RESEARCHERID
THOMSON REUTERS

*[Reddy *, 4(10): October 2017]*

ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

PERFORMANCE OF RECYCLED AGGREGATE CONCRETE (RAC) TOWARDS SUSTAINABILITY

Suchith Reddy[*1], N.Srikanth[2] & K. Srujan Varma[3]

[*1]Research Scholar, Department of Civil Engineering, NIT, Warangal, India
[2]Research Scholar, Department of Civil Engineering, JNTUH, Hyderabad, India
[3]Assistant Professor, Department of Civil Engineering, KITS, Warangal, India

ABSTRACT

Demolition of old and deteriorated buildings and traffic infrastructure, and their substitution with new ones, is a frequent phenomenon today in a large part of the world. The main reasons for this are structural deterioration, and natural disasters (earthquake, fire and flood). Crushing the concrete to produce coarse aggregate for the production of new concrete is one common means for achieving a more eco-friendly/sustainable concrete in addition to the reduction in valuable landfill space and use of natural resources. In order to promote the reuse of construction waste, it is necessary to achieve three basic concepts, Assurance of safety and quality, decrease of environmental impact and increase of cost effectiveness of construction. This study is aimed to discuss the possibility to replacement of Natural Coarse Aggregate (NA) with Recycled Concrete Aggregate (RCA) in nominal concrete to observe the performance of Recycled Aggregate Concrete (RAC) towards sustainability point of view. An investigation is carried out to find the strength properties of RAC. This work outlines the application of RCA in to the conventional concrete to the possible extend using processed aggregate (Los Angeles' abrasion), for achieving sustainable concrete

Keywords: Natural Coarse Aggregate (NA), Recycled Concrete Aggregate (RCA), Recycled Aggregate Concrete (RAC).

I. INTRODUCTION

After few decades, possibly the most pressing issue is the environmental impact of aggregate production. The environmental effects the aggregate quarries by atmosphere mainly continuous background noise from plant and machinery, as well as intermittent noise from blasting; dust from drilling, moving vehicles, and crushing and screening or mainly by ground waters where quarries cause modification of the ground water flow and the water table which can affect local water exploitation and water quality. When comes to Landscape concerns the visual impact of a quarry, it is becoming very difficult to operate the production sources in urban or near-urban localities due to opposition from resident groups and concerned environmentalists. So, we used RCA on a large scale may help to reduce the effects of the construction on these factors by reusing waste materials and preventing more NA from being harvested. After demolition of old roads, buildings and other infrastructure, the removed concrete is often considered worthless and disposed of as demolition waste. So, the most promising alternatives for the natural aggregates can be Recycled Aggregate (RA) and Recycled Aggregate Concrete (RAC).Crushed, sound and clean waste concrete of at least 95% by weight of concrete with typical total contamination lower than 1% of the bulk mass may be referred to as RCA. The study focuses on RCA, which is the coarse aggregate from the original concrete that is created after the mortar is separated from the rock which is reused. The use of RCA in new construction applications is still a relatively new technique. Buck (1977) cites the beginning of RCA use to the end of World War II, when there was excessive demolition of buildings and roads and a high need to both get rid of the waste material and rebuild Europe. After the immediate need to recycle concrete, the use of RCA tapered off. In the 1970s, the United States began to reintroduce the use of RCA in non-structural uses, such as fill material,

foundations, and base course material (Buck 1977). Since this time, some research has been conducted regarding how viable RCA is as an option to replace unused natural aggregate (NA) in structural concrete.

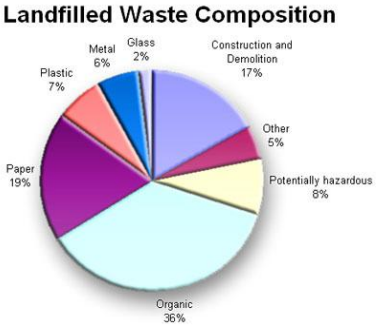


Fig1. Land Filled Waste Composition

Fig2. Construction Demolition waste

II. RECYCLED AGGREGATE CONCRETE: A SUSTAINABLE BUILT ENVIRONMENT

In the present study the influence of recycled coarse aggregate (RCA) obtained from three different sources having different ages of structures are on the properties of recycled aggregate concrete (RAC) are investigated. RAC mixes are prepared with each source of RCA separately. In order to assess the performance of RAC in comparison with normal concrete, two normal concrete mixes prepared with 100% natural coarse aggregate. Locally available natural sand is used in all mixes.

Recycling of construction and demolition waste has been considered from two main environmental aspects point of view: solving the increasing waste disposal crisis and save the depletion of natural resources. In the recent time due to significant increase in prices of natural raw materials of construction, and rise in the cost of waste storage in many regions, it has also become a burning issue (Ajdukiewwicz and Kliszczewicz, 2007).There is a scarcity of conventional building materials due to rapid construction activity and growing demand of houses in urban areas. Rapid industrialization has lead to the generation of huge quantities of construction and demolition wastes, which arises major problems of disposal. The disposal and utilization of construction and demolition waste is one of the major problems in India. The recycling technology, not only solves the problem of waste disposal, but reduces the cost and preserves environment also. This also gives the way for the sustainable built environment in the construction industry.

III. AIM AND OBJECTIVES

The aim of our project is to determine the possibility to replace Natural Coarse Aggregate (NA) with Recycled Concrete Aggregate (RCA) in nominal concrete to achieve sustainable concrete.

The objective of the project is to determine the workability and strength properties of Recycled Aggregate Concrete using unprocessed & processed concrete aggregate (for zero and partial replacement) and comparing the results with the normal concrete thereby determining the optimum percentage replacement without adversely affecting the conventional properties.

IV. RELATED WORK

Valeria Corinaldesi, investigated on mechanical behavior and elastic properties of Recycled Aggregate Concrete (RAC) .Results obtained show that structural concrete up to C32/40 strength class can be manufactured by replacing 30% virgin aggregate with coarse Recycled Concrete Aggregate.

Bilal Riaz and Muhammad Sohai, has performed the experimental investigation to examine the workability and compressive strength with recycled aggregate as a replacement to natural aggregate. It has been observed that the workability has been reduced by increasing the Percentage replacement of NCA with RCA. It was also observed that the concrete manufactured with RCA provided less compressive strength as compared to NCA.

Yasuhiro Dosho, studied the development of a recycling system and application of Recycled Aggregate Concrete produced by the aggregate replacing method. Result of this study showed that Recycled Aggregate Concrete using the aggregate replacing method can acquire sufficient quality as structural concrete and/or precast concrete.

Ashraf M. Wagih, Samir H. Okba, investigated the properties of RAC. Tests were carried out for compressive strength, splitting strength and elastic modulus. The results showed that a significant reduction in the properties of Recycled Aggregate Concrete (RAC) made of 100% RCA was seen when compared to Natural Aggregate Concrete (NAC), while the properties of RAC made of 25% RCA showed no significant change in concrete properties.

Katrina McNeil, and Thomas H.K. Kang, discusses the properties of RCA, the effects of RCA use on concrete material properties, and the large scale impact of RCA on structural members. They say that replacing NA in concrete with RCA decreases the compressive strength, but yields comparable splitting tensile strength. The modulus of elasticity is also lower than expected.

N.Sivakumar and S.Muthukumar, investigated the strength and durability characteristics of high strength structural concrete by using recycled coarse aggregates. From the experimental investigation it was found that recycled coarse aggregates can be used for making high strength concretes by adjusting the w/c ratio and admixture contents of the mix.

V. EXPERIMENTAL PROGRAM

Materials Used:
Portland cement, fine aggregates, coarse aggregate, coarse aggregate, water, unprocessed recycled aggregates (UPRA), Processed Recycled aggregates (PRA).

Portland cement:
The cement used in this investigation is Ultratech, 53-grade Portland, for casting of the cubes and cylinders. Tests on 53 grade Portland cement like standard consistency, specific gravity, Initial and final setting time are carried out confirming to IS: 4031:1988. (Sampling of cement for these tests is done as per IS:3535-1986 clause 5.7.2)

Fine aggregate:
Sand is generally used as fine aggregate for production of the concrete. For the present experimental work river sand procured from Manair is used as Fine Aggregate.

Coarse aggregate:
Crushed hard granite stone or gravel is generally used as coarse aggregate. The coarse aggregate procured from Jayagiri, Hanamkonda is used for investigation. Here, 10mm and 20mm natural coarse aggregates are used for the investigation.

Water:
Water used for both casting and curing in the experimental study is from bore well. It is free from impurities and is Potable.

Unprocessed Recycled Aggregate (UPRA)
The laboratory waste like cubes and cylinders are collected from the dumping yard in KITSW and are mechanically crushed and graded. The material passing IS sieve 20 mm and retained on IS sieve 18.5 mm is collected and is used as Unprocessed recycled aggregate.

Fig3. Crushed concrete waste

Fig4. Sieving of crushed concrete waste

Processed Recycled Aggregates (PRA)

The Unprocessed Recycled aggregate is subjected to abrasion using Deval's abrasion machine for 500 Revolutions. The material thus obtained is termed as Processed Recycled aggregates (PRA).

Fig5. Deval's abrasion machine

Fig6. Processed Recycled Aggregate

Both UPRA and PRA are used as substitute for natural coarse aggregate in varying percentages i.e. 10 %, 20%, 30% and 40%.

Table1. Properties of cement

S.No	Type of Test	Result
1	Standard Consistency	32%
2	Specific Gravity	3.06
3	Initial Setting time	35min
4	Final Setting time	10hrs

Table2. Aggregate properties

Properties	Natural Fine Aggregates	Natural Coarse Aggregates	UnProcessed Recycled Aggregates	Processed Recycled Aggregates
Bulk Density	1.65	1.421	1.27	1.393
Porosiy	35.8%	48.5%	53.9%	50.8%
Viods ratio	0.6	0.947	1.16	1.03
SpecificGravity	2.57	2.865	2.75	2.83
Finess modulus	2.98	7.06	7.1	6.1

Mix proportions

The according to IS 10262 mix design procedure, the mix proportions is 1:1.143:2.502 and w/c ratio=0.43 adopted. Out of 100% aggregate,75% is constituted by 20 mm aggregate.(This proportion is replaced by UPRA/PRA by % weight in varying percentages i.e. 10% , 20%, 30% & 40 %.) and remaining 25 % is constituted by 10 mm aggregate.

Table3. Materials required for casting cubes and cylinders

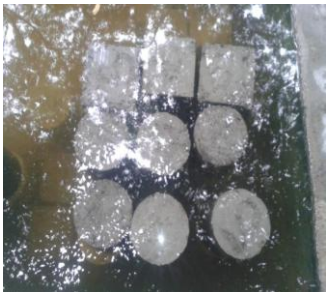
%	Coarse aggregate(Kg)		Fine aggregate(Kg)	UPRA/PRA (Kg)	Cement (Kg)	Water (Lit)
	20 mm	10 mm				
0 %	17.82	5.94	10.86	----	9.5	4.1
10 %	16.04	5.94	10.86	1.782	9.5	4.1
20 %	14.256	5.94	10.86	3.564	9.5	4.1
30 %	12.474	5.94	10.86	5.346	9.5	4.1
40 %	10.692	5.94	10.86	7.128	9.5	4.1

Fig.8. Slump test for conventional concrete

Fig.9. Slump of 10 % UPRA concrete

(a)

(b)



(c)

Fig.11 (a) Compaction of cubical specimen by hand (b) Compaction of cylindrical specimen by hand (c) Curing of specimens (pond curing)

(a)

(b)

(c)

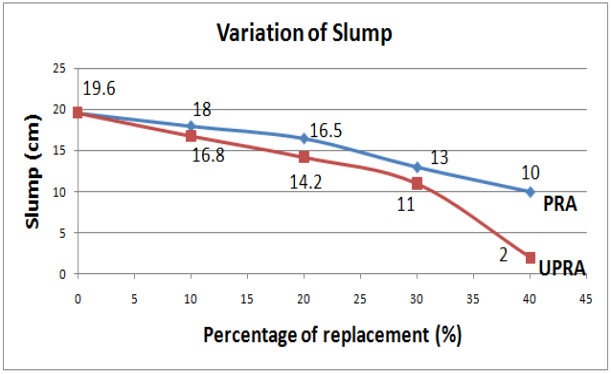
Fig12. (a) Compression testing machine (b) Testing of 10 % UPRA cube (c) Testing of Split tensile strength of 10 % UPRA cylinder

VI. RESULTS AND DISCUSSIONS

The workability of concrete decreased with increase in percentage of Recycled concrete aggregate (both in case of UPRA and PRA concrete) for all percentages of replacement, but the workability of Processed Recycled Aggregate (PRA) concrete is comparatively more than that of Unprocessed Recycled Aggregate(UPRA) concrete. The cementious mortar present on the RCA is the reason for low workability values. As the cementious mortar is more porous in nature, it absorbed considerable amount of water, thereby decreasing the workability.

Table 4. Slump values

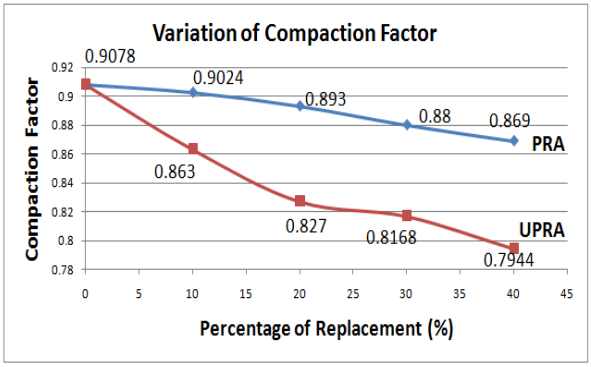
% Replacement	Normal concrete Slump value (cm)	UPRA concrete Slump values (cm)	PRA concrete Slump values (cm)
0 %	19.6	--	
10 %	--	16.8	18
20 %	--	14.2	16.5
30 %	--	11	13
40 %	--	2	10



Graph 1. Variation of Slump with percentage replacement of recycled aggregates

Table 5. Compaction factor

% Replacement	Normal concrete Compaction factor	UPRA concrete Compaction factor	PRA concrete Compaction factor
0 %	0.9078	--	--
10 %	--	0.863	0.9024
20 %	--	0.827	0.893
30 %	--	0.8168	0.88
40 %	--	0.7944	0.869



Graph 2.Variation of compaction factor with percentage replacement of recycled aggregates

Compressive strength of hardened concrete decreased with increase in percentage of Recycled coarse Aggregate (both in case of PRA and UPRA concrete) for all percentages of replacement, but the compressive strength of PRA concrete is comparatively more than that of UPRA concrete. The extent of bonding of cement with the aggregate is responsible for the strength of concrete. This bonding of aggregates is prevented by the cementitious mortar present on Recycled aggregates. Hence the strength values are lower than normal concrete. But in case of PRA, the cementitious mortar is removed to some extent through abrasion. Hence the strength of PRA concrete is more than that of UPRA concrete.

Split tensile strength of concrete decreased with increase in percentage of Recycled concrete aggregates for all percentages of replacement, but the variation is very small. The reason for less compressive strength of Recycled Aggregate concrete also applies to the less split tensile strength of Recycled Aggregate concrete.

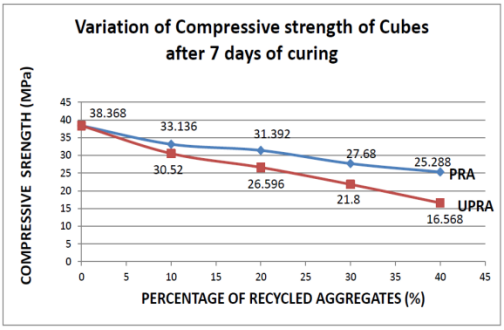
The hardened concrete is used to find the compressive and Split tensile strength after 7days and 28 days of curing. The result obtained by tests are shown in table

Table.6 Compressive strength values

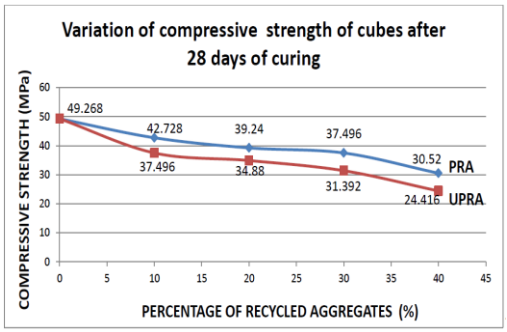
% Replacement	Strength of concrete cubes using UPRA (N/mm^2)		Strength of concrete cubes using PRA (N/mm^2)	
	7 Days	28 days	7 Days	28 Days
0 %	38.368	49.268	38.368	49.268
10 %	30.52	37.496	33.136	42.728
20 %	26.596	34.88	31.392	39.24
30%	21.8	31.392	27.68	37.496
40 %	16.568	24.416	25.288	30.52

Table.7 Split tensile strength values

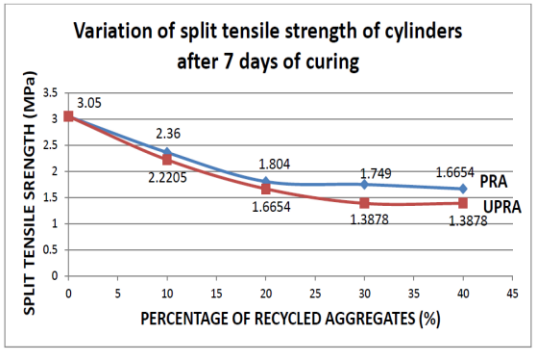
% Replacement	Strength of concrete cylinders using UPRA (N/mm^2)		Strength of concrete cylinders using PRA (N/mm^2)	
	7 Days	28 days	7 Days	28 Days
0 %	3.05	3.88	3.05	3.88
10 %	2.2205	3.3308	2.36	3.6083
20 %	1.6654	3.192	1.804	3.496
30%	1.3878	2.9144	1.749	3.0535
40 %	1.3878	2.3593	1.6654	2.7756



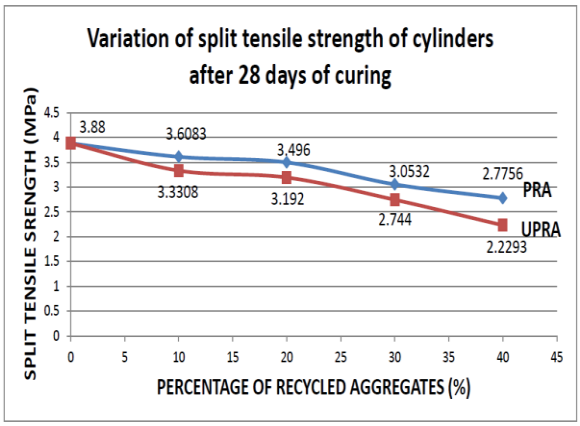
Graph 3.Variation of Compressive strength of cubes after 7 days of curing



Graph 4. Variation of compressive strength of cubes after 28 days of curing



Graph 5. Variation of split tensile strength of cylinders after 7 days of curing



Graph 6. Variation of split tensile strength of cylinders after 28 days of curing

VII. CONCLUSION

- The physical and mechanical properties of recycled aggregates such as specific gravity, water absorption, bulk density, crushing value, impact value and abrasion value can be improved by suitable chemical or mechanical treatments.
- From the experimental investigations it was observed that the slump reduced by 14.30 % to 22.50% and 8% to 21.20% upto 30% replacement of UPRA and PRA respectively. It was observed that compaction factor reduced from 4.9% to 1.23% and 0.5% to 1.45% upto 30 % replacement by UPRA and PRA respectively.
- As the cementicious mortar is more porous in nature, it absorbs considerable amount of mixing water. Therefore, it is suggested to use RA in saturated surface dry conditions along with the use of superplasticizer in order to enhance the workability. The workability of the concrete decreases with increase in percentage of Recycled concrete aggregate (both in case of UPRA and PRA concrete),but the workability of Processed Recycled aggregate concrete is comparatively more than that of Unprocessed Recycled aggregate concrete. The cementicious mortar present on the Recycled Concrete Aggregate is the reason for low workability values.
- The compressive strength reduced by 23.9% to 50.44 % for a replacement of UPRA by 30% and also the compressive strength reduced by 13.27% to 38.05 %for a replacement of PRA upto 30%. The Compressive strength of hardened concrete decreases with increase in percentage of Recycled coarse Aggregate (both in case of PRA and UPRA concrete),but the compressive strength of PRA concrete is comparatively more than that of UPRA concrete.
- It was observed that split tensile strength reduced by 14.15% to 39.19% for a replacement of UPRA by 30% and also the split tensile strength reduced from 7.7% to 28.46% for a replacement of PRA upto 30%. Hence, the cementitious mortar is to be removed to improve the compressive and split tensile strength of RAC. The Split tensile strength of concrete decreases with increase in percentage of Recycled concrete aggregates but the variation is very small. Based upon the results obtained, it can be concluded that the optimum percentage of replacement for recycled concrete aggregate (processed from Deval's abrasion for 500 revolutions) is around20%without compromising with the workability and strength.
- The extent of bonding of cement with the aggregate is responsible for the strength of concrete. This bonding of aggregates is prevented by the cementitious mortar present on Recycled aggregates. Hence the strength values are lower than normal concrete. But in case of PRA, the cementitious mortar is removed to some extent through abrasion. Hence the strength of PRA concrete is more than that of UPRA concrete.
- Therefore, reuse, recycle and reutilisation of construction and demolition waste in the form of PRA and UPRA as a new construction material fulfil one of the main objectives with respect to sustainable construction activities.

VIII. SCOPE OF FURTHER WORK

- The Strength properties of different grades of Recycled aggregate concrete above M25 grade of concrete need special attention.
- The Durability Studies on Recycled aggregate concrete for partial replacement of aggregates need to be studied.
- The Bond strength of recycled aggregate concrete need to be studied.
- The Workability and Strength properties of concrete prepared using recycled aggregates processed to different degree of processing i.e. 100 rev, 300 rev, 1000 rev etc. need to be studied.
- The study of properties of concrete prepared using recycled fine aggregates and a combination of both fine and coarse recycled aggregates is significant in future.
- The economic studies of recycled aggregates are significant work to be carried out.

REFERENCES

1. *V. Corinaldesi, "Mechanical and elastic behavior of concretes made of recycled concrete coarse aggregates", Construction and building materials, vol. 24, no. 9, pp. 1616–1620, 2010.*
2. *Katrina Mc'Neil, "Recycled concrete aggregates: a Review", International journal of concrete structures and materials", vol.7, no.1, pp.61–69, March 2013.*
3. *Ashraf M. Wagih, "Recycled construction and demolition concrete waste as aggregate for structural concrete", Housing and Building National Research Center, HRBC journal (2013).*
4. *N.Sivakumar, "Experimental studies on high strength concrete by using recycled coarse aggregate", Research inventy: International journal of engineering and science vol.4, issue 01 (January 2014)*
5. *V.S.Babu, A.K.Mullick, "Mechanical properties of high strength concrete using recycled aggregates - influence of processing", The Indian concrete journal, May 2014.*
6. *M. Chakradhara Rao, S. K. Bhattacharyya, and S. V. Barai, "Influence of field recycled coarse aggregate on properties of concrete," materials and structures, vol. 44, pp. 205–220, 2011.*
7. *K. Rahal, "Mechanical properties of concrete with recycled coarse aggregate," building and environment, vol. 42, no. 1, pp. 407–415, 2007.*
8. *M. C. Limbachiya, E. Marrocchino, and A.Koulouris, "Chemical-mineralogical characterization of coarse recycled concrete aggregate," waste management, vol. 27, no. 2, pp. 201–208, 2007.*
9. *A. K. Padmini, K. Ramamurthy, and M. S. Mathews, "Influence of parent concrete on the properties of recycled aggregate concrete," construction and building materials, vol. 23, no. 2, pp. 829–836, 2009.*
10. *S. W. Tabsh and A. S. Abdelfatah, "Influence of recycled concrete aggregates on strength properties of concrete," construction and building materials, vol. 23, no. 2, pp. 1163–1167, 2009.*
11. *Kumar P.R. and Prasad M.L.V, ''Utilization of Recycled Aggregate from Demolished waste for Structural Concrete'', Journal of Indian National Group of the International Association of Bridge and Structural Engineering (ING-IABSE), 38(1), March (2008).*