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Flexural Behaviour of Self Compacting Concrete Beams Modified using Recycled Concrete Waste Aggregates

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Abstract: This study presents an investigation on the flexural behaviour of normally vibrated concrete and self-compacting concrete beams subjected to loading tests. Seven specimens were cast to investigate the flexural behaviour. This experimental analysis mainly varied the parameters such as (1) Percentage of coarse aggregate replacement (RCWA), and (2) percentage of Steel fibres. Results are exhibited in terms of flexural strength, stiffness, failure modes, and deflection curves. The test results revealed that RCWA could be successfully used in SCC. The flexural behaviour of beam decreased with the addition of RCWA. However, the addition of RCWA in combination with SF in SCC significantly improved the overall flexural behaviour. Finite element model also developed to study the behaviour of beams produced by SCC with RCWA content.

Index Terms: SCC (Self Compacting Concrete), C&DW (Construction & Demolition Waste), Recycled waste concrete aggregate, crack pattern, deflection.

I. INTRODUCTION

SCC is a unique type of concrete which flows over the surface without any vibration. [1, 2, 3]. SCC has become an emerging technology in the construction sector due to its excellent behavioural properties like tensile parameters, ductility, and energy absorption [4, 5,6]. Complex structural shapes are easily constructed using SCC [7]. The mixture composition, raw materials, and strength characteristics of the SCC have made changes on properties, including bond, durability, and structural performance. A large amount of waste materials is produced by Construction and demolition activities. Globally 35% of construction and demolition waste (CDW) directed to dump, and the remaining 65% is reused. In this paper, an attempt to reuse the Concrete waste aggregate as coarse aggregate in SCC beams have been made. The influence of RCWA in SCC beams is studied with the help of rheological properties, crack pattern study and load vs. deflection curve.

II. MATERIALS & METHODS

Ordinary Portland Cement (OPC) of IS-8112(1989) was used in this investigation [8].

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Fly ash is the mineral admixture taken from the thermal power plant located in nearby area. Chemical properties of fly ash were tested. Locally available river sand with a maximum size of 4.75 mm conforming to grading zone II as per IS 383-1970 was used as a fine aggregate, and crushed granite stones of 10 to 12 mm were used as coarse aggregates [9].

The fresh and hardened properties of SCC strongly influenced by the chemical composition of mineral admixture. To enhance the workability properties of SCC, Conplast SP 430 was utilized in this investigation. RCWA of size 10 to 12mm obtained from the construction and demolition waste (C&DW) from the nearby locality was used as a replacement material to coarse aggregates. Normal water was used for mixing and curing process.

Table I Chemical composition of cement and fly ash

Chemical composition	Cement	Fly ash
CaO	61.20	22.92
SiO2	23.27	39.80
$Al2O_3$	3.56	10.54
Fe_2O_3	3.55	9.24
MgO	3.04	4.54
SO_3	-	3.09
K_2O	0.45	1.02
Na_2O	0.18	0.70

I. Mix proportion

Mix proportioning of the control mixes were achieved by adopting the guidelines given in IS456 -2000. The SCC mixture was proportioned using cementitious materials consisting of ordinary Portland cement and Class C fly ash attain an optimum characteristic compressive strength of 37.5 N/mm^2. To obtain an optimum SCC mix, the proportions of fine and coarse aggregates and dosages of cement, SF were carefully proportioned.

III. EXPERIMENTAL INVESTIGATION

A. Flowability and Passing ability tests

To measure flowability and passing ability, tests such as slump flow, V-funnel, L-box, and J-ring tests were conducted. Table II shows the results of the fresh state tests. The values of (D) and T500 represents the slump flow diameter and Time. The Indian Guidelines were followed to test self-Compacting Concrete (IS 516: 1959). The prepared mixes were tested within 15 minutes to avoid loss of workability with respect to time. The slump values range from 705–735 mm, T500 Sec time varied from 1.99 s to 4.17 s and the V-funnel time varied from 8.23 s to 11.05 s. The designed SCC exhibited favourable formability and flowability.

Figure1 V-Funnel Test Setup

Figure2 Slump flow test

Figure3 L-Box Test Setup

Figure4 J-Ring Set up

II. Hardened state tests

Cube moulds were cast to obtain compressive strength values of SCC specimens with size of 150×150×150 mm as per IS: 516, Cylindrical specimens with the size of 150×300 mm were cast to attain the values of split tensile strength, whereas flexural strength was obtained using beam mould of 150×150×450 mm as per IS: 516. As shown in Table III each mix is designed to study the effects of RCWA and steel fibre in concrete mechanical properties. The hardened state properties were measured after 7, 14 and 28 days of curing.

Table II Test results of Fresh State test

MIX ID	Fresh state test				
	Slump flow		J-ring (mm)	L-Box (mm)	V- Funnel (Sec)
	D (mm)	T_{500} (Sec)			
NSCC	735	1.99	7.0	1.1	8.23
RC1	724	2.05	7.3	0.95	8.79
RC2	728	2.47	7.5	0.93	9.05
RC3	725	2.98	8.2	0.88	9.19
RCSF1	716	3.09	8.5	0.85	10.13
RCSF2	711	3.20	9.2	0.84	10.47
RCSF3	705	4.17	9.9	0.80	11.05

Table III Test results of Hardened State test

	Hardened state test								
Mix ID	**Compressive strength (N/mm²)**			**Flexural strength (N/mm²)**			**Split tensile strength (N/mm²)**		
	7D	**14 D**	**28 D**	**7 D**	**14 D**	**28 D**	**7 D**	**14 D**	**28 D**
NSCC	18.23	24.39	37.32	2.33	3.17	3.25	1.74	2.47	2.77
RC1	17.57	21.03	34.25	2.27	2.37	3.07	1.67	2.15	2.66
RC2	14.49	18.60	28.07	2.17	2.47	3.17	1.51	2.09	2.60
RC3	11.13	15.27	25.19	2.04	2.67	2.67	1.57	2.03	2.47
RCSF 1	16.70	22.13	35.35	2.47	2.53	3.12	1.79	2.30	2.60
RCSF 2	16.45	20.06	30.05	2.25	2.25	3.17	1.67	2.32	2.47
RCSF 3	13.17	17.19	27.27	2.37	2.59	3.31	1.89	2.37	2.63

III. Test on Beams

The SCC beams were tested using the 500kN capacity testing machine at the age of 28 days. Four-point bending configuration is utilized to test the flexural strength of SCC beams. The beams constructed using SCC with RCWA was aligned carefully in the testing machine. A four-point load was applied to the beam and the deflection at the centre and one-third distance from the right and left support was measured by using dial gauges.

Table IV Load and Deflection at Salient Stages

Sl. No	Specimen Designation	First Crack Load (kN)	Ultimate Load (kN)	Deflection at first Crack (mm)	Ultimate Deflection (mm)	ANSYS Results
1	NSCC	30	58.20	1.98	20.23	20.43
2	RC1	33.3	65.15	1.39	18.10	18.06
3	RC2	28.12	60.33	1.72	18.36	18.37
4	RC3	31.26	62.47	1.85	19.44	19.48
5	RCSF1	29.15	56.87	1.45	17.25	17.23
6	RCSF2	31.22	59.23	1.63	18.66	18.67
7	RCSF3	28.98	58.66	1.39	17.94	17.95

The applied load was increased at a uniform rate, and the deflection of the beam due to the applied load was determined until the beam finally fails. The deflection due to the load applied is observed by using Linear Variable Displacement Transducers (LVDT). This loading procedure is continued until the beam failure. Load and corresponding deflection values are recorded in the table IV.

Figure5 Casting beam specimen

Figure6 Curing beam specimen

IV. RESULT AND DISCUSSION

A. Crack Pattern Study

The comparison made between SCC with RCWA beams and normal SCC beams from the comparison results it is evident that the RCWA content strongly influences the timing of the first crack and the performance of beams subjected to load. Normally average cracking moment is present over the beams during the initial stages of loading. When the tensile stress applied to SCC beams less than its tensile strengths, then the beam is capable of resisting flexural moment. Further increase in loads causes vertical cracks. Normally, flexural cracks initiated the cracking in SCC beams. These cracking appeared out of the flexural zone. Further increase in load causes shear cracks which appeared at the diagonal areas of beam. The loading of the test increases these types of cracks developed until the ultimate failure of the beams. Crack patterns and the cracking models of the tested beams were observed. These patterns and values indicate that the ultimate load values are same. Shear cracking are less in SCC with RCWA compared to normal SCC beams. Usage of RCWA in SCC beams enhanced the mechanical performance of beams in terms of its flexural cracks and the width of the cracks.

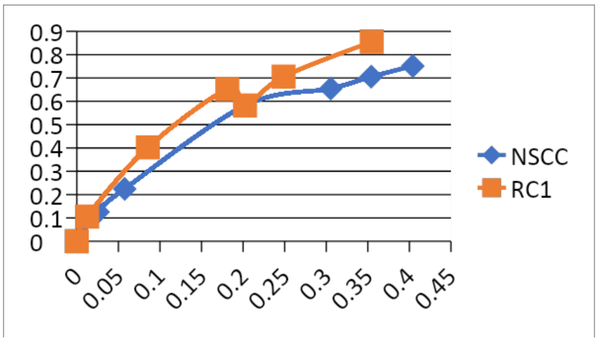

Fig7 Load Vs Deflection for NSCC& RC1

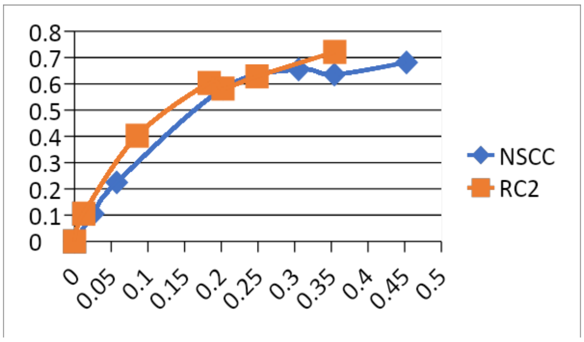

Fig 8 Load Vs Deflection for NSCC& RC2

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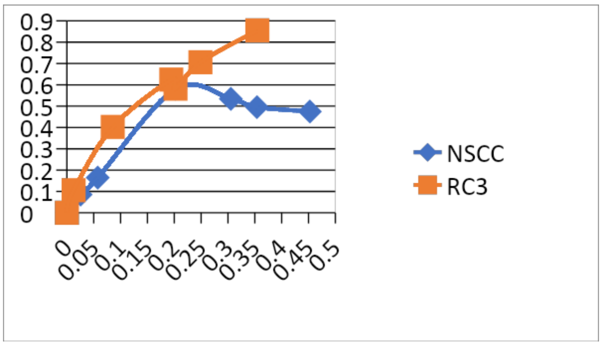

Fig 9 Load Vs Deflection for NSCC& RC3

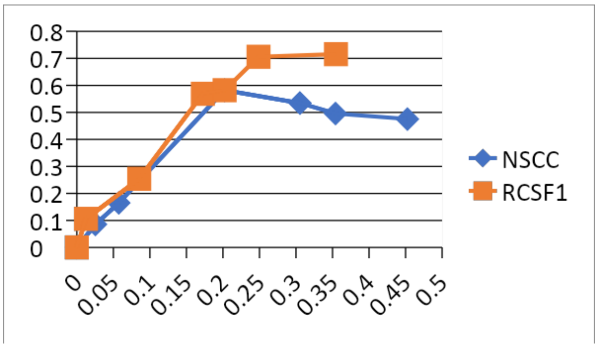

Fig 10 Load Vs Deflection for NSCC& RCSF1

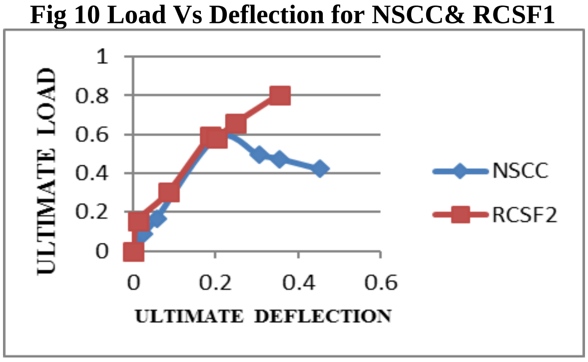

Fig 11 Load Vs Deflection for NSCC& RCSF2

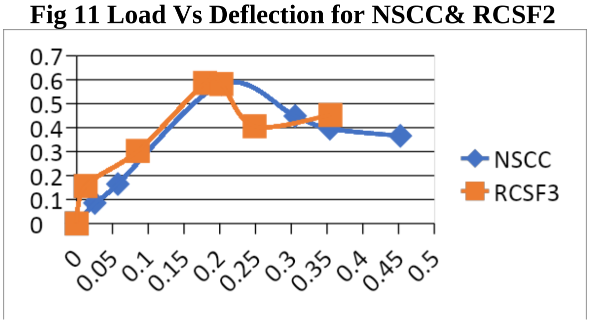

Fig 12 Load Vs Deflection for NSCC& RCSF3

V. ANSYS RESULTS

Finite element modelling is developed using ANSYS software. Total deformation of the beams was recorded in various loads applied over the beams. The results are coincided with the experimental values and this provides the proper understanding of using RCWA in SCC mix while producing beam structures. Fig 13 -19 shows the deflection of beams.

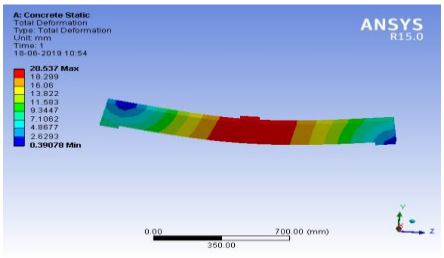

Fig 13 Deflection of NSCC

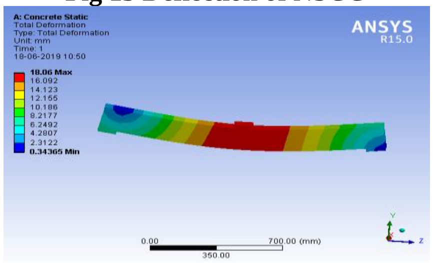

Fig 14 Deflection of RC1

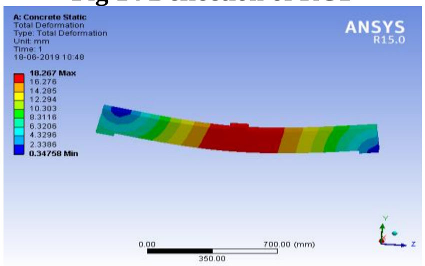

Fig 15 Deflection of RC2

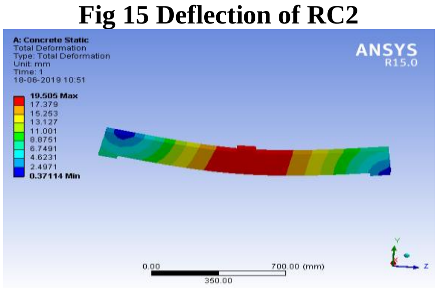

Fig 16 Deflection of RC3

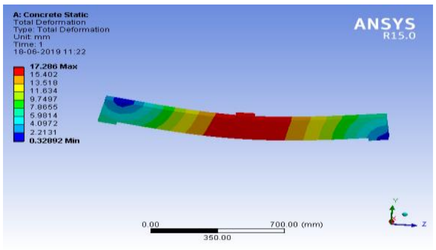

Fig 17 Deflection of RCSF1

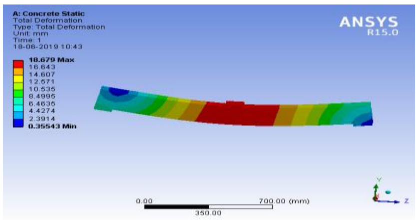

Fig 18 Deflection of RCSF2

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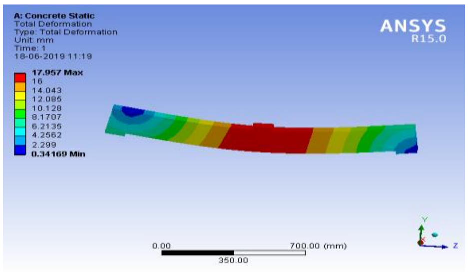

Fig 19 Deflection of RCSF3

IV. CONCLUSION

The experimental results have shown the beneficial effects of using recycled waste concrete aggregate in Self Compacting concrete. Recycled concrete waste aggregate contents limited from 30% to 50%. In which 30% of RCWA content in SCC mix beam have shown better mechanical performance in terms of compressive, flexural and split tensile strengths. From the test results it is evident that the inclusion of RCWA in SCC beams significantly reduces the shear cracking in SCC beams and enhanced the mechanical performance of beams in terms of its flexural cracks and the width of the cracks. Addition of hybrid steel Fibres also increased the mechanical behaviour of beams.

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