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EXPERIMENTAL INVESTIGATION ON FRESH AND HARDENED PROPERTIES OF SELF COMPACTING CONCRETE WITH RECYCLED COARSE AGGREGATE

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Abstract* — Self compacted concrete (SCC) can be defined as a concrete that is able to flow under its own weight and completely fill the formwork, even in the presence of dense reinforcement without any compaction, while maintaining the homogeneity of concrete. SCC is also known as super workable concrete. In recent years certain countries have consider the reutilization of construction and demolition waste as a new construction material has being one of the main objectives with respect to sustainable construction activities. Currently, recycled coarse aggregate is mainly being used as a substitute material for natural aggregate. This paper provides an overview on the experimental investigation on the fresh and hardened properties of self compacting concrete using recycled coarse aggregate in both processed and unprocessed state, and where the optimum percentage of recycled coarse aggregate required for better results. In the present experimental investigation M35 grade of concrete was designed based on 'Nan Su et-al method' of mix design. The natural coarse aggregate (NCA) was replaced by recycled coarse aggregate (RCA) at different percentages such as 0%, 25%, 50%, 75% and 100%. Various tests were performed on the recycled aggregates in processed and unprocessed state. The mineral additive used in present study was class-F fly ash. To reduce the water binder ratio and to increase the flow ability of SCC, poly carboxylic ether based super plasticizer was used. Tests on SCC such as slump flow test, V-funnel test, L-box test, compressive strength, split tensile strength were carried out. The fresh properties of SCC in processed state for 500 revolutions have shown better results compared to unprocessed state. For SCC using processed (500, 1000 revolutions) and unprocessed RCA the optimum value of compressive strength, split tensile strength value is obtained at 50% replacement of NCA with RCA for 14 and 28 days.

Keywords*—self compacted concrete, recycled coarse aggregate, processed and unprocessed state, Compressive strength, Split tensile strength.

I. INTRODUCTION

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.

Disposal and treatment of construction and demolition (C&D) wastes are often costly and harmful to the environment. Their recycling could lead to a greener solution to the environmental conservation and lead towards sustainability. This study utilizes demolished concrete as coarse aggregate often termed as recycled coarse aggregate (RCA) for producing industry quality concrete. Large scale recycling can substantially reduce the consumption of natural aggregate and help to preserve the environment. The use of RCA is a very cost effective option if the quality remains comparable to the conventional concrete.

II. EXPERIMENTAL INVESTIGATION

A. Cement and Fly ash

An ordinary Portland cement (Grade 53) conforming to IS 269-2016 was used as the main binder for the experimental investigation. Other cementations materials such fly ash is used as a mineral admixture.

Table I: Physical properties of cement and fly ash

Physical properties	Cement	Fly ash
Specific gravity	3.15	2.25
Initial setting time	150min	-
Final setting time	220min	-

B. Fine Aggregates

Locally available crushed sand conforming to of IS 383:2015 was used in the present investigation. Physical properties of Fine Aggregates were listed in table II.

Table II: physical properties of fine aggregates

Physical properties	Values
Specific gravity	2.45
Bulk density (kg/m^3)	1550
Fineness modulus	3.1

C. Natural Coarse Aggregates

A locally available crushed granite coarse aggregate has been used. Physical properties of Coarse Aggregates were listed in table III.

Table III: Physical properties of Natural Coarse Aggregates

Physical properties	Values
Specific gravity	2.98
Bulk density(kg/m^3)	1568
Fineness modulus	7.6
Water absorption	0.52%

D. Recycled Coarse Aggregates

The recycled aggregates were obtained from concrete waste material from the Concrete technology laboratory in KITSW. The concrete waste is transported to nearby crusher which is situated at Mulkanuru village. The maximum size of aggregate was limited to 20mm. Initially the waste concrete was crushed manually to suitable mechanical crusher feeding. Tests on Recycled Coarse Aggregates were listed in table IV.

Fig 1: Concrete waste material from Concrete Technology laboratory in KITSW

2: Recycled Coarse Aggregate

The RCA obtained from crushed concrete consists of adhered mortar on original aggregates. In the present work Recycled coarse aggregates is classified as:

1. Unprocessed Recycled Coarse Aggregates

2. Processed Recycled Coarse Aggregates

1. Unprocessed recycled coarse aggregates

Unprocessed recycled coarse aggregates are the aggregates which are directly obtained from recycled plant. To determine the mix proportions it is necessary to determine the Specific gravity, bulk density, porosity, percentage of voids and water absorption of the aggregate.

2. Processed recycled coarse aggregates

Processed recycled coarse aggregates are the aggregates which are obtained from the recycled plant after removing adhered mortar by performing Deval's abrasion test of various revolutions **i.e.** 500R,1000Rand also determine the specific gravity, bulk density, porosity, % of voids and water absorption of aggregates for various revolutions.

Fig 3: Devals abrasion test

Table IV: Tests on Recycled Coarse Aggregate

S. No	Test	Recycled coarse aggregate		
		Unprocessed	Processed	
			500R	1000R
1	Deval's Abrasion Test	-	24	23
2	Specific Gravity	2.83	2.5	2.53
3	Bulk Density	1370	1310	1360
4	% voids and Porosity	45.71	47.43	46.29
5	Water Absorption	4.08	2.3	2.1

E. Super plasticizer

Poly carboxylic ether based super plasticizer was used.

F. Water

Clean portable fresh water which is free from concentration of acid and organic Impurities has been used for mixing in the concrete.

Quantities of materials and mix proportion of M35 grade concrete as per Nan-su method of mix design

Table V: Quantities of materials

Cement+ Fly ash(kg/m^3)	Fine aggregate(kg/m^3)	Coarse aggregate(kg/m^3)	Water(liter/m^3)	w/c ratio	Super plasticizer(liter/m^3)
523.61	924	680	195.20	0.38	6.28

Mix proportions

Table VI: Mix proportions for one cubic meter of concrete

Cemententious materials	Fine aggregate	Coarse aggregate
1	1.76	1.30

Tests on fresh properties of SCC

A. Slump Flow test

The slump flow test is used to assess the filling ability of SCC. The time for 500mm spread of concrete and diameter is measured in Unprocessed and Processed State and is shown in Table-VII. The time for 500mm spread of concrete i.e., T_{50} values at various replacement levels of RCA in Unprocessed and Processed State is shown by bar chart representation in figure-5. The diameter spread of concrete at various replacement levels of RCA in Unprocessed and Processed State is shown by bar chart representation in figure-5.

Fig 4: Slump cone test apparatus

Table VII Results of Slump Flow Test in Unprocessed and Processed State

% of NCA replaced by RCA	**M35 Grade of Concrete**					
	Unprocessed State		**Processed State (500 R)**		**Processed State (1000 R)**	
	T_{50} (sec)	Slump Diameter (mm)	T_{50} (sec)	Slump Diameter (mm)	T_{50} (sec)	Slump Diameter (mm)
0%	5	580	-	-	-	-
25%	5	600	4	700	4	680
50%	2	610	3	680	3	655
75%	4	600	2	720	3	705
100%	3	630	3	690	2	720

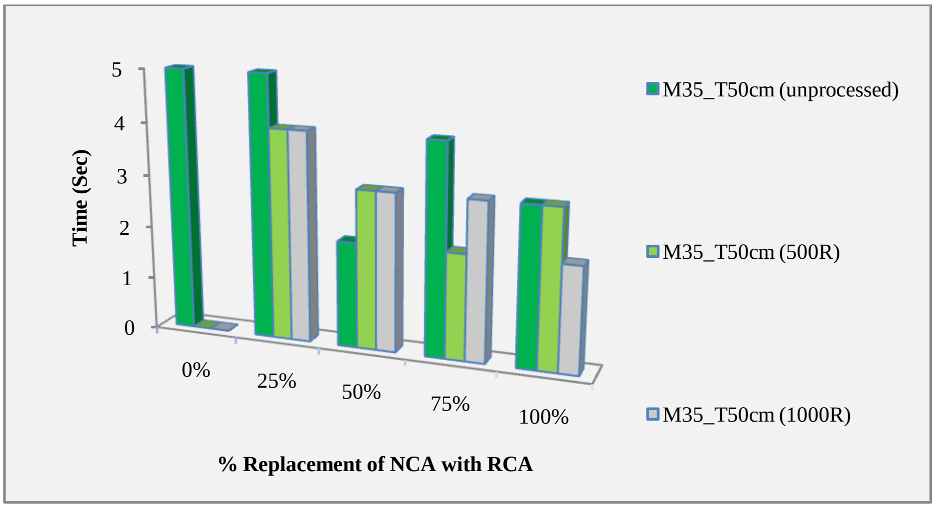

Fig 5: T_{50} values of Slump flow test for various replacement levels of RCA

B. V-Funnel Test

The V-funnel test is used to assess the segregation resistance of the concrete. The T_{5min} time of SCC is measured in Unprocessed and Processed State and is shown in Table-VIII. The time after 5 minutes is measured in V-funnel test i.e., T_{5min} values at various replacement levels of RCA in Unprocessed and Processed State is shown by bar chart representation in figure-7.

Fig 6: V-funnel test apparatus

Table VIII Results of V-Funnel Test in Unprocessed and Processed State

% of NCA replaced by RCA	M35 Grade of Concrete		
	Unprocessed State	Processed State (500 R)	Processed State (1000 R)
	T_{5mins}	T_{5mins}	T_{5mins}
0%	18	-	-
25%	20	19	19
50%	18	18	18
75%	15	15	15
100%	10	11	11

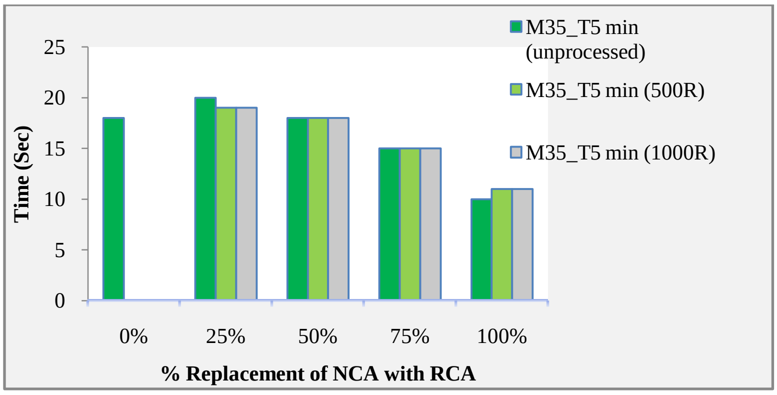

Fig 7: T_5min values of v-funnel test for various replacement values of RCA

C. L-Box Test

This test is used to assess passing ability of SCC. The concrete is allowed to pass through the reinforcing bars and blocking ratio (H2/H1) is measured. The blocking ratio of SCC at various replacement levels of RCA in Unprocessed and Processed State is shown in Table-IX. Results of L-Box Test in Unprocessed and Processed State is shown by bar chart representation in figure 9.

Fig 8: L-box test apparatus

Table IX : Results of L-box test in unprocessed and processed state

% of NCA replaced by RCA	M35 Grade of Concrete		
	Unprocessed State	Processed State (500 R)	Processed State (1000 R)
	Blocking Ratio (H2/H1)	Blocking Ratio (H2/H1)	Blocking Ratio (H2/H1)
0%	0.71	-	-
25%	0.71	0.75	0.76
50%	0.72	0.73	0.72
75%	0.70	0.74	0.74
100%	0.70	0.69	0.68

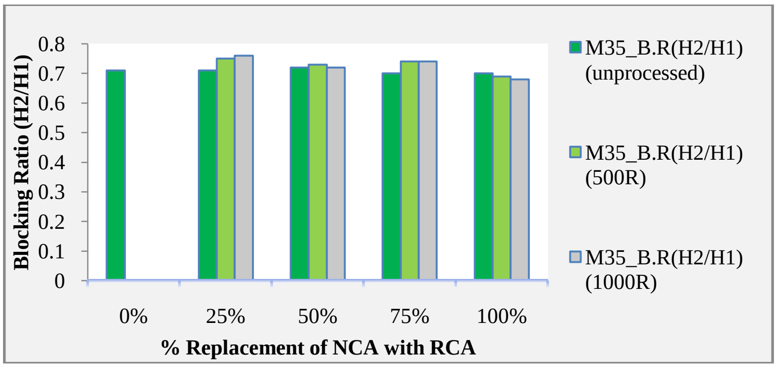

Fig 9:Blocking ratio values of L-box test for various replacement levels of RCA

TESTS ON HARDENED PROPERTIES OF SCC

A. Compressive Strength Test :

Compressive strength is carried on 150mmX150mmX150mm cube specimens with compression testing machine. The moulds for cubes are cleaned thoroughly. The inner surface of the mould is coated with a thin layer of oil to avoid adhesion of concrete with the walls of mould and the moulds are filled with SCC mixture and finished the surface with trowel. Cubes are demoulded after the SCC has hardened. After curing of specimens the compressive strength test was carried out.

Fig 10:Compressive strength test on cube specimen

The compressive strength of SCC at various replacement levels of RCA in Unprocessed and Processed State for 14 days and 28 days are shown in Table-X. The bar chart representation in figure-11 shows that there is an increase in compressive strength up to 50 percent replacement of RCA in Unprocessed and Processed State.

Table X: Compressive strength of cube specimens in unprocessed and processed state

% of NCA replaced by RCA	M35 Grade of Concrete					
	Unprocessed State		Processed State (500 R)		Processed State (1000 R)	
	Compressive Strength (N/mm2)		Compressive Strength (N/mm2)		Compressive Strength (N/mm2)	
	14 Days	28 Days	14 Days	28 Days	14 Days	28 Days
0%	31.35	36.07	-	-	-	-
25%	41.41	46.24	41.21	51.90	41.02	49.55
50%	42.68	50.86	43.41	52.61	42.79	51.32
75%	40.54	43.74	41.21	50.83	40.91	48.32
100%	32.55	36.91	38.35	45.18	37.61	44.90

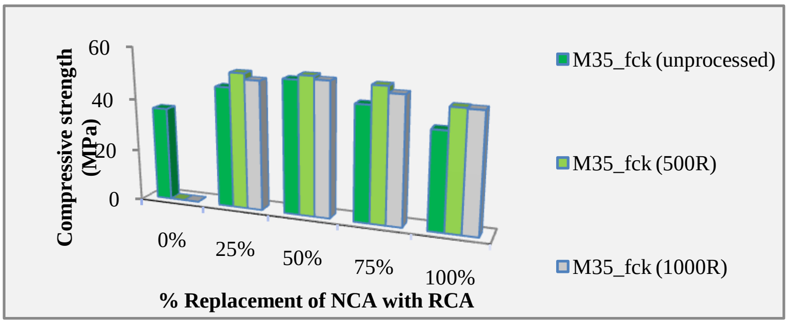

Fig 11: Compressive strength of SCC at various replacement levels of RCA

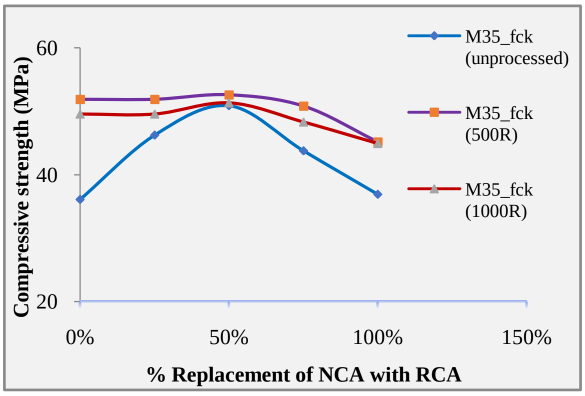

Fig12: Compressive strength of SCC at various replacement levels of RCA

B. Split Tensile Strength Test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. Split tension test for normal conventional concrete is an established fact. The present experimentation using RCA under self compacting conditions will become an important parameter from tensile strength point of view. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members shows crack. The Split Tensile Strength of SCC at various replacement levels of RCA in Unprocessed and Processed State for 14 days and 28 days are shown in Table-XI. The bar chart representation in figure-13 shows that there is an increase in Split Tensile Strength up to 50 percent replacement of RCA in Unprocessed and Processed State.

Table XI: Split Tensile Strength test for cylinders in unprocessed state and processed state

% of NCA replaced by RCA	M35 Grade of Concrete					
	Unprocessed State		Processed State (500 R)		Processed State (1000 R)	
	Split Tensile Strength (N/mm2)		Split Tensile Strength (N/mm2)		Split Tensile Strength (N/mm2)	
	14 Days	28 Days	14 Days	28 Days	14 Days	28 Days
0%	1.47	1.52	-	-	-	-
25%	1.61	1.75	1.80	2.90	1.73	2.71
50%	2.12	2.44	2.40	2.95	2.40	2.92
75%	1.66	2.40	2.12	2.67	2.02	2.80
100%	1.42	1.66	1.61	1.89	1.51	1.72

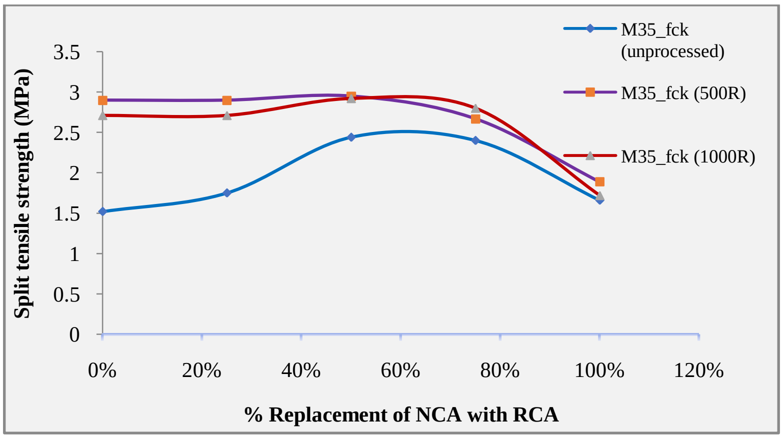

Fig13: Split tensile strength of SCC at various replacement levels of RCA

CONCLUSIONS

1. The fresh properties of SCC in processed state for 500 revolutions have shown better results compared to unprocessed state with respect to self compacting.
2. For SCC using processed (500, 1000 revolutions) and unprocessed RCA the optimum value of Compressive strength, Split Tensile strength is obtained at 50% replacement of NCA with RCA for 14 days and 28 days curing.
3. In M35 grade of concrete 100% replacement of NCA by RCA without sacrificing the compressive strength and split tensile strength when compared with conventional SCC.
4. By processing of RCA up to 500 revolutions the compressive strength and split tensile strength can be improved.

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