JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

STANDARD RECYCLED AGGREGATE CONCRETE INCORPORATE WITH MICRO SILICA

UTKARSH PRADEEP KULKARNI
ME Student, Department of Civil Engineering, KJEI'S Trinity College of Engineering And Research, Pune

PROF. VAIBHAV SHELAR
Professor, Department of Civil Engineering, KJEI'S Trinity College of Engineering And Research, Pune

Abstract: - The continuous global demand for infrastructure due to persistent increase in population growth implies that more aggregate and cement would be required in concrete production. This would eventually lead to more extraction and depletion of natural resources and increased carbon emission. The continuous global demand for concrete comprises that more aggregate and cement requirement. This leads to more extraction, depletion of deposits of natural gravel, and increased CO_2 emission from quarrying activities. Partial substitution of natural aggregate with recycled aggregate would lead to reduction in construction cost and carbon emission of the construction industry. Concrete is a heterogeneous material comprising fine aggregate, coarse aggregate, potable water and the binder known as cement. The presence of coarse aggregates contributes more to the heterogeneity. An aggregate consumes about 60% to 75% of the overall volume of concrete. The aim of this research work was to develop high performance concrete using recycled coarse aggregate, microsilica, and synthetic macro fibre with the object to boost higher use of recycled coarse aggregate in the construction industry. 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 day's 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. In this paper experimental results were shown for recycled aggregate incorporating with micro silica.

Key words:- 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. The presence of coarse aggregates contributes more to the heterogeneity. An aggregate consumes about 60% to 75% of the overall volume of concrete. Although, concrete is characterized by very advantageous features ranging from cost effectiveness, durability, outstanding compressive strength, and availability, 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, as a result of depletion of the natural resources. Growing disposal problems and huge energy consumption in quarrying activities, has affects the nature. The increasing demand for infrastructure, As a result of industrialization and urbanization has lead to more consumption of concrete. Concrete is the most widely consumed resource in the world after water and also the most widely used construction material in the last few decades.

1.1 Background

During the crushing process and due to having loose mortar cover on surface of aggregate, Recycled aggregate has micro cracks on it. As a result of this, bond between cement and aggregate is weak. This is responsible for the low concrete strength and low workability.

By using recycled aggregate compressive strength of concrete get reduced as compare to the concrete from natural aggregate Researchers found that the replacement up to 30% [2], but this replacement gives lower strength than virgin aggregate. The use of mineral admixture (i.e. micro silica) could enhance the physical and engineering properties of recycled aggregate concrete. Micro silica contributes both physically and chemically in concrete mix. The size of micro silica particles is smaller than that of cement. This will results in reduction of the average size of pores present in cement paste. While the chemical contribution takes place mainly by acting as an efficient pozzolanic material, which enables even distribution and higher volume of hydration products.

1.2 Aim

The major aim of this research is to develop conventional standard concrete using recycled coarse aggregates as substitute for natural coarse aggregate and mineral admixture (micro silica), in order to improve the properties of recycled aggregate concrete. With an additional goal to boost the potential of increasing its uses from the recommended 30% level from some past researchers. Adequate factual scientific information is thereby required to establish the mechanical and physical characteristics of concrete incorporating above-mentioned materials.

1.3 Objectives

The objectives are to;

1) Determination of fresh and hardened properties of concrete incorporating various percentage of recycled coarse aggregate content;
2) Evaluate the effect of addition of mineral admixture (micro silica) on concrete produced in (1) above;
3) Determine the optimal use of micro silica required to achieve good strength concrete produced in (2) above;
4) Evaluate the flexural performance of nominal reinforced concrete incorporating micro silica which produced the optimal effect in above.

The outcome of this research will provide better understanding about the properties of recycled aggregate concrete produced from the aforementioned materials, and contribute greatly in ensuring that the construction sector increases the use of recycled coarse aggregate beyond the current recommendation. This research is also limited to the use of recycled coarse aggregate as a replacement for natural coarse aggregate, microsilica as an addition to cement respectively.

1.4 Significance of Research

The following listed are potential benefits from this research work to the construction industry and the environment. These are;

1) Reduction of pressure on landfills from construction and demolition debris;
2) Potential to increase the use of recycled coarse aggregate beyond the maximum recommended 30%;
3) Conservation of natural resources through reduction in the use of natural coarse aggregate for concrete work;
4) Mitigation of performance issue like low strength associated with recycled aggregate by incorporating micro silica (mineral admixture) in the concrete mix;
5) Potential application of recycled coarse aggregate in structural concrete.

2. LITERATURE SURVEY

Claudio Javier Zega and Angel Antonio Di Maio has done research on recycled concretes made with waste ready-mix concrete as coarse aggregate. In this paper they have prepared cubes and cylinders for 17Mpa & 30Mpa grade. For low-grade concrete (17Mpa), the objective was to produce recycled concrete with characteristics similar to those of the source concrete. For M30 concrete, the goal was to manufacture a recycled concrete with a satisfactory strength level and acceptable durability properties. They were used recycled coarse aggregates obtained by crushing waste ready-mix concrete. The mechanical and durability properties of recycled concretes has checked for concrete made by using 25, 50, and 75% of replacement of recycled aggregates. The compressive strength up to 50%

replacement of aggregate gave 10% lower strength and 75% replacement of aggregate gave 19% lower strength. Split tensile test was also shown low result.

De-jianYANG ,Ya-han HAO and Tie-cheng W, has done experimental Research on Recycled Aggregate Concrete for Highway Pavement 2010**;** This research paper uses recycled aggregate replacements for 30%, 50%, 70% and 100% were investigated. They prepared M25 grade concrete. From obtained results they conclude that the replacement ratio of recycled aggregate gives less results for compressive strength of concrete.

RattaponSomna; Chai Jaturapitakkul, A.M.ASCE; WichianChalee; and PokpongRattanachu did research on the effect of the Water to Binder Ratio and Ground Fly Ash on Properties of Recycled Aggregate Concrete. This research paper gives results for the mix proportions of normal concretes and recycled aggregate concretes, which had W/C (water to cement ratio) of 0.45, 0.55, and 0.65. For normal concrete, the mix proportion was designed by using ACI method. Recycled aggregate concrete was made with the same mix proportion of normal concrete, except that the recycled coarse aggregate was fully used to replace the crushed limestone. In addition, ground fly ash was also used to replace the OPC at 20, 35, and 50% by weight of cement in the recycled aggregate concretes. From this replacement & W/C ratio the maximum compressive result obtained was 42.7Mpa at 0.45 ratios with 20 % replacement of ground fly ash. Latter increasing W/C ratio and replacement of ground fly ash will decrease the compressive strength.

Verma Ajay, Chandak Rajeev and Yadav R.K. have explained the effect of microsilica on The strength of concrete with ordinary portland cement 2012)**ISCA[4]** *Vol. 1(3), 1-4, Sept. (2v 012)***;**

In this they prepared M30 concrete with different % of micro silica like 5%, 10%, 15% & 20%, they found following results.

They conclude that silica fume increases the strength of concrete up to 25%. Silica fume is much cheaper then cement therefore it very important form economical point of view. Silica fume is a material which may be a reason of Air Pollution this is a byproduct of some Industries. Use of silica fume with concrete decrease the air pollution. Silica fume also decrease the voids in concrete. Addition of silica fume reduces capillary, Absorption and porosity because fine particles of silica fume reacts with lime present in cement. The results obtained are as below.

Viviana Letelier , Ester Tarela, Pedro Munozb, Giacomo Moriconi done their research on combined effects of recycled hydrated cement and recycled aggregates on the mechanical properties of concrete. In these paper analyses of the mechanical properties of concrete manufactured replacing different amounts of cement and natural coarse aggregates with recycled hydrated cement and recycled aggregates respectively. The goal is to determine their optimal combination to maximize the reuse of recycled materials, and also maintaining the performance of the material and minimizing its environmental impact. The levels of the percentage of RA considered were 20%, 30% and 40%. The levels of the percentage of RHC replacing cement considered were 5%, 10% and 15%, chosen.

The strength of control specimen was 32.1, as the replacement of aggregate & recycled hydrated cement the compressive strength of concrete was reduced. The maximum results obtained after replacement was 28.6 at the replacement of 20% aggregate & 5% recycled hydrated cement. After that strength was reduced rapidly. From this they conclude that the amount of cement replaced by the reused powder shows a low significance, but still perceptible. A loss of the strengths, both compressive and flexural, takes place when the amount of the RA increases, due to the low quality of the aggregates used.

Bin Yan, Liang Huang, Libo Yan, Chang Gao, BohumilKasal has gave behaviour of flax FRP tube encased recycled aggregate concrete with clay brick aggregate. In researcher use recycled aggregates mainly came from concrete rubble, but the use of RAs from masonry rubble for recycled aggregate concrete is very rare. This study reported the compressive behaviour of flax FRP tube encased recycled aggregate concrete containing partially clay brick aggregate which was termed as FFRP- recycled aggregate concrete - clay brick aggregate. For the recycled aggregate concrete, up to 70% of natural coarse aggregates were replaced by recycled aggregates. The recycled aggregate consisted mainly of 60% of recycled clay brick aggregates and 40% of recycled concrete and mortar aggregates. A total of 36 cylindrical specimens including 24 FFRP-RAC-CBA and 12 unconfined RAC-CBA were tested under uni-axial compression. The testing variables included: (i) strength of RAC-CBA (i.e. 27.5 MPa and 32.8 MPa); (ii) thickness of FFRP tube (i.e. 3, 6, 9 and 12 FRP layers); and (iii) size of cylinder (i.e. 75 X 150, 150 X 300 and 300 X600, unit of mm). Tests results indicated that the natural FFRP tube enhanced the ultimate strength and ductility of the confined RAC-CBA remarkably, the enhancement was more pronounced in specimens with higher concrete strength. Increasing FFRP thickness led to higher compressive stress and strain of the FFRP-RAC-CBA. Compared with natural aggregate concrete, the RAC-CBA had reduced compressive strength.

FFRP tube confinement had significantly enhancement on both strength and ductility of the tube confined RAC-CBA cylinders, i.e. for medium-sized FFRP-RAC-CBA, the ultimate compressive strength increased by 51% due to 9-layer FFRP tube confinement. With an increase in FFRP tube thickness, the ultimate compressive strength of the confined RAC-CBA increased.

NwzadAbdul jabar Abdulla explain the effect of recycled coarse aggregate type on concrete. In this research paper they promote the use of local waste as 100% alternative coarse aggregate in construction industry, an experimental program was carried out using samples of main Iraqi building waste. The types of aggregate used represent the three main constituents within recycled aggregates: unbound stone, crushed concrete and crushed brick. Tests for mechanical properties of different types of recycled aggregate included crushing value and abrasion resistance. Using multilinear correlation analysis, the influences of these aggregate characteristics and other parameters on the properties of recycled aggregate concrete were evaluated.

In this they have taken different test on recycled aggregate like size & shape, water absorption strength. The particle shape was determined by the EI and FI index. These values affected the strength of the particles and were higher for RA because of the crushing process, which resulted in less equidimensional, rough-surface, angular particles when compared with the rounded, smooth-surface, uncrushed Natural Aggregate. The strength of different types of aggregates was measured by the crushing value and abrasion test (Los Angeles). All types of RA exhibited lower resistance to crushing under gradual compressive load than that of NA. The open structure bricks and limestone were more brittle and resulted in CV values higher than that of NA by 92, 120, and 89%. In the slump testing they observed that The shape and texture of recycled aggregate affected the workability, yielding higher water absorption values over that of natural aggregate, which affects the slump values (40, 50, and 45 mm) compared with the 55-mm target for natural aggregate concrete. The density for replaced aggregate concrete was less than that of natural aggregate by 8, 9, and 5%, despite originating from the same parent aggregates. From this they conclude that recycled aggregate have low density so it can be used for light weight concrete. The concrete which is made by using recycled aggregate cannot be used for road & pavement purpose it can only be used for normal concreting work.

3. EXPERIMENTAL INVESTIGATION

To work with recycled aggregate concrete standard size moulds were used, total 84 specimens were casted, out of which 39 cubes of 150mm x 150mm x 150 mm size, 39 cylinder of 150mm x300 mm size. The beams were casted for maximum results obtained from the cube & cylinder for single replacement and addition design. The size of beam was 150mm x150mm x700mm.

2.1 Materials

2.1.1 Cement

Cement used is Ordinary Portland cement. (OPC). The color of the cement is due to iron oxide. In the absence of impurities, the color of cement is gray. Ordinary Portland cement (OPC) – 53 grade (Birla Shakti Cement) is used.

2.1.2 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.

2.1.3 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.

2.1.4 Recycled Coarse Aggregate

Aggregate was obtained from college campus, the beam & cube 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

2.1.4.1 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.

2.1.5 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 efflloresce, 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 → 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		0.40
Chloride (Cl)		0.03

%by mass	BS EN 196-2	
Loss on Ignition % by mass		2.10

2.1.6 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. Firstly, 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.

4. 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. firstly 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) in three layers with each layer compacted by 25 times using tamping rod & the vibrating table in order to expel any entrapped air.

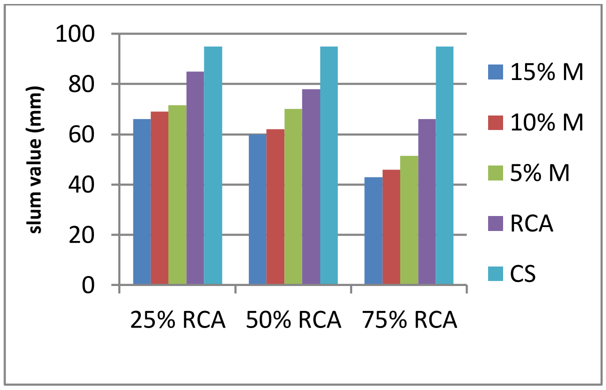
The surface was gradually levelled with steel hand trowel. The concrete samples were thereafter de-moulded and cured in the water tank at about 20°C.

5. 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 microsilica.

4.1 Workability test: slum test-

The result shows that as the percentage of recycled coarse aggregate, incorporating with increasing percentage of microsilica 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% microsilica.



Graph 1: slum value experimental results

Table1: Result of slump test for concrete mix

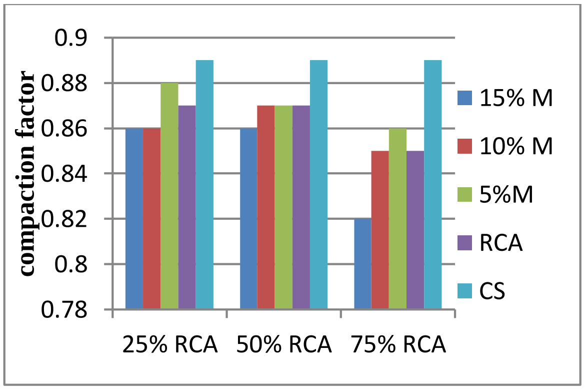
RCA (%)	0%M (mm)	5% M (mm)	10% M (mm)	15% M (mm)
0	95	-	-	-
25	82	71.5	69	66
50	78	70	62	60
75	66	51.5	46	43

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

The incorporation of microsilica 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

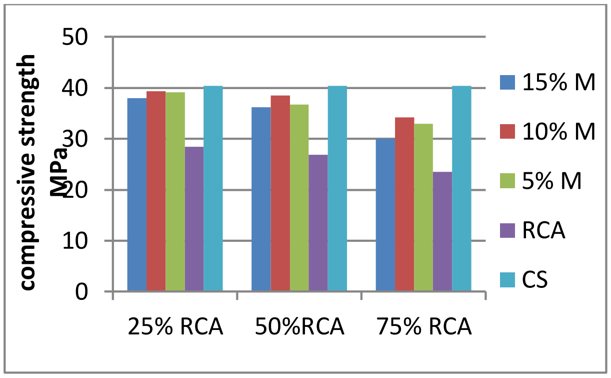
RCA (%)	0% M	5% M	10% M	15% M
0	0.89	-	-	-
25	0.87	0.88	0.86	0.86
50	0.87	0.87	0.87	0.86
75	0.85	0.86	0.85	0.82

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

as the percentage of RCA and microsilica 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

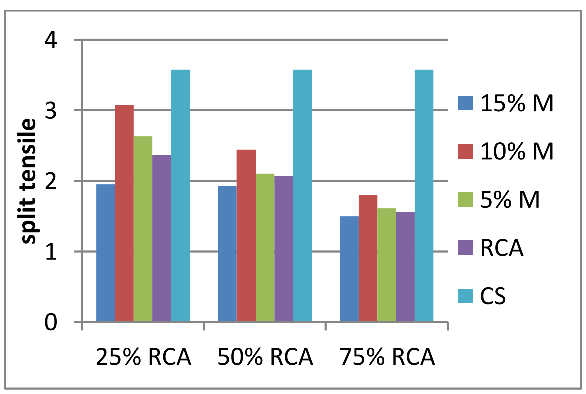
RCA (%)	0% M	5% M	10% M	15% M
0	40.38	-	-	-
25	28.49	39.16	39.37	37.93
50	26.92	36.72	38.52	36.16
75	23.47	32.98	34.18	30.05

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

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

5. Conclusion

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 decreases.
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