A Study on Mechanical Properties of Fiber Reinforced High Strength Concrete using Recycled Coarse Aggregate

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Abstract

High Strength Concrete: The term high-strength concrete (HSC) is generally used for concrete with compressive strength higher than 41 MPa. ACI Committee had defined High Strength Concrete (HSC) is the concrete that can attain specified compressive strength for design of at least 41 MPa, or more. With the development of high grade cement and availability of proper mineral admixtures and chemical admixtures, it has become quite common to adopt concrete with compressive strength of 60 MPa and above. Development of high strength concrete has made it possible to build taller and long span structures. Fibre Reinforced Concrete: Plain concrete and High Strength Concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are present in the concrete and its poor tensile strength is due to the propagation of such micro cracks. In plain concrete, structural cracks (micro-cracks) develop even before loading, due to drying shrinkage or other causes of volume change. The width of these initial cracks is few microns, but their other dimensions may be of higher magnitude. When loaded, the micro cracks propagate and open up, and additional cracks form in places of minor defects. The development of such micro cracks is the main cause of inelastic deformations in concrete. The addition of small closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties. This type of concrete is known as Fiber Reinforced Concrete.

Keywords: Portland Cement, Concrete, Rice Hush Ash (RHA), Specimen Preparation, Testing, Recycled Aggregate

I. INTRODUCTION

Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. The aim for this on – going project is to determine the strength characteristic of recycled aggregates for application in high strength structural concrete, which will give a better understanding on the properties of concrete with recycled aggregates, as an alternative material to coarse aggregate in structural concrete.

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

Due to the critical shortage of natural aggregate, the availability of demolished concrete for use as recycled concrete aggregate (RCA) is increasing. Using the waste concrete as RCA conserves natural aggregate, reduces the impact on landfills, decreases energy consumption and can provide cost savings. Recycled aggregates are the materials for the future. The application of recycled aggregate has been started in many countries for construction projects.

A. Applications of Recycled Aggregates

Traditionally, the application of recycled aggregate is used as landfill. Nowadays, the applications of recycled aggregate in construction areas are wide. The applications are different from country to country.

- Concrete Kerbs
- Granular Base Course Materials
- Embankment Fill Materials

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- Paving Blocks
- Backfill Materials
- Building Blocks

1) *Advantages of Recycled Coarse Aggregate*

There are many advantages through using the recycled aggregate. The advantages that occur through usage of recycled aggregate are listed below.

a) Environmental Gain

The major advantage is based on the environmental gain. According to CSIRO, construction and demolition waste makes up to around 40% of the total waste each year (estimate around 14 million tons) going to land fill. Through recycled these material, it can keep diminishing the resources of urban aggregated. Therefore, natural aggregate can be used in higher –grade applications.

b) Save Energy

The recycling process can be done on site. According to Kajima Technical Research Institute (2002), Kajima is developing a method of recycling crushed concrete that used in the construction, known as the Within-Site Recycling System. Everything can be done on the construction site through this system, from the process of recycled aggregate, manufacture and use them. This can save energy to transport the recycled materials to the recycling plants.

c) Cost

Secondly is based on the cost. The cost of recycled aggregate is cheaper than virgin aggregate. According to PATH Technology Inventory, the costs of recycled concrete aggregate are sold around $3.50 to $7.00 per cubic yard. It depends on the aggregate size limitation and local availability. This is just around one and half of the cost for natural aggregate that used in the construction works. The transportation cost for the recycled aggregate is reduced due to the weight of recycled aggregate is lighter than virgin aggregate. Concrete Network stated that recycling concrete from the demolition projects can saves the costs of transporting the concrete to the land fill (around $0.25 per ton/ mile), and the cost of disposal (around $100 per ton). Besides that, Aggregate Advisory Service also state that the recycling site may accept the segregates materials at lower cost than landfill without tax levy and recycled aggregate can be used at a lower prices than primary aggregate in the construction works.

d) Sustainability

The amount of waste materials used for landfill will be reducing through usage of recycled aggregate. This will reduce the amount of quarrying. Therefore this will extend the lives of natural resources and also extend the lives of sites that using for landfill.

e) Market is wide

The markets for recycled concrete aggregate are wide. According to Environmental Council of Concrete Organization, recycled concrete aggregate can be used for sidewalk, curbs, bridge substructures and superstructures, concrete shoulders, residential driveways, general and structural fills. It also mentioned that recycled concrete aggregate can be used in sub bases and support layers such as unstabilized base and permeable bases.

2) *Disadvantages of Recycled Coarse Aggregate*

a) Lack of Specification and Guidelines

There is no specification or any guideline when using recycled concrete aggregate in the constructions. In many cases, the strength characteristic will not meet the requirement when using recycled concrete aggregate. Therefore, more testing should be considered when using recycled concrete aggregate.

b) Water Pollution

The recycled process will cause water pollution. Morris of National Ready Mix Concrete Association had mentioned that the wash out water with the high pH is a serious environmental issue. According to Building Green (1993), the alkalinity level of wash water from the recycling plants is pH12. This water is toxic to the fish and other aquatic life.

II. LITERATURE REVIEW

Chetna M.Vyas, Prof. Jayesh kumar Pitroda (2013) [1] have studied about the sustainability of Fly Ash and Recycled Coarse Aggregate in Concrete. In their study Fly Ash is used as a replacement to cement and they obtained good results when compared to conventional concrete.

Dr.Salahaldein Alsadey 2012 [5] studied the Influence of Super plasticizer on strength of concrete. In this study it is focused on the effects of super plasticizer admixture on properties of concrete. Concrete mixes with SP dosages of 600,800,1000 and 1200ml/100 kg of cement i.e 0.6,0.8,1.0,1.2% respectively were prepared of grade M30. After casting, normal curing was carried out on the concrete samples. Compressive Strength was determined after 28 days of curing. The Compressive strength was improved by dosage 1.0% of SP by 55N/mm^2 for M30 grade concrete.

P.Muthupriya et al., (2011) [2] studied the behavior of short columns produced from High Performance Concrete (HPC). In the investigation HPC grade M60 was manufactured with usual ingredients such as cement, fine aggregate, coarse aggregate, water and mineral admixtures such as silica fume and fly ash at various replacement levels and the super plasticizer(1.5% by weight of cement). The water binder ratio adopted was 0.3. Specimens such as cubes, cylinders and prisms were casted and tested for various mixes viz., seven mixes M1 to M7 are casted with 0%, 5%, 7.5% and 10% replacement of silica fume to cement and another replacement of fly ash to study the mechanical properties such as compressive strength, split tensile strength and flexural strength at different ages of concrete 3,7,28,56 and 90 days. The result showed that the optimum replacement of silica fume is at 7.5%.

Neela Deshpande et al., (2011) [3] have studied the Effectiveness of using Coarse Recycled Concrete Aggregate in Concrete. In their study concrete mixes were designed with 28 day compressive strength as 25MPa .The concrete mixes were designed using IS 10262:2009 with

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conventionally used coarse aggregates and 100% replacement of coarse recycled aggregate. With reference to the experimental results, analysis of important properties of both the types of concrete is done and the suitability of use of recycled concrete aggregate for new concrete is judged.

Y. V. Akbari et al., (2011) [4] have studied the effect on recycled aggregate on concrete properties. The experimental program includes variation in water cement ratio and replacement of natural aggregates by recycled aggregates. Three different water ratios 0.60, 0.52 and 0.43 and aggregate replacement of 0%, 15%, 30%, 50% were accounted in experimental program.

Comment: Experimental results shows up to 25% reduction in compressive strength, 23% reduction in flexural strength, 26% reduction in split tensile strength and a noticeable reduction in workability was observed with the increase in percentage of aggregate replacement.

Kenai and Debieb (2010) [4] examined the possibility of using crushed clay bricks as coarse and fine aggregate for a new concrete and found out that with the percentage of recycled aggregates limited to 25% and 50% for the coarse and fine aggregates respectively produce concrete with similar characteristics to those of natural aggregates concrete. A substitution of coarse aggregate with crushed fine clay brick up to 40% in concrete at 28 days curing had a higher mechanical strength compared to the natural aggregate concrete . The applications of recycled aggregate as partial replacement of coarse aggregate in the range of 20 to 40% have been reported to be successful.

K.Jagannadha Rao and T. Ahmed Khan (2009) [5] examined the suitability of glass fibers in High Strength Recycled Aggregate Concrete. In this study the fresh and hardened state properties of partially replaced recycled aggregate concrete, with varying percentages of glass fibers, are compared with the corresponding conventional aggregate concrete. The compressive, split tensile and flexural strengths of M50 grade concrete with 0% RCA and 50% RCA have increased as the fiber content increased. The maximum values of all these strengths were obtained at 0.03% of fiber content for both the concretes of 0% RCA and 50% RCA. Large deflections of beams before failure indicated improved ductility with the addition of fibers.

Madan Mohan Reddy.K et al., (2000) [6] have examined the use of crushed construction and demolition waste as a Recycled Concrete Aggregate (RCA) in the production of new concrete. The RCA are collected from local demolished structure. The studies were conducted with an M20 mix with the selected w/c ratio: 0.5 and the development of compressive strength of the RAC and NAC at the age of 7 & 28 days were studied.

Limbachiya et al., (2000) [7] conducted experimental investigations on RCA concrete indicate that there is no effect on strength of concrete compared to that of Conventional aggregate concrete. Recycled aggregate concrete had 7 to 9% lower relative density and 2 times higher water absorption than that of natural aggregate concrete while there is no effect on strength of concrete for RCA replacements upto 30%. The commonly accepted ACI relationships for the prediction of the modulus of rupture and split tensile strength for normal concrete was found to be adequate for the prediction of properties for RCA concrete also but the relationship to determine the modulus of elasticity of normal concrete is not valid for recycled aggregate concrete

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

Table - 1
% of Recycled Coarse Aggregate Compressive Strength (MPa) 7 days

S. No	*Mix Designation*	*% of Recycled Coarse Aggregate*	*Compressive Strength (MPa) 7 days*
1.	*M50 CM*	*0*	*34.66*
2.	*M50 5%S.F+5% RCA*	*5*	*35.55*
3.	*M50 (5%+10%)*	*10*	*35.11*
4.	*M50 (5%+15%)*	*15*	*34.66*
5.	*M50 (5%+20%)*	*20*	*33.77*
6.	*M50 (7.5%+5%)*	*5*	*37.77*
7.	*M50 (7.5%+10%)*	*10*	*36.44*
8.	*M50 (7.5%+15%)*	*15*	*36.88*
9.	*M50 (7.5%+20%)*	*20*	*37.33*
10.	*M50 (10%+5%)*	*5*	*36.44*
11.	*M50 (10%+10%)*	*10*	*35.55*
12.	*M50 (10%+15%)*	*15*	*34.66*
13.	*M50 (10%+20%)*	*20*	*31.11*

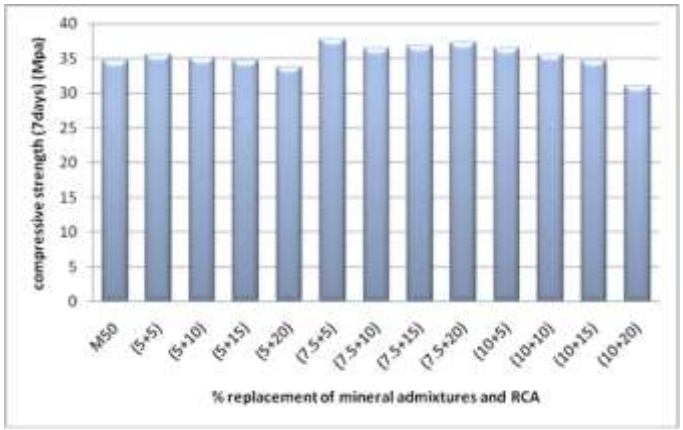

Fig. 1: Graph showing 7 days compressive strength

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- From the above graph, it is seen that the compressive strength is obtained maximum of mix M50 (7.5%) SF with a replacement of 5% recycled coarse aggregate.
- The effect of mineral admixture Silica Fume is predominant on the strength properties of the concrete.

Table - 2
Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate at 28 days

S. No.	*Mix Designation*	*% of Recycled Coarse Aggregate*	*Compressive Strength (MPa) 28 days*
1.	*M50 CM*	*0*	*58.22*
2.	*M50 5%S.F+5% RCA*	*5*	*55.11*
3.	*M50 (5%+10%)*	*10*	*53.77*
4.	*M50 (5%+15%)*	*15*	*53.33*
5.	*M50 (5%+20%)*	*20*	*52.44*
6.	*M50 (7.5%+5%)*	*5*	*53.77*
7.	*M50 (7.5%+10%)*	*10*	*54.22*
8.	*M50 (7.5%+15%)*	*15*	*54.66*
9.	*M50 (7.5%+20%)*	*20*	*56.88*
10.	*M50 (10%+5%)*	*5*	*48.94*
11.	*M50 (10%+10%)*	*10*	*47.11*
12.	*M50 (10%+15%)*	*15*	*45.77*
13.	*M50 (10%+20%)*	*20*	*42.66*

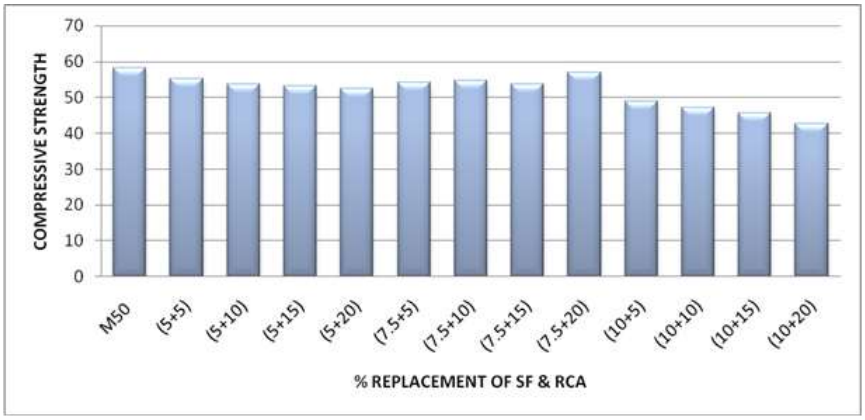

Fig. 2: Graph showing compressive strength for 28days when replaced with R.C.A

- The Compressive strengths are consistently decreasing with the increase in the recycled aggregate content from 5% to 20% in the 5% partial replacement of Silica Fume admixture by 9.4% to 9.0% respectively when compared with the control mix.
- The compressive strengths are increasing with the increase in partial replacement of Silica Fume admixture by 7.5% and the percentage increase is 9.3% to 9.7% when compared with the control mix.
- The compressive strengths are decreasing with the further increase in both the recycled aggregate content and mineral admixture content.

Table - 3
Test Results of compressive strength High Strength Concrete using RCA

S. No.	*Mix Designation*	*% of Recycled Coarse Aggregate*	*Compressive Strength (MPa) 7 days*	*Compressive Strength (MPa) 28 days*
1.	*M50 CM*	*0*	*34.66*	*58.22*
2.	*M50 5%S.F+5% RCA*	*5*	*35.55*	*55.11*
3.	*M50 (5%+10%)*	*10*	*35.11*	*53.77*
4.	*M50 (5%+15%)*	*15*	*34.66*	*53.33*
5.	*M50 (5%+20%)*	*20*	*33.77*	*52.44*
6.	*M50 (7.5%+5%)*	*5*	*37.77*	*54.22*
7.	*M50 (7.5%+10%)*	*10*	*36.44*	*54.66*
8.	*M50 (7.5%+15%)*	*15*	*36.88*	*53.77*
9.	*M50 (7.5%+20%)*	*20*	*37.33*	*56.88*
10.	*M50 (10%+5%)*	*5*	*36.44*	*48.94*
11.	*M50 (10%+10%)*	*10*	*35.55*	*47.11*
12.	*M50 (10%+15%)*	*15*	*34.66*	*45.77*
13.	*M50 (10%+20%)*	*20*	*31.11*	*42.66*

- From the above table, it is concluded that the 7 days maximum strength is obtained at partial replacement of silica fume at 7.5% with 5% recycled coarse aggregate and the percentage increase is 10.80% when compared with the control mix.

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- It is seen that, at 28 days the compressive strengths are decreasing with the increase in mineral admixture content and recycled aggregate content.

Table - 4
Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate at 7 days

S. No.	*Mix Designation*	*% of Recycled Coarse Aggregate*	*Compressive Strength (7 days) MPa*
1.	*M50 7.5%S.F+1.5%SP 30% RCA*	*30*	*36.88*
2.	*M50 7.5%S.F+1.5%SP 40% RCA*	*40*	*36.00*
3.	*M50 7.5%S.F+1.5%SP 50% RCA*	*50*	*34.66*
4.	*M50 7.5%S.F+1.5%SP 75% RCA*	*75*	*33.33*
5.	*M50 7.5%S.F+1.5%SP 100% RCA*	*100*	*31.55*

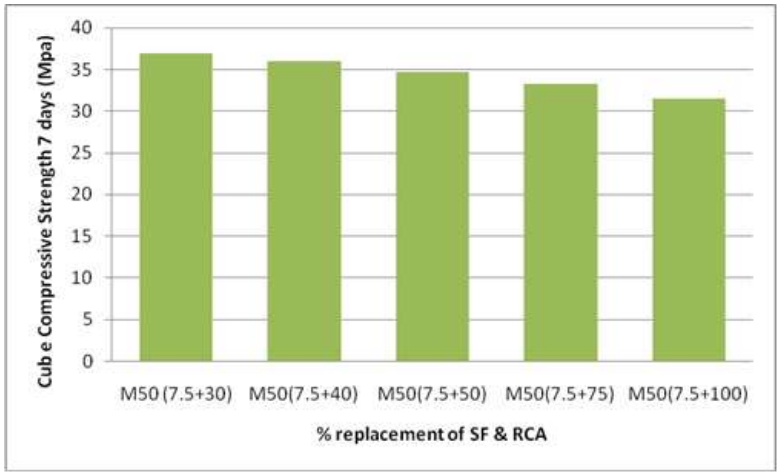

Fig. 3: Graph showing cube compressive strength for 7 days

- From the above comparison, the cube compressive strength is maximum at the trail mix proportion M50 (7.5% SF + 30% RCA).
- With the increase in the recycled coarse aggregate content, there is a decrease in the compressive strength.

Table - 5
Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate at 28 days

S. No.	*Mix Designation*	*% of Recycled Coarse Aggregate*	*Compressive Strength (28days) Mpa*
1.	*M50 7.5%S.F+1.5%SP 30% RCA*	*30*	*55.11*
2.	*M50 7.5%S.F+1.5%SP 40% RCA*	*40*	*54.22*
3.	*M50 7.5%S.F+1.5%SP 50% RCA*	*50*	*52.00*
4.	*M50 7.5%S.F+1.5%SP 75% RCA*	*75*	*48.94*
5.	*M50 7.5%S.F+1.5%SP 100% RCA*	*100*	*41.22*

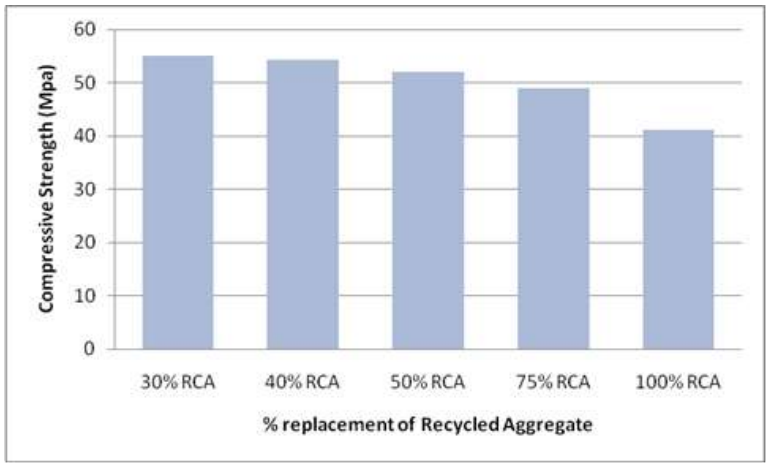

Fig. 6: Graph showing compressive strength when replaced with R.C.A

- With the increase in the recycled coarse aggregate content, the cube compressive strengths are decreasing.
- The percentage decrease of compressive strength with respect to control mix is about 9.4% , 9.31%, 8.93%, 8.41%, 7.0% for 30%, 40%, 50%, 75% and 100% replacements of recycled coarse aggregate content to natural coarse aggregate content.

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– From the above comparison, it can be concluded that 50% of recycled coarse aggregate can be used in high strength concretes which is an optimum.

Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate

Table – 6

Test Results of compressive strength of High Strength Concrete using Glass Fiber

S. No.	*Mix Designation*	*% of glass fibers*	*Compressive Strength (7 days) Mpa*	*Compressive Strength (28days) Mpa*
1.	*M50 7.5%S.F+1.5%SP 50% RCA*	*0*	*34.66*	*52.00*
2.	*M50 7.5%S.F+1.5%SP 50% RCA*	*0.5%*	*36.88*	*56.00*
3.	*M50 7.5%S.F+1.5%SP 50% RCA*	*1.0%*	*39.55*	*58.66*
4.	*M50 7.5%S.F+1.5%SP 50% RCA*	*1.5%*	*41.33*	*60.88*
5.	*M50 7.5%S.F+1.5%SP 50% RCA*	*2.0%*	*40.44*	*60.00*

Table – 7

Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate

S. No.	*Mix Designation*	*% of Recycled Coarse Aggregate*	*Compressive Strength (7 days) Mpa*	*Compressive Strength (28days) Mpa*
1.	*M50 7.5%S.F+1.5%SP 30% RCA*	*30*	*36.88*	*55.11*
2.	*M50 7.5%S.F+1.5%SP 40% RCA*	*40*	*36.00*	*54.22*
3.	*M50 7.5%S.F+1.5%SP 50% RCA*	*50*	*34.66*	*52.00*
4.	*M50 7.5%S.F+1.5%SP 75% RCA*	*75*	*33.33*	*48.94*
5.	*M50 7.5%S.F+1.5%SP 100% RCA*	*100*	*31.55*	*41.22*

Table - 8

Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate at 7 days with glass fibers

S. No.	*Mix Designation*	*% of glass fibers*	*Compressive Strength (7 days) MPa*
1.	*M50 7.5%S.F+1.5%SP 50% RCA*	*0*	*34.66*
2.	*M50 7.5%S.F+1.5%SP 50% RCA*	*0.5%*	*36.88*
3.	*M50 7.5%S.F+1.5%SP 50% RCA*	*1.0%*	*39.55*
4.	*M50 7.5%S.F+1.5%SP 50% RCA*	*1.5%*	*41.33*
5.	*M50 7.5%S.F+1.5%SP 50% RCA*	*2.0%*	*40.44*

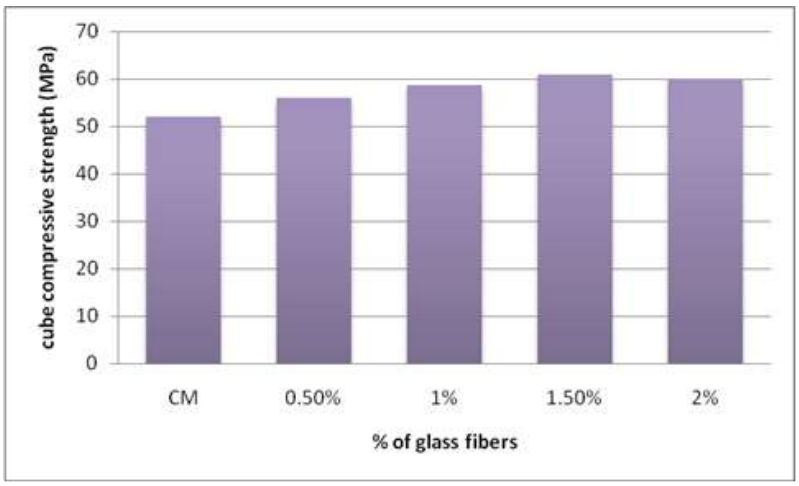

Fig. 7: Graph showing compressive strength when replaced with R.C.A and addition of glass fibers

Table - 9

Test Results of compressive strength of High Strength Concrete using Recycled Coarse Aggregate at 28 days with glass fibers

S. No.	*Mix Designation*	*% of glass fibers*	*Compressive Strength (28 days) MPa*
1.	*M50 7.5%S.F+1.5%SP 50% RCA*	*0*	*52.00*
2.	*M50 7.5%S.F+1.5%SP 50% RCA*	*0.5%*	*56.00*
3.	*M50 7.5%S.F+1.5%SP 50% RCA*	*1.0%*	*58.66*
4.	*M50 7.5%S.F+1.5%SP 50% RCA*	*1.5%*	*60.88*
5.	*M50 7.5%S.F+1.5%SP 50% RCA*	*2.0%*	*60.00*

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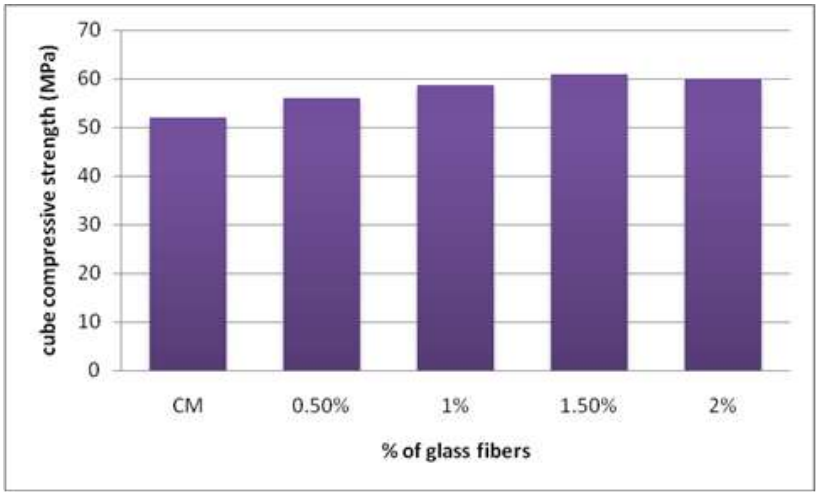

Fig. 8: Graph showing compressive strength when replaced with R.C.A and addition of glass fibers

Based on the experimental investigations conducted on the casted cubes, the following conclusions were drawn.

- With the increase in recycled coarse aggregate content, the compressive strength is decreasing.
- Of all the trial mixes, M50 (7.5% SF) with a replacement of 20% RCA has showed better results and it is taken as reference for the next phase of work.
- More than 50 MPa compressive strength has been achieved by using 50% of recycled coarse aggregate with the trail mix M50 (7.5% SF).
- 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.
- 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.
- Of all the trial mixes with glass fibers, the mix M50(7.5% 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(7.5% SF) (50% RCA).

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