Water Absorption and Compressive Strength of Self-Compacting Concrete Incorporating Fly Ash and Quarry Dust

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Abstract:
Self-compacting concrete or also known as self-consolidating concrete (SCC), an innovation in concrete technology is being regarded as one of the most promising developments in the construction industry due to numerous advantages that it has over conventional concrete. The cement and sand consumption in concrete production can be reduced by using a combination of industrial waste materials like fly ash and quarry dust and at the same time lead to energy and cost reduction. In this project, work is done on experimental study on fresh and hardened properties of SCC such as slump flow test, J-ring test, water absorption test, and compressive strength test of M35 grade of SCC. Five mixes with different percentages of quarry dust (0%, 10%, 20%, 30%, and 40%) as partial replacement for sand and a constant 10% of fly ash as partial replacement for cement is considered. The test results for water absorption and compressive strength were carried out after 7 days and 28 days of curing. The results obtained showed that the optimum dosage of quarry dust was 30% and that incorporating QDFA in SCC as green, sustainable and eco-friendly materials in SCC resulted in high workability, enhanced the strength and durability properties in term of water absorption.

Keywords: Fly Ash, QDFA, Quarry Dust, Superplasticizer, Self-Compacting Concrete, Water Absorption

1.0 Introduction

Highly fluid nature, easy handling and less noise are among the key advantage of self- compacting concrete. SCC significantly reduces the placement time of concrete in the large section due to easy handling technique. Self-compacting concrete (SCC) may reduce the noise on the worksite caused due to the vibrator use for concrete compacting purpose [1]. In the modern construction demand for concrete material has increased. The utilization of waste construction product has made possible to improve the compressive strength and workability of the concrete. Engineer's has made an effort to reuse the construction materials to unburden the environmental pollution always find new materials in the area of construction. The real problem exist the excessive waste or construction materials which should has to be reuse. Unlike other waste by products quarry dust is the waste material found from the crushing process of the stones and available abundantly from rock quarries at low cost[2]. Quarry dust may cause negative impact on environment [3]. Quarry dust has partially replaced with fine aggregate in concrete and significant improvement has witnessed [4], [5].

In the conjunction another most commonly waste material recommended and supplied in the construction is fly ash. Fly ash or pulverized fuel ash is a residue from the combustion of pulverized coal collected by mechanical separators, from the fuel gases of thermal plants. Fly ash consists mostly of silicon dioxide, aluminum oxide and iron oxide and is hence a suitable source of aluminum and silicon for geo polymers [3][4]. The use of fly ash reduces the demand for cement, fine fillers and sand, which are required in high quantities in SCC. Fly Ash has been shown to be an effective addition for SCC providing increased cohesion and reduced sensitivity to changes in water content [1]. The durability of concrete subjected to aggressive environments depends largely on transport properties. Moisture migration into concrete is the main cause of concrete degradation worldwide.

One of the primary water transport mechanisms in concrete is absorption. Water absorption affects the durability of concrete due to the influence of pore system and moisture migration through structure [6]. Strength performance of concrete is always the key concern and to achieve sufficient compaction and vibration by skilled workers are required to enhance the durability performance of concrete. SCC has been used worldwide for placement in congested reinforcement concrete structures where casting conditions are difficult and where pump ability properties are required especially in high-rise building. Therefore, the development of SCC enhances the concrete lifespan compared to conventional vibrated concrete [7], [8].

The objective of this study is to determine workability (filling ability and passing ability) of self-compacting concrete incorporating quarry dust and fly ash using the slump flow test and the j-ring test. Moreover to determine the water absorption and compressive strength performance of self-compacting concrete incorporating quarry dust at different percentages and fly ash at a fixed percentage.

2.0 Review

Ahmad,[1] conducted experimental study to replace sand with quarry dust with the proportion of 10, 20, 30 and 40% and super plasticizer was added 0.9%. Study found that workability and compressive strength has increased by 30% replacement of sand with quarry dust and further addition leads to the decrease the compressive strength and workability. Johnsirani, [9] has performed an experimental investigation on self-compacting concrete (SCC) with fine aggregate (sand) replacement of Quarry Dust (QD) (0%, 25%, 50%, 75%, 100%) and addition of mineral admixtures like Fly Ash (FA) and Silica Fume (SF) & chemical admixtures like super plasticizers (SP). The results of the hardened properties of SCC such as compressive strength and split tension strength shows that the higher strength has been obtained for SCC_25% mix of about 34.62 Mpa and 2.36 Mpa respectively, while fine aggregate replacement of quarry dust increases with the gradual decreases in the strength values after replacement of 25% of quarry dust. Completely removal or 100% replacement of sand with quarry dust is not recommended due to drastically reduce the compressive strength and split tensile strength of SCC. Vanjare, [10] added 5, 10, and 15% glass powder in the self-compacting concrete the findings indicated that the addition of glass powder in SCC mixes reduces the self-compatibility characteristics like filling ability, passing ability and segregation resistance. Bradu, [6] studied the water absorption of self-compacting concrete (SCC) addition of fly ash in the mixture.

Findings indicated that water absorption value of SCC is affected by with addition of fly ash, the cement type and w/c ratio. Significant improvement in the properties of SCC has seen by the addition of fly ash. Past studies [1], [2], [6], [8]–[12] concluded that water absorption has strong relation with the voids present in the concrete and voids carries fluid in the result absorption in the concrete increase. Fly ash incorporated with SCC resulted higher water absorption values compare to other materials. Moreover, cement plays an important role in the water absorption process. Study has concluded that self-compacting concrete compressive strength increase by reduction of water absorption value.

3.0 Methodology

3.1 Material Preparation

The material used in this study were Ordinary Portland Cement, water, sand, gravel, quarry dust, fly ash and super plasticizer. The fly ash was a class F fly ash and was obtained from Jimah Power Plant, Tanjong Sepat, and Selangor, Malaysia. Quarry dust was obtained from Negeri Roadstone, Nilai, Negeri Sembilan, Malaysia. Sand and quarry dust with maximum passing size 5 mm sieve, coarse aggregates from crush granite gravel with maximum size 10 mm sieve were used. The cube size 150 x 150 x 150 mm is used to test the compressive strength.

3.2 Mix design proportion

Different mixture designation of Control Mix (CM), SP, QDFA10, QDFA20, QDFA30, and QDFA40 with different percentages consist of 0%, 10%, 20%, 30% and 40% of quarry dust (QD) to replace sand as partial fine aggregate replacement with constant 10% of fly ash (FA) of total cement mass as supplementary cementitious material. The mighty 21HA superplasticizer of 1.0% of cement mass was added as water reducer in SCC as admixture. The proportion of partial fine aggregate replacement and supplementary cementitious material were designed based on volume replacement.

4.0 Results and Analysis

4.1 Workability Test Result

Self- Compacting Concrete is characterized by filling ability, passing ability and resistance to segregation. European federation of national trade associations representing producers and applicators of specialist building products (EFNARC) and ASTM recommended values for slump and J Ring test quoted from Ahmad, [1] is given in Table 1.

Table 1: Recommended Value [1]

	Property	**Range**
1.	Slump Flow Diameter	500-700 mm
2.	J-Ring	0-10 mm

The findings of slump flow diameter and J-Ring passing ability has shown in Figure 1 and 2. The slump flow diameter of the SCC mixes with different designation QDFA10, QDFA20, and QDFA30 and QDFA40 in SCC increased with the increase of quarry dust from 10% to 30% as fine aggregate replacement and constant 10% fly ash as cement replacement. The resulted outcome of slump flow diameter is 560 mm, 610 mm and 680 mm and 650 mm respectively. The slump flow diameter for QDFA10, QDFA20, and QDFA30 and QDFA40 in SCC are more than 500 mm and it can be considered as a proper slump required for a concrete to qualify for self-consolidating concrete. The workability of SCC increased with the increase percentages of quarry dust due to it physical properties and classified as less water absorbent material than sand. Additionally, the usage of superplasticizer in SCC increases the workability exponentially even though the water cement ratio for control and SCC with double blended QDFA are the same. The increases of slump flow diameter with the increase of quarry dust percentages and additional of superplasticizer improve the workability of SCC than conventional vibrated concrete. It indicates the optimum slump flow diameter for this research study is QDFA30 in SCC.

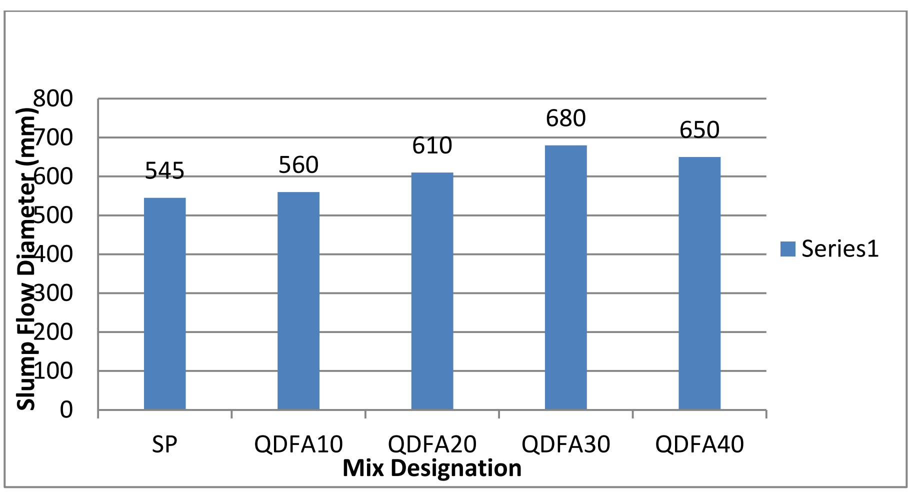

Figure 1: Slump Flow Diameter for all SCC mix designation

Figure 2 indicated J-Ring test values which lie between the ranges of recommended value 0-10mm. Workability by measuring the passing ability through openings. The passing ability increase when more Quarry dust is added at a constant amount of fly ash.

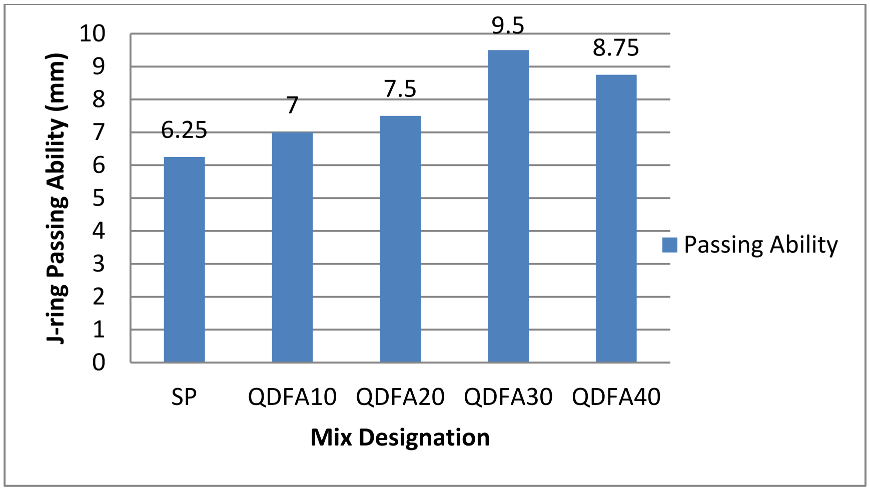

Figure 2: J-ring Test for Passing Ability for all SCC mix designation

4.3 Compressive Strength Test

Table 2 and Figure 3 indicated the findings of compressive strength of SCC mixed with quarry dust and fly ash. Compressive test were conducted in 7 and 28 days curing period. The obtained result shows higher compressive strength in 28 days curing period compare to 7-days curing. . The average compressive strength of concrete cubes for 10% quarry dust is 24.37 MPa at 7 days, which then increased to 34.82 MPa at 28 days. For 20%, the compressive strength develops from 25.32 MPa at 7 days to 35.67 MPa at 28 days. For 30% quarry dust increased from 29.19MPa at 7 days to 38.77 MPa at 28 days. For 40% quarry dust increased from 28.32 MPa at 7 days to 36.24 MPa at 28 days. As for SP, the first recorded strength is 27.03 MPa at 7 days and 36.15MPa at 28 days. The compressive strength result for QDFA10 and QDFA20 are lower than control concrete and the SCC with only superplasticizer while QDFA40 is lower than the SCC with only superplasticizer. However, the compressive strength result for QDFA30 is higher both the control concrete and SCC with only superplasticizer and it indicates the QDFA30 in SCC as the optimum result in this research study.
QDFA30 has the highest compressive strength amongst all the other design mixes, with an increase of 7.24% than control mix and 6.54% of the mix with only superplasticizer. In order to increase the workability of concrete, higher water to cement ratio is needed thus decreasing the strength of concrete.
However, by incorporating the Quarry dust and fly ash and the use of superplasticizer, higher compressive strength was achieved with the constant water cement ratio for all mixes.

Table 2: Compressive strength results of control mix and all SCC mix designation

Mixture Designation	Curing (Days)	Compressive strength in MPa
Control Mix	7 days	27.03
SP		27.96
QDFA10		24.37
QDFA20		25.32

QDFA30		29.19
QDFA40		28.32
Control Mix	28 days	36.15
SP		36.39
QDFA10		34.82
QDFA20		35.67
QDFA30		38.77
QDFA40		36.24

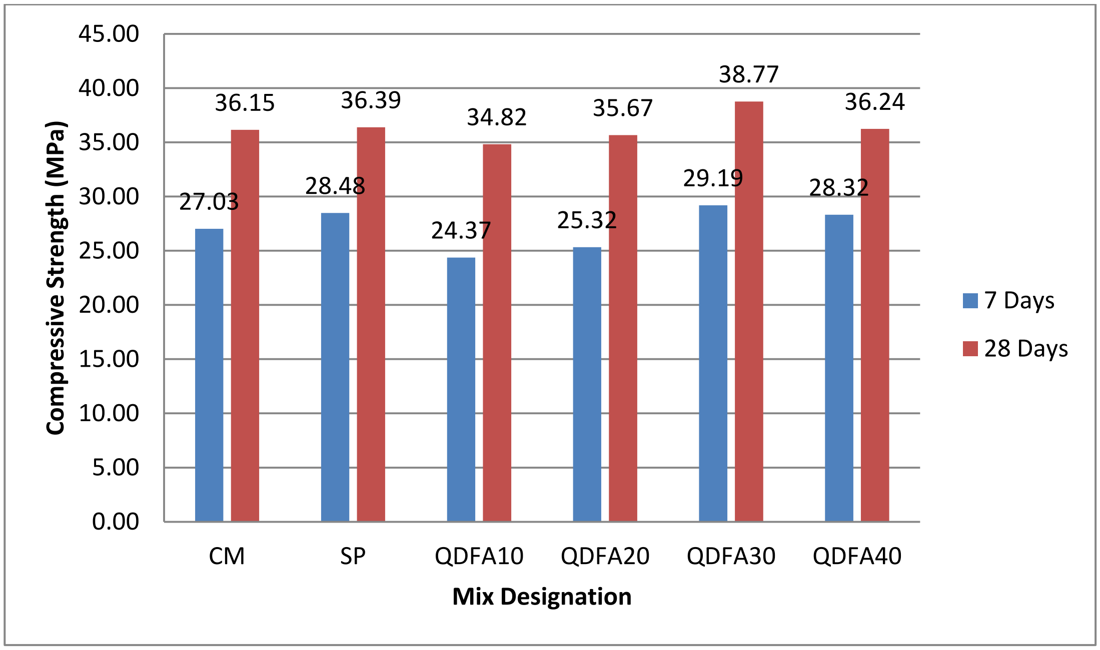

Figure 3: Compressive strength test for control and all SCC mixture designation

4.3 Water Absorption Test

The water absorption test was performed using BS 1881: Part 122: 1983. This Part of this British Standard specifies a method for the determination of water absorption of concrete specimens cored from a structure or precast component. The 50 mm Ø x 100 mm height cylinder was used for casting. The cylinder was immersed in water for 7 days and 28 days curing period. The specimen were dried in oven for 3 days and immersed in water at 30 minutes interval for 4 hours. The results for 7 days and 28 days test for water absorption of control and all SCC mixes with different mix designations are shown in the table 3. The water absorption of SCC containing fly ash and quarry dust in grade 35 concrete according to immersion time of 7 days and 28 days curing were classified as having average water absorption. The water absorption of concrete after 7 days curing at initial 30 minutes water immersion were not all below 3% except for QDFA30 which is slightly above 3% and for after 28 days curing it can be seen that most of the mix designation are below 3% and so this concrete can be classified as having low water absorption.

The fly ash added to the SCC mix served as a filler and helped to fill up the capillary pore structures that reduced water absorption in the SCC mix. Thus, reducing the size of the pores and the transport of water in the concrete mix. Water absorption of QDFA30 was lower than the control mixes for both 7 days and 28 days curing. Therefore, it shows that durability of QDFA30 was improved and made better compared to the control mix concrete.

Figure 4 indicated that water absorption for initial 30 minutes are not all below 3% after 7 days curing but for the bar chart of the results in Figure 10 most of the mix designations are all below 3% after 28 days curing therefore all concrete mixes can be classified as having good water absorption since 3% is the limiting value specified for initial surface water absorption. Based on the two graphs it can be seen that water absorption at 7 days curing is higher than water absorption at 28 days curing. Thus, water absorption of concrete reduces with the age of concrete.

From the results of water absorption stated below we can see that the SCC mix with mix designation QDFA30 had the least percentage of water absorption than the other mixes. Therefore, the optimum percentage of quarry dust in SCC with respect to water absorption is 30%.

Table 3: Water absorption of control mix and all SCC mix designation for 7 and 28 days curing

Mixture Designation	**Curing (Days)**	**Water Absorption (%)**							
		Duration of immersion (Hours)							
		0.5	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**
Control Mix	7 days	3.24	4.26	4.92	5.33	5.57	6.15	6.28	6.48
SP		3.96	4.59	4.75	5.40	5.74	5.98	6.20	6.41
QDFA10		3.82	4.57	4.86	5.67	5.76	5.84	6.09	6.31
QDFA20		3.64	4.55	5.36	5.57	5.77	5.93	6.01	6.19
QDFA30		3.06	4.02	4.61	5.17	5.58	5.78	5.91	6.07
QDFA40		3.19	4.14	4.85	5.33	5.73	5.96	6.08	6.26
Control Mix	28 days	1.78	2.52	3.15	3.71	4.34	5.04	6.44	6.87
SP		2.39	3.14	3.58	3.78	4.28	4.69	5.10	5.50
QDFA10		2.77	3.19	3.94	4.29	4.78	5.11	5.72	6.35
QDFA20		3.01	3.62	4.17	4.57	5.07	5.58	6.03	6.47
QDFA30		1.78	2.47	2.94	3.31	3.83	4.26	4.80	5.31
QDFA40		3.10	4.13	4.85	5.38	6.02	6.72	7.30	7.92

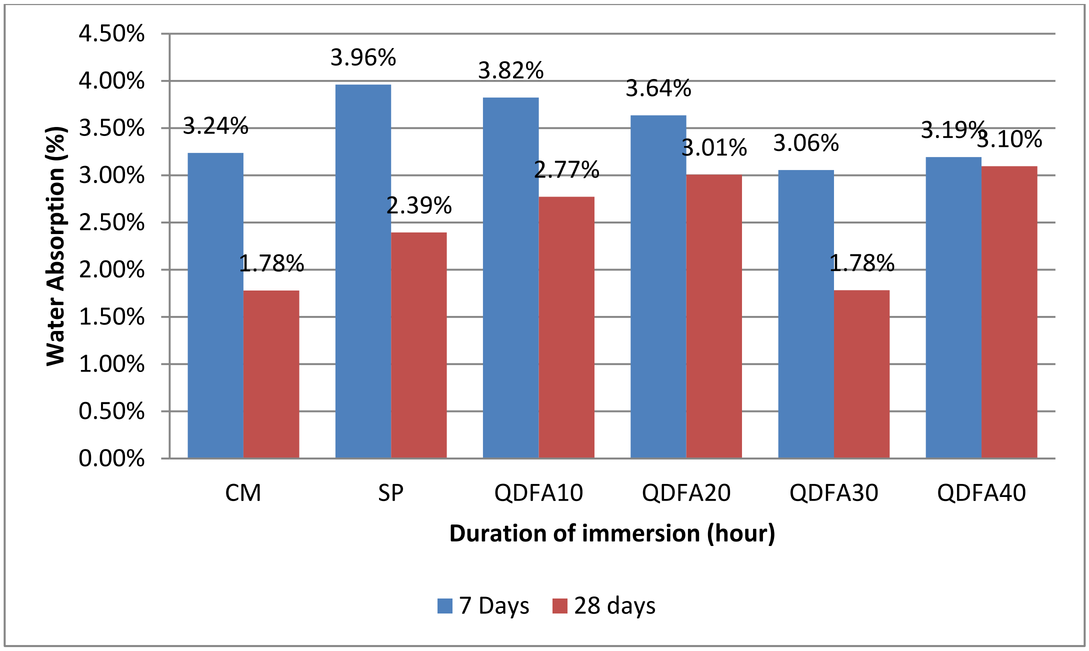

Figure 4: Water absorption of control mix and all SCC mix designation at initial 0.5 hour water immersion

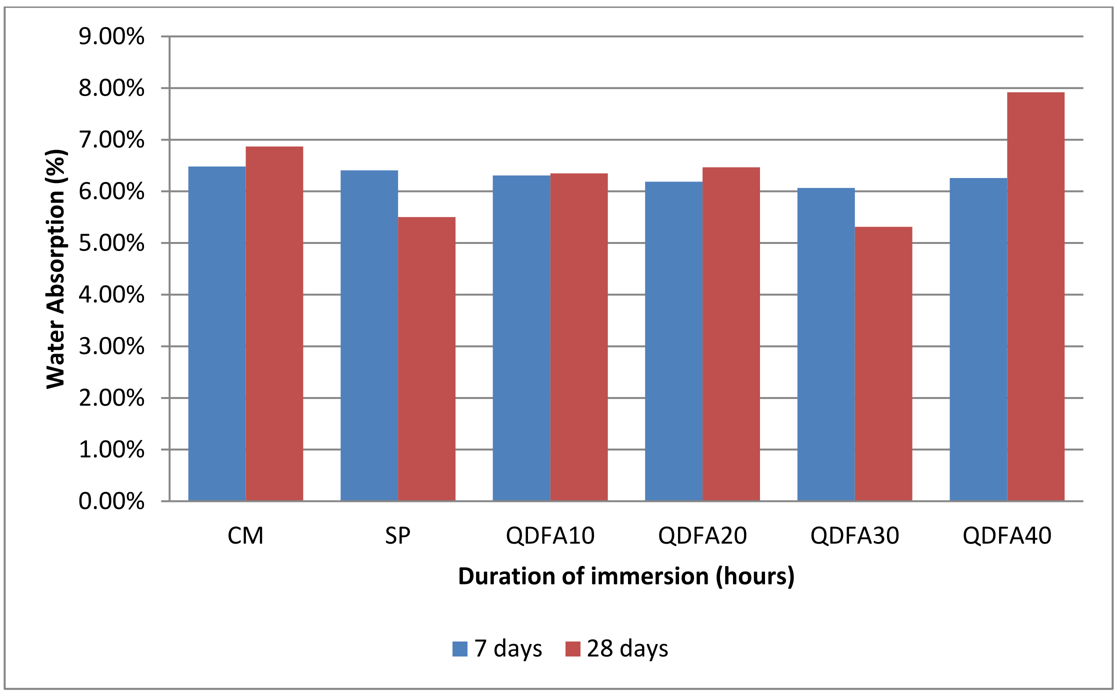

Figure 5: Water absorption of control mix and all SCC mix designation at final 4 hour water immersion

5.0 Conclusion and Recommendations

The following conclusions are outlined based on experimental result

SCC workability in terms of slump flow value and j-ring value increases by the reduction or sand with replacement of quarry dust from 0% - 30%. Further replacement of quarry dust with sand above 30% resulted reduce workability. This indicates that the optimum amount for the replacement of sand by quarry dust in SCC is 30% and at this percentage the workability of SCC was greatly improved. From the water absorption test, it was observed that the percentage of water absorption was least at 30% replacement of sand with quarry dust and 10% replacement of cement with fly ash. The water absorption value of self-compacting concrete containing quarry dust and fly ash was generally lower compared to the one containing no quarry dust and fly ash. From the compressive strength test, increase in percentage of partial replacement of fine aggregate with quarry dust at 0%-30%, resulted in the increase in compressive strength. Further, with increase in percentage partial replacement of fine aggregate with QD at 40% decreased the strength gradually. The best compressive strength was achieved at 30% replaced of quarry dust with sand and 10% replacement of cement with fly ash. Study concluded that the partial replacement of quarry dust with sand more than 30% caused reduction of compressive strength and water absorption. Hence, the optimum amount of quarry dust for this research is 30%.

More research needs to be done to make effective use of waste materials like quarry dust and fly ash to improve the workability, durability and compressive strength of self-compacting concrete. This will lead to less waste materials released to the environment and as this same time produce a cheaper SCC mix with good durability and strength properties. Some other recommendations for future research are as follows: Additional test can be conducted on SCC mix incorporated with quarry dust and fly ash such as split tensile test, flexural test and other durability test such as acid resistance test and sulphate attack test. A different water cement ratio and a different grade of SCC can be designed other type of superplasticizers can be used for future research. The percentage of fly ash can be increased to see the effects on the concrete properties. The curing duration can be increased to 60 days to see if there will be future strength increase.

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