EFFECT OF RECYCLED AGGREGATE ON STANDARD CONCRETE INCORPORATE WITH MICRO SILICA

BHAVANA B. JADHAV, DR. SANJAY KULKARNI
Bhavana Jadhav, Department of Civil Engineering, Dr. D.Y. Patil School of Engineering & Technology, Charholi (BK), Lohgaon, Pune-412 105, India
Dr Sanjay Kulkarni, Department of Civil Engineering, Dr. D.Y. Patil School of Engineering & Technology, Charholi (BK), Lohgaon, Pune-412 105, India

ABSTRACT

Concrete is most important material used in the construction industry. Large amount of natural aggregates were used in concrete, this causes the nature. Now-a-days many structures are demolished & rebuilt, demolishing of structures causes problem with dumping of waste material. An important aspect of sustainable construction is recycling or reuse of the construction material and demolition waste. It will maintain a friendly green environment. Recycled aggregates has micro cracks on its surface causes low strength, low workability of concrete. This draw back can be avoided by using micro silica. Concrete be designed for 28-day compressive cube strength of 30MPa. Micro silica was incorporated up to 15% of cement content at 5% intervals, while the natural coarse aggregate substitution by recycled coarse aggregate ranges between 25 - 75% at 25% interval. Workability, compressive cube strength, tensile splitting strength and flexural strength these test were taken on fresh and hardened concrete. The result suggests that there is a potential to increase the optimum fraction of recycled aggregate from 25-75% in concrete, with incorporation of 10% micro silica as result shows more strength for mix design of M30 grade concrete.

Keywords: Micro silica; Recycled aggregate; Natural aggregate; Construction and demolition waste; Recycled concrete.

1. INTRODUCTION:

Concrete is a heterogeneous material comprising fine aggregate, coarse aggregate, potable water, and the binder known as cement and the presence of coarse aggregates in concrete contributes more to the heterogeneity. As compare to other ingredients of concrete, requirement of coarse aggregate is more. Generally, aggregates account for a huge proportion (60-75%) of the overall volume of concrete. concrete is characterized by very advantageous features ranging from cost effectiveness, durability, outstanding compressive strength, and availability these make it very useful.

There is increasing demand of infrastructure due to continuous rise in population, and high rate of urban drift. Concrete has more consumed because of industrialization and urbanization. Concrete is the most widely consumed resource in construction industry. The continuous global demand for concrete implies that, more aggregate and cement would be required in the production of concrete, thereby leading to more extraction and depletion of deposits of natural gravel and increased CO_2 emission from quarrying activities. Also the continuous use of conventional concrete, (that is concrete produced with virgin aggregates and ordinary Portland cement) has proved to be very unfriendly to the environment.
This implies that, partial substitution of natural aggregate with recycled aggregate would lead to reduction in construction cost and carbon emission of the construction industry. Coarse aggregate as partial substitute for virgin coarse aggregate in concrete is not new to the construction industry, and significant progress has been made over the past years since recycled aggregate properties were first investigated by Gluzhge in 1946. This eventually lead to the current use of recycled coarse aggregate for non-structural concrete applications such as embankment fills, low-grade concrete production, coarse materials for road sub-base, paving blocks, drainage etc. In spite of many research studies and findings, there is urgent need to improve the engineering properties of recycled coarse aggregate concrete. This would help to reduce the current high level of uncertainty associated with the structural use of the material in concrete production.

In the process of crushing of aggregate because of impact CA have micro cracks on its surface. As the recycled aggregates have micro cracks on its surface this tends to have low strength of concrete, so there is a need to add some mineral admixture to improve the properties of RA concrete. The use of mineral admixture (i.e. micro silica) can enhance the physical and engineering properties of recycled aggregate concrete. These interactions would be

investigated with a view to evaluate the potential to increase the optimum fraction of recycled coarse aggregate in concrete, from the currently recommended 30% level of replacement.

Microsilica contributes both physically and chemically in concrete mix. The physical contribution occurs through its action as nucleation sites, which reduces the average size of pores present in cement paste thereby enhancing concrete properties. While the chemical contribution takes place mainly by acting as an efficient pozzolanic material, which enables even distribution and higher volume of hydration products.

Most researchers incorporated micro silica as partial replacement for cement in concrete mix, while this research work incorporates micro silica as an addition with the intent to evaluate the optimum required addition that would produce the best significant result in terms of strength, durability and workability.

2. MATERIAL AND METHODS

2.1 Experimental Investigation

To work with recycled aggregate concrete standard size moulds were used, total 87 specimens were casted, out of which 39 cubes of 150mm x 150mm x 150 mm size, 39 cylinder of 150mm x300 mm size and 9 beams of size was 150mm x150mm x700mm. The beams were casted for maximum results obtained from the cube & cylinder for single replacement and addition design.

2.2 **Materials**

2.2.1 Cement

Cement used is Ordinary Portland cement. (OPC). Ordinary Portland cement (OPC) – 53 grade (Birla Shakti Cement) is used.

2.2.2 Fine Aggregate

Crushed sand is used which is also called as artificial sand which is locally available in nearby area having specific gravity 2.63.

2.2.3 Coarse Aggregate

Natural coarse aggregate used which are locally available. Aggregates have specific gravity 2.79. 20mm & 10mm size of aggregate were use, in 60% & 40% respectively.

2.2.4 Recycled Coarse Aggregate

Aggregate was obtained from a demolished site in Pune, the cubes, cylinders and beams casted for testing purpose was crushed & 20mm & 10mm aggregate were separated by sieving.

Aggregates having mortar layer over the surface, and having micro cracks on it so the water absorption, density and bonding with cement paste were low. This may give result in low workable concrete and low strength of concrete.

	Natural	RCA
Impact value	13.84%	20.2%
Abrasion value	17.2%	26.4%
Sp. gravity	2.79	2.69

2.2.4.1 Impurities in Recycled Coarse Aggregate

The performance of recycled coarse aggregate can be reduced due to the presence of impurities, which emanated from demolition process including porous mortar and cement paste attached to the parent aggregate. The effect could also lead to general reduction in characteristics of recycled aggregate concrete. Some of the impurities identified through visual inspection from the recycled coarse aggregate.

The average percentage impurities present in the recycled coarse aggregate amounted to about 5% of the total mass of the sample. Although there is visual evidence to show the presence of adhered mortar on the parent material, it was practically impossible to estimate their percentage. However, the adhered mortar does not seem to be of significant quantity but its impact on the characteristics of recycled coarse aggregate concrete cannot be neglected.

2.2.5 Micro silica

Micro silica used is ASTM C1240 of cetex brand, having specific gravity 2.11.
When water is added to cement, hydration occurs as shown below:-
OPC + H2O → CSH (Calcium silicate hydrate) + $Ca(OH)_2$(Free lime)
The free lime does not contribute to strength, when combined with carbon dioxide; it forms a soluble salt, which leaches through the concrete causing effloresce, a familiar architectural problem. Concrete is also more vulnerable to chemical attack & detoriation, when it is added, the following reaction takes place.

$Ca(OH)_2 + SiO_2 \rightarrow H_20 + CSH$
The reaction reduces the amount of calcium hydroxide in the concrete.

Chemical property	Test Method	Result
Silicon Dioxide(SiO_2) % by mass	BS EN 196-2	92.0
Elemental Silicon % by mass	ISO 9286	0.12
Free Calcium Oxide %by mass	BS En 451-1	0.34
Sulphate (SO_2		0.14
Total Alkali (Na_2O_{eq}) %by mass	BS EN 196-2	0.40
Chloride (Cl) %by mass		0.03
Loss on Ignition % by mass		2.10

2.5.6 Water

Water fit for drinking is generally considered fit for making concrete. Water should be free from acid, oils, alkalis, vegetables or other organic impurities. Soft water also produces weaker concrete. Water has two functions in concrete mixes. First, it reacts chemically with the cement to form a cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Secondly, it serves as a vehicle or lubricant in the mixture of fine aggregate & cement.

3. Concrete Mix Design

M-30 Concrete mix was designed as per IS-10262. The 28 days characteristic strength is 30Mpa having water cement ratio 0.45.

RCA (%)	**0%**	**25%**	**50%**	**75%**
Cement (kg/m³)	438	438	438	438
Sand (kg/m³)	703.48	703.48	703.48	703.48
Gravel (kg/m³)	1111.54	833.65	555.77	277.88
RCA. (kg/m³)	1111.54	277.88	555.77	833.65
Water (kg/m³)	197	197	197	197
Micro silica (kg/m³)				
5%	0	21.9	21.9	21.9
10%	0	43.8	43.8	43.8
15%	0	65.7	65.7	65.7

3.1 Concrete Mixing and Placing

Concrete is mixed by hand mixing on concrete base which is absorbent. Hence because of absorbent surface water is sprayed over it. Then coarse aggregate were placed after that fine aggregate was placed over coarse aggregate this is covered by cement & micro silica. First dry mixing was done. After proper dry mixing required quantity of water was sprayed on the dry mix and then mix it thoroughly. After ascertaining consistency, the concrete was placed in various lubricated moulds (cubes, cylinders & beams) in three layers with each layer compacted by 25 times using tamping rod & the vibrating table in order to expel any entrapped air. The surface was gradually levelled with steel hand trowel. The concrete samples were thereafter de-moulded and cured in the water tank at about 20°C.

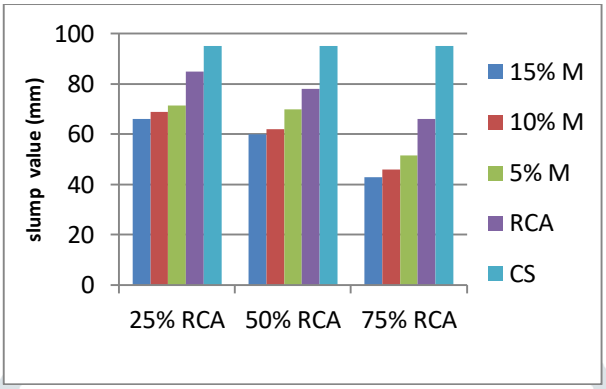
4. RESULTS AND DISCUSSION

Different tests were conducted on fresh and hardened concrete like on fresh concrete slum test and compaction factor test were carried out to know the workability of concrete, and compressive strength test, split tensile strength and flexure test were carried out on hardened concrete to know the properties of hard concrete having recycled

aggregates incorporating with micro silica the graph shows the variations with respect to percentage variation of recycled aggregate and micro silica.

4.1 Workability test: slump test-

The result shows that as the percentage of recycled coarse aggregate, incorporating with increasing percentage of micro silica decreases the water-cement ratio. The percentage decrease in water cement ratio for 25%, 50% and 75% are 36.02%, 45.16% and 75.36% respectively for addition of 15% micro silica.



Graph 1: slump value experimental results

Table1: Result of slump test for concrete mix

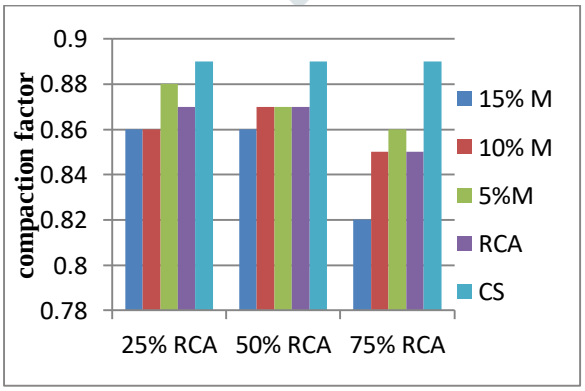
RCA (%)	0%M (mm)	5% M (mm)	10% M (mm)	15% M (mm)
0	95	-	-	-
25	82	71.5	69	66
50	78	70	62	60
75	66	51.5	46	43

RCA --- Recycled Coarse Aggregate, M --- Micro silica

The incorporation of micro silica in the mix significantly affects the characteristics of fresh concrete due to the strong cohesiveness of the concrete mix which result in very little bleeding or absence of bleeding in the concrete mix.

4.2 Workability test: compaction factor test

Compaction factor test also gives low results; were shown by graph for compaction factor test,



Graph 2: compaction factor experimental results

Table2: Result of compaction factor test for concrete mix

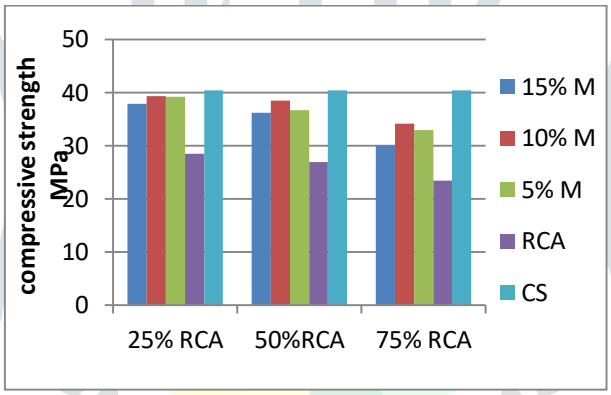
RCA (%)	0% M	5% M	10% M	15% M
0	0.89	-	-	-
25	0.87	0.88	0.86	0.86
50	0.87	0.87	0.87	0.86
75	0.85	0.86	0.85	0.82

RCA --- Recycled Coarse Aggregate, M --- Micro silica

as the percentage of RCA and micro silica increased in mix the workability of concrete were reduced. The percentage of reduction is 3.84%, 3.84% and 8.18% for 25 %, 50% and 75% respectively as compare to control specimen.

4.3 Compressive strength

The results of the compression tests carried out at age 28 days for the recycled concretes and for the conventional for the different replacement percentages are shown Fig. 3. Each of the reported values represents the average of three tests. Fig. 3 shows that for recycled concretes, the compressive strength of recycled concrete is lower to that of the original concrete.



Graph 3: compressive strength experimental results

Table 3: Result of compressive strength (Mpa) test for concrete mix

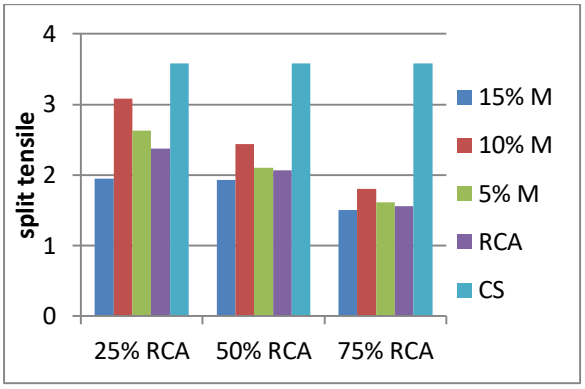
RCA (%)	0% M	5% M	10% M	15% M
0	40.38	-	-	-
25	28.49	39.16	39.37	37.93
50	26.92	36.72	38.52	36.16
75	23.47	32.98	34.18	30.05

RCA --- Recycled Coarse Aggregate, M --- Micro silica

But as compare to target strength the 25% replacement with addition of 10% micro silica gives more compressive strength. As the percentage of replacement of aggregate and addition of micro silica were increased the compressive strength got decreased to 6.25%, 11.02% and 29.33% for 25%, 50% and 75% replacement respectively for max micro silica dose.

4.4 Splitting Tensile Strength

The splitting tensile strengths of recycled concretes and of conventional concretes as the average of three tests in each case are presented in Fig. 4. For RCA concretes,



Graph 4: split tensile experimental results

Table 4: Result of split tensile strength (Mpa) test for concrete mix

RCA (%)	0% M	5% M	10% M	15% M
0	3.58	-	-	-
25	2.37	2.63	3.08	1.95
50	2.07	2.10	2.44	1.93
75	1.56	1.61	1.80	1.5

RCA --- Recycled Coarse Aggregate, M --- Microsilica

the splitting tensile strength of recycled concretes were decreased as the percentage of recycled aggregate and micro silica increased, whereas the concrete made with 75% of recycled aggregate exhibits a very low strength that is 81.80% lower.

5. CONCLUSIONS

The graph plotted using the results are shows results with addition of microsilica. Hence from the results we can conclude that Micro silica improves the strength as discussed before.

1) The water absorption of recycled aggregate is more as compare to the natural aggregate.
2) As the percentage of microsilica increases workability of concrete get decreased.
3) The incorporation of microsilica, significantly improves properties of recycled aggregate concrete up to 10% beyond which it get declines.
4) The outcome of research suggests potential to increase current recommended fraction of recycled aggregate in concrete.

REFERENCES:

1) Claudio Javier Zega and Angel Antonio Di Maio 2011, “Recycled Concretes Made with Waste Ready-Mix Concrete as Coarse Aggregate”. ASCE
2) De-jian YANG ,Ya-han HAO and Tie-cheng W 2010, “Experimental Research on Recycled Aggregate Concrete for Highway Pavement”. ASCE
3) Rattapon Somna, Chai Jaturapitakkul, A.M.ASCE, Wichian Chalee and Pokpong Rattanachu 2012, “Effect of the Water to Binder Ratio and Ground Fly Ash on Properties of Recycled Aggregate Concrete”. ASCE
4) Verma Ajay, Chandak Rajeev and Yadav R.K. 2012, “Effect of Micro Silica on The Strength of Concrete with Ordinary Portland Cement,” IJSR Vol. 1(3), 1-4, Sept.
5) Viviana Letelier , Ester Tarela , Pedro Munozb, Giacomo Moriconi 2016, “Combined effects of recycled hydrated cement and recycled aggregates on the mechanical properties of concrete”. Science Direct
6) Nwzad Abduljabar Abdulla 2014, “Effect of Recycled Coarse Aggregate Type on Concrete”. ASCE
7) IS 456:2000, Plain and Reinforced Concrete- code of practice (fourth revision), Bureau of Indian Standards, New Delhi- 110002
8) IS 10262, Recommended Guidelines for Concrete Mix Design (fifth revision), Bureau of Indian Standards, New Delhi- 110002