INFLUENCE OF BASALT FIBER AND RECYCLED CONCRETE AGGREGATE ON SELF COMPACTING CONCRETE AGAINST MECHANICAL AND DURABILITY TESTS

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ABSTRACT. The experimental investigations were carried out on self-compacting concrete (SCC) to study the influence of basal fibre and recycled concrete aggregate (RCA) through mechanical and durability tests. The percentage of recycled concrete aggregate replacement was varied as 0, 50 and 100% whereas the basalt fiber was varied as 0, 2 and 4 kg/m^3. The compressive strength of mix having nil RCA and 2 kg/m^3 fiber was found to be increased up to 11.5%. The split tensile strength of mix having 50 RCA and 4 kg/m^3 basalt fiber was found to be increased 27% as compared to conventional SCC. The maximum value of flexural strength was observed for R50B2 which was 22.05% more than the plain concrete. 100% replacement of RCA decreased the strength and the lowest was found in R100B0, which was 42.64% lower than the conventional concrete. It was observed that the carbonation depth of concrete was found to be increased with the increase of recycled concrete aggregate as well as basalt fiber. When recycled concrete aggregate alone was introduced, in 28 days of exposure period the carbonation depth increased to 16.67% in the case of 100% replacement of recycled concrete aggregate. Best result was shown by the control mix only and the worst result was noticed in R100B4 which was 50, 71.4 and 84% more than control mix in 28, 56 and 90 days respectively.

Keywords: Self compacting concrete; Recycled concrete aggregate; Basalt Fiber; Mechanical test; Carbonation test;

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INTRODUCTION

Fibre-reinforced concrete has been produced using variety of fibers such as steel, carbon and glass fibres for almost three decades. These type of concrete have already proven that the addition of fibres can enhance the mechanical and physical properties of concrete. However, basalt fibre-reinforced concrete may also have the potential to improve the mechanical properties of concrete. Basalt fiber is one of the material, which has the advantages of light weight, high tensile strength, endurance of corrosion, crack resistance, high temperature as well as good capability [1-4]. Few investigators has been carried out an experiments to study the mechanical behaviour basalt fiber reinforced concrete using conventional concrete as well as natural aggregate, [5-8]. In addition to that, the response of basalt fiberous reinforced concrete using conventional concrete against dynamic and impact loading was studied [9-11]. From the beginning of 2000, recycled aggregate seems an effective measures to utilize the destruction of natural ecological environment caused materials through various sources cause environmental pollution. However, it is well understood that a significant number of experimental investigations has been carried out by various researchers and their groups world-wide. It has been observed that the high water absorption capacity, durability and behaviour of the RAC is always lower than that of normal concrete due to the lack of bonding between recycled aggregate and cement matrix. These deficiencies can be eliminated by reinforcing it with discrete fibres of randomly oriented. In case of fibrous reinforced concrete, it was noticed that one of the major problems that are to be faced related to concrete is at the time of placing is congestion [12-13]. These limitations can be taken care by a special type of concrete, known as fibrous self-compacting concrete. Although a variety of fiber reinforcing materials exist, fiber reinforced concrete used for structural applications is most often made with steel fibers, since the most beneficial properties of steel fiber reinforced concrete (SFRC) are improved flexural toughness, flexural fatigue endurance as well as impact resistance. However, SFRC poses several issues, like increased dead-load, less workability, fiber balling at high dosages and susceptibility to corrosion problems [14-17]. Based on the detailed literature survey, the studies focused on the mechanical properties of the concrete with varying replacement ratios of recycled coarse aggregates and basalt fiber content. It has been found that with increasing the proportion of RCA there is a decrease in the concrete density, splitting tensile strength as well as flexural strengths of concrete. I was also noticed that the addition of basalt fiber leads to an increase density of concrete and compressive strength. It was described that although the mechanical properties of the RAC was decreased with increasing RCA replacement proportions, however it could be improved by addition of basalt fiber in its optimum volume fraction. Therefore, it is concluded that the previous studies conducted on basalt fiber reinforced concrete were confined to its mechanical, thermal, electrical and the chemical properties whereas the durability of the basalt fiber reinforced concrete is found to be limited heretofore. Also, it is observed that the previous studies mainly focused on normally vibrated concrete whereas the studies on self-compacting concrete along with basalt fiber were found limited heretofore. The single length of fiber were used by various researchers however the possibility of hybridization is not been explored by the research community. Therefore, the present study is based on experimental investigations in combination of basalt fiber and recycled aggregate along with self-compacting concrete to explore the mechanical and durability properties. The studies were carryout to find the optimum percentage for replacing natural aggregate with recycled aggregate as well as basalt fiber in light of effective utilization of basalt fibers along with recycled concrete aggregate for reducing the construction waste.

MATERIALS AND METHODOLOGY

In this Section, there is an elaborate depiction of the materials which has been used in the experimental work. The method that has been adopted to carry out the work has also been described. The experimental program includes compressive strength test, split tensile strength test and durability tests and discussed here.

Source Materials

Basalt fiber has good hardness and thermal properties, can have various application as construction materials. The basic characteristics of basalt materials are high-temperature resistance, high corrosion resistance, resistance to acids and alkalis, high strength and thermal stability. Basalt materials have been used as a reinforcing composite material for the construction industry, specifically as a less expensive alternative to carbon fiber. When the fiber in contact with other chemicals they produce no chemical reactions that may damage health or the environment. Basalt base composites can replace steel (1 kg of basalt reinforces equals 9.6 kg of steel, [11]) as light weight concrete can be get from basalt fiber. Ordinary Portland Cement (OPC) grade 43 (Shree Cement) was used in the present study. The fine aggregates were available locally and used to carry out the experimental investigations. The sand was dry and free from any unwanted materials. Specific gravity tests were performed to find the specific gravity of fine and coarse aggregate (includes natural aggregate (NA) and recycled concrete aggregate (RCA)). The specific gravity of fine aggregates are 2.63 whereas the coarse aggregate of NA and RCA was found to be 2.59 and 2.44 respectively. Super plasticizers, also known as high range water reducers, are chemical admixtures used where well-dispersed particle suspension is required. The flyash has been used as cementitious materials in concrete and a detailed proportions are given in the next Section.

Mix Proportions

For assessing the mechanical properties of the concrete tests on compressive strength, split tensile strength and durability tests to be carried out. Similarly, carbonation test has to be conducted for obtaining the durability aspects of the concrete. The overall performance of the concrete has to be evaluated by varying both basalt fiber and recycled concrete aggregates. Dosage of basalt fiber was varied as 0, 2 and 4 kg/m^3 by keeping recycled concrete aggregate at 0%, 50% and 100% replacement levels. The percentage replacement level of recycled concrete aggregate ‘R’ and basalt fibers ‘B’ are named according to dosage of represents the of recycled concrete aggregate and represent the basalt fiber content. The number describes in the name of mix is directly related to the dosage of basalt fiber and RCA content. Compression test of the concrete was carried out with 100 mm X 100 mm X 100 mm size specimen and is tested at 7 days, 28 days and 90 days. Similarly split tensile strength test was conducted with 100 mm X 100 mm X 100 mm size cubical specimens at 28 days, 56 days and 90 days. Accelerated carbonation test was conducted after 28 days of curing with an exposure period of 28 days on 100 mm X 100 mm X 50 mm size specimens. The repetition was carried out for compression and split tensile test is two whereas the number of repetitions for and accelerated carbonation test was three. Beam specimens of size 100 x 100 x 500 mm for flexural test. Two beam specimens from each batch were tested in static flexure to determine average static flexural strength of the batch.

The SCC mixes were designed as per [18] was discussed in [17]. The mixes were proposed here were further modified through several trial mixes. The size of natural aggregates as well as recycled concrete aggregate was considered in the range of 10 to 4.75 mm and it is considered as well graded aggregate. The proportion of NA was kept fixed i.e. 10 mm aggregate was 20%, 6.3 mm aggregate was 60% whereas the 4.75 mm aggregate was 20 % for all the mixes. Similarly the proportion of RCA was kept same as natural aggregate. Therefore, the gradation of coarse aggregate was not studied. The particle size of sand was kept below 4.75 mm, however the gradation of fine aggregate was studied. The fineness modulus of sand was 2.98 and it is used for conducting the experiments.

Tests on Fresh Concrete

The workability tests (V-funnel flow time, Slump flow, T500mm flow time) prescribed by [19], were performed in accordance with SCC specification. The result of the workability test for various mixes are given in Table 1.

Table 1 Workability properties of various mixes

MIX DESIGNATION	SLUMP FLOW		V-FUNNEL TEST (S)
	T500 mm (s)	Diameter (mm)	
R0B0	2.4	695	6.4
R0B2	2.8	688	6.8
R0B4	3.1	685	7.1
R50B0	2.6	690	6.8
R50B2	2.9	685	7.2
R50B4	3.3	682	7.6
R100B0	3.1	685	6.9
R100B2	3.3	683	7.4
R100B4	3.6	680	8

Test on hardened concrete

Compressive strength of all the specimens were tested on 100 mm X 100 mm X 100 mm size cubes in accordance with Indian Standards, [20]. Compressive strength tests were performed on various mixes after 7, 28 and 90 days of curing period. Split tensile strength of all the specimens were on 100 mm X 100 mm X 100 mm size cubes in accordance with Indian Standards, [20]. Split tensile strength tests were performed on various mixes after 28, 56 and 90 days of curing period. For accelerated carbonation test the prisms of size of 100 mm X 100 mm X 50 mm were prepared. The casted specimens were cured for a period of 28 days. Then the samples were oven dried for conditioning of specimens. The concentration of CO_2 was maintained at 4% with relative humidity was between 40% and 70% and temperature was kept at 25 ± 2 ºC. The specimens were exposed to CO_2 for a period of 4 weeks. The depth of carbonation was measured in accordance with RILEM recommendations, [21]. The static flexural tests were conducted on a 100 kN Servo-controlled Actuator and the load-deflection curve for each specimen was recorded. The specimens were simply supported over a span of 450 mm and loaded at four points. Static flexural tests were conducted after 28 days of curing.

RESULTS AND DISCUSSION

In hardened concrete, compressive strength, split tensile strength test, flexural test and accelerated carbonation test were conducted and their behaviour was compared with the various combination of RCA and basalt fiber on self-compacting concrete. The compressive split tensile strength and flexural strength as well as carbonation behaviour for various mix combinations have been discussed in this Section.

Compressive Strength Results

The compressive strength of hybrid fibre reinforced self-compacting concrete containing different proportions of basalt fiber and recycled concrete aggregate have been studied. The compression tests were carried out at 7, 28 and 90 days curing period [17]. The compressive strength of conventional SCC has been found to be increased marginally with increase of basalt fiber upto 2 kg/m^3, however the compressive strength of concrete was found to be decreased by 14% as compared to R0B2 mix, see Fig. 1. The compressive strength of R0B2 was found to be maximum among the chosen mix proportions. The reason may be due to the presence of porosity in large amount which leads to reduce the density of concrete. Overall, it is observed that the compressive strength of concrete was found to be achieved 65% of target mean strength at 7 days. However, it is observed that the 28 days strength was found to be almost same to that of 90 days. Therefore, it is concluded that the basalt fibre does not contribute much in the case of compressive strength of the concrete. The highest compressive strength was found to be R0B2 mix. When increasing the RCA content, the strength increased in the case zero basalt fibre content however, when introduced basalt fibre in concrete the strength gets reduced as we in increase the RCA content.

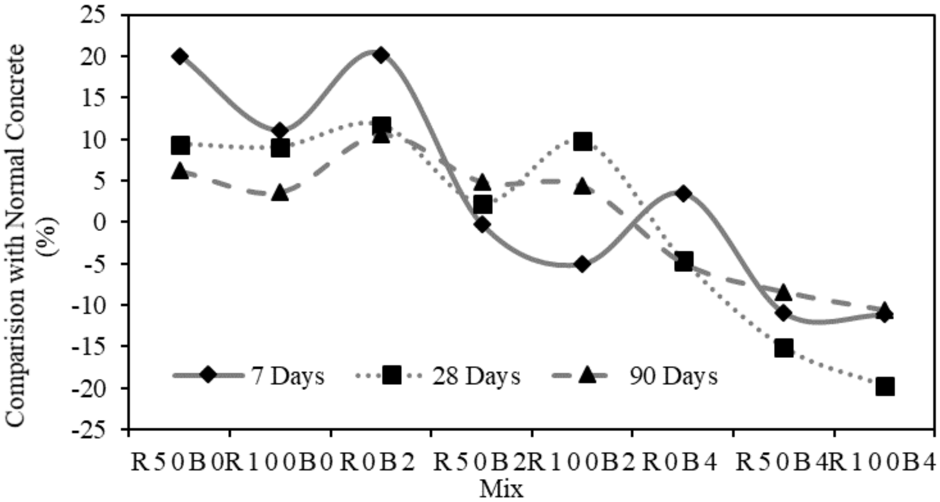

Figure 1 Percentage variation of compressive strength

Split Tensile Strength Results

The split tensile strength of hybrid fibre reinforced self-compacting concrete containing different proportions of basalt fiber and recycled concrete aggregate have been studied. The split tensile tests were carried out at 28, 56 and 90 days curing period [17]. The split tensile strength of hybrid fibre reinforced self-compacting concrete containing different proportions of basalt fiber and recycled concrete aggregate have been studied. It is observed from Figure

2(a)-(c), the split tensile strength has found to be increased considerably with increasing basalt fiber. The split tensile strength of R50B0 has been found to be increased 14% as compared to conventional SCC R0B0 concrete, however the strength of R50B0 concrete was found to be decreased by 22% as compared to R100B0 mix. Overall, it is observed that the split tensile strength of concrete was found to be decreased after 56 days except the mix R100B0. It is also observed that the strength was found to be reduced small amount at 90 days. As the fibre content was increased the split tensile strength was found to be increased. Therefore, it is concluded that the basalt fibre shows significant improvement against the addition of fiber.

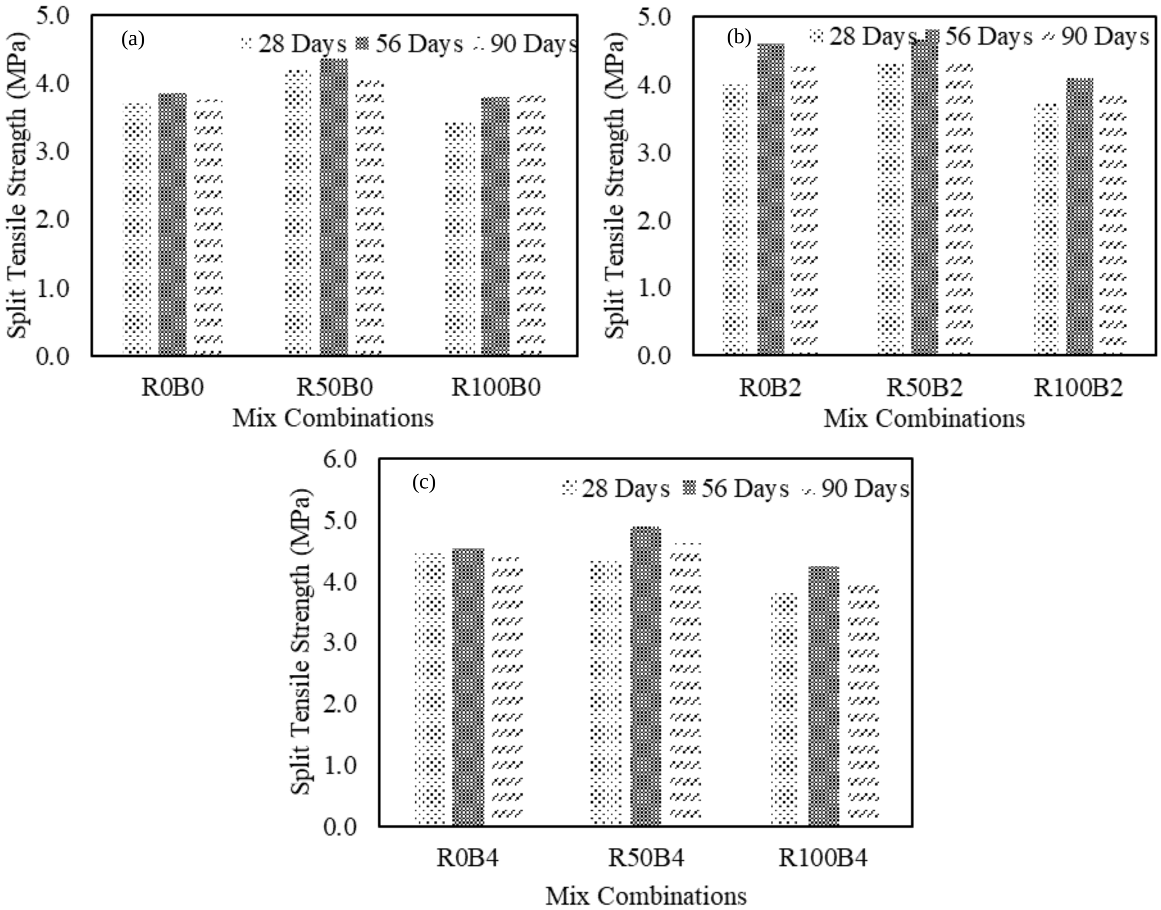

Figure 2 Split tensile strength of concrete containing recycled aggregare concrete along with (a) 0 (b) 2 and 4 kg/m^3 basalt fibers at 28 days

Flexural Strength Test

The flexural strength of fiber reinforced self-compacting concrete containing different proportions of basalt fiber and recycled concrete aggregate was studied. After casting the specimens were tested by Servo-controlled Actuator at 28 days of curing. The load-deflection curve of hybrid fiber reinforced self-compacting concrete containing different proportions of basalt fiber and recycled concrete aggregate was studied. It was observed from Fig 3, the flexural strength was found to be increased with increasing basalt fiber.

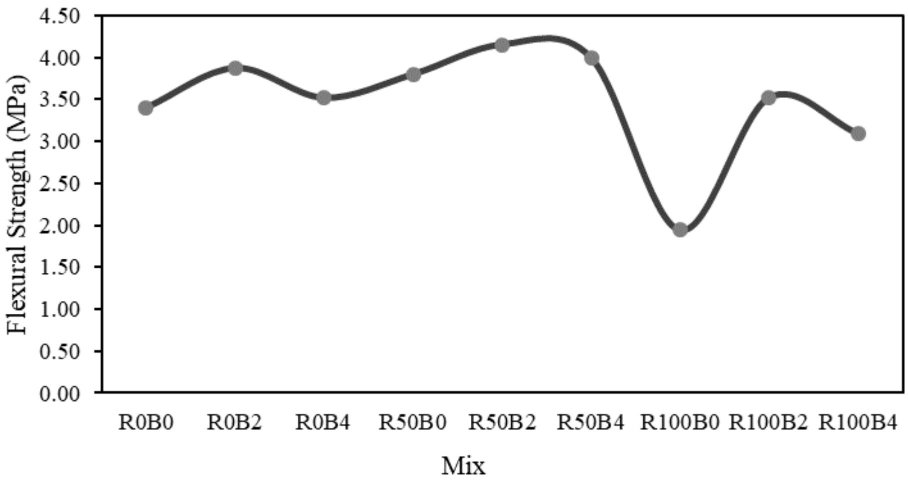

Figure 3 Flexural strength of various mixes

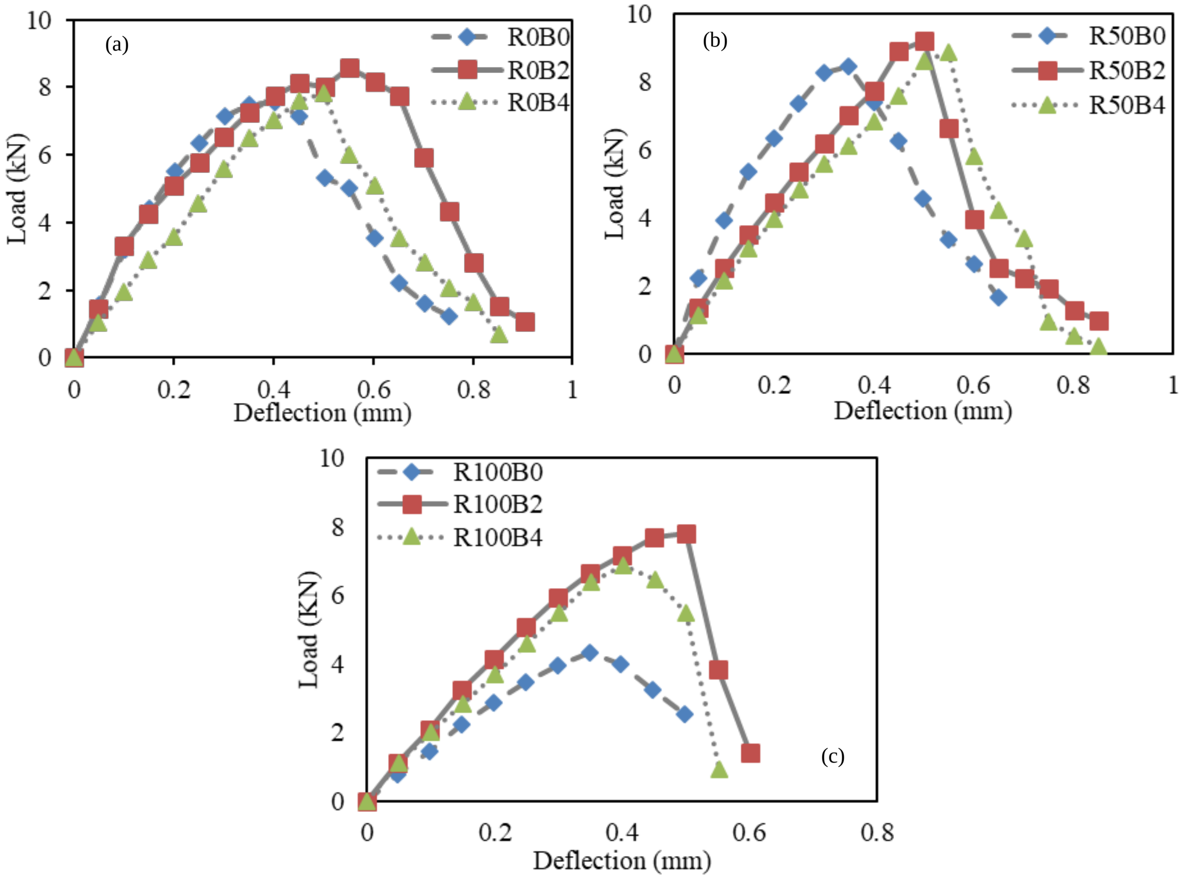

Figure 4 Flexural strength of concrete containing RCA at (a) 0 (b) 50 and (c) 100 % at 28 days

Addition of basalt fiber and recycled concrete aggregate as an effect in the ultimate flexural strength of the concrete. In the case of concrete made with basalt fiber without using recycled concrete aggregate, the flexural strength of the concrete increased for 2 kg/m^3 by 14% and the percentage increase was decreased to 3.5% when the basalt fiber content was 4 kg/m^3. When the replacement was 50% for recycled concrete aggregate, a similar trend was seen when the fiber was added. For R50B0 the strength increased by 11.64% and when the fiber was added the strength increased by 22.05% and 17.47% for 2 kg/m^3 and 4 kg/m^3 respectively. But 100% replacement of the recycled concrete aggregate reduced the strength of the concrete but the addition of the fiber increased the strength of the concrete in the case of R100B2. The lowest strength was obtained for R100B0 and highest flexural strength was seen for R50B2. We could observe that both recycled aggregate and basalt fiber showed enhancement in the flexural strength of the concrete.

From the load-deflection curve of all specimen as shown in Fig 4(a)-(c), the flexural toughness of the concrete was found out and it is shown in Fig 5. After cracking, the cracks cannot extend without stretching and debonding of the fibers. As a result, a large additional energy was absorbed before complete separation of the specimen occurs. Flexural toughness can be measured by calculating the area under the load-deflection curve of the specimen in flexure. It was seen that the energy absorption capacity of the basalt fibers was less as compared to the steel fibers. At the same time, we could also see improvement in the toughness when the fiber was added. Maximum toughness was obtained for R0B2 which increased the toughness around 40% as compared to the control mix R0B0.

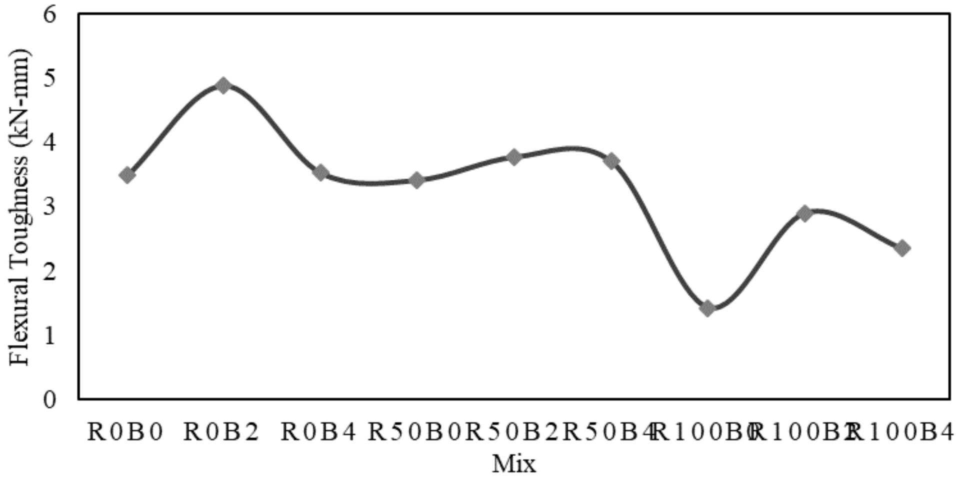

Figure 5 Flexural toughness of the specimens containing various percentage of RCA and fiber

Carbonation Test Results

The accelerated carbonation test was conducted on prisms of size of 100 mm X 100 mm X 100 mm. The casted specimens were cured for a period of 28 days. Then the samples were oven dried for conditioning of specimens. The concentration of CO_2 was maintained at 4% with relative humidity was between 40% and 70% and temperature was kept at 25 ± 2 ºC. Then the specimens were exposed to CO_2 for a period of 28 days using accelerated carbonation chamber. After 28 days, the specimen surface was prepared which is freshly broken surface and phenolphthalein solution have been applied over the surface. The carbonation depth of concrete was measured where the colourless portion exist in the chosen surface. Based on the measurement, the average carbonation depth for varying mix proportions were shown in Fig 6. It is observed that the carbonation depth of concrete was found to be increased with increase of recycled concrete aggregate as well as basalt fiber. The minimum value of carbonation depth was found to be conventional SCC concrete R0B0 and the maximum value was for R100B4. The increase in both RCA and basalt fiber in turn increase the carbonation depth of the concrete. Best result was shown by the control mix only and the worst result was noticed in R100B4 which was 50, 71.4 and 84% more than control mix in 28, 56 and 90 days respectively.

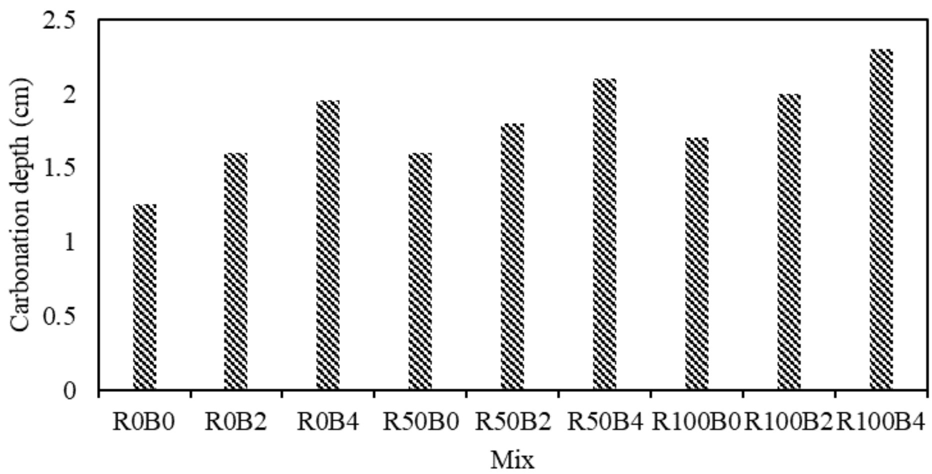

Figure 6 Effect of carbonation depth after a curing period of 28 days and for an exposure period of 90 days

CONCLUDING REMARKS

The experimental investigations were carried out on fibrous self-compacting concrete (SCC) elements subjected to monotonic loading to study the influence of basalt fiber in terms of compressive and split tensile strength tests. Also the durability properties of fibrous self-compacting concrete (SCC) elements were studied in terms of carbonation depth. The tests were carried out on hardened concrete as well as fresh concrete and the following conclusions were drawn:

- Basalt fibre does not contribute much in the case of compressive strength of the concrete. The highest compressive strength was found to be R0B2 mix. When increasing the RCA content, the strength increased in the case zero basalt fibre content however, when introduced basalt fibre in concrete the strength gets reduced as we in increase the RCA content.
- Basalt fibre shows significant improvement in case of split tensile strength. It is also observed that the strength getting reduced a bit at 90 days. As the fibre content was increased the split tensile strength is getting increased. Addition of 50% RCA gave better result as compared to other cases.
- Flexural strength of the concrete increased when the fiber was introduced. It was noticed that even though energy absorbed before cracking was less, the deflection increased when the fiber was added. The maximum value of flexural strength was observed for R50B2 which was 22.05% more than the plain concrete. 100% replacement of RCA decreased the strength and the lowest was found in R100B0, which was 42.64% lower than the conventional concrete.
- It was observed that the carbonation depth of concrete was found to be increased with the increase of recycled concrete aggregate as well as basalt fiber. Best result was shown by the control mix only and the worst result was noticed in R100B4 which was 50, 71.4 and 84% more than control mix in 28, 56 and 90 days respectively.

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