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ROLE OF RECYCLED COARSE AGGREGATE IN CONCRETE

L Satyanarayana[1], S Sudhakara Rao[2].

1 M.Tech Student, MVR College of Engineering & Technology, Kanchikacherla, India.*

2 Associate Professor, MVR College of Engineering & Technology, Kanchikacherla, India.*

ABSTRACT

Construction activities have increased phenomenally for the past two decades. With these construction activities going up, we are falling short of the construction materials, especially aggregates. So, finding an alternate resource is the need of our project. Recycled aggregate proves to be a good alternative here.

Since mid-90's the recycling, reuse and reduction of construction and demolition waste have received increasing attention. Use of recycled aggregate in concrete 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. This paper reports the basic properties of recycled fine aggregate and recycled coarse aggregate & also compares these properties with natural aggregates that have been concluded from various other research work. 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. In general, present status of recycled aggregate in India along with its future need and its successful utilization are discussed here.

INTRODUCTION

Research established that the global demand for construction aggregates was expected to exceed 26 billion tonnes by 2011. Leading this demand, are the single user: China (25%), EU (12%) and the USA (10%). However, because of industrialization and significant infrastructure and construction development, there were expectation of significant increase in use of aggregates in India (which is already one of the major national markets at 3%) beyond 2011. In India, about 14.5 MT of solid wastes are generated annually from construction industries, which include wasted sand, gravel, bitumen, bricks, and masonry, concrete. However, some quantity of such waste is being recycled and utilized in building materials and share of recycled materials varies from 25% in old buildings to as high as 75% in new. Hence the subject of concrete recycling is regarded as very important in the general attempt for sustainable development in our times. The recycling of Construction and Demolition Wastes has long been recognized to have the potential to conserve natural resources and to reduce energy used in production. In some countries it is a standard alternative for both construction and maintenance, particularly where there is a shortage of construction aggregate.

In a parallel manner, it is directly connected with

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- increase of demolition structures past out of performance time,
- demand for new structures and
- results—of destruction by natural phenomena (earthquakes, tsunami etc.).

Figure 1: Recycled Aggregate from C & D Waste

DETAIL STUDY OF RECYCLED COARSE AGGREGATE

DEFINITION

Construction & Demolition (C&D) wastes are normally composed of concrete rubble, bricks and tiles, sand and dust, timber, plastics, cardboard and paper, and metals. Concrete rubble usually constitutes the largest proportion of C&D waste. It has been shown that crushed concrete rubble, after separation from other C&D waste and sieved, can be used as a substitute for natural coarse aggregates in concrete or as a sub-base or a base layer in pavements. This type of recycled material is called recycled aggregate.

Advantages of recycling of construction materials:

- Used for construction of precast & cast in situ.
- Cost saving: - There are no detrimental effects on concrete & it is expected that the increase in the cost of cement could be offset by the lower cost of Recycled Concrete Aggregate (RCA).
- 20% cement replaced by fly ash is found to control alkali silica reaction (ASR).
- Save environment: - There is no excavation of natural resources & less transportation. Also less land is required.
- Save time: - There is no waiting for material availability.
- Less emission of carbon due to less crushing.

Disadvantages of recycling of construction material:

- Less quality (e.g. compressive strength reduces by 10-30%).
- Duration of procurement of materials may affect life cycle of project.
- Land, special equipment machineries are required (more cost).
- Very high water absorption (up to 6%).
- It has higher drying shrinkage & creep.

COMPARISION BETWEEN RECYCLED AND NATURAL COURSE AGGREGATE

NATURAL AGGREGATES	RECYCLED COARSE AGGREGATES
Aggregates are derived from a variety of source rocks and mined primarily by surface methods	Aggregates are derived from debris of road and building construction projects.
Mining requires environmental monitoring and reclamation. Costs for exploration, permitting, overburden removal, site preparation, and both ongoing and final site reclamation must be considered.	Recycling requires limited monitoring and reclamation. Costs for exploration, mining or stripping are not incurred, but costs for ongoing reclamation, site clean-up, and site and noise reduction may be incurred
Quality depends primarily upon the physical and chemical properties of the source deposit	Quality varies significantly due to large variation in type and impurities of debris sources.
Processing primarily consists of crushing, sizing and blending	Processing similar to natural aggregates, but increased wear of equipment may result because of variable size and angularity of feed and the presence of deleterious material.
Location dependent upon resource. Equipment selection depends upon numerous technical, economic and market factors. Transportation distances and costs among resources, processing facilities and market affect end use.	Location determined by feed sources and markets. Location, equipment selection and plan layout effect operational economics. Transportation distances and cost affect both feed supply and markets.
Mine and plant layout in part determines the efficiency of an operation.	Recycler must be able to adjust material feed and output to meet changing products and requirements.
Processing generally occurs at mine site, often outside city limits. Resource suitable for multiple products.	Processing often at centrally located site in urban area using mobile equipment. Product mix often limited
Mobile on site plans may be used for large projects; time required for takedown, transport and setup.	Mobile plan commonly relocates 4 to 20 times each year, affecting productivity, time required for take down, transport and setup
Products marketed locally or regionally, mostly in urban areas. Higher valued products may have large marketing area.	Products marketed locally in urban areas. Lower valued product mix may constrain markets.

VARIOUS EXPERIMENT ON AGGREGATES

- IMPACT VALUE TEST
- CRUSHING VALUE TEST

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MIX DESIGN OF CONCRETE

CALCULATION OF MIX DESIGN OF M25 CONCRETE

DESIGN STIPULATION

1) GRADE DESTINATION	M25
2) TYPE OF CEMENT	OPC (GRADE 43)
3) MAXIMUM NOMINAL SIZE OF AGGREGATE	20mm
4) DEGREE OF WORKABILITY	100 mm SLUMP TEST
5) DEGREE OF QUALITY CONTROL	GOOD
6) EXPOSURE CONDITIONS	MODERATE
7) METHOD OF CONCRETE PLACING	PUMPING
8) DEGREE OF SUPERVISION	GOOD

TEST DATA FOR MATERIALS

1) CEMENT USED	OPC (GRADE 43)
2)SPECIFIC GRAVITY OF CEMENT	2.7
3) SPECIFIC GRAVITY OF	
• COARSE AGGREGATE	2.7
• FINE AGGREGATE	2.6
4) WATER ABSORPTION	
• COARSE AGGREGATE	0.5%
• FINE AGGREGATE	1.0%
5) SURFACE MOISTURE	
• COARSE AGGREGATE	0.0%
• FINE AGGREGATE	0.0%

DESIGN PROCEDURE:

TARGET STRENGTH FOR MIX PROPORTIONING

$\mathbf{f_{ck'} = f_{ck} + 1.65 \times S}$

$f_{ck'}$= Target Average Compressive Strength

$f_{ck'}$ = Characteristic Compressive Strength @28 Days

From IS 10262: 2009 → Code for Mix Design → Table 1

S=4 for M25so fck'= 25+(1.65×4) = 31.6 N/mm^2

SELECTION OF WATER CEMENT RATIO

From table 5 of IS 456:2000, for moderate exposure conditions maximum w/c ratio=0.5
so we will adopt w/c ratio as 0.5

SELECTION OF WATER CONTENT

Table 2 of **IS 10262 :2009** maximum water content for 20mm size aggregate =186kg

for (slump 25mm-50mm)

So let us increase water requirement by 3% for every 25mm increase in slump

⇒So estimated water content for slump 100 mm

=186+(2×5.58) = 197 kg

CALCULATION OF CEMENT CONTENT

W/C ratio =0.5

cement content = (197/0.5)

=394 kg

According to **IS 456: 2000** Table 5, minimum cement content for moderate exposure condition = 300kg/m^3, so our value is okay. No modification required.

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

Sieve analysis for

coarse →confirming to Table 2 of **IS 383: 1970**

fine→confirming to grading zone 3 of Table 4 of **IS 383: 1970**

Now from Table 3 of **IS 10262: 2009** volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate for water cement ratio of 0.5 is

volume=0.64

In present case w/c ratio is 0.5 hence no correction is required

(note: - The rate of correction is ± 0.01 for every ± 0.5 change in w/c ratio)

For pump able concrete these values should be reduced by 10%

Volume of coarse aggregate = 0.64×0.9

=0.576 ~ 0.6

Volume of fine aggregate =1.0−0.6 = 0.4

MIX CALCULATION

Let us assume Volume of concrete = 1m^3

So, Volume of cement = (M/sp.gravity) × (1/1000)

= (394/2.7) × (1/1000)

=0.15 m^3

Volume of water = 0.197 m^3

volume of total aggregate in concrete = 1.0 −(0.15 +0.197) =0.653 m^3

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Mass of coarse aggregate = total aggregate × specific gravity (coarse)

× volume of coarse aggregate×1000

= 0.653×2.7×0.6×1000

= 1057.86 kg

Mass of fine aggregate = total aggregate ×specific gravity (fine)

× volume of fine aggregate×1000

= 0.653×2.6×0.4×1000

= 679.12 kg

The mix proportion then becomes

Cement	Fine aggregate	Coarse aggregate	Water
394 kg	679.12 kg	1057.86 kg	197 kg
1	1.7	2.68	0.5

CALCULATION AND RESULT

TEST ON AGGREGATE

1. IMPACT VALUE

IMPACT VALUE=B/A X 100%

A = WEIGHT OF AGGREGATE INITIALLY TAKEN

B = AGGREGATE PASSING THROUGH 2.36 mm SIEVE

C = AGGREGATE RETAINED ON 2.36 mm SIEVE

FOR NATURAL AGGREGATE

A= 339.0 gm

B= 54.0 gm

C=284.5 gm

IMPACT VALUE= (54/339) x 100 % = 16%

FOR RECYCLED AGGREGATE

A=300 gm

B = 57 gm

C = 242.5 gm

IMPACT VALUE= (57/300) x 100 % = 19%

RESULT:

IMPACT VALUE SHOULD BE LESS THAN OR EQUAL TO 30 % HENCE BOTH VALUES SATISFY OUR CONDITIONS

2.CRUSHING VALUE

CRUSHING VALUE=(B/A) ×100%

A= WEIGHT OF AGGREGATE INITIALLY TAKEN

B= AGGREGATE PASSING THROUGH 2.36 mm SIEVE

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FOR NATURAL AGGREGATE

A= 2677 gm

B= 540 gm

CRUSHING VALUE = (540/2677) x 100 % = 20.17%

FOR RECYCLED AGGREGATE

A = 2329.5 gm

B = 685 gm

CRUSHING VALUE = (685/2329.5) x 100 % = 29.5%

RESULT:

CRUSHING VALUE SHOULD BE LESS THAN OR EQUAL TO 30 % HENCE BOTH VALUES SATISFY OUR CONDITIONS

DISCUSSION AND CONCLUSION:

1.IMPACT VALUE

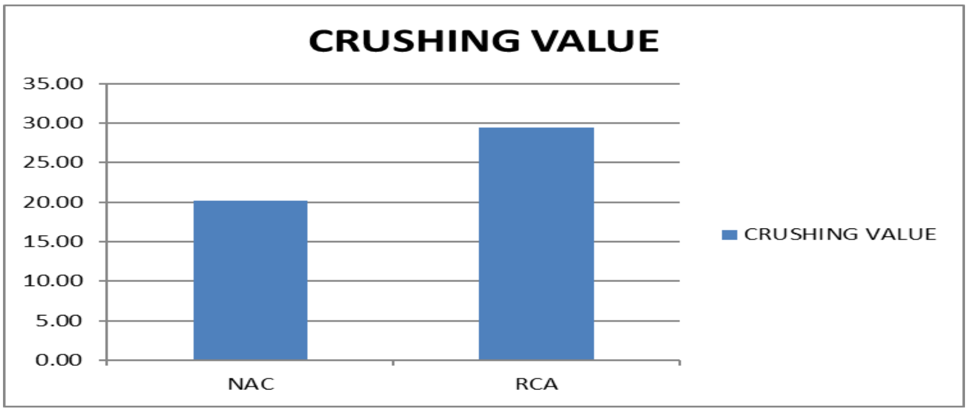
DETAILS	A	B	C	IMPACT VALUE
NAC	339	54	284.5	15.93
RCA	300	57	242.5	19

Table 1: Impact Value

2. AGGREGATE CRUSHING TEST

DETAILS	A	B	CRUSHING VALUE
NAC	2677	540	20.17
RCA	2329.5	685	29.41

Table 2: Crushing Value



Graph 1:Crushing Value Difference in NCA & RCA

TEST ON CONCRETE

1.COMPRESSIVE STRENGTH TEST

CALCULATION:

AFTER 7 DAYS

σ = P/A

σ =COMPRESSIVE STRENGTH OF CUBE N/mm^2

P = FAILURE LOAD KN

A = AREA OF CUBE mm^2

FOR SAMPLE NAC

σ = (850.5×1000) ÷ (150×150) =37.80 N/mm^2

FOR SAMPLE RCA$_{25}$

σ = (834.5×1000) ÷ (150×150) =37.08 N/mm^2

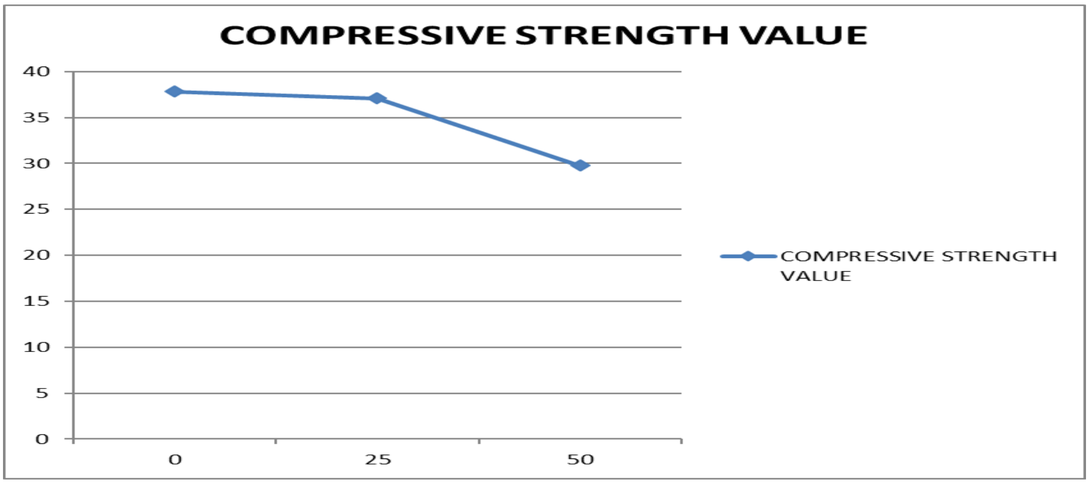
FOR SAMPLE RCA$_{50}$

σ = (670.2×1000) ÷ (150×150) =29.78 N/mm^2

RESULT:

% OF RECYCLED AGGREGATE	WEIGHT	PEAK LOAD	7 DAYS CUBE STRENGTH	AREA
	KG	N	MPa	mm^2
0	8600	850.5	37.8	225
25	8300	834.5	37.08	225
50	8330	670.2	29.78	225

Table 3: Peak Stress Values in Compressive Testing Machine



Graph 2: Compressive Strength Behaviour Change Due to RCA

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FLEXURAL STRENGTH TEST

CALCULATION OF FLEXURAL STRENGTH OF BEAM

AFTER 7 DAYS

$\sigma = (3\times F\times L)/(4bd^2)$

σ = FLEXURAL STRENGTH OF BEAM IN N/mm^2

F = FAILURE LOAD IN KN

L = LENGTH OF THE SUPPORT IN mm

b = WIDTH OF BEAM mm

d = DEPTH OF THE BEAM mm

FOR NAC

$\sigma = (3\times15\times1000\times400) / (4\times100\times100^2) = 4.5$ N/mm^2

FOR RCA$_{25}$

$\sigma = (3\times16\times1000\times400) / (4\times100\times100^2) = 4.8$ N/mm^2

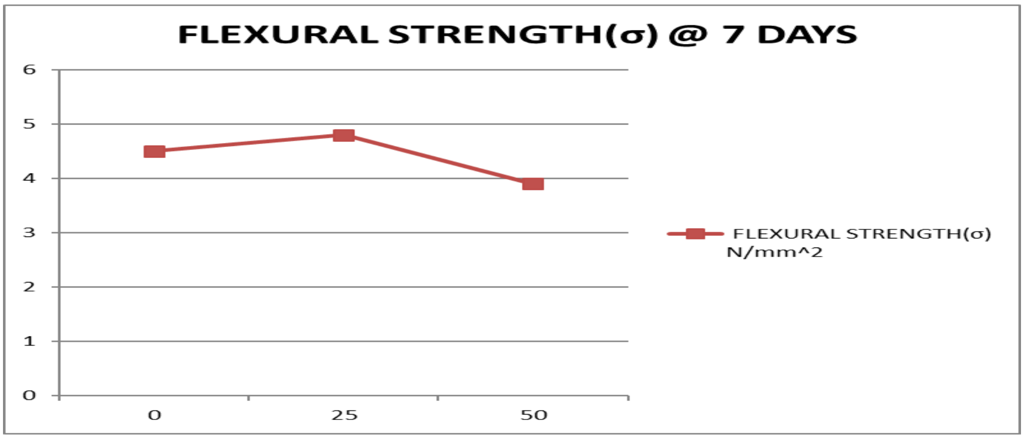
FOR RCA$_{50}$

$\sigma = (3\times13\times1000\times400) / (4\times100\times100^2) = 3.9$ N/mm^2

RESULT:

% OF RCA IN CONCRETE	FAILURE LOAD	LENGTH OF THE SUPPORT	WIDTH OF BEAM	DEPTH OF BEAM	FLEXURAL STRENGTH(σ)
	KN	mm	mm	mm	N/mm^2
0	15	400	100	100	4.5
25	16	400	100	100	4.8
50	13	400	100	100	3.9

Table 4: Flexural Strength in N/mm^2



Graph 3: Flexural Strength Behaviour Change Due to RCA

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SPLIT TENSILE STRENGTH TEST

CALCULATION OF SPLIT TENSILE STRENGTH OF CYLINDER

AFTER 7 DAYS

$\mathbf{T_{sp} = (2P) / (\pi DL)}$

T_{sp} = SPLIT TENSILE STRENGTH OF STRENGTH IN N/mm^2

P = FAILURE LOAD IN KN

L = LENGTH OF THE SPECIMEN IN mm =600mm

D = DIAMETER OF THE SPECIMEN mm =150 mm

FOR NAC

$T_{sp} = (2 \times 180 \times 1000) / (\pi \times 150 \times 600) \quad = 1.27\ N/mm^2$

FOR RAC_{25}

$T_{sp} = (2 \times 210 \times 1000) / (\pi \times 150 \times 600) \quad = 1.49\ N/mm^2$

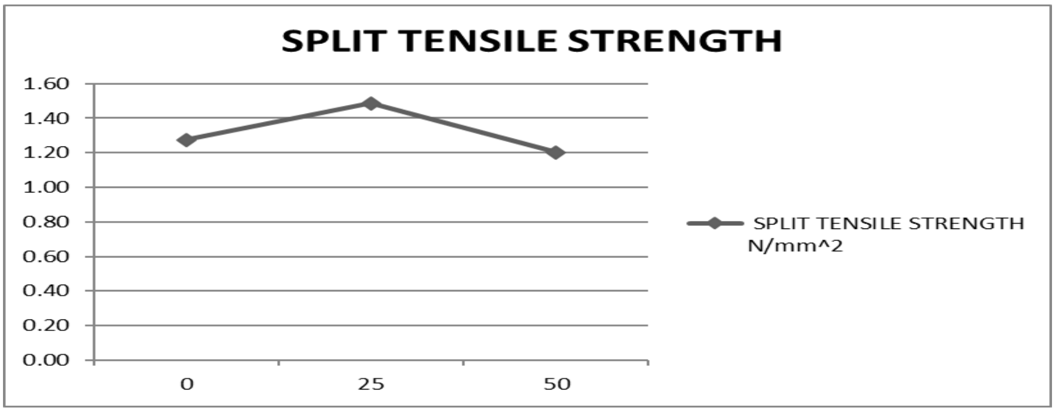
FOR RAC_{50}

$T_{sp} = (2 \times 170 \times 1000) / (\pi \times 150 \times 600) \quad = 1.2\ N/mm^2$

RESULT:

% OF RCA IN CONCRETE	FAILURE LOAD	LENGTH OF THE CYLINDER	DIAMETER OF BEAM	SPLIT TENSILE STRENGTH
	KN	mm	mm	N/mm^2
0	180	600	150	1.27
25	210	600	150	1.49
50	170	600	150	1.20

Table 5: Split Tensile Strength



Graph 4: Variation of Split Tensile Strength

CONCLUSION FROM ALL THE TEST RESULT:

Recycled aggregate can be used in construction of buildings and pavements etc. But there is a certain % beyond which the strength of concrete decreases.

In our project the aggregate was holding good till 25% Replacement were made beyond that the strength starts to decrease.

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