

# Strength and Stiffness of Recycled Concrete Aggregates



Ankur Arun Kulkarni

**Abstract:** As the construction is in its highest pace, the demand of raw material especially coarse aggregate is in great demand. At the same time the renovation, demolition and refurbishing of old structures is a continuous process, it is resulting in significant source of recycled concrete aggregate (RCA). Bit uncertainty and great variation in properties of RCA has restricted its wide use in all engineering construction activities. From point of view of conservation of natural resources, use of recycled concrete aggregate reduces use of natural aggregates, utilization of waste and results in energy saving. Thus extensive study is carried out to ascertain the effects of use of recycled concrete aggregate (RCA) on strength and stiffness of concrete. The rejected precast concrete, unused ready mixed concrete and concrete from demolished old structures is considered for RCA. Compressive strength and stiffness gain tests are conducted for both natural and recycled concrete aggregate (RCA) is carried out and the results are presented in this paper. Direct volume replacement method is used for replacing a selected quantity of natural coarse aggregates (NCA) by an equal volume of recycled concrete aggregate (RCA).

**Keywords :** compressive strength, recycled concrete aggregate, strength, stiffness, impact value

## I. INTRODUCTION

Among the various materials used for construction purpose, concrete is the most widely used material. Its ease in availability, relatively lower cost and ability to get molded in any desired shape has made it dominant construction material. It also results in large quantity of construction waste. Recycled aggregates are the aggregates obtained from the processing of materials earlier used in construction. Recycled aggregates include aggregate obtained from waste concrete material of demolished structure, road repairing work and scrap tyres. Recycled concrete aggregate (RCA) is the concrete produced by replacing natural aggregate by recycled concrete aggregate. Due to demolition and reconstruction activities also produce lot of construction waste. Such large quantity of construction waste is crushed and used as recycled concrete aggregate (RCA). Use of RCA started almost 75 years ago, immediately after Second World War[01]. Numerous high rise structures and other buildings are constructed in various parts of the world like Germany,

Norway, United Kingdom, Finland, and Netherlands using RCA as partial or full replacement of natural aggregate (NCA)[02]. Though RCA is used widely across the globe since decades, still RCA is used sparingly in construction work in India. In most of the rural part of India as the natural aggregates are cheaply available at cheaper cost thus use of RCA is not that popular. From survey it is observed that in India the RCA is mainly used in road construction and in mass concreting work. Studies shows that the 2000 to 3000 million tons of waste is produced across the world due to demolition every year[03,04] out of which India produces 8 to 10 million tons alone[05]. As the infrastructure development and urbanization is at higher pace in India these numbers are increasing every year.

## II. EXPERIMENTAL WORK:

### 2.1 Preliminary tests

Elementary tests were conducted in the laboratory using the recycled aggregates to study and compare its performance with the naturally available aggregates. The tests were conducted on the aggregates which weren't subjected to any prior treatment.

**Table No.: 01**

	Recycled aggregate	Natural aggregate
Impact value	34.50%	29.75%
Abrasion value	47.00%	29.50%
Water absorption	04.45%	00.45%
Crushing value	22.15%	20.55%

Concrete cubes were cast in laboratory using recycled aggregates and natural aggregates. The recycled concrete aggregate used for casting cubes was that passing through IS sieve 40 mm and retained on IS sieve 4.75 mm. For controlled concrete the natural stone chips of same nominal size was used in making concrete.

**Table No.: 02**

	Concrete made from recycled aggregate	Concrete made from natural aggregate
Compressive strength	16.55 MPa	20.50 MPa
Flexural strength	84%	79%

The results of preliminary laboratory tests conducted on concrete made from recycled aggregate and natural aggregate are given in Table 01. These results shows that ,the impact value for recycled aggregate is observed as 34.5% and that for natural aggregate as 29.75%. The abrasion value for recycled aggregate is observed as 47.00% and that for natural aggregate as 29.50%.

Revised Manuscript Received on January 30, 2020.

\* Correspondence Author

Ankur Arun Kulkarni\*, \*Formerly with Protective Technology Research Centre, NTU-Singapore, Professor in Civil Engineering, Shri Rawatpura Sarkar University, Raipur (CG), India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

## Strength and Stiffness of Recycled Concrete Aggregates

There is a vast variation in water absorption of concrete made from recycled aggregate (4.45%) and water absorption is found to be higher when compared to the natural aggregate (0.45%).

From Table No. 02, it is observed that compressive strength of concrete made from the recycled aggregate is about 75% of the strength of concrete made from natural aggregate for normal strength concrete (M20). Flexural strength of the recycled aggregate concrete is almost 84% and 79% of natural aggregate concrete

### 2.2 Compressive test

Extensive experimental work is carried out to verify the effect of recycled aggregate on strength of the concrete. The cube compressive strength tests were performed in accordance with IS: 516 and IS: 456[06,07]. The compressive strength of hardened and cured concrete was determined by using 150 mm ×150 mm concrete cubes which were casted and water-cured at room temperature before being tested at ages of 7 and 28-days. A 200 ton compression testing machine was used in this experimental work for applying pressure on the specimen and load cell was used for transferring data directly to the computer.

Compressive strength tests were performed on concrete cubes after 7 and 28 days of curing. The tests were done on concrete consisting of varying RCA proportions from 0 to 100%. Both Ordinary Portland Cement (OPC) and Portland Slag Cement (PSC) were used for casting the cubes. Using water cement ratio of 0.5, in all 10 mix of various proportion of RCA and total thirty cubes are casted and tested. The detail of used proportions is given in Table No. 03.

**Table No. 03: Material proportions used for concrete test samples**

Type of Cement	ID	Mix type	Cement	Water	Fine aggregate	Coarse aggregate		W/C ratio
						RCA	Natural	
Ordinary Portland Cement (OPC)	Mix 1	0% RCA	38.2	19.1	76.4	0	112.4	0.5
	Mix 2	25% RCA	38.2	19.1	76.4	28.1	84.3	0.5
	Mix 3	50% RCA	38.2	19.1	76.4	56.2	56.2	0.5
	Mix 4	75% RCA	38.2	19.1	76.4	84.3	28.1	0.5
	Mix 5	100% RCA	38.2	19.1	76.4	112.4	0	0.5
Portland Slag (PSC) Cement	Mix 6	0% RCA	38.2	19.1	76.4	0	112.4	0.5
	Mix 7	25% RCA	38.2	19.1	76.4	28.1	84.3	0.5
	Mix 8	50% RCA	38.2	19.1	76.4	56.2	56.2	0.5
	Mix 9	75% RCA	38.2	19.1	76.4	84.3	28.1	0.5
	Mix 10	100% RCA	38.2	19.1	76.4	112.4	0	0.5

**Table No. 04: Determination of Impact Value for Natural and Recycled Aggregates**

	Natural Aggregates	Recycled Concrete Aggregates
Original weight of aggregates, $W_1$ gm	340 gm	310 gm
Weight of fraction passing through 2.36mm IS sieve, $W_2$ gm	100 gm	100 gm
Aggregate Impact Value $IV = (W_2 / W_1) \times 100\%$	29.41%	32.25%

According to IS 2386(Part 4)-1963, the aggregates is classified based on its impact value (IV) as, if IV is 10% → exceptionally strong, if IV is between 10–20% → Strong, if IV is between 20–30% → Satisfactory for road surfacing and if IV is greater than > 35% → aggregate is weak for road surfacing. From Table No. 04, it may be observed that the recycled concrete aggregates are not suitable to be used for road surfacing work. It can be used for other concreting work. The results obtained by performing tests on hardened concrete consisting of varying proportion of RCA are displayed in Table No. 05.

**Table No. 05: Compressive strength of concrete cubes**

Mix ID	7 Days			28 days		
	Ultimate load (kN)	Ultimate strength (MPa)	Average strength (MPa)	Ultimate load (kN)	Ultimate strength (MPa)	Average strength (MPa)
Using Ordinary Portland Cement (OPC)						
Mix 1	747.25	33.21	33.14	881.88	39.19	40.12
	749.38	33.31		921	40.93	
	740.38	32.91		905.5	40.24	
Mix 2	481.88	21.42	22.87	594.13	26.41	27.29
	501.25	22.28		621.75	27.63	
	560.63	24.92		626.5	27.84	
Mix 3	436.25	19.39	19.34	593	26.36	26.61
	453.13	20.14		608.38	27.04	
	416	18.49		594.5	26.42	
Mix 4	424.25	18.86	18.95	595.25	26.46	25.28
	418.75	18.61		567.25	25.21	
	435.75	19.37		543.88	24.17	
Mix 5	607.6	27	27.4	671.38	29.84	28.77
	638.25	28.37		658.5	29.27	
	603.63	26.83		611.88	27.19	
Using Portland Slag Cement (PSC)						
Mix 6	790	35.11	34.36	1048.2	46.59	46.97
	749.5	33.31		1140	50.67	
	779.9	34.66		981.9	43.64	
Mix 7	691.6	30.74	31.06	918.4	40.82	38.23
	700.9	31.15		852.1	37.87	
	703.8	31.28		810	36	
Mix 8	598.2	26.59	26.72	652.3	28.99	29.24
	603.7	26.83		648.2	28.81	
	601.4	26.73		673	29.91	
Mix 9	565.1	25.12	25.28	672.9	29.91	27.47
	573.5	25.49		578.2	25.7	
	567.9	25.24		603	26.8	
Mix 10	713.2	31.7	31.29	774.9	34.44	37.5
	699.8	31.1		855.4	38.02	
	699.4	31.08		901	40.04	

## III. RESULT AND ANALYSIS

In this paper a research work is presented in which initially impact test is performed on natural aggregates and recycled concrete aggregates. Later compressive strength tests were performed on concrete cubes after 7 and 28 days of curing. The tests were performed on concrete with varying proportions of RCA and natural aggregates,

using both Ordinary Portland Cement (OPC) and Portland Slag Cement (PSC). It is important to mention here that the average 28 day strength of both concrete cubes using types of cement from the different trials indicates that there is no significant influence of RCA replacement.

A maximum of 2% and 3.5% reduction in cube compressive strength is observed due to use of RAC30% and RAC100% respectively. Based on the laboratory tests conducted and explained in this research work it be observed that, 30% of coarse RCA can be replaced with NCA as a major aggregate in structural concrete. Before RCA is used for a particular construction activity, it is recommended that contaminant materials are screened for and removed, and the physical properties (absorption, density, flakiness, compressive strength) are needed to be evaluated. The surface texture and relatively higher absorption characteristics of RCA results in increase in creep and shrinkage strain but it may possible to get the same quality of characteristics in concrete with 30% replacement of NCA by RCA as in natural aggregate concrete. Compressive strength is a very important parameter in accessing the durability of concrete, and one of the methods of measuring strength is the 28 day cube test. In this paper, conventional curing in water method was used and the cubes were tested for 7 and 28 days for various proportions of RCA as shown in Table No. 05.

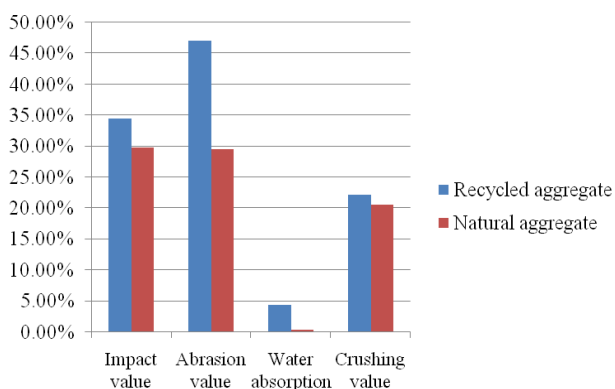


Fig. No. 01 Comparative analysis of concrete using recycled and natural aggregates

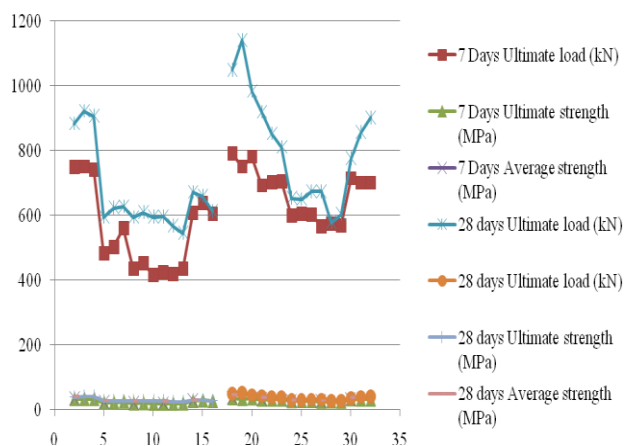


Fig. No. 02 Compressive strength of concrete cubes using recycled and natural aggregates

#### IV. CONCLUSION

Generally RAC leads to a lower workability of fresh concrete than NAC. The results of the above experimental studies

have shown that the compressive strength, for concrete with various % of RCA variations are marginally less compared to conventional concrete. It is also observed from Fig. 01, that the strength is reducing with % increase in RCA and accordingly RCA can replace natural aggregate up to 25% for low cost constructions.

But as the total demand for aggregates is expected to increase due to the fast growing urbanization trend worldwide, the use of RAC is unavoidable. The recycling of construction materials is growing as the demand for aggregates is increasing. Potential sources for recycled materials will certainly increase as maintenance and replacement of infrastructure continues. As less energy is required in processing RCA, it leads to lowering of the project cost. This study concludes that up to 25% of RCA replacement can be used with confidence in structural concrete without any noticeable change in the properties.

From Fig. No. 02, it is observed that by using Portland Slag Cement (PSC), it is possible to obtain concrete cube strength of 38.23 MPa with RCA with a crushing value of 22.15 and absorption of less than 4.45%, without changing the water/cement ratio. In this paper it is observed that RCA with impact value 34.5%, and absorption of 4.45% were used with w/c=0.5, with insignificant influence on compressive strength even with 100% replacement of NA of density 2.74 and absorption 0.45%.

#### ACKNOWLEDGEMENT:

The experimental work described here was supported by Savitribai Phule Pune University, Pune and Shri Rawatpura Sarkar University, Raipur.

#### REFERENCES

1. S. A. Abukersh, "Recycled aggregate concrete produced with red granite dust as a partial cement replacement," Construction and Building Materials, (2009)
2. J. Vyncke, "Use of recycled materials as aggregates in the construction industry," Network Management, Belgian Building Research Institute, (2000)
3. Paul S. C and Van Zijl, "Mechanical properties of concrete containing recycled concrete aggregates", Proceedings of the Concrete Society Conference, 3<sup>rd</sup>-4<sup>th</sup> August, Emperor's Palace, ISBN Number: 978-1-920017-46-0, (2010)
4. Hubert Chang, Ryan Morgan, Umet Aziz, Simon Herfellner, Kenneth Ho., Performance and Implementation of Low Quality Recycled Concrete Aggregate, 2013, Vol 10, Iss 1, Pp 74-84.
5. Ravindra R S et al. "Shrinkage modeling for recycled aggregate concrete", Vol. 3, Page 1-23, ISSN-4195, (1983)
6. IS 516 (1959): Method of Tests for Strength of Concrete
7. IS 456: 2000 Indian Standard Plain and Reinforced Concrete – Code of Practice (Fourth Revision)

#### AUTHORS PROFILE



First Author Prof. (Dr.) Ankur Kulkarni, Professor in Civil Engg & Vice chancellor, Shri Rawatpura Sarkar University- Raipur  
PhD Civil-Structures from NTU, Singapore Worked on Ministry of Defense- Singapore funded research project, Participated in field explosion tests in Australia at Woomera.