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"RECYCLED COARSE AGGREGATES"

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Abstract— The amount of construction waste has been dramatically increased in the last decade, and social and environmental concerns on the recycling of the waste have consequently been increased. Waste concrete is particularly crucial among the construction wastes. Recent technology has also improved the recycling process. In this rapid industrialized world, recycling construction material plays an important role to preserve the natural resources. This study aims to evaluate physical properties of concrete using recycled coarse aggregate. In this research concrete waste is from demolished structure (Near Kamla Nehru Park, Bhandarkar Rd, Pune) has been collected and coarse aggregate of different % is used for preparing fresh concrete. The amount of recycled coarse aggregate used in this research is approximately 125 kg. Many researchers state that recycled aggregates are only suitable for non-structural concrete application. This research, however, shows that the recycled aggregates that are obtained from concrete specimen make good quality concrete. The compressive strength of recycled coarse aggregate (RCA) is found to be higher than the compressive strength of normal concrete when used upto a certain %. Recycled aggregate concrete is in close proximity to normal concrete in terms of split tensile strength. The slump of recycled aggregate concrete is more than the normal concrete. At the end it can be said that the RCA upto 50 % can be used for optaining good quality concrete.

Keywords- *recycle, construction material, coarse aggregate, demolished structure, compressive strength, split tensile strength.*

I. INTRODUCTION

Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, low and high-rise buildings, defense installations, environment protection and local/domestic developments. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixture(s). Among these, aggregates, i.e. inert granular materials such as sand, crushed stone or gravel form the major part. Traditionally aggregates have been readily available at economic price. However, in recent years the wisdom of our continued wholesale extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection. In light of this, the availability of natural resources to future generations has also been realized. Given this background, the concept of sustainable development put forward almost a decade ago, at the 1992 Earth Summit in Rio de Janeiro, and it has now become a guiding principle for the construction industry worldwide.

In fact many governments throughout the world have now introduced various measures aimed at reducing the use of primary aggregates and increasing reuse and recycling, where it is technically, economically, or environmentally acceptable. For example, the UK government has introduced a number of policies to encourage wider use of secondary and recycled coarse aggregate (RCA- defined as minimum of 95% crushed concrete) as an alternative to naturally occurring primary aggregates. These include landfill and future extraction taxes to improve economic viability, support to relevant research and development work.

Need to use RCA

Waste arising from Construction and Demolition constitutes one of the largest waste streams within the EU, Asian and many other countries. For example, it is estimated that core waste (described as those types of materials which are obtained from demolished building or civil engineering infrastructure) amounts to around 180 million tonnes per year or 480kg/person/yr in the EU. This ranges from over 700 kg/person/yr in Germany and the Netherlands to under 200 in Sweden, Greece and Ireland. The estimates for the UK are 30million tonnes/yr and just over 500 kg/person/yr respectively, putting the UK in second place behind Germany. At the same time, the results of a recent study undertaken by the CSIR Building and Construction Technology has revealed that nearly a million tonne of C & D waste ends up in landfills in South Africa. This is in addition to large quantities that are dumped illegally. Thus, construction demolition waste has become a global concern that requires sustainable solution.
It is now widely accepted that there is a significant potential for reclaiming and recycling demolished debris for use in value added applications to maximize economic and environmental benefits. As a direct

result of this, recycling industries in many part of the world, including South Africa, at present converts low-value waste into secondary construction materials such as a variety of aggregate grades, road materials and aggregate fines. Often these materials are used in as road construction, backfill for retaining walls, low-grade concrete production, drainage and brickwork and block work for low-cost housing. While accepting the need to promote the use of RCA in wider applications, it must be remembered that the aggregate for concrete applications must meet the requirements set in relevant specifications for its particular use. The gap between these interests has to be reduced in steps that are manageable and the use of RCA in structural concrete has to be promoted gradually. Similarly considerable attention is required to the control of waste processing and subsequent sorting, crushing, separating and grading the aggregate for use of the concrete construction industry. In some developed countries C & D waste is now regularly recycled and reused, albeit mainly as fill, drainage and sub-base materials, and there is considerable scope for increasing this market and the use of these materials. In addition, there is an urgent need for legislative or regulatory measures to implement sustainable C & D waste management strategy and encourage recycling for use in value added applications.

II. EXPERIMENTAL WORK

1 Introductory Remark:

The main aim of this research project is to utilize 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 include natural coarse aggregate, natural fine aggregate and RCA. Natural coarse aggregate used is microtonalite with maximum size of 25 mm. Natural fine aggregate used is river sand and RCA used from demolished concrete waste from which physical test such as specific gravity, absorption and sieve analysis are carried out. Then concrete cube and cylinders prepared for 0%, 25%, 50%, 75%, 100% and the same has been tested for 7 and 28 days for determination of compressive strength and tensile splitting test. The results at each testing age are reported as an average. The engineering properties of the RCA were also compared to those of the reference concrete.

2.2 Mix Design :

The mix design is done according to the IS design method and numerous trial mixes were conducted to obtain the optimum mix. Once the optimum mix is determined, it is used to produce concrete with 0%, 25%, 50%, 75% AND 100% replacement of RCA. The concrete is prepared to find out the compressive strength and the tensile splitting strength. The constituents of this optimum mix proportion are shown in the Table below.

Table 1 Mix Proportions

Cement Quantity (kg/m^3)	Sand (kg/m^3)	Gravel (kg/m^3)	Mix Proportion By Weight (C : S : G)	W/C ratioo
400	660	1168	1:1.65:2.92	0.5

The material required for this experiment are 100 kg cement, 150 kg sand and 125 kg of each natural aggregate and RCA.

2.3 Collection of Materials (Fine aggregate and Coarse aggregate):

The natural fine aggregate used for producing concrete is river sand of zone II type. The natural coarse aggregate used is microtonalite. The maximum size of this gravel is 25 mm. The cement used is OPC 43 grade Vikram (Grasim). Recycled aggregate used in this research is crushed concrete, i.e. RCA obtained from a site near K.N.P, Bhandarkar Rd Pune.

Figure 1 Coarse aggregate segregated from concrete waste

2.3.1 Physical properties of NA and RCA:

To compare the physical properties of RCA with virgin aggregates various test has been done on and following table shows the comparison between natural coarse aggregate and RCA.

Table 2 Physical properties of Natural and Recycled coarse aggregate

Sr. No.	Physical property	NA	RCA
1	Water absorption (%)	1.56	6.4
2	Specific gravity	2.63	2.3
3	Bulk Density (kg/m^3)	1469.8	1325.93

2.4 Treatment process for RCA :

To improve the quality of RCA some treatment process in terms of washing and heating is required which is given in detail.

2.4.1 Washing :

The aggregates collected by sieve analysis are washed by pressure washing. This is done so as to remove the mortar adhered to the aggregates. The pressure at which water is applied is 500 psi for about 15 to 20 mins. Washing process cleanes the aggregates to a considerable extent. The RCA were then kept for sun drying for about 30 mins. The figure no 2 below shows the washing process for coarse aggregates by a pressure system.

Figure 2 Washing of RCA

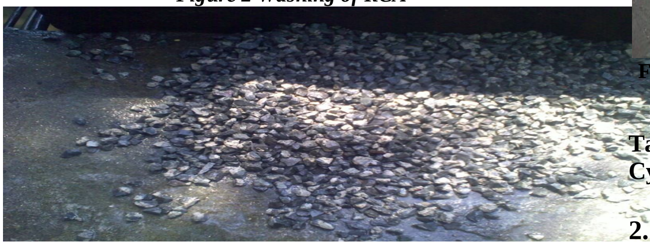

Figure 3 Drying of RCA

2.4.2 Heating :

The RCA were then heated in an oven at temperature of around 150 º C for about an hour. The RCA were kept in trays and heated .The end result turned out to be great with more clean RCA than before. The figure below shows the RCA in trays before the start of the heating process.

Figure 4 Heating of RCA

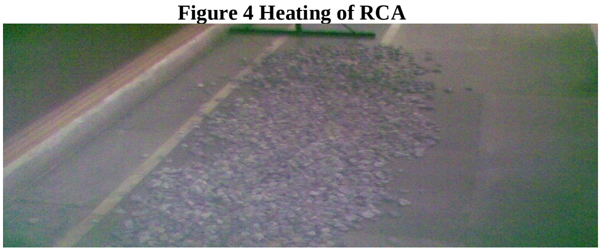

Figure 5 Cooling of RCA

2.5 Casting process for cube and cylinder:

2.5.1 Batching :

After cleaning the aggregates, batching process was started for 7 and 28 days cube, 28 days cylinder. The different percentage of mixtures used as 0%, 25%, 50%, 75% and 100% replacement of RCA. For each proportion three specimen (cube + cylinder) has been tested for compressive strength and tensile splitting strength. The proportions used for cube and cylinder is given in the table below. The table shows batching process of 5 different % used in the process.

Figure 6 Batching of Cement Sand and Aggregates before the mixing and filling process

Table 3 Proportions of materials in each Cube and Cylinder

2.5.2 Slump test:

The slump is taken for each mixing of concrete with 0%, 25%, 50%, 75% and 100% replacement of RCA. The results show that slump of concrete made with natural aggregates is higher while the concrete with 100% replacement of RCA has less slump. The low slump in RCA is caused by the high absorption of RCA which absorbs water during the mixing process.

Table 4 Slump for each proportions

Sample	0%	25%	50%	75%	100%
7 days cube slump(cm)	25	28	28	28	29
28 days cube slump(cm)	25	28	28	28	29
28 days cylinder slump(cm)	26	27	27	28	29

It was observed that the slump of the sample

Sample	% Replacement	Cement (kg)	Sand (kg)	Water (litre)	NA (kg)	RCA (kg)
Cube	0	1.6	2.6	0.5	4.5	0
	25				3.375	1.125
	50				2.25	2.25
	75				1.125	3.375
	100				0	4.5
Cylinder	0	2.6	4.2	1.3	7.5	0
	25					
	50				3.75	3.75
	75					
	100				0	7.5

containing 0% RCA was the least while that containing 100% RCA was the most. The slump was 25cm for natural aggregate (0% RCA) was incorporated while it was 29cm when 100% RCA was used.

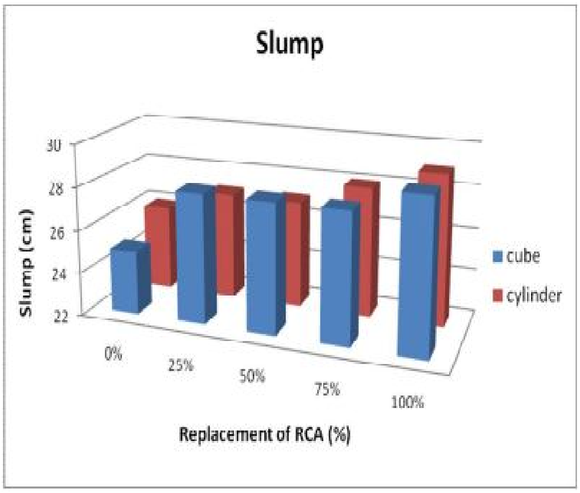

Figure 7 Slump of various proportions of mixes

2.5.3 Mixing and Filling of Concrete in Moulds :

After the batching process is done, water was added accordingly as per requirement and mixing was carried out by shovel by turning it over and over until uniformity in colour was achieved. Care was taken so as to avoid excess pouring of water. The homogeneous mixture so formed was filled in the moulds in 3 layers by tamping each layer 25 times so that voids get filled within the moulds and concrete is compacted. The figure nos 8 and 9 below show the manual compaction methods in cubes as well as in cylinders.

Table 5 No of specimens prepared

Sample	Size of mould	Specimens prepared
7 days cube	150X150X150	15
28 days cube	150X150X150	15
28 days cylinder	150X300	15

Figure 8 Filling of Concrete Mix in Cubes

Figure 9 Filling of Concrete Mix in Cylinders

2.5.4 Compaction :

After preparing mould with concrete the same is taken to the vibrating table for proper compaction of the concrete and filling voids if any in the cube. The mould is then covered with plastic sheet to prevent excess water from escaping. The hardened concrete samples are then demoulded after 24 hrs and submerged in a clean water bath for curing until the age of testing i.e. 7 days and 28 days.

Figure 10 Compaction of Concrete on a Vibrating table

2.6 Tests performed on Concrete :

2.6.1 Compressive strength test:

The compression test is carried out according to determine the characteristic strength of the concrete. In this test, 150 mm standard cube mould is used for concrete mix. The apparatus should be clean and free from hardened concrete and superfluous water before testing. The test is carried out for each cube. The reported compressive strength is the average of 3 measurements tested at the age of 7 and 28 days. Figure no 11 and 12 shows specimen of cube tested in compression testing machine.

Figure 11 Concrete cube specimen before failure

Figure 12 Concrete cube specimen after failure

2.6.2 Tensile Splitting Test:

The split cylinder test is performed to find the tensile strength of a cylindrical concrete specimen. The cylindrical specimen is placed with its axis horizontally and subjected to a line load along the length of the specimen. The diameter and length of the cylindrical concrete are 150 mm and 300 mm respectively. Two wooden-bearing strips, 3.2 mm thick, 25 mm wide and slightly longer than the length of the specimen, are placed between the steel bars and the specimen to take account of deviations in the surface of the specimen. The machine used is same as that used for compression test. Figure no 13 and 14 shows concrete cylinder specimen before and after failure.

Figure 13 Concrete Cylinder specimen before failure

Figure 14 Concrete cylinder specimen after failure

III. CALCULATION AND RESULT

3.1 Compressive strength test :
3.1.1 Calculations:

The Compressive strength can be calculated by dividing the max load applied to the area of the cube. The formula for finding the Compressive strength is,

$$C = P/A$$

Where,

P = Max load applied on the specimen

A = Area of cross section of the specimen

Eg : P= 50800kg

A = (150X150)

Thus, C = (50800kgX9.81)/(150X150) = 22.59MPa (7 days cube-0% RCA)

Similarly compressive strength of other cubes can be calculate and result of the same is shown in table below.

4.1.2 Result :

Table below shows the results of the 7 days and 28-days compressive strength of concrete. From the results, the compressive strength seems to increase slightly with the addition of RCA. This could be due to the higher absorption capacity of the recycled aggregate. When the water is absorbed by aggregate, more space left by the water being absorbed can be occupied by aggregates in a unit volume. Hence the density of recycled concrete is lower.

Table 6 Compressive strength of cubes

Sample	0%	25%	50%	75%	100%
7 days cube strength (MPa)	22.59	21.77	23.7	18.07	21.41
28 days cube strength (MPa)	33.5	33.63	34.96	27.11	30.93

The natural aggregate and recycled aggregate are used to produce 150 mm concrete cubes for compression test. Figure no 15, 16 and 17 shows the results of compressive strength of concrete with 0%, 25%, 50%, 75% and 100% replacement of RCA. From the results, compressive strength of concrete with 50% replacement of RCA has the highest 7-day and 28-day strength which reaches 23.7 MPa and 34.96 MPa respectively. The compressive strength of recycled concrete with 50% replacement of RCA is in close proximity with that of the control concrete. From the results obtained, it is observed that the development of compressive strength of recycled concrete is better during early stage but it exhibits lower compressive strength during later stage. Figure 15 and 16 are the results of 7 days and 28 days strength in graphical form. Also a graph showing the comparison of both the days strength is given.

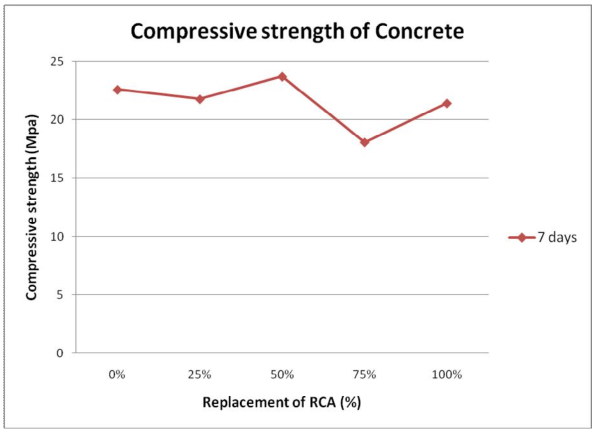

Figure 15 Compressive strength of cube at 7 days

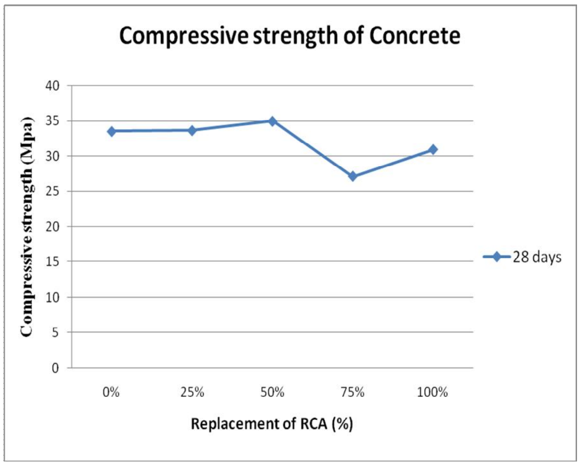

Figure 16 Compressive strength of cube at 28 days

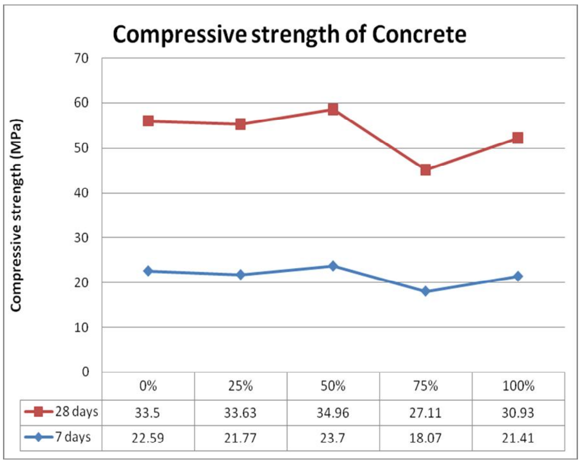

Figure 17 Comparison of Compressive strength of 7 days and 28 days cube

The figure no 17 compares the compressive strength of concrete tested at 7 days and 28 days respectively. It was seen that compressive strength increased with addition of RCA but only upto 50%. Further addition of RCA resulted in decrease of the strength. It is also seen that the compressive strength of 50% sample is in close proximity of the Natural aggregates sample. Thus it can be concluded that RCA upto 50% is satisfactory to use. It will also be economical with the reduce in transportation cost of dumping the aggregates. Primary reason of strength reduction may be the adhered mortar to the RCA and other non-aggregate material. This can be corrected by using proper cleaning techniques and casting methods under highly skilled supervision.

4.2 Tensile splitting test :

Split cylinder test is carried out on each concrete sample to find split tensile strength of concrete cylinder.

4.2.1 Calculation:

The tensile split strength can be calculated by the following fowmula,

T = 2P/∏LD

Where,

P = Max load applied on the specimen

L = length of the specimen

D = Diameter of the specimen

Eg : P = 27000kg

D = 150 mm

L = 300 mm

Thus, T = (2X27000X9.81)/(∏X150X300) = 3.82MPa (0% RCA)

4.2.2 Result:

The results of the split tensile strength for the tested concrete samples are shown in the table below. The figure and the table show the results of the tensile strength tests for the concrete mixtures at 28 days only, which is an average of three specimens.

Table 7 Splitting tensile strength of cylinder for various proportions

Sample	0%	25%	50%	75%	100%
28 days cylinder strength(MPa)	3.82	3.86	3.92	3.68	3.50

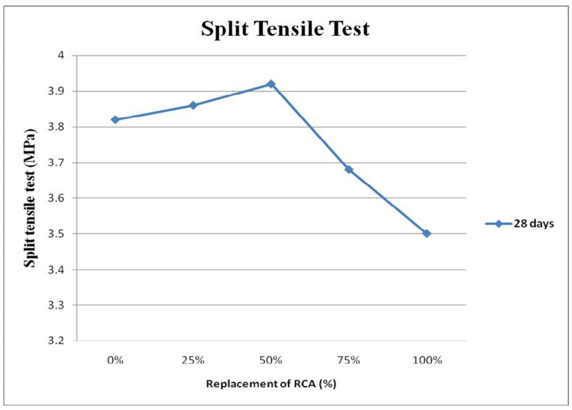

Figure 18 Splitting tensile strength of Cylinder

It is observed from the fractured surface of RCA with high amount of recycled coarse aggregates, the failure is not only through the interface but also through the recycled aggregates. The split tensile strength of RCA reduces with the increase in amount of RCA. The split tensile strength of recycled concrete with replacement of 50% of RCA was higher than the split tensile strength of the control concrete. The split tensile strength of recycled concrete with replacement of 100% RCA was less than split tensile strength of control concrete. As with the compressive strength, the split tensile strength of recycled concrete is higher during early stage but it gains strength at a slower rate during later stages. The splitting tensile strength gives more uniform results as compared to compressive strength.

CONCLUSION:

From the experimental work carried out on "Recycle of Concrete Aggregates" , the following conclusion can be drawn:
1.The water content used in all mixes is 0.5. The proportion of Cement: Sand: Gravel is 1:1.65:2.92
2.The slump of the normal concrete is observed to be less than the recycled one.
3.The compressive strength of concrete containing 50% RCA has strength in close proximity to that of normal concrete.
4.Tensile splitting test shows that concrete has good tensile strength when replace upto 25-50%.
5.The strength of concrete is high during initial stages but gradually reduces during later stages.
6.Water absorption of RCA is higher than natural aggregate.
7.Due to lack of treatment process for RCA adequate strength is not achieved but by applying more advanced and sophisticated treatment process the strength can be improved.
Thus the usage of RCA in concrete mixture is found to havestrength in close proximity to that of natural aggregate and can be used effectively as a full value component of new concrete.

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