

Experimental Study on the Workability of Self-Compacting Granite and Unwashed Gravel Concrete

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Abstract. This study deals mainly with the mix proportions using granite and unwashed gravel as coarse aggregate for self-compacting concrete (SCC) and its workability, by considering the water absorption of unwashed gravel aggregate. Mix proportions for SCC were designed with constant cement and fine aggregate while coarse aggregates content of granite-unwashed gravel combination were varied in the proportion 100%, 90%/10%, 80%/20%, 70%/30%, 60%/40%, 50% /50%, represented by SCC1, SCC2, SCC3, SCC4, SCC5 and SCC6. 100% granite (SCC1) serves as the control. The workability of the samples was quantitatively evaluated by slump flow, T₅₀₀, L-box, V-funnel and sieve segregation tests. Based on the experimental results, a detailed analysis was conducted. It was found that granite and unwashed gravel with SCC1, SCC2 and SCC3 according to EFNARC (2002) standard have good deformability, fluidity and filling ability, which all passed consistency test. SCC1, SCC2 and SCC3 have good passing ability while all mixes were in the limit prescribed by EFNARC (2002). It can be concluded that the mix design for varying granite-unwashed gravel combination for SCC presented in this study satisfy various requirements for workability hence, this can be adopted for practical concrete structures.

Introduction

Self-compacting concrete (SCC) is a flowing concrete that need no vibration compared to conventional concrete (CC) and can spread easily, encapsulate reinforcement and fill the formwork without any segregation or bleeding [1]. It helps to minimize hearing-related damages on worksite that are induced by vibration of concrete, and time required to place large section is considerably reduced. Another advantage is that less skilled labor is required in order for it to be placed, finished and made good after casting [2]. Okamura and Ouchi [3] reported that compared to conventional concrete, SCC possess enhanced qualities with better productivity and working condition. Because vibration is eliminated, the internal segregation between solid particles and the surrounding liquid is avoided which results in less porous transition zones between paste and aggregate and thereby improved strength, durability of SCC and reduced labour cost, noise pollution can be obtained. Workability is an important factor that affects the application and mechanical properties of SCC, in as much SCC in practical use is required to have high fluidity, good filling ability, deformability and moderate segregation resistance [4]. It should be noted that to ensure that reinforcement can be encapsulated and that the formwork can be filled completely, a suitable workability is essential for SCC [5]. Rizwan and Bier [6]; Sua-iam and Makul [7] reported that workability of SCC depends heavily on powder particle size, surface texture shapes and superplasticizer content.

Aggregate particles in SCC are required to be uniformly distributed and the minimum segregation risk should be maintained during the process of transportation and placement. The rheology of concrete can be affected by different factors: characteristics of the cement, mix proportions, time, aggregate properties and type of admixtures, mixing condition and temperature. Among all these factors, aggregate properties are the most important because the aggregate normally occupies up to 70-80 percent of the total volume of normal concrete [8] while aggregates generally constitute about

60% by volume of SCC [9]. Due to the large volume fraction that SCC occupies, aggregates exert a major influence on both fresh and hardened characteristic properties of SCC, and can be expected to have an important influence on other properties as well [10, 11]. Janssen and Kuosa [12] discovered that the selection of maximum aggregate size depends on the number of reinforcement bars and the space in between them, where higher proportions of maximum aggregate size may lead to blockage in the congested area with the reinforcement bars. Khaleel et al., [13] found that SCC is very sensitive to changes in aggregate shape, texture, maximum size, grading and morphology and concluded that selection of aggregate should be done carefully before using it in SCC. Kosmatka et al. [11] reported that close to half of coarse aggregate used in Portland cement concrete in North America is gravel while most of the remainder are crush stone. Babu and Kumar [14] concluded that it is possible to use natural, rounded, semi-crushed aggregate to produce SCC. Khaleel et al. [13] also discovered that the optimum coarse aggregate content depends on two parameters. The first parameter is the maximum size, where lower values of maximum lead to increased possibility of using high coarse aggregate content. The second parameter is the shape of the coarse aggregate, whether it's crushed or rounded, where a higher content of rounded shape leads to increased possibility of using a high coarse aggregate content. Granite and unwashed gravel were considered in this research as coarse aggregates. Gravel is in abundant supply and can be obtained at cheaper price than granite. In an attempt to reduce granite without compromising standard, the filling ability, passing ability, resistance to segregation of the combination of granite and unwashed gravel in varying proportion on SCC were investigated.

Material and methods

Ordinary Portland cement (CEM 42.5 R) in conformity with the requirement of European Standard EN 197-1 was used in this study. To achieve acceptable flow ability for SCC, Complast SP 432 MS was used as super-plasticizer in conformity to EN 943-2; 2000. Granite and unwashed gravel with maximum size 12.5 mm were used as coarse aggregates; natural river sand was used as fine aggregate. Natural odorless, colorless tap water flowing within Covenant University was used to simulate practical condition. It is also highlighted that no retarding agent was used to control the hydration process or the open time. Percentages of unwashed gravel in replacement for granite were 10, 20, 30, 40, 50, while 100% granite serves as control. Fine aggregates, cement and super-plasticizer were constant while water varied as considering some of the silt content of unwashed gravel. For each percentage replacement, the following workability tests were carried out in line with [15] standard. Slump flow and T_{500} tests, the former was used to measure the free horizontal flow (spread) of SCC on a plain surface without any obstruction while the latter (T_{500}) is the time required for the concrete to cover 500 mm diameter circle from the time the slump cone is lifted. V-Funnel test was used to evaluate the fluidity and ability of SCC in order to change its path through constricted area. L-Box test was conducted to assess the filling ability and passing ability of SCC .i.e. the ability of concrete to flow through rebar and fill a form and segregation test was conducted to evaluate the resistance of fresh concrete to segregation as shown in Fig.1-4, to determine the fresh properties of self-compacting concrete. It is important that the concrete used has high deformability with moderate viscosity to ensure uniform dispersion of concrete constituents during transportation, casting and setting time.



Fig. 1. V-Funnel test



Fig. 2. L-Box test



Fig. 3. Slump Flow test



Fig. 4. Segregation resistance test

Mix proportions

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 unwashed 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	Unwashed gravel		
1	SCC1	100	561	977	620	-	168.8	1.14
2	SCC2	90/10	561	977	558	62	170.8	1.14
3	SCC3	80/20	561	977	496	124	188.8	1.14
4	SCC4	70/30	561	977	434	186	199.8	1.14
5	SCC5	60/40	561	977	372	248	200.3	1.14
6	SCC6	50/50	561	977	310	310	210.5	1.14

Results and Discussion

Experimental study on the workability of self-compacting concrete granite-unwashed gravel combination as coarse aggregate was the main focus in this study. The data obtained from the tests were summarized in the Table 2. The analysis were carried out through statistical tools by using Tables, chart and graphs

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	636	2.45	4.34	0.8	6.9
SCC3	585	2.36	4.84	0.6	2.2
SCC4	563	2.11	4.56	0.75	2.1
SCC5	554	2.38	4.72	0.67	5.7
SCC6	635	2.01	3.91	0.87	3.9

A. Slump Flow and T₅₀₀ Test

Flow ability and fluidity of SCC were experimented using Slump flow and T₅₀₀ tests. EFRNARC [15] standard classified slump flow diameter ranging between 550 – 650 mm and T₅₀₀ ≤ 2 s as class 1 SCC and slump flow diameter ranging from 600 – 750 mm and T₅₀₀ ≥ 2s as class 2 SCC. SCC mixtures presented above show slump flow diameter between 554 mm and 660 mm. SCC1 which is 100% granite produced the highest slump flow diameter 660 mm, meanwhile SCC1, SCC2 and SCC6 fall into Class 2 SCC slump flow diameter 600 – 750 mm and T₅₀₀ ≥ 2s while SCC3, SCC4 and SCC5 fall into class 1 SCC slump flow diameter ranging between 550 – 650 mm and T₅₀₀ ≤ 2 s according to [15] standard. It was discovered that the T₅₀₀ for SCC3, SCC4 and SCC5 were greater than [15] requirement for Class 1. The results agrees with the findings of [14, 16, 17, 18]. The class 1 and 2 give indication of good filling ability and stability of the mix. It was observed that the higher the percentage of unwashed gravel the lower the slump flow diameter but reverse is the case for SCC6. This can be seen in Figures 5 and 6 respectively.

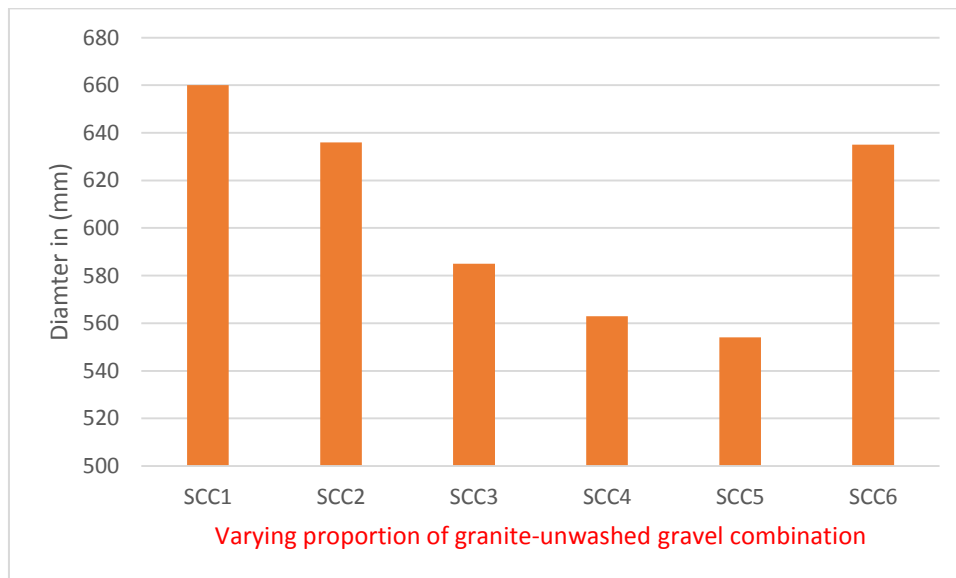


Fig. 5. Slump flow of SCC for varying granite-unwashed gravel combination

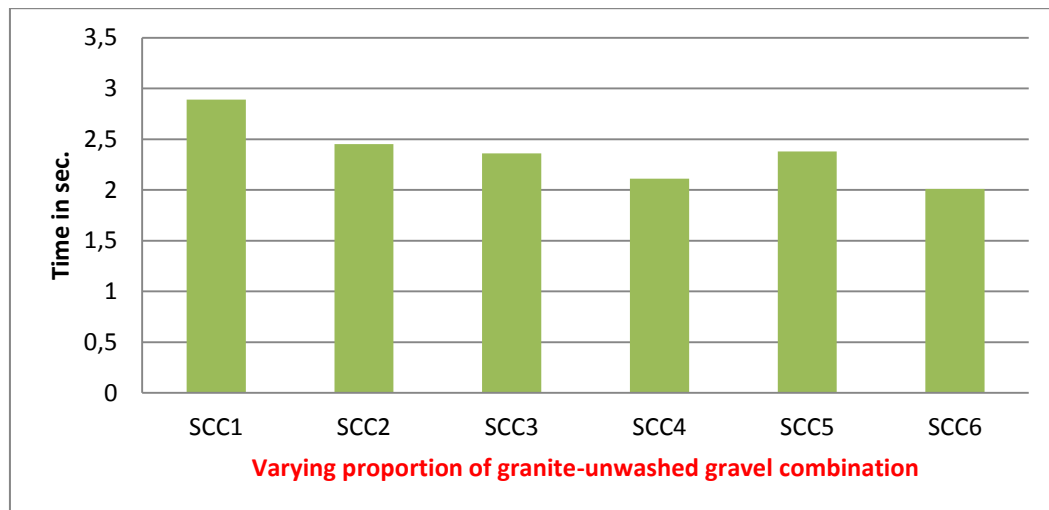


Fig. 6. T_{500} of SCC for varying granite-unwashed gravel combination

B. V-Funnel Results

V-funnel was used to evaluate the fluidity and ability of SCC in order to change its path through constricted area. All samples passed the V-funnel test with values less than 8s and they were classified as class 1 SCC in line with [15] limitation. This can be seen in Fig. 7. Comparing the results obtained with the findings of [14, 16, 17, 18] this study produced a better results.

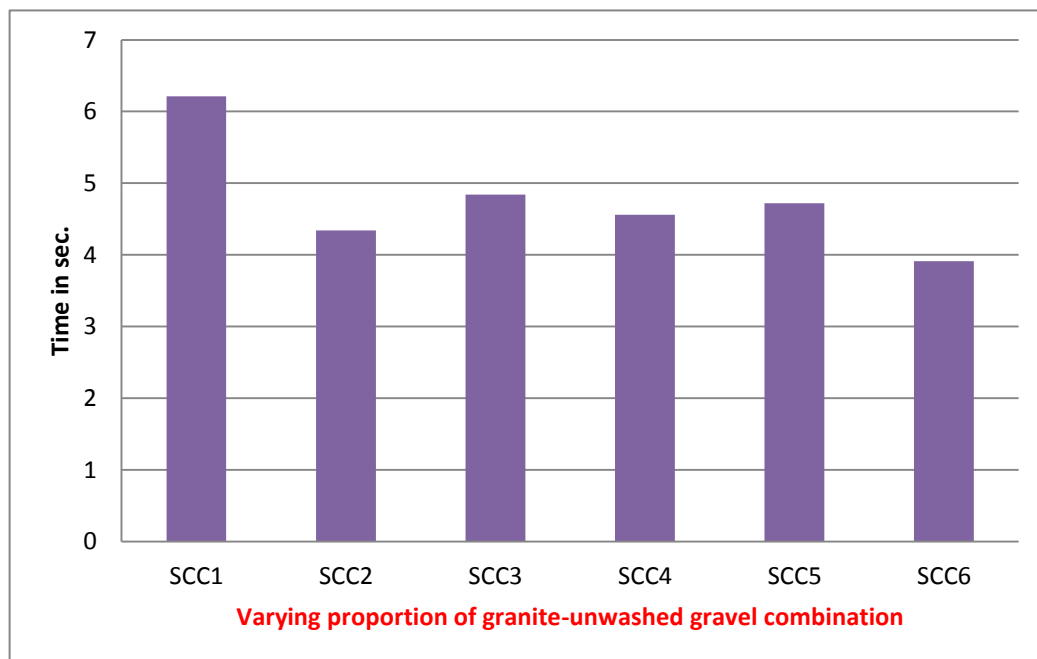


Fig. 7. V- Funnel of SCC for varying granite-unwashed gravel combination

C. L- Box Results

L-box was used to measure the ability of concrete to flow through rebar and fill a form. EFNARC [15] specified that when the ratio of h_2 to h_1 is greater than 0.8, SCC has good passing ability. As a result of this, SCC1, SCC2 and SCC6 satisfied the [15] requirement while SCC3, SCC4 and SCC5 fall below the range specified. This can be seen in Fig. 8. This agrees with the studies of [14, 16, 17, 18].

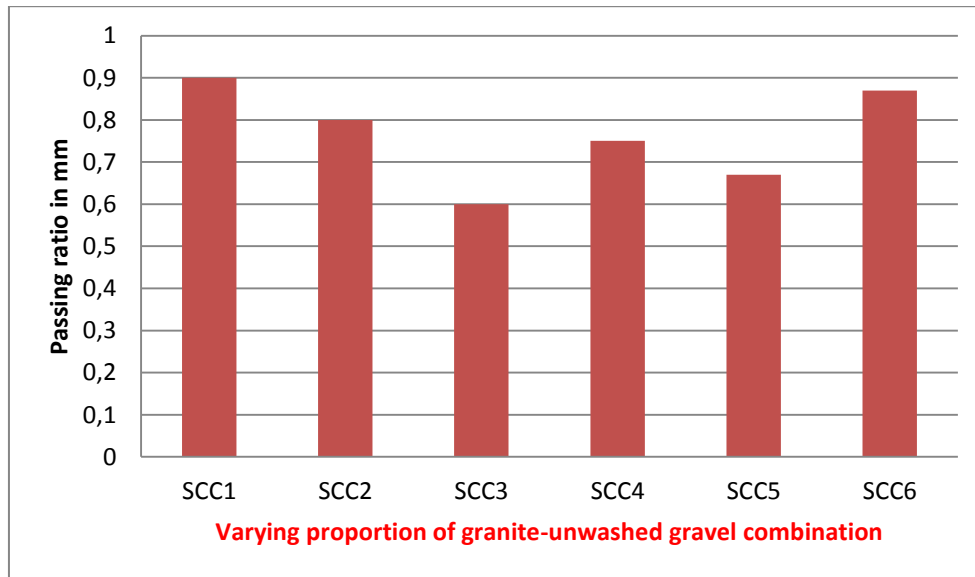


Fig. 8. L-Box of SCC for varying granite-unwashed gravel combination

D. Resistance to Segregation Test

Resistance to segregation was conducted to evaluate the resistance of fresh concrete to segregation. Fig. 9 shows the effect of granite and unwashed gravel combination on SCC. All samples satisfied the requirement of [15] standard, because all resistance to segregation percentage values was less than 15%. It is good to note that the smaller the value of segregation resistance, the larger the resistance of SCC to segregation. This study is in line with the findings of [14, 16, 17, 18].

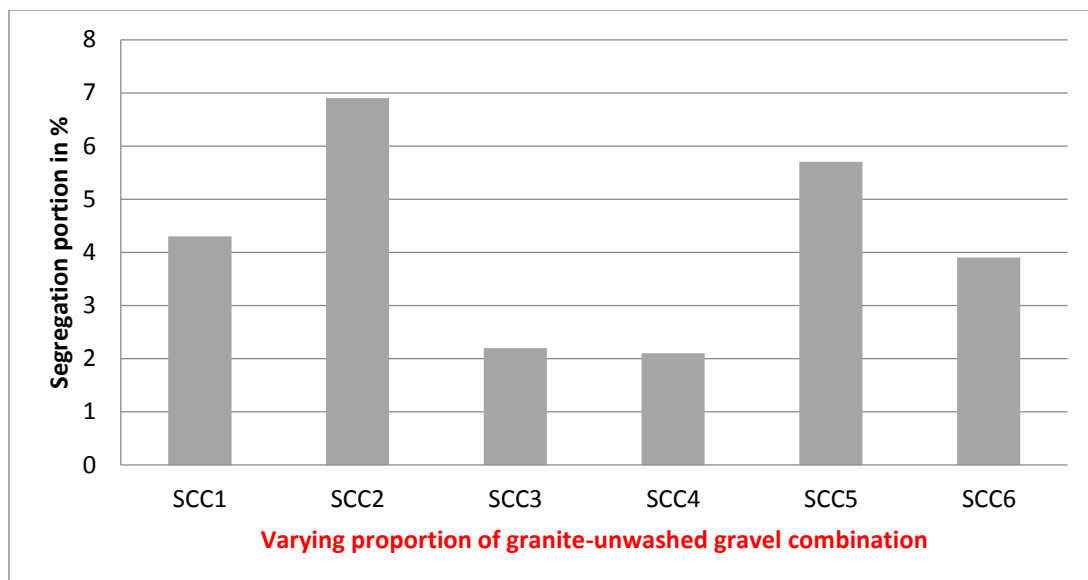


Fig. 9. Resistance to segregation of SCC for varying granite-unwashed gravel combination

Conclusion

Experimental studies on the workability of self-compacting granite-unwashed gravel combination in concrete production have been analyzed. Based on various tests performed, the workability of SCC has been evaluated. The deductions from the experimental work are summarized as follows:

- The higher the percentage of unwashed gravel content the higher the water requirement for mixing
- Considering slump flow test and T_{500} , SCC1, SCC2 and SCC6 passed the class 2 SCC while SCC3, SCC4 and SCC5 passed the class 1 SCC. Both class 1 and 2 give indications of good filling ability and stability of the mix
- All V-Funnel test results pass the fluidity and consistency of the mix.

- d). Only SCC3, SCC4 and SCC5 has bad passing ability.
- e). Silty materials from unwashed gravel increased the fine which led to increase in paste. SCC4 (30% unwashed gravel) has the highest resistance to segregation. Therefore 10 – 30% unwashed gravel are suitable for fresh properties of SCC.
- f) It is equally important that the study is justified as the methods and results of this work will benefit the design and engineers in construction industry.

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