

# A Study on the Properties of Self Compacting Concrete using Recycled Aggregate in Fresh and Hardened State

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**Abstract**—Construction and Demolition waste management issues have attracted researchers around the world. The boom in construction sector and large-scale mechanization in concrete production has led to setting up of several ready-mixed-concrete (RMC) plants. The present study aimed at producing fine and coarse aggregates from the hardened concrete waste available at the RMC plant on the outskirts of Bangalore. The material characterization for both fine and coarse aggregates was carried out as per IS: 2386 (Part IV) – 1963. The test results have shown that the properties of recycled aggregates satisfy the codal provisions specified for natural aggregates. The M-20 self compacting concrete mix with 0%, 25%, 50%, 75% and 100% replacement of fine and coarse aggregates were done separately in two batches. Third batch mixes consists of both fine and coarse aggregates replacement of 0%, 25%, 50%, 75% and 100%. Further the fresh and hardened properties of M-20 self compacting concrete mix has been carried out systematically. It was observed that 50% replacements in all the three batches of M-20 concrete mix have exhibited satisfactory flow and compressive strength values.

**Keywords**— Recycled aggregates, RMC hardened concrete waste, river sand, self compacting concrete, partial-to-full replacement, workability, strength.

## I. INTRODUCTION

Concrete is the most widely used material in the world and due to the advancement in the technology the RMC (Ready Mixed Concrete) usage is increasing. Nowadays no civil engineering projects will be undertaken without RMC, thus influencing the construction sector in a big way. It also decreases site supervising, labour cost and project time, thereby resulting in savings, proper quality control and economy in the use of raw materials. At the same time it has been observed that huge volumes of RMC waste is being piled up in RMC yards as shown in Fig. 1.

RMC plants around the world are increasing day by day to accommodate to the increasing demands of the construction. But at the same time the wastage at every RMC plant is on the rise. Also the number of dumping sites is depleting. Due to this reason, these waste aggregates are used as recycled

aggregates to attain sustainability. The transformation of this waste into RA (Recycled Aggregates) is an important step in the development of a more sustainable environment. Using RA in concrete is an alternative to dumping it and also helps in the sustainability of natural aggregates reserves.

Recycling of concrete is very much necessary from the view point of environmental preservation and effective utilization of resources. The utilization of recycled aggregate in the concrete production is limited at present and large portion of concrete waste gets piled up at disposal sites. Using these RMC wastes in concrete is a challenging issue for engineers and many research works are still going on.



Fig. 1 Waste concrete dumped in RMC plant

Concrete is the most widely consumed construction material in the world. Placing of the conventional concrete requires skilled operatives using slow, heavy, noisy, expensive, energy-consuming and often dangerous mechanical vibration to ensure adequate compaction to obtain the full strength and durability of the hardened concrete. It was against this background that SCC (Self Compacting Concrete), which eliminates the need for compaction, was developed in Japan in late 1980s. The concept of SCC was proposed in 1986 by Professor Hajime Okamura, but the prototype was first developed in 1988 in Japan, by Professor Ozawa at the University of Tokyo. SCC is an innovative concrete, as the name itself signifies concrete that flow or pass and compact under its own weight without any vibration or compaction.

When a huge amount of heavy reinforcement is to be placed in a reinforced concrete member, it is difficult to ensure that the formwork gets entirely filled with concrete, i.e., fully compacted without voids or honeycombs. This can be solved by SCC, which flows like honey that can pass around obstructions and fill all the nooks and corner without the risk of segregation or honey combs, giving a very smooth surface finish.

Self – compacting concrete is a fluid mixture, which is proper for placing it in difficult conditions and also in packed reinforcements, without any vibration. The SCC must:

- Contain a fluidity that allows self – compaction without external vibration
- Maintain homogeneous in a structure during and after the placing process and
- Flow easily throughout reinforcement

The use of SCC is gradually becoming more popular in Canada and USA. Some of the departments of transportation are currently accepting SCC in mix design in some of their projects. On the other hand, since SCC is a relatively new concrete, its durability & mechanical properties are not completely understood. European countries recognized the significance and potentials of SCC developed in Japan. During 1989, they founded European federations of natural trade association representing producers and applicators specialists building products (EFNARC). The utilization of self compacting concrete started growing rapidly. Most of the information particularly mix design guidelines for SCC is taken from EFNARC for this project. The main objective of this project is to develop, evaluate and compare the fresh and mechanical properties of new types of SCC mixtures incorporating RA.

## II. OBJECTIVES

The main objective of present work is:-

- To determine the properties of RFA (Recycled Fine Aggregates) and RCA (Recycled Coarse Aggregates) obtained from RMC plant waste.
- To propose a mix design of M-20 SCC using particular proportions of RA.
- To determine the workability of self compacting concrete using chemical admixtures and recycled coarse and fine aggregates.
- To determine the compressive strength, tensile strength and flexural strength of SCC using RCA and RFA.

## III. METHODOLOGY

The study has been divided into two parts:-

- In the first part, the material characterization of the recycled aggregates as per Indian standards was conducted.
- In the second part, the suitability of RFA and RCA in M-20 self compacting concrete mix was investigated.

The hardened concrete wastes from RMC plant are brought to the laboratory and it is crushed and sieved. The aggregates characterization are done by conducting the following tests as per IS 2386 Part III: 1990 and IS 2386 Part IV: 1990 and the properties of the crushed unprocessed aggregates were found. The properties of Recycled Fine Aggregate and Recycled Coarse Aggregate along with the properties of natural fine and coarse aggregates are presented in Table 1 and Table 2

TABLE 1: Properties of RFA and Natural fine aggregates

Physical Properties	Properties of RFA	Properties of NFA
Specific gravity	2.502	2.63
Absorption (%)	4.49	0.73
Bulk density (kg/m <sup>3</sup> )	1723.76	1250-1690
Fineness Modulus	3.1	3.258

TABLE 2: Properties of RCA and Natural coarse aggregates

Physical Properties	Properties of RCA	Properties of NFA
Specific gravity	2.56	2.64
Absorption (%)	3.43	0.40
Bulk density (kg/m <sup>3</sup> )	1407.30	1468.0
Rodded density (kg/m <sup>3</sup> )	1579.60	1538.0
Fineness Modulus	3.102	3.34

Both the test results have shown that the properties of recycled aggregates satisfy the codal provisions specified for natural aggregates except that the water absorption of recycled aggregate (RA) was higher than the values for natural aggregates (NA).

The mix with OPC and fly ash are considered. Three batches of M-20 mix were prepared:-

- **Batch-1** mixes has OPC and natural coarse aggregates (NCA) as determined in the mix design. Only the fine aggregates were substituted with the recycled fine aggregates in proportions of 25%, 50%, 75% and 100% replacement for natural fine aggregates.
- **Batch-2**, OPC and natural fine aggregates are taken as per mix design. However the coarse aggregates were substituted with RCA in the range of 25%, 50%, 75% and 100% replacement to natural coarse aggregates.
- **Batch-3** comprised of OPC, recycled fine aggregates and recycled coarse aggregates in varying proportions of 25%-25%, 50%-50%, 75%-25% and

100%-100% replacement for natural fine and coarse aggregate.

The mix design for M-20 of self compacting concrete using the unprocessed crushed aggregates was done as per “The European specification and guidelines for self compacting concrete”.

As per mix design, the cement, water and the aggregates required for 1m<sup>3</sup> of concrete is as shown in Table 3:

TABLE-3: Mix Proportions

Cement (kg/m <sup>3</sup> )	Fly ash (kg/m <sup>3</sup> )	Coarse Agg. (kg/m <sup>3</sup> )	Sand (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )	Admixtu-re (Glenium 8630)
320	88	820	968	190	3.26



Fig. 2: Compressive strength test set up



Fig. 3: Concrete cubes (150X150X150mm); Cylinders (150X300mm); Prism (500X100X100mm)

#### IV. RESULTS AND DISCUSSIONS

##### A. Tests on Fresh Property

Table 4 represents the Fresh property of M-20 concrete mix i.e Slump flow values of Batch-1, Batch-2 and Batch-3. Batch-1 comprised of OPC, 0-100% replacement of natural Coarse aggregates (NCA) with RCA and natural coarse aggregates, whereas Batch-2 is a replacement of natural fine aggregates (NFA) with RFA and Batch-3 is a replacement of natural Fine and coarse aggregates with RFA & RCA and natural Fine & Coarse aggregate.

TABLE-4: Slump Flow Values of M-20 concrete mix

Batch mix	Replacements of NCA and NFA with RCA and RFA	Slump flow (mm)
B1-0	RCA- 0%	740
B1-1	RCA- 25%	690
B1-2	RCA- 50%	650
B1-3	RCA- 75%	630
B1-4	RCA- 100%	580
B2-1	RFA- 25%	700
B2-2	RFA- 50%	670
B2-3	RFA- 75%	645
B2-4	RFA- 100%	600
B3-0	RCA-0% & RFA-0%	740
B3-1	RCA-25% & RFA-25%	650
B3-2	RCA-50% & RFA-50%	610
B3-3	RCA-25% & RFA-75%	600
B3-4	RCA-75% & RFA-25%	560
B3-5	RCA-100% & RFA-100%	500

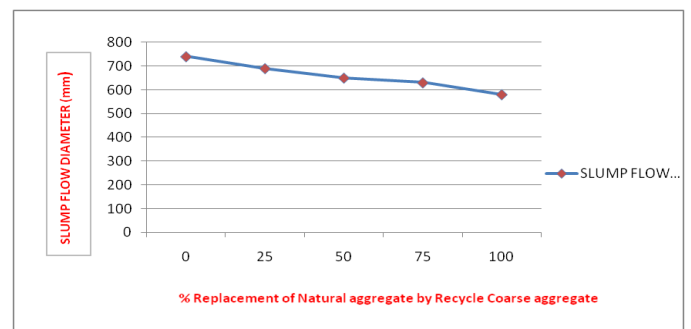


Fig. 4: Slump Flow values of Batch-1 mixes.

Fig. 4 presents the comparison of Fresh properties of M20 concrete mix with varying proportions of RCA. It can be observed that the slump flow diameter of B1-0 mix i.e NSCC (Normal Self Compacting Concrete) is 740mm, at 25% replacement is 690mm & it gradually decreases upto 580mm i.e for 100% replacement.

Same trend of values are observed in Batch-2 mix which is shown in Fig. 5 i.e with increase in the % of replacement of NFA by RFA the slump flow decreases from 740mm to 500mm.

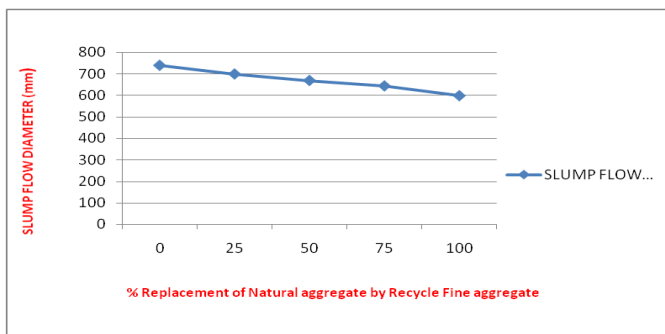


Fig. 5: Slump Flow values of Batch-2 mixes.

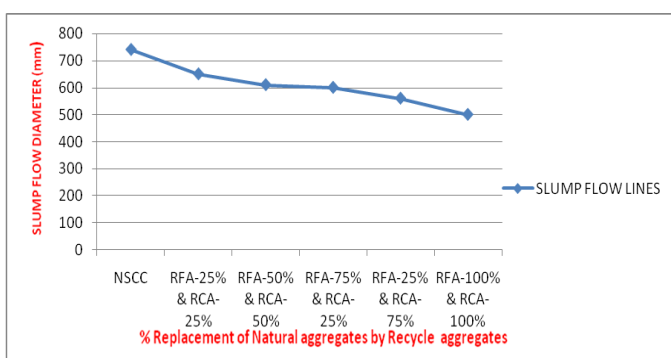


Fig. 6: Slump Flow values of Batch-3 mixes.

Fig. 6 presents the comparison of Fresh property of M20 concrete mix with varying proportions of RFA & RCA. It can be observed that the slump flow decreases from 740mm (0% replacement) to 500mm slump for 100% replacement.

From the above graph results, it is concluded that Batch-2 mix showed the good results than Batch-1 & Batch-3. Same pattern of results are observed in B-1 & B-2 whereas substantial decrease in values of flow are seen in batch-3 for higher replacements. This is mainly due to the reduction of the free water content in SCC mix due to the high water absorption of recycled aggregate. Also, the greater surface roughness and angularity of recycled aggregate enhance the friction between cement paste & coarse aggregates. These 2 effects are more prevailing for high percentages of recycled aggregate. Due to this, the SCC mixes with 75% and 100% recycled aggregate became more viscous and showed a lower slump flow values. This is attributed to decrease in the free water content in the Self Compacting Concrete mix due to the high absorption of water by recycled aggregates.

**B. Tests on Hardened property**

Table 5 represents the Hardened property of M-20 concrete mix i.e Compressive strength values of Batch-1, Batch-2 and Batch-3. Batch-1 comprised of OPC, 0-100% replacement of natural Coarse aggregates (NCA) with RCA and natural coarse aggregates, whereas Batch-2 is a replacement of natural fine aggregates (NFA) with RFA and Batch-3 is a replacement of natural Fine and coarse aggregates with RFA & RCA and natural Fine & Coarse aggregate.

TABLE-5: Hardened Property of M-20 concrete mix of Batch-1

Batch mix	Replacements of NCA and NFA with RCA and RFA	Avg Compressive Strength (Mpa)		
		7 days	14 days	28 days
B1-0	RCA- 0%	19.01	26.60	28.92
B1-1	RCA- 25%	13.23	22.35	27.60
B1-2	RCA- 50%	12.93	21.83	26.31
B1-3	RCA- 75%	13.08	21.63	25.45
B1-4	RCA- 100%	12.47	17.12	20.20
B2-1	RFA- 25%	16.77	21.02	27.56
B2-2	RFA- 50%	13.05	19.13	23.05
B2-3	RFA- 75%	11.34	15.87	18.17
B2-4	RFA- 100%	12.41	15.23	15.99
B3-0	RCA-0% & RFA-0%	19.01	26.60	28.92
B3-1	RCA-25% & RFA-25%	14.39	20.42	26.81
B3-2	RCA-50% & RFA-50%	15.58	22.93	25.87
B3-3	RCA-25% & RFA-75%	13.78	20.09	22.82
B3-4	RCA-75% & RFA-25%	13.37	19.39	22.00
B3-5	RCA-100% & RFA-100%	8.60	11.68	14.39

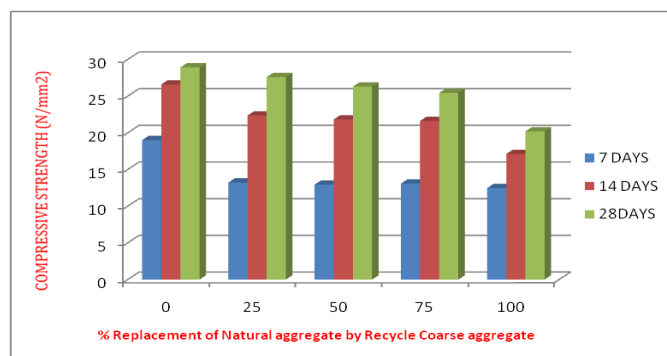


Fig. 7: 7 days, 14 days and 28 days compressive strength of M-20 concrete with varying proportions of RCA

Fig. 7 presents the comparison of Hardened property of M20 concrete mix with varying proportions of RCA. B1-0 mix comprising of OPC, NFA and NCA has exhibited compressive strength of 28.92MPa. Among the batch-1 mixes with replacement of NCA with RCA, B1-1 mix with 25% replacement has shown the highest compressive strength of 27.6MPa. As the percentage of replacement increased the compressive strength decreased. Same pattern of values are seen in Batch-2 mix which is shown in Fig. 8 i.e with increase in the % of replacement of NFA by RFA the strength decreases from 27.56MPa to 15.99Mpa.

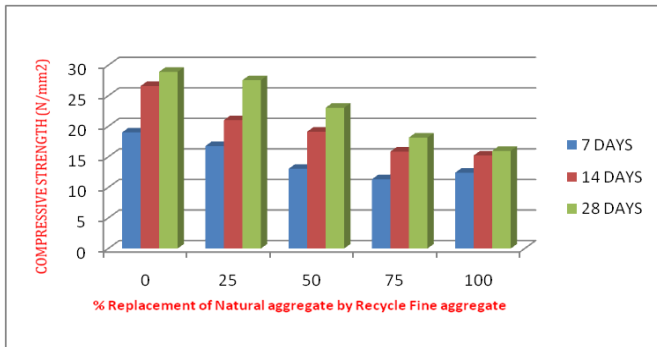


Fig. 8: 7 days, 14 days and 28 days compressive strength of M-20 concrete with varying proportions of RFA.

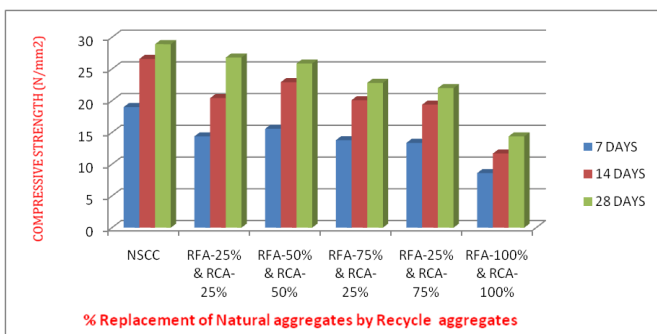


Fig. 9: 7 days, 14 days and 28 days compressive strength of M-20 concrete with varying proportions of Recycled aggregates.

Fig. 9 presents the comparison of Hardened property of M20 concrete mix with varying proportions of RFA & RCA. B3-0 mix comprising of OPC, NFA and NCA has exhibited compressive strength of 28.92MPa. Among the batch-3 mixes with replacements of recycled aggregates, B3-1 mix with 25% replacement of both RFA & RCA has shown the highest compressive strength of 26.81MPa. As the percentage of replacement increased the compressive strength decreased.

From the above chart results, it is concluded that Batch-1 blend showed better results than Batch-2 & Batch-3. Same pattern of results are observed in B-1 & B-2 whereas substantial decrease in values of strength are seen in batch-3 for higher replacements. The compressive strength of all the mixes developed at early stages is lower than that of the normal concrete mix.

## V. CONCLUSION

The following are the conclusions which are drawn from the experimental results:

1. From the current study it is observed that the properties of RCA and RFA are equivalent to that of NCA and NFA with the exception of water absorption value & a low density values.
2. Compressive strength are close to that of normal concrete in both Batch-1 and batch-2 mix. 100% replacement in

both batches showed least strength i.e decreased by 30.4% (batch-1) and 45.64% (batch-2)

3. In Batch-3 mix, concrete mix with 100% and 100% replacement of RFA and RCA has showed the least strength i.e decreased by 55.3%. While considering flow and strength values, 50% replacement can be taken as the optimum mix.
4. The density of hardened concrete slightly decreased as the rate of replacement by recycled aggregate increased, since the RCA presented a lower density compared to NCA surface.
5. Considering flow and strength values, 50% replacement can be considered as the optimum mix in all the three batches.

## REFERENCES

1. P.Revathi, R.S.Selvi, "Investigation on Fresh and Hardened properties of recycled aggregate Self compacting concrete", Journal of The Institution of Engineers (India): Series A , September 2013, Volume 94, Issue 3, pp 179-185
2. Prashant.O.Modani, Vinod M Mohitkar, "Self-compacting concrete with recycled aggregate: A solution for sustainable development", International Journal Of Civil And Structural Engineering, Volume 4, No 3, 2014.
3. C.Sumanth, Reddy, K.V.RatnaSai, Dr.P.RathishKumar, "Mechanical and Durability properties of Self Compacting Concrete with recycled concrete aggregates", International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013ISSN 2229-5518.
4. Mounir M. Kamal, Mohamed A. Safan, Zeinab A. Etman and Mahmoud A. Abd-elbaki, "Effect of Polypropylene Fibers on Development of Fresh and Hardened Properties of Recycled Self-compacting Concrete", International Journal of Engineering and Advanced Technology (IJEAT)ISSN: 2249 – 8958, Volume-2, Issue-5, June 2013
5. S.Girish, "Influence of Powder and Paste on SCC Using Recycled Concrete Aggregate", Bonfring International Journal of Industrial Engineering and Management Science, Vol. 2, No. 4, December 2012.
6. Tung-Chai Linga.b, Chi-Sun Poona, Hau-Wing Wonga, "Management and recycling of waste glass in concrete products: Currentsituations in Hong Kong", ELSEVEIR,Resources, Conservation and Recycling 70 (2013) 25– 31
7. B.KrishnaRao, V.Ravindra, and A.Rajagopal, "Experimental investigation on impact strength of steel fibres reinforced Normal and Self compacting concrete" , International Journal Of Civil And Structural Engineering,Volume 4, No. , 2011.
8. Gritsada Sua-iam , Natt Makul, "Use of recycled alumina as fine aggregate replacement in self-compacting concrete", ELSEVEIR,Resources, Conservation and Recycling 47 (2013) 701–710.
9. Khalid Mohammed Breesem, Faris Gorashi Faris, and Isam Mohammed Abdel-Magid, "Behavior of Self-Compacting Concrete Using Different Sludge and Waste Materials– A General Overview", International Journal of Chemical, Environmental & Biological Sciences (IJCEBS) Volume 2, Issue 3 (2014) ISSN 2320–4087
10. Mr.S.Manimaran, Mr.K.Suresh Raja, "Study of the Influence of Recycled Aggregate (Class-I Brick Bats) and Corrugated Steel Fibers in Self Compacting Concrete Beams", International Journal of Scientific Engineering and Applied Science (IJSEAS) Volume-1, Issue-1, February 2015 ,ISSN: 2395-3470
11. EFNARC, "Specification and guidelines for self-compacting concrete", European Federation of Producers and Applicators of Specialist Products for Structures, May 2005
12. "Concrete Technology – theory and practice", by M S Shetty, S. Chand Company Ltd, Delhi, First multi-colour illustrative revised edition, reprint 2008.