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STUDY ON FLEXURAL BEHAVIOR OF RECYCLED AGGREGATE CONCRETE BEAMS USING GLASS FIBERS

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In this work, an attempt is made to investigate the influence of the glass fiber on the natural and recycled aggregate concrete. Ten beams of size 1500 mm x150 mm x 230 mm were cast and curing was done for 28 days. The flexural behavior of beams is studied in the present work with glass fiber for recycled aggregate concrete. There was total of five batches of concrete mixes for the grade M30 for natural and recycled aggregate. The glass fibers were added in proportion by 0.50%, 1%, 1.5% and 2% by weight of cement. The load carrying capacity of specimens with 100% (RCA) with 2% fiber content is increased by 14% compared to that of 100% (RCA) with 0.5% fiber content. Compared to beam A (NCA) 0%fibre, the moment of beam E (RCA) at 2%fibre is decreased by 6%. The investigations indicated encouraging results for Recycled Aggregate Concrete (RAC) beams with glass fibers in all aspects, thus, pointing to recycled aggregate as potential alternative source of aggregate.

Keywords: Recycled coarse aggregate, Natural aggregates, Glass fiber, Load-deflection, Moment-curvature.

1 INTRODUCTION

The transformation from a conventional consumption based society to a sustainable society is urgently required due to the pollution of the natural environment, the exhaustion of the natural resources and the decreasing capacity of the final waste disposal facilities. One of the ways to solve this problem is to use Building Demolished Waste (BDW) concrete as aggregate in structural concrete. The aggregate thus obtained can be called as Recycled Concrete Aggregate (RCA).It is therefore no wonder that the concepts of recycling are waste material and using it again in some form or the other as gathered momentum. As recycling not only solves the waste disposable problem, but are also reduces the cost and conserves the non-renewable natural resources an urgent need is being increasingly felt to evolve a suitable and variable technology for recycling.

One such area where this technology has made considerable headway is in the recycling of demolished concrete. The quantities of such concrete discarded every year have reached staggering figures of about 60 million tons in the United States of America; 50 million tons is in the European Economic Community’s and 10 to 12 million tons in Japan. It is estimated that these figures will increase nearly threefold in near future, thus necessitating urgent steps to recycle this waste materials.

Traditionally, Portland concrete aggregate from the demolition construction is used for landfill. But nowadays, Portland concrete aggregate can be as a new material for construction usage. According to recycling of Portland cement concrete, recycled aggregate are mainly produced from the crushing of Portland concrete payment and structures building. It stated that the isolated areas of 1 inch of asphalt concrete could be used to produce the recycled aggregate. The main reason that choosing the structural building as this source for recycled aggregate is because there is a huge amount of crushed demolition Portland cement concrete can be produced.

1.1 Need for the Present Work

The advent of high strength concrete has helped construction activity in many ways for example to build high rise buildings by reducing column sizes and increasing available space and to put the concrete into service at much earlier age etc. Concrete the most widely used structural material in the world is prone to cracking for a variety of reasons. These reasons may be attributed to structural or environmental factors, but most of the cracks are formed due to inherent weakness of the material to resist tensile forces, when it shrinks and it is restrained, it will crack. The randomly oriented fibers assist in controlling the propagation of micro-cracks present in the matrix, first by improving the overall cracking resistance of the matrix and later by bridging across even smaller cracks formed after the application of load on to the member, thereby preventing their widening into major cracks. Thus, proper introduction of fibers in concrete improves both mechanical properties and durability.

1.2 Objectives

- To obtain the flexural behavior of recycled aggregate concrete beams of M30 grade for different percentages of fibers.
- To evaluate load carrying capacity and moment carrying capacity of recycled aggregate concrete beam elements.
- To study the load-deflection parameters and moment-curvature relationship of recycled aggregate concrete elements using glass fibers.

1.3 Scope of Work

- M30 grade of concrete mix is used in present experimental work.
- 10 beams (1500 mm x 150 mm x 230 mm) have been cast by using recycled and natural aggregate with partial replacement of cement by fiber with different percentages (0.5%,1%, 1.5%, 2%) by weight of cement.

2 LITERATURE REVIEW

Kumar *et al.* (2004) carried out experiments to study various physical and mechanical properties of recycled aggregate concrete. The properties of recycled aggregate are different from normal aggregate and the concrete made from them has specific properties. Choi and Yuan (2005) investigated the relationship between the splitting tensile strength and compressive strength of glass fiber reinforced concrete (GFRC) and polypropylene fiber reinforced concrete (PFRC). The splitting tensile strength and compressive strength of GFRC and PFRC at 7, 28 and 90 days are used. Yuwaraj and Deshmukh (2006), conducted an experimental investigation on the glass fiber modified properties of structural concrete. Alkali-resistant glass fibers are used in the investigation. The effects of these fibers on workability, density, and on various strengths of M20 grade concrete are studied. Fiber content varies from 0.5 to 4.5% by weight of cement. In Prasad and Kumar's (2007) study, glass fiber reinforced recycled aggregate concrete (GFRRAC) was produced. The mechanical properties of GFRRAC with M20 and M40 grade concrete for different replacements of natural aggregate with that of recycled concrete aggregate were studied. Kishore and Bhikshma (2008) investigated the mechanical properties of recycled aggregate concrete (RAC) of mixes M20-M35 with 0.22% of Recron fibers and compared them with conventional aggregate concrete of same mixes with 0.22 % of Recron fibers.

3 EXPERIMENTAL PROGRAM

The materials that are used for the present thesis work are Cement, Fine Aggregate, Conventional Coarse Aggregate, Recycled Coarse Aggregate, Glass Fiber and Water. The properties of coarse and glass fibers are presented in Tables 1 and 2.

Table 1. Physical properties of coarse aggregate (natural & coarse aggregate).

Property		Natural Aggregate	Recycled Aggregate
Specific gravity		2.74	2.67
Fineness modulus		7.07	7.04
Bulk Density	Loose	1498 kg/m3	1489 kg/m3
	Compacted	1710 kg/m3	1711 kg/m3
Aggregate impact value		17.30%	16.80%
Water absorption		0.25%	0.82%
Crushing strength		22.00	21.00

Table 2. Properties of glass fiber.

Property	Value
Density in g/cm3	2.7
Elastic Modulus GPa	72
Tensile strength in MPa	1700
Density in micron	14
Length in mm	12
No. of fibers in million /kg	212
Electrical Conductivity	Very low
Chemical resistance	Very high
Aspect ratio	857

Material: Alkali Resistant Glass (manufactured with high Zirconia content in compliance with ASTM C1666/0 1666/M-07 and EN 15455).

Table 3. Proportion of concrete mix.

Grade of Mix	Cement	Fine Aggregate	Coarse Aggregate	Water	Glass Fiber %
M30 (NCA)	1	1.36	2.95	0.45	0
M30 (RCA)	1	1.39	2.75	0.45	0.5
M30 (RCA)	1	1.39	2.75	0.45	1.0
M30(RCA)	1	1.39	2.75	0.45	1.5
M30 (RCA)	1	1.39	2.75	0.45	2.0

Table 4. Properties of reinforced steel.

Diameter mm	Properties of Reinforced Steel		Percentage of Elongation (mm)
	Proof Stress N/mm2	Ultimate tress (N/mm2)	
8	430	455	28
12	440	458	24
16	442	459	24

Table 5. Reinforcement details of beam specimens.

Beam Designation	No. of Beams	Reinforcing Bars	Spacing
A(NAC)	2	2-8mm+2 -16mm	2L-8mm stirrups @ 230 mm c/c
B(RAC)	2	2-8mm+2 -16mm	2L-8mm stirrups @ 230 mm c/c
C(RAC)	2	2-8mm+2 -16mm	2L-8mm stirrups @ 230 mm c/c
D(RAC)	2	2-8mm+2 -16mm	2L-8mm stirrups @ 230 mm c/c
E(RAC)	2	2-8mm+2 -16mm	2L-8mm stirrups @ 230 mm c/c

Table 6. Ultimate values of beams.

Type of Beam	Glass Fiber Content (%)	Ultimate Load (kN)	Ultimate Deflection (mm)	Ultimate Moment (kNm)	Ultimate Curvature (x10-4)
A(NAC)	0	180	7.90	36	3.545
B(RAC)	0.5	150	9.24	28	3.244
C(RAC)	1.0	165	10.57	30	3.575
D(RAC)	1.5	170	11.85	32	3.867
E(RAC)	2.0	175	12.35	34	3.926

4 RESULTS AND DISCUSSIONS

4.1 Load-Deflection

The experimental programmer on reinforced concrete beams shown the load-deflection variation. In this investigation the beam of size 1500 mm x 150 mm x 230 mm size were firstly placed on the supports. Then two points loading was applied and the corresponding deflections were noted using dial gauge attached at the center of the specimen. The reading at the time of failure of the specimen was noted. In which with addition of fibers the load increases and deflection value decreases. It was observed that the failure took place gradually with formation of cracks with addition of glass fibers in mix. A maximum of 3% reduction in ultimate load is observed for RAC beams compared to NAC beams. The specimens with 0% fiber for M30 (NAC) the deflection is less compared to specimens with (0.5%, 1%, 1.5%, 2%) glass fiber of M30(RAC). It is found that at 2% fiber of M30 (RAC) the deflection is increased by 36% compared to M30 (NAC) with 0% fiber. Test results are presented in Tables 3-6.

4.2 Moment Curvature

In this experimental programmer the beams specimens were tested by two point loading method and the results were tabulated. It was observed that with the increase in glass fiber percentages the moment and curvature values increases gradually. Compared to moment of beam A 0% fiber (NAC) it showed decrease in moment by 5% of beam E 2% fiber (RAC).The moment and curvature gradually increase with increase in fiber percentages from 0.5% to 2% for M30 mix (RAC) concrete. It was observed that curvature of beam E 100% (RAC) with 2% fiber content was increased by 9.7% compared to that of natural aggregate concrete with no fiber content.

4.3 Crack Patterns and Failure Mode

The cracks at the mid-span open widely near failure, near peak load, the beams deflected significantly, thus indicating that the tensile steel must have yielded at failure. The final failure of the beams occurred when the concrete is in the compression zone, crushed, accompanied by buckling of the compressive steel bars. The failure mode was typical of that of an under-reinforced concrete beam.

4.4 Flexural Capacity

The ultimate moment and the corresponding mid-span deflection of test beams are given in Tables 8 show the effect of tensile reinforcement on the flexural capacity of each series of beams. These test trends show that, as expected, the flexural capacity of beams increased significantly with the recycled aggregate ratio because all beams are under reinforced, they observed increased flexural strength is approximately proportional to the increase in the tensile reinforcement ratio.

5 CONCLUSIONS

- A maximum of 3% reduction in ultimate load and 5% reduction in ultimate moment is observed for RAC beams compared to NAC beams.

- Up to 36% higher deflections are observed for RAC beams specimens compared to that of NAC specimens.
- The first crack is found at 90 kN for NAC and for RAC at 2% fiber content have been found at 120 kN. The first crack of RAC at 2% fiber content has increased by 25% compared to that of NAC with no fiber.
- The load carrying capacity of specimens of RAC with 2% fiber content has increased by 14% compared to that of RAC with 0.5% fiber content.

References

Choi, Y. and Yuan, R. L., Experimental Relationship between Splitting Tensile Strength and Compressive Strength of Gfrc and Pfrc, *Cement and concrete Research*, 35(8), 157-159, 2005.

Kishore, R. and Bhikshma, V., Strength Characteristics of Recycled Aggregate Concrete with Polyester Fibres, 7th International RILEM symposium on fiber reinforced concrete, design and applications, 2008.

Kumar, S., Barai, V., and Major Rakshvir, Studies on Recycled Aggregate Based Concrete, Dept. of Civil Engrg, IIT Kharagpur, 2004.

Prasad, M. L. V. and Kumar, P. R., Strength Studies on Glass Fiber Reinforced Recycled Aggregate Concrete, *Asian Journal of Civil Engineering (Building and Housing)*, 8(6), 677-690, 2007.

Yuwaraj, M. and Deshmukh, S. B., Performance of Alkali- Resistant Glass Fiber Reinforced Concrete, *Journal of Reinforced Plastics and Composites*, 25, 617-630, 2006.