–1.1%. The air content increased as time passed and the spread of diameter decreased. It was particularly noticeable for the fresh concretes with the cements CEM I 42.5R and CEM II/A-V, which exhibited the air content of 0.8 to 2,4 % and 0.9 to 2.4 %, respectively.

All the fresh concretes showed resistance to the vertical segregation and the results for all the compositions did not differ in this aspect significantly (Table 5), therefore proving that this characteristic of the fresh concrete is not influenced by the cement type. It is necessary to note that segregation resistance plays an important role in SCC technology because poor segregation means poor deformability and blocking of aggregate particles around reinforcement. Moreover, it can cause high drying shrinkage and nonuniform compressive strength of the concrete [Bui et al. 2002].

The results in Table 6, shows that the highest temperature (40°C) was recorded for the mix with the cement CEM I 42.5R. It was also the same mix in which the initial setting time was the earliest, i.e. after 4 hours. Three degrees centigrade lower, i.e. 37°C, was the maximum temperature of the fresh concrete with the cement CEM II/A-V 42.5N. The concrete mix with the cement CEM I 42.5N HSR NA reached the maximum temperature of 33°C. The lowest maximum temperature (27°C) and the latest initial setting time (as shown in Table 6 – after 10.5 hours) was observed for the mix with the cement CEM III/A. The blast furnace slag cement releases less hydration heat and does it slower than the other cements of the same strength class [Spiratos et al. 2006]. The hydration heat of the cement CEM III/A is lower than that for the Portland cement CEM I what was confirmed by the temperature measurements and the initial setting time results.

It is worth emphasising, that the results described above are in agreement with the results of compressive strength tests performed after early periods of hardening. The higher the maximum temperature the concrete mix reached and the earlier the initial setting time was (Table 6) the higher 1- and 2-day compressive strength of hardened concrete was obtained (Fig. 3).

The low hydration heat of the cement CEM III/A is accompanied by slower strength development. In the initial period of hardening it is slower than for the Portland cement CEM I. After more than 28 days the continuous increase of strength of composites with the cement CEM III/A can be observed [Kurdowski et al. 2006].

In this study the compressive strength of concrete samples with the cement CEM III/A was supposed to rise also in later periods of hardening. However, the analysis of the results presented in Figure 3 indicates, that this cement did not behave "typically". Though the strength of a 1-day old sample was low ($f_{cm,1}$ = 11 MPa), when compared with the other concrete samples, it grew slowly in time. Unfortunately, it stabilised after 90 days and did not grow any more. The difference of the strength after 28 and 180 days was only 5 MPa ($f_{cm,28}$ = 76 MPa and $f_{cm,180}$ = 81 MPa). As shown in Table 6, this concrete exhibited also the least satisfactory results concerning water tightness and water absorption (the mean depth of water penetration – 27 mm, the mean water absorption – 3.57%), whereas the best results concerned the concrete made from the cement CEM I 42.5R (the mean water penetration depth – 15 mm, the mean water absorption – 2.94%).

It is commonly known, that concrete with the cement CEM III/A presents better tightness, smaller porosity, better internal frost resistance and less salt frost scaling than most of the other cement types [Giergiczny et al. 2002, Persson 2003]. The water tightness and water absorption experiments were carried out on 28 days old samples. It is probable, that the experiments carried out on more mature samples would yield more satisfactory outcomes due to the long-term tightening of concrete with the cement CEM III/A, resulting from the hydration in the later period.

Furthermore, the value of the w/c ratio was the highest (0.41) among all the tested samples in case of the concrete with blast furnace slag cement.

In case of the Portland blended fly ash cement CEM II/A-V, after a longer period of hardening, the compressive strength of concrete samples including this cement with the fly ash reaches values similar or higher than those corresponding to the Portland cement CEM I of the same strength class [Giergiczny et al. 2002]. The compressive strength after 28 days for the concrete from the cement CEM II reached a value about 8 MPa higher than that for the CEM I ($f_{cm,28}$ = 84 MPa and $f_{cm,28}$ = 76 MPa, respectively). After 180 days these values were almost equal. The difference was only 2 MPa, with the advantage to the Portland cement (for the CEM I $f_{cm,180}$ = 103 MPa and for the CEM II $f_{cm,180}$ = = 101 MPa).

Results of testing of the compressive strength after 28 days, i.e. after the period when the concrete class is assessed, allowed qualifying all these composites to the class of the high strength concrete. The highest value ($f_{cm,28}$ = 84 MPa) was recorded for concrete with the cement CEM II/A-V, the lowest one ($f_{cm,28}$ = 76 MPa) – for concrete with the cement CEM I 42.5R.

It is hard to make a generalisation, based on the above mentioned studies, which from the selected cements affected the properties of self-compacting concretes the best. The highly probable reason for this is a large number of factors influencing cement – superplasticiser performance. Moreover, the effect of these factors can be enhanced by the complexity of their combined action.

CONCLUSIONS

Based on the results presented in this paper, the following conclusions can be drawn:

1. All the selected cements proved to be suitable for the application in self-compacting concretes.

2. The best retention of slump-flow both in unconfined and confined conditions (J-ring), was observed for the concrete mix with the blast furnace slag cement (CEM III/A).

3. No significant influence of the cement type on the air content in fresh concrete after self-deaerating was found. On the contrary, differences were noticeable after 90 minutes. In all cases the air content grew with time and with the decrease of fluidity of concrete mixes.

4. The earliest initial setting time and the highest temperature was recorded for the concrete mix with the cement CEM I 42.5R, while the latest initial setting time and the lowest maximum temperature – for the mix with the cement CEM III/A.

5. The best physical properties (water tightness and water absorption) were obtained for concrete with the cement CEM I 42.5R, the least advantageous ones – for concrete with the blast furnace slag cement. The type of cement influenced water tightness rather than the water absorption.

6. Concretes with all the selected cement types featured high compressive strength in any tested age. The values of $f_{cm,28}$ allowed qualifying all the concretes to the group of the high strength composites.

7. The highest early strength values (after 1 and 2 days) were obtained for concretes with the Portland and Portland blended fly ash cements.

8. The compressive strength values after the longest period of testing (180 days) were similar for concretes with the cements CEM I 42.5R, CEM II 42.5N HSR NA and CEM II/A-V 42.5N. They exceeded the value of 100 MPa.

9. It was not possible to specify which cement performs with the superplasticiser in the best way, taking into account all considered properties of self-compacting concrete.

Acknowledgment

The authors thank Mr R. Sauć from Bauchemie, Środa Wielkopolska Poland for his assistance in designing and testing of self-compacting concrete made of blast furnace slag cement.

REFERENCES

Bui V.K., Montgomery D., Hinczak J., Turner K., 2002. Rapid testing method for segregation resistance of self–compacting concrete. Cement and Concrete Research 32, 1489–1496.

Domone P.L., 2006. Self-compacting concrete: An analysis of 11 years of case studies. Cement and Concrete Composites 28, 197–208.

Felekođlu B., Tosun K., Baradan B., Altun A., Uyulgan B., 2006. The effect of fly ash limestone fillers on the viscosity and compressive strength of self-compacting repair mortars. Cement and Concrete Research 36, 1712–1726.

Giergiczny Z., Małolepszy J., Szwabowski J., Śliwiński J., 2002. Portland blended cements in technology of new generation concretes. Wydawnictwo Górażdże Cement, Opole (in Polish).

Hamada D., Saito F, Yamada F., Mizunuma T., 2000. Development of New Superplasticizer and Its Application to Self-Compacting Concrete. In: Proc. of the Sixth CANMET/ACI Int. Conference on Superplasticizers and Other Chemical Admixtures in Concrete. Ed. V.M. Malhotra. Nice, October, 269–290.

Kaszyńska M., 2003. Self-compacting concrete – prospects of technology and results of tests. Proc. of the Conference Days of Concrete. Tradition and Trends. Wisła, 1–16 (in Polish).

Kinoshita T., Nawa T., Yida T., Ichiboji H., 2000. Effect of Chemical Structure on Fluidizing Mechanism of Concrete Superplasticizer Containing Polyethylene Oxide Graft Chains. In: Proc. of the Sixth CANMET/ACI Int. Conference on Superplasticizers and Other Chemical Admixtures in Concrete. Ed. V.M. Malhotra. Nice, October, 163–179.

Kurdowski W., Garbacik A., Chłądzyński S., 2006. Influence of cement type on concrete properties. Zeszyty Naukowe Politechniki Gdańskiej. Budownictwo Lądowe LIX, 602, 161–171 (in Polish).

Li C.-z., Feng N.-q., Li Y.-d., Chen R.-j., 2005. Effect of polyethylene oxide chains on the performance of polycarboxylate-type water-reducers. Cement and Concrete Research 35, 867–873.

Okamura H., Ouchi M., 1999. Self-compacting concrete development. Present use and future. Proc. of the First RILEM Int. Symposium on Self-Compacting Concrete. Stockholm, September, 3–14.

Okamura H., Ouchi M., 2003. Self-Compacting Concrete. Journal Advanced Concrete Technology 1 April, 5–14.

Papayianni J., Tsohos G., Oikonomou N., Mavria P., 2005. Influence of superplasticizer type and mix design parameters on the performance of them in concrete mixtures. Cement and Concrete Composites 27, 217–222.

Persson B., 2003. Internal frost resistance and salt frost scaling of self-compacting concrete. Cement and Concrete Research 33, 373–379.

Proc. of the Sixth CANMET/ACI Int. Conference on Superplasticizers and Other Chemical Admixtures in Concrete, 2000. Ed. V.M. Malhotra. Nice, October, 163–179.

Ramachandran V.S., 1995. Concrete Admixtures. Handbook, Park Ridge. Noyes Publications, New Jersey.

Rixom R.R., Mailvaganam N., 1999. Chemical Admixtures for Concrete. Spon Press, London.

Schwartzentruber L.D'Aloia, Le Roy R., Cordin J., 2006. Rheological behaviour of fresh cement pastes formulated from a Self-Compacting Concrete (SCC). Cement and Concrete Research 36, 1203–1213.

Spiratos N., Pagé M., Mailvaganam N., Malhotra V.M., Jolicoeur C., 2006. Superplasticizers for Concrete: Fundamentals, Technology and Practice. Marquis. Quebec.

Takada K., Pelova G.J., Walraven J.C., 1999. Influence of microfillers on proportioning of mortar in self-compacting concrete. Proc. of the First RILEM Int. Symposium on Self-Compacting Concrete. Stockholm, September, 537–548.

Termkhajornkit P., Nawa T., Nakai M., Sato R., 2005. Effect of fly ash on autogenous shrinkage. Cement and Concrete Research 35, 473–482.

Tseng Y.C., Wu W.L., Huang H.L., Wang K.C., Hsu K.C., 2000. New Carboxylic Acid Based Superplasticizer for High Performance Concrete. In: Proc. of the Sixth CANMET/ACI Int. Conference on Superplasticizers and Other Chemical Admixtures in Concrete. Ed. V.M. Malhotra. Nice, October, 401–413.

Zhu W., Gibbs J.C., 2005. Use of different limestone and chalk powders in self –compacting concrete. Cement and Concrete Research 35, 1457–1462.

RODZAJ CEMENTU A WŁAŚCIWOŚCI BETONU SAMOZAGĘSZCZALNEGO

Streszczenie. Beton samozagęszczalny (BS) to kompozyt cementowy nowej generacji. Jego projektowanie i wykonawstwo wymagają szczególnej staranności, aby uzyskać wymagane właściwości mieszanki betonowej. Jest wrażliwy nawet na minimalne zmiany składu i warunków otoczenia przy wykonywaniu go zarówno w laboratorium, jak i na budowie. Dobór składników do betonu samozagęszczalnego – szczególnie cementu i superplastyfikatora, które współdziałają ze sobą we właściwy sposób, jest istotny w technologii tego betonu. W badaniach przedstawionych w artykule zastosowano cztery rodzaje cementu, różniące się właściwościami fizycznymi i chemicznymi oraz składem fazowym, i sprawdzono ich kompatybilność z superplastyfikatorem nowej generacji, oceniając właściwości wykonanych z nich mieszanek betonowych i betonów.

Słowa kluczowe: beton samozagęszczalny, cement, superplastyfikator, kompatybilność

Accepted for print – Zaakceptowano do druku: 15.12.2008