A Study on Effect of Recycled Coarse Aggregate on Fresh and Hardened Properties of SCC

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Abstract— Now-a-days there is scarcity of natural coarse aggregates (NCA) in various zones of the world. The use of recycled aggregate (RCA) from construction and demolition wastes is showing potential relevance in construction industry as a substitute of NCA. The present study focuses on the basic properties of SCC designed by partially replacing NCA with RCA along with us of fixed proportions of fly ash and quarry dust. In this paper carried out to know the combined outcome of using RCA, fly ash and quarry dust in Scc. The properties such as flowing ability, passing ability, compressive strength, and tensile strength are also discussed by conducting various laboratory tests. The results obtained regard the possibility of SCC using RCA, strength parameters.

Key words: Self Compacting Concrete Recycled Coarse Aggregate, Natural Coarse Aggregate, Quarry Dust, Flowing Ability, Passing Ability

I. INTRODUCTION

SCC is a special type of concrete introduced by the Japanese researchers in the year 1980 especially for complicated constructions with congested reinforcement. The usage of SCC has become popular and accepted in recent years. SCC is a concrete that after being poured into formwork does not require any vibration but flows under its own weight. The usage of SCC achieves the same engineering properties as conventional vibrated concrete. Application of SCC with variations in mix proportions i.e. partial replacement of coarse aggregate or fine aggregate has shown its respective effects on strength properties .This study focuses on the fresh and hardened properties of SCC produced with RCA.

II. LITERATURE REVIEW

A noteworthy variation on engineering properties of concrete made with recycled concrete aggregate has been reported [T.C. Hansen 1985, S. Hasaba, 1981, Japanese researchers in BCSJ 1978].

Tabsh and Abdelfatah through their research work concluded that because of the use of RCA there is loss in compressive and tensile strength which is noteworthy in a weak concrete compared to the strong concrete. Recycled concrete mixes require more water than traditional concrete mixes to maintain the same slump without the use of admixtures.

"Kou, S.C., Poon, C.S" 2009 Studied the fresh and hardened properties of SCC with recycled concrete aggregates as both coarse and fine aggregates states. Three sets of SCC mixes with partial replacement of recycled fine aggregate with river sand were prepared the percentage of coarse recycled aggregates was fixed at 100%. The cement content was kept constant for all concrete mixtures.

Grdic, et.al 2010 studied the flow ability and strength characteristics of SCC, and additionally emphasized on its ecological value. Three sets of concrete mixtures were prepared, where the partial replacement of coarse aggregate by recycled aggregate was varied by 0%, 50% and 100%. Equal consistency was achieved in all concrete mixes.

III. EXPERIMENTAL INVESTIGATION

A. *Materials Used:*

1) *Cement:*

Ordinary Portland cement (OPC) of grade 43 conforming to IS 8112-1989 is used . Various lab tests conforming to 4031-1996(part-1) carried out.

2) *Fly Ash:*

Fly ash (classF) obtained from NTPC Visakhapatnam is used. Fly ash is not processed and used as received.

Sl no.	Physical Properties	Observed value for cement	Observed values for fly ash
1	Specific Gravity	3.14	2.2
2	Initial Setting (minutes)	30 min	45 min
3	Final Setting (minutes)	600 min	280 min
4	Consistency (%)	30%	35
6	Fineness (m^2/kg)	225 m^2/kg	368m^2/kg

Table 1: physical Properties Of Cement And Fly Ash

Sl. No.	Test Conducted	Observed Values (%)	Requirement as per IS:3812 (Part- I):2003 Reaffirmed: 2013
1	Loss of Ignition	2.53	5.0(max)
2	Silica as SiO_2	59.51	35 (min)
3	$SiO_2+Al_2O_3+Fe_2O_3$	86.85	70(min)
4	Available alkalis as Na_2O	0.43	1.5 (max)
5	Reactive silica	29.32	20(min)
6	Magnesium as MgO	1.97	5.0 (max)
7	Sulphate as SO_3	2.07	3.0 (max)
8	Total Chloride	0.032	0.05 (max)
9	Lime Reactivity	4.9 N/mm^2	4.5(min)

Table 2: Chemical Properties of Fly Ash

3) *Admixture:*

Poly carboxylic ether based super plasticizer with viscosity modified admixture named master Glenium sky 8630/8632.

Aspect	Light brown liquid
Relative density	1.08 ± 0.01 at 25ºC
pH	≥ 6 at 25ºC
Chloride ion content	< 0.2%

Table 3: Chemical Properties

4) Aggregates:

Coarse aggregate: Locally available crushed stone of 20mm graded size has been used as coarse aggregate.

Re-cycled coarse aggregate (RCA): Locally available crushed concrete cube specimens from cement and concrete lab is used to prepare RCA.

Test property	Natural coarse aggregate	RCA
Specific gravity	2.75	2.47
Water absorption	0.25%	5.9%
Aggregate crushing(%)	24	27
Aggregate impact(%)	29	28.2

Table 4: characteristics of CA

5) Fine aggregate:

River sand from river bed having following characteristics.

Specific gravity	2.63
fineness	2.60
Water absorption	2.56

6) Mix proportioning:

In this study SCC mixes of M40 grade are produced as per code IS 10262-2009 with six different weight percentages of RCA as replacement of CA and 30% replacement of FA to study the effect on flow ability, compressive and tensile strength. The use of fly ash in concrete is taken 30%, water binder ratio is taken 0.4. The detailed proportions of various ingredients of SCC below.

Mix no	Cement	% fly ash	% RCA	RCA (kg)	W/B ratio	CA (kgs)	FA (kgs)	Water(litr)	Admix% (HRWR+VMA)	QD (30%)
1.	270	30	0	0	0.36	976	665.64	163	2.2	298
2.	270	30	10	87.9	0.36	880.6	665.64	168	2.2	298
3.	270	30	20	175.7	0.36	782.8	665.64	173	2.2	298
4.	270	30	30	263.6	0.36	684.9	665.64	178	2.2	298
5.	270	30	40	351.5	0.36	587.1	665.64	183	2.2	298
6.	270	30	50	439.4	0.36	489.2	665.64	188	2.2	298

Table 6: Mix Proportion M40

7) Test procedure:

Flow ability test result: The various flow ability tests conducted in lab where as per EFNARC (2002) and the test conducted were Slump Flow Test. The results of the slump flow tests of fly ash induced SCC with different percentage of RCA. The spread diameter of slump flow varied between the ranges of 655-725 mm. A minimum slump flow of 650 mm is generally recommended for SCC.

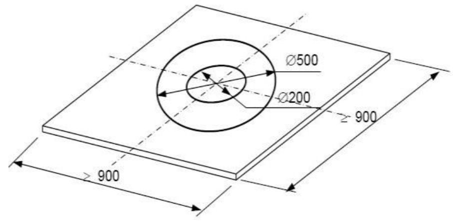

Fig. 1: Schematic Diagram of Slump

The flow ability and the flow rate of SCC without obstructions is accessed by Slump flow and T500. The result indicates the filling ability of SCC, and the T500 time measures the speed of flow. Finally, the viscosity of the paste can be visualized.

A good estimation of filling ability can be determined by Slump flow and T500 test. A slump flow value of 650mm at least is required for SCC.

Further, the T50 time is one of the indications of flow ability for SCCs mixes. If the flow time is between 2-5 seconds then it is useful or acceptable for housing application and if the flow time is within 3-7 sec then it is acceptable for civil engineering purposes.

8) L -box test:

This test method provides a procedure to determine the passing ability of SCCs mixes. It measures the reached height of fresh SCC after passing through the specified gaps of steel bars flowing within defined flow distance. With this reached height, the passing or blocking behavior of SCC is estimated.

L-box has arrangement and the dimensions as shown in Figure. The H2/H1 ratio is known as blocking ratio. A minimum acceptable value for this blocking ratio is in the range of 0.8 to 1. Obvious blocking of coarse aggregate behind the reinforcing bars can detected visually.

This test indicates the passing ability, or the degree to which the concrete passes through the bars. The diameters and spacing of the bars is in accordance with normal reinforcement provided at the construction sites. However, three times the maximum size of aggregate is considered appropriate.

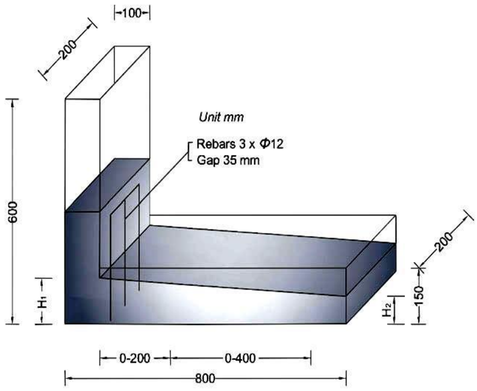

Fig. 2: L-Box

9) V-Funnel Test:

The V-Funnel Test equipment developed in Japan consists of a V-shaped funnel. Arrangement and the dimensions are shown in Figure.

It determines the ability to fill (flowability) of SCC with a maximum aggregate size of 20mm. This test measures the ease with which the concrete flows. If the flow time of concrete through the V funnel is less than 10 seconds then the concrete can be classified as SCC. The inverted cone shape of the funnel is assumed to restrict the flow, and extended flow times gives indication of the vulnerability of the mix to blocking.

Fig. 3 Flow Ability In L-Box And V-Funnel Test

Tests for strength in compression: Two types of compression test specimens are used: cubes and cylinder. In the present work cube specimens were preferred. Cube Moulds were 150 mm size conforming to IS: 10086-1982

The specimens were tested for compressive strength on compression testing machine provided with two steel bearings platens with hardened faces. The load is applied without shock and is increased continuously at a rate 140/cm2/min (approx) until the specimen breaks. The measured compressive strength is calculated by dividing the maximum compressive load by the cross-section area calculated from the mean dimension of the specimen.

Fig. 4: Compressive Strength Test of Cub

10) Split Tensile Strength Test:

This comes under indirect tension test methods. The test specimen was placed horizontally between the loading faces of a compression testing machine and the load was applied gradually until failure occurs, along the vertical diameter.

A concrete cylinder of size 150mm diameter and 300mm height was subjected to the action of a compressive force along two opposite edges. The cylinder was subjected to compression near the loaded region and the length of cylinder is subjected to uniform tensile stress.

Horizontal tensile stress = 2P/Π D L

P= Compressive load, L= length of cylinder, D= diameter of cylinder

Fig. 5: Tensile Test of Cylinder

IV. RESULTS AND DISCUSSIONS

A. Fresh Properties:

The following are the results obtained in various laboratory tests carried out in this study.

Mix no	% RCA	slump flow test (t in sec)			L value(h_2/h_1)	v (t in sec)
		300mm	500mm	700mm		
1	0	1	2.2	6.5	0.98	9.6
2	10	1.5	2.8	11.15	0.82	4.8
3	20	1.1	2.6	11	0.87	4
4	3	0.85	2.5	10	0.96	3
5	40	0.75	2.4	8	0.98	2.8
6	50	0.75	2.4	5	1	2.5

Table 6: Flowability Results

T500 is the time for which the concrete reaches the diameter of 500mm and was measured during slump flow test. This value for all the mixes with RCA is between 2-3 sec and with a minimum flow of 650mm as recommended for engineering applications.

The filling and flowing measured using v-funnel ranges from 2-5 sec, passing test using L-box gives less than 1which are acceptable.

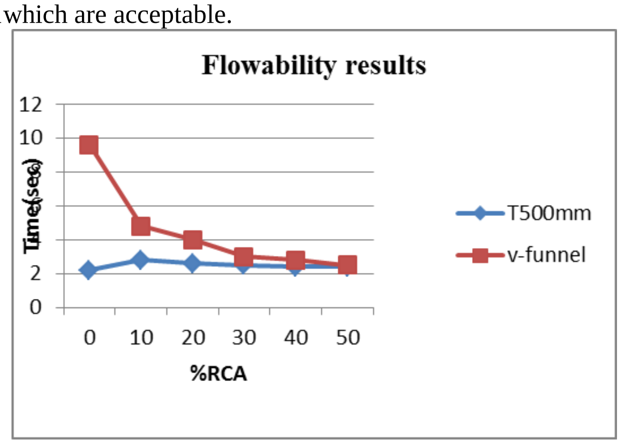

Fig. 6: Graph representing flowability results

The graph is plot between time in sec and %RCA indicating the flow ability. It can be seen that as %RAC increases the flow time decreases.

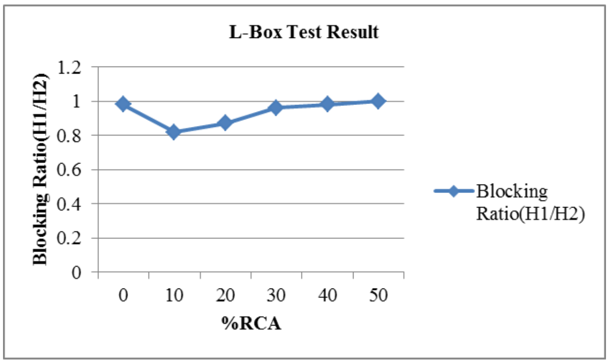

Fig. 7: %RCA (vs.) Blocking Ratio

A graph is plot between percent RCA on X-axis, blocking ratio in Y-axis, which indicates as RCA increases blocking ratio initially decreases than increases but are within limits.

Hardened properties: The compressive and tensile strengths of the all concrete mixes determined at 7days, 28 days are given below

Strength results

Mix no	% RCA	Compressive strength(mpa)			Tensile strength		
		3days	7days	28days	3days	7days	28days
1	0	15.6	23.41	46.82	1.2	1.71	3.6
2	10	15.4	23.1	45.64	1.17	1.6	3.52
3	20	15	22.55	45.1	1.16	1.51	3.49
4	3	14.8	22.3	44.76	1.13	1.41	3.4
5	40	14.1	21.8	42.56	1.12	1.34	3.37
6	50	14	21.1	42.26	1.1	1.3	3.3

It is clear from the results that reduction in compressive strength and tensile is marginal compared to natural aggregate concrete (NASCC) with recycled coarse aggregate concrete (RASCC) up to 50% replacement.

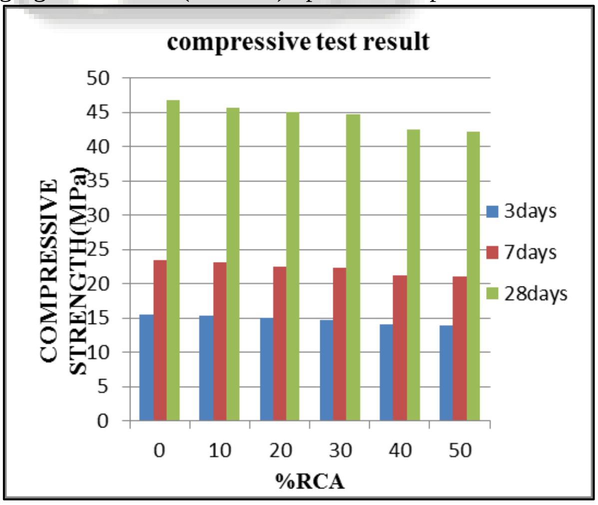

Fig. 8: %RCA (vs.) Compressive Strength

This graph plotted between percentRCA on X-axis and compressive strength on Y-axis shows the variation of strengths with increase in %RAC at 3,7,28 days respectively.

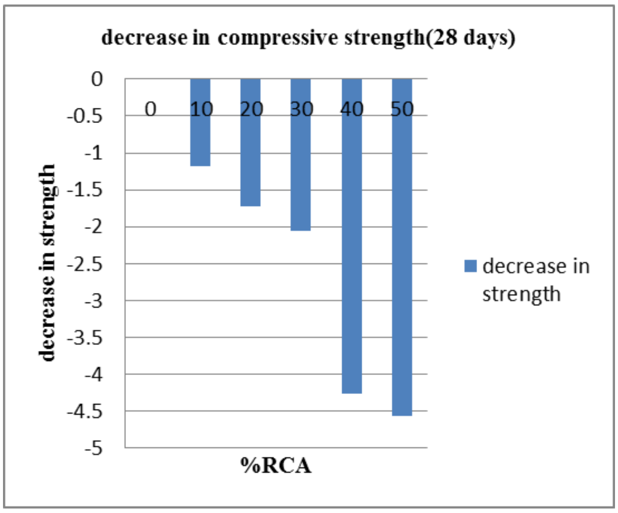

Fig. 9: %RCA (vs.) decrease in strength

This graph indicates the decrease in compressive strength (28days) with increase in the % RCA

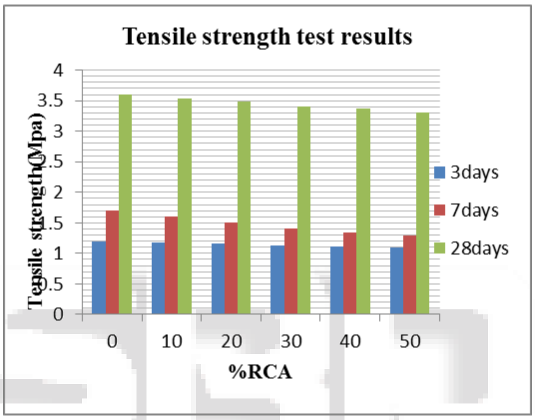

Fig. 10: %RCA (vs.) Tensile Strength

This graph plotted between %RCA on X-axis and tensile strength on Y-axis shows the variation of strengths with increase in %RAC at 3,7,28 days respectively.

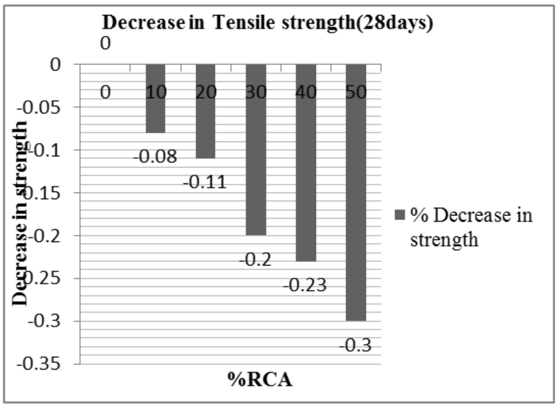

Fig. 11: %RCA (vs.) Decrease in Tensile Strength

This graph indicates the decrease in tensile strength (28days) with increase in the % RCA.

V. CONCLUSIONS

In this study, comparative analysis is carried out to understand the effect of replacing natural coarse aggregate with varying percentages of recycled concrete aggregates. The following conclusions can be drawn:

Based on the experimental results reported in present study, it is seen that the slump flow, passing ability of the mixes decreases with increase in percentage of RCA.

1) The slump flow varied between the ranges of 650-725mm
2) At 2.2% doses of HRWR and inbuilt VMA, the flow time decreases and within limits, the bleeding tendency was less.
3) The results were very consistent at 20% replacement of NCA with RCA.
4) Increasing the recycled concrete aggregate content from 0% to 20 % has caused nominal decrease in cube compressive strength by 5% as compared to reference mix.
5) When the recycled concrete aggregate replacement was increased beyond 20%, the compressive strength loss was almost in the range of 15 to 24% as compared to reference mix.
6) The splitting-tensile strengths of recycled concrete aggregate SCC mixtures are decreases with increase in percentage of recycled concrete aggregate.
7) The decrease in splitting tensile strength was almost 2.5% at 20% replacement while it was almost 12% for replacement beyond 20%.

The decrease in compressive strength and split tensile strength is marginal for 20% replacement of recycled concrete aggregate with normal coarse aggregate.

Further, the visual of split tensile fracture surface indicates that in SCC, the matrix of cement, coarse aggregate, fine aggregate, fly ash and recycled concrete aggregate are homogeneous.

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