Overcoming the slump loss of fresh self compacting concrete by overdosing technique for different transportation times

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Abstract

Slump loss is a common phenomenon at the job sites because it results from gradual stiffening and setting of hydrated portland cement paste, which is associated with the formation of hydration products such as ettringite and the calcium silicate hydrate. In the present investigation a study had been undertaken to study the effectiveness of overdosing the chemical admixture which was used to provide the initial optimum admixture dosages resulting in suitable self compacting concrete (SCC) for different transportation times. A suitable SCC was designed for a slump flow of 680mm with very high stability. Five different transportation times such as 10, 30, 60, 90 and 120 minutes were used. The test results indicated that the selected overdosing method was successful in producing SCCs with a similar unconfined flowability, stability and passing ability to those obtained at the control transportation time of 10 minutes.

Keywords: self compacting concrete, slump flow, transportation, overdosing, slump loss

1. Introduction

The development of self-compacting concrete (SCC) also referred to as "Self-Consolidating Concrete" has recently been one of the most important developments in building industry (Brouwers and Radix, 2005). SCC can flow through and fill gaps of reinforcement and corners of moulds without any need for vibration and compaction during the pouring process. Due to its rheological properties, many advantages can be mentioned. SCC may contribute to a significant improvement of the quality of concrete structures and open up a new field for the application of concrete. It has got the ability to compact itself only by means of its own weight without the requirement of vibration (Okamura, 1997). It fills all recesses, reinforcement spaces and voids, even in highly reinforced concrete members. While flowing in the formwork SCC is able to deaerate almost completely.

However, SCC has also some disadvantages. These are SCC needs a high level of quality control of the materials being used (sand, coarse aggregate, filler, superplasticitizer and cement) and of the adopted mix, since the concrete properties in fresh state can be altered presenting excessive fluidity, segregation or excess of cohesion. However, when SCC is sensibly utilized, the reduction of costs by better productivity, shorter construction time and improved working conditions will compensate the higher material costs. (Okamura, 1997). On the other hand, in densely reinforced sections, such as those in columns and beams in moment-resisting frames in seismic areas and in some repair sections, it is quite difficult to cast normal concrete and ensure that all spaces in the formwork are filled with concrete. The use of SCC is necessary in these cases. Retention of flowability of SCC at the point of discharge at the jobsite is an important issue. Hot weather, long transportation distances and delays on the job site can result in the reduction of flowability whereby the benefits of using SCC are reduced. Overdosing the admixture amount in attaining the target slump at the job site or retempering with admixture instead of water are the preferred methods in remediation of the slump loss, since the use of extra water in retempering or in making a higher initial slump can induce side effects on the properties and serviceability of the hardened concrete (i.e. decrease in strength and durability, increase in permeability and drying shrinkage, etc.) (ACI 237-07, Kosmatka et al. 2002). In the case of SCC full capacity mixer truck load may not be feasible with very high flowability due to potential spillage. In such situations it is prudent to transport SCC at lower flowability and adjust the mixture with HRWR admixtures at the jobsite.

The aim of the present study is to overcome the adverse effect on the delay in transportation times on freshly-mixed self-compacting concretes made by an overdosing method. The method consisted of using sufficient initial admixture dosages to obtain the target fresh properties of the trial mixtures at various transportation times. Five different transportation times, namely: 10, 30, 60, 90 and 120 minutes, were used. The slump flow and the passing abilities of the remediated SCCs were evaluated at the end of each transportation time, and compared to the equivalent fresh properties obtained at the control transportation time of 10 minutes.

2. Experimental Program

2.1 Materials

The properties of materials used are as follows:

- The cement used in all mixes was normal Ordinary Portland cement (53 grade) conforming to IS 12269.

- Classified Class F Fly ash obtained from Dirk India, was used as mineral additive; it has a specific gravity of 2.2, and a specific surface of 400 m^2/kg (Blaines). Metakaolin with a surface area of 12000m^2/kg (BET) and a specific gravity of 2.5 was also used as mineral additive.

- Crushed granite of specific gravity 2.88 was used as coarse aggregate and river sand with a specific gravity of 2.65 was used as fine aggregate. The coarse aggregate had a nominal maximum size equal to 12.0 mm.

- A novel, commercially available polycarboxylic ether based superplasticizer (SP) was used in all concrete mixtures.

2.2 Mixture proportion

All the mixes were prepared with a constant water-to cementitious materials ratio of 0.30, a uniform cement content of 356 kg/m^3, fly ash content of 171 kg/m^3 and metakaolin content of 43 kg/m^3. In proportioning the aggregate contents, particular attention was given to the coarse-to-fine aggregate ratio due to its critical role in generating a sufficient amount of mortar for the selected self compacting concretes. The optimum volumetric coarse to-fine aggregate ratio, utilized in the proportioning of the concrete constituents, was found at 0.52/0.48. The different size fractions of coarse aggregates (12 mm down graded and 6 mm downgraded) were taken in order to get a dense concrete. The specific gravities of aggregates were determined experimentally. The quantities of coarse and fine aggregates used in the mixtures were 901 and 765 kg/m^3, respectively. The optimum (minimum) dosages of the high range water-reducing admixture (HRWRA) used at the control transportation time of 10 minutes was 1% of the total cementitious content respectively. These dosages were obtained by evaluating the consistency and stability of concrete using different trial batches until a satisfactory slump flow of 650±25 mm was attained. Table 1 displays the measured fresh properties at the selected transportation times.

2.2 Mixing, Sampling and Testing

Ready mix concrete plant central mixer was used to produce self-compacting concretes. The capacity of the mixer is 1.5m^3 and the concrete is batched 2 times so as to make the whole capacity to 3m^3. The truck mixer was then loaded then to the minimum required capacity of 3

$m^3$and kept aside to simulate the different delay in transportation times on the fresh SCCs. The initial mixing speed of the transit mixer (14.5 rpm) was changed to an agitating speed of (7.25 rpm) until the desired delay in transportation time was achieved. The concrete mixtures at the end of each transportation time were used to determine the slump flow and J-ring passing ability in accordance with the ASTM.

Table 1 Fresh properties of SCC at different transportation times

Transportation Time (min)	*Slump flow (mm)*	*Slump flow loss (mm)*	*% reduction in slump*	*J-Ring difference (mm)*
10	*670*	*0*	*0*	*20*
30	*600*	*-80*	*12*	*28*
60	*545*	*-135*	*20*	*48*
90	*500*	*-180*	*27*	*
120	*450*	*-230*	*34*	*

** J-Ring difference is more than 50mm.*

3. Test Results and Discussions

The delay in transportation time affected the fresh performance of self-consolidating concretes in the form of decrease in the workability especially the slump flow. The dynamic stabilities of the fresh concretes remained unchanged. Table 1 presents the changes in the fresh properties of self compacting concrete as affected by the delay in the transportation times.

Table 2 Required optimum dosages of admixtures for overcoming the slump loss

Transportation Time (min)	*HRWA (%)*	*HRWA (kg/m^3)*
10	*0*	*5.70*
30	*12*	*6.38*
60	*20*	*6.84*
90	*27*	*7.24*
120	*34*	*7.64*

An overview of slump flow loss and the involved mechanism of action is necessary before proceeding with the discussion on overcoming the slump loss. The fundamental mechanism of slump flow loss of concrete during its transportation has been established and reported by several, studies (Kosmatka et al. 2002, Jolicoeur and Simard. 1998, Flatt et al. 1997). It involves mainly the additional fines brought to the concrete mortar by the grinding of aggregates and cement particles, the growth of the cement hydration products, and the competitive adsorption between the superplasticizer and the sulfate ions (SO_4^{2-}) on the cement hydrated products throughout the transportation time. Since the fluidity of concrete is mostly controlled by the fluidity of the mortar portion, the slump flow losses recorded during the present investigation can be explained through the increase in specific surface area of concrete mortar and the change in the adsorption amount of chemical admixtures. In order to overcome the above mentioned adverse effects, an overdosing remediation method was used. This technique consisted of using sufficient initial admixtures amount to attain the target fresh properties at the end of the selected transportation times. Table 2 displays the required optimum dosages of admixtures and Table 3 documents the measured slump flow and J-ring values of the remediated mixtures at different transportation times.

Table 3 Fresh properties of remediated SCC at various transportation times

Transportation Time (min)	*Slump flow (mm)*	*J-Ring difference (mm)*
10	*670*	*20*
30	*660*	*28*
60	*665*	*25*
90	*660*	*26*
120	*660*	*26*

Table 1 presents the percentage decrease in slump loss of the fresh self compacting concretes at different transportation times. This percentage decrease in slump loss was used to determine the extra amount of HRWA required to overcome the slump losses of the SCCs. The optimum dosage required for the control SCC at 10 minutes transportation time is 1% of the total cementitious content, which accounts to 5.7 kg/m^3 as shown in Equation (1).

The dosage of HRWA at 10min transportation time ($W_{spcontrol}$)= $n_{10}\% \times TCM$ (1)

$$= 1\% \times 570\ kg/m^3$$

$$= 5.7\ kg/m^3$$

Where $n_{10}\%$ is the dosage of HRWA used at 10 min transportation time and TCM is the total cementitious content.

The percentage decrease of slump flow loss for 30 minute delay in transportation time was found to be 12%. Now this percentage decrease is used to estimate the extra HRWA required to remediate SCC which is as shown below.

Extra HRWA required at 30 minutes transportation time $(W_{sp30}) = (pr_{30})\%\ X\ (W_{spcontrol})$ (2)

$$= 12\% X\ 5.7\ kg/m^3$$

$$= 0.684\ kg/m^3$$

Where $pr_{30}\%$ is the percentage decrease of slump loss at 30 minute transportation time. Similarly the extra amount of HRWA required for the other transportation times were also evaluated according to Equation (2). The optimum dosage of HRWRA in attaining the required workability increased as the transportation time increased. In comparing to the optimum dosage at the reference 10 minutes transportation time, the selected SCCs required 12, 20, 27 and 34%, more HRWRA at 30, 60, 90, and 120 minutes transportation times, respectively. Also shown in Table 2, the selected self-compacting concretes did not require any viscosity modifying agent (VMA) neither in the control SCC nor in the remediated SCCs at different transportation times. The viscosity modifying admixture was mainly used in SCC to increase its viscosity and stability. However, metakaolin used in the mixture served the purpose of VMA. As reported in Table 2, the test results showed that all remediated self-consolidating concretes were within the target slump flows±25 mm, and J -Ring values between 0 and 50 mm. The test results indicate that the overdosing method was effective in obtaining the workability and passing ability which were similar to those of the control transportation time (10 minutes).

4. Conclusions

The fresh performance of self compacting concrete was affected by the delay in the transportation times in the truck mixer. The changes were manifested in the form of loss in flow ability and increase in the viscosity. These changes in the fresh properties were overcomed by way of admixtures overdosing which produced self consolidating concretes with similar fresh properties to those obtained at the control transportation time. The additional amount of admixtures generated supplementary repulsive electrostatic and steric hindrance forces between the cement particles to assist in dispersing the cement agglomerations generated by the grinding and hydration of cement particles during transportation times.

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