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Research Article

STRENGTH PROPERTIES OF SELF-COMPACTING CONCRETE PREPARED WITH RECYCLED COARSE AGGREGATE AND MANUFACTURED SAND

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A B S T R A C T

There is great demand in the construction industry to adopt new processes which have negative impact on the environment. This paper presents the utilization of recycle coarse aggregate and manufactured sand on the strength properties of self compacting concrete (SCC). SCC mixtures were prepared with different replacement levels of recycle aggregate and Msand with a Water/Binder ratio of 0.36. Fresh properties and mechanical properties of these SCC mixtures were tested and the results were compared with EFNARC guidelines and also with past literature papers. Combining these two materials in production of SCC presents environment and economic advantages of using these materials leading to an new material which can be used in construction industry.

INTRODUCTION

In the recent years waste produced by construction industry and the consumption of natural aggregate has increased significantly. Due to environmental and economic crisis, the construction industry requires a different approach in terms of sustainable development. One of the high potential solutions is to use of recycled aggregates to produce new concrete. It will solve the problems like transportation and dumping of construction wastage and also reduce the consumption of natural aggregates. So it is proposed to utilize recycled coarse aggregate and manufactured sand in producing self compacting concrete (SCC) which is termed as a different kind of concrete having good deformability, segregation resistance as it will flow under its own weight and fill the form work even in congested reinforcement. Also it will have good characteristics like high fluidity and good segregation resistance. Based on IS 10292 [1] and EFNARC [2], Self Compacting Concrete can be produced by conducting tests like slump flow, T50 Slump, V-funnel and L-box, U-box.

Coirnaldesi *et al* [3] produced recycled aggregate SCC with 100% recycled coarse and fine aggregate with varying w/c ratio between 0.35-0.40. They concluded that there is increase in compressive strength due to retardment of pozzolanic activity.S.C.Kou and C.S.Poon [4] developed SCC with coarse and fine recycled aggregates with 100% coarse recycled aggregates and several percentages of fine recycled aggregates. They found that highest compressive strength is observed for 25% and 40% recycled aggregates and increase in split tensile strength due to the presence of fly ash .

Three types of recycled aggregate SCC were studied by Grdic *et al* [5] with different replacement percentages by 0,50 and 100% recycled aggregate in natural aggregate. Recycled aggregate were taken from a 40 year old bridge. They reported all the mixes develop strength up to 90% in 7 days and concluded strength decreases slightly as the replacement ratio increases.

Five types of recycled aggregate SCC were produced by Safiuddin *et al*. [6] with different replacement percentages of recycled aggregate. They achieved 50 MPa compressive strength with w/c of 0.40 with coarse recycled aggregate of 6 months old concrete cubes.

Pereira-de-Oliveria [7] studied four types of SCC with different percentages replacement of recycled aggregates. They found slight reduction in compressive strength and concluded that coarse recycled aggregate did not significantly influence the mechanical strength.

Prakash Nanthagopalan and Manu Santhanam [8] used manufactured sand in producing self compacting concrete. Fines of Msand contribute increase in paste volume which is useful in development of SCC.

Six types of recycled aggregate SCC with different percentage replacement of recycled aggregates were studied by Modani and Mohitkar [9]. They concluded there is slight reduction in compressive strength as the ratio of replacement of recycled

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aggregate increases. This may be due to the presence of non – hydrated cement in recycled aggregate which contributes to strength increase in the early ages and fading out over time.

S.Santos *et al* [10] have reported a complete and updated review on the properties of SCC produced with fine and coarse recycled aggregates. They observed the performance of SCC with recycled aggregates depend on the replacement ratio of natural aggregate and the inherent quality of recycled aggregate. They concluded that the use of recycled aggregate in SCC is viable and justified but it is necessary to take some precautions on the performance of concrete required in each case.

It can be observed from the literature, limited work has been done on Self compacting concrete produced with recycled coarse aggregate and M Sand. So in the present research it is aimed to study the strength properties of SCC with locally available demolished recycled coarse aggregate and M Sand.

Experimental Study

Materials

In this research, OPC with 53 grade corresponding to IS code12269: 1987 and class F fly ash according to ASTM: C 618 were used as the cementitious material in SCC mixtures. The chemical and physical properties of cement and fly ash are shown in Table (I and II) and III respectively.

Table I Chemical Composition of Cement

Constituent (%)	*Value*
SiO_2	19.79
Al_2O_3	5.67
Fe_2O_3	4.68
CaO	61.81
MgO	0.84
SO_3	2.48
Chloride	0.003
Lime Saturation Factor (LSF)	0.92
Alumina / Iron Oxide	1.21

Table II Physical properties of Cement

Parameter	*Value*	*Acceptable range*	*I.S Code*
Specific Gravity	3.05	-	IS 4031 (1988) – Part 1
Fineness (m^2/kg)	310.5	Min 25 m^2/kg	
Normal Consistency	31%	-	IS 4031 (1988) – Part 4
Initial Setting Time (min)	60	Min 30 min	IS 4031 (1988) – Part 5
Final Setting Time (min)	210	Max 60 min	IS 4031 (1988) – Part 5
Soundness mm	1.0	< 10 mm	
Compressive Strength (MPa)			
3 days	28	27	IS 4031 (1988) – Part 6
7 days	38	28	
28 days	58	53	

Natural Coarse aggregate and recycled coarse aggregates from local demolished building waste were used. Natural river sand as fine aggregate and manufactured sand were used. The properties of the aggregates were shown in Table IV. Polycarbolic ether super plasticizer a chemical based admixture was used to achieve good workability in this research. For mixing and curing of concrete, locally available potable water is used.

Table III Chemical and physical properties of fly ash

Constituent (%)	*Value*
Chemical Properties	
SiO_2	65.6
Al_2O_3	28.1
Fe_2O_3	2.9
CaO	0.95
MgO	1.55
SO_3	0.21
Ignition Loss	0.28
Physical Properties	
Fineness (m^2/kg)	360
Relative Density	2.13

Table IV Physical properties of coarse aggregate and fine aggregate

Sl.no	*Property*	*Coarse aggregate*		*Fine aggregate*	
		NCA	*RCA*	*River sand*	*M sand*
1	Specific gravity	2.66	2.52	2.58	2.46
2	Bulk density (kg/m^3)				
	i) Loose	1360	1200	1600	1620
	ii) Compacted	1500	1350	1800	1820
3	Water absorption (%)	053	5.06	0.95	1.20

Mixture Proportions

Three series of SCC mixtures with different replacement levels of recycled coarse aggregate and M-Sand with fixed water to binder ratio were prepared. In all the concrete mixes cement and fly ash were kept constant at 351 kg/m^3 and 150 kg/m^3 respectively. The recycled coarse aggregate (RCA) and M-Sand were replaced in natural coarse aggregate (NCA) and fine aggregate by 0,25,50,75 and 100%.

In series –I, five SCC mixtures were prepared with the w/b ratio of 0.36 for all the concrete mixtures. The recycled coarse aggregate are used as 0,25,50,75 and 100% by volume replacement of natural coarse aggregate keeping M-Sand as constant replacement at 0%. In series–II, five mixtures were prepared with replacement of M-Sand by fine aggregate, keeping coarse aggregate as constant replacement at 0%. In series–III, both natural coarse aggregate and fine aggregate were replaced with recycled coarse aggregate and M-Sand by 0,25,50,75 and 100%.

TEST METHODS

SCC produced with recycled coarse aggregate and Msand were confirmed with ERNARC guidelines and found satisfactory, Nirmala et al. [11].

Compressive Strength

The compressive strength test up for testing the cubes in 2000 kN capacity compression testing machine with a least count of 1kN is shown in Figure 1. The cube was placed in the compression testing machine and the load on the cube is applied at a constant rate till to failure of the specimen and the corresponding load is taken as ultimate load. Then cube compressive strength of the mix is calculated by knowing the ultimate load.

Fig 1 Compressive Strength Test Setup

Split Tensile Test

This split tensile test is also conducted on the same compression testing machine and it is presented in Fig 2. The cylinder is placed in the compression testing machine on the bottom plate of the compression testing machine and aligned in such a way that the center lines marked on the ends of the specimen are vertical. Then the top plate of the machine is brought into contact at the top of the cylinder and the load is applied at uniform rate until the cylinder fails and same load is taken in to account as ultimate load and from this load, the splitting tensile strength is analyzed for each specimen.

Fig 2 Split Tensile Test Setup

Analysis of Test Results and Discussion

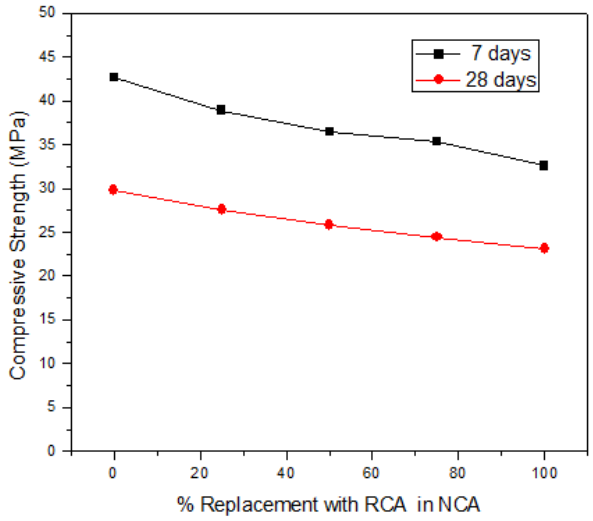
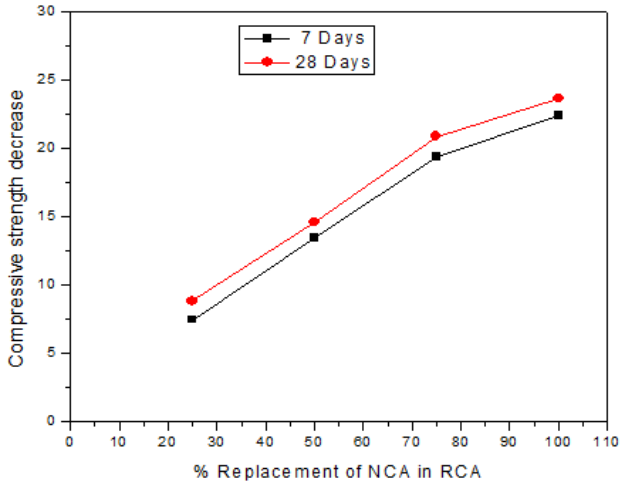


Fig 3 a) Compressive strength Vs % replacement of RCA



b) Compressive strength decrease Vs % replacement of RCA

The test results of compressive strength results are plotted in Fig 3 to Fig 5.

Compressive strength of RCA in NCA concrete mix with 0% M-Sand

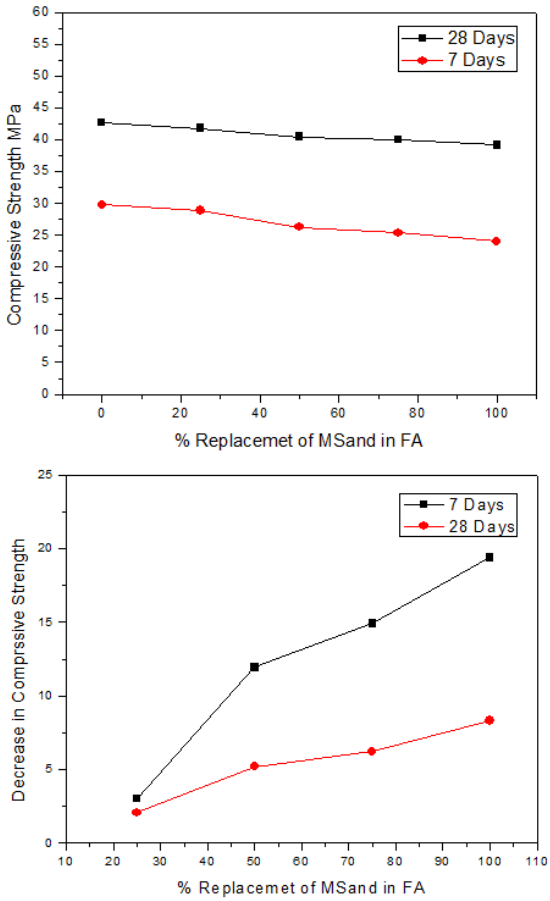


Fig 4 a) Compressive strength Vs % replacement of Msand
b) Compressive strength decrease Vs % replacement of Ms and

The cube compressive test results of recycled coarse aggregate replaced in natural coarse aggregate was shown in Fig No 3. From test results of compressive strength, it is noticed that as the replacement of recycled aggregate increases the ultimate compressive strength decreases continuously (Fig No 3). From the literature review similar results are noticed by the other researchers also. In the present research the mix, R0M0 compressive strength is taken as reference mix for all the

mixes. The first letter R indicates recycled aggregate, second letter indicates % of recycled coarse aggregate in natural coarse aggregate, the third letter M indicates Manufactured sand and fourth letter indicates % replacement of fine aggregate with Manufactured sand. The 28 days strength of the mix with 100% RCA in NCA is found to be 32.58 N/mm^2. As per IS 456 :2000 the standard grade of concrete ranges from M25 and the mix with 100% RCA value is above so the present research can satisfy for M25 grade concrete also. It is seen that the compressive strength of cubes having 100% NCA has the compressive strength and the compressive strength decreases with increase in recycled coarse aggregate replacement ratio in 7 days and 28 days. This may be due to the quality of recycled aggregate is inferior than natural aggregate. The % decrease in compressive strength for 7 days with respect to R0M0 are 7.45, 13.43,19.38 and 22.37% for 25,50,75 and 100% replacement of recycled coarse aggregate (Fig No3) . The % decrease in compressive strength for 28 days with respect to reference mix are 8.86,14.58,20.83 and 23.62 % for 25,50,75 and 100% replacement of recycled coarse aggregate.

Compressive strength of M-Sand replacement in FA with 0% replacement of recycled aggregate

The compressive test results of replacing M sand in fine aggregate was shown in Fig No 4. In this research the fine aggregate was replaced by M-Sand in variations of 0,25,50,75 and 100% and the percentage of recycled aggregate is taken as 0%. From test results of compressive strength it is observed that the replacement of M-Sand increases the ultimate compressive strength decreases continuously. The 28 days mix strength of 100% M-Sand in SCC is found to be 29.77 N/mm^2 and it is seen that the compressive strength of cubes is decreasing with the increase of M-Sand replacement in fine aggregate. This may be due to the reason that the crushing process of M-Sand affects the shape and grading of M-Sand and the proportion of micro fines may be not the same as fine aggregate. The % decrease in compressive strength for 28 days with respect to R0M0 are 2.08, 5.20, 8.86, 6.23 and 8.32 % for 25,50,75 and 100% replacement of recycled coarse aggregate. The present investigation was done to use the possibility of replacing 100% sand by M-Sand. By using Msand, the water demand may increase because of high fines in it, however the fines in M-Sand contribute to increase in paste volume which is useful in developing of SCC.

Compressive strength of recycled coarse aggregate concrete and replacement of M-Sand in fine aggregate

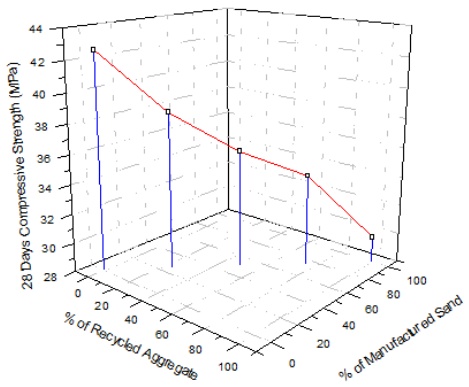


Fig 5 % Replacement of NCA with RCA and % Replacement of Fine Aggregate with M-Sand

The compressive test results of recycled coarse aggregate replaced in natural coarse aggregate and replacing M sand in fine aggregate were shown in Fig No 5 . From test results of compressive strength it is noticed that, as the replacement of recycled aggregate and Msand increases the ultimate compressive strength decreases continuously for 7 days and 28 days. However it is to mention that all the researchers were used different waste materials other than M-sand in fine aggregate. The % decrease in compressive strength for 7 days with respect to reference mix R0M0 are 8.93, 14.91, 16.42, and 28.35 % for 25,50,75 and 100% replacement of recycled coarse aggregate and M-sand in fine aggregate. The % decrease in compressive strength for 28 days with respect to reference mix are 9.37, 15.61, 19.78 and 30.21 % for 25,50,75 and 100% replacement of recycled coarse aggregate and M-sand in fine aggregate. However the mix having 100% recycled aggregate and 100% M-Sand compressive strength value is 29.77 MPa which is almost equal to M-25 grade concrete. So it can be recommended to utilize 100% recycled aggregate and M-sand in producing SCC.

Split Tensile strength of RCA in NCA concrete mix with 0% M-Sand

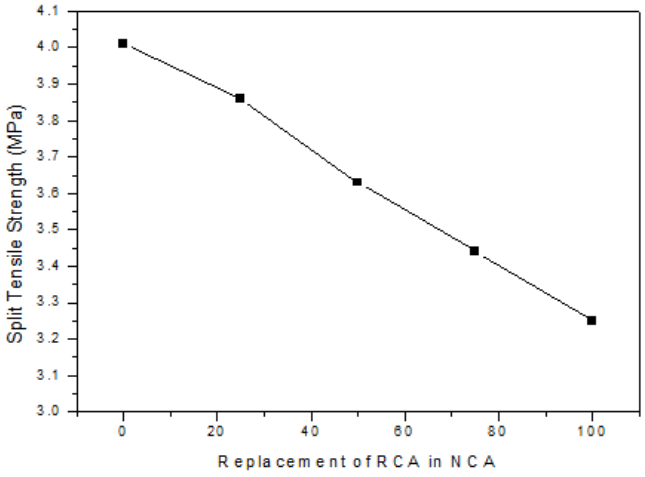


Fig 6 Split Tensile strength Vs % replacement of RCA in NCA

From test results of split tensile strength it is noticed that, as the replacement of recycled aggregate increases the split tensile strength decreases continuously (Fig No 6). As per literature available, all the researchers observed decrease in strength when recycled aggregate percentage is increased except M.Seethapathi *et al* [12] observed a reverse trend and stated that the split tensile strength increased with the percentage of recycled aggregate is increased however they have not given any specific reason for their conclusion, In the present research the mix R0M0 compressive strength is taken as reference mix for all the mixes. The 28 days split tensile strength of 100% recycled coarse aggregate is found to be 3.25 N/mm^2. It is seen that the split tensile strength decreases with increase in recycled aggregate replacement ratio in 28 days. This may be due to the inferior quality of recycled aggregate compared to natural coarse aggregate. The % decrease in split tensile strength for 28 days with respect to reference mix are 3.74,9.47,14.21 and 18.95 % for 25,50,75 and 100% replacement of recycled coarse aggregate.

Split Tensile strength of MSand in Fine Aggregate with 0% Recycled Coarse Aggregate

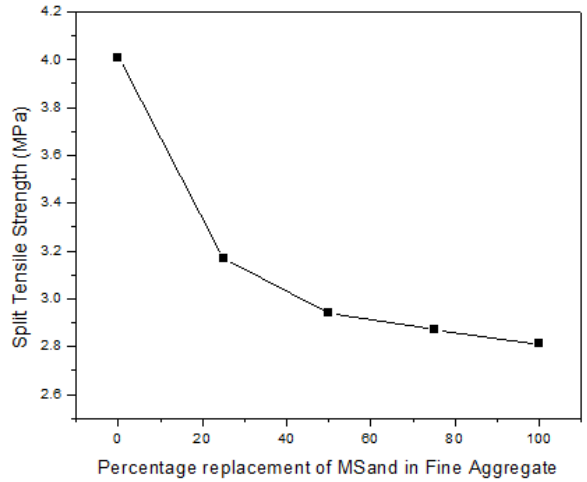


Fig 7 Split Tensile strength Vs % replacement of Msand in FA

The split tensile strength of replacing M sand in fine aggregate is shown in Fig No 7. It is noticed that, as the replacement of M Sand increases the split tensile strength decreases continuously The 28 days split tensile strength of 100% M Sand in fine aggregate is found to be 2.81 N/mm^2. It is seen that the split tensile strength decreases with increase in RCA replacement ratio in 28 days. This may be due to the quality of M Sand varies with river sand. The % decrease in split tensile strength for 28 days with respect to reference mix R0M0 are 20.94, 26.68, 28.42 and 29.92 for 25,50,75 and 100% replacement of M Sand in fine aggregate.

Split strength of Recycled coarse aggregate concrete and replacement of M-Sand in fine aggregate

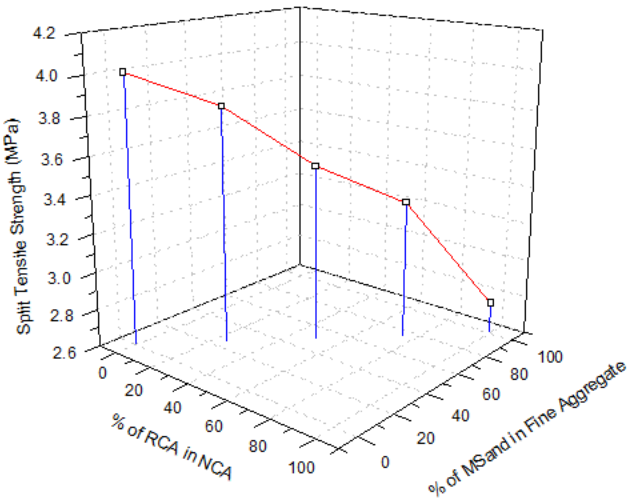


Fig 8 % Replacement of NCA with RCA and % Replacement of Fine Aggregate with M-Sand.

The split tensile strength results of recycled coarse aggregate replaced in natural coarse aggregate and replacing M sand in fine aggregate were shown in Fig No 8.It is noticed that as the replacement of recycled coarse aggregate increases and fine aggregate by M-Sand increases the split tensile strength decreases continuously for 28 days. From the literature reviewed for this research no work has been seen on replacing RCA in NCA and M Sand in fine aggregate. The % decrease in split tensile strength for 28 days with respect to reference mix R0M0 are 4.42, 11.97, 16.95 and 30.92 % for 25,50,75 and 100% replacement of recycled coarse aggregate and M-Sand in fine aggregate. However the mix having 100% recycled aggregate and 100% M-Sand split tensile strength value is 2.77 MPa. So it can be recommended to utilize 50% recycled aggregate and M-Sand in producing SCC in terms of split tensile strength.

CONCLUSIONS

From the above research work, the following conclusions can be drawn

1. The results of the present investigation it can be recommended recycled coarse aggregate and M-Sand can be used in producing SCC.
2. The compressive strength of SCC is decreasing with the increase in percentage replacement of recycled coarse aggregate in natural coarse aggregate and Msand in fine aggregate.
3. The split tensile strength of SCC is decreasing with the increase in percentage replacement of recycled coarse aggregate in natural coarse aggregate and Msand in fine aggregate.
4. The compressive strength of the mix having 100% recycled aggregate and 100% M-Sand compressive strength value is 29.77 MPa which is almost equal to M-25 grade concrete
5. The split tensile strength of the mix having 100% recycled aggregate and 100% M-Sand compressive strength value is 2.77 MPa.

From the strength properties observed, SCC can be produced with recycled coarse aggregate replacement and M-Sand replacement.

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