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Effects of granulated blast furnace slag and superplasticizer type on the fresh properties and compressive strength of self-compacting concrete

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ABSTRACT

This paper presents the results of an experimental investigation carried out to study the effect of granulated blast furnace slag and two types of superplasticizers on the properties of self-compacting concrete (SCC). In control SCC, cement was replaced with 10%, 15%, 20%, and 25% of blast furnace slag. Two types of superplasticizers: polycarboxylate based superplasticizer and naphthalene sulphonate based superplasticizers were used. Tests were conducted for slump flow, the modified slump test, V-Funnel, J-Ring, U-Box, and compressive strength. The results showed that polycarboxylate based superplasticizer concrete mixes give more workability and higher compressive strength, at all ages, than those with naphthalene sulphonate based superplasticizer. Inclusion of blast furnace slag by substitution to cement was found to be very beneficial to fresh self-compacting concrete. An improvement of workability was observed up to 20% of slag content with an optimum content of 15%. Workability retention of about 45 min with 15% and 20% of slag content was obtained using a polycarboxylate based superplasticizer; compressive strength decreased with the increase in slag content, as occurs for vibrated concrete, although at later ages the differences were small.

1. Introduction

Increased productivity and improved working environment have had high priority in the development of concrete construction over the last two decades. Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under its own-weight with little or no vibration effort, and which is at the same time cohesive enough to be handled without segregation or bleeding [1]. For this reason, self-compacting concrete (SCC) has been increasingly used in concrete construction. The principal reasons for the growing interest in SCC is because of the ease in placement of this type of concrete in heavily reinforced areas which are otherwise difficult to access, the reduced effort in accomplishing some of the casting tasks and the significant reduction of the construction period. Along with these advantages, in terms of environment, this technology will enable a considerable reduction of the acoustic noise levels and the use of secondary raw materials [2]. Additionally, the technology has improved the performance in terms of hardened material properties such as strength, durability, and surface quality.

SCC is a complex system that is usually proportioned with one or more mineral admixtures and one or more chemical admixtures. A key factor for a successful formulation is a clear understanding of the role of the various constituents in the mix and their effects on the fresh and hardened properties [3]. Successful self-compacting concrete must have adequate rheological properties [4]. Variations in cement or mineral additives due to changes in the production process as well as changes in aggregate type, e.g. from one sand pit to another, were observed to cause large variations on properties of fresh SCC. Therefore, it is of great importance to have a robust mixture, which is minimally affected by the external sources of variability [3]. The robustness checking is recognised as an important step in the SCC design process [5].

Superplasticizers added to concrete provide a better workability. Understanding and quantifying effects of superplasticizers in concrete is a complex task. Even for non-reactive systems, such as ceramic suspensions, the stabilising effects of dispersants are a subject of ongoing research. In cementitious systems, hydration reactions can perturb the behaviour of suspensions [6]. Dispersion of agglomerated cement particles is recognised to constitute the main method by which superplasticizers improve the workability of concrete without increasing the water content. Quantifying this mechanism is a difficult task and is further complicated by the ongoing hydration reactions of cement. Understanding these effects is a key aspect for predicting which combinations of cement and superplasticizers will lead to best workability and which ones will not.

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Dispersion forces, often also referred to as Van der Waals forces, are the main cause for agglomeration of cement particles in concrete and of the poor resulting flow properties. To counter these forces and improve flow, dispersants are added [7]. Important factors are the length of graft chains, degree of polymerisation, and the density of graft chains. The characteristics of superplasticizers depend on the raw materials and the synthesis conditions. Therefore, the effect of the chemical structure of superplasticizers on their performance can be different when the manufacturer is different although the basic structure and working mechanism are the same. This is one of the difficult points of the fundamental study of superplasticizers [8].

According to Sicker et al. [9], the fluidity of cement pastes with conventional superplasticizers of type naphthalene sulphonate (PS2) was found to depend on the molecular weight (viscosity). Furthermore the retardation effect of this superplasticizer type was shown to be roughly proportional to naphthalene sulphonate concentration and strongly dependent on the C_3A content of the cement. They added that, the operative mechanism of new superplasticizers of "polycarboxylic ether" type owing to electrostatic repulsive forces is based on the negative charge of polycarboxylate and steric repulsive forces on the cement particles based on long side strains.

The mechanism of action of naphthalene sulphonate based superplasticizer is different from the one of a polycarboxylate based superplasticizer. The first one acts by electrostatic repulsion, and the second one acts by steric hindrance effect [10]. This clearly represents an objective of great practical importance.

One of the disadvantages of SCC is its cost, associated with the use of chemical admixtures and use of high volumes of Portland cement. One alternative to reduce the cost of SCC is the utilisation of mineral admixtures. The utilisation of supplementary cementitious materials is well accepted because of the several improvements possible in the concrete composites and due to the overall economy [11]. Due to the better engineering and performance properties, mineral admixtures such as Silica Fume, Fly Ash and Ground Granulated Blast-Furnace Slag are normally included in the production of high strength and high-performance concrete [12]. The use of any of these mineral admixtures could increase the fluidity of the concrete and may reduce the requirement of superplasticizer necessary to obtain a similar slump flow compared with the same concrete containing cement only [13]. In addition, the incorporation of these fine materials can enhance the grain size distribution and the particle packing, thus ensuring greater cohesiveness [14]. Slag is a mineral admixture that has a chemical composition very close to the one of cement and relatively constant. In the world, there is about 250 million tonnes of slag generated per year. Out of which only 90 million tonnes are used in the production of concrete. Besides, it also offers several advantages like low heat of hydration, high sulphate and acid resistance, better workability, lower permeability and higher corrosion resistance [15]. Sahmaran et al. [16], have compared two types of superplasticizers, a polycarboxylate base superplasticizer and a melamine formaldehyde based superplasticizer, with silica fume and metakaolin as mineral additions, and found out that the first one is more efficient than the second one.

This paper reports on an ongoing research project on the performance of SCC using slag. In this paper, we report mainly the properties of fresh and hardened SCC looking for the optimum dosage of slag to use. The second aim of this research project is to compare the performance of two types of superplasticizers especially concerning the loss of workability. The objective of comparing two different chemical admixtures is to make the point on their effectiveness with respect to workability and strength.

Table 1
Chemical analysis and physical properties of cement and slag used (%).

Chemical constituent	Cement (%)	Slag (%)
SiO_2	21.7	40.1
CaO	65.7	42.2
Al_2O_3	5.2	6.0
Fe_2O_3	2.7	2.0
MgO	0.7	4.7
SO_3	0.6	0.15
MnO	–	2.6
K_2O	0.4	1.2
TiO_2	–	1.2
Na_2O	0.7	–
CI	0.01	–
Loss on ignition	0.3	–
Specific gravity	3.15	2.95
Blain (m^2/kg)	300	350
C_3S	58.2	
C_2S	18.5	
C_3A	9.3	
C_4AF	8.2	

2. Experimental methods

2.1. Materials

The materials used in this study were readily available on the market. In this research Ordinary Portland Cement (OPC), Ground Granulated Blast Furnace Slag (GGBFS), Sand, Gravel and Superplasticizers were used. The concrete mixtures were prepared with cement CEM I 42.5 with fineness of 3000 cm^2/g and a specific gravity of 3.15. The granulated slag used a fineness of 3500 cm^2/g and a specific gravity of 2.95. The physical and chemical properties of cement and slag used and their mineralogical composition are given in Table 1. Continuously graded crushed coarse aggregates (3/8 and 8/15 mm) and a river sand (0/4 mm) were used. The water absorption capacities of coarse aggregates (3/8 and 8/15) and sand were 1%, 1% and 1.2%, respectively. In this study, two types of superplasticizers were used, a polycarboxylate based superplasticizer (SP1) and a naphthalene sulphonate based superplasticizer (SP2). Polycarboxylate based superplasticizers are known for their increased efficiency and their ability to develop strength faster compared to those of the other generations. SP1 has a solid content of 30% and a specific density of 1.07%, whereas SP2 has a solid content of 40% and a specific density of 1.1%.

2.2. Mix proportions and preparation

The basic components for the mix composition of SCC are the same as used in vibrated concrete. However, to obtain the desired properties of fresh SCC, a higher proportion of ultra-fine materials and the incorporation of chemical admixtures, in particularly an effective superplasticizer, are necessary. The mixture proportions were based on Okamura et al. method [17], with improvements made on the methods of selecting the fine aggregates content. The sand-mortar weight ratio (Vs/Vm), the water-powder weight ratio (Vw/Vp) and the superplasticizer-powder weight ratio (Sp/p) were selected by a simple evaluation test for assessing the stress transferability of fresh mortar [18]. For evaluation of the coarse aggregate contents, Okamura's method is maintained.

Superplasticiser were diluted in water before added to the concrete for a better distribution of admixtures within the mass of SCC and practice in general confirms this [19].

SCC normally requires a more efficient mixing, longer mixing time, to make sure that all constituents have been mixed thoroughly [20]. Hence, the following mixing procedure consisted in mixing the aggregates with cement and slag together for half a minute before adding 70% of necessary water during 1 min then adding the remaining 30% of water containing the superplasticizer during another 1 min. The mixing procedure is continued for another 5 min, after that the whole mix is kept for settling for 2 min before remixing for just half a minute, immediately then we started workability tests.

2.3. Test methods

2.3.1. Workability of mortar

Mortar serves as the basis for the workability properties of SCC and these properties could be assessed by investigating self-compacting mortars [19]. In fact, assessing the properties of SCMs is an integral part of SCC design [21]. The aim of mortar tests is to find the optimum dosage of both superplasticizers that can give the best workability of mortar without segregation or bleeding.

Tests on mortar include flow spread and the V-Funnel for mortar. In the flow spread test, the truncated cone mould is placed on the plate, filled with mortar, and lifted. The subsequent diameter of the mortar is measured in two perpendicular directions, and the mean is taken. The V-Funnel test for mortar, suggested by Okamura et al. [17], was used along with flow spread test to select a suitable water-powder ratio in the mix design and to observe its variation with mix proportion. The Funnel is filled with 1.1 l of mortar, and the flow time is that between opening the orifice and the first daylight appearing when looking vertically down through the funnel. Six tests (for each superplasticizer) on mortar have been carried out for a constant water/cement (W/C) ratio of 0.4 using six superplasticizer dosages Sp/C(%) = 1.2%, 1.4%, 1.6%, 1.8%, 2.0% and 2.2%.

2.3.2. Workability and rheology of concrete

The functional requirements on a fresh SCC are different from those on a vibrated fresh concrete. The difference can be summarised in three requirements:

2.3.2.1. Filling ability. Complete filling of formwork and encapsulation of reinforcement and inserts. Substantial horizontal and vertical flow of the concrete within the formwork with maintained homogeneity. In this study, the filling ability was measured by slump flow, V-Funnel tests for concrete and T50 flow time.

2.3.2.2. Passing ability. Passing of obstacles such as narrow sections of the formwork or closely spaced reinforcement without blocking caused by interlocking of aggregate particles. In this study, passing ability was measured by the J-Ring and U-Box tests (Fig 1).

2.3.2.3. Resistance to segregation. Maintaining of homogeneity throughout mixing and during transportation and casting. The dynamic stability refers to the resistance to segregation during placement. The static stability refers to resistance to bleeding, segregation and surface settlement after casting.

The aim of carrying concrete workability tests is to find the optimum dosage of slag that gives a good self-compacting concrete without segregation or bleeding. Slag was added as a substitution to cement by weight in the proportions of concrete with 10%, 15%, 20% and 25%.

Workability was measured immediately after mixing which takes about ten (10) minutes. In addition to these tests, the slump flow was measured at four different times after mixing to assess the workability retention. The four times were: 0, 30, 60 and 90 min after the end of the mixing.

Tattersall was one of the pioneers of concrete rheology when, in 1991, he proposed using an instrumented mixer to obtain a more complete characterisation of the flow characteristics of fresh concrete. He proposed describing the behaviour of fresh concrete using the Bingham model in the following form:

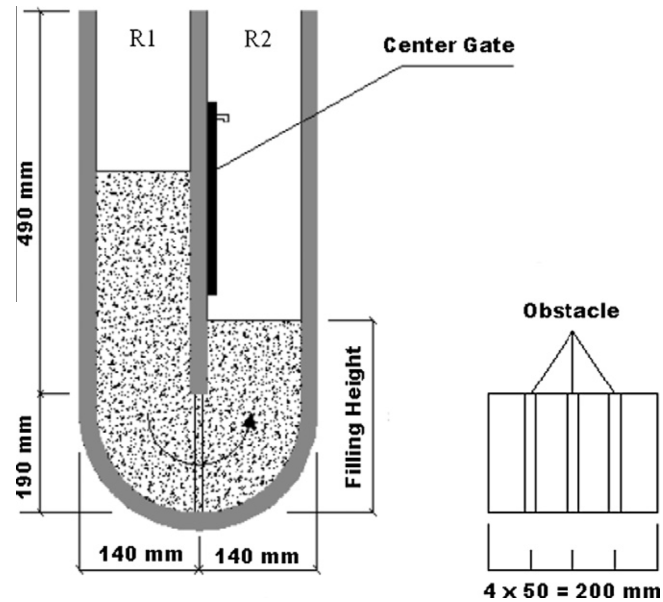

Fig. 1. U-Box test.

$$\tau = \tau_0 + \mu\dot{\gamma} \quad (1)$$

where τ is the shear stress applied to the material (in Pa), $\dot{\gamma}$ is the shear strain rate (also called the strain gradient)(in s^{-1}), τ_0 is the yield stress (in Pa) and μ is the plastic viscosity (in Pa s). The last two quantities (the Bingham parameters, τ_0 and μ) characterise the flow properties of the material. A modification of the slump cone was developed to allow the measurement of viscosity [22]. The standard slump test can only be correlated with the yield stress. The modification consists of measuring not only the final slump height but also the speed at which the concrete slumped (Fig. 2). The principle of the modified slump test consists of measuring necessary time T for top surface of concrete sample inside Abram's cone to slump down at a height of 100 mm. The final slump is then measured.

The yield stress, τ_0, can be calculated from the final slump S, using the following empirical equation:

$$\tau_0 = \frac{\rho}{347}(300 - S) + 212 \quad (2)$$

where ρ is the density expressed in kg/m^3, and S is the final slump in mm. The viscosity can be determined from the 100 mm slump time using an empirical equation [23].

$$\mu = \rho T \times 1.08 \times 10^{-3}(S - 175) \quad (3)$$

where ρ is the density (in kg/m^3), S the final slump (in mm) and T is the partial slump time (in s).

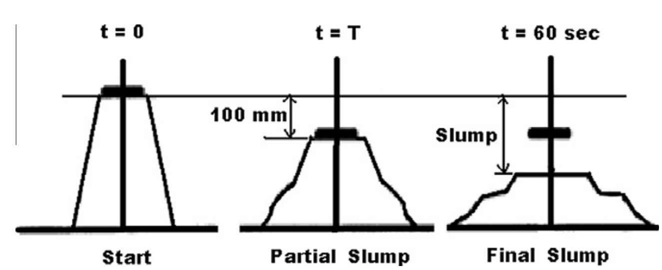

Fig. 2. Design and dimensions of the modified slump test apparatus.

The modified slump test is carried out to measure these two rheological tests, yield stress and plastic viscosity, and find their optimum values with respect to slag dosage.

2.3.3. Strength

In this study, compressive strength test on 150 mm cubes at four different ages 7, 28, 56 and 90 days was carried out for different slag contents.

3. Results and discussion

3.1. Mortar

The effect of two superplasticizers dosage on slump flow and V-Funnel flow time are given in Table 2 and Figs. 3 and 4.

Fig. 3 shows the effect of both superplasticizers on the slump flow. SP1 dosages of 1.6% and 1.8%, and SP2 dosages of 1.8% and 2.0% are within the range of slump flow of 250–300 mm as proposed by Domone and Jin [19], 2% and more for SP1 and 2.2% for SP2 have clearly shown some bleeding and segregation. Fig. 3 also shows values of slump flow for mixes using SP1 higher than those using SP2 for all dosages. Here we can clearly notice that a good self-compacting mortar is obtained with a dosage of 1.6% of SP1 and 1.8% of SP2.

Fig. 4 shows the effect of both superplasticizers on the V-Funnel Flow Time. SP1 dosages of 1.6% and 1.8% have had the lowest flow times within the test of V-Funnel for mortars. SP2 dosages resulted in the lowest flow times for 1.8% and 2.0%. For both superplasticizers, these lowest flow times are within the values of 2 to 10 s as proposed by Domone and Jin [19]. The optimum percentages found for the slump test are confirmed by the V-Funnel test.

Sicker et al. [9], concluded that different rheological properties depend on the type of pozzolan and the polycarboxylic ether based superplasticizer was the best for silica fume as well as for metakaolin. Our research using slag confirms this result.

From both mortar tests, Slump Flow and V-Funnel, we can recommend the followings:

For mortar mixes using SP1, the best dosage to use for concrete mixes is 1.6%.

For mortar mixes using SP2, the best dosage to use for concrete mixes is 1.8%.

Mortar mixes with SP1 accuse a better workability than for mortar mixes with SP2. This was predictable since SP1 represents the new generation of superplasticizers for mortar and concrete mixes.

3.2. Concrete

Table 3 summarises the fresh concretes compositions. Table 4 summarises the fresh concrete tests results.

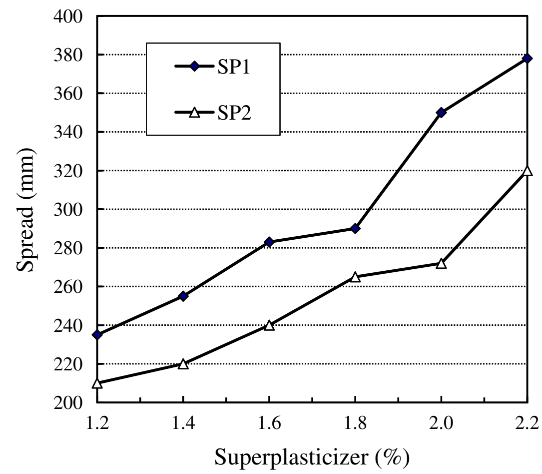

Fig. 3. Slump flow for mortar.

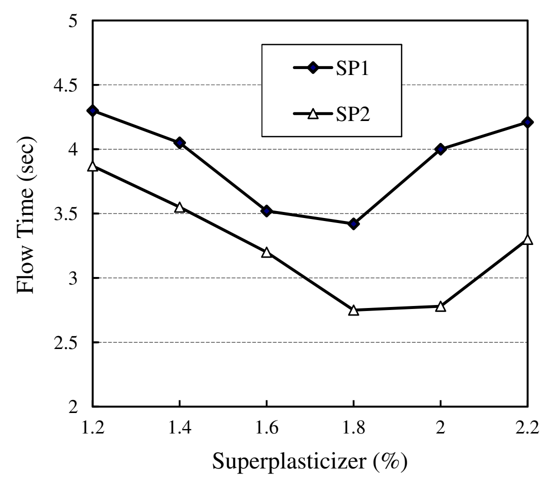

Fig. 4. V-Funnel flow time for mortar.

Fig. 5 shows the results of mortar passing through 5 mm sieve for segregation resistance for concrete mixes for both superplasticizers. Empirical observations suggest that if the percentage of mortar which has passed through the sieve, the segregation ratio, is between 5% and 15% of the weight of the sample, the segregation resistance is considered satisfactory. Below 5% the resistance is excessive, and likely to affect the surface finish (blow holes likely). Above 15%, and particularly above 30%, there is strong likelihood of segregation [21,24]. It is evident from Fig. 5 that for concrete mixes with 10% and 15% slag content, for both superplasticizers, the segregation resistance is satisfied, but higher than 15%, the presence of bleeding and segregation is confirmed. The effect of slag addition

Table 2
Mix proportions and target properties for mortar.

Mortar		M1	M2	M3	M4	M5	M6
Cement (kg/m^3)		696	696	696	696	696	696
Fine aggregate (kg/m^3)		1348	1348	1348	1348	1348	1348
Water (kg/m^3)		278.4	278.4	278.4	278.4	278.4	278.4
Superplasticizer (%)		1.2	1.4	1.6	1.8	2.0	2.2
Slump flow (mm)	SP1	235	255	283	290	350	378
	SP2	210	220	240	265	272	320
V-Funnel flow time (s)	SP1	4.3	4.05	3.52	3.42	4	4.21
	SP2	3.87	3.55	3.2	2.75	2.78	3.3

SP1: polycarboxylate based superplasticizer.
SP2: naphthalene sulphonate based superplasticizer.

Table 3
Fresh concretes compositions.

Mixture			SCC1	SCC2	SCC3	SCC4	SCC5
Cement		(kg/m^3)	465	420	397	374	352
Slag content		(%)	0	10	15	20	25
		(kg/m^3)	0	44	66	88	110
Coarse aggregate (3/8)		(kg/m^3)	280	280	280	280	280
Coarse aggregate (8/15)		(kg/m^3)	560	560	560	560	560
Fine aggregate		(kg/m^3)	867	867	867	867	867
Water		(kg/m^3)	186	185	185	185	185
Superplasticizer	SP1	(%)	1.6	1.6	1.6	1.6	1.6
		(kg/m^3)	7.44	7.42	7.40	7.39	7.38
	SP2	(%)	1.8	1.8	1.8	1.8	1.8
		(kg/m^3)	8.37	8.35	8.33	8.32	8.32

SP1: polycarboxylate based superplasticizer.
SP2: naphthalene sulphonate based superplasticizer.

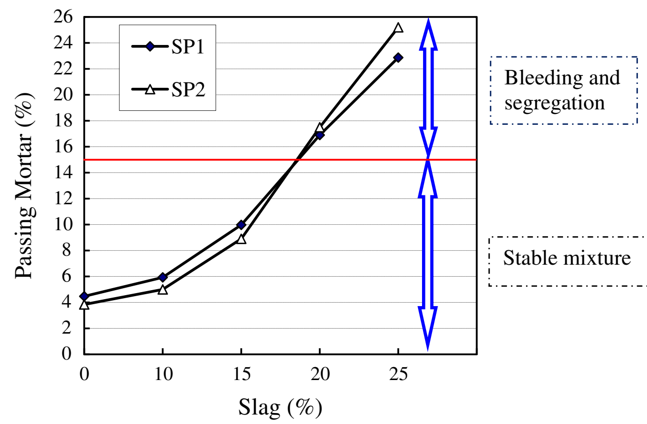

Fig. 5. Segregation resistance with 5 mm sieve test.

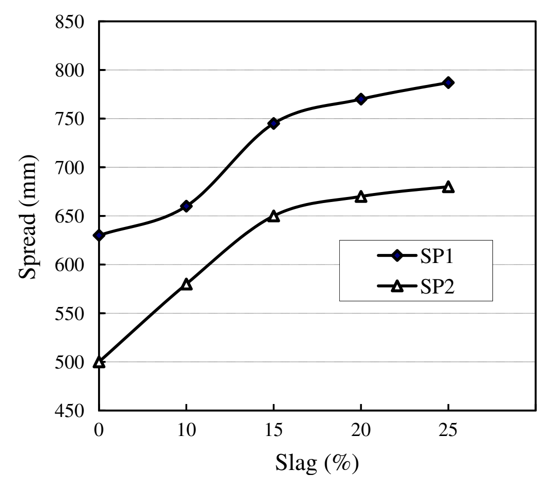

Fig. 6. Slump flow.

on the slump flow is given in Fig. 6. From this figure, it is observed that spread values were higher for concrete mixes where SP1 was used than the mixes where SP2 was used. For polynaphthalene based superplasticizers, Jolicoeur and Simard [25], suggested that the retardation was mainly due to the adsorption of admixtures on nucleating hydrate particles and intercalation into hydrate phases already formed such as ettringite which inhibit the development of hydration products. For polycarboxylate based superplasticizers, Uchikawa et al. [26] showed that a chelate formed in pastes as a result of interaction between Ca^{2+} ions and the admixture molecules would lower the Ca^{2+} concentration in the system, thus hinder solid phase nucleation and hydration products growth, and retard cement hydration.

It is also clear from this figure for both the superplasticizers that the slope of the graph decreased starting from slag content higher than 15%, which means that slag content of 15% is at its best as far as workability is concerned. Some researchers suggested a slump flow between 650 and 700 mm to get a good self-compacting concrete [27].

The variation of partial slump time, is measured by means of the modified slump test proposed by Ferraris and De Larrard [22], with respect to slag content. Partial slump time, which is also a rheological parameter, increases rapidly, for both superplasticizers though mixes with SP2 seem to be less workable accusing partial slump times higher than those with SP1.

Fig. 7 shows the variation of yield stress with increasing slag content. Here as well, the higher the slag contents the lower yield stress, for both superplasticizers, with an optimum at 15% of slag content.

The variation of plastic viscosity with respect to slag content is shown in Fig. 8. Plastic viscosity decreases with increasing slag content for both superplasticizers as found by Sicker et al. [9]. The most efficient superplasticizer, as far as plastic viscosity is concerned, is the one based on polycarboxylate ether because of its longer PEO side chains [28].

For both, yield stress and plastic viscosity, Shi et al. [29] demonstrated that these latter decrease with increasing slag content. They believe that the plastic viscosity and yield stress can be significantly decreased by partially substituting the cement with vitreous powders. The semi crystalline powders, although only at the higher substitution levels, can also achieve a noticeable effect in lowering the viscosity.

Table 4
Results of concrete tests.

Slag content (%)			0%	10%	15%	20%	25%
Slump test	T50 flow time (s)	SP1	1.25	1.22	0.66	1	1.2
		SP2	1.4	1.07	0.82	1.1	1.3
	Slump flow (mm)	SP1	630	660	745	770	787
		SP2	500	580	600	660	700
J-Ring test	Difference height (mm)	SP1	9.75	9.25	7.75	9.75	18.25
		SP2	11.23	10.6	8.8	11	19.01
V-Funnel test	Flow time (s)	SP1	7	6	4	9.14	14.8
		SP2	10	7.5	5.2	9.6	13.8
5 mm sieve test	Passing mortar (%)	SP1	4.47	5.93	9.975	16.9	22.87
		SP2	3.84	5	8.9	17.5	25.2
U-Box test	Filling height (mm)	SP1	325	350	390	305	230
		SP2	285	335	375	285	207

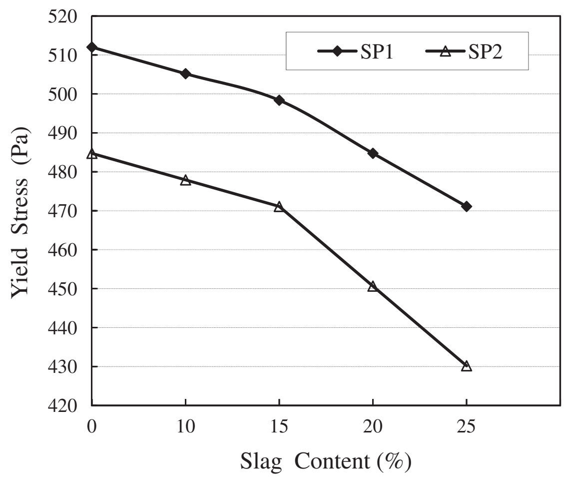

Fig. 7. Yield stress vs slag content.

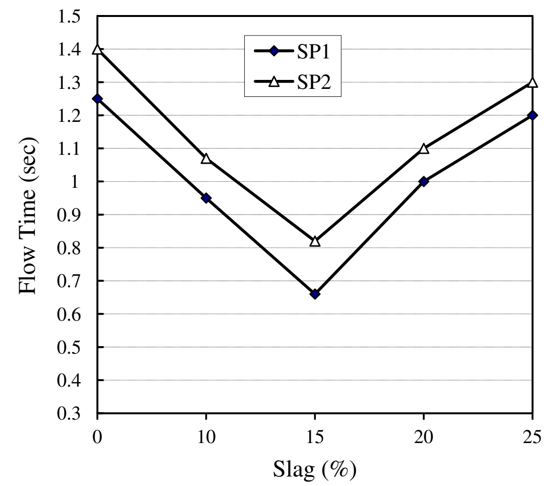

Fig. 9. T50 Flow time.

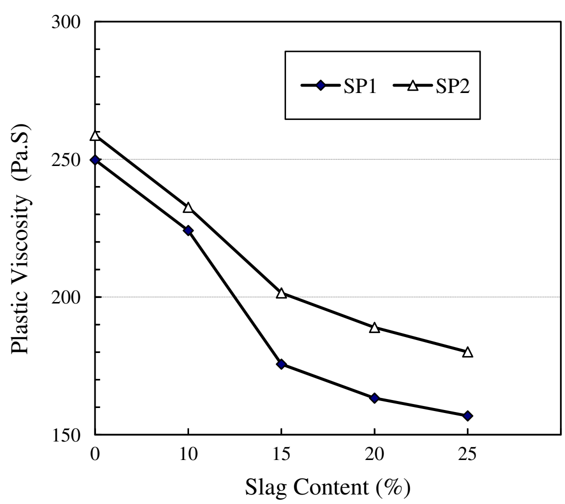

Fig. 8. Plastic viscosity vs slag content.

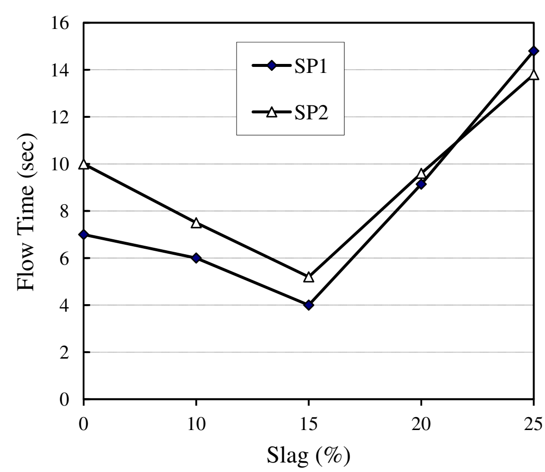

Fig. 10. V-Funnel flow time.

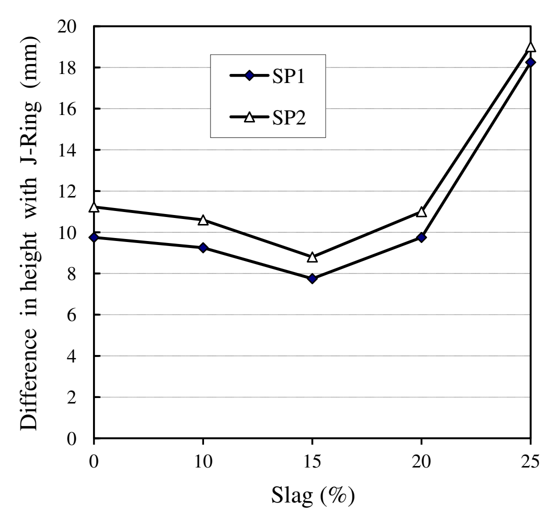

Fig. 11. Difference in height with J-Ring.

Fig. 9 shows the effect of slag content on the T50 flow time, where 15% slag content gave the lowest flow time for concrete mixes with both superplasticizers. Here as well, the best time is obtained with concrete mix using SP1. In this study, it was observed that values are slightly lower than those in literature, for instance some researchers proposed values between 2 and 4 s, this could be explained by the high results of slump flow (Fig. 6) compared to those proposed elsewhere [27].

V-Funnel flow time values are shown in Fig. 10. The V-Funnel test indicates the filling ability of the mix. Values are acceptable till 20% of slag content for concrete mixes with both superplasticizers, as compared to the suggested values between 2 and 10 s proposed by Domone and Jin [19]. The optimum time was obtained at 15% slag content for concrete mix containing SP1.

The J-Ring difference height results are shown in Fig. 11. It is at its minimum with 15% slag content for both superplasticizers. The recommended difference height is up to 10 mm [30]. Fig. 12 gives values of U-Box filling ability height, here as well; it was noticed that filling heights are higher for mixes containing SP1 than those containing SP2 with acceptable values above the 300 mm proposed by EFNARC [5].

According to [8], SP1 is more efficient than SP2 because this latter is produced in a molecular size that is suitable as cement dispersant, but do not have a significant air entraining effect and have poor slump retention in many cases. They are not suitable for ready mixed concrete requiring a long slump life, whereas SP1 is composed of three essential parts; a backbone of polyethylene, grafted chains of POE and carboxylic groups as adsorbing functional groups. By modifying these chemical structures, various

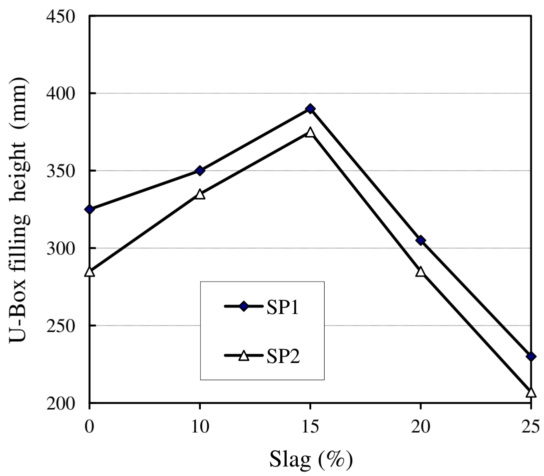

Fig. 12. U-Box filling height.

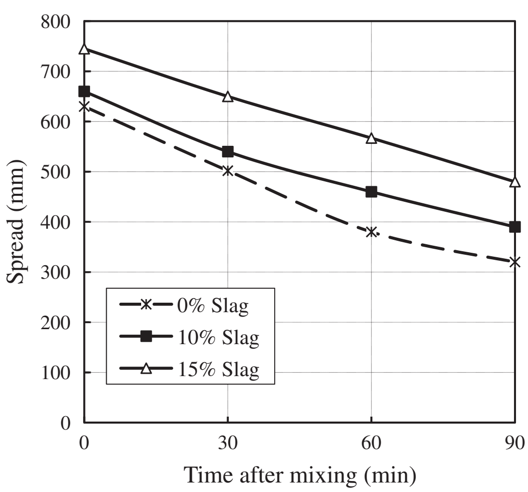

Fig. 13. Loss of workability of concrete mixes with SP1.

properties such as dispersion performance just after mixing, slump retention, and setting can be controlled.

Fig. 13 shows the loss of workability of concrete mixes with SP1 at 0, 30, 60 and 90 min after mixing for 0%, 10% and 15% slag content. It is well known that loss of workability is a rheological parameter. This figure reveals that the slope of workability retention is less important for mix with 15% of slag content than for mixes without or with 10% of slag content. Mixes with 15% slag content remain workable till 60 min after mixing. The authors have earlier [31], found that concrete mixes without slag or with 10% slag lost a part of their workability even at 30 min after mixing.

From all these tests on workability of concrete mixes, it can be confirmed the efficiency of the new generation of superplasticizers based on polycarboxylate.

3.3. Strength

Strength test results for concrete mixes with superplasticizer SP1 were inferior to those with SP1. A decrease in compressive strength with increased slag content at all ages was observed for concrete mixes with SP1 (Fig. 14). Comparing our results to those given by Khatib and Hibbert [32], it was noticed that slag has the same effect on compressive strength for both self-compacting concrete and vibrated concrete. The same effect on compressive strength has been observed with natural pozzolana for vibrated

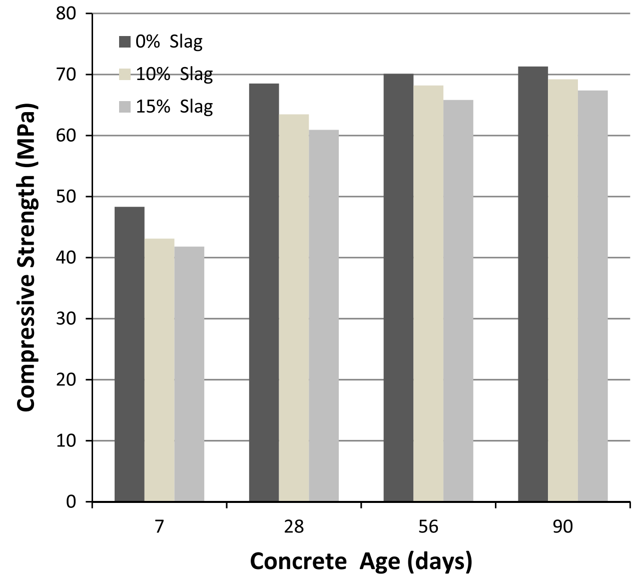

Fig. 14. Variation of compressive strength with slag of concrete mixes with SP1.

concrete [33]. Fig. 14 shows also that this decrease of compressive strength is less important at late ages (56 and 90 days after mixing).

4. Conclusion

The main objective of this paper was the evaluation of incorporating slag on the properties of fresh and hardened self-compacting concrete. The second objective was to compare two superplasticizers, a polycarboxylate based superplasticizer with a naphthalene sulphonate based superplasticizer belonging to the new generation and the second generation respectively. The Okamura method, with modifications to meet local materials' requirements, was found appropriate to make self-compacting concrete. As predicted, the polycarboxylate based superplasticizer gave more workability and higher compressive strength, at all ages, to concrete mixes than the naphthalene sulphonate based superplasticizer. The addition of slag by substitution to cement was found to be very beneficial to fresh self-compacting concrete. An improvement of workability was observed up to 20% of slag content with an optimum content of 15%. Yield stress and plastic viscosity had shown decreasing values, for both superplasticizers, with increasing slag content. The deflexion point was at 15% of slag content. Workability retention of about 45 min with 15% and 20% of slag content was obtained using a polycarboxylate based superplasticizer. However, the disadvantage of mineral additives against the chemical admixtures is the reduction in early strength when part of the cement is replaced by the mineral additives. Compressive strength decreases with increase of slag content at early age, as is the case of vibrated concrete but at later ages (56 and 90 days) the strength is comparable to that of reference concrete.

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