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EFFECT OF PARTIAL REPLACEMENT OF AGGREGATES BY RECYCLED CONCRETE DEBRIS ON STRENGTH OF CONCRETE

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Abstract: Lot of construction debris are generated during the construction and demolition of any concrete structure like buildings, roads, bridges etc. and sometimes, even from catastrophes like wars and earthquakes. Discarding these wastes is a very serious problem because it requires huge space for its disposal and very little demolished waste is recycled or reused. This debris after recycling can be used as aggregates in fresh concrete in order to protect natural resources and to reduce the space required for the landfill disposal thus minimising environmental pollution. In recent times, scarcity of river sand is also another major problem faced by the construction sector in India. In this paper, experimental investigations have been carried out to gauge the effect of partial replacement of natural coarse aggregates (NCA) and natural fine aggregates (NFA) by recycled coarse aggregates (RCA) and recycled fine aggregates (RFA) on compressive strength, tensile strength and flexural strength of recycled concrete. 10%, 20%, 30% of NCA and NFA were replaced with RCA and RFA respectively & the results obtained from compressive strength test, split tensile test and flexural test were compared with the conventional concrete. From the experimental study, it was observed that compressive strength & tensile strength of concrete with recycled aggregates increased up to 20% replacement of natural aggregates with recycled aggregates whereas the flexural strength of recycled concrete was found to decrease with increase in percentage of RCA & RFA. In this paper, feasibility of utilizing concrete debris after recycling in the construction industry from strength point of view has been studied.

Keywords: *Construction, demolition wastes, recycled aggregates, compressive strength, split tensile strength, flexural strength.*

1.0 Introduction

Huge quantities of construction and demolition wastes are generated not only in India but all over the world. These wastes are increasing every year predominantly. Construction waste recycling is gaining importance in construction industry as it protects natural resources and also reduces environmental pollution by eliminating the need to dispose them in landfills by readily using them as a source of aggregate to

produce new concrete (Sami and Akmal, 2009). The raw materials used in construction are largely naturally occurring and a non-renewable resource hence needs to be used cautiously (Yadav and Pathak, 2009). Continuous use of natural resources, like river sand has led to its shortage which is a major problem faced by the construction sector in some places in India. It is thus our duty to protect and conserve natural resources like stones, sand etc.

To reduce the quantity of natural aggregates used in concrete, recycled aggregates can be used as the partial replacement material. Recycled aggregates consist of crushed, graded inorganic particles processed from the materials that are retrieved from construction and demolition debris (Manish and Dilip, 2014). Recycling of concrete debris is a relatively simple process. It involves breaking, removing, and crushing existing concrete into a material with specified size and quality (Kumutha and Vijai, 2010). Reinforcing steel and other embedded items like cladding materials, lumber, dirt, steel, hardware's, wood, plastics, glass, paper, roofing materials etc. must be removed (Manish and Dilip, 2014). Recycled aggregates contain not only the original aggregates, but also hydrated cement paste which reduces the specific gravity and increases the porosity when compared with similar natural aggregates (Manish and Dilip, 2014). Higher porosity of recycled concrete aggregate leads to higher absorption (Limbachiya *et al.*, 2000). In recycled concrete, NCA and NFA are partially replaced with RCA and RFA and the quality of concrete with recycled aggregate is very dependent on the quality of the recycled material used (Padmini *et al.*, 2009).

In this paper, strength characteristics of concrete containing recycled aggregates (henceforth referred as recycled concrete) is compared with conventional concrete containing natural coarse and fine aggregates (henceforth referred as natural concrete). For both the types of concrete, water cement ratio, maximum size of aggregate and mix proportion are kept constant. The concrete is expected to achieve a 28 day compressive strength of not less than 20 MPa. In one set of investigations, 10%, 20% & 30% of NCA were replaced by RCA with all other raw materials being same as natural concrete to determine the optimum replacement of NCA by RCA. Similarly in another set of tests, 10%, 20% & 30% of NFA were replaced by RFA with all other raw materials being same as natural concrete to obtain the optimum replacement of NFA by RFA.

A series of laboratory tests were carried out to determine the compressive strength, split tensile strength and flexural strength of natural concrete and recycled concrete. Experimental results showed that strength of recycled concrete gradually increased with increase in percentage of RCA and RFA as evaluated by compression test and split tensile test. It was also found that recycled concrete cannot take flexure as observed in flexural strength test.

2.0 Materials and Methods

2.1 Materials

In the experimental study, Portland pozzolana cement having a specific gravity of 3.095 and fineness of 5.27% was used. Standard consistency of cement was found to be 27%. NCA of maximum 20 mm size having specific gravity of 2.73 and fineness modulus of 6.57was used. NFA consisting of river sand having specific gravity of 2.66 and fineness modulus of 2.674 was used. Concrete debris from the construction and demolition wastes was segregated and were crushed in the laboratory and sieved to obtain RCA and RFA of specified size. RCA passing through 20 mm sieve and retained on 4.75 mm sieve having a specific gravity of 2.61 and RFA passing through 4.75mm sieve and retained on 0.075mm sieve having a specific gravity of 2.44 were used. Portable water was used for concreting and curing.

2.2 Mix Proportions

Plain Cement Concrete (PCC) representing natural concrete had a proportion of 1 (Cement): 1.425 (Fine aggregate): 3.10 (Coarse aggregate) to achieve target strength of 20MPa at 28 days. Water cement ratio of 0.5 was maintained for all the concrete mixes. In mixes designated as 10% RCA, 20% RCA & 30% RCA, NCA were replaced with 10%, 20% & 30% RCA by weight respectively. In mixes designated as 10% RFA, 20% RFA & 30% RFA, NFA were replaced with 10%, 20% & 30% RFA by weight respectively. 7 different concrete mixes including one of PCC were used to determine the effect of recycled aggregates on strength characteristics of concrete.

3.0 Results and Discussions

3.1 Compressive Strength Test

Results of the compressive strength test conducted on cubes after 7 days and 28 days of curing is presented in Table 1. Graphical representation of 28 day compressive strength for the different concrete mixes is shown in Figure 1.

Table 1: Compressive Strength of Recycled Concrete

Sr. No.	*Specimen Designation*	*Compressive Strength (N/mm^2)*		*% increase in 28 day compressive strength with respect to PCC*	*% decrease in 28 day compressive strength with respect to PCC*
		7 Days	*28 Days*		
1.	PCC	22.65	32.5	-	-
2.	10% RCA	29.045	35.8	10.15	-
3.	20% RCA	26.885	33.24	2.3	-
4.	30% RCA	24.28	29.1	-	10.46
5.	10% RFA	27.765	38.24	17.66	-
6.	20% RFA	25.375	36.52	12.37	-
7.	30% RFA	24.32	30.20	-	7.08

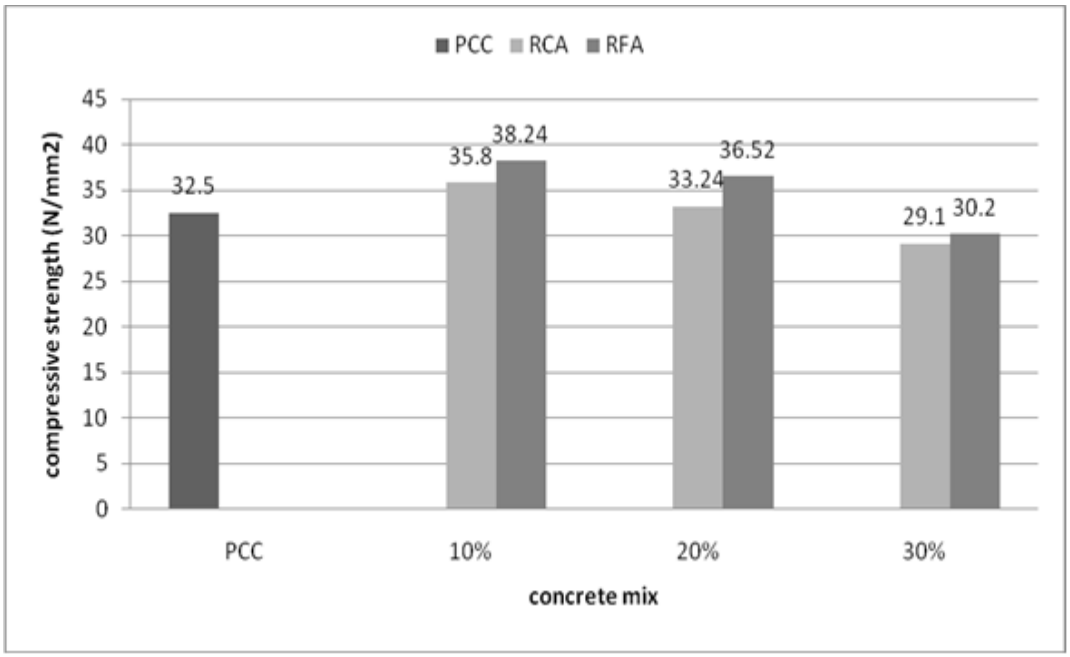

Figure 1: Effect of recycled aggregate on compressive strength of concrete

Results showed that compared to PCC, compressive strength of concrete at 7 days and 28 days was found to be more up to 20% replacement of NCA with RCA (Monish *et al*., 2013). Maximum increase in compressive strength occurred in concrete with 10% RCA and the percentage increase was found to be 10.15%. Compressive strength of concrete with 30% RCA was found to be higher than the target strength of 20 MPa but was lower than that of PCC and the percentage reduction was found to be 10.46%.

Similar result was observed in concrete with RFA. Compared to PCC, compressive strength of concrete at 7 days and 28 days was found to be more up to 20% replacement of NFA with RFA (Dabhade *et al.,* 2012). Maximum increase in compressive strength occurs in concrete with 10% RFA and the percentage increase was found to be 17.66%. Compressive strength of concrete with 30% RFA was found to be higher than the target strength of 20 MPa but was lower than that of PCC and the percentage reduction was found to be 7.08%.Also the compressive strength of concrete with RFA was found to be higher than that of concrete with RCA for all percentage of replacement of natural aggregates with recycled aggregates.

From the observed results, it can be said that compared to PCC, concrete with up to 20% recycled aggregates was found to be good in compression (Dhir *et al*., 1999). Even at 30% replacement of natural aggregates with recycled aggregates, target strength is found to be achieved. Thus in compression members like concrete blocks, concrete pavements etc. recycled aggregates up to 20% can be used without compromising on strength (Poon *et al*., 2002). In minor civil engineering works like foot paths, gutters, paving blocks etc., recycled concrete with 30% replacement or more can be used from economic point of view (Kumutha and Vijai, 2010). With reference to compressive strength, optimum replacement of NCA and NFA with RCA and RFA respectively is found to be 10%.

3.2 Split Tensile Strength Test

Results of the split tensile strength test conducted on cylinders after 7 days and 28 days of curing is presented in Table 2. Graphical representation of tensile strength at 28 day for the different concrete mixes is shown in Figure 2.

Table 2: Split Tensile Strength of Recycled Concrete

Sr. No.	Specimen Designation	Split Tensile Strength (N/mm^2)		% increase in 28 day split tensile strength with respect to PCC	% decrease in 28 day split tensile strength with respect to PCC
		7 Days	28 Days		
1.	PCC	2.165	3.11	-	-
2.	10% RCA	2.48	3.29	5.79	-
3.	20% RCA	2.55	3.355	7.88	-
4.	30% RCA	2.21	2.89	-	7.07
5.	10% RFA	2.47	3.18	2.25	-
6.	20% RFA	2.61	3.29	5.79	-
7.	30% RFA	2.05	2.90	-	6.75

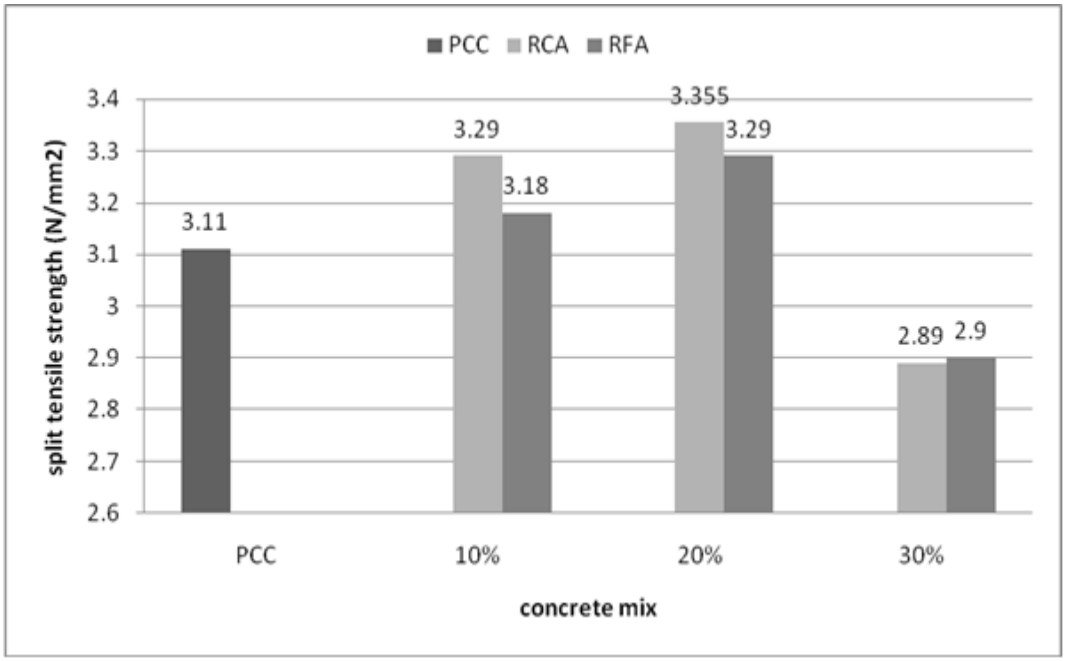

Figure 2: Effect of recycled aggregate on split tensile strength of concrete

Results showed that compared to PCC, split tensile strength of concrete at 7 days and 28 days kept on increasing up to 20% replacement of NCA with RCA beyond which it decreased. Maximum tensile strength was observed in concrete with 20% RCA and the percentage increase was found to be 7.88 %. Split tensile strength of concrete with 30%

RCA was found to be lower than that of PCC and the percentage reduction was found to be 7.07 %.

Similarly for the concrete with RFA, split tensile strength at 7 days and 28 days was found to increase up to 20% replacement of NFA with RFA beyond which it decreased. Maximum increase in tensile strength was observed in concrete with 20% RFA and the percentage increase was found to be 5.79 %. Split tensile strength of concrete with 30% RFA was found to be lower than that of PCC and the percentage reduction was found to be 6.75 %. Also the split tensile strength of concrete with RCA was found to be higher than that of concrete with RFA for 10% and 20% replacement of natural aggregates with recycled aggregates.

From the experimental results, it can be said that compared to PCC, recycled concrete up to 20% replacement of natural aggregates with recycled aggregates can resist tensile stress much better than PCC (Dabhade *et al.*, 2012). Optimum replacement of NCA and NFA with RCA and RFA respectively is found to be 20% from tensile strength point of view.

3.3 Flexural Strength Test

Results of the Flexural strength test conducted on beams after 7 days and 28 days of curing is presented in Table 3. Graphical representation of flexural strength at 28 day for the different concrete mixes is shown in Figure 3.

Table 3: Flexural Strength of Recycled Concrete

Sr. No.	**Specimen Designation**	**Flexural Strength (N/mm^2)**		**% decrease in 28 day flexural strength with respect to PCC**
		7 Days	**28 Days**	
1.	PCC	4.655	5.72	-
2.	10% RCA	4.32	5.58	2.45
3.	20% RCA	4.25	5.21	8.92
4.	30% RCA	3.905	4.685	18.09
5.	10% RFA	4.628	5.4	5.6
6.	20% RFA	4.105	5.28	7.69
7.	30% RFA	3.655	5.01	12.4

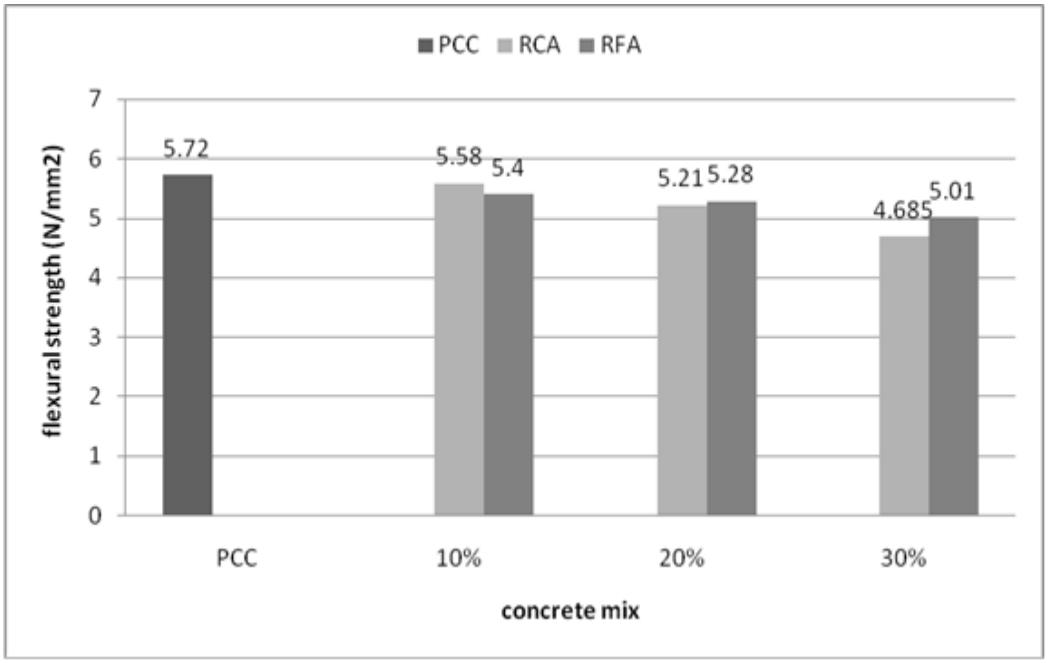

Figure 3: Effect of recycled aggregate on flexural strength of concrete

Experimental results showed that flexural strength of recycled concrete was found to be lower than that of PCC at 7 days & 28 days of curing (i.e. 4.655 N/mm^2 at 7 days & 5.72 N/mm^2 at 28 days). Flexural strength of recycled concrete was found to be decreasing with increasing percentage of recycled aggregates (Kumutha and Vijai, 2010). Also the flexural strength of concrete with RFA was found to be higher than that of concrete with RCA for 20% and 30% replacement of natural aggregates with recycled aggregates except for 10% replacement.

Thus it can be concluded that, recycled concrete can take tension & compression individually but cannot take flexure. This was observed from the experimental results which showed that compressive strength & tensile strength of recycled concrete was greater than that of PCC up to 20% replacement of natural aggregates with recycled aggregates whereas the flexural strength of concrete was found to decrease with the inclusion of recycled coarse and fine aggregates. Further investigations regarding improving flexural strength of recycled concrete by incorporating reinforcements needs to be carried out so that it can be used in the construction of structural members like concrete slabs, beams, columns etc.

4.0 Conclusion

1) Optimum replacement of NCA and NFA with RCA and RFA respectively was found to be 10% from compressive strength point of view. Recycled concrete with 10 to 20% recycled aggregates can be used in the construction of compression members like concrete blocks, concrete pavements etc. as the compressive strength developed is higher than that of natural concrete.

2) Compressive strength of concrete with RFA was found to be higher than that of concrete with RCA.

3) From tensile strength point of view, optimum replacement of NCA and NFA with RCA and RFA respectively was found to be 20%.

4) Tensile strength of concrete with RCA was found to be higher than that of concrete with RFA.

5) Flexural strength of recycled concrete was found to be lower than that of PCC and was found to be decreasing with increasing percentage of recycled aggregates.

6) As recycled concrete cannot take flexure, reinforcements can be incorporated to increase the flexural strength so that the recycled concrete can be utilised in the construction of structural members like concrete slabs, beams, columns etc.

7) The present study shows that construction and demolition wastes can be effectively utilised as an alternative for partial replacement of natural aggregates in construction sector.

8) Also construction and demolition wastes are easily available and exist in abundance everywhere, thus its use reduces the cost of construction, conserves the space required for its disposal and also prevents the depletion of natural resources like river sand thus preserving our environment.

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