International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 08, August-2018

Experimental Investigation of Concrete Blocks Manufactured Using Recycled Coarse and Fine Aggregates Obtained from Building Demolition Waste

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***Abstract*—Large quantities of demolished waste are generated from construction industry every year. Re-use of this demolished waste reduces the carbon footprint and results in a sustainable construction. An effort has been made in this research work to utilize the demolished waste in manufacturing solid concrete blocks. Hundred percent natural coarse aggregate has been replaced by recycled coarse aggregate and up to forty percent of M-sand is replaced by recycled fine aggregate and solid concrete blocks are manufactured. The blocks have been subjected to various tests such as block density, water absorption, drying shrinkage, compressive strength and also durability tests like weight loss and strength loss after acid attack. It has been observed from the test results that natural coarse aggregates can be hundred per cent replaced by recycled coarse aggregates and up to twenty per cent of natural fine aggregates and m-sand can be replaced by recycled fine aggregate obtained from building demolished waste without compromising much on the strength and durability criteria.**

Keywords*— Concrete blocks; recycled Aggregates; durability; shrinkage.

I. INTRODUCTION

There is a huge amount of solid waste is being generated as development countries requires a large amount of construction materials, land sites etc. The waste which is being generated from different activities like agricultural, domestic, industrial are causing major problems to the environment as they are not disposed in a right way. As the construction industry is growing the old buildings and structures are demolished and new buildings are constructed or the existing buildings are retrofitted. The construction activity requires several materials such as concrete, steel, brick, glass, wood etc. out of which concrete is considered as the most important construction material.

Concrete is made of coarse aggregate, fine aggregate, cement and Water in specific mix proportions. It is a good construction material because of its longer life, lower maintenance and better performance compared to other construction materials. Construction industry is a huge consumer of natural resources and it also produces a lot of waste products. To reduce the consumption of the natural resources, the solid waste which is generated from the above mentioned activities can be recycled for the sustainable construction. The material which is used for sustainable construction should match with the needs of society without causing any negative effect on the environment.

A.Demolition Waste:

Demolition waste is the waste obtained or produced from existing buildings which collapse due to natural calamities like earth quake or when old buildings are demolished or retrofitted to construct new buildings or structures. Demolished waste consists of electrical wiring, tiles, plastics, glass, wood, concrete, bricks and various other materials. In India 14.5 million tons out of 48 million tons of total solid waste generated per annum is due to construction and demolition waste.

B.Recycled Aggregates:

Recycling is the act of processing the used material to create a new product and re-use it. Cement concrete is an important building material and to achieve the sustainability inconstruction,thedemolishedwastefromconcretebuildingandstructuresareusedas new construction material. When the demolished waste is recycled by using crushers, it results in formation of aggregates which can be both fine and coarse. Such aggregates obtained by recycling is called as recycled aggregates.

II. LITERATURE REVIEW

M S Dina [2011] investigated the physical and mechanical properties of solid cement bricks manufactured by crushed clay bricks as recycled aggregate. It was found that the compressive strength and unit weight of the concrete decreased where as water absorption increased as compared to natural aggregates.

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M Monish, V C Agarwal et al.[2012] investigated the effect of partial replacement of fine aggregate by demolished waste to test the workability and compressive strength. It was found that with increase in percentage of demolished waste the slump and compressive strength decreases by around 20% as compared to conventional concrete.

S R Parvathy and M Praveen [2014] presented the results on experimental study conducted on masonry blocks. Various tests like compressive strength, block density and water absorption was carried out and it is found that these results are within the permissible limits as per IS code.

K Rekha and Dr M Potharaju[2015] investigated concrete mix made with recycle brick aggregates(RBA). Coarse aggregates are replaced with 25% crushed clay bricks. The compressive strength was checked for both the concretes before and after 1000^{0}c and it was found that the concrete containing RBA was better than GA.

M T Wadhah, H Taimoor et al.[2016] investigated the possible use of crushed pavement blocks as coarse aggregates in concrete. With the 100% replacement of NCA by RCA the compressive strength increases and workability decreases as compared to conventional concrete..

A Criticle review of literatures:

1. The compressive strength and unit weight of the concrete decreased whereas water absorption increased for recycle aggregates as compared to concrete with natural aggregates.

2. With increase in percentage of demolished waste the workability and compressive strength decreases. The optimum replacement level of fine aggregate with recycle fine aggregate is around 10percent.

3.Various tests for blocks like compressive strength, block density and water absorption was carried out and these results are within the permissible limits as per IS 2185:2005 part 1.

4.With the 100 percent replacement of NCA by RCA the compressive strength increases and workability decreases as compared to conventional concrete.

5. Excessive amount of water is used in recycle aggregates to produce Workable mix (considering water absorption or keeping the aggregates in saturated surface dry condition).
6. Incorporating the additional admixtures improves the strength and durability of the recycled aggregate concrete apart from which even shrinkage will reduce in recycled aggregate concrete mix.

III. PROBLEM STATEMENT AND OBJECTIVES

A. Problem statement:

To reduce the impact of recycled/ waste concrete aggregates dumping on land sites and to utilize and study this in a solid concrete blocks for sustainable construction (reduction of carbon foot print).

B. Objectives:

1. To experimentally investigate the suitability of recycled aggregate concrete in preparation of solid cement blocks with replacement of 100% NCA with RCA and replacement of M-Sand by RFA at increments of 10%, 20%, 30% and 40%.

2. To study the strength parameters of concrete blocks.

3. To study the durability parameters of 100 mm concrete cubes.

IV. RESEARCH METHODOLOGY

In this Project work an attempt has been made to manufacture solid concrete blocks by replacing normal coarse and fine aggregates by aggregates obtained from building demolished waste. The physical properties of the materials involved in preparing the concrete play a very important role in fresh and hardened properties of the concrete. Therefore all the ingredients namely recycled coarse aggregate, manufactured sand, recycled fine aggregate and cement are subjected to all the tests to understand the physical properties of the same. The fine and coarse aggregates are subjected to various tests such as water absorption, specific gravity and sieve analysis whereas cement is subjected to standard consistency, compressive strength, fineness and specific gravity tests. The mix proportions are calculated as per IS 10262:2009 and a nominal mix to achieve characteristic strength of M20 is chosen. The concrete block size of 400mm X 200mm X 150mm is chosen as per IS 2185: 2005. The manufactured concrete blocks are subjected to strength, durability and shrinkage tests to evaluate the use of the blocks as load bearing block units.

Table 1: Nomenclature of material used

Material	Nomenclature
NCA	Natural Coarse Aggregate
MS	Manufactured Sand
RCA	Recycled Coarse Aggregate
RFA	Recycled fine Aggregate

Table 2: Description of trail mixes

Mixes	Description
Mix 1	100% NCA + 100% MS
Mix 2	100% RCA + 100% MS
Mix 3	100% RCA + 90% MS + 10% RFA
Mix 4	100% RCA + 80% MS + 20% RFA
Mix 5	100% RCA + 70% MS + 30% RFA
Mix 6	100% RCA + 60% MS + 40% RFA

V. EXPERIMENTAL INVESTIGATION

A. Parametric studies on materials:

Various materials are used namely OPC of 53 grade, M Sand, recycle fine aggregate, natural coarse aggregate, recycled coarse aggregate and the basic material test is conducted for this material as follows.

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i. Cement:
OPC of 53 grade (BIRLA Super) is chosen for this project confirming to IS 12269:2013.

Table 3: Physical properties of cement

1	Specific gravity	3.15
2	Standard consistency	34%
3	Initial Setting Time	46 min
4	Compressive strength	28.5 Mpa

ii. Fine Aggregate:
There are two types of fine aggregate used in this project namely manufactured sand and recycled fine aggregate. Basic material tests are done for these materials as per specification given in IS 383:1970 and IS 2386-1963(Part 1 and Part 3).
The sieve analysis is conducted for both materials with different trail mixes and fine modulus of these materials lies under Zone 2 as per code. The graph shows the fineness modulus of all trail mixes.

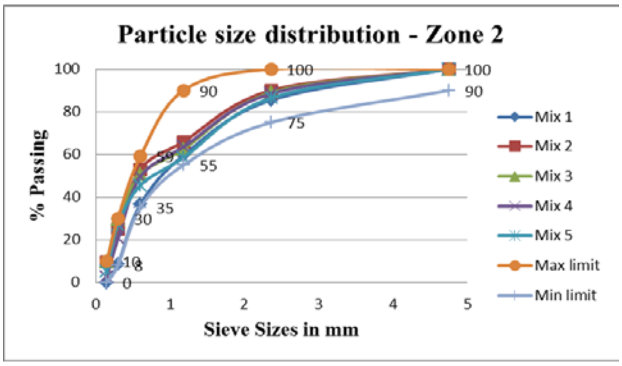

Figure 1: Graph indicating Fineness modulus of Fine Aggregates

Table 4: Specific gravity and water absorption.

Tests	M - Sand	Recycled fine aggregate
Specific Gravity	2.34	2.19
Water absorption	9.8%	16.8%

iii. Coarse aggregates:
There are two types of fine aggregate used in this project namely natural coarse aggregate and recycled coarse aggregate. Basic material tests are done for these materials as per specification given in IS 383:1970 and IS 2386-1963(Part 1 and Part 3).

Table5: Physical properties of coarse aggregate

Tests	NCA	RCA
Specific Gravity	2.6	2.36
Water absorption	3.09%	5.56%

B. Fresh concrete properties:
When the concrete is freshly prepared it has to be mixed, transported, compacted and finished. The ease at which the mentioned functions are executed represent the quality of concrete in plastic state. Therefore it is important to check the workability of concrete. Some of the factors which affect the workability are, water content, mix proportions, size of aggregates, shape of aggregates, surface texture of aggregates, grading of aggregates, use of admixtures, time and temperature. There are several tests recommended for workability of concrete namely slump test, compacting factor test, Vee Bee consistometer test etc. Among these, slump test is chosen to find workability of concrete.

Table6: Slump value of all trail mixes

Trail Mix	Slump(mm)
Mix 1	26
Mix 2	20
Mix 3	15
Mix 4	12
Mix 5	7
Mix 6	4

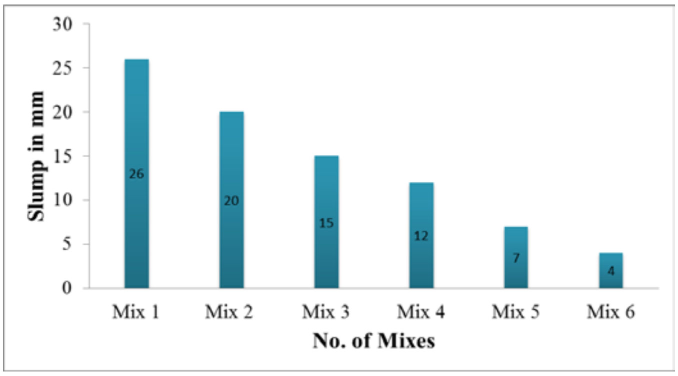

Figure 2: Graph indicating slump value of all trail mixes

C. Hardened concrete properties:
Testing of hardened concrete gives an idea of actual performance of concrete. The main property of harden concrete is to check the desired strength when the concrete is casted at site and when it is exposed to working environment. There are several test performed in this project to find out hardened properties of concrete such as density, water absorption, drying shrinkage, compressive strength and durability. In this project 100mm cubes are casted to perform durability and water absorption test. 150mmcubesarecastedtoobtainthecharacteristicstrengthofmix, solid concrete blocks of size 400mm X 200mm X 150mm are used to find the real time performance of the mix and prism of size 75mm X 75mm X 290mm are casted to find the drying shrinkage of various trail mixes.

VI. RESULTS AND DISCUSSIONS

The hardened concrete properties like Block density, water absorption, drying shrinkage, compressive strength of blocks and durability(weight loss and compressive strength) are shown below,

A. Block Density:
Three blocks for each trail mix were taken for block density test, the average block density in Kg/m3 were calculated for 3 days, 7 days and 28 days, the values obtained are shown in table. The procedure followed as per IS 2185:2005 specifications.

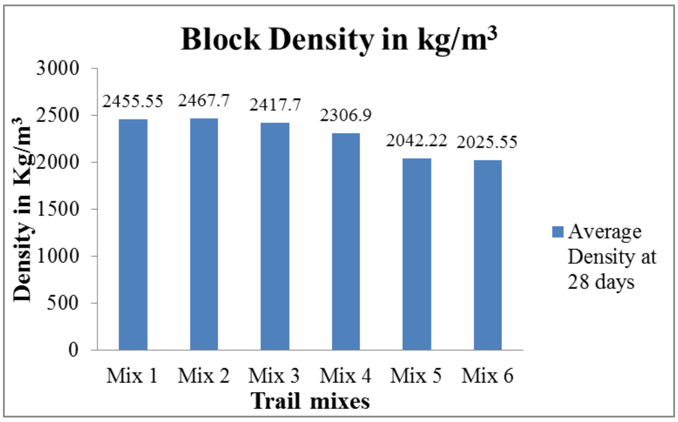

Figure 3. Graph indicating block density after 28 days

•According to the graph obtained the block density increases with the increase in number of days of curing, clearly indicating the fundamental strength property of concrete.

• The density of block slightly increases with replacement of normal coarse aggregate with recycle coarse aggregate which may be due to pre-existing mortar on coarse aggregate.

• However by replacement of M-sand with recycle fine aggregate, the density of block decreases with increase in percentage of RFA.

B. Water Absorption:

As the block we have chosen is of lager dimension, and does not easily fit inside. For convenience 100mm cubes are taken for the water absorption test. Three samples were considered for each trail mix and average water absorption after 24 hours are shown below for each trail mix.

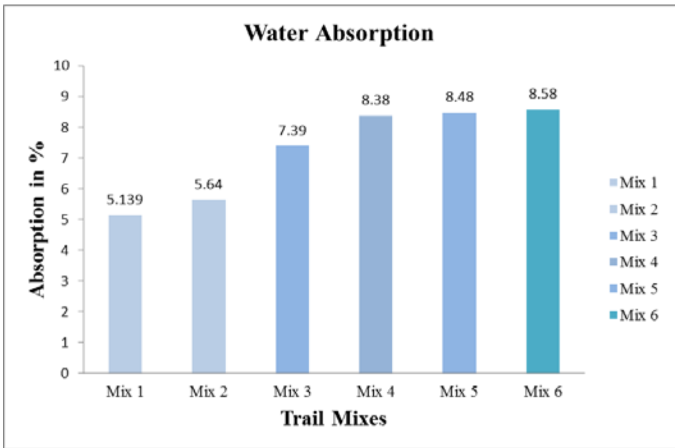

Figure 4: Graph indicating water absorption of all trail mixes

• For the normal concrete mix the water absorption is around 5 percent which is within the permissible limit. 37

• The water absorption is increasing with increase in the percentage of recycled aggregates .This may be due to the voids developed in the concrete mix due to lower level of compaction achieved due to reduced workability when RFA is added.

C. Drying Shrinkage:

For this test three specimens of size 75mm x 75mm x 290mm were taken for each trail mix. The average value of shrinkage in micro strain for each trail mix is shown in table below. The procedure is followed as per IS 2185:2005.

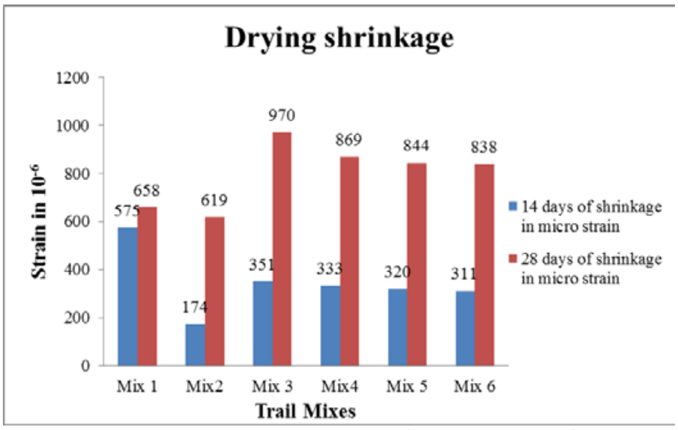

Figure 5: Graph indicating drying shrinkage for 14 and 28 days for all trail mixes

• From shrinkage point of view, the trail mix 2 (100percent RCA and 100percent M-Sand) mix gives lesser shrinkage values.

• There is a clear downward trend when RFA is added to the mix.

• The shrinkage reduces with increase in percentage of RFA, however the values of shrinkage are higher compared to conventional concrete.

•The comparison between the values of 14 and 28 days of shrinkage clearly shows that shrinkage increases with time.

D. Compressive strength:

Total of 3 blocks each were taken for 3 days and 7 days calculation of compressive strength. Total of 5 blocks were taken to find the average compressive strength for 28 days. The compressive strength of blocks as shown in the table below.

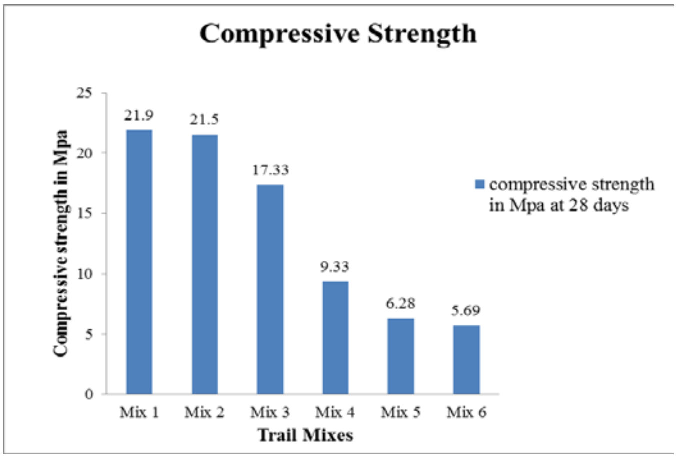

Figure 6: Graph indicating the compressive strength after 28 days

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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• The trend is also consistent when we check the strength of blocks for 3 days and 7 days curing.

• However with the increase in percentage of RFA the compressive strength decreases, but the values are still greater than 5 Mpa limit specified for solid load bearing unit of type C5 as per IS 2185:2005.

• The trail mix 2 achieved compressive strength almost as equal to trail mix 1, which is encouraging and indicating that NCA can be 100 percent replaced by RCA and does not affect the compressive strength of block.

•The strength achieved may be due to high level of compaction achieved as indicated by density value of more than 2000 Kg/m3 which is greater than the code specified value of 1800Kg/m3 for C5 grade.
• The trend is also consistent when we check the strength of blocks for 3 days and 7 days curing.

E. Durability:
Total of nine cubes of 100mm are casted out of which 3 cubes are used for normal water curing, 3 each are used for 30 days and 45 days of acid curing [5percent sulphuric acid solution]. For each of these cubes cured in acid solution, percentage of weight loss and reduction in compressive strength is calculated. The results of weight loss and compressive strength loss are shown below.

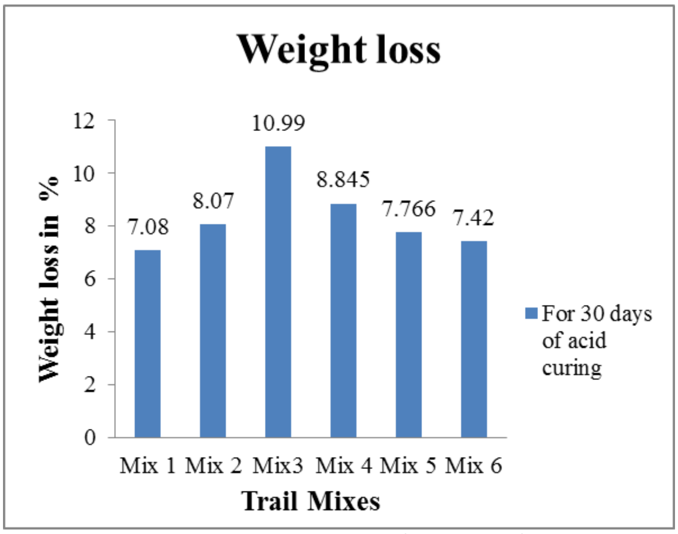

Figure 7: Graph indicating weight loss after 30 days of acid curing

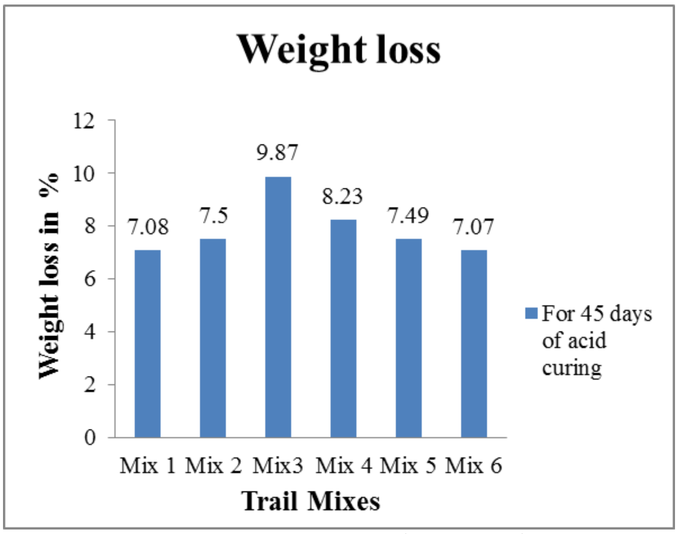

Figure 8: Graph indicating weight loss after 45 days of acid curing

• The Weight loss of cubes is highest for mix 3which has a least RFA.
• As the percentage of RFA increases the weight loss decreases indicating the use of RFA for concrete mix where durability is the main criteria.
• The same trend is indicated in strength loss also.
• The strength loss percentage also decreases with increase in percentage of RFA.
• The increase in durability performance of concrete mix due to RFA may be due to the presence of cement and mortar powder along with the fine aggregate.

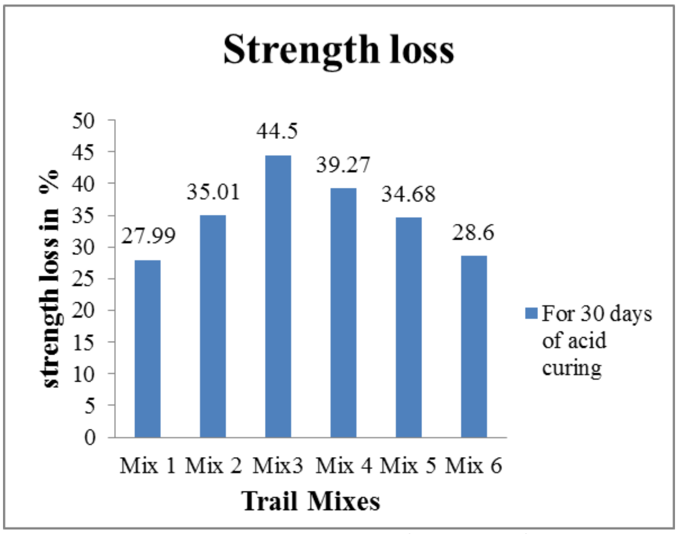

Figure 9: Graph indicating strength loss after 30 days of acid curing

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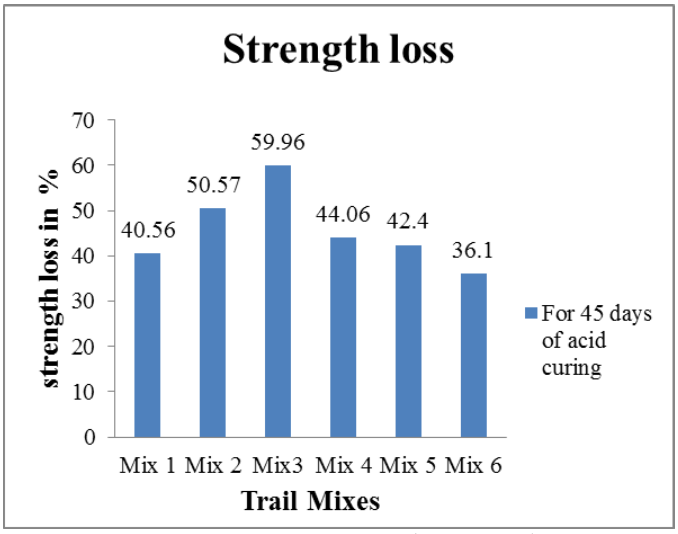

Figure 10: Graph indicating strength loss after 45 days of acid curing

CONCLUSION

Following are the conclusive points obtained from the study:

1. Water absorption increases with addition of demolished waste. The water absorption of increases by 9.72% when only NCA is replaced with RCA. The water absorption further increases from 9.72%to66.92%when40%ofM-sandispartiallyreplacedwith RFA.

2. The block density decreases with increase in RFA.When NCA is completely replaced with RCA and 10 percent M-sand replaced by RFA the density of concrete decreases by 1.54 %. It density decreases further up to 17.51% when 40% M-sand is replaced with RFA.

3. The drying shrinkage increases with addition of demolished waste. The drying shrinkage increases by 47% when NCA is 100% replaced with RCA and 10% M-sand is replaced with RFA.

4. However the shrinkage reduces with increase in percentage of RFA. It reduces from 47% to 28% when 40% of M-sand is replaced with RFA.

5. The compressive strength of blocks reduces with addition of demolition waste. The compressive strength decreases by 2% when 100% NCA is replaced by RCA. The strength reduces further to 74% of normal concrete when 40% of M-sand is replaced by RFA.

6. The weight loss is higher by 39.4% when 100% NCA is replaced with RCA and 10% M-sand is replaced with RFA. However with increase in replacement of M-sand by RFA the weight loss reduces from 39.4% to 1.5% as compared to normal concrete.

7. The strength loss is higher by 47.8% when 100% NCA is replaced with RCA and 10% M-sand is replaced with RFA. However with increase in replacement of M-sand by RFA the strength loss reduces from 47.8% to 2% as compared to normal concrete.

8. From the above points it can be concluded that concrete blocks can be manufactured using building demolition waste. NCA can be 100% replaced by RCA without much loss in strength and durability parameters. However M-sand can be replaced up to 20% by RFA without much compromise in strength and durability parameters.

ACKNOWLEDGMENT

I also extremely grateful to Mr. Arjun H R, Dr. Nabil Hossiney and Dr. Beulah M who have supported and helped me to carry out the project.

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