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A SUSTAINABLE SOLUTION FORSUPERSTRUCTURE WITH MASONRY BLOCKS USING RECYCLED CONCRETE WASTE MATERIALS

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Abstract*—The idea of recycling concrete of demolished buildings aims at preserving the environment. Indeed, the reuse of concrete as aggregate in new concrete mixes helped to reduce the expenses related to construction and demolition (C&D) waste management and, especially, to protect the environment by reducing the development rate of new quarries. This paper presents the results of an experimental study conducted on masonry blocks containing aggregates resulting from concrete recycling. The purpose of this study is to investigate the effect of recycled aggregates on compressive strength of concrete blocks. Tests were performed on series of concrete blocks: ten series each made of different proportions of recycled aggregates, and one series of reference blocks exclusively composed of natural aggregates. Tests showed that using recycled aggregates with addition of cement allows the production of concrete blocks with compressive strengths comparable to those obtained on concrete blocks made exclusively of natural aggregates.

***Keywords*— Concrete, Compressive strength, Recycled aggregate, Solid blocks, Residual Mortar Content**

I. INTRODUCTION

Use of recycled aggregate in solid blocks can be useful for environmental protection. Recycled aggregates are the materials for the future. The application of recycled aggregate has been started in a large number of construction projects of many European, American, Russian and Asian countries. Many countries are giving infrastructural laws relaxation for increasing the use of recycled aggregate. Urbanization growth rate in India is very high due to industrialization. Growth rate of India is reaching 9% of GDP. Rapid infrastructure development requires a large quantity of construction materials, land requirements & the site. For large construction, concrete is preferred as it has longer life, low maintenance cost & better performance. For achieving GDP rate, smaller structures are demolished & new towers are constructed.

Protection of environment is a basic factor which is directly connected with the survival of the human race. Parameters like environmental consciousness, protection of natural resources, sustainable development, play an important role in modern requirements of construction works. Due to modernization, demolished materials are dumped on land & not used for any purpose. Such situations affect the fertility of land. Out of the total construction demolition waste, 40% is of concrete , 30% ceramic's, 5% plastics, 10% wood, 5%metal, & 10% other mixtures. For production of concrete, 70-75% aggregates are required. Out of this 60-67% is of coarse aggregate & 33-40% is of fine aggregate. The use of recycled aggregate generally increases the drying shrinkage creep & porosity to water & decreases the compression strength of concrete compared to that of natural aggregate concrete. It is nearly 10-30% as per replacement of aggregate. Recycling reduces the cost (LCC) by about 34-41% & CO2 emission (LCCO2) by about 23-28% for dumping at public/private disposal facilities.

II. EXPERIMENTAL WORK

II.1 Objective and scope

- To find out the % use feasible for construction.
- To reduce the impact of waste materials on environment.
- To carry out different tests on recycled aggregates & natural aggregates & compare their results.
- To find out the ways of cost saving such as transportation, excavation etc.

II.2 Methodology

Plain cement concrete (PCC) & reinforce cement concrete is collected from sites respectively. This collected material is crushed by hammer to separate the aggregates & reduce their sizes in smaller fraction. On these separated aggregates various testes are conducted in laboratory as per Indian Standard code & their results are compared with natural aggregates. Solid blocks with dimensions corresponding to Indian Standard codes are cast using these natural aggregates and recycled aggregate. Blocks with RCA, RFA and a part replacement for cement with the recycled powder considering it as a pozzolanic material is also done. Before this its cementitious property shall be checked..Recycled aggregate reduces the impact of waste on environment.

By using some percentage in construction sector, cost is saved, due to reduction of transportation & manufacturing process. The properties of various materials used were tested and the results obtained were tabulated as follows.

TABLE I - Physical Properties of cement used

SL No.	Properties	Value	IS Specification And Test procedure
1	Specific gravity	3.15	IS:4031
2	Standard consistency	35%	IS:4031 & IS269
3	Initial Setting time in minutes	128	>30,IS:4031 & IS269
4	Final Setting time in minutes	364	<600, IS:4031 & IS269

TABLE II - Physical Properties of natural fine aggregates

Specific Gravity	2.68
Water absorption	13.89%

TABLE III - Physical Properties of recycled fine aggregates

Specific Gravity	2.47
Water absorption	23.45%

TABLE IV - Physical Properties of natural coarse aggregates

Specific Gravity	2.688
Water absorption	1.95%

TABLE V - Physical Properties of recycled coarse aggregates

Specific Gravity	2.339
Water absorption	5%

III. RESIDUAL MORTAR CONTENT

When recycled aggregates are obtained there will be a coating of cement mortar adhered to it. This mortar is referred to as residual mortar content. Percentage of this residual mortar content was experimentally found out. For this 1kg of oven dried RCA sample was taken and immersed in testing bath containing 26% sodium sulphate salt. Solution was made by mixing sodium sulphate salt and water well together until the full salt is dissolved in it. A sample was prepared and then placed in oven at 100^{o} C for a day time and placed in freezer in the evening till morning. The same procedure was repeated for 5 days. After alternate heating and cooling of sample for 5 days it was washed thoroughly under tap water by placing the sample in 4.75mm sieve. While washing it was noticed that the adhered mortar from RCA gets separated. The washed sample was kept in oven for 24 hours. The weight was taken after this.

Weight of oven dried sample taken (A) = 1 kg

Weight of oven dried sample taken after testing (B) = 0.756 kg

Residual Mortar Content = $\frac{A-B}{A}$ x 100 (%) = 24.4 %

IV. TEST PROCEDURES

IV.1 Introduction

In order to determine the properties of solid blocks made with NCA and RCA various test are done. The different tests are given below.

IV.2 Determination of compressive strength

The main aim was to determine the compressive strength of solid blocks prepared with NCA and RFA. The test specimens are of size 190 x 90 x 90 mm. for each mix three blocks was cast and compression test was done after 28 days curing. Compaction was done using table vibrator. The block for testing was place in the compression testing apparatus as shown in the figure. The compressive strength was obtained by dividing the ultimate applied load by the cross-sectional area of the cube.

IV.3 Determination of block density

Two blocks were taken at random from the samples selected and then dried to constant mass in a suitable oven heated to approximately 100°C. After cooling the blocks to room temperature the dimensions of each block shall be measured in centimeters and the overall volume computed in cubic centimeters. The block shall be weighed in kilograms and the density of each block can be calculated as follow,

$$\text{Density} = \frac{\text{Mass of block in kg}}{\text{Volume of specimen in cm3}} \times 10^6 \text{ kg/m}^3$$

The average of two blocks shall be taken as average density.

IV.4 Determination of water absorption

The test specimens shall be completely immersed in water at room -temperature for 24 h. The specimens shall then be weighed, while suspended by a metal wire and completely submerged in water. They shall be removed from the water and allowed to drain for one minute by placing them on a 10 mm or coarser wire mesh, visible surface water being removed with a damp cloth and immediately weighed. Subsequent to saturation, all specimens shall be dried in a ventilated oven at 100°C to 115°C for not less than 24 h and until two successive weightings at intervals of 2 h show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen. The water absorption was obtained as follow.

$$\text{Water absorption in kg/m}^3 = \frac{A-B}{A-C} \times 1000$$

$$\text{Water absorption in percentage} = \frac{A-B}{B} \times 100$$

Where,
A = wet mass of unit, in kg
B = dry mass of unit, in kg
C = suspended immersed mass of units, in kg.
The average of two blocks shall be taken as average value for water absorption.

IV.5 Determination of moisture movement

The specimens shall be immersed in water for 4 days, the temperature being maintained at 27 ± 2°C for at least 4 h prior to the removal of the specimen and the wet length measured. The moisture movement shall be determined as the difference between the dry and wet lengths and expressed as a percentage of the dry length for each specimen.

V. LIST OF SPECIMENS

TABLE VI - Details of specimens

SB1	natural coarse aggregate + natural fine aggregate
SB2	recycled coarse aggregate + natural fine aggregate
SB3	recycled coarse aggregate + recycled fine aggregate
SB4	recycled coarse aggregate + natural fine aggregate (residual mortar)
SB5	recycled coarse aggregate + natural fine aggregate (cement and fine aggregate reduced by 10%)
SB6	recycled coarse aggregate + natural fine aggregate (cement and fine aggregate reduced by 20%)
SB7	recycled coarse aggregate + natural fine aggregate (cement and fine aggregate reduced by 30%)
SB8	recycled coarse aggregate + recycled fine aggregate (cement reduced by 10%)
SB9	recycled coarse aggregate + recycled fine aggregate (cement reduced by 20%)
SB10	recycled coarse aggregate + recycled fine aggregate (cement reduced by 30%)

VI. RESULTS AND DISCUSSION

VI.1 Introduction

The results of test on solid blocks like compressive strength, moisture movement, water absorption and density of blocks were obtained. They are discussed in this chapter.

VI.2 Compressive strength test

The compressive strength of solid blocks with NCA as well as with RCA was determined. As per IS 2185 Part1 2005 the solid concrete blocks are used as load bearing units and shall have a block density not less than 1 800 kg/m^3 and these shall be manufactured for minimum average compressive strength of 4.0 and 5.0 N/mm^2 respectively. The results of compression test are given in the table below.

TABLE VII – Compressive strength

Mix ID	**Average compressive strength in 28 days (N/mm^2)**
SB1	8.771
SB2	8.596
SB3	8.070
SB4	7.309
SB5	6.905
SB6	6.432
SB7	6.257
SB8	5.555
SB9	5.380
SB10	4.912

VI.3 Block density

The block density of solid blocks with NCA as well as with RCA was determined. As per IS 2185 Part1 2005 the solid concrete blocks shall have a block density not less than 1 800 kg/m^3. The results of the test are given in the table below.

TABLE VIII– Block Density

Mix ID	**Density (kg/m^3)**
SB1	2331.491
SB2	2119.53
SB3	1991.93
SB4	2129.30
SB5	2048.88
SB6	1907.58
SB7	2013.56
SB8	1978.23
SB9	1937.24
SB10	1907.58

VI.4 Water absorption

The water absorption of solid blocks with NCA as well as with RCA was determined. As per IS 2185 Part1 2005 the water absorption, being the average of two units shall not be more than 10 percent by mass.The results of the test are given in the table below.

TABLE IX – Water absorption

Mix ID	**Water Absorption (%)**
SB1	6.06
SB2	6.66
SB3	5.51
SB4	7.290
SB5	7.068
SB6	7.280
SB7	7.50
SB8	7.068
SB9	7.507
SB10	8.079

VI.5 Moisture movement

The moisture movement of solid blocks with NCA as well as with RCA was determined. The moisture movement of the dried blocks on immersion in water, being the average of two units, shall not exceed 0.09 percent. The results of the test are given in the table below.

TABLE X – Moisture Movement

Mix ID	Moisture Movement (%)
SB1	0.016
SB2	0.016
SB3	0.012
SB4	0.012
SB5	0.016
SB6	0.016
SB7	0.016
SB8	0.016
SB9	0.012
SB10	0.016

VII CONCLUSIONS

The following conclusions were drawn from the present study.

1. From the compression test it was found that SB2 has strength almost equal to 98% of SB1. Similarly SB3 has a strength almost equal to 92% of SB1, SB4 has a strength almost equal to 83% of SB1, SB5 has a strength almost equal to 78% of SB1, SB6 has a strength almost equal to 73% of SB1, SB7 has a strength almost equal to 71% of SB1, SB8 has a strength almost equal to 63% of SB1, SB9 has a strength almost equal to 61% of SB1 and SB10 has a strength almost equal to 56% of SB1.
2. From the block density test it was found that the solid blocks were within the IS limit and it was obtained that the density of SB2 was 90% as that of SB1. Similarly SB3 has a block density almost equal to 85% of SB1, SB4 has a block density almost equal to 91% of SB1, SB5 has a block density almost equal to 87% of SB1, SB6 has a block density almost equal to 82% of SB1, SB7 has a block density almost equal to 86% of SB1, SB8 has a block density almost equal to 85% of SB1, SB9 has a block density almost equal to 83% of SB1 and SB10 has a block density almost equal to 82% of SB1.
3. The solid blocks were within the IS limit for the water absorption test from which it was obtained that SB1 has a water absorption less as compared to other samples in which NCA was replaced with RCA and NFA was replaced with RFA and residual mortar values were also incorporated.
4. From the moisture movement test it was obtained that all the specimens confirmed to IS specification and the values obtained was less than 0.09%.

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