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Effect of granite/gravel (washed) combination on fresh properties of self-compacting concrete

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Abstract

Flow ability, passing ability and segregation resistance are some of the properties that differentiate self-compacting concrete (SCC) from convectional concrete. It can then be rightly said that fresh concrete property is one of the cogent factors that differentiates self - compacting concrete from conventional concrete (CC). As a result of these properties to the overall self-compacting concrete performance, the trial test on it must be carried out to ascertain the right mix ratio for suitable workability. This study attempts to improve the flow ability, passing ability and resistance to segregations of self-compacting concrete via replacement of granite with washed gravel in varying percentage proportions of 10, 20, 30, 40, and 50, while 100 percent (%) granite serves as control at constant cement, fine aggregate, super-plasticizer and water to validate the improvement of self-compacting concrete properties. Slump flow and T_{500} tests were used to assess the spread, L-box test for passing ability, V-funnel test for filling ability and segregation test to check resistance to segregation of fresh concrete. The tests results were analyzed and it was discovered that passing ability, filling ability and resistance to segregation can be improved through the adoption of varying percentage of washed gravel in place of granite.

Keywords: Self-compacting concrete (SCC), granite, washed gravel, fresh properties, conventional concrete (CC).

INTRODUCTION

Self-compacting concrete (SCC) has been one of the most important developments in the building industry. It is a type of concrete that does not require vibration for placing and compaction which reduced the potential for durability defect due to compaction. It has ability to flow under its own weight without vibration, completely filling the formwork and achieving full compaction even in the presence of congested reinforcement. It was also discovered to offer economic, social and environmental benefit over traditional vibrated concrete construction. Banfill [1] discovered that without proper fresh properties where fresh means that the concrete is freshly mixed but not yet old enough to have set and begun to gain strength – even the most carefully engineered structural concrete is at risk of failure due to difficulties in filling moulds and compacting the material around the reinforcement steel. Inadequate compaction leads to low strength and poor durability of hardened concrete. Tattersall [2] found that fresh concrete must be capable of being transported and placed, flowing into moulds and around the reinforcement, compacted and finished, all without segregation. Yang and Huang [3] reported that SCC is a composite material of which the physical and chemical properties of the constituents determine the behaviour of material. Goodier [4] found that the properties of fresh SCC are much sensitive to variation in the quality and consistency of the mix constituents. As a result of this, greater sensitivity to variation, batching accuracy for all component material is essential for SCC to succeed. Tattersall and Banfill [5]; Sudarshan and Chadrasekhar Rao [6] and Banfill [7] all worked on SCC constituent materials and their relative proportions on the yield stress and plastic viscosity which helped the mix selection. Wenzhong and Gibbs [8] reported that super plasticizer is necessary for the production of highly fluid concrete mix, meanwhile powder materials or viscosity agent are required to maintain sufficient stability of the mixture in order to reduce bleeding, segregation and settlement. Su et al. [9] reported that aggregates constitute about 60% by volume of SCC. It exact a major influence on the characteristic properties of SCC. Due to the large volume that aggregates occupy in SCC, it is expected to have significant influence on other properties as well. The durability of the SCC and mechanical behavior are affected by the aggregate used [10]. Natural gravel (usually dug or dredged) and crushed stone (produced by crushing quarry granite rock) are the most commonly used coarse aggregate in concrete production. Granite is more expensive, while gravel is much more affordable. The economic condition makes gravel more attractive for building development to most low to middle income earners. The special properties of the fresh SCC are filling ability, passing ability and resistance to segregation. These properties are difficult to obtain in conventional concrete and are the most important factors that distinguish SCC from conventional concrete. Hence, it is important that the test on SCC is well established because any error will compromise the essence of using SCC in place of convectional concrete. This study presents the extensive test results of the effect of granite/gravel (washed) combination and super-plasticizer on fresh properties of self-compacting concrete.

MATERIALS AND METHODS

Granite and washed gravel with maximum size 12.5 mm were used as coarse aggregates; natural river sand as fine aggregate. Cement used was Ordinary Portland Cement CEM 42.5 R in conformity with the requirement of European Standard EN 197-1. To achieve acceptable flow ability for SCC, Complast SP 432 MS was used as super-plasticizer in conformity to EN 943-2; 2000. It was also important to know that no retarder agent was used to control the hydration process or the open time. Natural odorless, colorless tap water flowing within Covenant University was used for the concrete production. Fine aggregates, water, superplasticizer and cement were kept constant. Percentages of gravel in replacement for granite were 10, 20, 30, 40, and 50, while 100% granite serves as control. For each percentage replacement, the following tests were carried out; Slump flow and T_{500} tests, L-Box test, V-Funnel test and segregation test to determine the fresh properties of self-compacting concrete that is the deformability and flowability

MIX PROPORTION

In this study, six concrete mixture samples were analyzed. The samples were label SCC1 for 100% granite, SCC2, SCC3, SCC4, SCC5 and SCC6 for self-compacting concrete with 10%, 20%, 30%, 40% and 50% granite replacement with washed gravel. Batching and mixing with varying mix composition are summarized in Table 1:

Table 1: Mix proportions of SCC samples.

S/N	Mix Samples	Mix Proportion (%)	Cement (g)	Fine Aggregate (g)	Coarse Aggregate (g)		Water (g)	Super-Plasticizer (%)
					granite	gravel		
1	SCC1	100	561	977	620	-	168.8	1.14
2	SCC2	90/10	561	977	558	62	168.8	1.14
3	SCC3	80/20	561	977	496	124	168.8	1.14
4	SCC4	70/30	561	977	434	186	168.8	1.14
5	SCC5	60/40	561	977	372	248	168.8	1.14
6	SCC6	50/50	561	977	310	310	168.8	1.14

RESULTS AND DISCUSSION

This study discovered the effect of granite and washed gravel combination on fresh properties of SCC. The data obtained from the tests were summarized in the Table 2. The analyses were carried out with the aid of statistical tools such as Tables, chart and graph.

Table 2: Fresh properties of SCC with varying proportion of gravel

Mix Sample	Slump (mm)	T_{500} (sec.) (2-5 sec)	V-Funnel (sec)	L-Box (mm) (0.8 – 1.0)	Segregation resistance (%)
SCC1	660	2.89	6.21	0.9	4.3
SCC2	653	2.08	3.69	0.8	4.2
SCC3	624	2.21	3.43	0.82	4.0
SCC4	560	1.98	6.75	1	1.5
SCC5	552	1.70	4.68	0.75	3.3
SCC6	555	2.0	3.98	0.87	3.7

A. Slump Flow and T_{500} Test

Slump flow test as shown in Figure 1 was used to determine the free horizontal flow (spread) of SCC on a plain surface without any obstruction, while T_{500} is the time needed for the concrete to cover 500 mm diameter circle from the time the slump cone is lifted. SCC mixtures presented slump flow diameter between 552 mm and 660 mm. SCC1 which is 100% granite produced the highest slump flow diameter 660 mm, followed by SCC2 with 653 mm and SCC3 with 624 mm slump, all of which fall into Class 2 SCC slump flow diameter 600 – 750 mm and $T_{500} \geq 2s$ while SCC4, SCC5 and SCC6 with slump flow diameter 560, 552 and 555 mm fall into class 1 SCC slump flow diameter ranging between 550 – 650 mm and $T_{500} \leq 2\,s$ according to [10].The class 1 and 2 give indication of good filling ability and stability of the mix. Comparing the results with Topcu and Uygunoglu [11] with SCC slump value of 440 mm and Lopex et al., [12] which reported that slump flow test exhibit a clear decreasing trend of the spread as the replacement of natural sand with recycle one increases, at all time considered, it was concluded that the 0% and 20% mixes with recycle sand show similar behavior whereas the 50% and 100% mixes show severe reduction of spread after 45min leading to loss of SCC characteristics (spread less than 550mm) [13]. It was discovered that this study produced a better results with all SCC spread values greater than 550. It should be noted that the higher the percentage of washed gravel, the lower the slump flow diameter. This can be seen in Figures 2 and 3 respectively.

Figure 1: Slump flow test

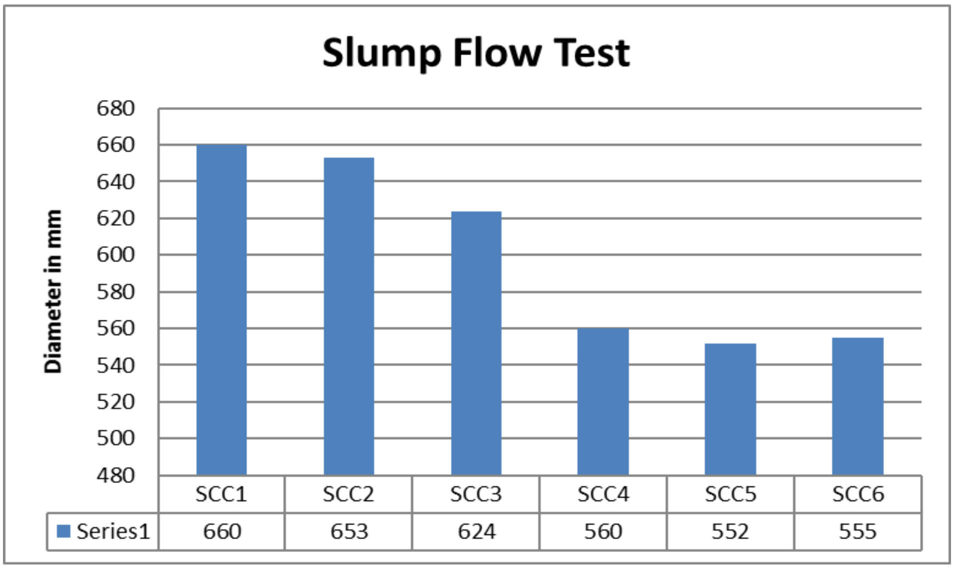

Figure 2: Bar chart showing Slump flow diameter.

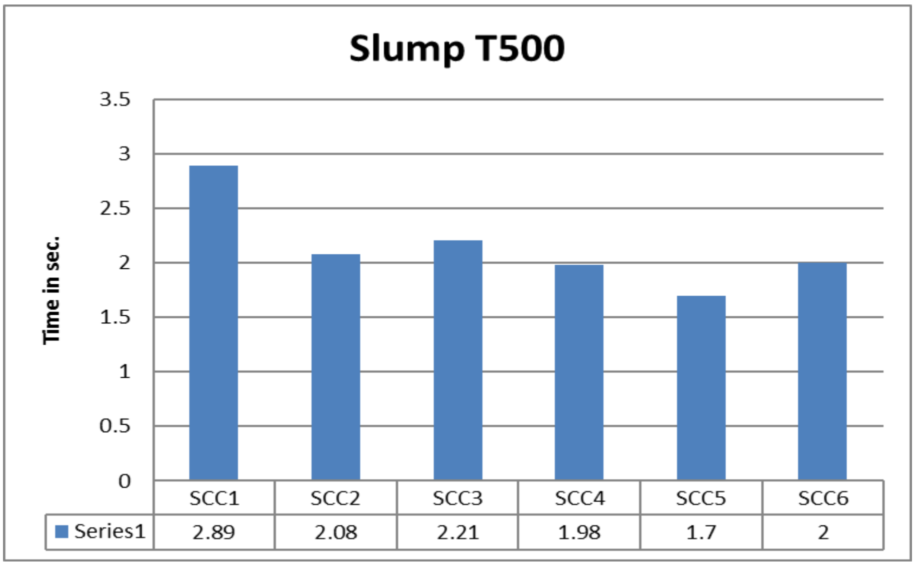

Figure 3: Bar chart showing T_{500} time of samples

B. V-Funnel results

V-Funnel test as shown in Fig. 4 was conducted to determine the fluidity and consistency of the mix. For SCC1, SCC2, SCC3, SCC4, SCC5 and SCC6 as can be seen in Fig. 5, the total time required to flow through the V-funnel results are less than 8s which falls into class 1 of SCC in accordance with [10] standard, and the mix were considered to be satisfactory. Comparing the results with Wu et al., [14] which produced 23.3s that is higher than [10] standard.

Figure 4: Bar chart showing T_{500} time of samples

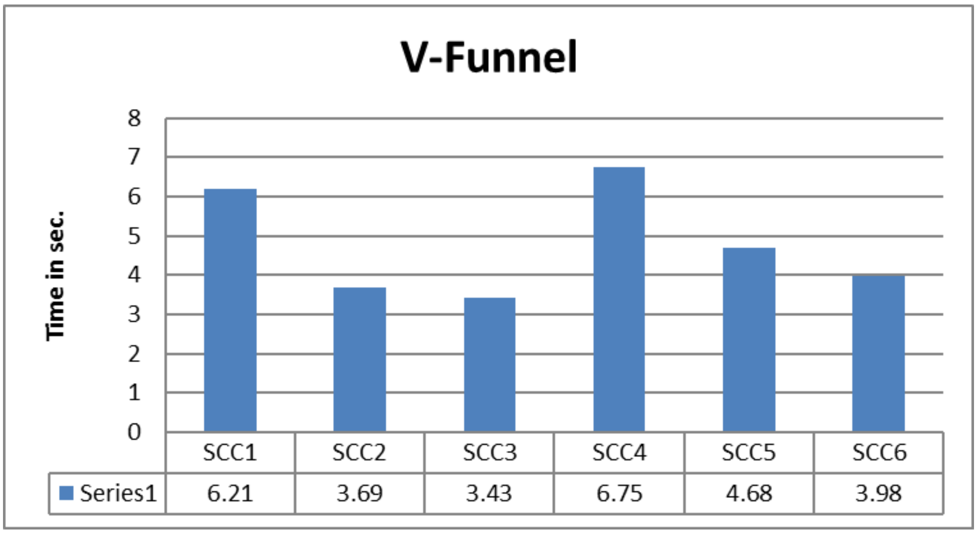

Figure 5: Bar chart showing flow time of the samples.

C. L- Box test

L- Box test as shown in Fig. 6 was conducted to assess the passing ability and filling ability of SCC. Uniformity of the mix was also examined by inspecting section of the concrete in the horizontal section of L- Box. According to [10] requirement SCC1, SCC2, SCC3, SCC4, SCC5 and SCC6 blocking values showing in Fig. 7 fall in between 0.8 and 1 mm and it indicates better passing ability. Wu et al., [14] produced 0.84 and 0.97mm which is also in line with [10] standard.

Figure 6: L-box test

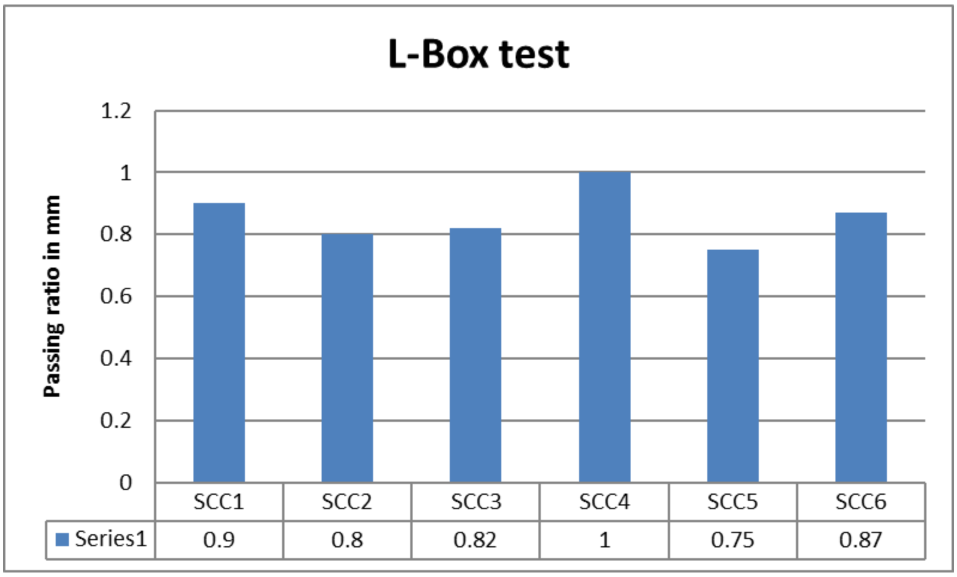

Figure 7: Bar chart showing passing ratio of the sample

D. Segregation Resistance

Sieve segregation as shown in Fig. 8 was used to quantitatively determine the resistance to segregation. According to EFNARC [10], the smaller the value of segregation resistance percentage, the larger the resistance of SCC to segregation. Therefore, resistance of SCC to segregation are in the following other SCC4, SCC5, SCC6, SCC3, SCC2 and SCC1, of which SCC4 has the highest resistance to segregation and SCC1 has the lowest as can be seen Fig. 9. Hence, all the mix samples passed segregation resistance requirement since all segregation resistance percentage do not exceed 15%. Comparing the results with Elyamany et al., [15] the results confirmed that the use of granite dust and marble dust improves the segregation resistance of SCC compare with other type of fillers.

Figure 8: Segregation test

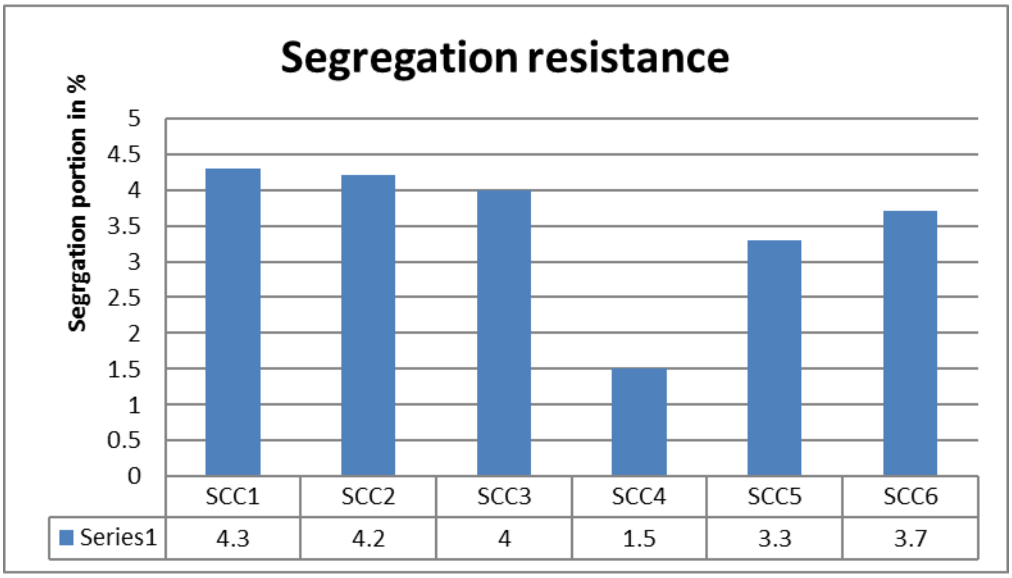

Figure 9: Bar chart showing segregation in % of the samples.

CONCLUSION

In this study, effect of granite and washed gravel on fresh properties of SCC has been presented. Based on various tests performed, the workability of SCC and uniformity distribution of granite and gravel has been evaluated. The conclusions are summarized below:

a) Considering slump flow test and T_{500}, the higher the percentage of washed gravel the lower the T_{500} and slump flow follow nearly the same pattern. But all the mix values are in the limit prescribed by the EFNARC (2002).

b) All V-Funnel test results pass the fluidity and consistency of the mix, which are in accordance with EFNARC (2002) requirement.

c) L-Box results presented in this study passed the requirement of EFNARC (2002), with only SCC5 (40% washed gravel) having 0.75 which is approximately 0.8

d) SCC4 (30% washed gravel) has the highest resistance to segregation value but all the mix values are in the limit prescribe by EFNARC (2002).

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