Performance Assessment and Cost Effectiveness in Replacement of Aggregates with Construction and Demolition Waste in Concrete

Gowri Shankar M, Nagarajan V, Eswaramoorthi P, Karthik Prabhu T

Abstract: ***The demand for Fine Aggregate and Coarse Aggregate is huge owing to infrastructure developments and also a scarcity of natural resources. On the other spectrum, the quantum of a huge quantity of Construction & Demolition Waste (C & D Waste) generated is increasing every year. Disposing of this C & D waste is a posing a very serious problem as it requires a large amount of space, it affects groundwater and also it is not cost effective in case of dumping (Land Filling). So recycling of such waste by means of Segregation Process and utilizing those materials as Recycled Aggregate (RA) for construction projects is a sustainable alternative that helps in the reduction of overutilization of natural resources. This paper is an experimental investigation by means of Compaction Factor, Compressive Strength, Water Absorption and Workability of Recycled Aggregate Concrete (RAC) and also analyzing the cost to evaluate the effect of replacement of Fine Aggregate and Coarse Aggregate by C & D Waste. The research has been conducted for M25 mix. The optimum mix 20% of Recycled Fine Aggregate (RFA) and 30% of Recycled Coarse Aggregate (RCA) was chosen as the optimum mix among the 4 different mixes depending on its promising results. As a result of cost analysis, the optimum mix is cost-effective when compared with Natural Aggregate Concrete (NAC).***

Keywords: Recycled Fine Aggregate (RFA), Recycled Coarse Aggregate (RCA), Natural Aggregate Concrete (NAC), Recycled Aggregate Concrete (RAC), Cost Analysis.

I. INTRODUCTION

One of the major problem being faced by cities and towns relates to the management of C & D Waste. Waste quantities are increasing and municipal authorities are not able to upgrade or scale up the facilities required for proper management of such wastes. Cities and towns, in future, will not get wastelands for the further dumping of wastes. In fact, there will be a need to go for 'total' recycling and re-use of waste and aim for 'Zero Waste' for landfilling. For the cubes, the replacement of coarse aggregate up to 30% by demolished waste gives strength closer to the strength of plain concrete cubes and strength retention was recorded in the range of 86.84 - 94.74% for the recycled concrete mix [2]. The maximum compression strength and split tensile strength is obtainedwhen 30% of ceramic tile aggregate was replaced with coarse aggregate [7]. Test results showed that up to 30% coarse RCA had no effect on the ceiling strength of concrete, but thereafter this reduces with increase in RCA content [14].

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II. LITERATURE REVIEW

B.Kavitha and M. Lenin Sundar (2017) suggested that when 15% of Cement and 25% of Coarse Aggregate was replaced with Glass Powder and Tile Waste, the compressive strength is found to be maximum of 36.44 N/mm2 for M30 Mix. D.V. Prasada Rao and P.L. Sindhu Desai (2014) stated that the Recycled Concrete Aggregate (RCA) has compressive strength comparable to the Natural Concrete Aggregate (NCA) compressive strength for all grades (M20, M25, and M30) of concrete. This can be attributed to the cement mortar coat of RCA participates in hydration process and contribute additional strength. They suggesting to go for 100% replacement of RCA in Structural Concreting. Vikas Srivastava,

Mohd Monish et.al (2015) narrated as M25 grade mix of recycled concrete can be replaced upto 10% of cement with waste powder; 20% of fine aggregate with waste fine aggregate; 30% of coarse aggregate with waste coarse aggregate, in a single mix. Mats D. Skevik Hole (2013) states that With a low replacement rate of up to 20 or 30% and the use of high- quality RCA the concrete properties is not severely affected. After their decision, this leads to possibilities of utilizing RCA concrete on both the construction sites and in prefabrication processes. The result of Equivalent Mortar Volume method in a worksheet shows that the environmental effects are positive. Not only preserving natural recourses and recycling waste concrete, but also reducing the CO_2 emission from the cement industry is possible. Farid Debieb and Said Kenai (2008) suggested that for an optimal utilization of this kind of concrete, the level of replacement should be limited to 25% for coarse and 50% for fine crushed brick aggregates respectively, in order to obtain minimum quality concrete. Due to the lower performance of concrete with crushed bricks aggregates, structural concrete applications should not be applicable for this kind of concrete. Prakash Somani, Brahmtosh Dubey et.al (2016) states that the compressive

strength of Demolished Aggregate Concrete (DAC) is relatively lower up to 15% than Natural Aggregate Concrete (NAC). Their suggestion is to use this concrete as a base material for roadways reduce the pollution involved in trucking material.

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III. MATERIAL PROCESSING AND METHODOLOGY

A. Materials

The materials which are used in this research are
Cement
Fine Aggregate
Natural Fine Aggregate (NFA)
Recycled Fine Aggregate (RFA)
Coarse Aggregate
Natural Coarse Aggregate (NCA)
Recycled Coarse Aggregate (RCA)

B. Processing Of Materials

Fig. 1 shows the processing of materials, which converts the construction and demolition waste into the replicable form of fine and course aggregates.

C. Testing of Materials

Materials are tested for its Specific gravity, Water Absorption and Impact value.

Aggregate Type	Specific Gravity	Water Absorption	Impact Value
NFA	2.56	1.00%	-
RFA	2.50	1.27%	-
NCA	2.72	0.84%	14%
RCA	2.54	1.51%	19%

Table 1Laboratory Test Results

From Table 1 the test results of Natural Fine and Coarse Aggregates and Recycled Fine and Coarse Aggregates are shown.

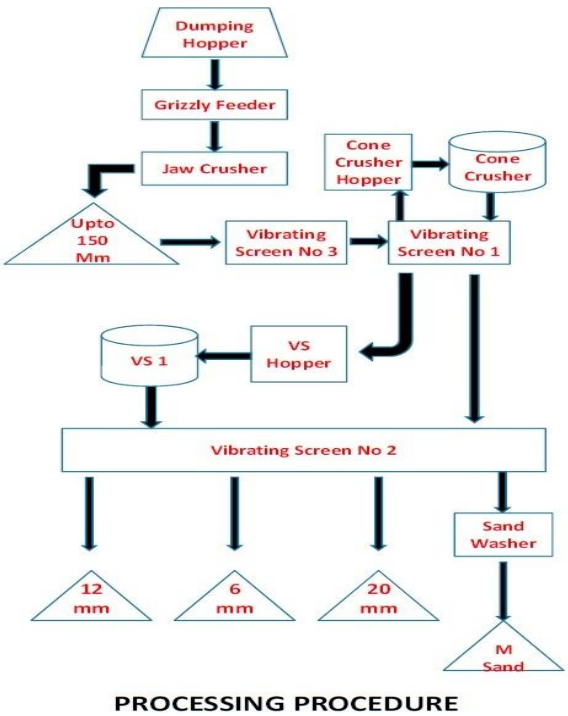

Fig. 1 Flowchart of Processing Procedure

D. Recycled Fine Aggregate

The fine aggregate is obtained by processing of Demolision waste material, that is, cement mortar and plastering from masonry work.

Before Processing **After Processing**

Fig. 2 Fine Aggregate Materials

E. Recycled Coarse Aggregate

The Course aggregate is obtained by processing of Demolision waste material, that is, from concrete.

Before Processing **After Processing**

Fig. 3 Course Aggregate Materials

F. Mix Design

By analyzing various mix proposition, following Mix design is obtained to work for concrete casting.

Grade designation	**M25**
Characteristic Compressive Strength at 28 days (fck)	25 N/mm^2
Type of cement	Maha Gold OPC 53 grade
Standard Deviation for good control of specified grade (S)	4.0 N/mm^2
Target Strength (f'ck = fck+1.65 S)	31.6 N/mm^2
Maximum W/C Ratio	0.50
Adopted W/C Ratio	0.40
Maximum Water Content (75mm Slump)	192 Kg/m^3
Maximum Cement Content	480 Kg/m^3
Minimum Cement Content	300 Kg/m^3
Volume of Concrete	1 m^3
Volume of Cement	0.15 m^3
Volume of Water	0.19 m^3
Volume of All in Aggregates	0.66 m^3
Fine Aggregate Proportion	0.44
Coarse Aggregate Proportion	0.56
Average Mix Ratio	**1:1.45:1.90**

Table 2 Grade of Concrete M2

From Table 2 the mix design for M25 is explained with mix ratio.

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G. Mix Proportion

Mix Type	W/C Ratio	Cement Content (Kg)	Fine Aggregate (Kg)		Coarse Aggregate (Kg)	
			NFA	RFA	NCA	RCA
V1	0.40	20.25	31.39	-	42.32	-
V2			24.95	6.24	33.53	8.39
V3			24.95	6.24	31.29	10.43
V4			24.95	6.24	29.06	12.45
V5			-	30.58	-	39.69
Total	-	101.25	106.24	49.30	136.20	70.96

Table 3 Total Material Quantity

From Table 3 the quantity of materials needed for testing is shown.

IV. TESTING & RESULTS

A. Slump Cone Test

Workability is measured by the slump test in which the concrete mix is prepared and filled in to a cone of specific dimensions. The slump value is usually the standing height of concrete filled in slump cone.

Mix Type	Slump Value (mm)	Degree of Slump	Type of Structure
V1	148	High	Trench fill, in-situ piling
V2	143	High	Trench fill, in-situ piling
V3	137	High	Trench fill, in-situ piling
V4	266	Very High	Tremie concrete
V5	89	Medium	Heavily reinforced sections in slabs, beams, walls, columns, slip-form work, pumped concrete

Table 4 Test Results of Slump Cone

From Table 4 mix type V4 is best in results of very high degree of slump.

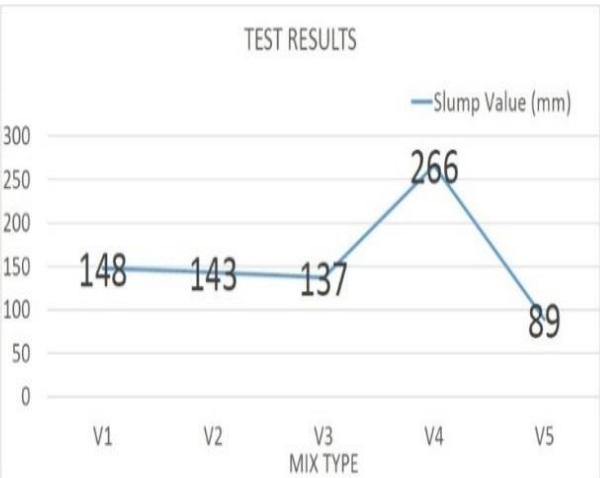

Fig. 4 Graphical Representation of Slump Cone Test Results

B. Compaction Factor Test

Mix Type	Partially Compacted Concrete Without Empty Cylinder (Kgs)	Fully Compacted Concrete Without Empty Cylinder (Kgs)	Compaction Factor
V1	11.8	12.7	0.93
V2	11.3	12.6	0.90
V3	11.6	12.5	0.93
V4	12.3	12.9	0.95
V5	11.1	12.2	0.91

Table 5 Test Values of Compaction Factor

Mix Type	Compacting Factor	Workability	Uses
V1	0.93	Medium 0.92 to 0.94	Concreting of lightly reinforced sections without vibrations or heavily reinforced sections with vibrations.
V2	0.90	Low 0.85 to 0.91	Foundation Concrete.
V3	0.93	Medium 0.92 to 0.94	Concreting of lightly reinforced sections without vibrations or heavily reinforced sections with vibrations.
V4	0.95	High Above 0.95	Concreting of heavily reinforced sections without vibrations.
V5	0.91	Low 0.85 to 0.91	Foundation Concrete.

Table 6 Results of Compaction Factor

From Table 6 mix type V4 is identified as high degree of workability

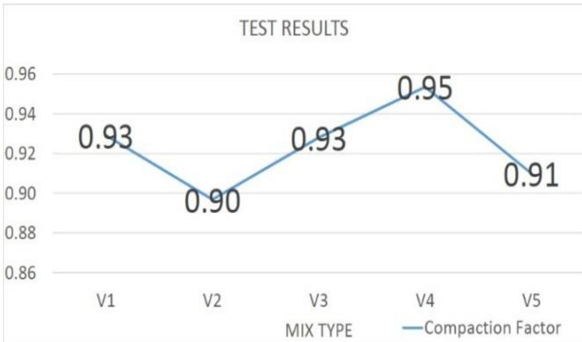

Fig. 5 Graphical Representation of Compaction Factor Test Results

C. Compressive Strength Test

Compressive Strength of the cubes were tested by using CTM (Compressive Testing Machine) in which compressive load is applied on the specimen till the specimen fails in compression that load at which the specimen fails is termed as compressive strength. For this study cubes of 150 mm nominal concrete cubes were casted.

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In this study we have taken 5 different mix proportions and casted the concrete cubes of 10 samples in each mix proportions then the compressive strength for 7, 14, 28 days strength was obtained. There are 9 samples in each mix and the compressive strength is the average of the 3 samples of 7, 14, 28 days

Mix Type	7th Day N/mm^2	14th Day N/mm^2	28th Day N/mm^2
V1	18.32	27.58	35.32
V2	29.14	30.69	35.13
V3	27.39	29.09	33.92
V4	28.56	43.99	40.21
V5	20.36	23.04	26.96

Table 6 Test Results of Compressive Strength

From Table 6 the compressive strength values of 7, 14, 28 days are shown.

Fig. 8 Graphical Representation of Compressive Strength Test Results

D. Water Absorption Test

It is a test to calculate the water absorption of a concrete cubes. The samples are cured for 28 days and then it should be dried in oven at 100°C for 24 hours and then dry in open for 1 hour to make the surface dry.

Mix Type	Weight 1 (Kgs)	Weight 2 (Kgs)	Weight 3 (Kgs)	Weight 4 (Kgs)	Water Absorption (%)
V1	8.214	8.354	8.336	8.158	2.18
V2	8.184	8.304	8.279	8.053	2.81
V3	8.367	8.496	8.463	8.237	2.74
V4	8.380	8.514	8.492	8.278	2.59
V5	7.580	7.732	7.710	7.408	4.08

Table 7 Test Results of Water Absorption

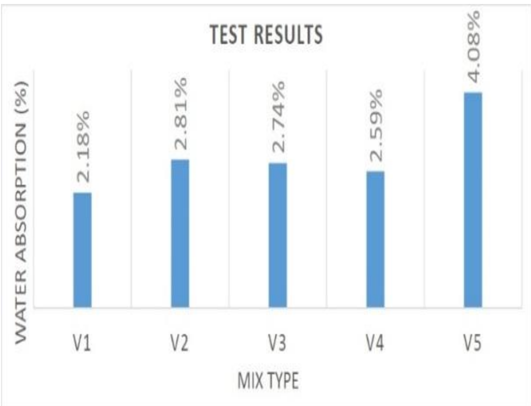

Fig. 9 Graphical Representation of Water Absorption of Test Results

Tests	Best Result	Best Mix
Slump Cone Test	266mm	V4
Compaction Factor Test	0.95	V4
Compressive Strength Test	40.21 N/mm^2	V4
Water Absorption Test	2.59%	V4

Table 8 Best values from test results

Table 8 Best values among the 4 different mix proportions (V2, V3, V4 and V5) except V1, because it is a Conventional Mix (0% of RFA and 0% of RCA). The V4 (20% of RFA and 30% of RCA) is chosen as an Optimum Mix.

V. COST ANALYSIS

The following costs are collected from crusher plants by site survey.

Processing Cost of Natural Aggregates				
S. No	Stage	Description	Natural Fine Aggregate (□)	Natural Coarse Aggregate (□)
1	Procuring	Collecting from Quarry	□ 611.00	□ 598.00
		Breaking into Pieces	□ 667.40	□ 653.20
2	Processing	Loading on Hopper	□ 940.00	□ 920.00
		Grizzly Feeder		
		Jaw Crusher		
		Screening 1	□ 869.50	□ 851.00
		Cone Crusher		
		Screening 2		
		Sand Washer		
3	Handling	Surface Finishing	□ 343.10	□ 335.80
		Transportation	□ 319.60	□ 312.80
Total			□ 3,750.60	□ 3,670.80

Table 9 Processing Cost of Natural Aggregates

Processing Cost of Recycled Aggregates				
S.No	Stage	Description	Recycled Fine Aggregate (□)	Recycled Coarse Aggregate (□)
1	Procuring	Collecting from Site	□ 178.60	□ 174.80
		Segregation	□ 291.40	□ 285.20
2	Processing	Loading on Hopper	□ 432.40	□ 423.20
		Grizzly Feeder		
		Jaw Crusher		

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		Screening 1	□ 404.20	□ 395.60
		Cone Crusher		
		Screening 2		
		Sand Washer		
3	Handling	Surface Finishing	□ 385.40	□ 377.20
		Transportation	□ 282.00	□ 276.00
Total			□ 1,941.00	□ 1,932.00

Table 10 Processing Cost of Recycled Aggregates

Cost Effectiveness = [(3750.60-1974.00)/3750.60]*100

Cost Effectiveness = 47%

VI. CONCLUSION & DISCUSSION

City Waste Management is maintained by clearing the C & D Waste from stockyards by the “Replacement of Fine Aggregate and Coarse Aggregate”. The Optimum Mix is V4 (20% of RFA and 30% of RCA) with Maximum Compressive Strength of 40.21N/mm2 with 2.59% of Water Absorption. The RAC is capable of constructing Massive Structures according to the test results. As a result of Cost Analysis, the optimum mix is 47% cost-effective when compared with the NAC. Environmental impacts will be reduced when “Recycling of Aggregates” is carried out. The above test results are obtained without using any admixtures.

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