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Recycled Aggregate Self Compacting Concrete: A Sustainable Concrete for Structural use

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***Abstract*— Recycling of construction and demolition waste is a promising way towards sustainable construction. Coarse recycled concrete aggregates have been widely studied in recent years, and reported as a suitable alternative for natural coarse aggregates. However an extensive study of use of recycled aggregate in a new generation concretes is a relatively scarce field. Hence this study is a step forward which justifies and encourages the use of recycled aggregate in self compacting concrete to create a sustainable solution to warrant the problem of environment protection. In this paper the effect of coarse recycled concrete aggregates on the fresh and mechanical properties of self compacting concrete are investigated. The results are very encouraging and open a new spectrum for use of recycled aggregates in modern concretes.**

Keywords: Recycled aggregates, sustainable, self compacting concrete, fresh, mechanical)

I. INTRODUCTION

India has established itself as one of the world's fastest growing economies and this growth has brought with it a significant boost in construction activities. Currently construction sector in India is growing at the rate of 10% per annum [1]. With the increasing demand for build spaces and scarcity of land, a trend of redevelopment projects is up-coming which is contributing to more and more construction and demolition waste. Presently construction and demolition waste generation in India accounts up to 23.75 million tons annually and these figures are likely to double fold up to 2016 [2]. The management of C&D waste is a major concern for town planners due to the increasing amount of construction waste, continuing shortage of dumping sites, increase in transportation and disposal cost and above all growing concern about pollution and environmental deterioration. Among various C&D wastes, reuse of recycled concrete aggregate has opened a whole new range of possibilities for reusing materials in construction due to its great environment effect. Maximizing the amount of recycled materials among concrete components is a very effective and promising approach toward sustainable construction. In fact, aggregate represent almost 80% of concrete thus their replacement with recycled materials can really help to transform traditional concrete into a sustainable material.

According to an estimate the concrete industry consumes approximately 40% of the total worldwide construction aggregate production. However at present its use of recycled aggregates is marginal with possibly as few as 3% of all aggregates being from recycled sources. In last decade a significant volume of research in the area of recycled aggregate concrete and its possible application in the construction industry was performed. The use of RCA for concrete production is not simply applied because the properties of RCA are different from natural aggregates. Furthermore, the quality of RCA fluctuates when collected from different sources. In physical terms, distinctive differences are observed between the properties of RCA since it not only consist of original aggregates, but also comprise of the remains of mortar (cement paste) adhering to the aggregate surfaces. The presence of mortars remain in the RCA is a main reason for deteriorated RCA quality as compared to natural aggregates [3,4] because adhered mortar is characterized as porous [5-7] and presents numerous micro cracks. As a result, RCA are characterized as having lower density, higher water absorption, and lower mechanical strength than the natural aggregates [8-11]. Consequently, when using RCA in production of new concrete, these characteristics of the aggregate may have adverse effect on interfacial bond between RCA and cement paste. But considering the use of recycled aggregates could reduce the dependence of the construction industry on natural aggregates, and thus, maintain aggregate security and still ensure sustainable development their use in concrete is negotiable.

Self compacting concrete (SCC) is considered as one of the most revolutionary development in high performance concretes in the recent decades. SCC is known for its exceptional performance and uniformity, which outperform the qualities of conventional concrete. It was developed by Okamura and associates [12] in Japan during 1988 and considered as a highly workable concrete that can flow through densely reinforced and complex structural elements and adequately fill all voids without segregation, excessive bleeding and the need for vibration or other mechanical consolidation [13-14]. The reported study was undertaken to examine the effect of coarse RCA on fresh and mechanical performance of in self compacting concrete. The use of RCA in the SCC is a relatively new research area on which a very limited scientific research has been carried out. This study discusses the experimental results of performance of recycled aggregates in self compacting concrete.

II. MATERIALS

A. Cement

An ordinary Portland cement (Grade 53) conforming to IS12269:1987[15] was used as the main binder for the experimental investigation. Its specific gravity, specific surface area and 28 days compressive strength were 3.18, 380 m²/kg, and 56.5 MPa respectively.

B. Fine Aggregate

Clean river sand obtained from a local river conforming to zone II of IS 383:1970[16] was used in the present investigation. The physical properties such as specific gravity, bulk density, water absorption and fineness modulus were investigated and found to be 2.63, 1380 kg/m^3, 0.8% and 2.36 respectively.

C. Coarse Aggregates

In this study, natural coarse aggregates used were crushed basalt obtained from a local quarry of specific gravity 2.65 and bulk density 1614 kg/m^3. The recycled aggregates were obtained from demolished cubes tested in concrete technology laboratory of specific gravity 2.19 and bulk density 1356 kg/m^3 respectively. the water absorption of natural aggregate was 1.31% whereas for recycled aggregate it was found to be 5.96%. The maximum size of aggregate was limited to 16 mm.

D. Silica fume

Due to the fresh property requirements of SCC, inert and pozzolanic/ hydraulic additions are commonly used to improve and maintain the cohesion and segregation resistance. In this investigation silica fume is used as an additional powder material for SCC obtained from Elkem. The specific gravity and bulk density of silica fume is 2.3 and 680 kg/m^3 respectively.

E. Superplasticizer

The superplasticizer used was a polycarboxylic-ether polymer based admixture, commercially branded as Auramix 400 obtained from Fosroc chemicals.

III. MIX DESIGN AND SPECIMEN PREPARATION

Concrete mix proportioning is governed by the properties required in the fresh as well as in the hardened state. Design of SCC mixes involves determination of the proportion of the constituents, cementitious materials (cement and silica fume), coarse and fine aggregates, water and chemical admixtures (superplasticizer), so that resultant composition produces a mix which will possess specified properties in fresh and hardened state. SCC should be designed in such a way that it has high fluidity, least or no segregation, and low risk of blocking. Generally SCC has high cement paste volume, low coarse aggregate and water content, and a proper dosage of superplasticizer. There is no standard method for SCC mix design and many academic institutions, admixture, ready-mixed, precast and contracting companies have developed their own mix proportioning methods [17].

For the purpose of the experiment six types of concrete mixes were made. In each mix natural coarse aggregate was replaced by recycled coarse aggregate in the ratio of 0%, 20 %, 40%, 60%, 80% and 100% by volume. The preliminary mix design was carried out using Nan-Su method[18] for target strength of 40 MPa. After the initial mix design, the trial mixes were prepared and tested for the fresh properties of SCC as per EFNARC guidelines [17]. The quantity of components required for making 1 m^3 of concrete was constant, with the exception of small variations in the quantity of superplasticizer for the purpose of achieving equal consistency for all the mixes and due to slightly higher water absorption by the recycled aggregate. To counteract the effect of higher water absorption of recycled aggregate, all the aggregates were immersed in water for 24 hours and surface dried before use. The composition of designed mixtures has been shown in table 1. The mixes were prepared in the laboratory using a pan mixer of 100 litre capacity and specimens were cast and cured in water up to the age of testing. The mixes were designated as a combintion of two numbers separated by an alphabet R for recycled aggregate. the first number represent the strength of concrete followed by R and a number which represent the percentage of recycled aggregate in concrete.

IV. TEST METHODS

The entire test program was divided into two parts. Testing of fresh properties of SCC followed by its Strength investigations.

A. Fresh State Properties

Self- Compacting Concrete is characterized by filling ability, passing ability, flowing ability and resistance to segregation. Different methods have been developed to characterize the properties of SCC. No single method has been found till date, which characterizes all the relevant workability aspects and hence, each mix was tested by more than one test method for the different workability parameters. In this investigation the fresh state properties of SCC were tested by following methods as suggested by EFNARC. Slump flow test and T50 slump flow for flowing ability and viscosity, L-box test for passing ability and V-funnel test for knowing the filling ability of concrete mixes. Table 2 gives the recommended values for different tests given by EFNARC for mix to be characterized as SCC.

Table 1. Details of mixes for $1m^3$ concrete

Mix Type	Cement, Kg	Coarse Aggregate, Kg		Fine Aggregate, Kg	Silica Fume, Kg	Water Kg	Dose of SP, Kg
		Normal	Recycled				
40R0	380	805	0	990	135	191	6.2
40R20	380	644	133	990	135	191	6.2
40R40	380	483	266	990	135	191	6.2
40R60	380	322	399	990	135	191	6.2
40R80	380	161	532	990	135	191	6.9
40R100	380	0	666	990	135	191	6.9

Table 2. Typical ranges of values for different tests for SCC

Sr. No.	Method	Unit	Typical range of values	
			Minimum	Maximum
1	Slump Flow	mm	650	800
2	T_{500} slump flow	Sec	2	5
3	V-Funnel	Sec	6	12
4	L-box	(h2/h1)	0.8	1.0

B. Strength properties

The hardened SCC mixes were tested for compressive, flexural and splitting tensile strengths. The compressive strength test was performed using compression testing machine of 3000 kN capacity at the age of 3, 7, 28 and 90 days as per IS516-1959 [19]. The specimen of 100 x 100 x 100 mm size was adopted for the test. The flexural and tensile strength were measured at 28 days according to IS516 and IS5816-1959 [20] respectively. The details of size, number of specimens and test methods are presented in table 3.

V. RESULTS AND DISCUSSIONS

A. Fresh State Properties

Results obtained by fresh concrete testing are displayed in Table 4. Slump flow test used to examine flowability property of SCC. All mixes exhibited slump flow in the range of 640-720 mm which ranks all the designed mixtures in the SF1 and SF2 class as per EFNARC guidelines[21] which is the most common class in general civil engineering usage and practice. The T_{500} slump flow is the time for which concrete reaches the diameter of 50 cm and it was measured during execution of slump flow test. It represents the viscosity of mixture. All the mixes recorded the T_{500} time between 2.51 sec to 3.45 seconds which belong to VS2 class. As per EFNARC specification V-funnel time ranging from 6 to 12 seconds is considered adequate. The test results of V-funnel test for all mixes meet the requirement of flow time for VF1 class which is an indication of good filling ability even with congested reinforcement. The L-box test examined another key property – passing ability. All the mixes meet the criterion that the ration of heights of concrete at the ends of L-box is no less than 0.8, and as the test was conducted with three rebars they were ranked to the PA2 class which is suitable for densely reinforced structures. All the mixes showed horizontal slump flow without any bleeding at the periphery which indicates good deformability and segregation resistance. Hence from the results of fresh properties of SCC, it is clear that the coarse recycled aggregates have a neglisible effect on the rheological properties of the self compacting concrete.

Table 4. Results of fresh state properties of SCC

Mix Type	Slump Flow, mm	T_{500} Slump Flow, sec	V Funnel, Sec	L - Box	Segregation Resistance %
40R0	680	2.87	6.32	0.90	10.15
40R20	645	3.45	7.08	0.85	11.20
40R40	670	3.08	6.71	0.92	9.88
40R60	640	3.41	7.41	0.87	11.65
40R80	720	2.51	5.16	0.95	10.04
40R100	650	3.1	6.71	0.90	12.35

B. Strength Investigations

1) Compressive stength

The result of the variation of compressive strength of concrete with respect to age of concrete for different percentages of recycled aggregate is shown in Figure 1. It is observed that all the mixes acheived the target strength of 40 MPa. Among all of the specimens, the mix containing only natural coarse aggregates achieves the highest strength, followed by mixes containing 20%, 40%, 60%, 80% and 100% levels of the RCA replacement. The results indicate a decreasing trend in the compressive strength towards the high level of the RCA content. The inverse relationship between the RCA content and compressive strength is due to the poor quality of the adhered mortar which has undergone the crushing process and which has created the zones of weakness in the concrete. At the age of 28 days, the percentage reduction in compressive strength was observed to be 5.05% and 7.06% for 20% and 40% replacement of natural aggregate by recycled aggregate. This reduction in strength goes up to 9.25%, 9.63% and 10.06% respectively for 60%, 80% and 100% replacement levels compared with concrete having only natural coarse aggregates. Since the maximum reduction in compressive stregth is just around 10%. It is very encouraging sign to promote the use of RCA in structural concrete.

Table 3. Details of strength test program

Property	Age at test, days	Size of specimen in mm	Test Method
Compressive strength	3, 7, 28, 90	100 x 100 x 100	IS 516-1959
Split Tension Test	28	300 diameter &150 Height	IS 5816-1999
Flexure test	28	100 x 100 x 500	IS 516-1959

Table 5. Results of strength investigations

Mix Type	Compressive Strength, N/mm^2				Tensile Strength, N/mm^2	Flexural Strength, N/mm^2
	3 days	7 days	28 days	90 days	28 days	28 days
40R0	25.72	35.87	46.69	54.60	5.97	9.28
40R20	25.40	33.66	44.33	51.92	5.8	8.82
40R40	25.15	34.66	43.39	50.55	5.48	8.35
40R60	23.78	30.67	42.37	48.88	5.16	7.78
40R80	23.17	30.83	42.19	47.80	4.95	7.56
40R100	20.17	28.67	41.99	47.63	4.86	7.32

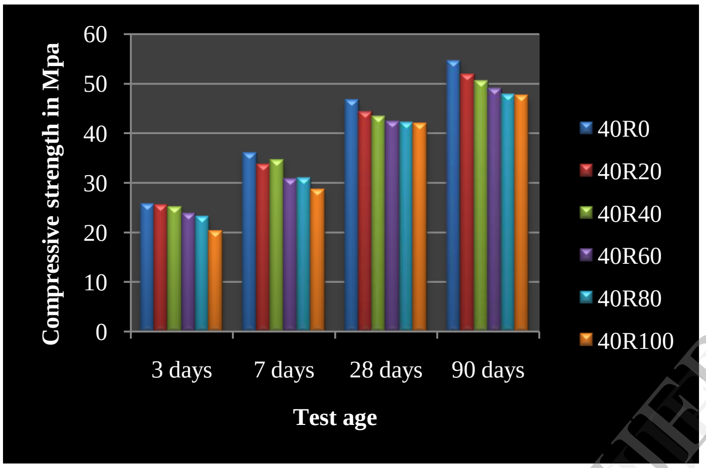

Figure 1 Age of test Vs Compressive strength for each series

2) Split tensile strength

The splitting tensile strengths of the concrete cured in water at the age up to 28 days are shown in figure 2. The results show that the variation in splitting tensile strength with recycled aggregate content was similar to that observed for compressive strength. The splitting tensile strength decreased with increase in recycled aggregate. However as compared with compressive strength the reduction in tensile strength is more at all replacement levels except at 20% replacement of NA by RA. At 28 days, the reduction in splitting tensile strength was recorded as 2.8%, 8.2%, 13.5%, 17.1% and 18.6% respectively with increasing RCA. Visual examination of crushed test specimens was carried out to assess the failure mode of recycled concrete specimens. Regarding the RCA failure pattern, aggregate splitting was evident in most RCA mixes. Figure 3 indicates the correlation between the 28 days compressive strength and a split tensile strength for all replacement levels. The correlation holds well between the two strengths with R^2 value above 0.86.

3) Flexural strength

The results of flexural strength are tabulated in table5 and shown in figure 4. The influence of RCA was clearly seen in the flexural strength results. The results are on the same trend as that of the compressive and split tensile strength results. As the replacement of NCA by RCA increased the flexural strength decreased. The reduction in flexural strength at 28 days was recorded to be 4.95%, 10.02%, 16.16%, 18.53% and 21.12% respectively. Figure 5 shows the corelation between Compressive strength and flexural strength. From the figure, it is evident that the R^2 value for the corelation is above 0.90 indicating better relationship between the two strength as compared with the corelation between compressive strength and tensile strength.

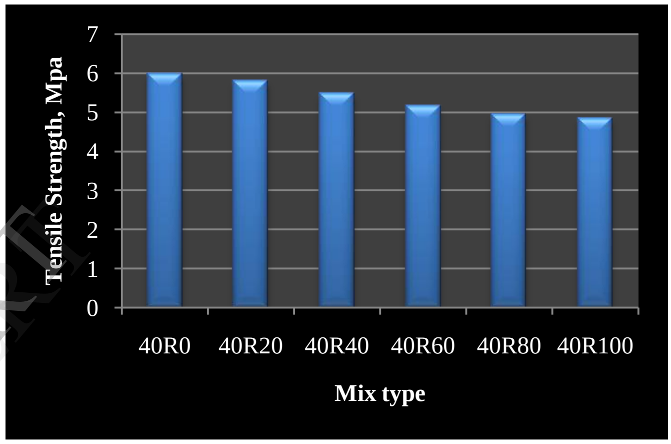

Figure 2 Result of split tensile strength

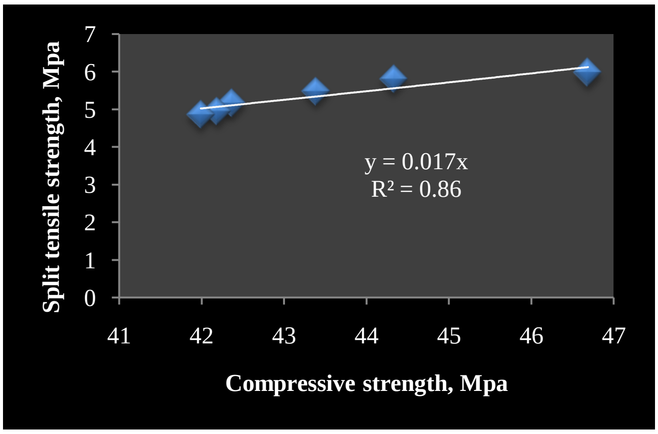

Figure 3 Compressive strength Vs tensile strength

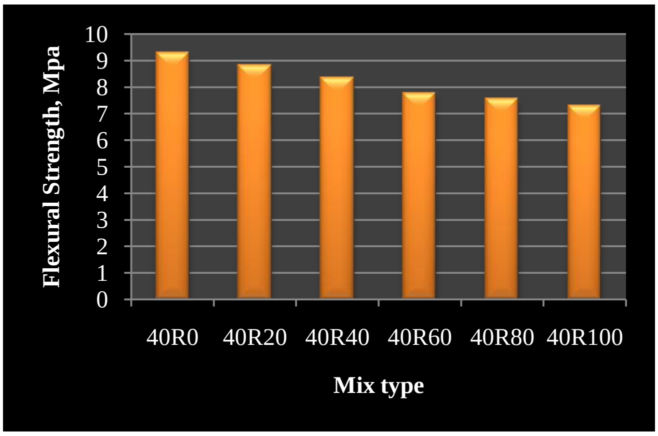

Figure 4. Result of flexural strength

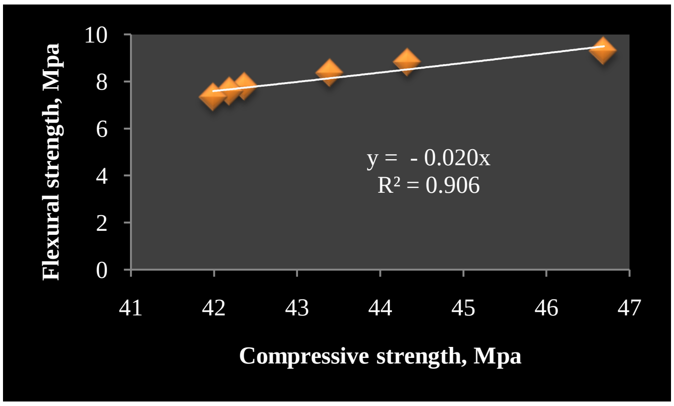

Figure 5 Compressive strength Vs Flexural strength

VI. Conclusions

From the experimental investigation following conclusions are drawn

1) There is a significant scope for utilization of recycled aggregate as an appropriate and green solution for sustainable development in construction industry.

2) There is a neglisible effect of incorporation of recycled aggregate on fresh properties of self compacting concrete.

3) The effect of recycled coarse aggregate on the compressive strength of concrete is evident from the results. However the loss in strength was not considerable which is an encouraging sign to promote the use of recycled aggregates in structural concrete.

4) The split tensile strength and flexural strength showed decreasing trend with increasing recycled aggregates. This may be due to weak interfacial transition zone in recycled coarse aggregate.

5) There is a need to investigate the effect of recycled aggregates on the durability properties of self comapacting concrete.

REFERENCES

[1] Anagal Vaishali, Nagarkar Geeta, Atnurkar Kanchan & Patel Anisha, Construction and demolition waste – A case study of Pune, Twenty-Eight National Convention Of Civil Engineers on Role of Infrastructure for Sustainable Development, organized by The Institution of Engineers (India), Roorkee, October 12-14, 2012.

[2] Job Thomas, Wilson P. M., Construction waste management in India, American Journal of Engineering Research, Volume-2, pp-06-09, 2013.

[3] Rao A, Jha KN, Misra S. Use of aggregates from recycled construction and demolition waste in concrete, Resource Conservation & Recycling, 50(1), pp.71–81, 2007.

[4] Abbas A, Fathifazl G, Fournier B, Isgor OB, Zavadil R, Razaqpur AG, Quantification of the residual mortar content in recycled concrete aggregates by image analysis, Material Characteristics, 60(7), pp. 716–28, 2009.

[5] De Juan MS and Gutiérrez PA, Study on the influence of attached mortar content on the properties of recycled concrete aggregate, Construction and Building Materials, 23(2), pp872–7, 2009.

[6] Padmini AK, Ramamurthy K, Mathews MS. Influence of parent concrete on the properties of recycled aggregate concrete. Construction and Building Materials, 23(2), pp829–36, 2009.

[7] Kou SC, Poon CS. Properties of concrete prepared with PVA-impregnated recycled concrete aggregates. Cement and Concrete Composites, 32(8), pp. 649–54, 2010.

[8] Tam VWY, Gao XF, Tam CM. Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach, Cement and Concrete Research,35(6), pp1195–203, 2005.

[9] Tam VWY, Le KN. Aggregate testing using 2nd-, 7th- and 10th-order interpolation polynomials, Resource Conservation & Recycling, 52(1), pp39–57, 2007.

[10] López-Gayarre F, Serna P, Domingo-Cabo A, Serrano-López MA, López-Colina C, Influence of recycled aggregate quality and proportioning criteria on recycled concrete properties. Waste Manage,29(12), pp3022–8, 2009.

[11] Chakradhara Rao M, Bhattacharyya S, Barai S. Influence of field recycled coarse aggregate on properties of concrete. Materials and Structures,44(1), pp205–20, 2011.

[12] Ozawa, K., Maekawa, K., Kunishima, H., and Okamura, H. Performance of concrete based on the durability design of concrete structures." Proc., 2nd East-Asia-Pacific Conf. on Structural Engineering and Construction, Vol. 1, Chiang Mai, Thailand, pp445–456, 2011.

[13] Khatib, J. M. ,Performance of self-compacting concrete containing fly ash." Constr. Build. Mater., 22(9), 1963–1971, 2008.

[14] Khayat, K.,Workability, testing, and performance of self consolidating concrete." ACI Mater. J., 96(3), 346–354, 1999.

[15] IS 12269:1987, Indian standard code of practice for specification for 53 grade ordinary Portland cement, (Reaffirmed 2004), Bureau of Indian Standards, New Delhi.

[16] IS 383:1970, Indian standard code of practice for specification for coarse and fine aggregates from natural sources for concrete, (Reaffirmed 2002), Bureau of Indian Standards, New Delhi.

[17] EFNARC (European Federation of national trade associations representing producers and applicators of specialist building products), Specification and Guidelines for self-compacting concrete, February 2002.

[18] Nan Su, Kung-Chung Hsu, His-Wen Chai, A simple mix design method for self compacting concrete, Cement and Concrete Research, 31, pp 1799-1807, 2001.

[19] IS 516:1959, Indian standard method of tests for strength of concrete, Reaffirmed 1999, Bureau of Indian Standards, New Delhi.

[20] IS 5816:1999 Indian standard method of tests splitting tensile strength of concrete, , Bureau of Indian Standards, New Delhi.

[21] EFNARC (European Federation of national trade associations representing producers and applicators of specialist building products), Specification and Guidelines for self-compacting concrete, 2005.