IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 21, Issue 5, Ser. III (Sep - Oct 2019), PP 64-73
www.iosrjournals.org

Characteristics of Self Compacting Concrete (SCC) Due to Addition of Fly-Ash and Use of Un-Crushed Coarse Aggregate (CA)

Biswajit Choudhury [1], Abhijit Mangaraj[2]
[1](*Department of Civil Engineering, Gandhi Engineering College, India*)
[2](*Department of Civil Engineering, Gandhi Institute For Technology, India*)

Abstract
This exploration paper talks about the adjustment in the usefulness and quality attributes of Self Compacting Concrete (SCC) because of expansion of fly-debris and utilization of un-squashed Coarse Aggregate (CA). Lab based exploratory work was done by getting ready 12 SCC blends among which six blends contained squashed total and other six blends contained un-squashed coarse total. A sum of 550 kg/m3 cover content and fixed Water-Binder (W/B) proportion as 0.35 were utilized. Two blends were constrained by utilizing Portland Cement (PC) and other ten blends contained PC and Fly Ash (FA). Droop stream time, droop stream distance across and J-ring tallness tests were led to contemplate the new properties of SCC. Besides, compressive quality was determined at 7, 14 and 28 days of restoring. The results demonstrated that the droop stream time, droop stream breadth and J-Ring stature for all the blends are inside the cutoff points indicated by EFNARC rules. The compressive quality of SCCs relies on measurements of fly debris. Compressive quality for SCCs with squashed CA was better than got in the event of un-squashed CA. The most extreme compressive-qualities were seen as 64.58 MPa and 58.05 MPa for SCC with squashed and un-squashed CA individually.
Keywords: *Self-Compacting Concrete; SCC; Fly Ash; Un-crushed Coarse Aggregates; Fresh Properties; Compressive Strength.*

I. Introduction

Compaction at narrow places is one of the major problems observed in reinforced concrete construction. However, the SCC is the best option in such situations. SCC is the one that flows through its own weight and hence is very effective in pouring at heavily-reinforced, narrow and deep sections without any vibrational efforts required [1-3]. SCC is the mixture of cement, aggregates, water, admixtures and some mineral additives analogous to the normal concrete. Unlike normal concrete, SCC requires more amount of fillers materials and Super Plasticizers (SP) to give better strength and workability. SCC results in reduction of labour work and also economizes the cost of concreting [4-8]. High quantity of fine-materials such as fly-ash is utilized for acquiring required workability to SCC. This also reduces the issue of segregation and bleeding while transportation and placement of concrete. Many researchers concerned with environmental conservation have criticized the use of cement as a binding material.

Since the demand of cement in concrete production is amplified, it has caused resource depletion, environmental damages and huge amount of carbon-dioxide (CO_2) emission during cement manufacturing process [9]. This has made serious concern of the practitioners and researchers to bring alternative materials of cement such as fly ash. These types of materials are considered safer for emitting. Thus, investigating symbolic properties of these waste materials open new possibilities for concrete development [10]. Use of such waste material in concrete is also very useful in enhancing the properties of concrete and also enhancing durability values [11–14]. Hence, this study has focused to conduct symbolic work for studying behaviour of fly ash in SCC. Fly ash generated from burnt coal is waste material and available at huge amount worldwide which creates more chances to use it as an alternate for cement concrete works. When the fly ash is inserted in concrete, it forms Calcium Hydrated Silicate Gel due to its reaction with calcium hydroxide during process of hydration at ambient temperature. Research works has highlighted that availability of Fly ash can provide the opportunity of replacing OPC up to 60% of its mass [9].

Several researchers have proposed and tested fly ash as mineral admixture for improving the properties at fresh and hardened state as well as the durability of the SCCs. Phathak and Siddique (2012) investigated of SCC with class F Fly ash by replacing cement with (0%, 30%, 40% and 50%) of fly-ash while temperature variation was considered as 20^oC, 100^oC, 200^oC and 300^oC. Test results revealed that compressive strength was in between 21.43 MPa and 40.68 MPa while tensile strength was recorded in between 1.35 MPa (min) and 3.60 MPa (max). The authors concluded that 28 days curing caused increment in compressive as well as tensile strength. Further, it was noted that compressive strength had improvement at the temperature of 200^oC to 300^oC

while tensile strength was slightly reduced when temperature was raised above 20^{o}C [15]. Fernando et al. (2018) developed SCC with reduced amount of cement. They added metakaolin and fly-ash as cementitious materials in SCC for evaluating flow ability and strength characteristics of concrete. From research work, it can be argued that metakaolin and fly ash addition is very usable in manufacturing low strength SCC with required workability and lower use of binder [16].

A research work conducted by Dinesh et al. (2017) showed comparison of effect of silica-fume and fly-ash as cementitious materials. The study revealed that silica fume exhibited positive results in increasing the concrete properties as compared to fly ash [17]. Jalal et al. (2015) studied the rheological characteristics of SCC when cement was partially replaced by silica nano, SF and fly ash. Experiments showed that fly ash is helpful in improving the rheological properties when compared with the other materials. However, when SF and silica nano particle are mixed together as cementitious material, they revealed considerable effect on both the mechanical and rheological characteristics [18]. Considering the need of sustainability, it is more advisable to utilize waste materials as new construction materials. This will exert positive impact on environment as well social values. Hence, this study is aimed to use fly ash as cementitious material to reduce the quantum of OPC. Also un-crushed coarse aggregates obtained from sieving of hill sand are used as coarse aggregate. For this purpose, total 12 concrete mixes were designed. Out of them six mixes for crushed and six for un-crushed CA with respect to the inclusion of fly ash. Fly ash has partially replaced (by weight), the cement at the levels of 0% to 20% with 4% increment. This article is structured systematically to study the behavior of fly ash in SCC. It is stated with introduction following the material and methodology used for conducted the research work. Finding of the current work are presented and the article is ended up with conclusion of the research work.

II. Materials and Methods

Methodology is systematic process for carrying out any research work. Stepwise approach used for this research is presented in following figure.

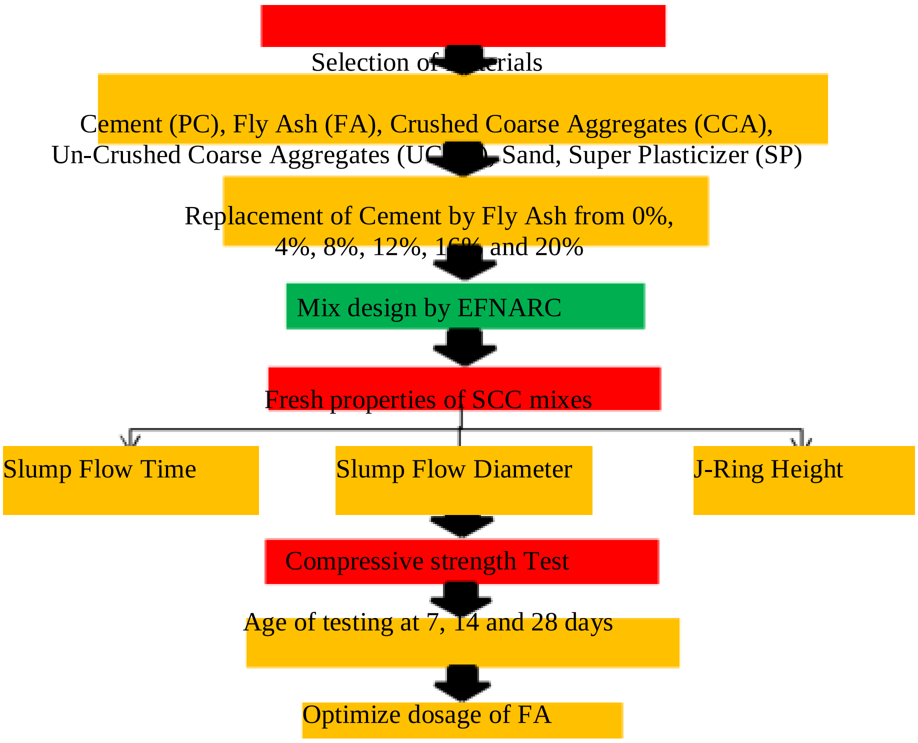
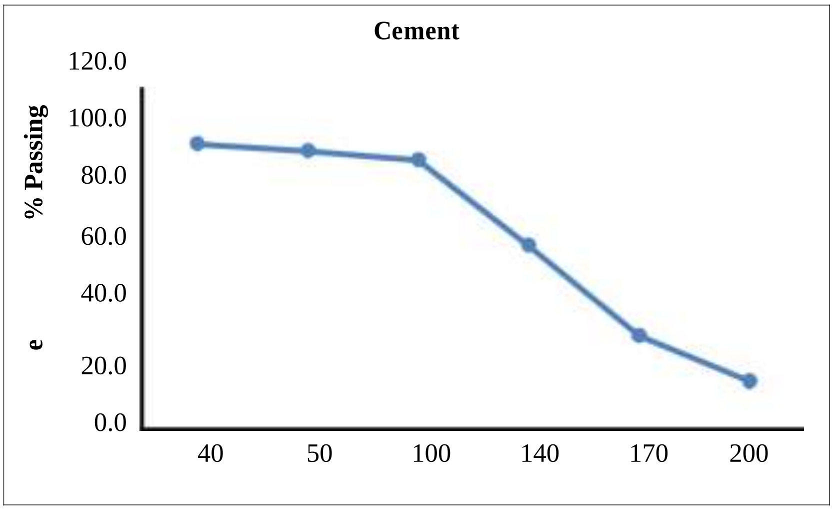


Figure 1. Flowchart to produce optimum SCC mix design

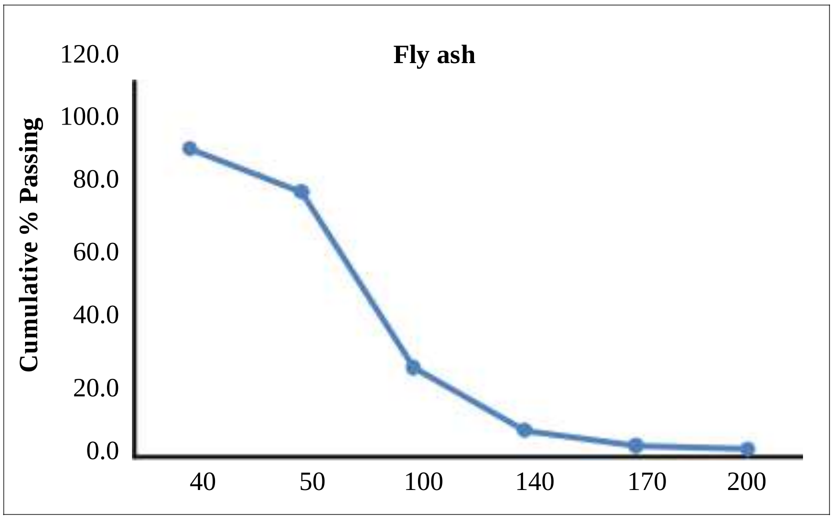
694

Figure 1 above depicts that the first step for conducting this study is selection of the material. The SCC mixtures used in this study were prepared with PC; lucky brand; conforming to the requirements specified in ASTM C150/C150M-18, class F fly ash (FA) according to ASTM C 618, the coarse aggregate used was both crushed and un crushed in nature with a maximum size of 13 mm, while crushed hill sand passing from number 4 sieve was used in this study. The gradation curves for used material are presented in Figures 2 to 6.



Sieve #

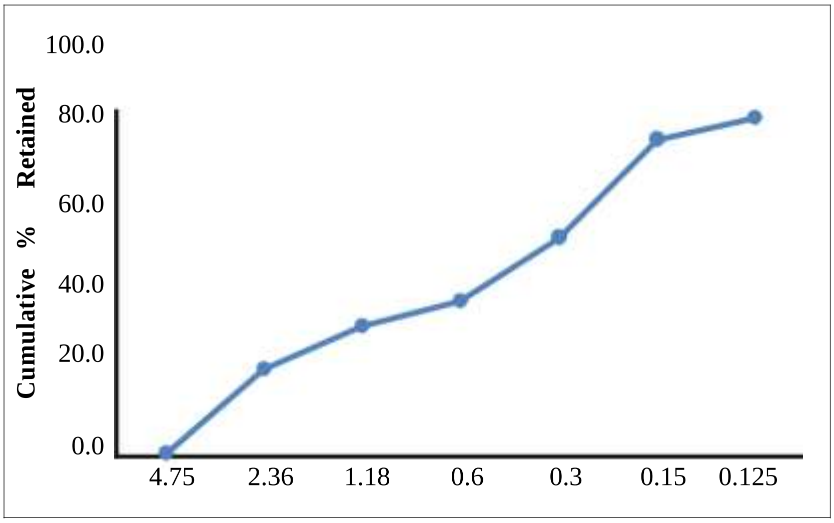
Figure 2. Gradation of Cement



Sieve #

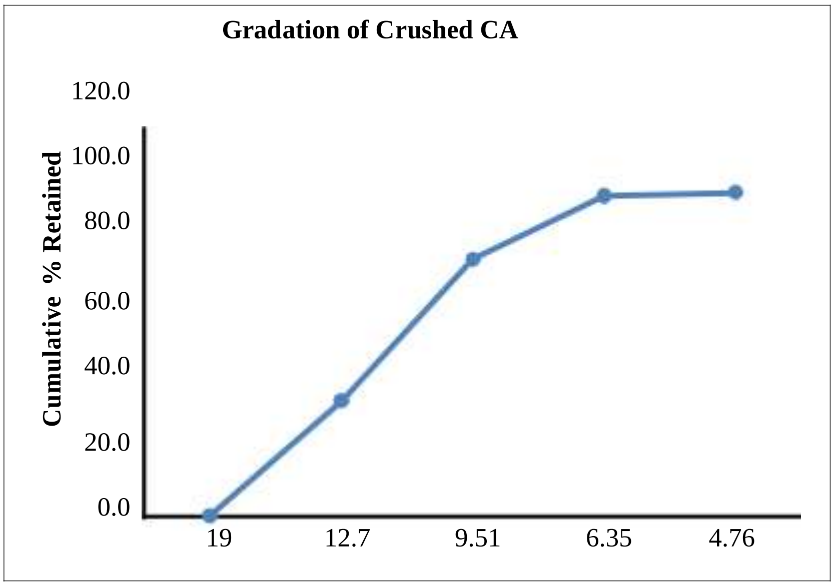
Figure 3. Gradation of Fly Ash

Gradation of sand



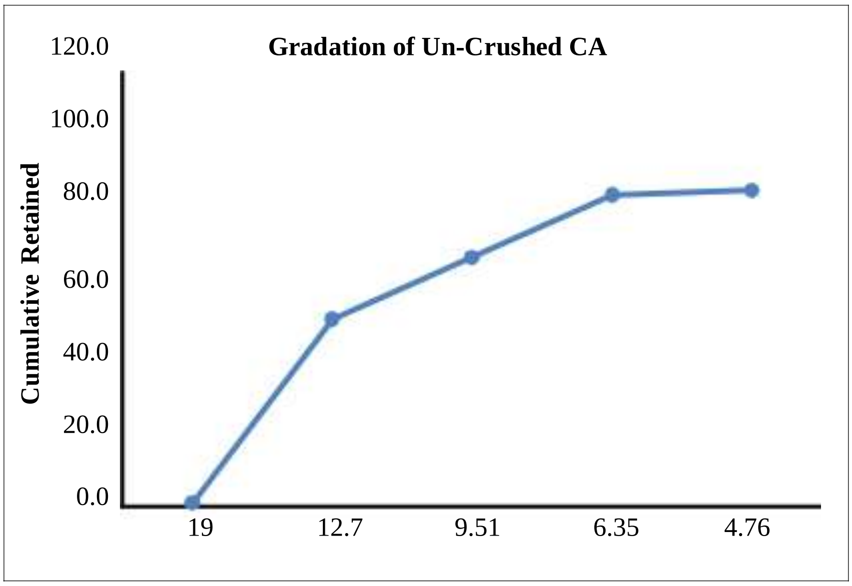
Sieve size (mm)

Figure 4. Gradation of Sand



Sieve size (mm)

Figure 5. Gradation of Crushed Coarse Aggregates



Sieve size (mm)

Figure 6. Gradation of Un-Crushed Coarse Aggregate

A polycarboxylic-ether based super plasticizer having relative density of 1.08 and pH value equals to 6.2 was used in all mixtures. For comparing the effect of fly ash, 10 mixes were prepared as binary mixes i.e. blending OPC and FLA where fly ash replace equal amount of cement by weight while remaining 2 mixes were control mixes i.e. OPC was used as binder. W/B ratio for these mixes was taken as 0.35. Initially, mix proportions were considered in accordance with EFNARC guidelines [19] which were finalized through several laboratory trials. Description of various mix proportions are shown in Table 1.

Table 1. A detail of SCC mixes with quantities of ingredients for 1 m^3

S. No.	Mix ID		Cement kg/m^3	Fly ash kg/m^3	Binder kg/m^3	W/B (%)	SP (%)	Sand kg/m^3	CA kg/m^3	SP kg/m^3	Water kg/m^3
1		CM	550	0	550	0.35	2	850	890	11	192.5
2	4%	Fly ash	528	22	550	0.35	2	850	890	11	192.5
3	8%	Fly ash	506	44	550	0.35	2	850	890	11	192.5
4	12%	Fly ash	484	66	550	0.35	2	850	890	11	192.5
5	16%	Fly ash	462	88	550	0.35	2	850	890	11	192.5
6	20%	Fly ash	440	110	550	0.35	2	850	890	11	192.5

In assessing fresh properties of the mix compositions, flow ability was measured through slump flow time and flow diameter test while passing ability test was performed through J-ring test. Furthermore, compressive strength was checked at 7, 14 and 28 days curing to appraise the hardened properties of the concrete. Flow ability of all the mixes was controlled by slump flow diameter to maintain the required range i.e. 70 to 80 cm as advised by EFNARC (2002)

[19]. For each mix proportions, several trial batches were prepared by varying the amount of super plasticizer to obtain the preferred value of slump flow diameter. Cubes having dimensions as 100 × 100 × 100 mm were casted and tested under compression to assess the hardened properties of the SCCs. Five cube specimens of each mix were casted from each batch. Ultimate compressive strength was computed based on average of five values as shown in Tables 3 and 4.

III. Results and Discussions

3.1. Fresh Properties

The Slump Flow time, Slump flow diameter and J- Ring Tests were performed in lab as EFNARC guidelines [19]. The results of the slump flow tests of concrete with fly ash are presented in Table 2. The spread diameter of slump flow ranges between 69.5-76.3 cm. From the Table 2 it can clearly be interpreted that spread diameter raised with enhancement in fly ash percentage, indicating that fly ash reduces the viscosity of the SCC mixes and thus encourages segregation. The same findings have also been reported by Bouzoubaa and Lachemi (2001) [20]. An identical trend is observed in slump flow time and J-Ring height for all the mixes within the limits specified by [19]. Un-crushed coarse aggregates have a flat surface. The flatness of the coarse aggregates enhances workability parameters. Table 2 depicted that workability of SCC mixes is more pronounced while using un-crushed CA.

Table 2. A fresh property of SCC mixes

S. No.	Mix ID	Slump flow time T_{50} (sec) limits 2-5 sec		Slump flow diameter (cm) limits 65-80 cm		J-ring height (mm) limits 0-10 mm	
		Crushed	Un-Crushed	Crushed	Un-Crushed	Crushed	Un-Crushed
1	CM	4.6	4.3	69.5	70.4	9.6	9.4
2	4% Fly ash	4.4	4.2	70.25	71.2	9.53	9.2
3	8% Fly ash	4	3.84	71.45	72.9	9.46	9
4	12%Fly ash	3.92	3.79	72.15	74	9.2	8.6
5	16%Fly ash	3.72	3.6	73.6	75.6	9.13	8.3
6	20%Fly ash	3.54	3.2	74.8	76.3	8.9	8

Figure 7. Pictorial views of slump flow and J-ring tests

3.2. Compressive Strength

The results of average compressive strength with crushed and un-crushed (CA) at various testing curing ages are drawn in tabular form as in Tables 3 and 4.

Table 3. Average Compressive strength (Crushed Aggregates)

S. No.	Mixes	Compressive Strength (MPa)		
		7 days	14 days	28 days
1	0% FA	53.46	56.03	60.50
2	4% FA	56.07	60.84	61.82
3	8% FA	62.97	63.45	64.58
4	12% FA	53.42	56.54	57.92
5	16% FA	44.99	48.74	52.00
6	20% FA	42.66	45.65	47.47

Table 4. Average Compressive strength (Un-crushed Aggregates)

S. No.	Mixes	Compressive Strength (MPa)		
		7 days	14 days	28 days
1	0% FA	45.90	51.39	55.85
2	4% FA	48.83	54.17	57.38
3	8% FA	51.44	55.18	58.05
4	12% FA	39.81	45.02	47.23
5	16% FA	38.95	44.20	45.94
6	20% FA	32.92	37.02	38.72

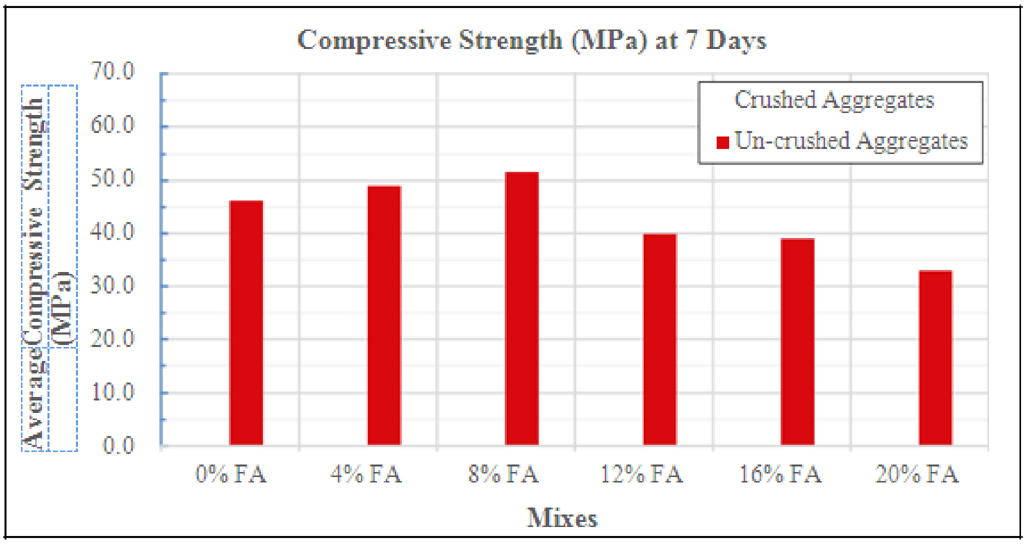


Figure 8. Compressive strength at 7 days curing with crushed and un-crushed coarse aggregates

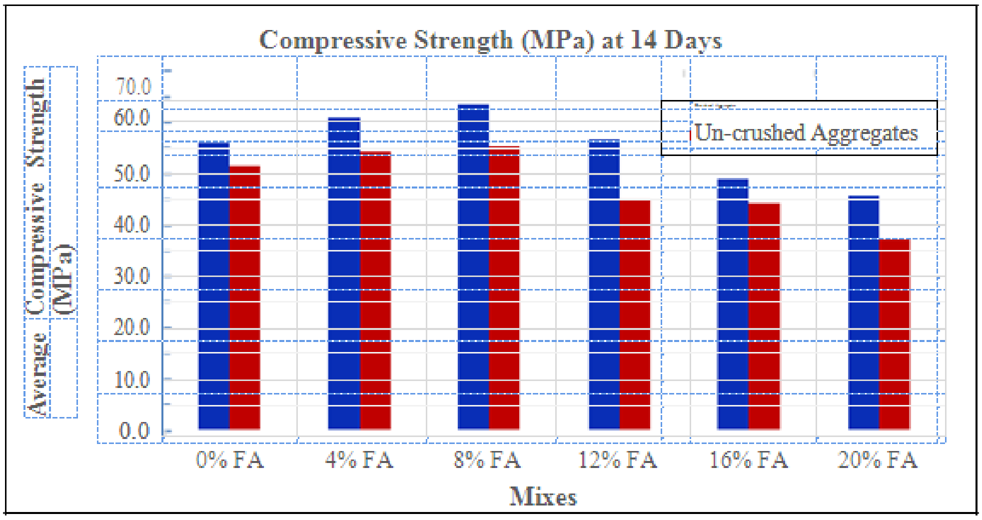


Figure 9. Compressive strength at 14 days curing with crushed and un-crushed coarse aggregates

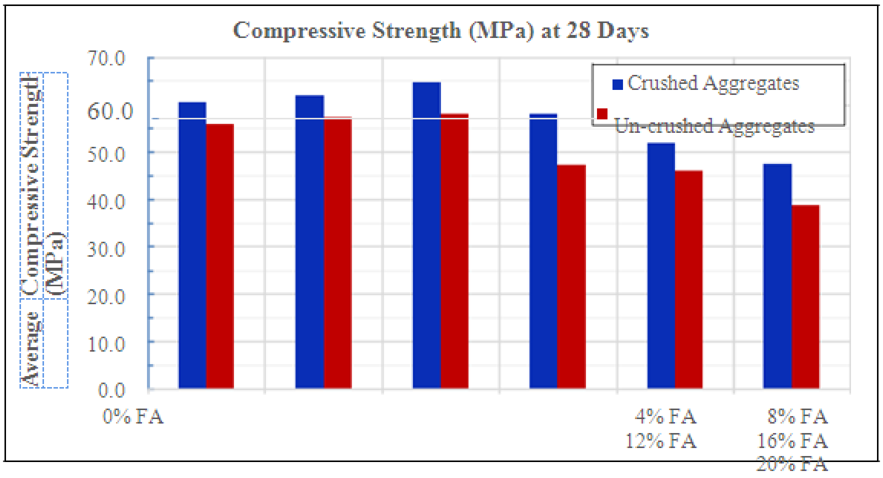


Figure 10. Compressive strength at 28 days curing with crushed and un-crushed coarse aggregates

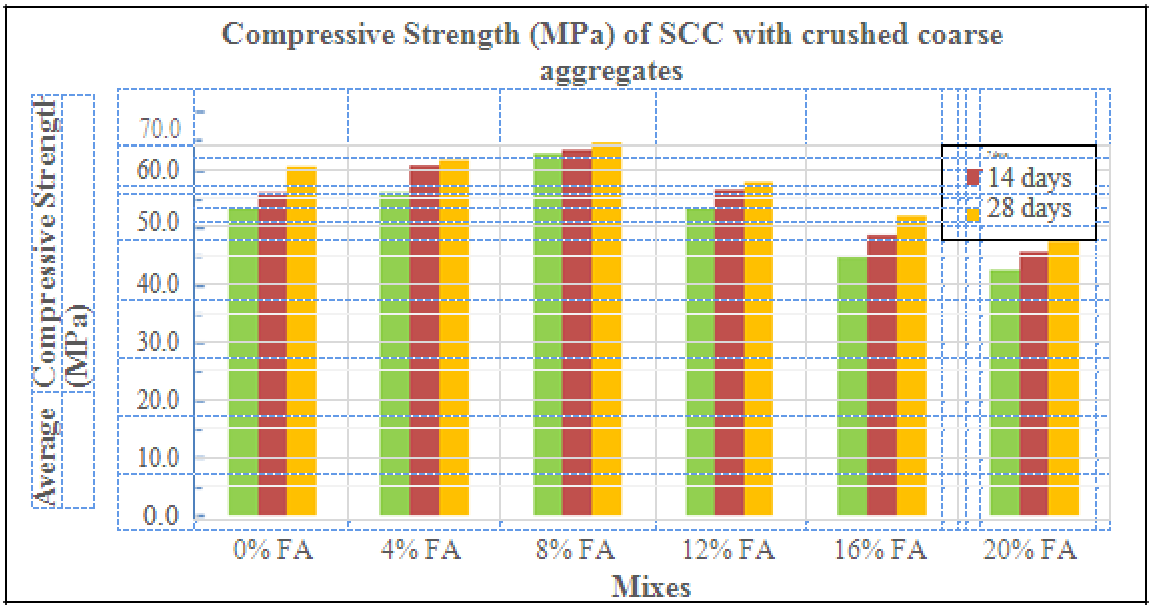


Figure 11. Compressive strength at 7, 14 and 28 days curing with crushed coarse aggregates

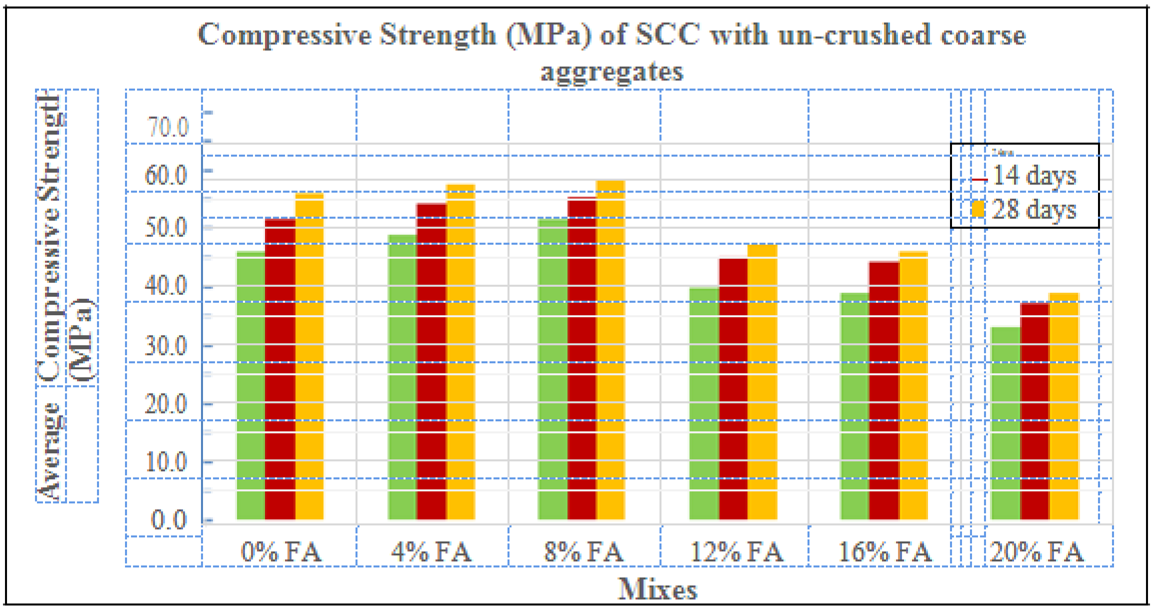


Figure 12. Compressive strength at 7, 14 and 28 days curing with un-crushed coarse aggregates

Tables 3 and 4 presents the results of the average compressive strength profile of SCCs using crushed and un-crushed coarse aggregates at different curing ages respectively. It is observed that the compressive strength is improved by raising the dosage of fly ash up to 8%. The average increase was observed 6.7% and 4% at 28 days curing for SCC manufactured by using crushed and un-crushed aggregates respectively. While for more replacement levels of fly ash, the compressive strength is slightly decreased for both the concretes at all curing ages. Similar study was conducted by Jalal et al. (2015) by adding 10% fly ash where compressive strength measured at 28 day was recorded as 37.3 MPa [18]. Comparing the results of current study as in Table 2 with the work of Jalal et al. (2015), it can concluded that the compressive strength with 8% fly ash at 28 days obtained is approximately 18% higher than that achieved by Jalal et al. (2015). Figures 8, 9 and 10 shows the graphical comparison of compressive strength of proposed concrete by using crushed and un-crushed coarse aggregates for 7, 14 and 28 days curing respectively. Figures 11 and 12 gives graphical view of compressive strength at all curing ages for crushed and un-crushed aggregates concretes respectively. From these figures it may be observed that SCCs manufactured with crushed CA exhibited the higher compressive strength than concretes with un-crushed CA in the respective group of mixes having the same replacement levels of fly ash and curing ages.

IV. Conclusions

From the obtained results subsequent conclusion are drawn:

- Fresh properties of SCC depend upon mix proportions and these can be adjusted with the appropriate dosage of SP;
- The optimum dosage of SP used to maintain the required specified values of slump flow diameter between 70 to 80 cm is 2%;
- An identical trend was observed in slump flow time and J-Ring height for all the mixes were found to be within the limits specified for EFNARC;
- It was observed that the values of fresh properties are remarkably increased while using un-crushed CA;
- Compressive strength of SCCs depends upon the dosage of cement replacement levels of fly ash;
- The 28 days compressive strength of SCC with crushed and un-crushed CA increases by raising the percentage of fly ash to 8% instead of 6.7% and 4% of their respective controlled mix;
- The strength properties were improved when SCC was manufactured with crushed CA. The maximum compressive strength at 28 days was recorded 64.58 MPa at 8% replacement level of fly ash.

Acknowledgements

The authors would be very thankful to Quaid-e-Awam University of Engineering, Science & Technology Nawabshah Sindh Pakistan for the support

Conflicts of Interest

The authors declare no conflict of interest.

References

[1]. Memon, Noor Ahmed, Muneeb Ayoub Memon, Nawab Ali Lakho, Fareed Ahmed Memon, Manthar Ali Keerio, and Ammaar Noor Memon. "A review on self-compacting concrete with cementitious materials and fibers." Engineering, Technology & Applied Science Research 8, no. 3 (2018): 2969-2974.

[2]. Gholhaki, Majid, Ali kheyroddin, Mohammad Hajforoush, and Mostafa Kazemi. "An Investigation on the Fresh and Hardened Properties of Self-Compacting Concrete Incorporating Magnetic Water with Various Pozzolanic Materials." Construction and

[3]. Building Materials 158 (January 2018): 173–180. doi:10.1016/j.conbuildmat.2017.09.135.

[4]. El Mir, Abdulkader, and Salem G. Nehme. "Utilization of Industrial Waste Perlite Powder in Self-Compacting Concrete."

[5]. Journal of Cleaner Production 156 (July 2017): 507–517. doi:10.1016/j.jclepro.2017.04.103.

[6]. Iqbal, Shahid, Ahsan Ali, Klaus Holschemacher, and Thomas A. Bier. "Mechanical Properties of Steel Fiber Reinforced High Strength Lightweight Self-Compacting Concrete (SHLSCC)." Construction and Building Materials 98 (November 2015): 325-333. doi:10.1016/j.conbuildmat.2015.08.112.

[7]. Kamal, M.M., M.A. Safan, A.A. Bashandy, and A.M. Khalil. "Experimental Investigation on the Behavior of Normal Strength and High Strength Self-Curing Self-Compacting Concrete." Journal of Building Engineering 16 (March 2018): 79–93. doi:10.1016/j.jobe.2017.12.012.

[8]. Brouwers, H.J.H., and H.J. Radix. "Self-Compacting Concrete: Theoretical and Experimental Study." Cement and Concrete

[9]. Research 35, no. 11 (November 2005): 2116–2136. doi:10.1016/j.cemconres.2005.06.002.

[10]. Nguyen, Hoang-Anh, Ta-Peng Chang, Jeng-Ywan Shih, and Herry Suryadi Djayaprabha. "Enhancement of Low-Cement Self-Compacting Concrete with Dolomite Powder." Construction and Building Materials 161 (February 2018): 539–546. doi:10.1016/j.conbuildmat.2017.11.148.

[11]. Kannan, V. "Strength and Durability Performance of Self Compacting Concrete Containing Self-Combusted Rice Husk Ash and Metakaolin." Construction and Building Materials 160 (January 2018): 169–179. doi:10.1016/j.conbuildmat.2017.11.043.

[12]. Rangan, B. Vijaya. "Design, Properties, and Applications of Low-Calcium Fly Ash-Based Geopolymer Concrete."

[13]. Developments in Porous, Biological and Geopolymer Ceramics (2010): 347–362. doi:10.1002/9780470339749.ch31.

[14]. Aprianti S, Evi. "A Huge Number of Artificial Waste Material Can Be Supplementary Cementitious Material (SCM) for Concrete Production – a Review Part II." Journal of Cleaner Production 142 (January 2017): 4178–4194. doi:10.1016/j.jclepro.2015.12.115.

[15]. Khodabakhshian, Ali, Mansour Ghalehnovi, Jorge de Brito, and Elyas Asadi Shamsabadi. "Durability Performance of Structural Concrete Containing Silica Fume and Marble Industry Waste Powder." Journal of Cleaner Production 170 (January 2018): 42–60. doi:10.1016/j.jclepro.2017.09.116.

[16]. Singh, Navdeep, Mithulraj M, and Shubham Arya. "Utilization of Coal Bottom Ash in Recycled Concrete Aggregates Based Self Compacting Concrete Blended with Metakaolin." Resources, Conservation and Recycling 144 (May 2019): 240–251. doi:10.1016/j.resconrec.2019.01.044.

[17]. Matos, Paulo Ricardo de, Maiara Foiato, and Luiz Roberto Prudêncio. "Ecological, Fresh State and Long-Term Mechanical Properties of High-Volume Fly Ash High-Performance Self-Compacting Concrete." Construction and Building Materials 203 (April 2019): 282–293. doi:10.1016/j.conbuildmat.2019.01.074.

[18]. Khan, Mehran, and Majid Ali. "Improvement in Concrete Behavior with Fly Ash, Silica-Fume and Coconut Fibres."

[19]. Construction and Building Materials 203 (April 2019): 174–187. doi:10.1016/j.conbuildmat.2019.01.103.

[20]. Pathak, Neelam, and Rafat Siddique. "Properties of Self-Compacting-Concrete Containing Fly Ash Subjected to Elevated

[21]. Temperatures." Construction and Building Materials 30 (May 2012): 274–280. doi:10.1016/j.conbuildmat.2011.11.010.

[22]. Pelisser, Fernando, Alexandre Vieira, and Adriano Michael Bernardin. "Efficient Self-Compacting Concrete with Low Cement Consumption." Journal of Cleaner Production 175 (February 2018): 324–332. doi:10.1016/j.jclepro.2017.12.084.

[23]. Kumar, C. S., and K. Reena. "Experimental study on self-compacting self-curing concrete by replacing river sand by quarry dust for M50 grade concrete." International Journal of Engineering and Management Research (IJEMR) 5, no. 5 (2015): 180-186.

[24]. Jalal, Mostafa, Alireza Pouladkhan, Omid Fasihi Harandi, and Davoud Jafari. "Comparative Study on Effects of Class F Fly Ash, Nano Silica and Silica Fume on Properties of High Performance Self Compacting Concrete." Construction and Building Materials 94 (September 2015): 90–104. doi:10.1016/j.conbuildmat.2015.07.001.

[25]. EFNARC. "Specification and Guidelines for Self-Compacting Concrete." (2002).

[26]. Bouzoubaâ, N, and M Lachemi. "Self-Compacting Concrete Incorporating High Volumes of Class F Fly Ash." Cement and

[27]. Concrete Research 31, no. 3 (March 2001): 413–420. doi:10.1016/s0008-8846(00)00504-4.