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VARIATION IN STRENGTH OF RECYCLED AGGREGATES CONCRETE USING MICRO SILICA

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Abstract- Recycled Aggregate in concrete can be useful for Environmental Protection. Recycled Aggregates are the materials for the Future. The Application of Recycled Aggregate has been started in a large number of Construction Projects of many European, American, Russian and Asian countries. The Waste generated during the Construction and Demolition activities include Sand, Gravel, Concrete, Bricks, Metal, Plastic, Glass etc. This Construction and Demolition Waste is mainly disposed in Landfills. Recycling and reuse of this Waste will result in preservation of Natural Resources, effective utilization of Growing waste stream, saving landfill space. The main aim of the study involves with the utilization of Recycled Aggregates as Coarse Aggregates in the preparation of Concrete.

In the present study Fresh aggregate Concrete, 100% Recycled Aggregate concrete and 5% Micro Silica+ 100% Recycled aggregate concrete had been prepared and compared their respective Compressive, Tensile and Flexural Strength for 7, 14 and 28 days. Recycled aggregate was used as replacement for Crushed gravel between 0-100% and addition of 5% of micro silica to the mix which consist of 100% recycled aggregates to investigate the use of higher percentage of recycled aggregates. There was a reduction in physical and mechanical properties with increase in the Recycled Aggregate content. Addition of 5% micro silica to the mix with 100% RA had shown a Compressive strength slightly higher than 100% RA without any Admixture.

Keywords - Recycled aggregate, Demolition, Natural Resources, Micro Silica, Compressive, Tensile and Flexural Strength.

I. Introduction

Concrete is a composite material composed of aggregate bonded together with fluid cement which hardens over time.

Any construction activity requires several materials such 2as concrete steel, brick, stone, glass, fibers, clay, mud, wood, and so on.

Rapid industrial development causes serious problems all over the world such as depletion of natural aggregates and creates enormous amount of waste material from construction and demolition activities. One of the ways to reduce this problem, is to utilize Recycled concrete aggregate (RCA) in the production of concrete .many significant researches have been carried out to prove that recycled concrete aggregate could be a reliable alternative as aggregate in production of concrete.

It is necessary to know the characteristics of RCA and the effects of using RCA in concrete. There are limited reliable data on the use of RCA in concrete and thus, more researches on the utilization of RCA should be carried out. In this research, the main concern is the testing of RCA and the resulting concrete made by it. RCA is the main component of old concrete and for many reasons there is a need to re-use them.

II. Advantages of Recycled Aggregates

It helps to promote sustainable development in the protection of natural resources, and reduces the disposal of demolition waste from old concrete.

It increases the drying shrinkage creep & porosity to water & decreases the compression strength of concrete compared to that of natural aggregate concrete.

It is important in getting rid of demolished concrete, which increases with time and use.

III. Disadvantages of Recycled Aggregates

- Less quality.
- Duration of procurement of materials may affect life cycle of project.
- Land, special equipments machineries are required (more cost).
- Very high water absorption (up to 6%).
- It has higher drying shrinkage & creep.

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Flow chart of micro silica

Micro silica is a mineral admixture composed of very fine solid glassy spheres of silicon dioxide (SiO2). Most micro silica particles are less than 1 micron (0.00004 inch) in diameter, generally 50 to 100 times finer than average cement or fly ash particles. Frequently called condensed silica fume, micro silica is a by- product of the industrial manufacture of ferrosilicon and metallic silicon in high-temperature electric arc furnaces. The ferrosilicon or silicon product is drawn off as a liquid from the bottom of the furnace. Vapor rising from the 2000-degree-C furnace bed is oxidized, and as it cools condenses into particles which are trapped in huge cloth bags. Processing the condensed fume to remove impurities and control particle size yields micro silica.

III Experimental Program

An experimental study is conducted to find out the compressive strength, Tensile strength and Flexural strength of concrete at 7days, 14 days and 28 days. In concrete mixing of 5% Micro Silica by weight of cement and natural aggregates (20mm) by weight, recycled aggregates (20mm) by weight and 4 grades of concrete was considered.

- M-30 grade of concrete were designed by IS method.
- The effect of partial replacement of cement by micro silica (5% by weight) and natural aggregate once and recycled aggregate once on compressive strength, tensile strength and flexural strength of concretes are investigated.

Design stipulations:

a) Grade of concrete: 30

b) Degree of quality control: Good

c) Characteristic Compressive Strength required in the field at 28 days 30 MPa.

d) Degree of Workability: low

e) Type of Exposure: moderate

f) Design Mix Target Slump (mm): 25-50mm

g) Standard Deviation for specified concrete: 5

Test Data of Materials:

a) Type of Materials

i) cement : Birla Samrat PSC(as per IS:455)

ii) Maximum size of Coarse aggregate(mm) :20mm

iii) Fine Aggregate: Zone-1

b) Specific Gravity:

i) cement:2.91

ii) C.A :2.80

iii) F.A: 2.76

c) Water Absorption:

i) CoarseAggregate (%):0.53

ii) Fine Aggregate (%):1.16

d) Grading of Coarse Aggregate (20mm)

Sieve Designation	% Finer	Permissible Limit	Remarks
40.00mm	100	100	Conforms to IS: 383-1970
20.00mm	98.6	85-100	
10.00mm	13.3	0-20	
4.75mm	1.1	0-5	

e) Grading of Fine Aggregate :

IS Sieve Size(mm)	% Finer	Permissible Limit	Remarks
10	100	100	Conforming to Grading Zone - I of IS: 383-1970
4.75	98.4	90-100	
2.36	81.8	60 - 95	
1.18	54.55	30 - 70	
0.6	26.2	15 - 34	
0.3	10.7	5.- 20	
0.15	4.8	0-10	

Target Mean Strength of Concrete : Trial - II

For a tolerance factor of 1.65 (Ref. Table - 30 of SP: 23-1982) and using Table - 8 (Clause 9.2.4.2 and Table - 11 of IS: 456-2000) for certain Standard Deviation , the target mean strength for the specified characteristic cube strength is :

Target Mean Strength = fck + t x s

= 30 + 1.65 x 5

= 38.25 N/mm²

Selection of Water - Cement Ratio :

From Table 5 of IS: 456-2000,

Maximum Water - Cement Ratio = 0.5

Based on the experience , adopt Water - Cement Ratio as = 0.39

0.39 < 0.5, Hence O.K

Selection of Water Content :

From Table 2 of IS: 10262-2009 , Maximum Water Content for 20 mm Coarse Aggregate = 186 Litre. (for 25 to 50mm Slump range) (Ref. IS:10262-2009, Cl. 4.2, Page-2)

Estimated Water Content for 25mm-50mm Slump = 186 Litre.

As Admixture (Hindplast - MMF) is used , the water content can be reduced up 20% and above Based on trials with Admixture, water content reduction of 10.8 % has been achieved.

Hence, the arrived water content = 186 X 89.2/100 Litre = 165.9 Litre.

Calculation of Cement Content :

Water - Cement Ratio = 0.39

Cement Content = 165.9 / 0.39 kg/m³ = 425 kg/m³

From Table 5 of IS: 456-2000, Minimum Cement Content for Moderate exposure condition = 300 kg/m³.

425 kg/m³ > 300 kg/m³ , Hence O.K.

Proportion of Volume of Coarse Aggregate and Fine Aggregate Content :

From Table 3 of IS: 10262 - 2009, Volume of Coarse Aggregate corresponding to 20 mm size aggregate and Fine aggregate Zone - I for Water - Cement Ratio of 0.50 = 0.60.

In the present case Water - Cement ratio is 0.39 .

Therefore, Volume of Coarse aggregate is required to be increased to decrease the fine aggregate Content .

As the Water-Cement ratio is lower by 0.11 the proportion of volume of Coarse aggregate is increased by 0.03 (as the rate of +/- 0.01 for every +/- 0.05 change in Water - Cement Ratio.)

Therefore, Corrected proportion of volume of Coarse Aggregate for the Water-Cement Ratio of 0.39 = 0.63

Therfore, Volume of Coarse Agrregate = 0.63

Volume of Fine Aggregate = 1 - 0.63 = 0.37

Design Mix Calculations (Ref. IS: 10262-2009) :

The Mix Design Calculations per unit Volume of Concrete shall be as follows :

a) Volume of Concrete = 1 m³

b) Volume of Cement = Mass of Cement /Specific Gravity of Cement X 1000

= 425.00 /2.91 X 1000 = 0.146 m³

c) Volume of Water = Mass of Water /Specific Gravity of Water X 1000

= 165.90 /1 X 1000= 0.166 m³

d) Volume of Admixture= Mass of Admixture /Specific Gravity of Admixture X 1000

= 2.125/ 1.03 X 1000= 0.002 m³

e) Volume of all in Aggregate = [Vol. of Concrete - (Vol. of Cement + Vol. of Water + Vol. of Admixture)]

= 1 - (0.146 + 0.166 + 0.002)

= 0.686 m³

f) Mass of Coarse Aggregate = Vol. of all in Aggregate X Vol. of Coarse Aggregate X Specific Gravity Coarse X 1000

= 0.686 X 0.63 X 2.8 X 1000

= 1210.1 Kg.

g) Mass of Fine Aggregate = Vol. of all in Aggregate X Vol. of Fine Aggregate X Specific Gravity Fine X 1000

= 0.686 X 0.37 X 2.76 X 1000

= 700.54 Kg.

Mix Proportions for Trial Mix :

Cement (kg/m³) = 425.00

Water (kg/m³) = 165.90

Fine Aggregate (kg/m³) = 700.54

Coarse Aggregate(kg/m³) = 1210.1

Water-Cement Ratio = 0.39

(60% of 20mm Coarse Aggregate & 40% of 10mm Admixture (kg/m³) = 2.13 Coarse Aggregate)

Result of Trial Mix :

Three trial tests were carried out in the Laboratory to get the above target mean strength i.e = 38.25 N/mm²

Based on the three trials Trial - II is recommended for Mix Design of M30 Grade Concrete considering all aspects.

Slump = 35mm

Trial - I

Average 7 days Cube Compressive Strength = 25.58 N/mm² Average 28 days Cube Compressive Strength = 36.22 N/mm² **Trial - II (Recommended)**

Average 7 days Cube Compressive Strength = 29.64 N/mm² Average 28 days Cube Compressive Strength = 39.46 N/mm²

Trial - III

Average 7 days Cube Compressive Strength = 32.22 N/mm² Average 28 days Cube Compressive Strength = 43.48 N/mm²

The Slump shall be measured and the Water Content and dosage of Admixture shall be adjusted for achieving the required slump based on the trial, if required .

The mix proportions shall be reworked for the actual Water-Cement and checked for durability requirement. Two more trials have variation of +/- 10% of Water-Cement Ratio have been carried out. However, durability requirement has been taken care of.

Normally 3 trials are done. The based on three trials the optimum test results (Trial -II) are recommended. Hencec other two are not normally given.

IV RESULTS AND DISCUSSIONS

IV.I Results of Compressive Strength:

Table 4.1 Compressive strength of NA, RA and RA+5% MS.

S.No	Materials (**cubes**)	7 days	14 days	28 days
1	Natural Aggregates	38.4 N/mm^2	40.5 N/mm^2	42.7 N/mm^2
2	Recycled Aggregates	32.75 N/mm^2	36.1 N/mm^2	38.9 N/mm^2
3	Recycled Aggregates + 5% micro silica	35.10 N/mm^2	38.7 N/mm^2	41.7 N/mm^2

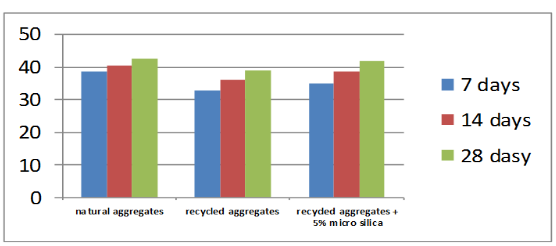


Fig: 4.1 Bar Chart showing the Compressive Strength

Fig: 4.2 Showing the Test Performance

IV.II **Results of Split Tensile Strength**

The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force.

Table 4.2 Flexural strength of NA, RA and RA+5% MS.

S.No	Materials (**beams**)	7 days	14 days	28 days
1	Natural Aggregates	5 N/mm^2	4.10 N/mm^2	4.56 N/mm^2
2	Recycled Aggregates	4.25 N/mm^2	3.64 N/mm^2	4.15 N/mm^2
3	Recycled Aggregates + 5% micro silica	4.5 N/mm^2	3.9 N/mm^2	4.45 N/mm^2

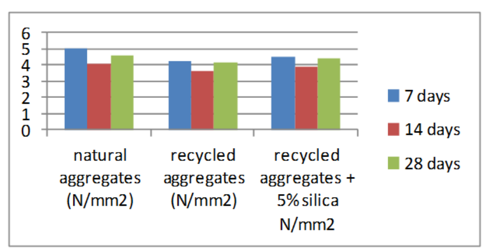


Fig: 4.3 Bar Chart showing the Split Tensile Strength

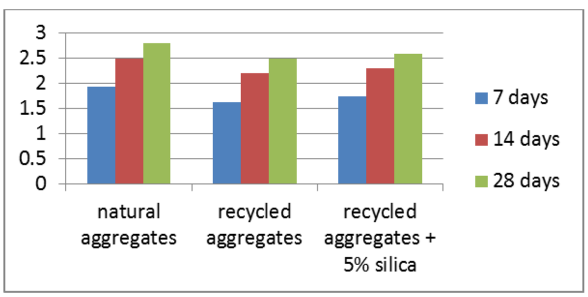
Fig: 4.4 showing test by Split Tensile Strength

IV. III Results of Flexural Strength

For a rectangular sample under a load in a four-point bending setup where the loading span is one-third of the support.

Table. 4.3 Split tensile strength of NA, RA and RA+5% MS.

S.No	Materials (cylinders)	7 days	14 days	28 days
1	Natural Aggregates	1.94 N/mm^2	2.5 N/mm^2	2.8 N/mm^2
2	Recycled Aggregates	1.64 N/mm^2	2.2 N/mm^2	2.5 N/mm^2
3	Recycled Aggregates + 5% micro silica	1.75 N/mm^2	2.3 N/mm^2	2.6 N/mm^2



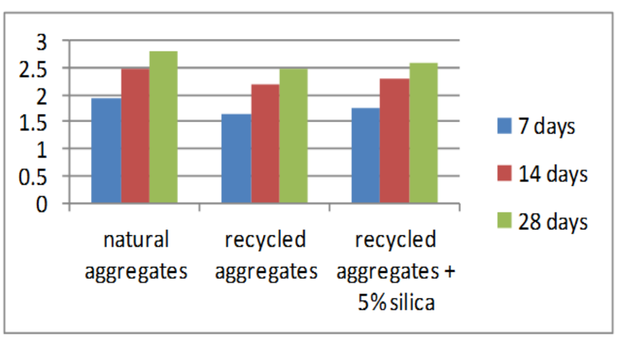


Fig: 4.4 Bar Chart showing the Flexural Strength

Comparative Graph

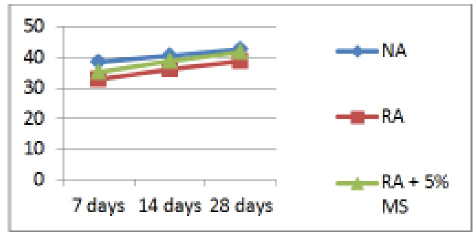


Fig: 4.5 Graph showing Compressive strength between NA, RA, RA+5% MS

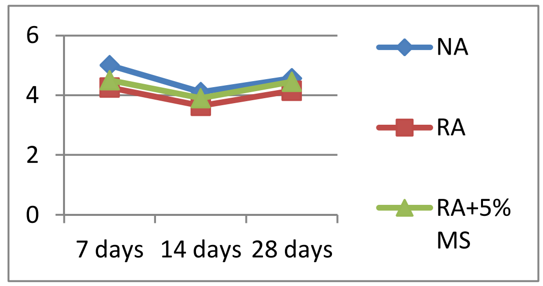


Fig: 4.6 Graph showing the Flexural strength between NA, RA, RA+5% MS

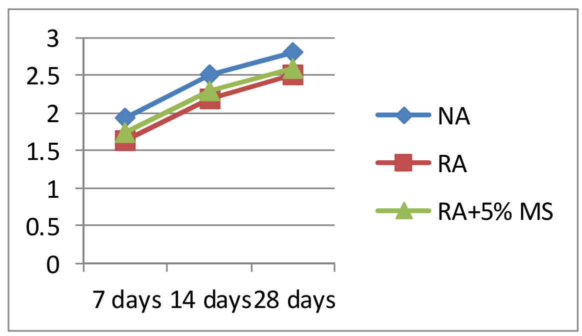


Fig: 4.7 Graph showing the Split tensile strength between NA, RA, RA+5% MS

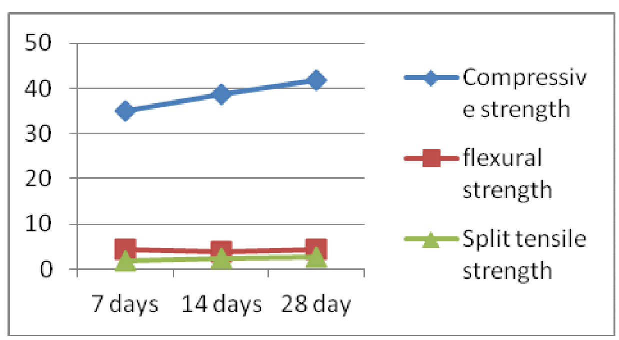


Fig: 4.8 Graph showing the Difference between Compressive strength , flexural strength and Split tensile strength of recycled aggregates + 5% micro silica for 7, 14 and 28 days.

V. Conclusions

Based on the experimental investigation carried out, the following conclusions are.

1. The 7 days/ 14 days/ 28 days compressive strength of all the reference concrete mixes with M30 grade was satisfying the required design strength criteria.
2. The recycled admixture concretes are showing decreasing in strength but the strength is reduced marginally with the addition of recycled aggregates used as replacement to conventional aggregates. However, the strengths are agreeable for practical construction.
3. The addition of Micro Silica is helpful in increasing the compression and split tensile strength with recycled aggregate.
4. The compressive strength and split tensile strength consisting of micro silica almost follow the same pattern of the compressive strength with addition of recycled aggregate.
5. The Micro Silica may be costly but the utilization of recycled aggregate can be increased with blending of cement with micro silica.
6. On the whole 5 % micro silica is found to give optimum concrete mixes with recycled aggregates.
7. By resorting to concretes admixture with micro silica and using recycled aggregates more sustainable concrete can be produced possessing economy and more durability also.
8. Use of recycled waste aggregate contributes towards cleaner environment.

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