EXPERIMENTAL STUDIES ON SCC WITH RECYCLED AGGREGATE AND FLY ASH

Revathi Purushothaman[1], Kavitha.P[2], Senthamilselvi.R[3]

[1]*Assistant Professor, Department of Civil Engineering, Pondicherry Engineering College, Pondicherry, India*
[2]*M.Tech Student, Department of Civil Engineering, Pondicherry Engineering College, Pondicherry, India*
[3]*A Research Scholar, Department of Civil Engineering, Pondicherry Engineering College, Pondicherry, India*

Abstract

Self-compacting concrete (SCC) is a new type of concrete which can be placed in every corner of formwork under its weight without any segregation. On the other hand, the cost of SCC is high due to its expensive ingredients such as mineral and chemical admixtures and cement. Hence, with the aim of reducing the production cost of SCC ,without sacrificing on its strength and durability performances, the authors have attempted to produce by SCC incorporating the waste materials such recycled aggregate (RA) and fly ash (FA). In this study RA as coase aggregate and FA are used, in the production of SCC in varying percentage replacements. The natural coarse aggregate (NA) are replaced at 0, 50, and 100% by volume replacements of RA .FA are used in proportions of 0, 20, 40 and 60 % by volume of cement. The experimental program of the study consisted of twelve concrete mixes which reflect the key variables and their effects on the fresh and mechanical properties of the produced SCC. The test results for acceptance characteristics of SCC such as slump flow, J-Ring , V-funnel and L-Box are presented. Further, the compressive strength at the ages of 7, 28 and 56 days was also determined and results are presented. The obtained results in all of the studied mixes indicate that the performance of SCC produced with RA and FA are comparable with that produced with natural aggregate. It is also found that the strength variations are within 10% for SCC produced with RA.

Keywords: *Self compacting concrete, Recycled aggregate, Fly ash, Natural aggregate, Fresh properties, and Compressive strength.*

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1. INTRODUCTION

Concrete is an excellent construction material around the world. Various types of concrete have been developed to meet current demands and requirements in the construction field. The problem occurs when more quantity of reinforcement placed in the reinforced concrete (RC) member, it is difficult to ensure that the formwork gets completely filled with concrete, that is fully compacted without voids or honey combs

Compaction by manual or by mechanical vibrators is exceptionally troublesome in this circumstance. The common strategy for compaction, vibration, creates delays and extra cost in the tasks. Underwater concreting always require fresh concrete, which could be put without the need to compaction; in such conditions vibration had been basically impossible. This issue can now be solved with self-compacting concrete (SCC).SCC differs from conventional vibrated concrete by its rate of flow in fresh state. The use of SCC has many advantages than vibrated conventional concrete in terms of economic, social and environmental benefits. On the other hand our natural resources are diminishing day by day. So usage of an innovative waste material has tremendous significance.So by using RA from waste generated in construction industry, it serves as an excellent solution to our problems. Some of this concrete waste is utilized as backfill material, and much being sent to landfills. Recycling concrete by using it as replacement to new aggregate in concrete could decrease concrete waste and conserve natural sources of aggregate. This has encouraged the use of recycled concrete as aggregate in concrete production.

The ordinary high substance of portland cement in SCC is one of the primary difficulties in optimization of its mixture proportions. This high cement consumption increases the production cost of SCC and, considering the large amount of carbon di oxide emitted during portland cement production, is also undesirable from a natural perspective. Considering this aspect, there has been a growing emphasis on the utilization of waste materials and byproducts in construction activities.

2. REVIEW OF LITERATURE

Many authors have studied the rheological properties, mechanical properties,durability properties and cost effective of recycled aggregate concrete (RAC) and compared it with that of natural aggregate concrete (NAC). Tam [1] investigated the economic considerations in recycling concrete waste and concluded that application of recycled aggregate in the construction industry helps in saving the environment. The researchers have reviewed many studies it was found that the RA specific gravity decrease and water absorption increase than NA. The main reason for this is existence of loose paste in the demolished wastes. Due to the adhered mortar to the aggregates the water absorption increases substantially for the RAC.

Parekh and Modhera [2], Tangchirapat et al [3], Yong and Teo [4] have reported that the fresh properties of RAC and have concluded that the RA drastically lowers the workability of RAC. It is also an evident point that water absorption of RA is higher than NA. Even then, the required workability can be achieved by using various admixtures.

Sonawane and Pimplikar,[6] reported that the RA specific gravity is less than 2.4,it may cause segregation and honeycombing and also yield of concrete may get reduced. Parekh and Modhera [2],Arjun and Gowda [14], Neil and Kang [8] and Deshpandeet al, [9] concluded that RCA had 9 to 11% lower density. Attached cement mortar and voids in that are the basic reason behind such behavior

Tangchirapat et al, [3],Poon et al, [10] and Kim et al, [11] reported that use of higher ratio of RCA yields better flowablitiy of fresh concrete, and the use of FA increase the flow ability of concrete. Khafaga [22] ,Safiuddin et al , [23] showed that RA can be used in SCC as a replacement of NA up to 50% by weight without affecting the fresh properties of SCC.The physical characteristics of RA such as surface roughness, angularity and surface porosity were not conducive to develop the fresh properties of SCC. These physical properties can act adversely to decrease the fresh properties of SCC at a higher content of RCA. Also, these properties may contribute to cause non-uniform distribution of coarse aggregates, thus developing the heterogeneity leading to segregation in concrete, particularly at a higher RCA content.

Saravanakumaret al, [24] states that the greatest loss of 15% was seen that compressive strength in all the ages of RAC compared with NAC which is especially adequate in practice. Rao et al.[27] studied the compressive strength and durability of RA concrete and revealed that 25% of recycled coarse aggregate does not affect significantly the strength and durability of RAC. Etxeberria et al.,[12] used RA obtained by crushed concrete production and concluded that the young’s modulus of RAC was lower with respect to NAC.

Reddy et al, [25] reported that RA concrete failed to attain strengths same as that of natural concrete, but the inability is less than 10% but increasing with the grade of concrete. The RA concrete has higher strength gain when compared to NA, this was partially attributed to the use of admixtures like FA and silica fume, hence RA concretes are better when coupled with mineral admixtures.Salomon et al, [28] reported that the Concrete made with RA (20%, 50%, and 100% replacement) from old concrete can achieve the same fresh workability,compressive strength of concrete made by NA in the range of 20–40 MPa at 28 days.

Kim et al, [11] Uysal and Sumer [26] reported that when the replacement of mineral admixture increased as the strength loss decreased, the strength loss of FA 35%, was about 6.91%, compared to 10.34% for the FA 15 % specimen. FA increased the compressive strength of concrete at later age. Replacing 25% of PC with FA resulted in strength of more than 105 MPa at 400 days.

3. EXPERIMENTAL INVESTIGATION

3.1 Materials and their Properties

3.1.1 Cement

Ordinary portland cement of 43 grade was used for the present study. The physical properties of the cement were tested in accordance with IS: 4031(1988) and the test results are given in the Table 1

Table 1 Physical properties of cement

Physical properties	Test results
Specific gravity	3.14
Standard consistency (%)	28
Initial setting time (mins.)	135
Final setting time (mins.)	415

3.1.2 Fly Ash

Fly ash obtained from Ennore Thermal power plant, falling in the category of class F grade has been used for entire experimental work. The physical properties of FA is presented in the Table 2

Table 2 Physical properties of fly ash

Physical properties	Test results
Specific gravity	2.05
Fineness,Percentage passing on 150 micron sieve (%)	99.6
Fineness,Percentage passing on 90 micron sieve (%)	98.1

3.1.3 Aggregates

Locally accessible river sand passing through 4.75mm belongs to Zone I conforming to IS: 383-1970 was used as fine aggregate. Crushed granite stone was used as coarse aggregate for experiment work. The Crushed concrete obtained from Pondicherry Engineering college laboratory were collected and crushed manually and mechanically. The crushed specimen was used as recycled aggregate. The NA and RA passing through 16mm and retaining on 12.5mm and passing through 12.5mm and retaining on 4.75mm sieves were used for experimental work. The physical properties of NA and RA are presented in Table 3. The reported results are the average of three values obtained.

Table 3 Physical properties of coarse aggregate (Average)

S. No	Test Property	Natural Aggregate	Recycled Aggregate
1	Specific Gravity	2.73	2.27
2	Water Absorption (%)	0.7	7.79
3	BulkDensity (kg/m³)	1506	1210

3.1.4 Water and Admixture

Potable drinking water with pH value ranging between 6 to 7 was used for mixing and curing of concrete .Super-plasticizer (SP) is generally added to increase the flow with reduced water content. Poly-carboxylic ether was used in this study.

3.2 Mix Proportioning

In this experiment twelve series of concrete mixes were made.were produced adopting Particle Packing methoddue to Nanthagopalan and Santhanam [22],In each mix NA was replaced with RA in the ratio of 0%, 50 %, and 100% by volume.

After the initial mix design, the trial mixes were prepared and tested for the fresh properties of SCC as per EFNARC guidelines. In order to account for the effect of higher water absorption of RA, all the aggregates were immersed in water for 24 hours and surface dried before use. The composition of designed mixtures is shown in Table 5

Table 4 Experimental Scheme

Fly Ash (%)	Recycled Coarse Aggregates (%)		
	0	50	100
0	SCC 0,0	SCC 50,0	SCC 100,0
20	SCC 0,20	SCC 50,20	SCC 100,20
40	SCC 0,40	SCC 50,40	SCC 100,40
60	SCC 0,60	SCC 50,60	SCC 100,60

3.3 Casting and Curing of Test Specimens

From each mix sufficient number of 100 mm cubes were cast for the determination of compressive strength test at 7,28 and 56 days. All the specimens were removed from the mould after 24 hours. The de-moulded specimens were placed in water for curing until the age of testing.

3.4 Testing of Concrete Mixes

3.4.1 Fresh Properties of SCC

Self-compacting concrete is characterized by its flowing ability, passing ability, filling ability and segregation resistance. For any concrete to be characterized as self compacting it should possess the above mentioned characteristics. In this study, the following test methods as suggested by EFNARC are used.

The test include Slump flow, T50cm, V funnel, J-Ring and L-Box. In this experiment the flowability of SCC is tested by Slump flow , T50cm and V-funnel. The passing ability is checked by J-Ring and L-box. The Segregation resistance is tested by V-funnel T5mins.

Table 5 Mix proportion of various SCC mixes

SCC MIXES	Cement (kg/m³)	FA (kg/m³)	Fine Aggregate (kg/m³)	NA (kg/m³)		RA (kg/m³)		Water content (kg/m³)	SP Dosage (kg/m³)
				16mm	12.5mm	16mm	12.5mm		
SCC 0,0	560	-	788	495	325	-	-	196	5.60
SCC 0,20	448	73	788	495	325	-	-	196	4.53
SCC 0,40	336	146	788	495	325	-	-	196	4.19
SCC 0,60	224	219	788	495	325	-	-	196	3.85
SCC 50,0	560	-	788	247	163	222	147	196	5.60
SCC 50,20	448	73	788	247	163	222	147	196	4.53
SCC 50,40	336	146	788	247	163	222	147	196	4.19
SCC 50,60	224	219	788	247	163	222	147	196	3.85
SCC 100,0	560	-	788	-	-	444	294	196	5.60
SCC 100,20	448	73	788	-	-	444	294	196	4.53
SCC 100,40	336	146	788	-	-	444	294	196	4.19
SCC 100,60	224	219	788	-	-	444	294	196	3.85

4. TEST RESULTS AND DISCUSSION

4.1 Flow Properties of SCC

The test results of Slump flow, Slump T50cm, J-Ring,V-funnel ,V-funnel T5mins and L-box test of all the SCC mixtures are shown in Table 6.

The slump flow diameter was aimed to be maintained as per EFNARC guidelines in the range of 650-800 mm for all mixes. The effect of RA on the slump flow of SCC is evident from Fig.1, which shows that the slump flow diameter of the mix SCC 100,60 obtained was 740 mm and mix SCC 50,60 and SCC 100,60 was 730 mm. The larger slump flow diameter was obtained due to higher quantity of FA and RA.

The slump flow time T50 results of the concretes with different RCA percentages are given in Table 6. The T50 value for all the mixes with and without recycled aggregate ranged from 2.08 to 3.43 sec. As per EFNARC guidelines T50 interval between 2-5 seconds and minimum final flow of 650 mm is recommended for all engineering applications. The obtained values of T50 are within this acceptable range.

It is evident from Table 6 that the J-ring passing ability characteristics of all the mixtures satisfy the EFNARC requirements

Table 6 Fresh properties of various SCC mixtures

Mix	Slump		J-Ring		V-funnel		L-Box
	S (mm)	TS 50cm (sec)	SJ (mm)	TJ 50cm (sec)	T (sec)	T5min (sec)	
SCC 0,0	650	3.18	640	3.50	13.00	15.00	0.98
SCC 0, 20	680	3.11	600	3.00	12.50	14.39	0.94
SCC 0,40	670	3.43	670	2.49	10.00	13.00	0.93
SCC 0,60	690	2.08	690	2.30	10.10	13.04	0.86
SCC 50,0	710	2.38	680	2.40	11.00	14.40	0.96
SCC 50,20	725	2.26	695	2.75	9.49	14.34	0.92
SCC 50,40	700	2.30	675	2.28	10.12	14.00	0.89
SCC 50,60	730	2.48	690	2.27	9.80	14.10	0.82
SCC 100,0	715	2.36	695	2.65	10.10	13.40	0.94
SCC 100,20	725	2.48	700	2.10	9.40	14.00	0.90
SCC 100,40	730	2.21	710	2.39	8.45	13.40	0.86
SCC 100,60	740	2.17	720	2.2	6.54	9.08	0.73

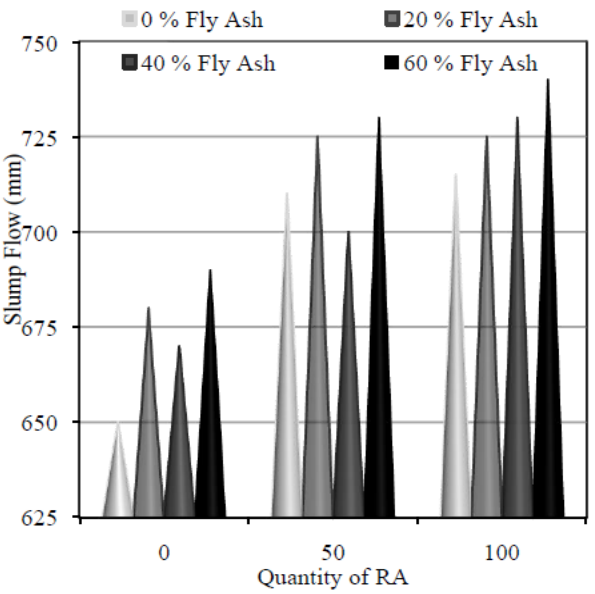

Fig 1. Slump flow of Various SCC mixtures (S)

It is observed from Table 6 the V-funnel flow times (T) are in the range of 6–13 sec. The V-funnel flow times are within the acceptable limits except for the mix SCC0,20. A high flow time can be caused either by a low flowing ability (filling ability/passing ability) or a blockage of the flow .On the other hand, of all concrete mixes passed V- funnel test after 5 minutes (T 5min). The results were not more than (T +3 seconds) and then they are compatible with the EFNARC limits. The effect of RA on V-funnel flow times (T) of SCC is shown in Fig. 2, which reveals that the passing time increase as the quantity of FA and RA increases.

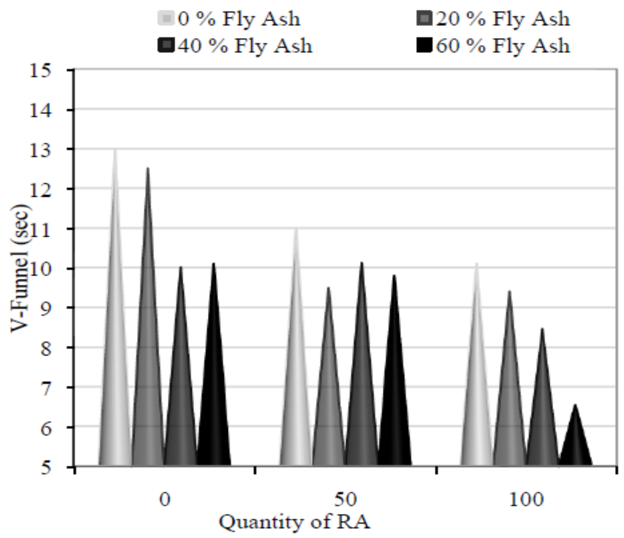

Fig 2 V-Funnel of Various SCC mixtures

From the Table 6 it is seen that the L-Box blocking ratio are in the range of 0.7–0.98.for all the mixes. The horizontal slump flow without any bleeding at the periphery which indicates good deformability and segregation resistance. Fig 3 shows that the passing time increase as the quantity of FA and RA increases.

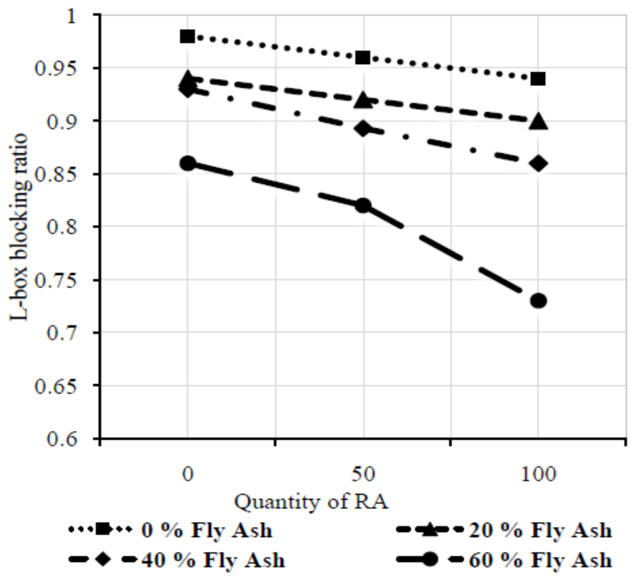

Fig 3. L-box of Various SCC mixtures

4.2 Compressive Strength of SCC

The compressive strength results of SCC for various mixes are given in Table 7

It is seen from, the Table 7 that the compressive strength of SCC mixes are reduced with increase RA content. However the reduction is only within 10% variation. This rate of reduction in compressive strength reduces at 56 days of age.

The similar trend is observed for all the mixes with constant quantity of FA .If the mixes are compared for various FA replacement ratios, it is seen that the compressive strength reduces with increase in FA content, for obvious reasons. However the results are encouraging for the use of RA in SCC upto 100% drastically affects the compressive strength

Table 7 Compressive strength of various SCC mixtures

Mix	Compressive Strength (MPa)		
	7 Days	28 Days	56 Days
SCC 0 ,0	38.54	51.25	65.70
SCC 0, 20	37.54	45.64	55.29
SCC 0,40	31.36	34.68	43.78
SCC 0,60	14.56	17.88	26.74
SCC 50,0	35.30	50.42	62.10
SCC 50,20	33.75	46.84	52.30
SCC 50,40	19.33	36.82	52.34
SCC 50,60	10.67	24.95	33.33
SCC 100,0	30.40	46.10	56.80
SCC 100,20	25.98	42.42	49.15
SCC 100,40	25.43	32.13	42.34
SCC 100,60	15.46	23.21	26.40

5. CONCULSION

The mineral admixtures improves significantly the workability properties of SCC. It is be seen that all SCC mixtures have remained in target range of EFNARC.The Slump flow is satisfied for all SCC Mixes even with 100% RA and 20% fly ash.

The higher ratio of RA generally resulted in the improved flowability of fresh concrete, and the use of FA better the flowability of concrete.

Hardened properties of concrete decreased as the percentage of RCA content increased due to presence of inferior mortar on RA.

Replacement of cement with 20-40% of FA in SCC satisfies and further higher replacement level drastically affects the compressive strength .

Based on the analysis of the test results it is seen that replacement of cement with fly ash decrease the strength even at 20%.Keeping the fresh and compressive strength properties it is proposed to limit the amount of FA and RA to 20% and 50 % respectively.

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BIOGRAPHIES

Dr.P.Revathi is presently Assistant professor in civil Engineering at Pondicherry Engineering College. She obtained her PhD in structural Engineering from IIT Madras in 2006.Her area of interest includes Reinforced concrete, Composite structures and Construction materials.

P.Kavitha is presently Design Engineer .She completed her Master degree in Advanced Construction Technology from Pondicherry Engineering College.She worked as a assistant Structural designer in the duration of 2011-2014.Her M.Tech project is SCC produced with Recycled aggregate and flyash.

R.Senthamilselvi had completed her UG and PG in the year 2007 and 2011respectively.She worked as Assistant professor in the duration of 2011-2013.Presently she is doing her doctoral programme in Civil Engineering department at Pondicherry Engineering College.