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A Study on Recycled Aggregate as a Substitute to Natural Aggregate for Sustainable Development in India

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ABSTRACT

The recycling of Construction and Demolition Wastes has long been accepted to have the possible to conserve natural resources and to decrease energy used in its production. RCAs fit into present day motto of 'Reducing, Reusing, Recycling and Regenerating'. In some nations it is a standard substitute for both construction and maintenance, particularly where there is a scarcity of construction aggregate. The use of recycled aggregate weakens the quality of recycled aggregate concrete which limits its application. This paper deals with the review of the existing literature work for understanding thoroughly about RCAs and the use of recycled concrete as aggregates in concrete and proposes an approach for use of recycled concrete aggregate without compromising the strength in view for better economic growth to pave way for new construction as the old structures brought down.

KEYWORDS: Recycled Coarse Aggregates (RCAs), Natural Aggregate (NA), Reusing, Recycling, Construction waste

INTRODUCTION

Recycled Coarse Aggregates (RCAs) are obtained by crushing of concretes from demolition of concrete structural components in many structures such as: old buildings, concrete pavements, bridges & structures, at the end of their service life & utility, structures deteriorated beyond the possibility of repairs, structures that are turned into debris resulting from natural disasters (such as floods, earthquake, tsunami, manmade disaster/war, etc.), structures not serving the needs in present scenario, old structures to be brought down to pave way for new construction for better economic growth. RCAs actually results from crushing of waste concrete and this material as a replacement for natural aggregates can be employed in many applications such as: construction of low rise buildings, manufacture of paving blocks & tiles, laying of flooring and approach lanes, in sewerage structures and sub-base course of pavement, besides drainage layer in highways and retaining walls.

SCENARIO

Central Pollution Control Board reported in 2004 that solid waste generation in India was about 48 million tons/annum and more than 25% of this is from construction industry which consists of about 7-8 million tons of concrete and brick waste. The waste quantities are estimated to reach to level of atleast 85 million by 2013. RCAs is particularly very promising source of aggregates as 75 per cent of any typical concrete is made of aggregates. RCAs present a unique solution to the problems of large scale demolitions occurring now-a-days in India. This recycling industry for waste concretes helps reducing management/maintenance costs of dumpsites/ landfills and transportation costs.

TYPES OF RCAs

TABLE 1
TYPES, SOURCE AND USES OF RCAs

Type	Source	Use
RECYCLE CONCRETE AGGREGATE (RCA)	Crushed Stone & clean waste concrete of at least 95% by weight of concrete with typical total contamination lower than 1% of bulk mass.	Partial replacement (30%) of natural aggregate in concrete used in sidewalks, kerbs and gutters. Also for structural concrete with mix adjustments and inferior permeability & shrinkage properties
RECYCLE CONCRETE AND MASONARY (RCM)	Graded aggregate produced from sorted and clean waste concrete and masonry	Road base course and sub base course
RECLAIMED AGGREGATE (RA)	Coarse aggregate reclaimed from returned concrete by separating the aggregate from water cement slurry	Upto 32 MPa concrete with 100% reclaimed aggregate and as partial replacement of natural aggregate in grades upto 80 MPa
RECLAIMED ASPHALT PAVEMENT (RAP)	Old asphalt concrete	New asphaltic concrete pavement
RECLAIMED ASPHALT AGGREGATE (RAA)	Reclaimed coarse aggregate and recycled asphalt granules from waste asphalt concrete	Concrete with penalties in mix adjustment

Source: Report by Patel Vivek on Techno Economical Study On Recycle Aggregate Concrete

PROPERTIES

- **SPECIFIC GRAVITY**

Specific gravity of an aggregate is defined as the ratio of the mass of a solid to the mass of an equal volume of water at the same temperature.

- **SURFACE TEXTURE AND SHAPE**

Recycled Concrete Aggregates have an irregular and granular structure, due to the adhered mortar which can be a point of concern as it is a factor which contributes toward higher water absorption, workability and ultimately the strength characteristics of the concrete made using RCAs. The structure of RCAs mainly depends upon the parent source of concrete rubble. RCAs from poorly compacted concrete are of irregular shape and the adhered mortar is not dense and thus exhibits weak bond between the mortar and the aggregate. While aggregates derived from concrete cubes yields aggregates with irregular shape and better bond between mortar and aggregate.

- **FLAKINESS AND ELONGATION INDEX**

Flakiness index: It is defined as the percentage by weight of Particles in it whose least dimension is less than three fifths of their mean dimension.

Elongation Index: It is defined as the percentage by weight of particles whose greatest dimension is greater than 1.8 times their mean dimension. The test procedure is followed as per IS: 2386 (Part I)-1963 to find the flakiness and elongation index of RCAs.

- **BULK DENSITY, CRUSHING AND IMPACT VALUES**

Bulk Density: It is defined as Mass of an aggregate per unit Volume.

Crushing Value: The Value which gives a relative Measure of Resistance of an aggregate under a gradually applied compressive load is called Crushing Value of an Aggregate.

Impact Value: The value which gives a Relative Measure of the resistance of an Aggregate to sudden shock or Impact is Called Impact Value of an Aggregate. Test for bulk density carried out using IS: 2386 (Part III) – 1963.

TABLE 2
PROPERTIES OF NCA AND RCAs

Properties of aggregate	NCA-20mm	RCA-20mm
Sp. Gravity	2.86	2.50
Elongation index	34.82%	26.8%
Flakiness Index	14.7%	6.2%
Loose Bulk Density	1.41kg/lit	1.17kg/lit
Water Absorption	1.99%	5.61%
Impact Value	16.22%	32.19%
Crushing Value	21.67%	29.8%

Source: Report by Patel Vivek on Techno Economical Study on Recycle Aggregate Concrete

PROBLEMS AND EFFECTS

Following are the problems related with Recycle Aggregate:

- Poor properties than that of natural aggregate;
- Higher water absorption (3 – 9%);
- Lower density (2000 – 2500 kg/m3);
- Lower resistance to abrasion;
- Higher content of impurities;
- Lower specific gravity;
- Lack of strong bond between cement paste and RCAs in concrete matrix.

Following are the effects of using Recycle Aggregate in hardened concrete:

- Lower compressive strength (upto 40%);
- Lower modulus of elasticity (upto 50%);
- Increased shrinkage (upto 50% if only bigger recycled fractions are used, up to 70% in case of all recycled fractions including recycled sand);
- Reduced durability;
- Higher water absorption, water permeability and gas permeability;
- Lower freeze-thawing resistance.
- Increased resistance to abrasion: For a 100% amount of the recycled fraction was determined 30% lower LA abrasion los than in the case of the original concrete.

APPLICATION OF RECYCLE AGGREGATE

In general applications of recycle aggregate are as follows:

- Many types of general bulk fills;
- Bank protection;
- Base or fill for drainage structures;
- Road construction;
- Noise barriers and embankments;
- Construction of low rise buildings;
- Manufacture of paving blocks & tiles;
- Laying of flooring and approach lanes;
- In sewerage structures and sub-base course of pavement;
- Besides drainage layer in highways and retaining walls.

CASE STUDY

The use of high percentages of recycled aggregates in concrete would usually worsen the concrete properties. In this study, M65 concrete mixtures was prepared with water-to-binder W/B ratios of 0.45 and the recycled aggregate was used as 0%, 20%, 50% and 100% by weight replacements of natural aggregate.

A concrete mixture was prepared in the laboratory with a water-to-binder W/B ratio and a cement content of 0.45 and 400 kg / m3, respectively. The absolute volume method was adopted to design the mix proportions of the concrete mixtures as shown in Tables 3.

TABLE 3
PROPORTIONING OF THE CONCRETE MIXTURES

Notation	RCA %	Constituents kg/ m3				
		Water	Cement	Sand	Granite	RCAs
R0	0	180	400	708	1,108	0
R20	20	180	400	708	886	215
R50	50	180	400	708	554	538
R100	100	180	400	708	0	1,075

Source: Paper by Shi Cong Kou

For each concrete mixture, 100 mm cubes were casted to determine the compressive strength of concrete. All the specimens were cast in steel molds and compacted using a vibrating table. Three cubes were immediately used after demoulding to measure the 1 day compressive strengths. The rest of the specimens were cured in a water-curing tank at 27 ±1°C until the age of testing.

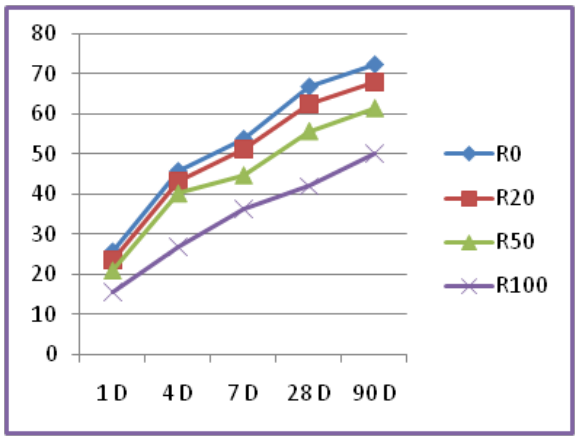
The compressive strength of concrete was determined using a Denison compression machine with a loading capacity of 3,000 KN. The loading rate applied in the compressive test was 200 KN/min. The compressive strengths were measured at the ages of 1, 4, 7, 28, and 90 days. The results obtained are as shown below in table 4 and same are represented in figure 1.

TABLE 4
COMPRESSIVE STRENGTH OF THE CONCRETE MIXTURES

Notation	RCAs %	Compressive strength MPa				
		1-day	4-day	7-day	28-day	90-day
R0	0	25.8	45.8	53.8	66.8	72.3
R20	20	23.6	43.2	51.2	62.4	68.0
R50	50	21.1	40.3	44.8	55.8	61.5
R100	100	15.5	26.8	36.2	42.0	50.2

Source: Paper by Shi Cong Kou

FIGURE 1 The effects of the incorporation of recycled aggregate on the 28-day compressive strength



CONCLUSION

The use of RCAs in civil construction works will reduce environmental pollution, and reduce the cost of production of natural resource as well as solving the problem of construction-waste management by putting into use this waste. Adding RCAs to concrete resulted in increased water demand, reduction in workability and reduced strength compared to the control sample. This results show reduction in strength of concrete with increase in percentage replacement of RCAs. Here, we can say that up to 20% RCAs utilized for economical and sustainable development of concrete. Uses of RCAs in concrete can save the construction-waste disposal costs and produce a 'greener' concrete for sustainable construction.

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