STUDY ON PROPERTIES OF RECYCLED AGGREGATE CONCRETE WITH HYBRID FIBRES AT LOW VOLUME FRACTIONS

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ABSTRACT: For sustainability considerations, the use of recycled aggregate from construction and demolition waste as a replacement of normal coarse aggregate has been increased in recent years to reduce the heavy usage of natural sources in the construction sector. The use of recycled aggregate in concrete has attracted many interests in the research studies as there is reduction in the consumption of coarse aggregate. In this study normal coarse aggregate is replaced with recycled aggregate in the proportions of 20%, 30%, 40% and 50% and for each proportion hybrid fibres are added to the recycled concrete to form hybrid fibre reinforced recycled aggregate concrete upto 1% of total volume. These hybrid fibres formed from a combination of various varieties of fibres which have varied material properties, when added in concrete stay bonded with it and retain their properties. Workability of fresh concrete for each mix of varied proportions is carried out by finding the slump using slump cone test. In this paper the strength characteristics such as flexural strength, compressive strength and split tensile strength are evaluated for each proportion of replaced aggregate and hybrid fibres and are compared with control mix concrete.
Keywords: Hybrid fibre, recycled coarse aggregate, compressive behavior and mechanical properties.

I. INTRODUCTION

Concrete materials being used in construction abundantly, in order to reduce the consumption of construction materials. Many researches have been carried out to replace these materials fully or partially. Many recent studies proposed the use of recycled aggregates which are obtained from demolished concrete waste. The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. Recycled aggregate posses high rate of water absorption as compared to normal aggregate because of presence of layers of cement paste previously over aggregate. The recycled aggregate generally meets all the standard requirements of aggregate used in concrete. De Brito and Miguel[1] mentioned that higher replacement levels of recycled coarse aggregate, there is considerable reduction in the compressive strength and various properties like young's modulus compared to normal aggregate concrete. Poon and Kou[2] reported that more than 50% replacement level of recycled aggregate leads to significant decrease in strength. So in this study maximum replacement level of recycled aggregate is restricted to 50%. Even though small replacement level of recycled coarse aggregate gives optimum results, for comparative study proportions of 20%, 30%, 40% and 50% have been carried out in this study. Yong-chang Guo[3] mentioned that it is not fusible that recycled aggregate concrete gives more strength than that of normal concrete, but it can be enhanced by addition of hybrid fibres. In each proportion hybrid fibres are added on volume basis and the maximum percentage of fibres are restricted to 1 % of total volume of concrete. The constituents used in hybrid fibres are polypropylene and hooked-end steel fibres and the combinations of both fibres are mentioned in Table-1 According to Kou SC[4] that the negative result of RCA on durability can be mitigated by adding a definite quantity of hybrid fibres with water reducing admixtures. Jianzhuang Xiao[5] found that on the average, the 56-day cube strength was 5% and 3% higher than the 28-day strength for RAC and NAC, respectively. Hence, the present research program aimed at generating experimental data and mechanical properties necessary for characterizing the behavior of recycled aggregate concrete with hybrid fibres.

II. EXPERIMENTAL PROGRAM

A total of 5 sets of concrete mixes were carried out and mix design was calculated for M25. In each set there are 4 types of combinations of fibres were added as mentioned in Table-1. After the optimization of RCA concrete mix the suitable fibre combination was found out and for that combination of mix split tensile and flexure strength tests were conducted.

A, Constituent materials:

- Ordinary Portland cement used and grade of concrete is 53grade.
- Naturally sourced river sand conforming to zone-2 was used in the entire study.
- Natural coarse aggregate with maximum particle size of 20mm was used.
- Recycled Coarse Aggregate: The Recycled coarse aggregate was used in this study are of size ranging from 10mm to 30mm.The water absorption capacity of recycled aggregate was found to be 4.21% which is relatively high when compared to 0.9% of natural coarse aggregates.
- Steel Fibre: The fibre used in this entire study was hooked-end steel fibre of length of 30mm, aspect ratio (l/d) 60 and tensile strength of 600Mpa.
- Polypropylene Fibre: The length of PP fibre is

20mm and having the tensile strength of 350Mpa.

III. MIX PROPORTIONING

The design mix was obtained by using IS 10262:2009 and the mix proportions are mentioned in Table-1. The grade of concrete M25 was adopted to entire study and the mix proportions are 1:1.6:2.49 (C: FA: CA) with 0.45 W/C ratio.

Table-1: Mix proportions (kg/ m^3)

MIX-ID	CEMENT	FA	NCA	RCA	W/C	SP
CC	437	841	1091	0	197	1%
S-20	437	841	873	218	197	1%
S-30	437	841	764	327	197	1%
S-40	437	841	655	436	197	1%
S-50	437	841	546	546	197	1%

Note: RCA= Recycled coarse aggregate, S-20, S-30, S-40 and S-50 for weight substitution ratio of RCA is 20%, 30%, 40% and 50%, FA= Fine aggregate, NCA= Natural Coarse aggregate, W/C= Water cement ratio, SP= Super Plasticizer, SF= Steel fibre, PPF= polypropylene fibre, CC= Control Concrete

IV. DETAILS OF SPECIMEN PREPARATION

A total 5 sets of concrete mixes were designed and prepared. In each set there are 4 different combinations of fibre are added so totally 20 mixes were prepared as mentioned in Table-2. The natural coarse aggregate was added in the first concrete mix as a control concrete(CC), while in the remaining 4 mixes are replaced with recycled coarse aggregates up to 20%, 30%, 40% and 50%. In each mix hybrid fibres are reserved up to 1% of total volume basis and the constant water cement ratio of 0.45 is maintained throughout the mixes. An addition of 4% water by weight of recycled coarse aggregate was added to the all concrete mixes except control concrete to cater for the more consumption of water. The workability of fresh concrete was measured by slump cone test for each mix during casting. The slump value was maintained in the range of 80mm to 100mm by adding 1% of super plasticizer by weight of cementcontent.

Table-2: Compressive strength values of total mixes for 7 & 28 days (MPa)

SETS	MIX ID	Recycled Coarse Aggregate	Normal Coarse Aggregate	Steel Fibre (V_f)	PP Fibre (V_f)	7-days	28-days
CC	M-1	0%	100%	1.0%	0%	33.7	49.8
	M -2			0.9%	0.1%	28.7	44.2
	M -3			0.8%	0.2%	25.1	39.4
	M-4			0.7%	0.3%	22.8	35.2
SET-20	M -5	20%	80%	1%	0%	30.4	47.6
	M -6			0.9%	0.1%	27.3	42.3
	M -7			0.8%	0.2%	24.7	37.8
	M -8			0.7%	0.3%	21.8	32.9
SET-30	M -9	30%	70%	1.0%	0%	28.7	43.8
	M -10			0.9%	0.1%	25.1	39.4
	M -11			0.8%	0.2%	23.9	35.4
	M -12			0.7%	0.3%	19.7	30.4
SET-40	M -13	40%	60%	1.0%	0%	26.5	40.0
	M -14			0.9%	0.1%	23.3	36.2
	M -15			0.8%	0.2%	20.7	31.5
	M -16			0.7%	0.3%	18.5	27.7
SET-50	M -17	50%	50%	1.0%	0%	24.5	37.1
	M -18			0.9%	0.1%	22.4	33.9
	M -19			0.8%	0.2%	19.9	29.8
	M -20			0.7%	0.3%	23.2	26.3

V. TESTS AND SPECIMEN PREPARATION

The following parameters were studied to figure out the influence of recycled aggregates on durability of concrete

A. COMPRESSIVE TEST:

Compressive test was carried out in 6 standard cubes of each having volume of 100mmx100mmx100mm were casted for each mix. The procedure of preparing the concrete mixture was as follows: coarse aggregates, fine aggregate, cement

and remaining fibre materials were placed in the mixture. The machine was then started to mix them for 2 min before water and super plasticizer were added. The mixer machine was then run for further 3 min to produce the fresh concrete of evenly dispersed materials. Slump cone test was carried out to maintain constant slump value and then specimens were casted. After demolding of specimens the casted cubes were immersed in water for curing until the testing age of 7 and 28-days.

B. SPLIT TENSILE TEST:

Split tensile test was carried on small cylinders of 100mm diameter and 200mm length using compressive testing machine of 2000KN capacity across the diameter along its length till the cylinder splits. Total 4 mixes were prepared by replacing recycled coarse aggregates with 20%, 30%, 40% and 50% each mix having 0.8%-SF and 0.2%-PPF.

C. FLEXURAL STRENGTH:

Flexural test was carried on beam specimens of having dimensions of 100mmx100mmx500mm. Total 4 mixes were prepared and flexural strength was calculated by taking area under the load-deflection curve after peak stress. The flexural strength test was done after 28-days of curing

VI. EXPERIMENTAL TEST RESULTS

Results of Compressive strength, flexural strength and split tensile strength for M25 grade of concrete on specimens with 0.8%- SF, 0.2%- PP fibre are mentioned in Table-3

Table-3: The 28-day strength results of compressive, split tensile and flexural strength are

MIX-ID	Compressive Strength(MPa)	Split tensile strength(MPa)	Flexural Strength(MPa)
CC	25.4	4.1	5.7
S-20	21.5	3.9	5.6
S-30	16.5	3.6	5.3
S-40	18.3	3.2	4.8
S-50	17.4	3.0	4.6

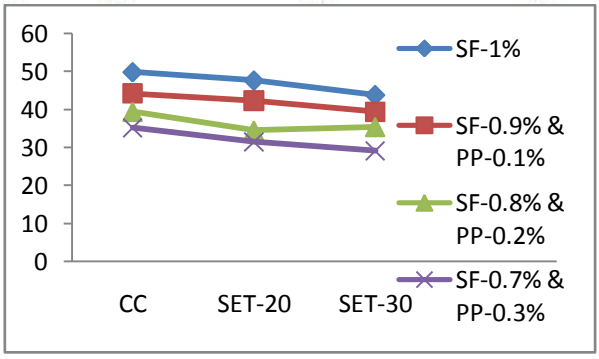

Fig (1). 28-Day Compressive strength values of S-20 and S-30.

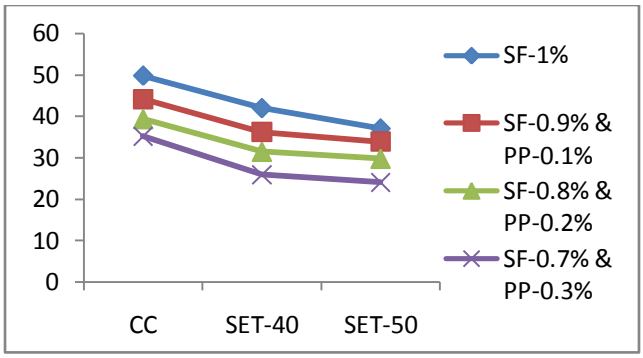

Fig (2). 28-Day Compressive strength values of S-40 and S-50.

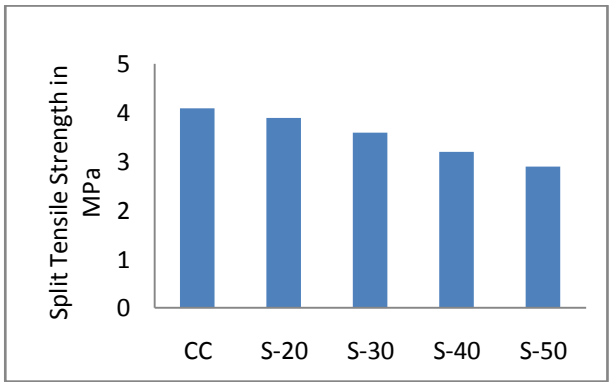

Fig (3). Split tensile strength at 28 days

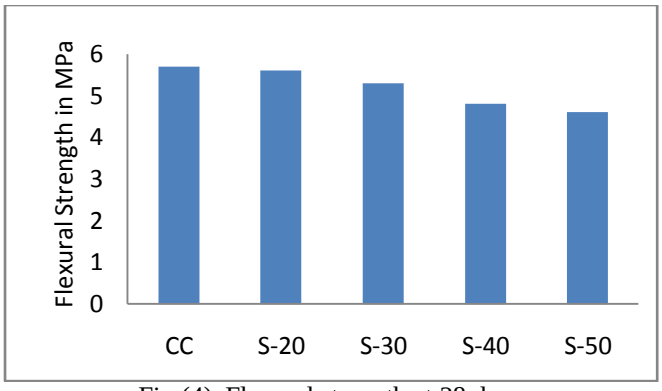

Fig (4). Flexural strength at 28 days

A. COMPRESSIVE STRENGTH

The compressive strength test was carried out on total 60 cubes. By increasing the percentage of the recycled aggregates there is little decrease in compressive strength was observed and the mean values of strength of all mixes are mentioned in Table-1.This indicates all the composites affect the compressive strength of the concrete. The utilization of hybrid fibres has, however, a higher effect than the use of recycled coarse aggregate. In this study the use of recycled aggregate in replacement ratios ranging from 20% to 50% and found that up to replacement level of 30% the reduction in the compressive strength of the natural aggregate concrete is not significant. The strength reduction with the replacement of 30% recycled aggregate leads to 8.3% while the replacement of 50% leads to 33.6% reduction. Hence, the optimum replacement of recycled

aggregates should be confined to 30% for better results in comparison to control concrete. The obtained test results for the test are specified in the Fig (1) and Fig (2). By observing the compressive strength characteristics of 20 mixes the result of cubes with 0.8% steel fibre and 0.2% PP fibre shows good results as to control concrete. So the remaining mechanical properties of split tensile test and flexural test were carried out with 0.8%, 0.2% of SF and PPF respectively.

Replacement Level	20%	30%	40%	50%
% Strength reduction	15.2%	21%	30.1%	31.8%

B. SPLIT TENSILE STRENGTH

The spilt tensile strength of the proportion- SF-0.8%, PPF-0.2% and up to 50% replacement level of recycled aggregate which shows considerable values in strength. Improved tensile strength will be achieved by increasing the proportion of steel fibres. The increase in the PP fibre content will result in the high stiffness of steel fibres and improved performance in split tensile strength. The obtained test results for the test are specified in the Fig (3). The strength reduction with the replacement of 30% recycled aggregate leads to 12.2% while the replacement of 50% leads to 26.3% reduction. Split tensile strength of recycled concrete was lower than that of control concrete, the minimum reduction in strength is about 4.9% for 20% replacement and maximum reduction being about 26.3% for 50% replacement.

Replacement Level	20%	30%	40%	50%
% Strength reduction	4.9%	12.2%	22%	26.3%

C. FLEXURAL STRENGTH

Experimental results which evaluated the effects of hybrid fibre addition on the flexural strength of hardened recycled aggregate concrete can be observed in Fig (4). Hybrid fibre addition consequently leads to significant improvement on the flexural strength when the concrete mix is added with the combination of 0.8%SF and 0.2% PPF.

Replacement Level	20%	30%	40%	50%
% Strength reduction	2.76%	7.02%	15.7%	19.3%

VII. CONCLUSIONS

- Acceptable strength results was observed in SF0.8% and PPF0.2%, i.e., 80% of steel fibre and 20% of polypropylene fibre because of high elastic modulus of steel fibre and low elastic modulus of PPF work in perfect combination.
- 30% Replacement of recycled coarse aggregates shows considerable results when compared to the control concrete.
- The compressive strength reduction with the replacement of 30% recycled aggregate leads to 12.5% while the replacement of 50% leads to 25% reduction.
- Split tensile strength of recycled concrete was lower than that of control concrete, the minimum reduction in strength is about 4.9% for 20% replacement and maximum reduction being about 26.3% for 50% replacement.
- The reduced Flexural strength of recycled aggregate concrete was about 2.76% for 20% replacement and maximum reduction being about 19.3% for 50% replacement.
- By observing the test results of hardened concrete properties the effect of RCA was higher on split tensile strength compared to compressive and flexural strength.
- Concrete with shorter fibre has better workability as compared to longer fibre when it is mix with water reducing admixtures.

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