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An experimental analysis of recycled aggregate concrete over conventional concrete

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ABSTRACT: Concrete is the world's second most consumed material after water, and its widespread use is the basis for urban development. It is estimated that 25 billion tones of concrete are manufactured each year. Twice as much concrete is used in construction around the world when compared to the total of all other building materials combined. The construction and demolition waste (C&DW) have recycling schemes to avoid dumping to landfill, as suitable landfill sites are becoming scarce particularly in heavily populated countries the reuse of hardened concrete as aggregate is a proven technology - it can be crushed and reused as a partial replacement for natural aggregate in new concrete construction. The hardened concrete can be sourced either from the demolition of concrete structures at the end of their life – recycled concrete aggregate, or from leftover fresh concrete which is purposefully left to harden – leftover concrete aggregate. Alternatively fresh concrete which is leftover or surplus to site requirements can be recovered by separating out the wet fines fraction and the coarse aggregate for reuse in concrete manufacture – recovered concrete aggregate.

KEYWORDS: demolition waste (C&DW), natural aggregate, recycled aggregate, hardened concrete, crushed and reused

I.INTRODUCTION

The key to local ingredients recovery and the recycling industry sector is to achieve a balance between economic pressures and ecologically sound practices. This balance is critical not only to ensure a sustainable future for the industry, but also to secure essential quality improvements and development of markets for value-added products, which are required to make recycled materials more attractive and economical.

Construction aggregates make up more than 80 percent of the total aggregate market, and are used mainly for building constructions and pavements. With the construction activities increasing tremendously, and we falling short of construction aggregates it has become necessary to find an alternate source for the material. Projections for building material requirement of the housing sector indicate a shortage of aggregates to the extent of about55,000 million cu. m. An additional 750 million cu. m aggregates would be required for achieving the targets of the road sector. At this stage the concept of using recycled aggregate has proved to be a good alternative. When structures made of concrete are demolished or renovated, concrete recycling is an increasingly common method of utilizing the rubble. Concrete was once routinely trucked to landfills for disposal, but recycling has a number of benefits that have made it a more attractive option in this age of greater environmental awareness, more environmental laws, and the desire to keep construction costs down.

II. SIGNIFICANCE OF THE SYSTEM

One of the major challenges of our present society is the protection of environment. Some of the important elements in this respect are the reduction of the consumption of energy and natural raw materials and consumption of waste materials. These topics are getting considerable attention under sustainable development nowadays. The use of recycled aggregates from construction and demolition wastes is showing prospective application in construction as alternative to primary (natural) aggregates. It conserves natural resources and reduces the space required for the landfill disposal.

This paper presents the experimental results of recycled coarse aggregate concrete and results are compared with the natural aggregate concrete. The fine aggregate used in the concrete, i.e. recycled and conventional is 100 percent natural. The recycled aggregate are collected from four sources all demolished structures. For type of concrete i.e. M-20, w/c ratio, maximum size of aggregate (20mm) and mix proportion (1:2:4) are kept constant. The development of compressive strength of recycled aggregate concrete at the age of 7, 14, and 28 days are investigated. The results show the compressive strengths of recycled aggregate are on average 70% to 80% of the natural aggregate concrete

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III. LITERATURE SURVEY

STRENGTH CHARACTERISTICS OF CONCRETE WITH REYCLED AGGREGATE
(International Journal of Engineering Research And Applications (IJERA)
ISSN: 2248-9622 www.ijera.com
VOLUME 2, ISSUE 5 (SEPTEMBER-OCTOBER 2012))

The objective of the subject is to utilize recycled aggregates in concrete, using IS 10262:2009 for designing the concrete with grade M25. A comparison with control mix mainly their compressive strength, split tensile strength and flexural strength will allow assessing the suitability of using recycled aggregate in concrete was studied.

EXPERIMENTAL STUDY ON RECYCLED AGGREGATE CONCRETE
(International Journal of Engineering Research and Applications (IJERA)
ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 2, Mar-Apr 2012, pp.407 -410)

The objective of the subject is that the use of recycled aggregate weakens the quality of recycled aggregate concrete which limits its application. For improving the quality of recycled coarse aggregate, various surface treatment methods such as washing the recycled aggregates with water and diluted acid were investigated. Strength properties of the treated and untreated coarse aggregate were compared. The results indicated that the compressive, flexure and split tensile strength of recycle aggregate is found to be less than the natural aggregate.

MECHANICAL PROPERTIES OF RECYCLED AGGREGATE CONCRETE WITH DEFORMED STEEL RE-BAR
(Journal of Marine Science and Technology Vol. 20, No. 3, pp. 274-280 (2012) Paper submitted 02/10/11; revised 08/15/11; accepted 11/21/11)

This study investigates fundamental properties of the recycled aggregate which was produced through recent hi-technique of recycling. In addition, the mechanical properties of the concrete that was made by the recycled aggregate were compared to the concrete made of natural aggregate. The primary objective of this study was to characterize the concrete-rebar bonding properties of the recycled aggregate concrete.

PERFORMANCE EVALUATION OF RECYCLED AGGREGATE USED IN CONCRETE
(International Journal of Engineering Research and Applications (IJERA)
ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 4, July-August 2012, pp.1387-1391)

In this paper the literature related to the recycling and reuse of waste concrete aggregate is
presented and conventional coarse recycled aggregate is being replaced with recycled aggregate. The investigation was carried out using workability test, compressive test, split tensile test and bulk density, water absorption, impact value test, crushing value test, Fineness modulus. There were total of sixth batches of concrete mixes, consists of every 20% increment of recycled aggregate replacement from 0% to 100%. Moreover, 100% of recycled aggregate mix batches included, different water/cement ratio of 0.5, 0.6 and 0.7. The workability of concrete considerably reduced as the amount of recycled aggregate increased. For the strength of characteristics, the results showed that a gradually increasing in the compressive strength up to 20% of recycled aggregate and as well as for the tensile strength as the percentage of recycled aggregate.

STUDY ON THE USE OF RECYCLED AGGREGATE IN CONCRETE
(International Journal of Engineering Science and Research Technology)
ISSN: 2277-9655 www.ijesrt.com

A TECHNO-ECONOMICAL STUDY ON RECYCLED AGGREGATE CONCRETE
(International Journal of Advanced Engineering Technology E-ISSN 0976-3945)

The aim for this project is to determine the strength characteristic of recycled aggregates which will give a better understanding on the properties of concrete with recycled aggregates, as an alternative material to coarse aggregate in structural concrete by cost. The scope of this project is to determine and compare the strength and cost of concrete by using different percentage of recycled aggregates. There were total of six batches of concrete mixes, consists of every 20% increment of recycled aggregate replacement from 0% to 100%. The test results show maximum strength at 40% replacements of recycled aggregates.

USE OF RECYCLED AGGREGATE IN CONCRETE
(International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181 Vol. 2 Issue 1, January- 2013)

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This paper reports the basic properties of recycled fine aggregate and recycled coarse aggregate & also compares these properties with natural aggregates. Basic changes in all aggregate properties are determined and their effects on concreting work are discussed at length. Similarly the properties of recycled aggregate concrete are also determined. Basic concrete properties like compressive strength, flexural strength, workability etc. are explained here for different combinations of recycled aggregate with natural aggregate.

EXPERIMENTAL INVESTIGATION FOR RECYCLED COARSE AGGREGATE REPLACED FOR NATURAL COARSE AGGREGATE IN CONCRETE

(International Journal of Civil, Structural, Environmental And Infrastructure Engineering Research and Development (IJCSEIERD)

ISSN 2249-6866

Vol. 3, Issue 2, Jun 2013, 35-42 © TJPRC Pvt. Ltd)

This Research paper reports the basic properties of recycled coarse aggregate. It also compares these properties with natural aggregates. Basic changes in all aggregate properties were determined. Basic concrete properties like compressive strength, workability etc. are explained here for different combinations of recycled course aggregate with natural aggregate.

CHARACTERIZATION OF RECYCLED AGGREGATE CONCRETE

(International Journal of Advanced Engineering Technology)E-ISSN 0976-3945

This paper reports the basic properties of recycled fine aggregate and recycled coarse aggregate. It also compares these properties with natural aggregates. Basic changes in all aggregate properties were determined and their effects on concreting work were discussed at length. Similarly the properties of recycled aggregate concrete were also determined and explained here. Basic concrete properties like compressive strength, flexural strength, workability etc are explained here for different combinations of recycled aggregate with natural aggregate. Use of recycled aggregate has been found useful for pavement construction. Reasons, of use of recycled aggregate concrete in pavement construction, with technical proofs are explained here in detail. Individual performance of recycled fine aggregate in concrete, use of silica fumes in recycled aggregate concrete, use of fly ash in recycled aggregate concrete etc are shown with experimental reasons.

EFFECT OF RECYCLED COARSE AGGREGATES IN PROPERTIES OF CONCRETE (JOURNAL OF GREEN BUILDINGS)

Volume 3, Issue- 4, fall 2008 pp. 130-137

The properties of concrete containing coarse recycled aggregates were investigated. Laboratory trials were conducted to investigate the possibility of using recycled aggregates from the demolition wastes available locally as the replacement of natural coarse aggregates in concrete. A series of tests were carried out to determine the density, compressive strength, split tensile strength, flexural strength and modulus of elasticity of concrete with and without recycled aggregates. The water cement ratio was kept constant for all the mixes. The coarse aggregate in concrete was replaced with 0%, 20%, 40%, 60%, 80% and 100% recycled coarse aggregates. The test results indicated that the replacement of natural coarse aggregates by recycled aggregates up to 40% had little effect on the compressive strength, but higher levels of replacement reduced the compressive strength. A replacement level of 100% causes a reduction of 28% in compressive strength, 36% in split tensile strength and 50% in flexural strength.

IV. METHODOLOGY

The main stages involved in the project are;

- Collection of aggregate sample
- Laboratory analysis
- Comparisons
- Conclusions

1. Collection of Aggregate Samples

Collection of aggregate samples is the first and foremost step involved in the project. It is the most difficult and time consuming part of the project. Two kinds of aggregate samples are required for the project. They are:

- Fresh/Virgin aggregate sample
- Scrap/Used aggregate sample

For used aggregate samples, cement concrete cubes are collected from laboratory waste (i.e. concrete technology lab, MREC). This collected material is crushed by hammer to separate the aggregates & reduce their sizes in smaller

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fraction. On these separated aggregates various testes are conducted in laboratory as per Indian Standard code & their results are compared with natural aggregates. 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. We collected about 132kg of each aggregate sample which was required for this project.

2. Laboratory Analysis of Aggregate Samples

The second step involved in the project after collection of aggregate samples was laboratory analysis. Laboratory analysis of aggregate samples involves a set of quality control tests to be performed on each aggregate sample using appropriate lab equipments to know their characteristics better.
The following quality control tests were performed on aggregate samples-

- Impact Test
- Specific Gravity Test

These tests were performed with reference to proper Indian Standard guidelines.

3. Location Where Tests Were Performed

All the above stated tests were performed in our college at Construction Technology Laboratory, MREC.

4. Experimental program

The main aim of this research project is to utilise recycled concrete as coarse aggregate for the production of concrete. It is essential to know whether the replacement of RCA in concrete is inappropriate or acceptable. Three types of aggregates are used in this project which includes natural coarse aggregate, natural fine aggregate and RCA. Natural coarse aggregate used is microtonalite with maximum size of 25 mm. Natural fines aggregate used is river sand and RCA used is crushed concrete from tested concrete cubes. Tests are carried out on these aggregates to determine the specific gravity and absorption; bulk density; moisture content and sieve analysis. After testing, a mix design is produced in accordance with the properties obtained from test results. Concrete is then produced with replacement of 0%, 50% and 100% of RCA as well as 100% replacement of saturated surface dry (SSD) RCA with the same mix proportion. Tests conducted on these concretes include the slump of fresh concrete. For the hardened concrete, the 28-days air-dry density, compressive strength, split tensile strength and flexural strength were determined. Except for the 28-days air-dry density, tests were conducted at the ages of 3, 7 and 28 days and the results at each testing age are reported as an average. The engineering properties of the RAC were also compared to those of the reference concrete.

The natural fine aggregate used for producing concrete is river sand. The source of this sand is river beds. The natural coarse aggregate available in the Civil Engineering Laboratory is microtonalite. The maximum size of this gravel is 20 mm. Recycled aggregate used in this research is crushed concrete, i.e. RCA. The site tested concrete cubes of 28-days are crushed together using hammer. Since the natural aggregate is less than 25 mm in size, the recycled concrete is sieved through 25 mm sieve and 4.75 mm in a mechanical shaker. Recycled aggregate passing 25 mm and retained on 4.75 mm sieve is collected to produce recycled concrete.

The mix design is produced with the selected slump of 30~60 mm, design compressive strength of 30 MPa and the maximum aggregate size of 25 mm. Other aggregate properties available from previous tests are used in the calculation for mix design. Numerous trial mixes are carried out to produce concrete with 0% replacement of RCA. This concrete serves as reference concrete (control concrete) and tests are conducted on this concrete to determine its properties. The other three mixes are carried out to produce concretes with 50% and 100% replacement of RCA as well as 100% replacement of SSD recycled concrete coarse aggregate. The concretes with replacement of RCA are tested and their properties determined. Directly after casting, the fresh concrete is covered with plastic sheet to avoid excess evaporation of water. The hardened concrete samples are then de-moulded after 24 hours and submerged in a clean water bath for curing until the age of testing.

V. EXPERIMENTAL RESULTS

1. Initial setting time and final setting time

Result:
Initial setting time for the given sample of cement = 64mins.
Final setting time for the given sample of cement = 446mins.

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2. Impact value test

Result:
Fresh Aggregate
Weight of empty cylinder = 813 gm
Weight of aggregate + cylinder = 1118 gm
Total weight of aggregate sample filling the cylindrical measure, W1 = 305 gm
Weight of the material passing through IS sieve 2.36 mm, W2 = 40 gm
Weight of the material retained on IS sieve 2.36 mm, W3 = 265 gm
Aggregate Impact Value = w2/w1 ×100 %
Aggregate Impact Value =40/305 × 100 %
Aggregate Impact Value = 13.10 %

Recycled Aggregate
Weight of empty cylinder = 813 gm
Weight of aggregate + cylinder = 1135 gm
Total weight of aggregate sample filling the cylindrical measure, W1 = 322 gm
Weight of the material passing through IS sieve 2.36 mm, W2 = 60 gm
Weight of the material retained on IS sieve 2.36 mm, W3 = 262 gm
Aggregate Impact Value =w2/w1 × 100 %
Aggregate Impact Value =60/262 × 100 %
Aggregate Impact Value = 18.63 %

3. Specific gravity test

Results:
Fresh aggregate
1) Weight of empty container W1= 675 gm
2) Weight of container with material W2= 844 gm
3) Weight of container + material + water W3= 1653 gm
4) Weight of container + water W4= 1548gm

Specific gravity = W2 - W1 / ((W4 - W1) - (W3 - W2))
= 844-675/ (1548-675)-(1653-844)= 2.64
Specific gravity, G = 2.64

Recycled aggregate
1) Weight of empty container W1= 675 gm
2) Weight of container with material W2= 870 gm
3) Weight of container + material + water W3= 1665gm
4) Weight of container + water W4= 1548gm
Specific gravity = W2 - W1 / ((W4 - W1) - (W3 - W2))
= 870-675/ (1548-675)-(1665-870) = 2.50
Specific gravity, G = 2.50

S.NO	PARTICULARS	VALUES	
		NATURAL AGG.	RECYCLED AGG.
1	IMPACT TEST	13.10 % LOSS	18.63 % LOSS
2	SPECIFIC GRAVITY	2.64	2.50

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Table 1
Slump cone test
Natural aggregate concrete

S.no	W/c	Height of cone (slump) cm
1.	0.45	30
2.	0.50	26
3.	0.55	17
4.	0.60	Collapse

Table 2
Recycled aggregate concrete (50% natural aggregate)

S.no	W/c	Height of cone (slump) cm
1.	0.45	29
2.	0.5	28
3.	0.55	27
4.	0.60	25

Table 3
Recycled aggregate concrete (0% natural aggregate)

S.no	W/c	Height of cone (slump) cm
1.	0.45	29
2.	0.5	25
3.	0.55	23
4.	0.60	17

Table 4
4.Compressive strength test
Natural aggregate concrete

S.no	Age of Concrete	Load in KN	Area In mm^2	Compressive strength in N/mm^2
1.	7 days	331.5	22500	14.73
2.	14 days	434	22500	19.28
3.	28 days	556	22500	24.71

Table 5
Recycled aggregate concrete (50% natural aggregate)

S.no	Age of Concrete	Load in KN	Area In mm^2	Compressive strength in N/mm^2
1.	7 days	550	22500	24.45
2.	14 days	620	22500	27.56
3.	28 days	750	22500	33.34

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Table 6
Recycled aggregate concrete (0% natural aggregate)

S.no	Age of Concrete	Load in KN	Area In mm^2	Compressive strength in N/mm^2
1.	7 days	310	22500	13.77
2.	14 days	410.12	22500	18.22
3.	28 days	499.01	22500	22.17

Table 7
Comparison of RAC, CVC and RAC (50% natural aggregate)

Compressive Strength Of Age Of Concrete (N/mm^2)	Natural Aggregate Concrete	Recycled Aggregate Concrete (50% Natural Aggregate)	Recycled Aggregate Concrete (0% Natural Aggregate)
7 days	14.73	24.45	13.77
14 days	19.28	27.56	18.22
28 days	24.71	33.34	22.17

Table 8

VI.CONCLUSION AND FUTURE WORK

By considering the above results and calculations, we conclude that use of recycled aggregate up to 50% does not affect the functional requirements of the structure as per the findings of the test results.

Various tests conducted on recycled aggregates and results compared with natural aggregates are satisfactory as per IS 2386.

Due to use of recycled aggregate in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.

Recycling and reuse of building wastes have been found to be an appropriate solution to the problems of dumping hundreds of thousands tons of debris accompanied with shortage of natural aggregates. The uses of recycled aggregates in concrete prove to be valuable building materials in technical, environment and economical respect.

Recycled aggregate possess relatively lower bulk density, crushing and impact values and higher water absorption as compared to natural aggregate. The compressive strength of recycled aggregate concrete is relatively lower up to 15% than natural aggregate concrete. The variation also depends on the original concrete from which the aggregates have been obtained.

There are several reliable applications for using recycled coarse aggregate in construction. However, more research and initiation of pilot project for application of RCA is needed for modifying our design codes, specifications and procedure for use of recycled aggregate concrete. The subject of use of RCA in construction works in India should be given impetus, because of big infrastructural projects are being commissioned.

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