Experimental Study on Engineering Performance of Recycled Aggregate Concrete Made from Crushed Concrete

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Abstract

Recycled Concrete aggregates (RCA) are comprised of crushed, graded inorganic particles processed from the materials are used in the constructions industry. The aim of this project is to determine the strength characteristics of recycled aggregates for application of structural concrete in high strength, which will give a better understanding on the properties of concrete with RAC, as an alternative material to coarse aggregate (NA) in structural concrete. The scope is this project is to determine and compare the strength of concrete by using different percentage of recycled concrete aggregates. Recycled aggregate is also the type of artificial aggregate which is obtained from (C&D) wastes i.e. Construction and demolition. Constructions and demolitions are processes that go hand in hand. In India the demolished building rubble generally goes to waste materials in landfills. Recycling of these concrete waste materials from demolition building can provide a solution to this problem. The investigation was carried out using Specific gravity test, sieve analysis test, Impact test, Water absorption test, Crushing value test, Workability test and compressive strength test. There are total six batches of concrete mixes, consisting of every 20% increment of recycled aggregate replacement, from 0% to 100%.

Keywords: Recycled Aggregate, Impact Test, Coarse Aggregate, Crushing Value Test, Compressive Strength Test Workability Test

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I. INTRODUCTION

Construction and demolitions are processes that go hand in hand. The demolished building rubble in India generally goes to waste in landfills. After few years construction and demolition waste will be more than half of the National total waste materials in most countries of the World so recycling of these concrete waste materials from building demolition can provide a solution to this problem. Landfills are becoming increasingly difficult to find, are too remote from the demolition site, or are too costly to maintain. At the same time sources of supply of suitable aggregate for making concrete are continuously being exhausted. The recycling of building demolition waste materials into new buildings can provide a solution to these problems. Grinding reinforced concrete buildings can reduce the volume of land filled debris by roughly 80%. While volume reduction itself is beneficial, recycling the waste creates a product that can be sold or used for fill, bank stabilization, pavement for trails and other purposes, thereby reducing further environmental burdens by substituting recycled aggregates for natural virgin aggregates. Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled concrete aggregate can be used as the replacement materials. Recycled concrete aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris.

II. MATERIALS USED

Conventional materials- Portland cement, fine aggregates and coarse aggregates were purchased from the local vendors. RCA- The main source of recycled concrete aggregate was demolished structure mainly the columns and beams which were free from any reinforcement or other contaminants, cubes from this material were casted and tested in the laboratory. The local crushing plants were not able to crush the concrete waste and thus the crushing and sieving had to be done manually. The concrete rubble remains (Fig.1) were broken initially manually and then sieving was done using IS sieves. The process generated, recycled

concrete aggregate-10mm and recycled concrete aggregate-20mm size. (Fig 2) shows how the concrete was crushed manually and then used.

Fig. 1: Concrete Rubble

Fig. 2: Recycled Aggregate Natural Aggregate

III. EXPERIMENTAL METHODOLOGY

A. Mix Design and Casting of Concrete

1) Proportioning of Concrete

Before having any concrete mixing, the selection of mix materials and their proportion must done through a process called mix design. There are various methods to determine concrete mix design. Six batches of mixtures were determined in this project. The initial mix batch is using 100% natural aggregate was used. In second mix batch 80% natural aggregate and 20% recycled aggregate. Successive batches were made by successively adding 20% extra recycled aggregates & corresponding decrease in natural aggregate as shown in Table 1. First batch of mix called a control mixture used only natural aggregates, and five successive mixtures with increasing percentage of recycled aggregate and corresponding decrease of natural aggregate from 20% to 100% by weight. All these mixtures were prepared with cement, and aggregate in the proportion by weight, and were expected to achieve a target compressive strength of not less than 39.9 MPa at the age of 28 days

Table – 1
Percentage of aggregate used in all 6 batches of mixes.

	Batch 1	*Batch 2*	*Batch 3*	*Batch 4*	*Batch 5*	*Batch 6*
NA (%)	*100*	*80*	*60*	*40*	*20*	*0*
RAC (%)	*0*	*20*	*40*	*60*	*80*	*100*

B. Mix Design

1) D.O.E. (Department of Environment Method)

a) For 100% Natural Aggregate

First step is to find out the target mean strength.

Target mean strength = specified characteristic strength + std.deviation × risk factor = 30+ 6 x 1.65 = 39.9 Mpa

Second step is to find out the water cement ratio for 39.9Mpa concrete for this for OPC uncrushed aggregate for W/C ratio of 0.55,28 days compressive strength is 49Mpa.Find an intersection point for 49Mpa and 0.5W/C ratio .Draw a dotted line curve

parallel to the neighboring curve. From this curve read off the W/C ratio for a target mean strength of 30 Mpa. The water cement ratio is = 0.7

Check this W/C ratio from durability consideration from table 9.20.the maximum W/C ratio permitted is 0.55 adopt lower of the two, Therefore adopt W/C ratio of 0.55

Next decide the water content for slump of 60mm (highest slump is taken), 20mm crushed aggregate

The water content is 210kg/m^3 With W/C of 0.5 and water content of 210kg/m^3, the cement content works out to be 210/0.55=381.82kg/m^3, Check this cement content with that of durability requirement minimum cement content from durability point of view is 325kg/m^3.Adopt greater of the two. Therefore adopt cement content =381.82kg/m3

Next, find out the density of fresh concrete for water content of 210kg/m^3, 20mm uncrushed aggregate of specific gravity 2.75, The wet density = 2475kg/m^3

Next, find the weight of total aggregate 2475-(210+381.82) =1883.18kg/m^3 Next, find the percentage of fine aggregates For 20mm aggregate size, water cement ratio of 0.55 Slump of 60mm, for 50% fine passing through 425µ sieve, the percentage of F.A. = 35 percent

Weight of F.A. =1883.18X (35/100) =659.11kg/m^3
Weight of C.A. = 1883.18-659.11=1224.07kg/m^3
Estimated quantities in kg/m^3
Cement=381.82kg/m^3
F.A.=659.11kg/m^3
C.A. =1224.07 kg/m^3
Water =210 kg/m^3
Wet density =2475 kg/m^3

b) For 100% Recycled Aggregate

First step is to find out the target mean strength.

Target mean strength= specified characteristic strength + std.deviation × risk factor = 30+6x1.65 = 39.9 Mpa

Second step is to find out the water cement ratio for 39.9Mpa concrete, For this for OPC uncrushed aggregate for W/C ratio of 0.55,28 days compressive strength is 49Mpa. Find an intersection point for 49Mpa and 0.5W/C ratio .Draw a dotted line curve parallel to the neighboring curve. From this curve read off the W/C ratio for a target mean strength of 30 Mpa. The water cement ratio is = 0.7 Check this W/C ratio from durability consideration from table 9.20.the maximum W/C ratio permitted is 0.55 adopt lower of the two, Therefore adopt W/C ratio of 0.55, Next decide the water content for slump of 60mm, 20mm crushed aggregate The water content is 210kg/m^3 With W/C of 0.5 and water content of 210kg/m^3, the cement content works out to be 210/0.55=381.82kg/m^3

Check this cement content with that of durability requirement given. .Minimum cement content from durability point of view is 325kg/m^3.Adopt greater of the two. Therefore adopt cement content =381.82kg/m3, Next, find out the density of fresh concrete for water content of 210kg/m^3, 20mm uncrushed aggregate of specific gravity 2.85, The wet density = 2550kg/m^3 Next, find the weight of total aggregate 2550-(210+381.82) =1958.18kg/m^3

Next, find the percentage of fine aggregates from fig, For 20mm aggregate size, W/C ratio of 0.55 Slump of 60mm, for 50% fine passing through 425µ sieve, the percentage of F.A. =35 percent

Weight of F.A. =1958.18X (35/100) =685.36kg/m^3
Weight of C.A. = 1958.18-685.36=1272.82kg/m^3
Estimated quantities in kg/m^3
Cement=381.82kg/m^3
F.A.=685.36kg/m^3
C.A.=1272.82 kg/m^3
Water=210 kg/m^3
Wet density=2550kg/m^3

Table – 2
Proportion of each mix materials for six cubes

	Cement	*Sand*	*N.A.*	*R.A.*	*Water*
100%	*9.9kg*	*21.72kg*	*-*	*23.49kg*	*5.5lit*
80%	*9.9kg*	*21.72kg*	*4.7kg*	*18.79kg*	*5.5lit*
60%	*9.9kg*	*21.72kg*	*9.40kg*	*14.09kg*	*5.5lit*
40%	*9.9kg*	*21.72kg*	*14.09kg*	*9.40kg*	*5.5lit*
20%	*9.9kg*	*21.72kg*	*18.79kg*	*4.7kg*	*5.5lit*
0%	*9.9kg*	*21.72kg*	*23.49kg*	*-*	*5.5lit*

Table – 3
Physical properties of aggregates used

Particulars	*Recycled Concrete Aggregate (RCA)*	*Natural Aggregate (NA)*	*Sand*
Specific gravity	*2.85*	*2.75*	*2.65*
Water absorption (%)	*4.4%*	*1.83%*	*--*
Crushing Value Test	*22.46%*	*15.20%*	*--*
Impact test:	*11.33%*	*7.64%*	*--*

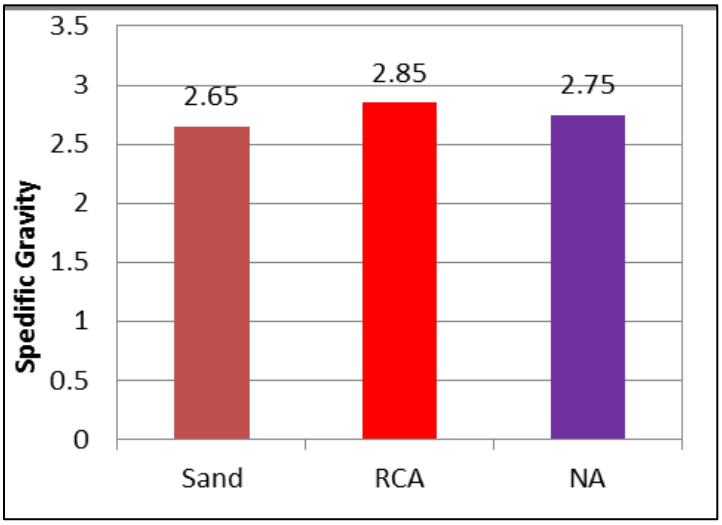

Fig. 3: Specific Gravity of Aggregate

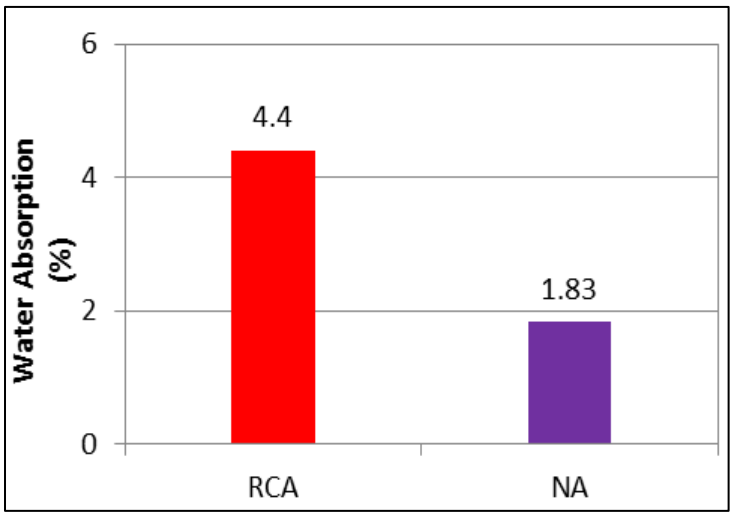

Fig. 4: Water Absorption of Aggregates

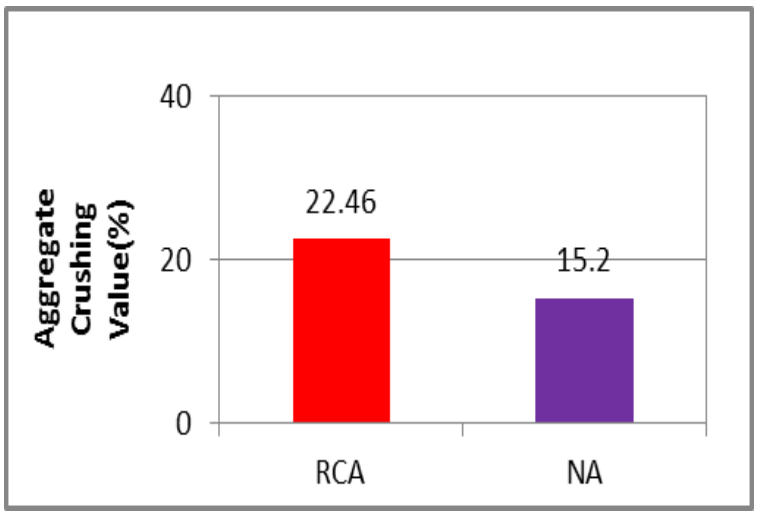

Fig. 5: Crushing Value of RAC and NA

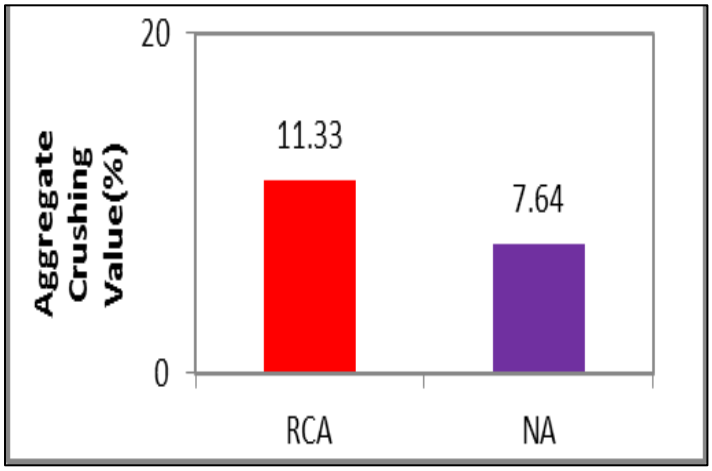

Fig. 6: Impact Value of RAC and NA

IV. RESULTS AND OBSERVATIONS

The compression test by CTM (Compressive Testing machine) indicates an increasing trend of compressive strength with age of the concrete specimens.

Table – 4
The slump result for each batch of mix concrete

Percentage of Recycled Aggregate (%)	*Slump (mm)*
0% recycled aggregate	*60*
20% recycled aggregate	*50*
40% recycled aggregate	*40*
60% recycled aggregate	*25*
80% recycled aggregate	*20*
100% recycled aggregate	*20*

A. Percentage of Recycled Aggregate

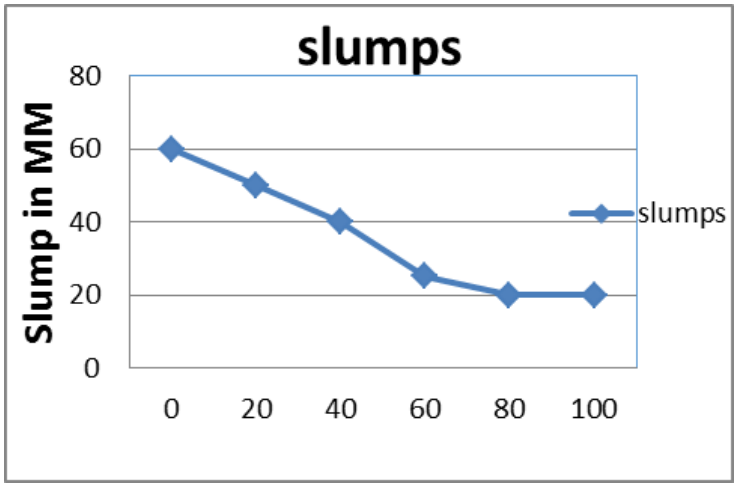

Fig. 7: Variation of Slump value

B. Compressive Strength Test Result

Table – 5
Variation of compressive strength (MPa)

% of RA	*0%*	*20%*	*40%*	*60%*	*80%*	*100%*
7 DAYS	*36.0 MPa*	*34.2 MPa*	*32.2 MPa*	*24.3 MPa*	*22.1 MPa*	*19.2 MPa*
28DAYS	*49.0 MPa*	*45.0 MPa*	*44.0 MPa*	*43.0 MPa*	*38.0 MPa*	*34.0 MPa*

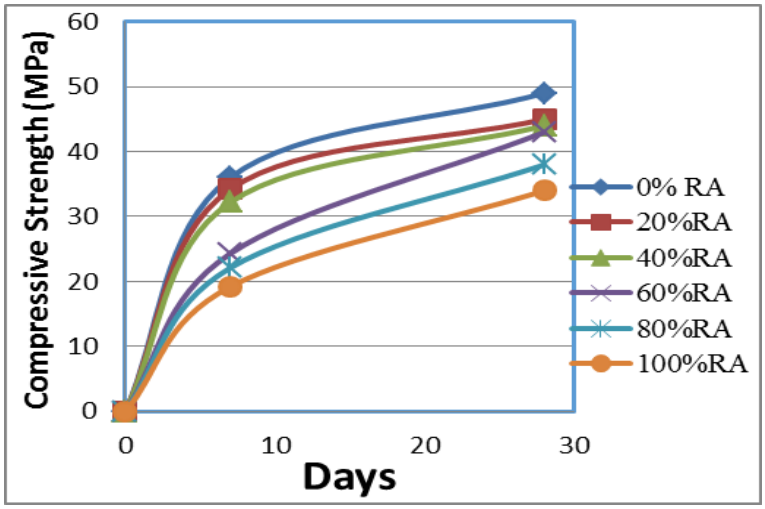

Fig. 8: Variation of Compressive Strength with Age

V. CONCLUSIONS

test results indicates that as the percentage of Natural Aggregate decreases by replacing the recycled Aggregate, the corresponding strength goes on decreasing, however up to 60% replacement it achieves target mean strength. Hence, for structural concrete natural Aggregate can be replaced by the recycled aggregate up to 60% limit.

- The workability of concrete considerably reduces as the amount of recycled aggregate increases.
- This research project is aimed to determine the strength characteristics of recycled aggregate concrete for potential application in the structural concrete.
- Whenever recycled aggregate is used, water content in the concrete mix has to be monitored carefully, owing to increased water absorption capacity of recycled aggregate.

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