An Experimental Study on Partial Replacement of Course Aggregate by Demolished Concrete Waste

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***Abstract*- This study is a part of comprehensive program wherein experimental investigations have been carried out to evaluate the effect of partial replacement of coarse aggregate by Construction and Demolition(C&D) Waste on compressive strength, tensile strength and workability of RAC (Recycled Aggregate Concrete). The main objective of this investigation is to find out up to what percentage the Natural Coarse Aggregate (NCA) can be replaced by Recycled Coarse Aggregate in the concrete mix for an equivalent application or purpose. So in this study we have taken the demolished concrete aggregate 10%, 20%, and 30% by weight of the conventional coarse aggregate and the concrete cubes were casted by Recycled Aggregate Concrete. Then further tests conducted such as Workability test, Compressive strength test and Split tensile test for that DAC at the end of 7 days and 28 days curing period. For the strength characteristics, the result showed a gradual decrease in Workability, Compressive strength and Split tensile strength as the percentage of recycled aggregate is increased.**

***Index Terms*- Construction and Demolition(C&D) Waste, Partial replacement, RAC (Recycled Aggregate Concrete), Natural Coarse Aggregate (NCA)**

INTRODUCTION

Development of infrastructural facilities is accompanied by construction, excavation, renovation, demolition, and roadwork associated activities. The construction industry in India is booming already at 10 per cent of the GDP.

It has been growing at an annual rate of 10 per cent over the last 10 years as against the world average of 5.5 per cent per annum. Almost 70 per cent of the building stock in India is yet to come up. The built-up area is expected to swell almost five times from 21 billion sq. ft. in 2005 to approximately 104 billion sq. ft. by 2030.[1]

Buildings are at the core of all over demands like water, energy and materials but they also create waste while its construction, renovation and mostly while demolition. Construction and demolition waste defined as a mixture of solid waste materials arising from any above mentioned activities.

In other word, C&D waste was usually defined as a mixture of inert and non-inert materials produced by any activity related to construction industry. Inert materials can be comprised of whether soft inert materials like soil, earth and slurry, hard inert materials of rocks and broken concrete. Non-inert materials have also involved wastes of metals, timber, plastics and wrapping.[2]

There is now a developing emphasis on environmental management which has resulted in growing pressure to investigate the viability of reuse of all categories of waste materials such as C&D waste materials. The use of recycled C&D waste material would greatly reduce the demand for landfill sites and for virgin sources of materials by reusing what would be normally regarded as a waste material.

The use of secondary materials may not completely remove the problem of the resulting shortage of any material or it may not give equivalent performance as virgin or fresh material but it can be used as its properties allows it and could alleviate the shortage of any material e.g. recycled wood, recycled aggregate, recycled brick, etc.

Construction and demolition waste is increasingly seen as a valuable source of engineering materials for the construction industry. However the percentage of use of these materials is not at desired or sustainable

level. There is also far too little knowledge of technically realistic ways to reuse C&D waste.

Recycled aggregate

Recycling is the act of processing the used material for use in creating a new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. Recycled aggregate is comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. Recycled aggregates are produced from the re-processing of mineral waste materials, with the largest source being construction and demolition waste.

These wastes are normally composed of concrete rubble usually, constitutes the largest proportion of C&D waste. 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 a sub-base or a base layer in pavements.

Recycling concrete wastes will lead to reduction in valuable landfill space and savings in natural resources. In addition to the environmental benefits in reducing the demand on land for disposing the waste, the recycling of construction and demolition wastes can also help to conserve natural materials and to reduce the cost of waste treatment prior to the disposal.

If the technology and public acceptance of using recycled aggregate are developed, there will be no requirement for normal aggregate if 100% of demolished concrete is recycled for new construction (Malešev et al., 2010; Uddin et al., 2006).

Therefore, the topic of recycling of the demolished concrete is getting considerable attention under sustainable development nowadays.

PROPERTIES OF AGGREGATE

After collecting concrete rubble waste sample from the site, it is crushed by hand hammer in the laboratory of LDRP-ITR and than sieved in different sizes from 10mm to 20mm. Laboratory tests for aggregate have been conducted on crushed concrete aggregate.

Specific Gravity:

The specific gravity in saturated surface dry condition of demolished concrete aggregate was found from 2.5 which is less but satisfying the results. If specific gravity is less than 2.4, it may cause segregation; honeycombing & also yield of concrete may get reduced.

Water Absorption:

The DCA from demolished concrete be made of crushed stone aggregate with old mortar adhering to it, the water absorption ranges from 0.32%, which is comparatively more than that of the natural aggregates. Thus the water absorption results are satisfactory.

Bulk Density:

The bulk density of demolished aggregate is lower than that of natural aggregate, thus results are not satisfactory; due to low Bulk Density the mix proportion gets affected.

Crushing and Impact Values:

The demolished aggregate is comparatively weaker than the natural aggregate against different mechanical actions. As per IS 2386 part (IV), the impact and crushing values for concrete wearing surfaces should not exceed 30% & for other than wearing surfaces 45% respectively. The crushing & impact values of recycled aggregate satisfy the BIS specifications limit. From crushing and impact test it is found that use of recycled aggregate is possible for application other than wearing surfaces.

Aggregate Test

SR. NO	PROPERTIES	NATURAL AGGREGATE	RECYCLED AGGREGATE
1	Specific gravity	2.4-3.0	2.5
2	Water absorption	0.29%-0.3%	0.32%
3	Bulk density	1678.2 KN/m^3	1469.8 KN/m^3
4	Crushing value	18.4%	36.3%
5	Impact value	17.65%	35.2%

Table.1 Properties of Recycled Aggregates compared with Natural Aggregate

PROPERTIES OF CEMENT (OPC 53 CEMENT)

Cement: Shree Ultratech Ordinary Portland cement of 53 grade is used and on batch is utilized throughout the work. This ordinary cement consists of two materials namely argillaceous and calcareous.

Sr No	Tests	Results	IS code
1	Fineness test	8.25 %	IS:4031(part-1)1988
2	Soundness test	10 mm	IS:4031(part-3)1988
3	Consistency test	30 %	IS:4031(part-4)1988
4	Specific Gravity	3.048	IS:4031(part-11)1988
5	Initial and final setting time	Initial – 30 min Final – 685 min	IS:4031(part-5)1988

Table.2 Properties of Cement

PROPERTIES OF FINE AGGREGATE

Locally available river sand of is used as a fine aggregate it passes through the sieve of 4.75mm.

Sr No	Tests	Results	IS code
1	Specific gravity	2.66	IS:2720(part-3)1980
2	Absorption	0.60 %	ASTMC 128-15

Table.3 Properties of Fine Aggregate

SLUMP TEST

	Height of slump		
Type of concrete	0 % RCA	10 % RCA	20 % RCA
Recycled Aggregate Concrete	107	104	99

Table.4 Slump height

COMPRESSION TEST

Compression tests are performed on brittle materials as these materials fail in shear. It is seen that the shear develops along a diagonal plane which is maximum on a plane inclined at 45° from the direction of compression load. In compression loading, the fracture of the specimen takes place due to bulging action.

The property of a material to bulge under compressive loading is called malleability. It is the ductility that is associated with tensile loading while it is malleability that is associated with compressive loading.

Compressive strength of concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

Concrete compressive strength for general construction varies from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher in commercial and industrial structures.

Ultimate compressive strength = $\frac{\text{Ultimate load}}{\text{Cross-sectional area}}$

RESULT OF COMPRESSIVE STRENGTH TEST OF CONCRETE

Replaced Aggregate	Cube-1 N/mm^2	Cube-2 N/mm^2	Cube-3 N/mm^2	Average N/mm^2
0%	27.84	29.30	26.82	27.99
10%	27.09	25.88	25.60	26.19
20%	25.35	27.79	24.08	25.74
30%	25.27	23.02	23.87	24.05

Table.5 Compressive Strength of M30 Concrete at 7 Days

Replaced Aggregate	Cube-1 N/mm^2	Cube-2 N/mm^2	Cube-3 N/mm^2	Average N/mm^2
0%	38.35	36.52	38.08	37.65
10%	34.59	37.24	38.03	36.62
20%	35.81	37.19	34.92	35.97
30%	33.57	32.11	35.20	33.62

Table.6 Compressive Strength of M30 Concrete at 28 Days

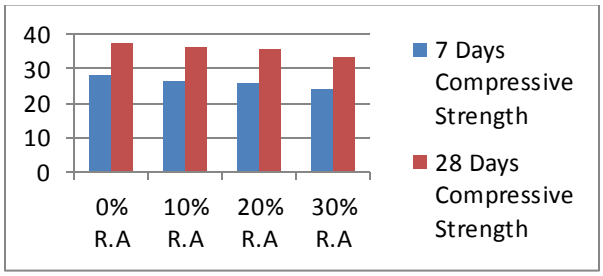

Fig.1Comparison of Compressive Strength of M20 Concrete

SPLIT TENSILE TEST

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

Split Tensile Strength,

$\mathbf{T} = \frac{2P}{\pi DL}$

Where, P = Applied load

D = Diameter of the specimen

L = Length of the specimen

RESULTS OF SPLIT TENSILE STERENGTH TEST OF CONCRETE

RCA (%)	Cube1 (ton)	Cube2 (ton)	Cube3 (ton)	Avg. (ton)	Split tensile strength (N/mm^2)
0%	16.73	16.12	15.97	16.27	2.25
10%	15.12	15.53	15.49	15.38	2.13
20%	15.09	14.27	13.41	14.25	1.97
30%	14.81	13.57	13.22	13.86	1.88

Table.7 Split Tensile Strength of M30 Concrete at 7 Days

RCA (%)	Cube1 (ton)	Cube2 (ton)	Cube3 (ton)	Avg. (ton)	Split tensile strength (N/mm^2)
0%	23.61	23.61	23.78	23.21	3.22
10%	22.36	22.36	22.57	22.14	3.07
20%	20.93	20.93	18.86	19.99	2.88
30%	18.12	18.12	17.69	18.07	2.50

Table.8 Split Tensile Strength of M30 Concrete at 28 Days

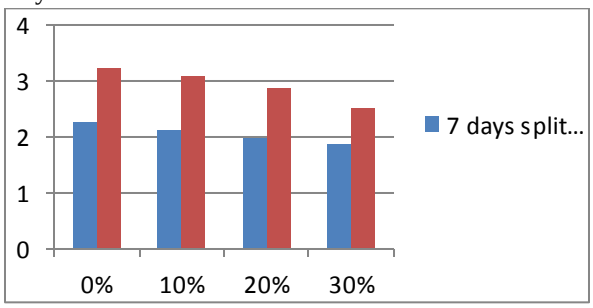

Fig.2 Comparison of Split tensile strength of M30 concrete

COST MINIMIZATION OF COURSE AGGREGATE

Rate of 1 ton Natural aggregate = 700 Rupees

Rate of 1 kg Natural aggregate = 700 / 1000 = 0.7 Rupees

According to mix design, required quantity of Natural aggregate in concrete of 1 cum,

= 1078 × 0.7

= 754 Rupees per cubic meter

If 10% of Natural aggregate is replaced by Demolished Aggregate,

= (Required quantity of Natural aggregate in 1 cubic meter) × (rate per kg)

= 970 kg × 0.7 Rupees

= 679 Rupees per cubic meter

Saving of Rupees per cubic meter,

= 754 – 679

= 75 Rupees

If 20% of Natural aggregate is replaced by Demolished Aggregate,

= (Required quantity of Natural aggregate in 1 cubic meter) × (rate per kg)

= 862 kg × 0.7 Rupees

= 603 Rupees per cubic meter

Saving of Rupees per cubic meter,

= 754 – 603

= 151 Rupees

If 30% of Natural aggregate is replaced by Demolished Aggregate,

= (Required quantity of Natural aggregate in 1 cubic meter) × (rate per kg)

= 754 kg × 0.7 Rupees

= 528 Rupees per cubic meter

Saving of Rupees per cubic meter,

= 754 – 528

= 226 Rupees

In this study, the cost of other ingredients like cement, sand etc. can't reduce because replacement of Natural Coarse Aggregate by Demolished Concrete Aggregate doesn't effects the proportion of such ingredients (cement & sand). So it remains unchanged.

So that, the total reduction of cost in the concrete is equal to the reduction of cost in Natural Course Aggregate.

ANALYSIS OF RESULTS

Workability

Results of Slump test shown in Table 6.3, indicates that Height of Slump continuously decreases with the increment in percentage of recycled aggregate. So that, it can be observe that Workability of RAC decreases as the amount of recycled aggregate increases compared to NAC. According to Recommended slump heights for various types of construction in general practice given in Table 6.4, taken RAC with replacement of 10%, 20% and 30% are suitable for Normal concrete works.

Compressive strength

The compressive strength for all mixes at 7 and 28 days of curing is presented in Table 5 and Table 6 respectively. The results show that 7 days compressive strength is found to be 60% – 80% of

the 28 days compressive strength. From graphical representation given in Fig 1, Reduction of compressive strength for 10%, 20% and 30% of replacement for 7 days of curing is about 6.4%, 8% and 14% of the compressive strength of natural concrete mix respectively. And for 28 days of curing, Reduction of compressive strength for 10%, 20% and 30% of replacement is about 2.8%, 4.6% and 11% of the compressive strength of natural concrete mix respectively. In short, the concrete specimens with more replacement of recycled aggregate have lower compressive strength when compared to the concrete specimen with less recycled aggregate for both 7 days and 28 days of curing.

Split tensile test

The results of split tensile test shows that, 7 days compressive strength is found to be 65% – 80% of the 28 days compressive strength. From graphical representation given in Fig 2, Reduction of split tensile strength for 10%, 20% and 30% of replacement for 7 days of curing is about 5.33%, 12% and 16.22% of the split tensile strength of natural concrete mix respectively. And for 28 days of curing, Reduction of split tensile strength for 10%, 20% and 30% of replacement is about 4.65%, 11.55% and 22.36% of the compressive strength of natural concrete mix respectively.

Split tensile test indicates a decreasing trend of split tensile strength at 7 days and 28 days of curing, when the percentage of recycled aggregate is increased. Because of this reduction of strength it can be conclude that 30% or more replacement of RAC is not appropriate for equivalent purpose as NAC taken in this study due to greater drop in split tensile strength.

Cost minimization

In this study, replaced aggregate have been considered as free of cost because, it is collected from demolished waste. So that, total cost of aggregate per cubic meter for any construction work, will decrease with the increment in the percentage of this costless RA in concrete mix in space of NA.

CONCLUSION

concrete mix with 30% replacement of an aggregate gives highest cost reduction among all the proportions taken in this study but at another side, Compressive strength and Split tensile strength gives major drop in strength for 30% recycled aggregate compare to 10% and 20% of recycled aggregate in to concrete mix.

So that it is advisable to use concrete mix with 20% replaced aggregate with recycled aggregate than 10% and 30% replacement because of both parameters Safety and Economy.

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