AN EXPERIMENTAL STUDY ON MECHANICAL BEHAVIOUR OF CONCRETE USING RECYCLED CONCRETE AGGREGATES

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ABSTRACT

The paper deals with restriction the use of natural aggregates in concrete and is concerned with selecting recycled aggregates for concrete to sustainable development by restricting the use of natural resources. An estimated 25 billion tonnes of concrete is manufactured globally every year in the US, Japan and Europe of which approximately 900 million tonnes of construction and demolition waste is generated yearly. In India, the total quantum of (C&D) waste is estimated to be 12 to 14.7 million tons per annum.The paper reveals studies carried out to obtain recycled aggregates from construction and demolition waste and its use in concrete construction. The paper also explores the feasibility of replacing fine aggregates by fly ash. It is demonstrated that recycled aggregates upto some percentage of replacement with natural aggregates can be used to effectively match the performance of conventional concrete.

Keywords: Recycling, Sustainability, Interfacial Zone, Water Absorption, Specific Gravity

INTRODUCTION

Concrete is the second most consumed material after water.Therefore construction & demolition waste has become a global concern that requires sustainable solution.C&D wastes is generated whenever any construction/demolition activity takes place such as buildings, roads, bridges, fly-overs etc. This C&D wastes either ends up in landfills or dumped illegally. It is thus desirable to completely recycle demolished concrete waste in order to protect natural resources. Recycling of demolished debris not only solves the waste disposal problem but also solves the use of natural resources in affective manner to maintain the ecological balance. Recycled aggregate are composed of the rubble from the demolition of buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes. They are derived from the processing of demolition waste including concrete, masonry and asphalt. Aggregate typically processed from demolition waste concrete is known as Recycled concrete aggregate.

CURRENT MATERIAL REQUIREMENTS FOR CONCRETE

The present paper emphasise the use of fly ash and recycled aggregate in concrete for sustainable solution towards conserving natural resources. Many governments throughout the world have now introduced various measures aimed at reducing the use of primary aggregates and increasing reuse and recycling of concrete wastes to be used as recycled aggregates. In Italy, the use of 30% recycled concrete aggregates instead of natural aggregate is definitely allowed for producing low strength concretes up to 30MPa since July 2009.

Japanese researchers agree that up to 30% of natural aggregate can be replaced by recycled concrete aggregates without significantly changing the properties of new concretes made with natural aggregates. The research by various countries indicated the positive sign to use the recycled aggregate in concrete.

ADHERED MORTAR CONTENT OF RECYCLED AGGREGATES

- Strength of recycled aggregate concrete mainly depends upon the mortar content adhered on the surface of recycled aggregates.
- Reduction in strength is due to weak bond between old adhered mortar and new cement paste

Quality of RCA can be improved by reducing the amount of mortar content adhered to its surface.

$$\%\ \text{Adhered Mortar} = \frac{\text{Mass of RCA} - \text{Mass of RCA after removal of mortar}}{\text{Mass of RCA}}$$

INTERFACIAL TRANSITION ZONE (ITZ) IN RECYCLED AGGREGATE CONCRETE (RAC)

- ITZ is generally the weakest link in concrete
- RAC possesses two ITZs, one between the RA and new cement paste (new ITZ) and the other between the RA and the old attached mortar (old ITZ).
- ITZ of recycled aggregate concrete (RAC) is weaker than natural aggregate concrete.
- Due to high porosity of adhered mortar on recycled concrete aggregates, less water is available for hydration at transition zone thereby making ITZ weaker.
- For high water-cement ratio concrete, old ITZ is stronger than the new ITZ, thus the strength of RAC is equal to that of normal aggregate concrete.
- For low water-cement ratio, old ITZ is weaker than the new ITZ, therefore the strength of RAC is lower than that of normal aggregate concrete.

SUSTAINABLE OPTIONS FOR CONCRETE

EXPERIMENTAL PROGRAMME:

Experimental programme was carried out to check the properties of the material used in the investigation. Table 1 to 6 represents the properties of Cement, Fine and Coarse aggregates, Recycled Coarse aggregates used in the investigation.

Table 1: Physical Properties of Cement

Sr. No	Characteristics	Experimental value	Specified value as per is:8112-1989
1	Consistency of cement	30 %	-
2	Specific gravity	3.14	3.15
3	Initial setting time	92 minutes	>30 minutes
4	Final setting time	298 minutes	<600 minutes
5	Comp. Strength(N/mm^2)	28.48	>23
6	Fineness(Dry Sieving)	2.5 %	<10%
7	Soundness (mm)	1.0	<10

Table 2:Sieve Analysis of Fine Aggregate

S.No	IS Sieve	Weight Retained	Cumulative Weight Retained (gms)	Cumulative % Retained, F	% Passing
1	4.75 mm	15.10	15.1	1.51	98.49
2	2.36 mm	25.20	40.30	4.03	95.97
3	1.18 mm	250.10	290.40	29.04	70.96
4	600 µm	160.00	450.40	45.04	54.96
5	300 µm	320.10	770.50	77.05	22.95
6	150 µm	217.10	987.60	98.76	1.24
7	Pan	12.40	1000.00	-	-

Cumulative percentage weight retained = 255.70
Fineness modulus of fine aggregate = $\sum F / 100 = 2.56$

Table 3: Physical Properties of Fine Aggregate

Characteristics	Values
Type	Natural
Grading	Grading zone II (IS:383-1970)
Fineness modulus	2.56
Specific gravity	2.62
Free moisture content	Nil
Water absorption	0.48%

Table 4: Sieve analysis of Coarse Aggregate

Sl.	IS Sieve	Weight Retained	Percentage Retained	Percentage Passing	Cumulative percentage Retained, F	IS 383-1970 Requirement For zone III
1	40 mm	0 gm	0	100	0	100
2	20 mm	30 gm	0.6	99.4	0.6	95-100
3	10 mm	3225 gm	64.5	34.9	65.1	25-55
4	4.75 mm	1730 gm	34.6	0.3	99.7	0-10
5	Pan	15 gm	0.3	$\sum F$	163.9	-

Cumulative percentage retained = 163.9
Fineness modulus of coarse aggregate = $(500+\sum F)/100 = 6.654$

Table 5: Sieve analysis of Coarse Recycled aggregate
(Recycled coarse aggregates (>4.75mm) were collected from demolition site of old building and typically, the waste contained asphalt, bricks, crushed stones and rubbles).

Sl.	IS Sieve	Weight Retained	Percentage Retained	Percentage Passing	Cumulative % Retained, F	IS 383-1970 Requirement For zone III
1	40 mm	0 gm	0	100	0	100
2	20 mm	20 gm	0.4	99.6	0.4	95-100
3	10 mm	3100 gm	62	37.6	62.4	25-55
4	4.75 mm	1855 gm	37.1	0.5	99.5	0-10
5	Pan	25 gm	0.5	∑ F	162.3	-

Cumulative percentage retained = 162.3
Fineness modulus of recycled coarse aggregate = (500+∑ F)/100 =

Table 6:Physical Properties of Natural & Recycled Aggregates

Characteristics	Natural Aggregates	Recycled Aggregates
Colour	Grey	Grey Brown
Shape of aggregate	Angular	Crushed
Free moisture content	Nil	Nil
Specific gravity	2.66	2.43
Fineness modulus	6.654	6.623
Water absorption	0.50%	4.18%

SUPER PLASTICISER

- Plastiment B V 40 M (Water reducing admixture)
  It is a plasticizing concrete and mixture based on modified Ligno-sulphonates. It enables large water reduction for same workability to produce good pump able concrete. Table 7 represents the physical properties of Super- Plasticizer used in the investigation.

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Table 7:Physical Properties of Super-Plasticiser

Characteristics	Result
Colour	Dark Brown Liquid
Density	Around 1.19 kg/ litre
Chloride Content	Nil to BS 5075
Air Entrainment	less than 1%
Dosage	0.4-1.2% by weight

Nine different types of concrete mixes were designed for the investigation with percentage replacement of recycled coarse aggregates from 0% to 70% and corresponding replacement of fly ash from 0% to 20%. Data pertaining to mix designation and mix proportioning is presented in Table 8 and Table 9.

Table 8: Mix Designation

FLY ASH	RECYCLED AGGREGATES		
	0%	30%	70%
0%	RM1	RM2	RM3
10%	RM4	RM5	RM6
20%	RM7	RM8	RM9

Table 9: Proportioning of Concrete Mixes

MIX	RM1	RM2	RM3	RM4	RM5	RM6	RM7	RM8	RM9
Cement	445	445	445	405	405	405	359	359	359
Flyash	0	0	0	45	45	45	89	89	89
Fine agg.	602	602	602	579	579	579	557	557	557
Coarse agg.	1173	820	352	1173	820	352	1173	820	352
Recycled	0	320	747	0	320	764	0	320	747
Admixture	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78
Water	177	177	177	177	177	177	177	177	177

CONCRETE STRENGTH PERFORMANCE

The compressive strength test is carried out on the cubes and the results are tabulated in Table 10. Figure 1 and Figure 2 represents the variation in the cubes compressive strength result for the mixes with percentage of fly ash varying from 0% to 20% and mixes with replacement by recycled aggregates.

Table 10: Compressive Strength Test results

CONCRETE MIX	AVERAGE COMPRESSIVE STRENGTH (MPa) (7days)	AVERAGE COMPRESSIVE STRENGTH (MPa)(28 days)
RM1	31.13	45.63
RM2	29.86	43.90
RM3	28.30	40.96
RM4	30.40	44.00
RM5	29.70	43.00
RM6	28.06	40.50

RM7	29.80	42.50
RM8	29.30	41.40
RM9	28.00	38.17

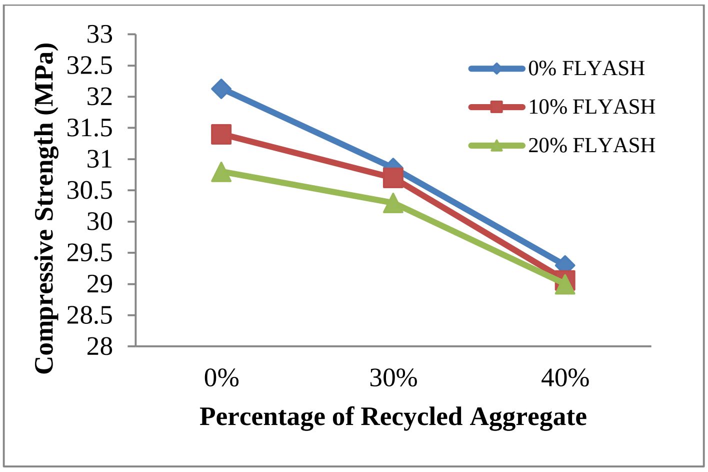

Figure 1: Variation of Cubes Compressive Strength Results

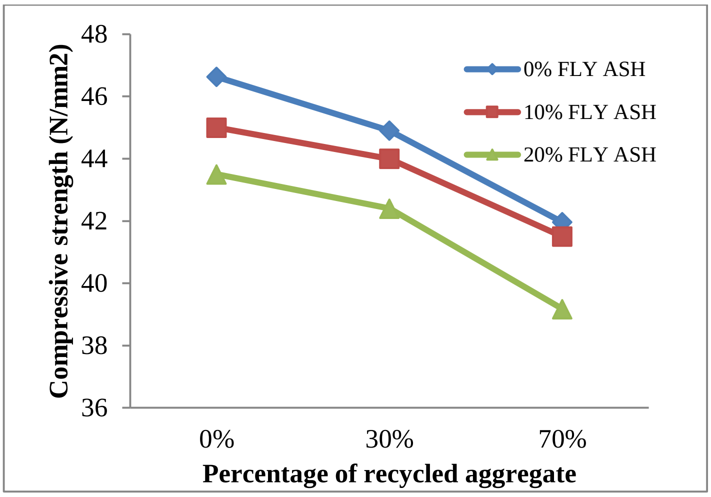

Figure 2: Variation of Cubes Compressive Strength Results

The compressive strength test and split tensile strength test is carried out on the cylinder and the results are tabulated in Table 11. Figure 3 represents the variation in the cubes compressive strength result for the mixes with percentage of fly ash varying from 0% to 20% and mixes with replacement by recycled aggregates and Figure 4 represents the variation in the cylinder compressive strength result for the mixes with percentage of fly ash varying from 0% to 20% and mixes with replacement by recycled aggregates.

Table 11: Compressive Strength And Split Tensile Strength Test Results

CONCRETE MIX	AVERAGE COMPRESSIVE STRENGTH (MPa) (28 days)	AVERAGE SPLIT TENSILE STRENGTH (MPa) (28 days)
RM1	37.5	4.18
RM2	36.5	3.95
RM3	35.2	3.57
RM1	36.23	4.00
RM5	35.1	3.77
RM6	33.7	3.38
RM7	35.03	3.76
RM8	34.76	3.48
RM9	32.63	2.96

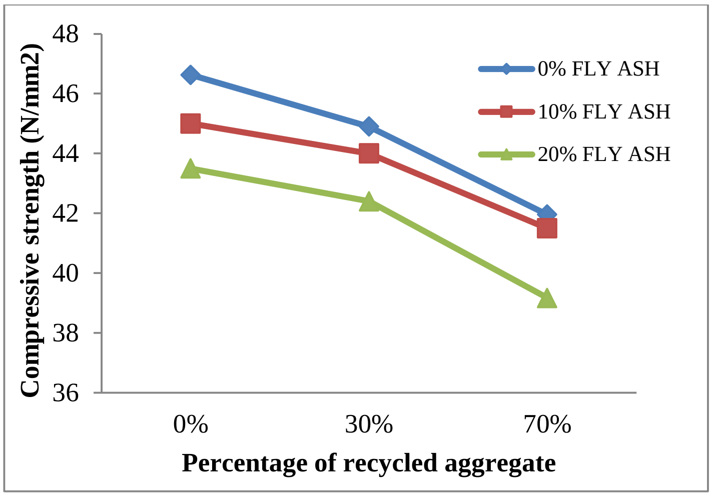

Figure 3: Variation of Cylinder Compressive Strength Results with replacement by recycled Aggregates

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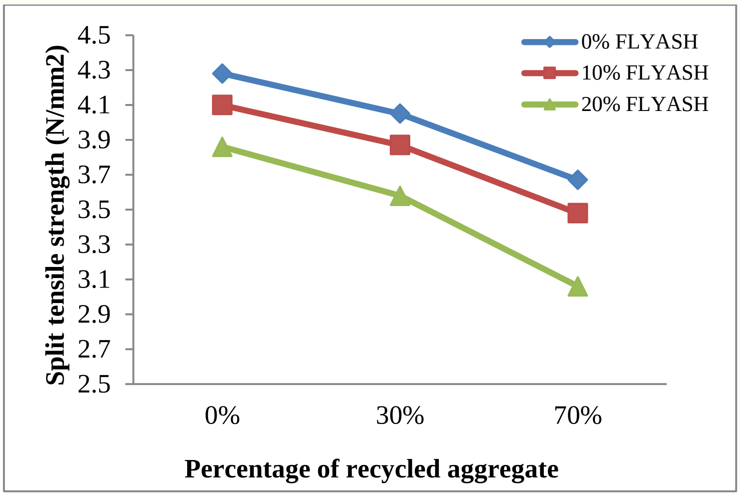

Figure 4: Variation of Cylinder Split Tensile Strength Results

The flexural strength test is carried out on the prisms and the results are tabulated in Table 12. Figure 5 represents the variation in the beams flexural strength test result for the mixes with percentage of fly ash varying from 0% to 20% and mixes with replacement by recycled aggregates.

Table 12: Flexural Strength Test results

CONCRETE MIX	AVERAGE FLEXURAL
RM1	9.6
RM2	9.2
RM3	7.6
RM4	8.8
RM5	8.2
RM6	6.6
RM7	7.6
RM8	6.8
RM9	5.8

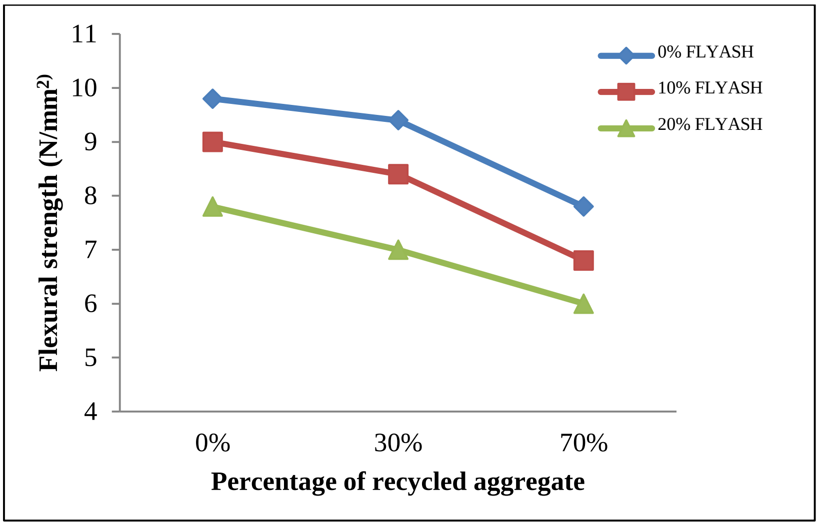

Figure 5: Variation of Flexural Strength Test Results

CONCLUDING REMARKS

- The water absorption of recycled aggregates was found to be greater than natural aggregates. The fact that the mortar adhered which was weak and more porous and thus absorbed more water was the main factor contributing towards decrease of compressive strength of concrete with recycled coarse aggregates.
- The lower value of specific gravity of recycled aggregates was an indication that recycled concrete aggregates were lighter than that of natural aggregates. The main reason for this was the existence of loose paste in the demolished wastes.
- 30% of natural aggregate can be replaced by recycled concrete aggregates in or below M35 grade concrete
- The cube specimens having 70% recycled aggregate in concrete mix were unable to achieve their target mean compressive strength of 43.25 MPa after 28 days of moist curing. Therefore 70% of recycled aggregates replacement is not suitable for M35 concrete or above.
- The compressive, split tensile and flexural strength of concrete decreased with increase in percentage replacement of recycled aggregate in concrete mix.
- Addition of 70% recycled aggregate in concrete mix decreased the split tensile strength and flexural strength drastically by more than 15%and 20% respectively.
- Therefore replacement upto 30% natural aggregate with recycled concrete aggregate may be recommended in M 35 grade concrete.

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