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Performance of concrete made from recycled coarse aggregates at different mix proportions

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Abstract

With the rapid urbanization, construction and demolition waste is generated in large scale. This waste comprises of hazardous material like insulation, nails, electric wiring, shingle, dredging materials, tree stumps and rubble. Construction waste also contains lead, asbestos and other hazardous materials. The major component of waste is made up of bricks, concrete, and wood. India generates 530 million tonnes of C&D waste annually estimated by the ministry of environment and forest. This waste is dumped in landfill sites or placed in roadsides or riversides which is the cause of reduction of natural resources and pollution like soil, air and water pollution. To reduce this threat for the future, we can recycle this waste to safeguard our environment. This study is based on replacement of natural coarse aggregate (NCA) by recycled coarse aggregate (RCA). Concrete was collected from different sites of Greater Noida and then was crushed to procure coarse aggregate of size 10 mm. Concrete of M20 grade was prepared and casted into 42 moulds of size 150mm×150mm×150 mm, different percentages of RCA were used to replace NCA viz. 0%, 25%, 50%, 75%, 90%, 100%. Seven cubes of each percentage were casted to get optimum results and were tested for compressive strength and density after 7, 14, and 28 days. The experimental analysis showed that compressive strength for 0%, 25%, 50%, 75%,90% and 100% replacement of NCA by RCA where recorded as 30.66 N/mm^2, 29.77 N/mm^2, 28.88 N/mm^2, 26.66 N/mm^2 , 24.44 N/mm^2 and 22.22 N/mm^2 respectively after 28 days.

Keywords: Compressive strength, Density, Natural Coarse aggregate (NCA), Recycle coarse aggregate (RCA).

1. Introduction

Demand of construction materials is increasing because of urbanization and industrialization which possess a serious problem of C&D waste disposal. To protect our environment and conserve the

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rapidly vanishing natural resources should be the base of sustainable development [1]. C&D waste is generated enormously, this waste causes many ill effects on environment and health, presence of asbestos and lead in C&D waste causes diseases like asthma, malaria, dengue etc. this waste contaminates soil, surface water and also causes air pollution, if the process continues it will be a big threat to environment in future. There are different ways for disposing this waste e.g. landfill sites, incineration plants, etc these are costlier and occupy lands, sometimes these methods of disposing the C&D waste can be frantic therefore recycling is the best option . The concept of recycling of C&D waste came when buildings and roads were demolished during World War II, there was need to recycle the waste which United States in 1970's tapered off [2]. If high quality recycled coarse aggregate is used for construction there will be no effect on strength of concrete [3]. Among the various reasons of using recycled coarse aggregate, one reason is to make construction green and eco friendly. Construction includes 50% of raw materials derived from nature more over it consumes 40% of total energy and produces 50% of total waste [4]. According to the previous survey, the most common reason for not using recycled construction waste is lack of awareness, lack of recycling techniques and possibilities of recycling [5]. There is a huge capital investment for disposing waste in landfills annually many countries have tried to develop various rules and regulations to minimize construction waste but only few have been successful to reduce C&D waste and maximize their reuse[6].

Construction from recycled coarse aggregates has prone to be economical and technically feasible [7]. This research is an alternative for the problems caused by C&D waste by replacing natural coarse aggregate in construction material by recycled coarse aggregate which was collected and crushed to get aggregates of size 10 mm and concrete mix of grade M20 was prepared at the ratio of 1:1.5:3 , further the procedures like mixing ,vibrating was done to cast 42 cubes of size 150mm×150 mm×150 mm with different replacement proportions (0% ,25%,50%,75%,90% and 100%) and curing was done up to 28 days .the testing program included sieve analysis of both natural and recycled coarse aggregate ,water absorption , moisture content , specific gravity test of both coarse and recycled aggregate , density and compressive strength tests were done. The result of the whole process proved to be efficacious and can be easily adopted in our daily construction practices.

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2. Materials and Methodology

2.1 Materials: Table 1 shows the materials and their total quantity used.

Table 1 Materials used

Material	**Quantity**
Cement opc 43 grade	64 kgs
Fine aggregate	106.814 kgs
Natural coarse aggregate	80.663 kgs
Recycled coarse aggregate	89.420 kgs
Water	31.993 ltrs

2.2 Methodology

2.2.1 Crushing of rubble: The rubble was collected and crushed into 10-12 mm aggregates.

2.2.2 Batching: Precise and accurate quantities of materials were weighed for different mix proportions. Table 2 shows the proper measured quantity of materials per cube.

Table 2 Batching of materials used

Replacement Proportion in percent	**Cement in Kg's per cube**	**Fine aggregate in Kg's per cube**	**Natural Coarse Aggregate in Kg's per cube(NCA)**	**Recycled coarse aggregate in Kg's per cube(RCA)**	**Water in liter per cube**
0	1.523	2.543	4.956	0	.761
25	1.523	2.543	3.718	0.944	.761
50	1.523	2.543	2.478	1.890	.761
75	1.523	2.543	1.238	2.836	.761

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90	1.523	2.543	0.495	3.404	.761
100	1.523	2.543	0	3.782	.761

2.2.3. Mixing: To bring uniform consistency in mix a concrete mixer was used for mixing and mixing time was 2-3 minutes, speed of mixer drum was 18-20 rpm

2.2.4. Workability: Slump test was performed with w/c ratio for 0%, 25% and 50% replacement was taken as 0.50 and for 75% and 90% replacement was taken as 0.55and for 100% replacement was taken as 0.60 to maintain the 75mm slump

2.2.5. Compaction: A table vibrator was used for compaction which is driven on electric motor.

2.2.6. Curing: Curing tank was used to cure the cubes for 28 days to attain maximum strength.

3. Tests and Results:

Following tests were performed during the whole process; the sequential analysis is described below

3.1 Fineness modulus Test

Table 3 Fineness modulus test results

Material	**Fineness modulus**
Fine aggregate	2.36
Natural Coarse aggregate	7.02
Recycled coarse aggregate	6.13

3.2 Specific gravity Test

Table 4 Specific gravity

Material	**Specific Gravity**
Fine aggregate	2.66
Natural coarse aggregate	2.69

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Recycled coarse aggregate	2.49
Cement	3.15

3.3 Moisture content Test

Table 5 Moisture content

Material	**Moisture content in percent**
Fine aggregate	0.5
Natural Coarse aggregate	Nil
Recycled coarse aggregate	Nil

3.4 Compressive Strength Test

Table 6 Compressive strength

Curing period	**Compressive strength in N/mm^2**					
	0% RCA	**25% RCA**	**50%RCA**	**75% RCA**	**90% RCA**	**100%RCA**
7 days	25.33	22.66	18.88	17.33	15.11	13.33
14 days	28.66	28.22	27.11	25.72	22.22	20.44
28 days	30.66	29.77	28.88	26.66	24.44	22.22

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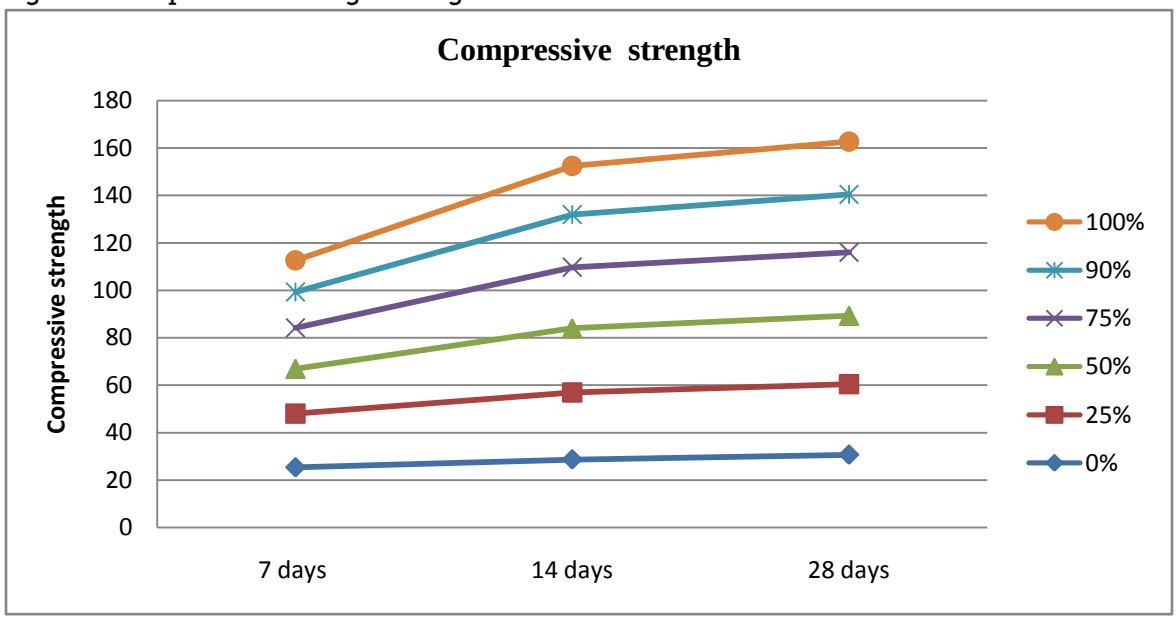
Figure 1 Compressive Strength Vs Age



3.5 Density

Density of concrete depends on ratio of Natural Coarse aggregate and recycled aggregate ratio. Density of concrete decreases as the percentage of recycled aggregate is increased i.e. density is inversely proportional to percentage of recycled aggregate. The results thus obtained are given in following table.

Table 7 Density

S.No	Proportion				Dry density(kg/m^3)
	Cement	Fine aggregate	Natural coarse aggregate	Recycled coarse aggregate	
1	1	1.5	3	0	2520
2	1	1.5	2.25	0.75	2470
3	1	1.5	1.50	1.50	2440
4	1	1.5	0.75	2.25	2400

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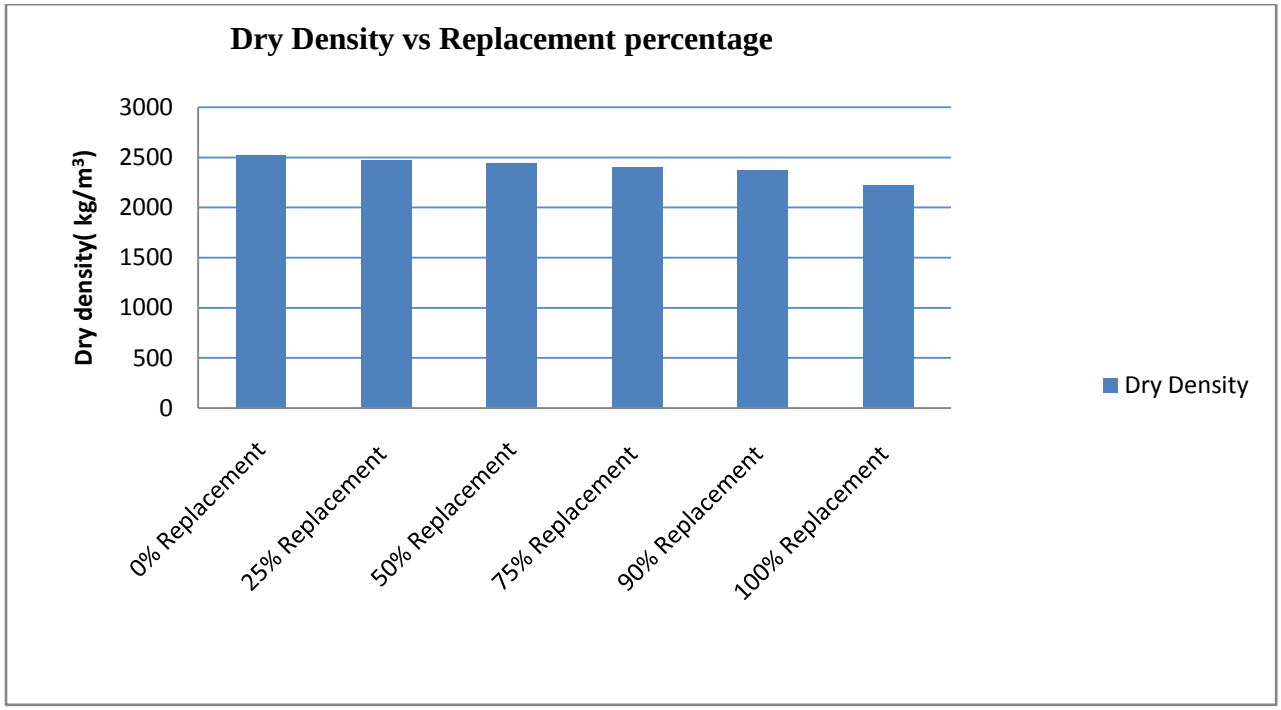
5	1	1.5	0.30	2.70	2370
6	1	1.5	0	3	2340

Figure 2 Dry density Vs Replacement percentages



4. Discussions

On the basis of above study the following observations are made regarding the properties and behavior of concrete. On the partial replacement of NCA by RCA:

1) Maximum compressive strength is attained at 50% replacement, strength of concrete decreases on increase in replacement of aggregates.

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2) The workability of concrete decreases on increase of percentage of recycled aggregate because water absorption is higher in Recycled aggregate than in natural aggregate.

3) The cement mortar adhered on recycled aggregates decreases the workability and compressive strength of concrete

4) The dry density of concrete decreases as percentage is increased after 28 days of curing.

Conclusions

Use of rubble waste reduces the production of waste through construction industries therefore it is an eco friendly construction material. Using of recycled aggregate in concrete saves energy protects environment and cost of transportation and excavation of natural resources. Construction by replacement of natural coarse aggregate by recycled coarse aggregate by 25% and 50% is suitable for construction purposes like lightly reinforced beams, slabs, walls, columns, floors, lining of canal, strip footing, mass concreting etc with minimal difference in strength parameters.

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