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Evaluation of Fresh and Hardened Properties of Self-Compacting Concrete

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Abstract

This paper compared the rheological properties and compressive strengths of self-compacting concrete (SCC) and conventional cement concrete. The flowability and segregation resistance of freshly mixed concrete specimens were examined by the V-funnel apparatus, while the characteristics of passing ability were investigated with the L-box apparatus. Cylindrical concrete specimens of 100 mm diameter × 200 mm length were investigated for compressive strength. The rheological properties of SCC are incomparable with those of the conventional concrete due to their diverse testing methods and characteristics of individual flow. The compressive strength results of hardened concrete showed that SCC gained strength slowly compared to the conventional cement concrete due to the presence of admixtures and its 28 days strength was lower than conventional cement concrete, but SCC eventually had potentials of higher strength beyond 90 days. Finally, the effect of water-cement ratio on the plastic properties of self-compacting concrete was quite negligible compared to conventional concrete.

Keywords

Concrete, Self-Compacting Concrete, V-Funnel, L-Box, Density, Compressive Strength

1. Introduction

Concrete is the most versatile heterogeneous construction material and the impetus of infrastructural development of any nation. Civil engineering practice and construction works around the world depend to a very large extent on concrete [1]. It is the world's most widely used construction materials because of its properties. Self compacting concrete (SCC) was thus developed to increase concrete usage by engineers in Japan in the early 1980s with the introduction of conventional super-plasticizers to create highly fluid concrete, while also using

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viscosity-modifying admixtures (VMA), which increased plastic viscosity thus preventing segregation up to a level of fluidity that would normally cause segregation [2]-[7].

Self-compacting concrete or self-consolidating concrete (SCC) is a highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation [8]-[10]. When large quantity of heavy reinforcement is to be cast in a reinforced concrete member, it is difficult to ensure that the formwork gets completely filled with concrete. Thus, fully consolidation without voids or honeycombs through compaction by manual or mechanical vibrators is very impractical in this situation, it generates delays and additional cost in the projects and hence, the development of SCC.

The dosage of the superplasticizer and viscosity modifying admixtures (VMA) is an important parameter; which influences the rheological properties of SCC. Many research works carried out in this area have proved that the role of chemical admixtures is inevitable in achieving good rheological properties of SCC [11]-[13]. SCC thus obtained is dense, homogeneous and has a superior surface finish [10] [14] [15]. The utilization of organic or waste materials as replacements for Portland cement in SCC, such as the works of [2] [6] [7] [13] [16]-[23] have been reported to significantly enhance the rheology and strength properties of SCC. It also reduces the high cost of SCC production per cubic meter, which has greatly influenced its use in developing nations. One of the biggest differences between SCC and usual concrete is their incorporation of materials. SCC is considered to be a concrete that can be placed and compacted with no vibration and segregation. Cement which is the most important part of the concrete is very expensive; hence, the use of SCC makes it more economical [19]. Therefore, the purpose of this research is to investigate the rheological properties and compressive strengths of SCC compared with conventional cement concrete.

2. Materials and Methods

2.1. Materials

Ordinary Portland cement (32.5 grade), fine (sharp river sand), coarse aggregate (20 - 25 mm granite stones) and Conplast SP430 Superplasticizers (a chloride free, super plasticising admixture based on selected sulphonated naphthalene polymers) were used in this research. Previous research studies showed that superplasticizer can be used to achieve good workability. The high flowability is achieved by using superplasticizer, while segregation resistance was either achieved by using large quantity of fine materials or appropriate VMA [24]-[28].

2.2. Mix Proportions and Curing

Two series of SCC mixes were compared with a conventional concrete as control mix to study the plastic and compressive strength properties. A water-to-cement ratio (w/c) of 0.5 was used for the control mix, while it was varied at 0.5 and 0.38 for the SCC mixes. Conplast SP430 Superplasticizers (a chloride free, super plasticising admixture based on selected sulphonated naphthalene polymers) was used to maintain high workability. The specimens were demoulded and cured in water until the test age. The mix proportions are given in **Table 1**.

2.3. Rheological Properties Test

Passing ability of the mixes was examined by the L-box apparatus while their flowability and segregation resistance were examined by the V-funnel apparatus.

2.4. Compressive Strength Test

Cylindrical concrete specimens of 100 mm diameter × 200 mm length were investigated for compressive strength at ages 7, 14, 21, 28 and 90 days. The compressive strength test was carried out as per ASTM C39 [29]. The reported results are the average of three samples [28]-[31].

3. Results and Discussion

3.1. Rheological Properties Test

Figure 1 shows a "foamy" chemical reaction of the superplasticizers on the SCC mix, which makes slump test unsuitable for the mix as the SCC mix had a total collapse when the slump cone was removed. **Figure 2** shows the L-box apparatus which tested the passing ability of SCC [30] [31] by measuring the ratio of the difference between the beginning and end of the box, while **Figure 3** shows the V-funnel tests for the filling ability and segregation resistance of the SCC mixes [30] [31]. The results of the rheological properties are presented on **Table 2** which revealed acceptable values for the passing ability, filling ability and segregation resistance of the SCC mixes [7] [9] [10] [14] [31]. The graphical illustration is also presented on **Figure 4**.

Figure 1. Reactive mix of SCC.

Figure 2. L-box test.

Table 1. Mix proportion.

Sample	w/c	Cement content (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Admixture (litres/100kg of cement)
Control	0.5	375	750	1500	-
SCC-1	0.5	375	890	875	2
SCC-2	0.38	375	890	875	2

Table 2. Results of rheological properties.

Sample	Slump (cm)	Flowability (sec)	Segregation resistance (sec)	Passing ability (h_2/h_1)
Control	15.0	-	-	-
SCC-1	0.0	10	11	0.8
SCC-2	0.0	10	14	0.9

Figure 3. V-funnel test.

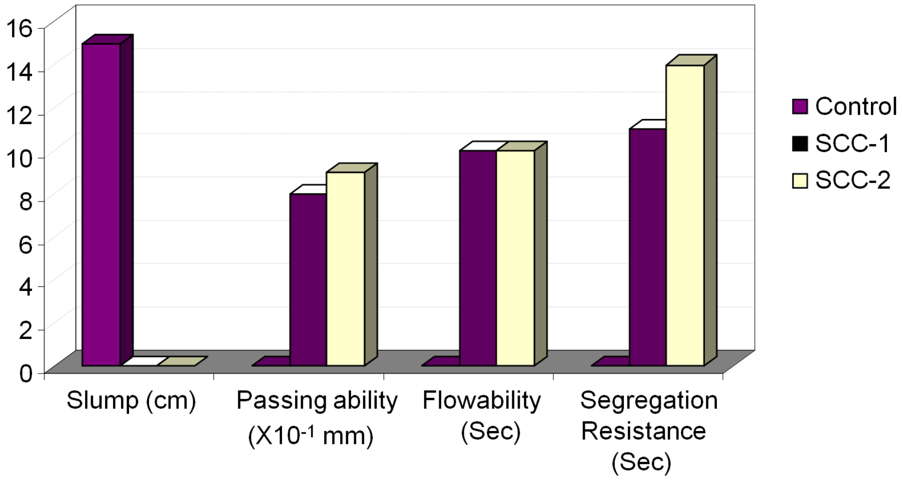

Figure 4. Rheological (plastic) properties.

3.2. Hardened Concrete Properties

The average densities and compressive strengths of SCC and conventional concrete (Control) specimens are presented in **Table 3** and **Table 4** respectively; while their graphical illustrations are presented in **Figure 5** and **Figure 6** respectively. The same mean density of 2500 kg/m^3 was obtained for the control and SCC-2 mixes, while that of SCC-1 was 2510 kg/m^3 at 28 days which fell within the specified range of 2200 - 2600 kg/m^3 for the densities of normal weight concrete [32]. Hence, the concrete samples are designated as normal weight concrete.

The compressive strengths of both SCC and conventional concrete developed continuously, but the rate of strength gain in the SCC mixes was slower than the conventional concrete until after 28 days; while the SCC-2

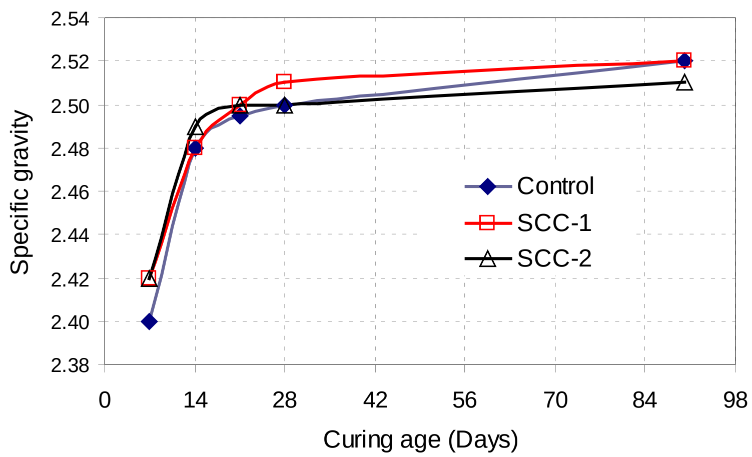

Figure 5. Specific gravity-curing age relationship of concrete specimens.

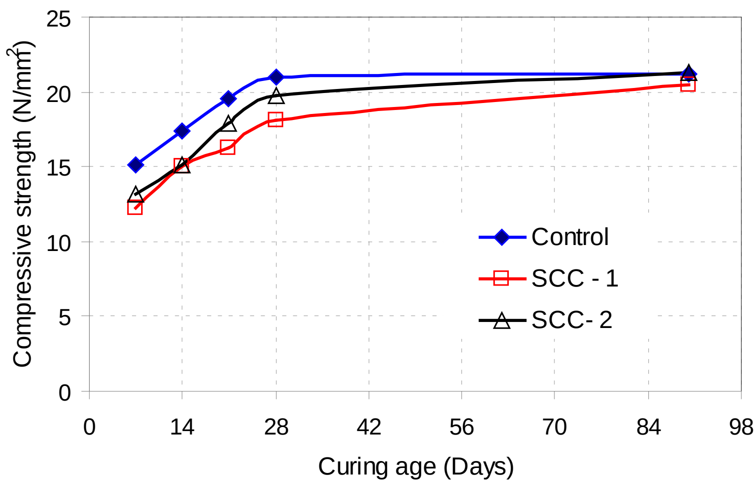

Figure 6. Compressive strength-age relationship (N/mm^2).

Table 3. Densities of hardened concrete specimens.

Sample	Average density (×1000 kg/m^3) for different curing ages				
	7 days	14 days	21 days	28 days	90 days
Control	2.40	2.48	2.48	2.50	2.52
SCC-1	2.42	2.48	2.50	2.51	2.52
SCC-2	2.42	2.49	2.50	2.50	2.51

Table 4. Compressive strength of hardened concrete cylinder specimens.

Sample	Compressive strength (N/mm^2) for different curing ages				
	7 days	14 days	21 days	28 days	90 days
Control	15.08	17.39	19.52	20.98	21.21
SCC-1	12.28	14.97	16.23	18.15	20.50
SCC-2	13.22	15.13	17.88	19.76	21.33

had 90 days compressive strength of 21.33 N/mm^2 which was about 1% greater than each of the control sample of 21.21 N/mm^2 and the SCC-1 of 20.50 N/mm^2. This implies that SCC has the potentials of greater compressive strengths than the conventional cement concrete after 28 days when properly mixed and cured. However, the hardened concrete examination indicated that water-cement ratio also influences the density and strength properties of SCC.

4. Conclusions

Based on the findings, the comparative assessment of conventional and self-compacting concrete, the following conclusions are drawn.

1) Rheological properties of conventional and self-compacting concrete are quite different.

2) Water-cement ratio influences the strength properties of self-compacting concrete as much as it does in conventional concrete, but its effect on the plastic properties of self-compacting concrete is almost negligible compared with conventional concrete.

3) The compressive strength of a well designed SCC mix at 28 days is in the range of 85% - 95% of conventional concrete, but shows a potential of greater compressive strength at 90 days and beyond.

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