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Investigating Fresh and Hardened Properties of Concrete Made with Laboratory Waste as Coarse Recycled Aggregates

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ABSTRACT

The objective of this research is to investigate the workability and compressive strength of recycled aggregate concrete (RAC) for M 20, M 30 and M 40 grade of concrete with 0, 25, 50, 75 and 100 % replacement of natural aggregates with recycled concrete aggregates (RA). A total of 90 cube specimens were cast for testing compressive strength of RAC after 7 days and 28 days and comparative analysis was made. Results of slump test showed that workability of concretes decreased with increase in the percentage of recycled aggregate and the values increased with the increase in the grade of concrete due to the higher cement content in the higher-grade mix. For strength characteristics, the results showed a gradually decreasing trend in compressive strength as the percentage of recycled aggregate used in the specimens increased. The strength of recycled aggregate concrete decreases with the increase in grade without any admixture but still the use of RA up to 50 % in concrete mixture is found to have workability and compressive strength near to that of natural aggregate concrete and can be used effectively for structural concrete. For M 20, recycled aggregates up to 100 % can be utilized without any chemical admixture.

Keywords: Workability, Mechanical Properties, Recycled Aggregate, Structural Concrete, Compressive Strength, Higher Grade.

I. INTRODUCTION

Recycled aggregate concrete is to re- cycle the disposed waste concrete as an aggregate, which is a new kind of green, environmental- friendly and energy efficient building material in line with today's world demands for energy- saving and emission reduction. Conservation of natural resources and rapid urbanization has prompted growing demand for natural aggregate by construction industry. This demand is compounded by considerable decline in the availability of good quality natural aggregate and enormous increase in the quantities of demolished concrete. The advantage of the conversion of large amount of available demolished waste in to an alternative source of building material will contribute not only as a solution to the growing problem of waste disposal, but it will also converse to resources of the building material and there by reduces the cost.

The alternative materials to cement in terms of fly ash and other pozzolanic materials were evolved, popular alternative material to coarse aggregate are being explored. Recycled aggregate is one such alternative and the present research work is a step forward in understanding the fresh and hardened properties of concrete with recycled aggregates, developing the strength characteristic of recycled aggregates for application in structural concrete.

II. RESEARCH SIGNIFICANCE

After reviewed many studies and according to Wrap report (2007), it is concluded that the most significant difference between RA and NA is the adhered mortar from the original concrete which plays an important role in determining the performance of concrete with respect to permeability and strength. Differences between RA concrete and natural aggregate concrete occurs at the interfacial zone (ITZ) between the mortar and coarse aggregate. In natural aggregate concrete, there is just one ITZ; however, two exist in RA concrete. The main aggregate properties that affect the performance of RA are the density, porosity, and water absorption of the aggregate, the shape and gradation of the aggregate, and the aggregate resistance to crushing and abrasion. Due to these reasons RA may perform differently when used in new concrete than NA. Limbachiya. et.al. (2004) reported that Because of the attached cement paste in the recycled aggregates, the density of these materials is about 3-10% lower and water absorption is about 3-5 times higher than the corresponding natural aggregates. According to Bashar & Ghassan (2008) cement mortar adhered to aggregate is a source of micro-cracks and reduced bond. Cracks in the adhered mortar due to crushing can be considered as a source of weakness. However, with a high strength matrix, cracks can be filled with new mortar to appreciably increase the matrix-aggregate bond. To arrive at the objectives defined above, a comprehensive experimental programme was undertaken.

III. MATERIALS AND METHODS

A. Cement and Fly Ash

Ordinary Portland Cement of 43 Grade available in local market with specific gravity 3.14, confirming to IS: 8112-1989 was used. The cement was tested according to IS 4031: 1988. A low-calcium fly ash obtained from the combined fields of the electrostatic precipitator of the thermal power plants was used. The 45-micron passing fraction in the unprocessed fly ash was more than 90 percent. The physical and chemical characteristics of the fly ash confirming to IS 3812: 1981 were used.

B. Fine Aggregates

Locally available natural river sand having a specific gravity of 2.58, water absorption of 1.10% and a fineness modulus of 2.68 was used as fine aggregate. The sand was sieved through a 75-micron sieve to make it free from lumps of clay and other foreign matter and was then thoroughly washed and air-dried in the laboratory before being used for casting the RAC mixtures. The fine aggregate confirmed to Zone II of IS 383: 1987.

C. Coarse Aggregates

Two types of coarse aggregates from two different sources named Natural Aggregate (NA) and recycled aggregates (RA) were used in the RAC mixes. A locally available crushed granite having a specific gravity of 2.70 was used as the natural coarse aggregate. Recycled aggregates were obtained from concrete of unknown strength, whatever the tested cubes, cylinders and beams available in the laboratory for commercial testing. Laboratory waste was crushed manually. To improve the quality of RA some treatment in terms of washing and sieving was given. The properties of recycled aggregates were studied in detail to overcome the negative impact of RA on the mechanical properties of RAC. The nominal maximum size of NA and RA was 20 mm. Sieve analysis was carried out on all coarse and fine aggregates before their use in the experimental work. The gradation curve of the coarse aggregates is shown in Figure 1 and Figure 2. Physical properties of NA and RA is listed in Table: 1

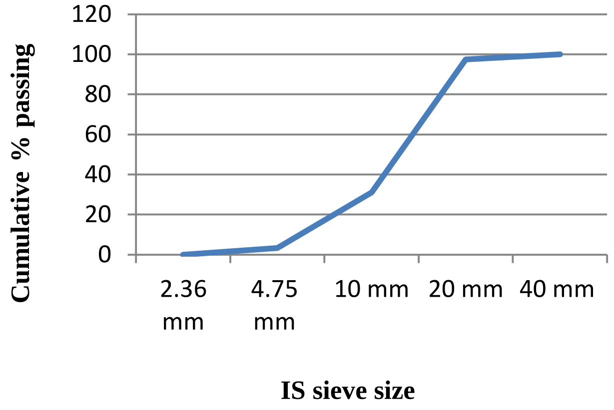

Figure 1: Gradation curve for coarse aggregates- NA

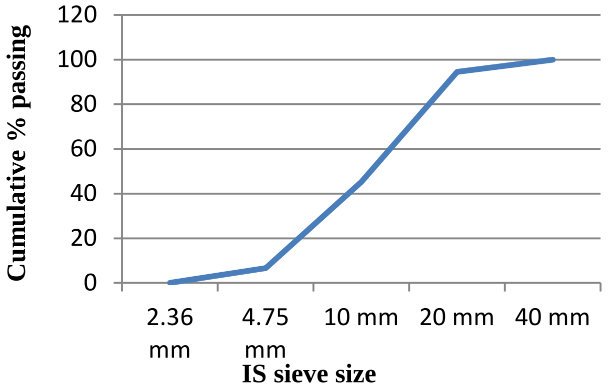

Figure 2: Gradation curve for coarse aggregates- RA

Table 1: Physical Properties of the Coarse Aggregate- NA and **RA**

Characteristics	Coarse aggregates	
	NA	RA
Fineness modulus	6.68	6.54
Specific gravity	2.70	2.48
Loose bulk density kN/ m^3	14.30	11.70
Water absorption (%)	1.1	5.3
Moisture content (%)	0.7	1.9
Los Angeles abrasion value (%)	9.3	23.2

D. Specimen Casting and Curing Details

In general, a common procedure was adopted for casting of the RAC specimens. Concrete cubes of 150 X 150 X 150 mm were cast for compressive strength. All specimens were cast in steel molds and compacted using a vibrating table. After casting, the specimens were cured in air for a period of 24 hrs. The hardened concrete samples were then demoulded after 24 hrs and submerged in a clean water bath for curing until the age of testing. For each proportion three specimens were tested and the mean value of these measurements was reported for compressive strength. The compressive strength of concrete was obtained using a compression testing machine. The rate of loading for the compressive tests was in accordance with Indian Standard specifications. The compressive strength tests on concrete cube specimens were carried out at the age of 7 and 28 days.

IV. CONCRETE MIX DESIGN

Three series of concrete mixes- M 20, M 30 and M 40 with 28 days nominal cube strengths of 20, 30 and 40 N/mm^2 respectively with constant water to cement ratio (w/c) 0.5 were used in this investigation. The mix design was done according to the IS: 10262- 2009 and numerous trial mixes were conducted to obtain the optimum mix. Once the optimum mix was determined for each grade, it was used to produce concrete with 0%, 25%, 50%, 75% and 100% recycled coarse aggregate by weight replacement of natural coarse aggregate. The water used was ordinary tap water for mixing as well as for curing of concrete. Concrete mix design was done without any super plasticizer, so that RAC can be used for all the types of routine construction work without any technical expertise.

The mix proportions were done by assuming the aggregates in saturated surface dry condition and appropriate moisture adjustments were made to cater for the different water absorption properties of the aggregates. To produce good quality RAC, the effective use of inexpensive mineral admixtures such as fly ash has been done as 25 % replacement of cement by weight for exploiting the wide range of advantages in increasing the strength and durability and to check segregation and bleeding of RAC. The details of RAC mixtures are given in Table 2.

Table 2: MIX Proportions with RA For Compressive Strength

Series	Mix notation	Recycled aggregate %	Constituents (kg/m^3)					
			Cement	Fly Ash	Sand	NA	RA	Water
I	M20R0	0	289	96	600	1360	0	192.5
	M20R25	25	289	96	600	1020	340	192.5
	M20R50	50	289	96	600	680	680	192.5
	M20R75	75	289	96	600	340	1020	192.5
	M20R100	100	289	96	600	0	1360	192.5
II	M30R0	0	337	113	562.5	1238	0	225

	M30R25	25	337	113	562.5	929	310	225
	M30R50	50	337	113	562.5	619	619	225
	M30R75	75	337	113	562.5	310	929	225
	M30R100	100	337	113	562.5	0	1238	225
III	M40R0	0	375	125	500	1250	0	250
	M40R25	25	375	125	500	938	313	250
	M40R50	50	375	125	500	625	625	250
	M40R75	75	375	125	500	313	938	250
	M40R100	100	375	125	500	0	1250	250

V. RESULTS AND DISCUSSIONS

A. Workability of Fresh Recycled Aggregate Concrete

The workability of fresh concrete depends on the properties of constituent materials, mix proportions and environmental conditions. Workable concrete exhibits very little internal friction between particles. As aggregate occupy approximately 70-75 % of total volume of concrete, properties of fresh concrete are greatly affected by size, shape, texture and grading of aggregates. The slump pattern for RAC was found similar to that of NAC in the form of true slump.

Table 3: Initial Slump Value of Fresh RAC Mixtures

% of recycled aggregate	Initial slump value in mm		
	M 20	**M 30**	**M 40**
0	65	70	85
25	63	65	82
50	58	63	78
75	55	60	77
100	53	58	75

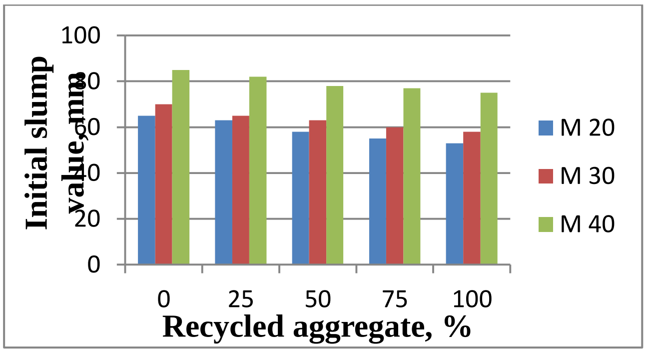

Figure 3 : Initial slump value for RAC mixes of different grades

Results showed that initial slump value of concretes decreased with increase in the percentage of recycled aggregate and the values increased with the increase in the grade of concrete due to the higher cement content in the higher-grade mix, but this remained essentially within the specified limits of medium workability range recommended by IS: 456- 2000. RAC mixes were found to be harsh, less cohesive and exhibited increased bleeding when compared to the corresponding NA concrete. When RA is used in saturated surface dry condition then there will be no difficulty in placing, finishing and casting. The rate of slump loss for RAC mixes was slightly higher than that for NAC, that is probably because of the higher porosity of the RA and the presence of old cement paste which absorb more water.

B. Compressive Strength of Recycled Aggregate Concrete

Table 4 shows the results of the 7 days and 28-days compressive strength of concrete.

Table 4: Compressive Strength of Concrete Mixes

Recycled aggregate (%)	M 20 Compressive strength (N/mm^2)		M 30 Compressive strength (N/mm^2)		M 40 Compressive strength (N/mm^2)	
	7 days	28 days	7 days	28 days	7 days	28 days
0	19.89	28.42	26.20	35.89	29.91	42.73
25	18.79	27.56	23.65	33.78	28.15	41.84
50	19.33	27.67	24.36	34.44	28.27	40.39
75	14.64	21.63	21.26	28.35	23.66	33.82
100	16.42	22.22	19.47	26.67	21.49	31.26

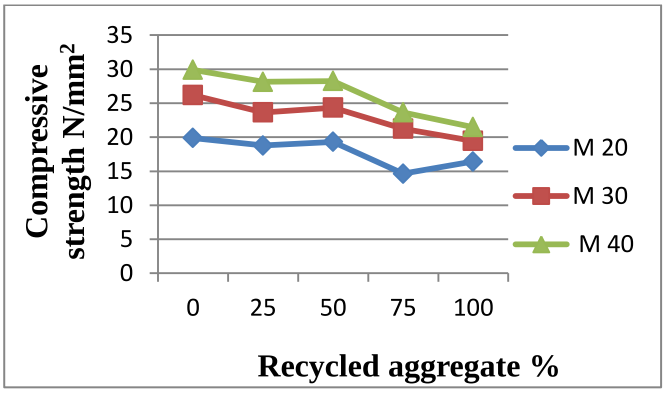

Figure 4: Compressive strength of concrete at 7 days

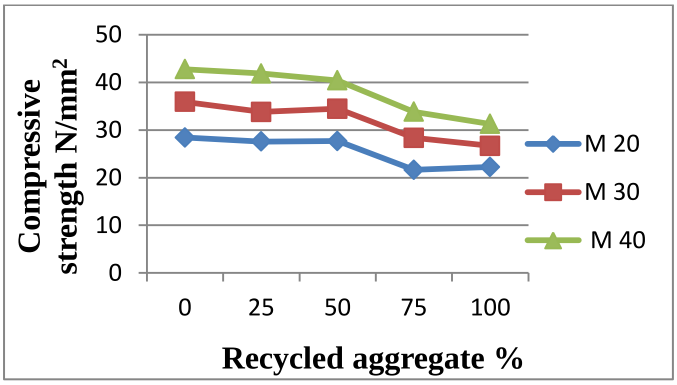

Figure 5: Compressive strength of concrete at 28 days

Figure 4 and 5 shows the results of compressive strength of M 20, M 30 and M 40 grade of concrete with 0, 25, 50, 75 and 100 % replacement of RA after

7 and 28 days. Result showed that almost similar trend was followed by M 20 and M 30 grade of concrete whereas significant reduction in 28 days compressive strength of M 40 grade of concrete for all the replacement levels of RA was found. Strength reduction was 27.9 % for M 20, 34.57 % for M 30 and 36.7 % for M 40 grade concrete. It is advisable to use super plasticizer for M 40 grade of concrete to improve its overall strength. For all the grades of concrete, the compressive strength of concrete with 25 % and 50 % replacement of NA were in close proximity with 100 % NA concrete (control concrete). Strength of M 20 grade of concrete with 75 and 100 % RA was also more than required target strength, whereas the values of compressive strength after 28 days for M 30 and M 40 were much below the required target strength with 75 % and 100 % recycled aggregates. Strengths were gradually decreasing with increase in percentage of recycled aggregates; however, significant decrease was observed with increase in the amount of RA beyond 50 % in all cases. From the results obtained, it was observed that the development of compressive strength of recycled concrete is better during early stage but it exhibits lower compressive strength during later stage.

VI. CONCLUSION:

From the experimental work carried out on M 20, M 30 and M 40 grades of concrete with 0, 25, 50, 75 and 100 % weight replacement of NA with recycled coarse aggregates, the following conclusion can be drawn:

1. To obtain the workability of RAC at par with NAC, the mix proportions of recycled aggregate concrete is to be done by considering the aggregates in saturated surface dry condition to cater for the different water absorption properties of the recycled aggregates.
2. To improve workability of RAC, the effective use of inexpensive mineral admixtures such as FA is to be done as 25 % replacement of cement by weight for exploiting the wide range of advantages in increasing the strength and durability and to check the stability in terms of segregation and bleeding of RAC.
3. The slump pattern for RAC was found similar to that of NAC in the form of true slump.

4. Workability of concretes decreased with increase in the percentage of recycled aggregate because of the sharp, angular and rough surface of RA with adhered mortar.
5. Workability of RAC is increased with the increase in the grade of concrete due to the higher cement content and reduced aggregate content in the higher-grade mix. Workability of M 40 mix is higher than M 20 mix with recycled aggregate.
6. The rate of slump loss for RAC mixes slightly higher than that for NAC, that is probably because of the higher porosity of the RA and the presence of old cement paste which absorb more water.
7. Compressive strength of M 20 grade of concrete for all the replacement levels were more than required target strength. So, for M 20 RA up to 100 % can be used without any adverse effect on strength.
8. 28 days compressive strength of M 40 grade of concrete for all the replacement levels of RA is found lower as compared to M 20 and M 30 grade of concrete.
9. The compressive strength of concrete containing 25 and 50% RA have strength in close proximity to that of normal concrete for all the three grades of concrete.
10. Compressive strengths are gradually decreasing with increase in percentage of recycled aggregates; however, significant decrease is observed with increase in the amount of RA beyond 50 % in all cases.
11. Due to lack of proper treatment process for RA, adequate strength is not achieved but by applying more advanced and sophisticated treatment process the strength can be improved.
12. At last it can be said that higher the grade of recycled aggregate concrete, higher will be the workability and lower will be the compressive strength and vice versa.

Thus, it can be concluded that the use of RA up to 50 % in concrete mixture is found to have workability and compressive strength near to that of natural aggregate concrete and can be used effectively as a full value component for structural concrete. To improve compressive strength of higher grade of concrete, w/c ratio can be reduced. It is recommended that admixtures such as plasticizer and super plasticizer should be added in the mix so that fresh as well as hardened properties of RAC can be improved.

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