EFFECT OF MINERAL ADMIXTURES ON THE FRESH PROPERTIES OF SELF COMPACTING CONCRETE PRODUCED WITH RECYCLED AGGREGATE

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Abstract:

The rising demand and decrease in supply of aggregates for the production of concrete result in the need to identify new sources of aggregates. On the other hand, majority of the countries are facing the problem of construction and demolition (C&D) wastes disposing. In view of this aspect, there has been a growing priority on the utilization of C & D waste and its by-products in construction activities. Self compacting concrete (SCC) having enormous advantages compared with the vibrated concrete which can be placed easily in congested reinforcements. Industrial by products/waste materials such as fly ash, Silica fume and granulated blast furnace slag are generally used as mineral admixtures in SCC. The mineral admixtures can improve particle packing, improve the quality of recycled aggregate (RA) and decrease the permeability of concrete.

This investigation is an attempt to examine the influence of different mineral admixtures such as Silica fume and Ground Granulated Blast Furnace Slag (GGBS) on the fresh properties of SCC produced with recycled aggregate (RA). Recycled concrete aggregate is used as coarse aggregate in the production of SCC, with varying percentage replacements of natural coarse aggregate (NA) from 0% to 100% with increment of 50%. Cement is partially replaced with Silica fume (5 %, 10% & 15%) and GGBS (20%, 40% & 60%) in various proportions. Fresh Properties of all the mixes are assessed by the following tests namely slump flow, T500, J ring, V funnel, T5mins and L-box. The test result shows that the mineral admixtures extensively increase the workability with an increase in the percentages of RA. The result also shows that all SCC mixtures satisfy the EFNARC standard values of fresh properties. From this it is concluded that recycled aggregate can be effectively used in the production of SCC.

Keywords: *Self Compacting Concrete Recycled Aggregate, Fresh Property, Mineral Admixtures.*

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1. INTRODUCTION

Self compacting concrete (SCC) is special type of concrete which can be placed easily in congested reinforcements and compacted under its own weight without segregation and bleeding (1). Its characteristics are passing ability, filling ability and segregation resistance (2). To achieve the above properties, SCC requires high Powder content, superplasticizer and viscosity modifying additives. However, costs of such concretes are high, due to high volume of Portland cement and chemical admixtures (3&4). Number of studies has been reported in the literature concerning the use of mineral admixtures such as Ground Granulated Blast furnace Slag (GGBS) and Silica Fume (SF) to enhance the flow properties of SCC. Boukendak dji (5) examined the fresh property of SCC with upto 25% of GGBS, with different types of super- plasticiser (SP), and concluded that the optimum usage of GGBS is 15% with the poly carboxylic ether type of SP. Bensalem (6) also studied the effective use of GGBS in SCC compared with Marble powder and Limestone filler. The result shows that SCC with

GGBS mixes having improved fresh property and lowest viscosity of the mixture. Yazici (13) investigated the fresh properties of SCC with SF in the presence of fly ash (FA). The author found that 10% SF with various percentages of FA content shows the better flowability of SCC. Turk (14) examined the incorporation of SF in SCC up to 20%. The result shows that increase in the amount of SF provide the increasing rate of fresh properties. Bingol (7) studied the fresh property of SCC with 5%, 10% and 15% of SF. The result also proves that increase in replacement of SF improves the fresh and mechanical properties.

The quantity of construction and demolition waste (C&D) generated is increasing throughout the year due to urbanisation. In recent times, a rising demand and decrease in supply of natural aggregates (NA) for the production of concrete result in the need to identify new sources of aggregates. In view of this aspect, there has been a growing priority on the utilization of C&D waste and its by-products in construction activities. Many researchers have studied the effect recycled aggregate (RA) with different percentages as replacement of natural aggregate (NA) on vibrated concrete (8 – 12). The main issue of using RA is, its water absorption, decreased specific gravity and lower density (13). The water absorption capacity of RA affects the workability of the concrete. Yong (14) suggested that to avoid higher water absorption, RA is used in saturated surface dry condition (SSD) condition to improve the workability of the concrete. The authors extensively studied the hardened properties of recycled aggregate concrete (RAC) and concluded that C&D wastes are used as an aggregate in concrete production. Sumanth reddy et al (15) studied the effect of RA in mechanical and durability of SCC. The study reveals that the mineral admixtures are used in the higher replacement percentages of RA to improve the performance. Khafaga (16) evaluated the feasibility of using RA in high strength SCC. The result shows that, there is a need for excessive water to fulfil the fresh properties of concrete. The test concluded that 75% of RA can be used in SCC without affecting the fresh property. Tang et al (17) investigated the fresh and mechanical properties of SCC with RA. Five different mixtures of SCC with replacement range of 0% to 100%. SF and PFA were also used in all the mixes and aggregates are used in SSD condition to reduce the higher water absorption of RA. The result concluded that only 25 % to 50% replacement of RA. This experimental work, investigates the effects of GGBS and SF on the fresh properties of SCC with 0%, 50% and 100% RA as coarse aggregate to prove the feasibility of using RA in SCC.

2. EXPERIMENTAL INVESTIGATIONS:

Materials Used:

Ordinary Portland cement of 43 grade was used throughout the study. SF with specific gravity of 2.85 and GGBS with specific gravity of 2.3 were used as mineral admixtures. The properties of cement and mineral admixtures are given in Table 1. Locally available river sand is used as natural fine aggregate. Crushed granite obtained from the local quarry was used as NA. Crushed concrete specimens from laboratory were used as the source of RA. These concrete specimens were crushed manually and subsequently crushed with a lab model jaw crusher and sieved. The aggregate passing in 16 mm sieve and retained on 4.75 mm sieve is used as RA. The nominal size of the natural and recycled coarse aggregates was 16 mm. The properties of NA and RA were determined in accordance with IS 2386-1963 (18) and presented in Table 1. Potable water available in the college campus was used for making concrete. Poly- carboxylic ether based SP is used at 1%.

Table 1: Properties of coarse NA, RA and FineAggregate.

S.No	Physical properties	Fine aggregate	Coarse aggregate (NA)	Recycled aggregate (RA)
1.	Specific gravity	2.59	2.73	2.27
2..	Bulk density (kg/m^3)	1375	1506	1209
3.	Water absorption (%)	1	0.7	7.79
4.	Fineness modulus	3.06	7.79	7.24

3. MIX PROPORTION:

In this study SCC mixes were produced adopting particle packing mix design approach, whose detailed proportions are presented in Table 2. The various replacement levels considered for SF in range of 5% to 15% and GGBFS in range of 20% to 60% respectively. Totally 19 mixes were selected, these included one reference mix produced with complete natural aggregate and OPC designated as SCCRA0. Three series of SCC mixes were employed to study the fresh properties of SCC. The first series (SCC RA0, SCCRA50, and SCCRA100) involved the replacement of NA with RA in the range of 0% to 100% and in addition to RA, each series comprised of OPC were replaced with GGBS in three proportions of the order of 20%, 40%, and 60%, SF were also replaced in the ratio of 5%, 10%, and 15%, respectively. Designed mixes are named as SCCRA0 SF5, SCCRA50SF5 and SCCRA100 SF5 same as for SF10, SF15, GGBS20, GGBS40 and GGBS60, respectively. For all SCC mixes, the amount of cementitious materials used was generally maintained as 560 kg/m^3 of concrete approximately, with a free water-to-binder ratio of 0.36-0.37.

Table 3: Mix proportions of SCC mixes.

Mix Designations	W/P (kg/m^3)	Water (kg/m^3)	Cement (kg/m^3)	GGBS (kg/m^3)	SF (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)		Recycled Aggregate (kg/m^3)		SP Dosage (%)
SCC RA0		196	560	--	--	788	497	325	--	--	1
0% RA											
SCC RA0 SF 5	0.36	196	532	--	20	788	497	325	--	--	1
SCCRA0SF 10	0.36	196	504	--	41	788	497	325	--	--	1
SCCRA0 SF15	0.37	196	476	--	60	788	497	325	--	--	1
SCC RA0GGBS20	0.36	196	448	101	--	788	497	325	--	--	1
SCCRA0GGBS40	0.36	196	336	203	--	788	497	325	--	--	1
SCCRA0 GGBS60	0.37	196	224	304	--	788	497	325	--	--	1
50% RA											
SCCRA50SF 5	0.36	196	532	--	20	788	247	162	222	147	1

SCCRA50SF10	0.36	196	504	--	41	788	247	162	222	147	1
SCCRA50SF 15	0.37	196	476	--	60	788	247	162	222	147	1
SCC RA50GGBS20	0.36	196	448	101	--	788	247	162	222	147	1
SCCRA50GGBS40	0.36	196	336	203	--	788	247	162	222	147	1
SCCRA50GGBS60	0.37	196	224	304	--	788	247	162	222	147	1
100% of RA											
SCC RA100SF 5	0.36	196	532	--	20	788	--	--	444	293	1
SCCRA100SF10	0.36	196	504	--	41	788	--	--	444	293	1
SCCRA100SF15	0.37	196	476	--	60	788	--	--	444	293	1
SCCRA100GGBS20	0.36	196	448	101	--	788	--	--	444	293	1
SCCRA100GGBS40	0.36	196	336	203	--	788	--	--	444	293	1
SCCRA100GGBS60	0.37	196	224	304	--	788	--	--	444	293	1

4. TESTING OF FRESH PROPERTIES:

Fresh properties of SCC

The slump flow, T500, V-funnel and L-box tests were performed according EFNARC guidelines to evaluate the characteristics of SCC such as passing ability, flowability and segregation resistance.

Slump flow and T500 time testing apparatus is shown in Fig 1. It is a test to assess the flowability and the flow rate of SCC in the absence of obstructions. The result is an indication of the filling ability of SCC, and the T500 time is a measure of the speed of flow. The diameter of the spread of the sample is measured, and at the time of testing, the time that the sample takes to reach a diameter of 500 mm (T50) is also measured. The Slump Flow test gives an indication about the filling ability of SCC.

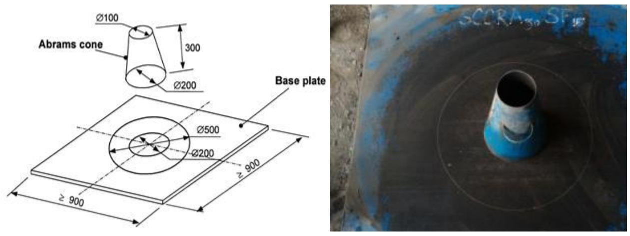

Fig 1: Slump cone apparatus

J- Ring test is to investigate both the filling ability and the passing ability of SCC. The apparatus is shown in Fig 2. It consists of a rectangular section open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. The J-ring bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete. After the test, the difference in height between the concrete inside and that just outside the J-ring is measured at four locations and the average is reported the result. This is an indication of passing ability, or the measure of degree to which the passage of concrete through the bars is restricted.

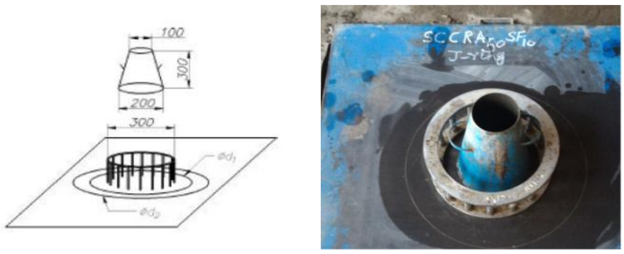

Fig 2: J - ring

5. V flow test:

The equipment consists of a V-shaped funnel as shown in Fig 3. The funnel is filled with the concrete and the time taken by it to flow through the funnel is measured. This test gives account of the filling capacity of SCC. The flow time for all of the concrete to exit the funnel is recoded as a measure of filling ability. For self-compacting concrete, the flow time should be less than 10 seconds. The shorter the flow time, the greater is the filling ability. A shorter flow time suggests a lower viscosity, where as a prolonged flow time indicates the blocking susceptibility of the mix.

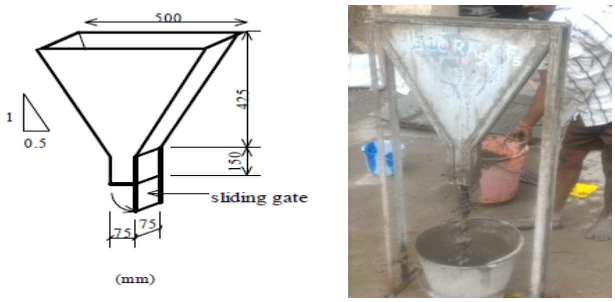

Fig 3: V-Funnel Apparatus

L-box test:

Fig 4. Shows L box apparatus having rectangular cross section, consisting horizontal and vertical part separated by the movable sliding door in front of which vertical rebars are arranged. When the flow of concrete ceases, the height of concrete at the end of the horizontal part and of the remaining concrete in the vertical part are measured (H_2/H_1). That is an indicator of the capacity of concrete to pass through the rebars, and it should be as close to one as possible.

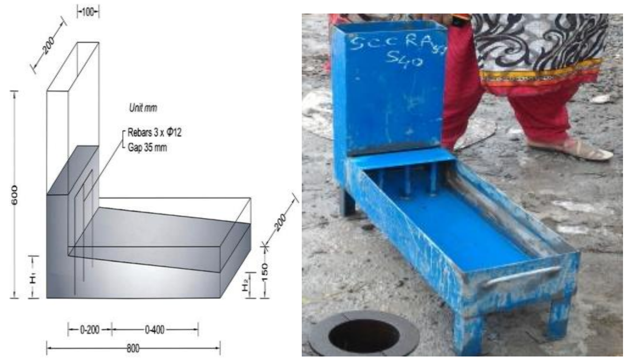

Fig 4: L-Box Apparatus

6. RESULT AND DISCUSSIONS:

Flow characteristics:

The slump flow value of various mixes incorporating GGBS and SF with 0%, 50% and 100% of RA are shown in the Fig 5, 6 and 7 respectively. It is evident from these figures that the slump flow increases with increasing the quantity of mineral admixture. The flow values of all the mixes increased for 0%, 50% and 100% of RA, respectively. The values of all the mixtures obtained are within the range specified in EFNARC guidelines. At the higher level replacement of cement by GGBS and SF contents increase the slump flow due to improved packing offered -and improve the filling ability of concrete. The paste volume of all the mixes is maintained constant. Obviously, the paste volume per unit aggregate content became higher, thus reducing the friction between recycled aggregate particles. As a result, the dispersion of the aggregates increased leading to a greater slump flow. The SSD conditions of RA are also had effect in the increase of slump flow, for all SCC mixes. Whereas SSD condition of RA attributed to increase in the free water content in the SCC mix during mixing. The result shows that the maximum percentage increase in slump flow of the mix is noted at 100% RA replacements, which is 40% and 60% for GGBFS mix, 15% for SF mix, when compared with control mix. Therefore, it is clear that the SCCRA with GGBS and SF show better flowability. At the time of testing, it was clearly noted that the addition of GGBS and SF helps in stability of mix without segregation even at higher RA replacements.

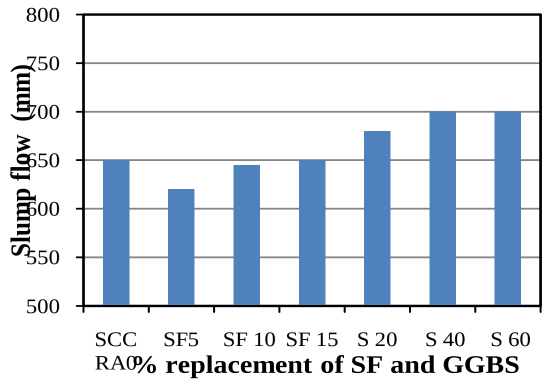

Fig 5: Effect of SF and GGBS on the slump flow values of SCC with 0% RA

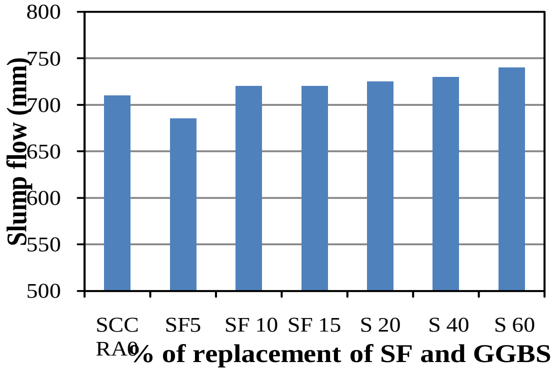

Fig 6: Effect of GGBS and SF on the slump flow values of SCC with 50% RA

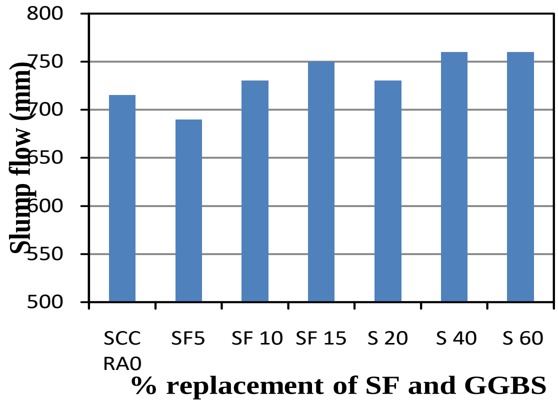

Fig7: Effect of SF and GGBS on the slump values of SCC with 100% RA

T-500 Slump flow:

The T-500 values of SCC mixtures with all the replacement of RA are shown in Fig 8-10. T-500 represents the test of mixture viscosity. Shorter time of T- 500 indicates the better flow capacity, but lower viscosity. As seen in Fig 8-10, T-500 values varied from 2.45 to 2.95s for 0% of RA mixtures and it's varied from 1.86 to 2.83s for 50% of RA mixtures. It shows the RA-SCC had a higher flowability than the control concrete and the difference increased with the increase of recycled aggregate content. According to EFNARC specifications and guidelines, the T-500 slump flow time of SCC generally ranges from 2 to 5 s. Hence, the T-500 slump flow times were within the acceptable range. This is mostly due to the increased content of powder and SSD condition of RA. However, the role of recycled aggregate content in reducing T-500 slump flow time was also predominant at 50% and 100% RCA. As a result, the SCC mixes with 50% and 100% RCA provided a lower T-500 slump flow time.

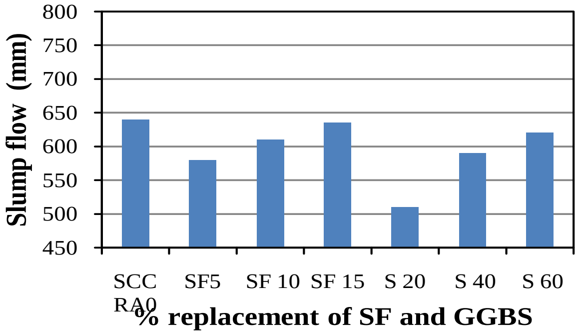

Fig 8: Effect of SF and GGBS on the slump flow values of SCC with 0% RA

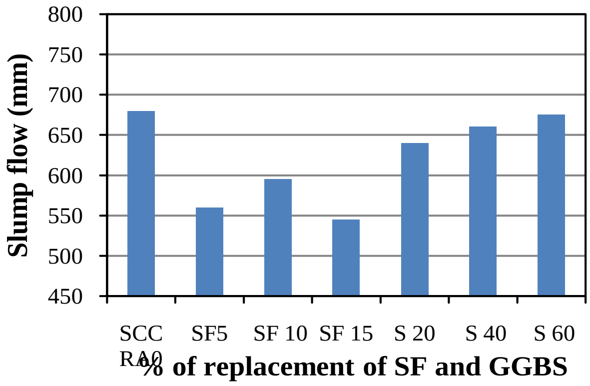

Fig 9: Effect of GGBS and SF on the slump flow values of SCC with 50% RA

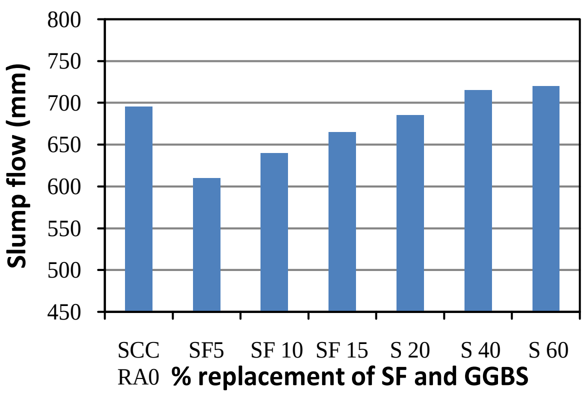

Fig 10: Effect of SF and GGBS on the slump values of SCC with 100% RA

J ring slump flow:

The slump flow values of J-ring are shown in the Fig 11-13. Flow ranges between 510 to 720mm, which is considered acceptable as per EFNARC and indicates a stable mix with good passing ability. In all series I and III having increase in slump value through the J ring in almost all the replacement of GGBS and SF. But in the Series II, there is some effect on the flow values which mainly attributed to the friction between NA and RA even at increasing replacement of admixtures. This is also considered to be acceptable and indicates satisfactory mix stability and segregation resistance for flow through reinforcement.

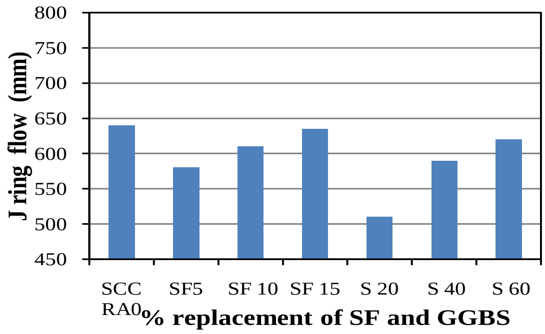

Fig 11: Effect of SF and GGBS on the J ring flow values of SCC with 0% RA

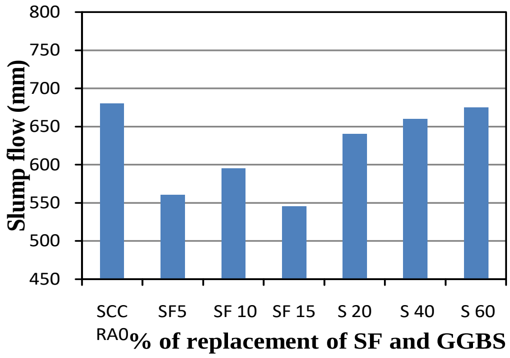

Fig 12: Effect of GGBS and SF on the slump flow values of SCC with 50% RA

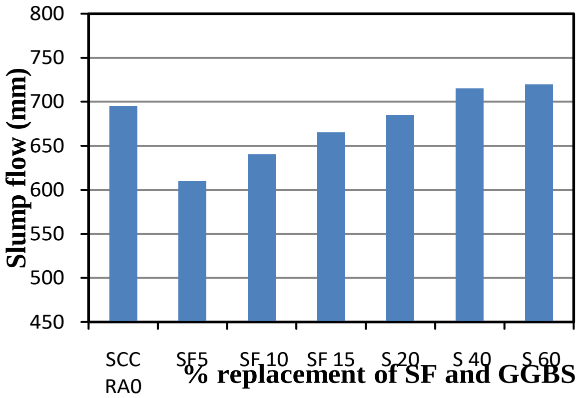

Fig 13: Effect of SF and GGBS on the slump values of SCC with 100% RA

7. V FUNNEL FLOW TIME:

The V-funnel times of different mixes are presented in Fig 14-16. From this, it can be seen that the V-funnel times for 0% RA, 50% of RA, and 100% of RA were in the range of 10–12.4 s, 7.6–10 s and 7.68–9.4 s, respectively. The highest V-funnel flow time of 13 s was measured for the control concrete. The V- funnel flow times of all mixtures satisfy this requirement of EFNARC guidelines. Incorporating GGBS, in SCC makes it highly flowable with decreased viscosity. But when SF is incorporated in SCC, it affects flow due to higher viscosity. Mineral admixtures influences the V funnel flow time of all the SCC mixes.

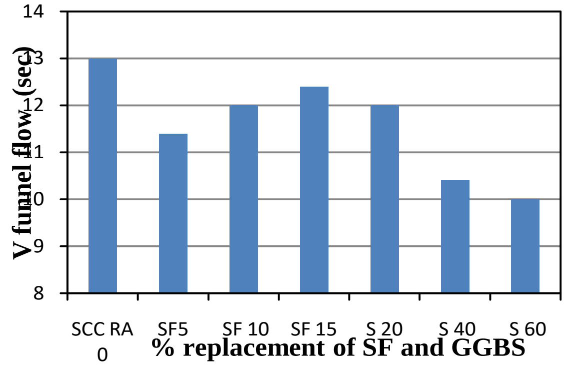

Fig 14: Effect of SF and GGBS on the V funnel flow of SCC with 0% RA

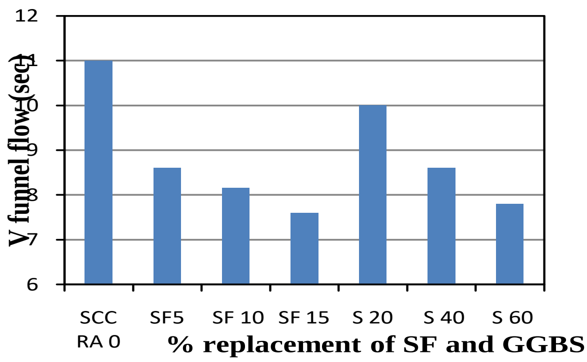

Fig 15: Effect of SF and GGBS on the V funnel flow of SCC with 50% RA

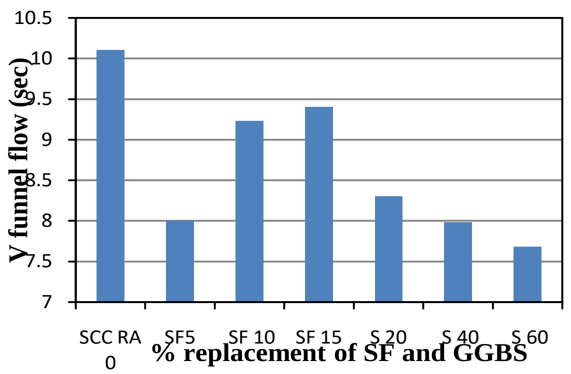

Fig 16: Effect of SF and GGBS on the V funnel flow of SCC with 100% RA

L box test:

The results from the L-box test are shown in the Fig.17 -19. The blocking ratio of SCC containing GGBS and SF changed from 0.8 to 0.98. All the SCC mixtures containing GGBS and SF shows satisfactory blocking ratio as per EFNARC recommendation. Also at the time of testing, the authors did not observe any tendency of blockage between reinforcement. Hence, it is revealed that all the mixes have good segregation resistance with good filling ability.

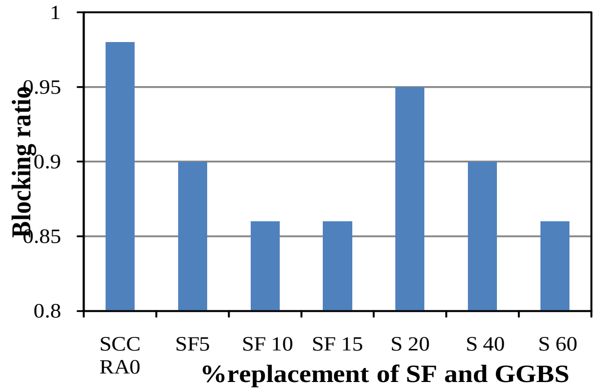

Fig 17: Effect of SF and GGBs on the blocking ratio of SCC with 0% RA

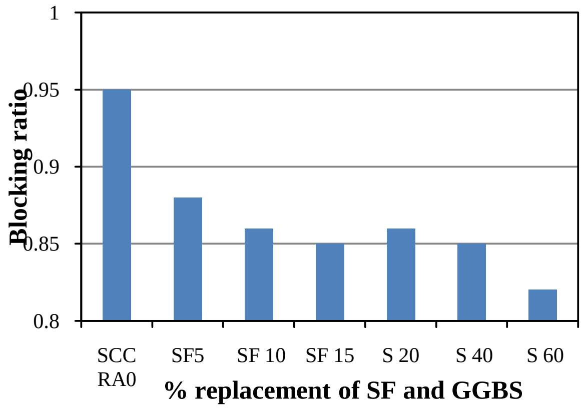

Fig 18: Effect of SF and GGBS on the blocking ratio of SCC with 50% RA

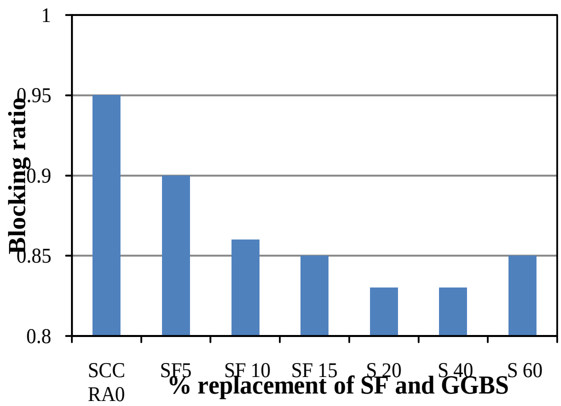

Fig 19: Effect of SF and GGBS on the blocking ration of SCC with 100% RA

CONCLUSION:

From the experimental study the following conclusions are made.

[1]. Fresh properties of SCC with incorporation 0%, 50% and 100% of RA are found to be good at every replacement level of mineral admixtures.

[2]. All mixes are achieving the fresh properties in accordance with EFNARC replacing the GGBS and SF in the lower and higher replacement level.

[3]. SCC shows the better flowability, passing ability and segregation resistance at 60% GGBS and 15% of SF.

[4]. GGBS and SF considerably reduce the cost of the SCC mixtures. And also these admixtures are used to improve the fresh property of RA in SCC. This may lead to the increase in usage of SCC with 100% RA.

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BIOGRAPHIES

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