Performance of Recycled Aggregate Concrete for M_{25} Grade Concrete

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ABSTRACT---Recycled aggregates (RCA) are the aggregates which are made up of crushed, inorganic particles that are obtained from the construction demolition debris. Now a day's protection of environment is the ultimate challenge to the society. So the usage of RCA's is the best alternative for the aggregates which are obtained naturally in the construction activity. The scope of using these recycled concrete aggregates is increasing day by day. It reduces the cost effectively as we are using waste concrete as recycled aggregates. The main focus of this paper is to use find the strength qualities of recycled aggregates so as to use it as an alternative for the natural aggregates in high strength concrete for various construction activities. Comparison of workability, compressive strength, tensile strength, elastic modulus and flexural strength of recycled aggregate concrete is made with natural aggregate concrete. Here M25 grade concrete is taken and the natural aggregates were replaced with recycled aggregates in various percentages of 0%, 25%, 50%, 75% and 100%. The mix design for these replacement ratios are done by using code of IS 10262-2009. In order to determine the properties which were mentioned above a total of 60 cubes, 10 beams and 40 cylinders were casted. The compressive strength and tensile strength of RCA concrete have been determined for 7 days and 28 days where as the modulus of elasticity and the flexural strength of RCA concrete are determined after curing for the period of 28 days. The tests done on RCA concrete are compared with concrete which is obtained by natural aggregates As per IS codification the parameters which were determined are reducing moderately as the amount of aggregates which are recycled is being raised.

Key words: Elastic Modulus, Tensile strength, compression strength, Recycled aggregates.

I. INTRODUCTION

Concrete, composite construction material made up of cement, sand (fine aggregate), gravel (coarse aggregate) and water. For over a century the concrete has been using as a leading construction material. It has been reckoned that the concrete production is approximately 2.5 tones i.e.; 1 m^3 per capita. After 2025 the overall world wide usage of naturally obtained aggregates will be around 10-13 billion tones.

At the same time the construction and demolition wastes are increasing significantly worldwide every year. More usage of aggregates which are obtained naturally and the increased amounts of construction and demolished wastes causing severe environmental problems and diminishing the people and the ecologist's desire for a society which is pollution free.

Fig.1. Recycled aggregates

Formerly, almost all the materials which are being utilized in the construction activity are obtained naturally and all the wastes which are obtained from the demolished buildings were disposed in large unauthorized open places. Over two decades the usage of RCA's which are acquired from demolition wastes of construction activity is having a greater importance as the availability of natural aggregates is reducing drastically year by year and the damage caused by the disposal waste is increasing. Due to advance techniques which are being used in the crushing industry and advancement in the equipment & recycling process, it became very easy to pulverise demolish waste larger boulders in to tiny pieces in order to produce recycled aggregates at reasonable cost.

Now a days the quality of recycled aggregates has been drastically increased because of good demolition practices and advancement in the crushing machinery. As a result of this the recycled aggregates of best quality are available at the rates equal to that of natural aggregates and giving a tough completion to the natural aggregates. Though these aggregates are available at reasonable rates, the usage is limited because of using low strength cement and poor quality aggregates and also the limitations of the standards. So by using latest technologies in concrete technology and material production the negative impact on the recycled aggregates have to be removed and usage of RCA's has to be increased in construction activity.

a. Need for the PresentWork:

Concrete is widely utilized material in the construction activity because of its easy availability of the cement, sand, gravel and water and also handled easily with low service maintenance. The ingredients of concrete are available at economical cost and are durable, offers good fire resistance and are strong in compression. Due to these factors these materials are used drastically which caused a scarcity and polluting the environment. So in order to overcome the scarcity of the aggregates and save the environment the use of RCA's in concrete production is taken in to deliberation.

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On the contrary, the demolition waste from the construction activity is rising day by day. In order to utilize these demolition waste materials their strength characteristics are to be analyzed especially for using them concrete of higher strength applications. With the help of these materials the RCA concrete is produced successfully. Due to this the usage of aggregates which are obtained by recycling for various construction activities will be increased. In order to compete with normal aggregate concrete, the strength and performance of RCA concrete has to be improved.

Fig.2. Recycled aggregate crusher

b. Applications of RCA's:

- RCA's are utilized in the concrete mix production up to M_{35} grade and also can be utilized in concrete of higher strength by analyzing the various parameters.
- In the road laying activity RCA is utilized as sub base materials
- RCA can be used for the manufacture of concrete blocks for paving operation.
- Recycled aggregates can be utilized for replacement of rock fills in sea walls
- RCA can be used for infill to gabion walls.

Recycled aggregates are most commonly used as land filling material. Based on the priorities and needs of different countries the RCA can be used for different works.

II. LITERATURE REVIEW

Tavaakoli (1994), According to Tavaakoli strength of the normal concrete, the ratio of aggregates in the normal concrete to RCA and the ratio of fine to the coarser aggregates in the normal concrete are the factors which influence the characteristics of strength of RCA's. He also indicated that the characteristics of strength of RCA's will be governed by Los Angles abrasion loss and water absorption.

Gumaster and Ramamurthy (1997), has given a report that the compressive strength of RCA concrete was considerably less & the change totally depends on the parent concrete strength which is made up of the acquired aggregate.

Leelawat and Limbachiya (2000), their conclusions are aggregates of the concrete made up of RCA are having the water absorption property which is almost double to that of the normal aggregates and their relative density is decreased to about 6 to 8% than natural aggregates. They also concluded that there is no adverse effect to the compressive strength up to 30 % replacement with recycled aggregates. It is also referred that the recycled aggregates can be used in the concrete mixes of higher strength also.

Mandal (2002), expressed that the RCA concrete strength can be improved by altering the W/C ratio while mixing the concrete. With the help of results obtained he gave a conclusion that specimens made up of RCA concrete are having almost same durability and engineering performance as that of the specimens made up of normal aggregates concrete for 28 days design strength.

Taylor, Brown &Sagoe (2002), gave a conclusion that distinction between the characteristic properties of RCA concrete of fresh state and RCA concrete in hardened state is comparatively small. The compressive strength and tensile strength of the RCA concrete is almost same as that of concrete made up of natural aggregates when replacement of normal aggregate with RCA is up to 5 %.

III. METHODOLOGY

❖ *Materials*

Cement: Joseph Aspidin has invented the cement which is the most commonly used binding material in 1824. The manufacturing of cement is done with various calcareous materials like lime stone and clay and various argillaceous materials like clay and shale.

Coarse Aggregate: Aggregates are classified as coarse and fine aggregates. If the aggregates size is larger than 4.75 mm then it is called as coarser aggregate. The various coarser aggregates used in construction activity are stone, ballast and gravel etc.

Fine Aggregate: As per code IS 383, if the size of the aggregates is less than 4.75 mm then it is called as fine aggregate. i.e. the aggregates going through 4.75 mm size sieve and holding on 75 micron size sieve then that type of aggregates are considered as finer aggregates. The various finer aggregates utilized in various construction activities are Sand, crushed stone ash, surkhi, cinder etc.

Water: At the time of construction activity the water is given less importance by the people. A vital role is played by the water in the construction activity. There should be no compromises in the quality of water used in construction activity. Only good quality of water should be used which is having the good pH value.

❖ *Mix Design*

Bureau of Indian Standards (B.I.S Method) is used for designing the concrete mix

According to codification IS 10262:2009

Stipulation of proportioning

- Concrete Grade =M-25
- Cement Grade = OPC 53grade
- Maximum size of aggregates =20 mm
- w/c ratio = 0.47(mild-M25)

The mean target strength for the concrete mix is given as

[f' ck = f ck + 1.65*s]

- Mean target strength of concrete = 25+1.65x4=31.6N/mm^2
- At 28 days Characteristic compressive strength of concrete =25 N/mm^2

Water content selection

- Max. water content = 186lts (at 50mmslump)
- Corrected water content = 186+(186 x6/100) W=197lts.

Cement content Calculation

- Water cement ratio =0.47
- Cement quantity=197lts/0.47 C=419kg/m^3

Coarse & fineaggregate calculation

According to the code Indian Standards 10262:2009, table 3 zone I and coarse (20mm) at w/c ratio 0.5

Volume of coarse aggregates= 0.6

Volume correction = 0.01/0.05 x0.03=0.006

= 0.6+0.006

Corrected volume of Coarse aggregate = 0.606m^3

Corrected volume of fineaggregate

= 1-0.606=0.394m^3

Material Calculations:

Volume of concrete = 1m^3

- Absolute volume of cement

= 19/3.13 x1/1000

= 0.133m^3

- Volume of water = 197/1000 = 0.197 m^3
- Materials Volume excluding aggregates

= 0.113+0.197 = 0.33m^3

- Volume of total aggregates

= 1-0.33 = 0.67m^3

- Coarse aggregate Weight

= 0.67* 0.606 * 2.77 * 1000

= 1125 kg per m^3

- Fine aggregate Weight

= 0.67*0.394*2.6 *1000

= 686.3 kg per m^3

Total Density = cement + fine aggregate + coarse aggregate + water = 2427 kg/m^3

Table-I: Material quantities in various proportions for 1 m^3

	% of Replacement				
	0	**25**	**50**	**75**	**100**
Cement	419	419	419	419	419
Fine Aggregate	686	686	686	686	686
Coarse Aggregate	1125	844	562.3	281	0
Recycled aggregate	0	49	497	746	944.75
Water	197	197+9	197+18	197+26	197+35

MIX PROPORTION

Cement: Fine aggregate: Coarse aggregate = 1:1.63:2.68

IV. RESULTS AND ANALYSIS

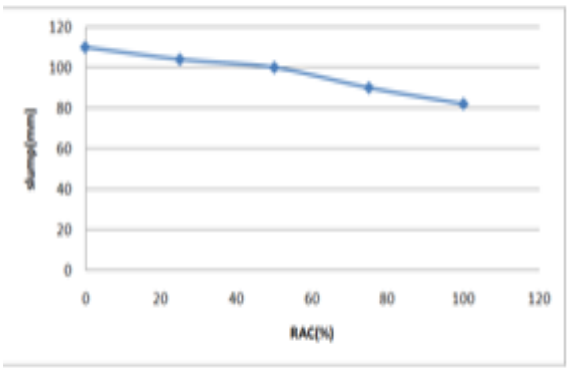
❖ *SLUMP TEST:*

In order to measure workability the most commonly used test is Slump test. This test can be done in the laboratory or at the place of the work. If the concrete is very wet or very dry then this method is not suitable.

Fig.3: Slump test

Table-II: Slump test for various proportions of recycled aggregate concrete

	RAC 0%	RAC 25%	RAC 50%	RAC 75%	RAC 100%
Slump @ 0Min	110mm	104mm	100mm	90mm	82mm
Slump @ 30Min	98mm	98mm	94mm	88mm	75mm



Graph-1: Graph showing variation of slump values for different proportions of RAC

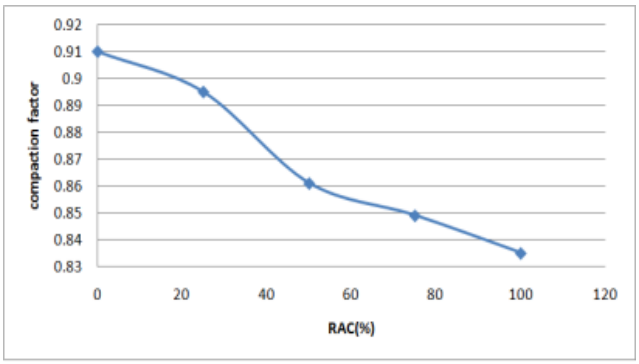
❖ *COMPACTING FACTOR TEST:*

The most commonly used method to test the workability of fresh concrete in laboratory is compaction factor test. This test gives more accurate results when compared to the slump test. It is best suitable for concrete mixes having very low workability

Fig.4: Compaction factor test apparatus

Table-III: Compaction factor test for various proportions of recycled aggregate concrete

RAC	0%	25%	50%	75%	100%
Compaction factor	0.91	0.895	0.861	0.849	0.835



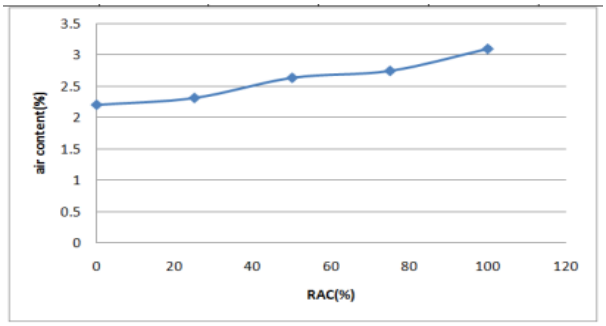
Graph-2: Graph showing variation of Compaction factor values for different proportions of RAC

❖ *AIR CONTENT:*

Fig.5: Type B pressure meter

Table-IV: Air content test for various proportions of recycled aggregate concrete

RAC	0%	25%	50%	75%	100%
Air Content (%)	2.2	2.31	2.63	2.74	3.09



Graph-3: Graph showing variation of Air content values for different proportions of RAC

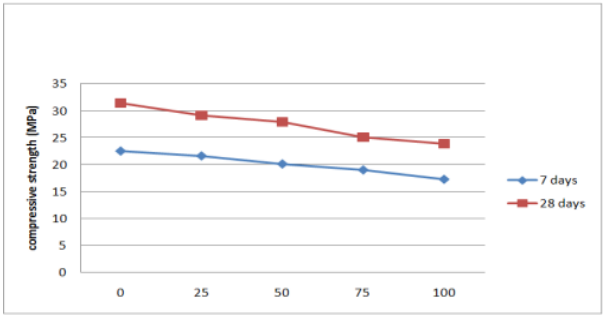
❖ *COMPRESSIVE STRENGTH TEST:*

The test which is used commonly for determining the strength of concrete which is in hardened state is compressive strength. The higher importance is given to this test because the characteristics of concrete mainly depend on its strength of compression.

Fig.6: Compression testing Machine

Table-V: Compressive strength values for 7 and 28 days for various proportions of recycled aggregate concrete

RAC	Density(kN/m3)	Compressive strength(N/mm2)	
		7 Days	28 Days
0%	2374	22.6	31.46
25%	2352	21.7	29.2
50%	2345	20.2	27.98
75%	2338	19.09	25.15
100%	2315	17.34	23.9



Graph-4: Compressive strength values for 7 and 28 days for various proportions of recycled aggregate concrete

❖ *SPLIT TENSILE TEST:*

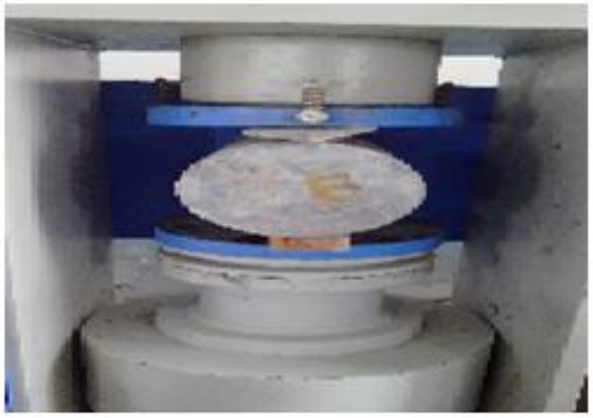
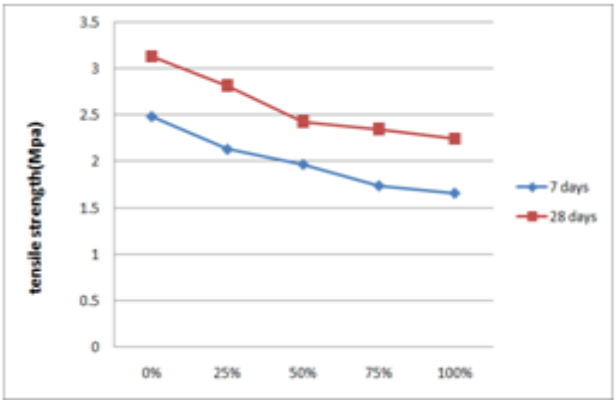


Fig.6: Split Tensile Test

Table-VI: Split Tensile Strength values for 7 and 28 days for various proportions of recycled aggregate concrete

RAC	Density (28days)KN/ m³	Tensile strength (2P/πDL) (MPa)	
		7 Days	28Days
0%	22.54	2.48	3.13
25%	22.40	2.13	2.815
50%	22.23	1.969	2.425
75%	22.10	1.74	2.345
100%	22.00	1.66	2.24



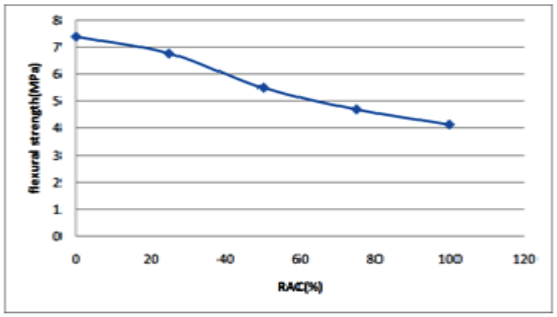
Graph-5: Split Tensile strength values for 7 and 28 days for various proportions of recycled aggregate concrete

❖ *FLEXURAL STRENGTH:*

Fig.7: Flexure Strength Test

Table-VII: Flexural Strength values for various proportions of recycled aggregate concrete

RAC	Density (KN/ m³)	Flexural strength (Mpa)
0%	23.74	7.38
25%	23.52	6.76
50%	23.45	5.5
75%	23.38	4.7
100%	23.15	4.14

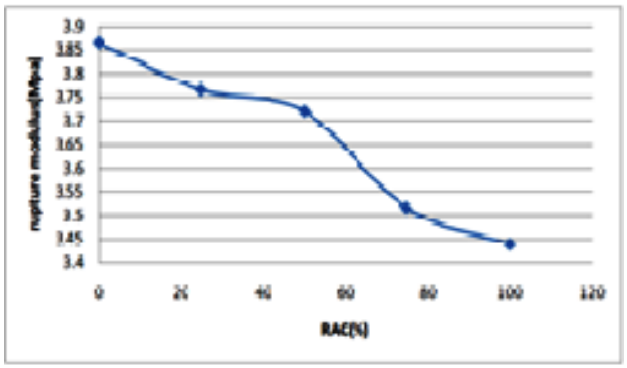


Graph-6: Flexural strength values for various proportions of recycled aggregate concrete

❖ *RUPTURE MODULUS:*

Table-VIII: Rupture Modulus values for various proportions of recycled aggregate concrete

RAC	Density (KN/ m³)	Compressive Strength (Mpa)	Rupture modulus (Mpa)
0%	22.54	30.5	3.864
25%	22.40	29	3.765
50%	22.23	28.3	3.72
75%	22.10	25.3	3.515
100%	22.00	24.2	3.44

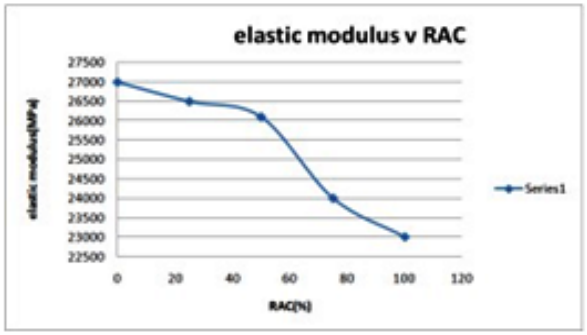


Graph-7: Rupture Modulus values for various proportions of recycled aggregate concrete

❖ *ELASTIC MODULUS :*

Table-IX: Elastic Modulus values for various proportions of recycled aggregate concrete

RAC	Compressive strength at28days (MPa)	Elastic modulus (5000√fck) (GPa)
0%	31.46	27000
25%	29.2	26500
50%	27.98	26100
75%	25.13	24000
100%	23.9	23000



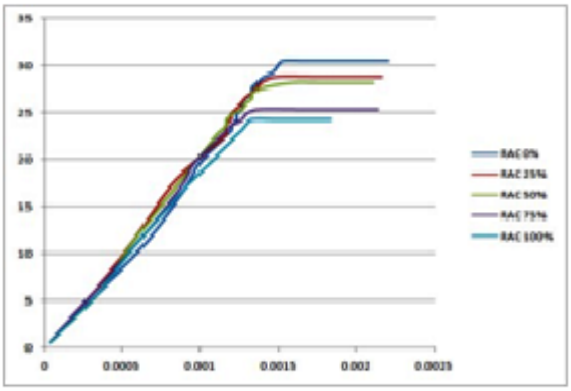
Graph-8: Elastic Modulus variation for various proportions of recycled aggregate concrete

❖ *DETERMINATION OF YOUNG'S MODULUS BY STRESS-STRAIN PARAMETERS*

Fig.8: Stress strain variation calculation

Table-X: Young's Modulus values for various proportions of recycled aggregate concrete

RAC	Load (T)	Area (mm^2)	Stress (Mpa)	Change in length	Length	Strain	Young's modulus (Mpa)
0%	54	1767.5	30.55	0.46	300	0.00152	0.2×10^5
25%	51	1767.5	29	0.45	300	0.00146	0.198×10^5
50%	50	1767.5	28.3	0.44	300	0.00145	0.194×10^5
75%	45	1767.5	25.3	0.41	300	0.00136	0.185×10^5
100%	43	1767.5	24.2	0.40	300	0.00134	0.18×10^5



Graph-9: Young's Modulus variation for various proportions of recycled aggregate concrete

V. CONCLUSIONS

As the population is increasing in the world, the material waste is also increasing drastically. So the research on the recycling of the waste materials is given a great importance now a days. As the recycled aggregates are cheaper and easily available when compared to the normal aggregates so many of the investigations are done on it.

Mining process is required for obtaining the normal aggregates, but for recycled aggregates this process can be avoided. The results of this paper give the strength qualities of RCA's for using them effectively in structural concrete which is having higher strength.

From test results obtained it can be deduced that the concrete made by the RCA workability has been decreasing with raise in the % of RCA's. The RCA concrete air content is increased so indirectly there will be decrease in the concrete bulk density. The parameters like concrete compressive strength, split tensile strength of concrete and flexural strength of concrete are reducing with raise in the % of recycled aggregates.

By observing the test results it is concluded that the aggregates which are obtained naturally can be replaced by recycled aggregate about fifty percentage is being recommended since it attains the similar strength compared to normal concrete .Further replacement above 50% can be done by introducing some admixtures to maintain the workability.

VI. RECOMMENDATIONS FOR FURTHER STUDIES

It is recommended that more number of tests and studies have to be done on the recycled aggregates to get more strength qualities of aggregates which are recycled more accurately for using it in concrete of higher strength

The following are the few recommendations which are made for future studies:

1. By reducing the w/c ratio the concrete strength can be enhanced but the workability is reduced. So in order to maintain workability additives such as super plasticizers and fume obtained from silica can be added.

2. More number of laboratory tests and investigations are to be done on strength characteristics of RCA. Various mechanical properties like creep, abrasion and durability are recommended to be done on recycled aggregate concrete. Testing to be conducted on various building components like beams, building slabs and structural walls etc.

3. Increased number of trails has to be done for different percentages of replacement of recycled aggregates for different sizes of aggregates like 10mm, 16mm etc. to get more accurate results and higher strength characteristics in the RCA concrete.

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