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Flexural Behaviour of Reinforced Recycled Aggregate Concrete Beams

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ABSTRACT

Recycling of waste concrete is one of the critical and sustainable solutions for the increasing disposal of waste crisis and depletion of natural coarse aggregate as well as fine aggregate sources. As a result, RCA i.e, recycled coarse aggregate is produced and upto now it has generally been utilized in low value applications like pavement base. But, it is essential to study in the terms of strength and durability of the RCA based concrete. In the present experimental study, in order to study the flexural behavior of RAC high strength concrete prepared with glass fibers when compared to the behavior of natural aggregate concrete beams under short-term loading. M50 grade concrete was developed by using silica fume as mineral admixture in the dosages ranging from 0-20% with increments of 5% and 1.5% SP along glass fibers in the volume fractions of 0.5-2% with increments of 0.5%. Further, RCA in the increments of 0-100% was studied and a optimal mix is chosen and glass fiber reinforced recycled coarse aggregate concrete beans were casted and tested for flexural behavior. It is concluded that, the utilization of RAC in concrete beams along with glass fibers is technically feasible.

KEYWORDS:*Recycled Aggregate, High Strength Concrete, Glass Fibers, Silica Fume*

INTRODUCTION

Large quantities of concrete waste have been scrapped and discarded throughout numerous countries, which makes demolished concrete waste a serious global environmental concern. Several efforts have been made to decrease its environmental impact and to encourage the recycling of demolished concrete. However, ways to reuse demolished concrete usually are limited to pavement base or backfill for retaining walls, which do not necessarily require structural high performance. Several studies (Dhir et al., 1999; Fathifazl et al., 2009; Khatib, 2005; Kim et al., 2002; Maruyama et al., 2004; Xiao et al., 2005) have been carried out in an attempt to expand the recycling rate and uses of concrete waste in the construction industry; these studies have examined mechanical properties, mixture design, design specifications and so on. It has been found that the mechanical properties of recycled aggregate concrete (RAC) may be inferior to those of conventional concrete that uses natural aggregate, but that RAC is still sufficient for some practical applications in the construction industry (Xiao et al., 2005). For example, recycled fine aggregate up to 20% or recycled coarse aggregate up to 30% can be used as replacement aggregate without any reduction in strength (Khatib, 2005). Furthermore, the material properties of recycled concrete with a replacement of 30–60% are comparable with those of reinforced concrete (RC) structures made of natural aggregate (Dhir et al., 1999). For structural applications, Kim et al. (2002) investigated the flexural behaviour of RAC with various replacement ratios of recycled coarse aggregate of 15%, 30%, 50% and 100%, and also investigated concrete compressive strength. Their results show that flexural strength decreases with 100% replacement of coarse aggregate, but with 50% replacement of coarse aggregate there is a possibility of practical applications for RAC. The yield load and maximum flexural capacity of the RAC beams are similar to those of RC members that use natural aggregate. Maruyama et al. (2004) investigated the flexural performance of RAC using various water–cement ratios and various types of recycled aggregate: virgin coarse and fine aggregate, recycled coarse aggregate with virgin fine aggregate, and recycled coarse and fine aggregate. Their results show that the maximum flexural strength decreases for specimens at 100% replacement ratio, regardless of the water–cement ratio. More recently, Fathifazl et al. (2009) proposed a new mixture proportioning method that also shows that the flexural performance of RAC beams can be comparable to that of beams made withnatural aggregates. In addition, these researchers show that flexural theory and existing specifications used for the flexural design of conventional concrete beams are applicable to RAC beams. In short, the literature (Fathifazl et al., 2009; Kim et al., 2002; Maruyama et al., 2004) shows that the structural performance of RAC is dependent on the replacement ratio, and that the flexural strength values of RAC beams can be computed using the existing flexural analysis method that is used for conventional RC beams comprising natural aggregate. However, existing specifications for recycled aggregate are limited and do not take into consideration the design of structural components such as beams and columns. The effective use of recycled concrete – even including low grades of recycled aggregate – as a reliable structural component would significantly improve the rate of reuse and promote the sustainability of concrete. To that end, this study investigates the structural performance of full-size structures as well as analyses flexure and design guidelines for RC members that use recycled aggregate. Further, with the aim of increasing the recycling rate, this research assesses the applicability of a blended aggregate that uses high- and low-grade recycled aggregate, which at present is not sufficient as a structural grade aggregate that would meet the Korean industrial standard (KS). KS F 2573 (Korea Agency for Technology and Standards, 2006) specifies that the specific gravity of recycled coarse aggregate and fine aggregate should be above 2.5 and 2.2 g/cm3, respectively. For the recycled coarse aggregate, the water absorption of grades I, II and III should be less than 3%, 5% and 7%, respectively. For the recycled fine aggregate, the water absorption of grades I and II should be less than 5% and 10%, respectively. In addition, the KS recommends the application of recycled aggregate for less than a compressive strength of 27 MPa.

Earthquakes are one of the most destructive of natural hazards. Earthquake occurs due to sudden transient motion of the ground as a result of release of elastic energy in a matter of few seconds. The impact of the event is most traumatic because it affects large area, occurs all on a sudden and unpredictable. Earthquake not only damage villages, towns and cities but also leads to economic and social system of a country. The vibration can affects settlement. Some of the soil types like, alluvial or sandy, silts get fail during earthquake when compare to other soils. Earthquake can be measured by Magnitude (M) which was obtained by recording the data of motions on seismograms. But shaking of the ground surface will have different intensities at different locations for the same magnitude. This can be measured by MMI scale

EXPERIMENTAL INVESTIGATION

The experimental investigation consists of casting and testing of 18 sets along with control mix. Each set comprises of 5 cubes, for determining compressive strength. The admixture silica fume was used in the study with different percentages of recycled aggregate. Cube specimen dimension is of 15cmx15cmx15cm. The moulds are applied with a lubricant before placing the concrete. After a day of casting, the moulds are removed. The cubes are moved to the curing tank carefully.

The material characteristics that are used in this study given in brief are as follows:

- Ordinary Portland Cement 53 grade with specific gravity of 3.15
- Locally available river sand with bulk density of 1710 kg/m^3 and specific gravity of 2.67 and confirming to zone-II

- Coarse aggregate with bulk density of 1685 kg/m^3 and specific gravity of 2.81
- Silica fume with specific gravity of 2.20
- Water confirming to the requirements of water of concreting and curing as per IS ; 456 – 2000.
- Super Plasticizer: Conplast 430.
- Glass Fibers

COMPONENT MATERIALS

CEMENT

The cement used was ordinary Portland cement of 53- grade. The cement should be fresh and of uniform consistency. Where there is evidence of lumps or any foreign matter in the material, it should not be used. The cement should be stored under dry conditions and for as short duration as possible.

Table 3.1: Physical Properties of Cement

S.No	Property		Test Result
1.	Specific Gravity		3.15
2.	Normal Consistency		30%
3.	Setting Time	Initial	49 Minutes
		Final	395 Minutes
4.	Compressive Strength @ 28 days		53 MPa
5.	Specific Surface Area		369 m^2/Kg

Table 3.2: Chemical Composition of Cement

Chemical Content	Amount (%)
Calcium Oxide (CaO)	62.7
Silicon dioxide (SiO_2)	19.8
Aluminum Oxide (Al_2O_3)	6.3
Iron Oxide (Fe_2O_3)	3.6
Magnesium Oxide (MgO)	2.8
Sodium Oxide (Na_2O)	0.8
Potassium Oxide (K_2O)	1.7
Sulphur Trioxide (SO_3)	2.3

FINE AGGREGATES

Grading of the sand is to be such that a mortar of specified proportions is produced with a uniform distribution of the aggregate, which will have a high density and good workability and which will work into position without segregation and without use of high water content. The fineness of the sand should be such that 100% of it passes standard sieve No.8 (2.36 mm).

The fine aggregate which is the inert material occupying 60 to 75 percent of the volume of mortar must get hard strong nonporous and chemically inert. Fine aggregates conforming to grading zone II with particles greater than 2.36 mm and smaller than 150 mm removed are suitable.

Sand shall be obtained from a reliable supplier. It should be clean, hard, strong, and free of organic impurities and deleterious substance. It should inert with respect to other materials used and of suitable type with regard to strength, density, shrinkage and durability of mortar made with it.

Table 3.3: Properties of Fine Aggregate

S.No	Property	Values
1.	Specific Gravity	2.62
2.	Fineness Modulus	2.6
3.	Water Absorption	1%
4.	Grading of Sand	Zone – II

WATER

Water used in the mixing is to be fresh and free from any organic and harmful solutions which will lead to deterioration in the properties of the mortar. Salt water is not to be used. Potable water is fit for use mixing water as well as for curing of beams.

Table 3.10: Permissible Limits of Water As Per IS: 456-2000

S.No	Impurity	Maximum limit	Result
1.	p^H Value	6 to 8.5	7
2.	Suspended matter mg/lit	2000	220
3.	Organic matter mg/lit	200	20
4.	Inorganic matter mg/lit	3000	150
5.	Sulphate(SO_4) mg/lit	500	30
6.	Chlorides mg/lit	2000 for P.C.C. 1000 for R.C.C	60

TEST RESULTS & DISCUSSIONS:

Table 5 : Test Results of compressive strength of High Strength Concrete using silica fume at 7 days & 28 days of conventional curing

S.No	Mix Designation		Slump Cone (mm)	Compressive Strength (MPa) 7 days	Compressive Strength (MPa) 28 days
1.	M50 CM 1.5% SP	M1	36	34.65	58.21
2.	M50 (5%S.F) 1.5% SP	M2	33	35.12	58.87
3.	M50 (10% SF) 1.5% SP	M3	30	36.42	59.34
4.	M50 (15% SF) 1.5% SP	M4	27	34.66	57.18
5.	M50 (20%SF) 1.5% SP	M5	25	33.77	56.32

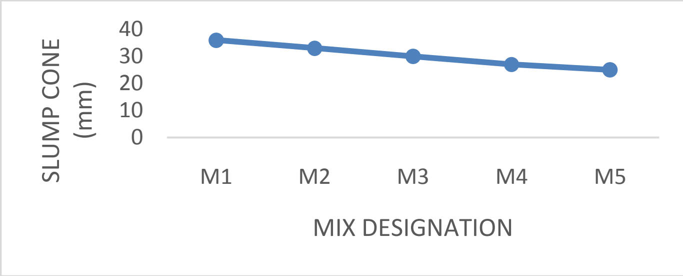

Fig.3 Slump Cone values of M50 grade HSC

From Fig.3, it can be concluded that with the increase in percentage replacement of mineral admixture i.e., silica fume, the workability values i.e., slump cone decreases.

Fig 4. Graph showing 7 &28 days compressive strength test results for M50 grade HSC

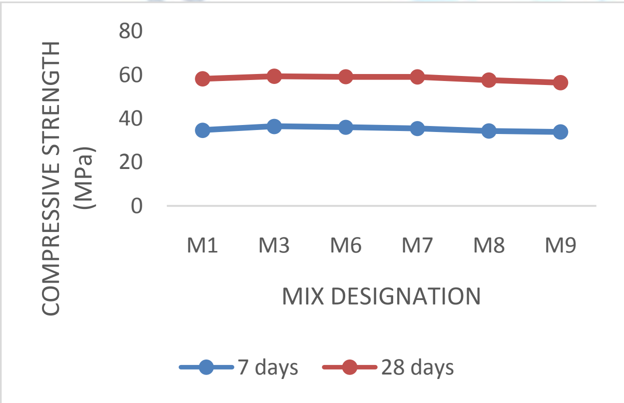

Table 6 : Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate at 7 & 28 days

S.No	Mix Designation		Slump Cone (mm)	Compressive Strength (MPa) 7 days	Compressive Strength (MPa) 28 days
1.	M50 CM	M 1	36	34.65	58.21
2.	M50 (10% SF)	M 3	30	36.42	59.34
3.	M50 (10%S.F+5 % RCA)	M 6	27	36.00	59.12
4.	M50 (10% SF+10% RCA)	M 7	25	35.42	59.00
5.	M50 (10% SF+15% RCA)	M 8	24	34.31	57.58
6.	M50 (10%SF+20 % RCA)	M 9	22	33.87	56.42

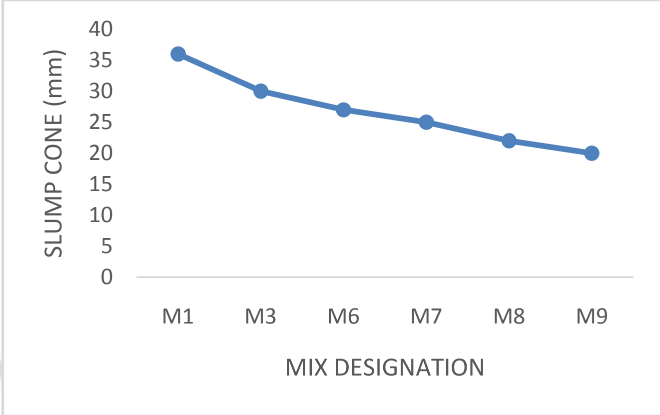

Fig.4 Slump cone values of M50 grade HSC with 10% SF and different replacement levels of RCA

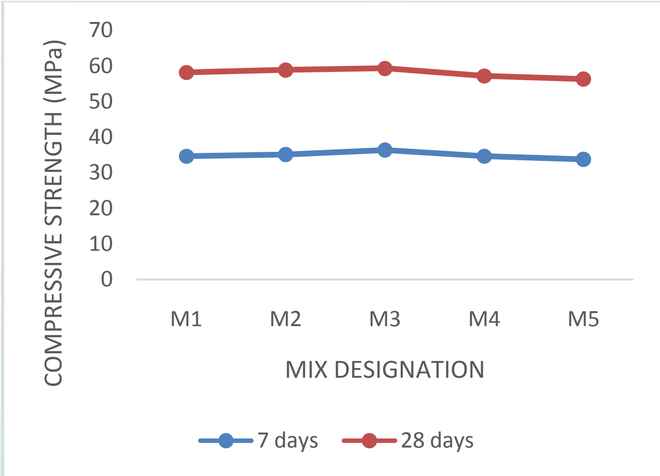

Fig.5 Graph showing compressive strength for 7, 28days when replaced with R.C.A

The Compressive strengths are consistently decreasing with the increase in the recycled aggregate content from 5% to 20% in the 10% partial replacement of Silica Fume admixture

(i) The compressive strengths are decreasing with the further increase in both the recycled aggregate content and mineral admixture content.

(ii) Eventhough the compressive strengths are not reaching the target mean strength of M50 grade HSC, the obtained values by utilizing RCA at 20% replacement levels are satisfactory.

(iii) Henceforth, Mix M-9 i.e., M50 grade HSC with 10% replacement of silica fume and 20% RCA was taken as reference mix in order to conduct the study with glass fibers.

Table 7 : Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate at 7 days& 28 days

S.No	Mix Designation		Compressive Strength (7 days) MPa	Compressive Strength (28days) Mpa
1.	M50 10%S.F+1.5%SP 30% RCA	M11	36.88	55.11
2.	M50 10%S.F+1.5%SP 40% RCA	M12	36.00	54.22
3.	M50 10%S.F+1.5%SP 50% RCA	M13	34.66	52.00
4.	M50 10%S.F+1.5%SP 75% RCA	M14	33.33	48.94
5.	M50 10%S.F+1.5%SP 100% RCA	M15	31.55	41.22

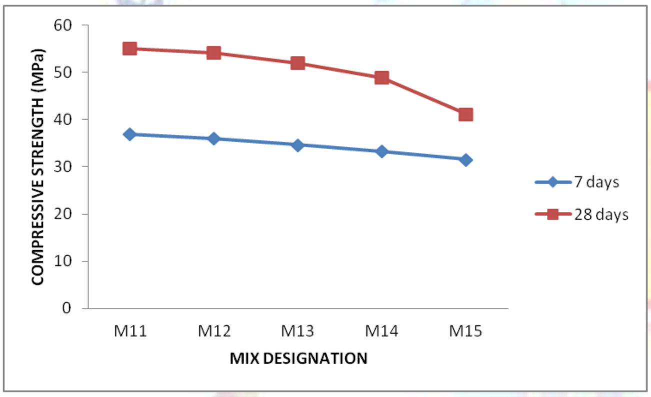

Fig.6 Graph showing cube compressive strength for 7,28 days

(i) From the above comparison, the cube compressive strength is maximum at the trail mix proportion M50 (10% SF + 30% RCA).

(ii) With the increase in the recycled coarse aggregate content, there is a decrease in the compressive strength.

(iii) Upto mix M13, the compressive strength values are found to be appreciable and henceforth, in order to increase the compressive strength, a strategy was follwed by imparting glass fibers to the mix.

Table :8 Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate and Glass Fiber

S.No	Mix Designation		% of glass fibers	Compressive Strength (7 days) MPa	Compressive Strength (28days) MPa
1.	M50 10%S.F+1.5%SP 50% RCA	M16	0	34.66	52.00
2.	M50 10%S.F+1.5%SP 50% RCA+0.5% GF	M17	0.5	36.88	56.00
3.	M50 10%S.F+1.5%SP 50% RCA+1% GF	M18	1.0	39.55	58.66
4.	M50 10%S.F+1.5%SP 50% RCA+1.5% GF	M19	1.5	41.33	60.88
5.	M50 10%S.F+1.5%SP 50% RCA+2% GF	M20	2.0	40.44	60.00

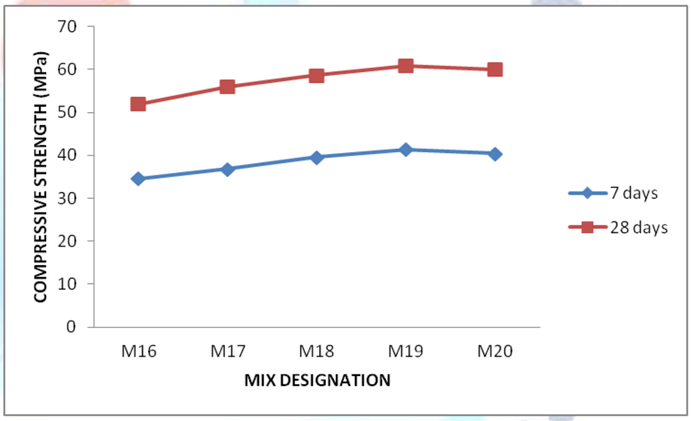

Fig.7 Graph showing compressive strengths after 7 and 28 days for M50 grade HSC with & without glass fibers

(i) From the above comparison, the cube compressive strength is maximum at the trail mix proportion M50 (10% SF + 50% RCA+1.5% GF)i.e, Mix M19.

(ii) With the increase in the fiber volume content, there is a increase in the compressive strength

(iii) M19 mix is considered as reference mix in order to cast the beam specimens to study the flexural behavior of concrete.

Load Vs Deflection of Beam

Table 9 : Shows the Load Vs Deflection of Reinforced Concrete Control Beam

S.No	Load (kN)	Deflection (mm)	Remarks
1	0	0	
2	5	0.162	
3	10	0.228	
4	15	0.424	
5	20	0.465	
6	25	0.525	FIRST CRACK
7	30	0.589	
8	35	0.680	
9	40	0.740	
10	45	1.020	
11	50	1.348	
12	55	2.465	
13	60	3.325	
14	65	4.681	
15	70	5.583	
16	75	6.430	ULTIMATE LOAD

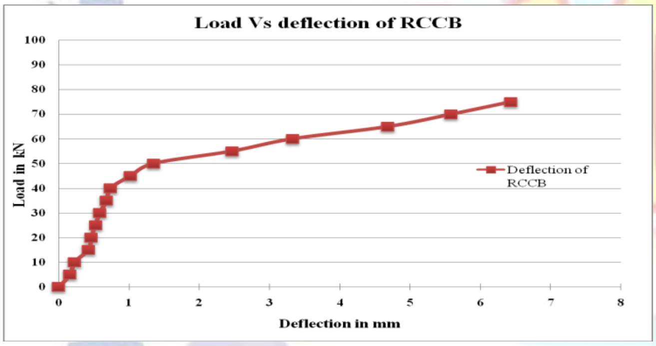

Fig.8 Graph Showing Load vs Deflection for Reinforced Concrete Control Beam

Table 10 : Shows the Load Vs Deflection of Glass Fiber Reinforced Concrete Beam

S.No	Load (kN)	Deflection (mm)	Remarks
1	0	0	
2	5	0.11	
3	10	0.13	
4	15	0.14	
5	20	0.26	
6	25	0.31	
7	30	0.33	
8	35	0.37	
9	40	0.40	
10	45	0.43	
11	50	0.48	FIRST CRACK
12	55	1.05	
13	60	1.50	
14	65	1.97	
15	70	2.35	
16	75	2.89	
17	80	3.12	
18	85	3.79	
19	90	4.12	ULTIMATE LOAD

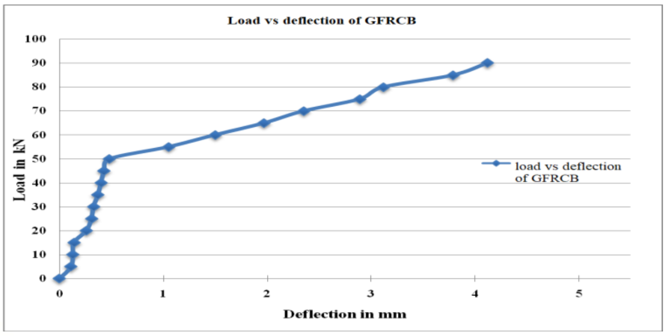

Fig.9 Graph Showing Load vs Deflection for Glass Fiber Reinforced Concrete Beam

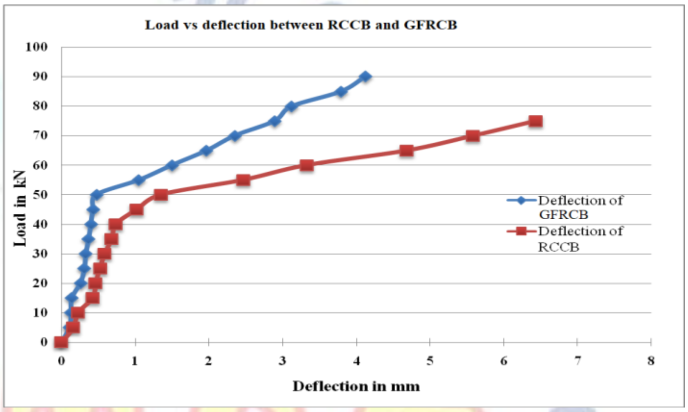

Fig.10 Graph Showing Load vs Deflection for RCCB AND GFRCB

CONCLUSION

(i) With the increase in recycled coarse aggregate content, the compressive strength is decreasing.

(ii) Of all the trial mixes, M50 (10% SF) with a replacement of 20% RCA has showed better results and it is taken as reference for the next phase of work.

(iii) More than 50 MPa compressive strength has been achieved by using 50% of recycled coarse aggregate with the trail mix M50 (10% SF).

(iv) It can be concluded that usage of 50% of recycled coarse aggregate in high strength concrete yields better economy without using glass fibers and in aspect of reducing environmental pollution & it is taken as reference for the next phase of work.

(v) With the addition of glass fibers it was found to be an increase in compressive strength of the high strength concrete with recycled coarse aggregate.

(vi) Of all the trial mixes with glass fibers, the mix M50(10% SF) and 1.5% glass fiber, showed an increase in compressive strength and the percentage increase was found to be 11.7% when compared with the mix without glass fiber i.e M50(10% SF) (50% RCA).

(vii) For M50 grade Reinforced Concrete Control Beam, the first crack load was obtained at a load of 25kN and the ultimate failure load was obtained at a load of 75kN.

(viii) For M50 grade Glass Fiber Reinforced Concrete Beam with silica fume as replacement to cement at 10% and with addition of glass fiber with a percentage of 1.5%, which has enhanced the mechanical properties of concrete, the first crack load was obtained at 50kN and the ultimate failure load was obtained at a load of 90kN.

(ix) With the use of silica fume and glass Fibers, the Concrete beam's performance was improved in terms of load carrying capacity.

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