Experimental Study of Compressive Strength of Recycled Aggregate Concrete

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***Abstract*— In developing countries like India, the generation of construction and demolition (C &D) waste is upto the tune of 23.75 million tones annually and these figures are likely to double fold in the next 7 years. On the other hand, the reuse of construction waste is highly essential from the view point of Life Cycle Assessment (LCA) and effective recycling of the construction resources. Using the demolished concrete debris as recycled concrete aggregate conserves natural aggregates, reduces the impact on landfills, decreases energy consumption and can provide cost savings. The use of recycled aggregates in concrete results in significant economical and environmental benefits. In the present work, attempts have been made to assess the effect of recycled concrete aggregate on the strength of ordinary concrete. The basic engineering properties of Recycled Concrete Aggregate (RCA) is evaluated and it is compared with the Normal Aggregate (NA). Similarly, the basic concrete properties like, compressive strength, workability etc. are studied for the different combinations of RCA with NA. The goal of this study is to develop the economical and sustainable concrete by using the concrete waste available on the site.**

Keywords—recycled, compressive strength, failure pattern, workability.

1. INTRODUCTION

1.1 Background:

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, low and high-rise building, defence installations, environment protection and domestic development. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and by products in cement and concrete used for new constructions.

The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. The enormous quantities of demolished concrete are available at various construction sites, which are now posing a serious problem of disposal in urban areas. This can easily be recycled as aggregate and used in concrete. It has been shown that crushed concrete rubble, after separation from other C&D waste and sieved, can be used as a substitute for natural coarse aggregates in concrete or as a sub-base layer in pavements. This type of recycled material is called recycled aggregate. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness.

1.2 Technical Benefits and Drawbacks of RCA:

Recycling can be one of the best ways for us to have a positive impact on the world in which we live. Recycling helps in preserving the resources available for our future generations. If the current generation can utilize the natural resources more efficiently by converting them into new products, it means they are saving the natural resources for the following generations.

1.2.1 Benefits of Recycling:

- Recycling saves energy
- Recycling creates extra job opportunities
- Recycling saves natural resources
- Economic benefits
- Recycling saves space for waste disposal
- Sustainability
- Good wide market

1.2.2 Limitations of Recycling:

- Lack of codes, specifications, standards and guidelines
- Air pollution
- Water pollution
- Poor image
- Lack of experience
- Low quality
- Variations in quality

1.3 Objective of the Study:

- To find out the optimum content of RCA that can be feasibly used in normal construction practice.
- To reduce the impact of waste materials on environment.
- To carry out different tests on RCA and NA, and compare their results.

2. EXPERIMENTAL MATERIAL AND METHODOLOGY ADOPTED

2.1 Material Used:

Cement:

In concrete mix, Ordinary Portland Cement of 53 grade was used in this project.

Fine Aggregate:

The fractions for 4.75 mm to 150 micron are term as fine aggregate. Sand and crushed sand is used in combination as fine aggregate conforming to the requirements of IS: 383 of grading zone II.

Coarse Aggregate:

The fraction from 20 mm to 4.75 mm is used for coarse aggregate in this project. Generally there are 2 types of coarse aggregate is used coarse aggregate I (grit, which is 10 mm down) and coarse aggregate II (20 mm down).

Recycled Concrete Aggregate:

The C&D waste was collected from Varachha Road near old Gitanjali Cinema at Surat. The demolished structure named "Shree Ram hospital" was mainly used for public and residential purpose. It was old about 25-30 years.

Figure 1: Concrete debris collected from site

Figure 2: Generated RCA from debris

Water:

Water is an important ingredient of concrete as its actually participate in chemical reaction with cement since it helps to form the strength quality and quantity of water is required to be looked in to very carefully therefore. Potable water was used in preparation of M25 grade concrete.

Chemical Admixture:

A super plasticizer named FAIRFLO-333 of company named FAIRMATE CHEMICAL PVT. LTD. has been used in the present work.

2.2 Material Testing:

Based on various parameters, various engineering properties were studied of experimental materials. The results are shown in tables below.

Table 1: Basic properties of OPC 53

Sr. No	Tests	Results	I.S. Requirements 8112: 2013
1.	Specific Gravity	3.15	3.15
2.	Setting Time		
	Initial	120 min	>30 min
	Final	235 min	<600 min
3.	Standard Consistency	29.00%	36.00%
4.	Comp. Strength (N/mm^2)		
	7 days	37.66 N/mm^2	37 N/mm^2
	28 days	54.73 N/mm^2	53 N/mm^2

Table 2: Basic Engineering Properties of CA-I (Grit)

Sr. No.	Tests	Results	IS Requirements 8112: 2013
1.	Fineness Modulus	2.577	-
2.	Specific Gravity	2.77	-
3.	Water Absorption	2%	Max 2%
4.	Bulk Density	1485 kg/m^3	

Table 3: Basic Engineering Properties of Fine Aggregate

Sr. No	Tests	Results	IS Requirements 8112: 2013
1.	Fineness Modulus	2.413	-
2.	Specific Gravity	2.70	-
3.	Silt Content	0.09%	< 3%
4.	Grading Zone	II	-
5.	Water Absorption	0.8%	< 2%
6.	Bulk Density	1578 kg/m^3	-

Table 4: Comparison of Engineering Properties between Natural Aggregate(CA II) and Recycled Aggregate

Sr. No	Tests	NA	RCA
1.	Fineness Modulus	2.293%	2.319%
2.	Specific Gravity	2.819	2.450
3.	Water Absorption	1.755%	4.115%
4.	Bulk Density	1481 kg/m^3	1292 kg/m^3
5.	Impact value	13.04%	37.92%
6.	Crushing Value	16.71%	26.23%

2.3 Methodology Adopted:

Plain cement concrete and Reinforced cement concrete waste was collected from site (Varachha Road near old Gitanjali Cinema at Surat). The collected material was crushed by hammer to separate the aggregates and to reduce their sizes in smaller fraction. Various tests were conducted on these separated aggregates as per Indian Standard codes and their results were compared with the NA. Similarly, the basic concrete properties like, compressive strength, workability etc. were evaluated for the different combinations (0%, 20%, 40%, 60%) of RCA with NA. A mix M25 grade was designed as per IS 10262: 2009 and the same was used to prepare the test samples. The design mix proportion is shown in Table 2.5. Recycled aggregates reduces the impact of waste on environment. Also, the problem of disposal and land fill cam be reduced.

Table 5: Mix Proportion

Cement	375 kg/m^3
Water	167.45 kg/m^3
Fine aggregate (sand)	709.48 kg/m^3
Coarse aggregate (10 down)	473.33 kg/m^3
Coarse aggregate (20 down)	780.80 kg/m^3
Chemical admixture	3.75 kg/m^3
Water/Cement	0.45

3. EXPERIMENTAL STUDY

3.1 Test Set-up:

In present experimental work, various concrete mix batches have been prepared such as, normal concrete i.e. 0% replacement, 20% replacement, 40% replacement and 60%. The testing of mechanical properties were conducted on Universal Testing machine after 28 days.

3.2 Parameter Studied:

During the experimental work, generally two parameters were studied i.e. compressive strength and workability.

Evaluation of Compressive Strength:

Compressive strength is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. To evaluate the compressive strength cubes of size 150 mm x 150 mm x 150 mm were casted using C.I. mould.

A test was conducted on the cubes of grade M25 at 28 days. Total four concrete mix batches were tested in which one mix was of normal aggregate concrete at 0% replaced by RCA and other are of Recycled aggregate concrete at 20%, 40% and 60% replaced by RCA. The result of the test are shown in the table 1.The compressive strength of the specimens was calculated by following formula.

$$F_{cr} = P/A$$

where, F_{cr} = Compressive Strength
P = Failure load in Compression (KN)
A = Loaded area of cube (mm^2)

Figure 3: Compressive strength test set up

Evaluation of Workability by Slump test:

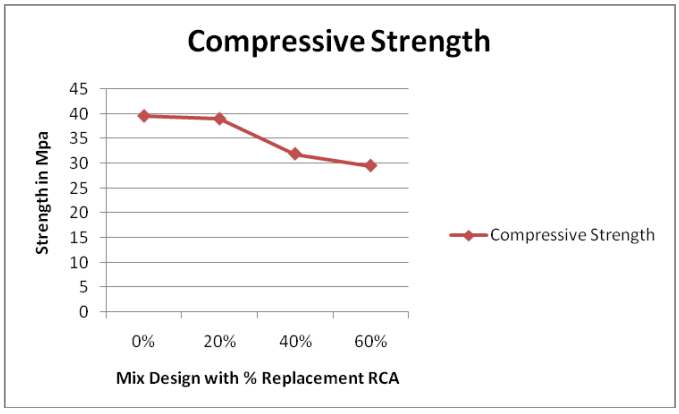
Workability of concrete refers to the ease with which the concrete can be mixed, transported, placed and compacted fully. This test method is used to determine the slump of freshly mixed concrete. Slump is the relative measurement of workability of concrete. The test may be done in the laboratory and in field.

Figure 4: Slump of Concrete at 40% Replacement

4. RESULTS AND DISCUSSIONS

The each cube of dimension 150 mm x 150 mm x 150 mm were tested in UTM for compression test as shown in figure 4. The load at which cube failed was recorded for every cube. The test results are shown in following table-6. Also, failure pattern of cube is shown in figure 5. The results of workability by slump test is also discussed in table 7.

Figure 5:Failure of concrete cube



Graph 1: Comparison of compressive strength

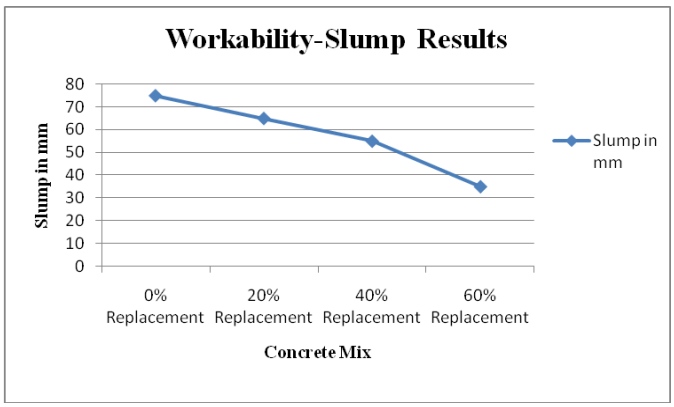
Table 6: Results of compressive strength

Sr. No.	Concrete Mix % Replacement	Load (KN)	Compressive Strength (N/mm^2)	Avg. Comp. Strength N/mm^2
1.	0%	870.7	38.69	39.53
		791.2	35.10	
		1010.0	44.80	
2.	20%	881.6	39.18	38.96
		875.6	38.90	
		875.3	38.81	
3.	40%	690.6	30.7	31.9
		749.3	33.30	
		713.2	31.70	
4.	60%	671.3	29.83	29.52
		668.5	29.71	
		653.0	29.02	

From the table 6 and graph 1 it can be seen that, the compressive strength of M25 grade normal concrete at 28 days is 39.53 N/mm^2. At the same time, the compressive strength at 20 % replacement is found to be 38.96 N/mm^2. Also, there is sudden fall in strength at 40% and 60% replacement, as the quantity of RCA increases. At 60% replacement, the compressive strength is about 29.52 N/mm^{2}which is less that 31.6 N/mm^2.

Table 7: Result of slump test

Concrete mix % of RCA	Slump in mm
0%	75 mm
20%	65 mm
40%	55 mm
60%	35 mm



Graph 2: Comparison of Slump Results

From, the results of slump it is seen that, the slump of normal concrete mix design of M25 grade is 75 mm. But, the slump of concrete mix with 20% and 40% replacement by RCA is 65 mm and 55 mm respectively. Since, there is a reduction in slump results because the water absorption of RCA is more. As the dust particles and cement paste may attached to RCA. At 60% replacement, there is sudden fall in slump i.e. 35 mm, as it is seen, if the quantity of RCA increases, the slump decreases.

4. COST IMPACT ON CONCRETE

The change in cost due to replacement of aggregates is worked out in Table 4.2. the basic market rates of materials are given in Table 4.1. The cost of transportation is not included. Cost decreases due to reduction in natural aggregates.

Table 8: Cost of Materials

Sr. No.	Materials	Rate (Rs/kg)
1.	OPC 53 (Ultratech)	6.00
2.	Fine Aggregate	0.60
3.	Coarse Aggregate I	0.65
4.	Coarse Aggregate II	0.65
5.	Chemical admixture	40.00

Table 9: Material cost Estimation

Concrete Grade	M25			
% replacement in concrete	0%	20%	40%	60%
OPC 53 (kg/m^3)	375.00	375.00	375.00	375.00
Fine Aggregate (kg/m^3)	709.48	709.48	709.48	709.48
Coarse Aggregate I (kg/m^3)	473.33	473.33	473.33	473.33
Coarse Aggregate II (kg/m^3)	780.80	624.64	468.48	312.32
RCA (kg/m^3)	0.00	156.16	312.32	468.48
Chemical admixture (kg/m^3)	3.75	3.75	3.75	3.75
Total cost per m^3	3601.83	3539.36	3437.86	3336.35
% change in cost	0.00	1.73	4.55	7.37

ACKNOWLEDGEMENT

The authors would like to acknowledge Mr. Mukesh Mehta for providing the materials required for the research work. We are indebted to Mr. Hitesh Desai for granting the permission to perform the experimental study at Unique Laboratory. We are indebted Dr. Pratima A. Patel for her help and valuable suggestions in needs. Also, we record thankfulness to Prof. Minakshi V. Vaghani for her motivational support and her valuable suggestion for presenting this study work.

CONCLUDING REMARKS

From the experimental work "Experimental Study of Compressive Strength of Recycled Aggregate Concrete", the following conclusion can be made:

- Recycling and reuse of building wastes have been found to be an appropriate solution to the problems of dumping hundred of thousands tons of debris accompanied with shortage of natural aggregates. The use of recycled aggregates in concrete prove to be a valuable building materials in technical, environment and economical respect. Use of RCA in concrete save the disposal and land filling cost and produce a sustainable concrete for construction.
- From the material testing, it can be concluded that, RCA exhibits comparatively less specific gravity than NA. As the water absorption of RCA was found greater then NA, because of adhering mortar and cement paste. This need to be compensated during mix design. On the other hand, RCA is having comparatively same Bulk Density as NA. But, the impact and crushing value of RCA are comparatively less than NA.
- The results of compressive strength shows that, the use of RCA up to 40% affect the functional requirements of concrete structure. Also the result of slump test shows there is continuous decrease in workability of concrete mix, as the cement mortar paste is attached to RCA.
- The cost analysis indicates that, the cost of construction per m^3 reduces up to certain extents. This research concludes that RCA can be used as constructional material.

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