The Asian Review of Civil Engineering
ISSN: 2249-6203 (P) Vol.1 No.1, 2012, pp.19-24

DOI: https://doi.org/10.51983/tarce-2012.1.1.2179

Experimental Investigation on Recycled Aggregate as Partial Replacement on Natural Aggregate

K. M. Gopalakrishnan[1], R.Murugesan[2] and V. Sampath Kumar[3]

[1&3]*Department of Civil Engineering, Erode Sengunthar Engineering College, Thudupathi, Erode - 638 057, Tamil Nadu, India.*

[2]*Department of Civil Engineering, IRTT, Erode District - 638 316, Tamil Nadu, India*

E-mail : gkrishnan004@gmail.com

(Received on 11 October 2011 and accepted on 22 March 2012)

Abstract - **In construction industry and in urban areas, many concrete structures like buildings, bridges and roads are razed after a period of time into their service life for purpose of replacement and also due to natural disasters like earthquakes, cyclones and man made disasters like war and bombing. Due to increasing construction activities and infrastructure development works the sources of basic construction materials are depleting. It is becoming increasingly difficult to obtain good quality aggregate at reasonable prize. The increase in cost is mainly due to the cost of transportation and availability of only few quarries. Considering the present situation one of the alternate solutions would be to reuse the demolished concrete. This work deals with an experimental investigation on the effectiveness of replacement of natural aggregates by recycled aggregates in different percentages like 0%, 5%, 15%, 25%, 35%, 45%, 55%, 65%, 75%, 85% and 95% on the strength characteristics of concrete. Experiments were carried out to determine compressive uplifting tensile and flexural strength of concrete with different percentage of recycled concrete aggregate and to compare them with those of concrete made with conventional course aggregate.**

I. Introduction

For any construction industry resource handling is very much important factor. Normal implementation of construction industry requires Coarse Aggregate testing of raw materials proves to be a remedial measure to avoid the delay in production. Increase in cost of materials is due to non availability of enough raw material and high shipping cost. The optimal use of wealth has also added to the process of recycling sector in the industry. A large amount of demolished concrete is generated as a waste. Most of the demolished waste is disposed of by dumping it as land fill or for reclaiming land. Athough numbers of research works are going on the recycling materials and the management has appeared. A very rare literature is found on recycled concrete as a structural component in reinforced concrete structures, only they are used as pavement material. According to Jianzhuang Xiaoa, Jiabin Lia, Ch. Zhangb (2005) the recycled concrete aggregate replacement percentage has a considerable influence on the stress–strain curves of recycled aggregate concrete. For all considered Cases % to 100%, the stress– strain curves show a similar behavior. Salomon M. Levy, Paulo Helene (2004) minimum water absorption and total pore volume for the recycled aggregates concrete were observed at 20%.When water absorption and total pore volume are increased, the replacement of Recycled aggregate also increases. When the natural aggregate is replaced by 20% of the recycled aggregates from old concrete or old masonry, the resulting recycled concrete will likely present same, and sometimes better. The experimental study proposes to attempt to evaluate the behavior and failure characteristics of a concrete specimen replacing recycled concrete as course aggregate in different percentage by weight for different mix proportions.

II. Aim And Scope Of Present Investigation

A. Aim

The aim of this investigation is to study the scope of recycled concrete aggregate as natural coarse aggregate subjected to compression test, split tensile test and flexural strength test.

B. Scope of the Investigation

1. To determine the behavior of concrete using Recycled Concrete Aggregate as Coarse Aggregate;
2. To reduce the cost of construction work and also maintain the same quality as Like Natural Coarse Aggregate in cement concrete;
3. To meet the scarcity of Natural Coarse Aggregate in future, the Recycled aggregate can be alternatively used;
4. To determine the optimum level of Recycled Concrete Aggregate to Natural Coarse Aggregate;

5. To determine the strength characteristics of concrete with Recycled Concrete Aggregate;
6. Vast quantities of waste concrete are produced from a number of different sources. In this investigation recycled aggregates are used by replacing natural aggregates at different percentages like 0%, 5%, 15%, 25%, 35%, 45%, 55%, 65%, 75%, 85% and 95%.

III. Materials

A. Introduction

A brief specification of the materials used in the specimen and their properties are explained.

B. Cement

PPC of 43 grade in one lot was procured and stored in air tight container. The cement used was fresh i.e. used within three months of manufacture. It should satisfy the requirement of IS12262. The properties of cement are determined as per IS4031:1968 & results are tabulated.

Table I Properties Of Cement

Properties of Cement	Values
Fineness	10%
Initial setting time	28min
Specific gravity	3.15

C. Fine Aggregate

Fine Aggregate obtained from the river is used for experimental purpose. It should be with less amount of clay and silt i.e., (<3% by weight). The hire from silt, clay, salt and organic material and it was clean and dry. It is of size passing through 4.75mm sieve.

D. Natural Coarse Aggregate

The Natural Coarse Aggregate is strongest and non porous component of concrete. Presence of Natural Coarse

Table II Properties of Natural Coarse Aggregate

Natural Coarse Aggregate	Values
Size	19mm – 11.4mm
Bulk density	1674kg/m^3
Fineness modules	6.23
Specific gravity	2.61
Water absorption	0.55%

The Natural Coarse Aggregate used is passes through 19 mm and retained in 11.4mm sieve. It is well graded (should be with different particle size and maximum dry packing density and minimum voids) and cubical in shape.

E. Recycled Concrete Aggregate

Recycled Concrete Aggregate is comprised of crushed concrete or stone that can be graded to meet the specific standard for both aggregates base as well as sub base. Specifying recycled materials creates a market for material that would otherwise be land filled and in most instances, is a more economical alternative to using virgin material.

Table III Properties of Recycled Concrete Aggregate

Recycled Concrete Aggregate	Values
Specific gravity	3.27
Impact value in %	22.7
Water absorption in %	2.70

F. *Applications of Recycled Aggregates*

- Many types of general bulk fill.
- River bank production.
- Base or fill for drainage structures.
- Noise barriers and embankments.
- In paved roads as aggregate base, aggregate sub-base, shoulders.
- In gravel roads as surfacing.
- As base for building foundations.
- As fill for utility trenches.

G. *Water*

Portable water is used for casting of all specimens of this investigation. Water helps in dispersing the cement even, so that every particle of the aggregate is coated with it and brought into ultimate contact with the ingredients.

IV. Concrete Mix

Grade of concrete selected is M30 (1:1.02:2.26) and water content adopted is 0.38. The mix proportion was designed in accordance with IS (456-2000) for good degree of quality control and moderate exposure condition. The controlled mixes were prepared by using natural sand as fine aggregate.

M 30 CONCRETE MIX DESIGN

A. *Design Stipulations*

1. Characteristic comp strength - 30.0MPa
2. Maximum size of aggregate - 20mm
3. Degree of workability - 0.90compacting factor
4. Degree of quality control - Good
5. Type of exposure - Mild

B. ***Test Data For Materials***

1. Specific gravity of cement - 3.15
2. Specific gravity of Coarse Aggregate - 2.61
3. Specific gravity of fine aggregate - 2.67
4. Water absorption:
   1. Course aggregate - 0.5%
   2. Fine aggregate - 1.0%
5. Free (surface) moisture: - Nil

C. ***Target Mean Strength Of Concrete***

$f_t = f_{ck} + k.s$

Where, f_t= target mean strength of concrete

f_{ck}=characteristics mean strength

k = risk factor ie. 1.65

s = standard deviation i.e. 4

$f_t = 30 + 1.65 \times 4 = 36.6\ N/mm^2$

D. ***Selection of Water-Cement Ratio***

The water-cement ratio required for the target mean strength of 36.6 MPa is 0.38.This is lower than the maximum value of 0.6 prescribed for 'mild' exposure. Hence W/C ratio of 0.38 is adopted.

E. ***Selection of Water and Sand Content***

For 20 mm maximum size aggregate, sand conforming to grading Zone II, water content per cubic meter of concrete = 186 kg and sand content as percentage of total aggregate by absolute volume = 35%. For change in value in water-cement ratio, compacting factor, for sand belonging to Zone III, following adjustment is required.

TABLE IV ADJUSTMENT OF VALUES IN WATER CONTENT AND SAND PERCENTAGE FOR OTHER CONDITIONS

Percent Adjustment Required		
Change in Condition	**Water**	**Sand in Total Aggregate**
For decrease in w/c ratio by (0.6-0.5)that is 0.10	0	-2.0
For increase in compacting factor(0.90.8),that is 0.10	+3.0	0
For sand conforming to Zone III	0	-1.5
Total	+3.0	-3.5

Therefore, required sand as percentage of total aggregate by absolute volume = 35-3.5 = 31.5%
Required water content = 186 + 186 X 3/100
= 191.61

F. ***Determination of Cement Content***

Water-cement ratio = 0.38
Water = 191.61 liter
Cement = 191.61/0.38 = 504.21 kg/m^3

G. ***Determination of Coarse and Fine Aggregate Contents***

For the specified maximum size of aggregate of 20mm, the amount of entrapped air in the wet concrete is 2%.

V = [W+C/Se+1/P X fa/Sfa] X 1/1000

0.98 = [191.61+504.21/3.15+1/0.315 X fa/2.61] X 1/1000,

Therefor fa = 515.03 kg/m^3

Coarse Aggregate = (1-P)/P X fa X S

Coarse Aggregate / Sfa = (1-0.315)/0.315 X 515.03 X 2.67/2.61
= 1137.2 kg/m^3

The mix proportion then becomes:

Water	Cement	Fine Agg	Coarse Aggregate
191.61	504.21kg	515.03kg	1137.2kg
0.38 :	1 :	1.02 :	2.26

H. ***Preparation of Test Specimen***

1. Concrete is mixed in roller type mixing machine. Care is taken to see that the concrete is properly placed beneath and along the sides of the mould with help of trowel and vibrating table. The specimens are casted to study the mechanical properties of conventional and replaced concrete.
2. 60No's of cube of size 150*150*150mm 3 No's per each mix for 7 and 28 days and each percentage of artificial aggregate (0%, 5%, to 95%).
3. 30 No's of cylinder of size 150mm diameter & 300mm height 3 No's per each mix for 28 days and each % of artificial aggregate (0%, 5%, to 95%).
4. 3No's of beam of size 100*100*500mm 3 No's per each mix for 28 days and each percentage of artificial aggregate (0%, 5%, to 95%).

TABLE V NUMBER OF SPECIMENS

S.No.	% of NCA	% of R CS	w/c ratio	Cubes		Cylind	Prism
				Days			
				7	28	28	28
1	100	0	0.38	3	3	3	3
2	95	5	0.38	3	3	3	3
3	85	15	0.38	3	3	3	3
4	75	25	0.38	3	3	3	3
5	65	35	0.38	3	3	3	3
6	55	45	0.38	3	3	3	3
7	45	55	0.38	3	3	3	3
8	35	65	0.38	3	3	3	3
9	25	75	0.38	3	3	3	3
10	15	85	0.38	3	3	3	3
11	5	95	0.38	3	3	3	3

V. Casting And Curing Of Specimen

1. Concrete using grade M30 (1:1.02:2.26) with water cement ratio 0.38 were used.
2. Cubes, beams and cylinders (7 & 28days) were prepared by using Recycled Concrete Aggregate and Natural Coarse Aggregte.

A. *Curing of Specimen*

The test specimen was De- mould after 24 hours of Casting. The De-mould specimen were immersed in the curing tank and stored in place free from vibration and at a temperature of 27°C. The moulds were allowed to cure up to 28 days.

VI. Testing And Analysis Of Specimen

A. *Introduction*

Testing of concrete plays an important role in controlling and confirming the quality of cement concrete. Cube, beam and cylinder are tested for its strength characteristics.

B. *Testing of Specimen*

1. *Cube Compression Test*

The cubes of size 150x150x150mm are placed in the machine such that load is applied on the opposite side of the cubes as casted and aligned carefully and load is applied, till the specimen breaks. The formula used for calculation. Compressive Strength= total failure load / area of the cube.

2. *Split Tensile Test*

The test is Carried out by placing cylinder specimen of dimension 150mm diameter and 300mm length, horizontally between the loading surface of compression testing machine and the load is applied until failure of the cylinder along the vertical diameter. The failure load of the specimen is noted. Tensile strength of cylinder is calculated by using the formula

Tensile strength= 2P / 3.14 DL

Where, P- Failure load of the specimen

D-Diameter of the specimen

3. *Flexural Test*

The test is carried to find the flexural strength of prism dimension 100 x 100 x 500 mm. The prism is then placed in the machine and load is applied to the uppermost surface as casted in the mould. Two points loading adopted on an effective span of 400 mm while testing the prism. The load is applied until the failure of the prism. By using the failure load of prism.

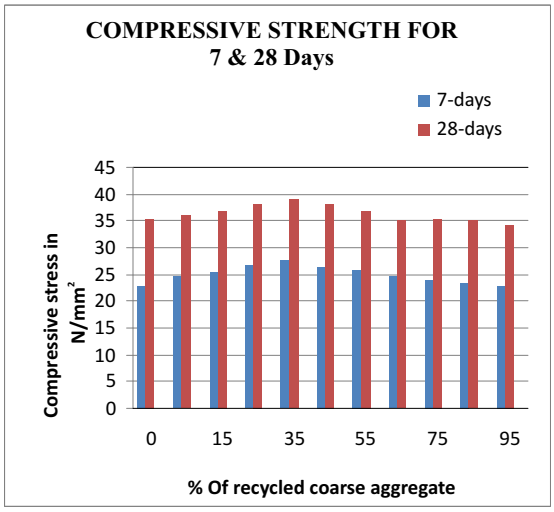
Flexural strength = PL/bd^2

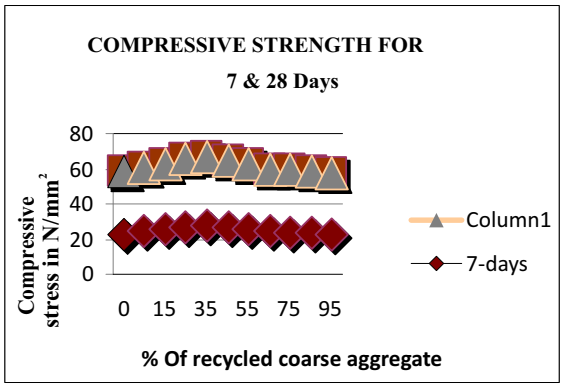
VII. Analysis of Test Result

Table VI Results For Compression Strength

S1.No.	% of RCA	% of NCA	Compressive Strength Mpa (7days)	Compressive Strength Mpa(28days)
1	0%	100%	22.7	35.5
2	5%	95%	24.5	36.0
3	15%	85%	25.6	36.9
4	25%	75%	26.6	38.0
5	35%	65%	27.7	39.1
6	45%	55%	26.3	38.1
7	55%	45%	25.7	37.0
8	65%	35%	24.6	35.2
9	75%	25%	24.0	35.3
10	85%	15%	23.4	35.0
11	95%	5%	22.9	34.2

It has been observed that the result produced from 0% to 95% replacement of Natural Coarse Aggregate by Recycled Concrete Aggregate, shows higher compressive strength. The maximum strength of concrete is at 35%. Replacement of Natural Coarse Aggregate, added Recycled Concrete Aggregate may absorb the additional quantity of water from the concrete mass making the water-cement ratio less without affecting the workability.



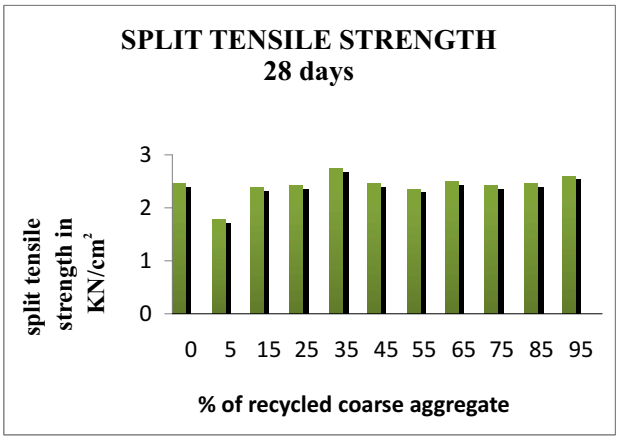


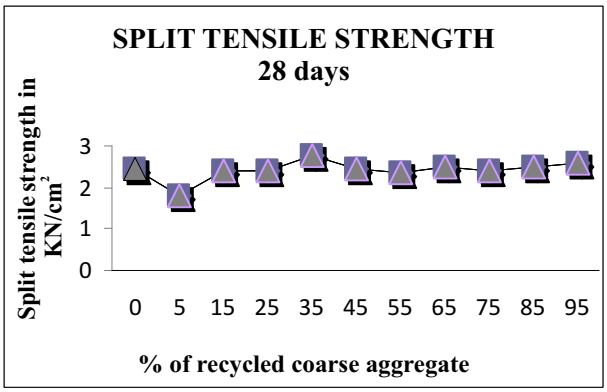
The result obtained from the tested cubes of 0% to 95% replacement of Natural Coarse Aggregate by Recycled Concrete Aggregate, shows maximum split tensile strength. The optimum strength of concrete is 35%; Replacement of Natural Coarse Aggregate added may absorb the additional quality of water from the concrete mass making the water-cement ratio less without affecting the workability.

The result obtained from 0% to 95% replacement of Natural Coarse Aggregate by Recycled Concrete Aggregate, shows maximum flexural strength as compared to other replacement. The optimum strength of concrete is 45%; Replacement of Natural Coarse Aggregate added may absorb the additional quality of water from the concrete mass making the water-cement ratio less without affecting the workability.

TABLE VIII RESULTS OF SPILITING TENSILE STRENGTH:

S.No	% of RCA	% of NCA	Split Tensile strength kN/cm² (28days)
1	0%	100%	2.45
2	5%	95%	1.78
3	15%	85%	2.40
4	25%	75%	2.42
5	35%	65%	2.75
6	45%	55%	2.45
7	55%	45%	2.36
8	65%	35%	2.49
9	75%	25%	2.42
10	85%	15%	2.47
11	95%	5%	2.59



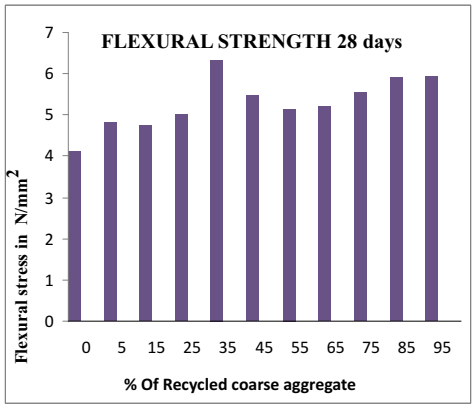


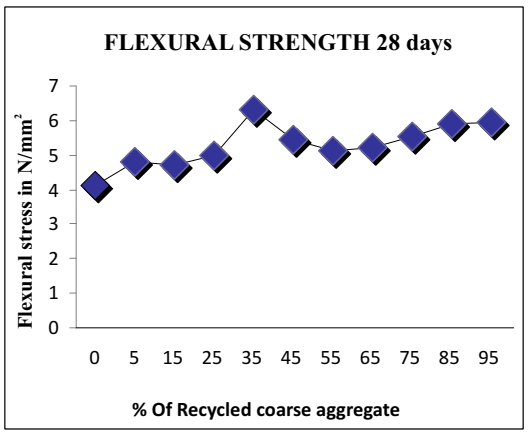
VIII. RESULT AND DISCUSSION

Based on this experimental investigation the behavior of Recycled Concrete Aggregate was concluded as that Recycled Concrete Aggregate used as Natural Coarse Aggregate has no detrimental effect on the strength and performance of concrete when designed correctly. The Recycled Concrete Aggregate used in this investigation is of free of cost since it is waste obtained from the demolished/collapsed structures. 35% replacement of Natural Coarse Aggregate by Recycled Concrete Aggregate gives the maximum compressive strength, tensile strength, flexural strength.

TABLE VIII RESULTS FOR FLEXURAL STRENGTH

S.No	% of RCA	% of NCA	Flexural strength N/mm^2 (28days)
1	0%	100%	4.13
2	5%	95%	4.80
3	15%	85%	4.73
4	25%	75%	5.00
5	35%	65%	6.33
6	45%	55%	5.46
7	55%	45%	5.13
8	65%	35%	5.20
9	75%	25%	5.55
10	85%	15%	5.89
11	95%	5%	5.9





IX. CONCLUSION

The result clearly shows that performance of percentage replacement of Natural Coarse Aggregate by Recycled Concrete Aggregate is better in Compression strength, Flexural strength and Split tensile strength. The replacement shows gradual and strong improvement. By considering the factor of safety this research has been concluded that 35% replacement of recycled concrete aggregate will gives optimal and safest replacement in accordance with the clear high performance in all the vital strength.

REFERENCES

[1] IS: 383-1970, "Specifi Coarse Aggregatetion for coarse and fine aggregate from natural sources for concrete", *Bureau of Indian standards,* New Delhi.

[2] M.Salomon Levy and Paulo Helene, "Durability Of Recycled Aggregates Concrete A Safe Way To Sustainable Development" *Cement And Concrete Research,* Vol.34,No. 19, 2004.

[3] B. Selva koodalingam and M. Palanikumar, "Partial Replacement of Sand In Concrete With Quarry Dust", Proceedings of the national symposium on Futuristic of Concrete Technology and Optimal Design of RCC structures, KIT, Coimbatore December 20-21, pp.41-48, 2002.

[4] M.S.Shetty, "Concrete Technology Theory and Practice", Chand and Company, 2001.

[5] T. S. Nagaraj and ZahidaBonn (1996): "Efficient Utilization Of Rock Dust And Pebbles As Aggregates In Portland Cement Concrete". *The Indian Concrete Journal,* Vol. 53-56, 1996.