

Study of self-compacting concrete using recycled waste concrete as coarse aggregate

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Abstract

Self-Compacting Concrete (SCC) represents one of the biggest modern innovations in the construction field worldwide. Until now, on an international level, the number of constructions using SCC as a main material is limited. Self-compacting concrete is a special type of concrete that is able to flow under its own weight, completely filling the formwork and consolidating without the need of vibration. Since its first development in Japan in 1980, SCC was widely accepted in Japan, Europe and USA due to its inherently distinct advantages. SCC provides better quality especially in the members improving durability of concrete and having reinforcement congestion or decreasing the permeability. In this presented post-graduate thesis, there is a complete report on mechanical properties and the major attributes of the fresh and hardened concrete, as well as on the methods of its production and the ingredients of the recycled materials. The primary research is to qualitatively and quantitatively explore the acceptability of destroyed concrete waste aggregate for the production of the SCC of high strength and desirable properties. It assesses experiments on various mixes of self-compacting concrete – one with the fresh coarse and fine aggregates, while the others with replacement of 15%, 30 %, 40% and 50% recycled coarse aggregates. Results in the experiments showed that the fresh, hardened and durability properties of all the concrete mixes were comparable. Wherein, the compressive strength of all the concrete mixes was measured at the age of 7 and 28days.

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1. Introduction

Construction is the backbone of infrastructural development and it derives its basic ingredients, which are sand and stone aggregate from nature. In the current scenario, the construction works is on boom, which leads to various environmental hazards such as

- The construction industry has ruined the ecological balance up to a great extent by taking away the natural stock of aggregates
- The heavy machinery involved to extract the stone aggregates from quarrying operates on fuels releasing obnoxious gases and fumes
- The air pollution from quarrying caused by release of suspended particulate matter into the atmosphere leads to danger for the working staff and the adjoining population

- The particulate matter from quarrying also runs off to the nearby rivers or water bodies, which pollute the water and destroy the aquatic life
- The required working quarry wants methods of transportation which means that the huge quantities of equipment and heavy traffic will be brought into the assignment area, ensuing into increase in local noise and air pollution.
- To facilitate the resistance from use of natural aggregates from the nature, various steps are continuously being taken by construction industry for infrastructure development. The recycled aggregates usage is one of the new steps in developing the concrete for the construction practices
- A simple mix Design method for self-compacting concrete” and the mix design of Self compacting concrete (M35) from Ambuja Cement.

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- Several changes were made through trials in the design to obtain the properties of self-compacting concrete.
- Initially the conventional self-compacting concrete was made and the fresh and hardened properties were checked.
- Proportion of 50%, 40%, 30% and 15% replacement of natural coarse aggregates were used in recycled coarse aggregates.
- Finally, there is comparison of the results of fresh and hardened properties for the conventional self-compacting concrete and the self-compacting concrete made from various proportions of replaced recycled coarse aggregates.
- Self-compacting concrete, also referred as self-consolidating concrete, is the concrete that has ability to flow due to its own weight and completely fill the formwork, while maintaining homogeneity even in the availability of congested reinforcement, and then consolidating without the requirement of vibration.
- Conventional concrete requires external compaction work by internal or external vibrators for proper compaction, filling of the formwork and covering of the reinforcement. Proper SCC fulfills the same quality level but with no vibration. SCC compacts itself automatically by its own weight. In order to create the self-compacting effect of SCC, the friction between the particles has to be reduced at the same time as satisfying stability of the fresh concrete has to be maintained. In comparison with normal concrete of mechanical properties similar to SCC, the material cost of SCC is more due to the relatively high requirement of cementitious materials and chemical admixtures including high range water reducing admixtures (HRWRA) and viscosity modifying admixtures (VMA).
- However, the construction time of SCC is shorter and its production is environment friendly. Furthermore, SCC produces a good surface finish and gives greater freedom in design. These advantages make SCC particularly interesting for use in pre-casting plants, or surface repair.

2. Experimentation Methodology

The experimental research targets to compare the hardened properties of various mixes of SCC made from different proportions of recycled fine aggregates and conventional concrete. The basic materials used in making the Self Compacting followed by a brief description about mix design and curing procedure adopted. At the end various tests conducted on the specimens are discussed.

2.1 Materials used for making SCC

In this section brief description on physical properties of the material used to prepare SCC mixes is discussed. The ordinary Portland Cement of Grade 43 from Ambuja Cement Ltd. has been used for making the Self Compacting Concrete. Properties of Cement are tabulated below.

Generally, water that is suitable for drinking is satisfactory for use in

concrete. Class F Fly ash obtained from Harduaganj Thermal Power Plant, Aligarh (U.P.) was used.

Table 1: Physical properties of Cement

Properties	Ordinary Portland Cement		
Specific Gravity	2.2		
Initial Setting Time	180 Minutes		
Final Setting Time	10 Hours		
Compressive Strength of mortar cubes (Conforming to IS:4031 part-6-1988)	3 day	7 day	28 day
	28.71 MPa	37.8 MPa	42.6 MPa

2.2 Fine Aggregates

The natural fine aggregates were procured from Kotputli source. The Properties of the natural fine aggregate used in the experimental work are tabulated in Table 2.

Table 2: Properties of the natural fine aggregate

S.No	Characteristics	Value
1	Specific gravity	2.50
2	Bulk Density	1,925 Kg/m ³
3	Water Absorption	0.83%

2.3 Coarse aggregate

Crushed stone is generally used as a coarse aggregate. Locally available coarse aggregate having the maximum size of 10 to 20 mm was used in our work. The aggregates were tested as per IS: 383-1970.

The results of different tests performed on the coarse aggregates are shown and recycled coarse aggregate were obtaining from demolished structure and their properties and their sieve analysis results show in table 3.

Table 3: Physical properties of coarse aggregate

Sr. No	Characteristics	Value
1	Type	Crushed
2	Specific Gravity	2.6
3	Total Water Absorption	0.55
4	Fineness Modulus	6.41

Table 4: Sieve analysis of recycle coarse aggregate

S.N	Sieve Size	Mass Retained (gm)	Percentage retained	Cumulative Percentage retained	Percent Passing
1	20mm	0	0	0	100
2	10mm	2502	83.4	83.4	16.6
3	4.75mm	468	15.6	99	1
4	PAN	12	0.4	Σ=182.4	

2.4 Admixture

Admixture used in this work is Superplasticizer of CICO brand, which complies with IS: 9103:1979 and BS: 5075 Part 3 and ASTM-C-494 type ‘F’ as a high range water reducing admixture. At the time of batching, Ultracon SP 430 is ready to use admixture which is mixed to the concrete. Ultracon SP430 is differentiated from conventional superplasticizers due to the fact that it is based on aqueous solution of lignosulphonates and organic polymer with long lateral chains. This greatly enhances the cement dispersion. Ultracon SP430 is brought as brown liquid which is instantly dispersible in water and also specially formulated to give high water reduction up to 25% without any loss of workability. Specific gravity is 1.22 to 1.225 at 30°C.

2.5 Mix Design

The base mix was designed for M35 concrete according to the guidelines given in IS: 10262 2009 (code of practice for mix design of normal concrete) and several changes were made through trials in the design to obtain the properties of self-compacting concrete. Changes include:

- Increase in the quantity of powder content (particle size <150µ).
- Optimal dosage of super plasticizer.

Initially two types of SCC were prepared- one completely with fresh coarse and fine aggregate and other with fresh fine aggregate and 100% replacement of fresh coarse aggregate with recycle done. The w/c and water to binder ratio of the base mix was kept as 0.45 and 0.35 respectively. However, slight modifications in the water quantity were introduced on the spot to achieve the desired workability, flow ability and to account for more water absorption of recycled fine aggregates than fresh ones. The intermediate mix designs with the replacement of 15%, 30% and 40% of recycled coarse aggregates were prepared for the comparison of fresh and hardened properties.

3. Results and discussion

This section comprises of the results for the fresh and hardened properties of various mixtures for making self-compacting concrete made from different proportions of recycled coarse aggregates. The results of fresh properties of all Self-compacting concretes are included. The Table shows the properties such as slump flow, V-funnel flow times, L-box and U- box. SCC prepared with the recycled coarse aggregates and natural fine aggregate requires more water than the conventional SCC in order to obtain the same workability.

3.1 Hardened Properties

3.1.1 Compressive Strength

The compressive strength tests result of self-compacting Concrete are given. As the percentage of recycled coarse aggregates increases, the compressive strength of the SCC decreases.

Table 5- Fresh concrete properties

Mixture	Slump(mm)		V-Funnel (Seconds)		L-Box (H2/H1)		U-Box (H2-H1) mm	
	Experiment Results	EFNARC Limits						
SCC-C	750	650-800	7	6-12	0.90	0.8-1	27	0-30
RCA15	710	650-800	8	6-12	0.88	0.8-1	25	0-30
RCA30	685	650-800	9	6-12	0.84	0.8-1	23	0-30
RCA40	660	650-800	10.5	6-12	0.832	0.8-1	20	0-30
RCA50	630	650-800	12	6-12	0.77	0.8-1	15	0-30

Table 6- Compressive Strength Test Results

Mix	Compressive Strength (N/mm ²)		Average Compressive	
	7 days	28 days	7 days	28 days
Conventional SCC	36.5	58.1	37.8	58.6
	41.2	60.7		
	35.8	57.1		
RCA 15	33.4	53.4	36.3	55.9
	39	56.5		
	36.7	57.9		
RCA 30	31.2	51.4	32.5	49.5
	35.5	48.1		
	30.8	49		
RCA 40	25.2	43.1	24.5	45
	27.8	46.7		
	20.7	45.3		
RCA 50	26.3	41.6	24.3	43.7
	22.1	45.7		
	24.6	44		

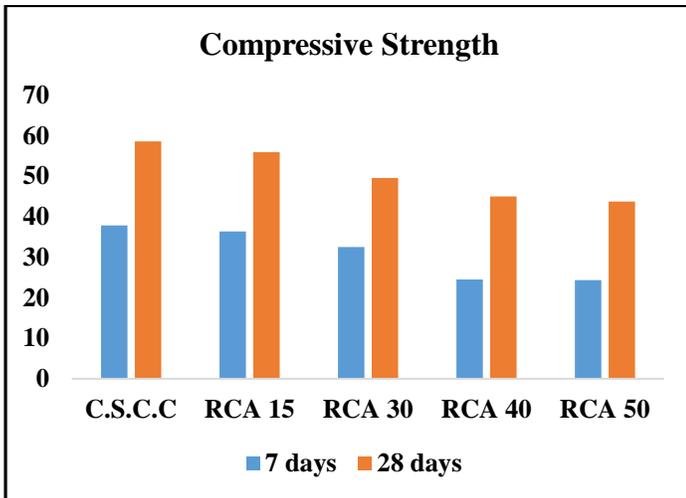


Figure 1- Variation of compressive strength with % replacement of RCA

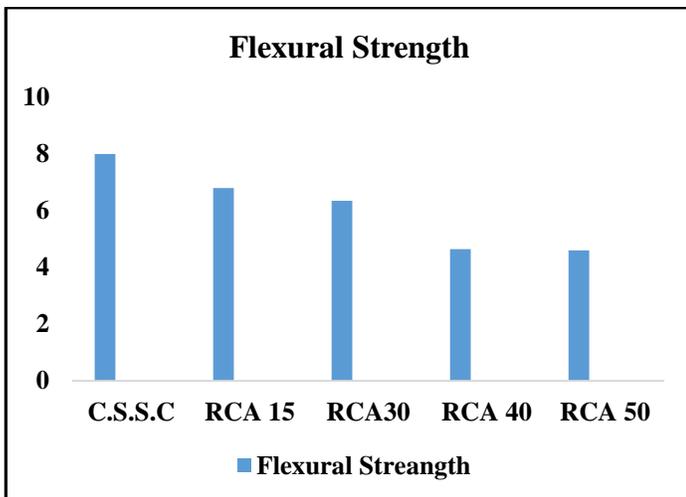


Figure 2- Variation of flexural strength with % replacement of RCA

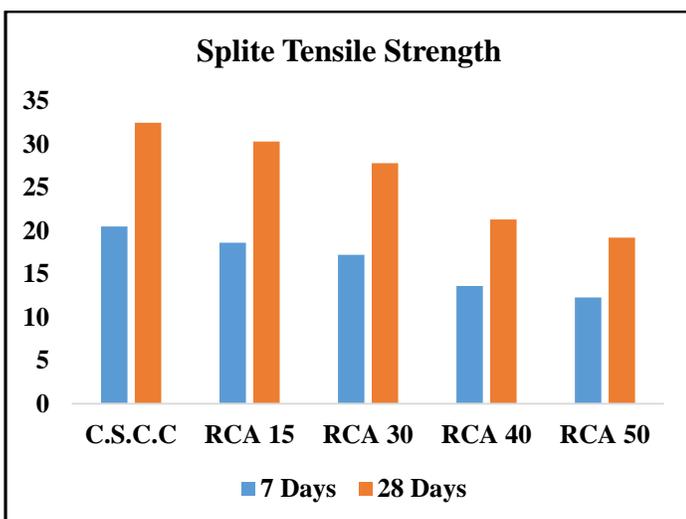


Figure 3- Variation of split tensile strength with % replacement of RCA

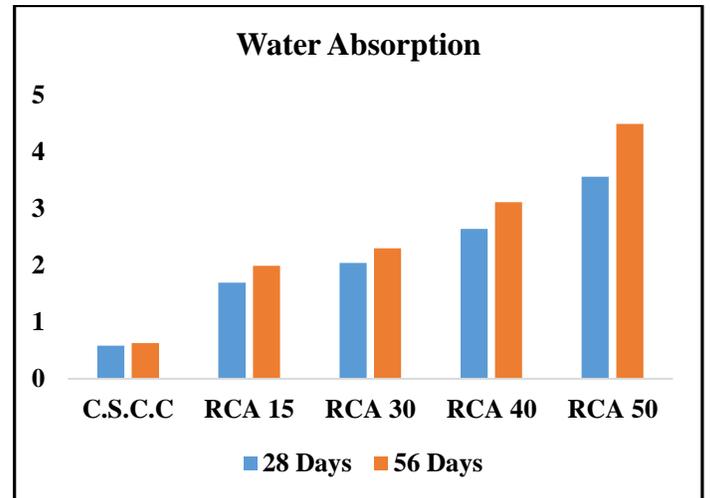


Figure 4- Percentage of water absorbed at various ages

4. Conclusions and Future scope

4.1 Fresh SCC Properties

- The current research shows that SCC prepared from recycled coarse aggregates (RCA) provides satisfied workability requirements as per the desired limits for acceptance.
- The slump flow test gives the readings from 650 mm to 750 mm, the V-funnel time gives the readings from 7 seconds to 12 seconds, the L-box test value ranges between 0.77 & 0.9 and the U-box test result shows the value between 15 mm to 30mm.
- Slump test, V-funnel test, L-box test and the U-box test values all fall in the range of EFNARC limits.
- It justifies the replacement or use of RCA in SCC. Hence, recycled fine aggregates can be used for the preparation of SCC.
- In general, as the SCC is made by replacing fresh aggregates with RCA, fall in initial as well as final compressive strengths is observed.
- It is due to the reason that as the replacement of CA with RCA increases, the microstructure becomes more porous, water requirement and absorption increases and hence, drop in compressive strengths is observed.
- 28 days' compressive strength of conventional SCC was found to be 58.6 N/mm², whereas the 28 days' compressive strength decreases to 43.7 N/mm² as the coarse aggregates were replaced by 50% recycled coarse aggregates.
- 7 days' compressive strength of SCC shows that there is a little more variation in result when replacement is increased from 0% to 50% of recycled coarse aggregates. The percentage drop in strengths is observed as 4.4%, 13.9%, 35% and 35.8% for 15%, 30%, 40% and 50% replacement of recycled coarse aggregates respectively.

- With the percentage replacement of 15% of recycled coarse aggregates, the 28 days compressive strength decreases by a small value of 5.1 %, with replacement of 30% of recycled coarse aggregates, the 28 days compressive strength decreases to 15.4 %, with replacement of 40% of recycled coarse aggregates, the 28 days compressive strength decreases to 23.12 % and with replacement of 50% of recycled coarse aggregates, the 28 days compressive strength decreases to 25.85 %.
- It was concluded that, for the replacement of recycled coarse aggregates up to 15%, the decrease in compressive strength is very low as compared to the replacement of recycled coarse aggregates by 30%, 40% and 50%.
- Therefore, it is justified from the results to replace CA with RCA up to 15-30% for the perspective of cost reduction and waste management.

4.2 Flexural Strength

- As the percentage of recycled coarse aggregates increases, the flexural strength of the SCC decreases. The 28 days' flexural strength of conventional SCC was found to be 8.0 N/mm², whereas the 28 days' flexural strength decreases to 4.6 N/mm².
- While replacing recycled coarse aggregates from 0% to 50%, The 28 days' flexural strength decreases. The percentage decreases are 16.4%, 21.4 %, 42.6% and 43.89% for 15%, 30%, 40% and 50% replacement of recycled coarse aggregates respectively.

4.3 Split Tensile Strength

- With the percentage replacement of 15% of recycled coarse aggregates, the 28 days compressive strength decreases by a small percentage of 6.7 %, with replacement of 30% of recycled coarse aggregates, the 28 days compressive strength decreases to 14.46%.
- %, with replacement of 40% of recycled coarse aggregates, the 28 days compressive strength decreases to 34.35 % and with replacement of 50% of recycled coarse aggregates, the 28 days compressive strength decreases to 40.7 %.
- The 7 days split tensile strength shows the decreases in strength from 20.5N/mm² to 12.3 N/mm² as the percentage of recycled coarse aggregates increases in the mixes of SCC.

4.4 Durability Properties

- From data of the results of water absorption, it is observed that the water absorption values of SCC containing the RCA are higher than that of the conventional SCC.
- The SCC made with 50% RCA shows 6.3 times higher absorption which is higher than conventional SCC at the

age of 28 days and 7.2 times higher than conventional SCC at the age of 56 days, which means water absorption values of all the RCA- SCC were higher than the conventional SCC.

- The absorption increased with an increase in percentage of RCA. It was due to the high absorption capacity of the RCA itself, which has created higher osmosis pressure within the concrete.

4.5 Overall Conclusions

- Further, the fresh properties for the SCC made with recycled Coarse aggregates gives satisfactory results for their use in SCC.
- The hardened and durability characteristics of modified SCC with replacement of CA with RCA variably shows marginal decrease in strengths as well as durability characteristics.
- 0% to 30% replacement of RCA to modify SCC, it shows very small marginal fall in compressive, flexural as well as split tensile strength values as compared to conventional SCC.
- Some admixture like silicafume, alccofine, etc. can be used to retrieve the loss in strengths.
- But the falls in strengths and durability parameters is not so large and hence, it justifies the use of waste fine aggregates in SCC from environmental and waste management issues.

4.6 Further scope of work

- Detailed investigation on optimal replacement of RCA in SCC without compromising on strength and durability.
- Study on the use of admixtures like alccofine, silica fumes, nano silica etc. can be made in SCC modified by waste concrete aggregates to improve the strength and durability.

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