Mechanical and Durability Properties of High Strength Copper Slag Concrete Reinforced With Basalt Fiber

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Abstract- This examination was directed to research the execution of high strength concrete (HSC) made with copper slag as a fine aggregate reinforced with basalt fiber at constant water cement ratio with suitable dosage of superplasticizer addition on the properties of high strength concrete.

Two series of concrete mixtures were prepared with different proportions of basalt fiber. The first series consisted of five concrete mixtures which prepared with different proportions of basalt fiber volume fraction i.e. 0%, 0.05%, 0.1%, 0.3% and 0.5% and 0%CS with suitable dosages of superplasticizer. The second five concrete mixtures prepared with various extents of basalt fiber volume fraction i.e. 0%, 0.05%, 0.1%, 0.3% and 0.5% and 50% copper slag replaced in place of sand at constant water binder ratio with suitable dosages of super plasticizer. Results revealed that at 0% supplanting of copper slag with 0.3% basalt fibers showed the maximum compressive strength improvement, whereas maximum split tensile strength and flexural strength improvement at 0% replacement of copper slag with 0.1% basalt fibers. Similarly 50% replacement of copper slag with 0.1% basalt fibers showed the maximum strength for compressive strength, split tensile strength and flexural strength. Therefore it can be drawn inferences that the use of copper slag as sand substitution improves HSC strength and durability characteristics at same workability while superplasticizer is vital role ingredient in HSC made with copper slag and basalt fiber in order to provide good workability and better consistency for the concrete matrix..

Keywords: Copper slag, Basalt fiber, Super plasticizer, workability of concrete compressive strength, tensile strength, flexural strength.

1. INTRODUCTION

Concrete is a widely used construction material around the globe, and its properties have been undergoing changes through state of the art technological advances. Anyway bond concrete is described by weak disappointment; it loses relatively entire loss of stacking limit once disappointment is started. This trademark, which restrains the use of the material that can be overwhelmed by the incorporation of a little measure of short haphazardly appropriated strands, for example, steel, glass, engineered and regular and can be polished among others that cure shortcomings of concrete, for example, low development opposition, high shrinkage breaking and low strength and so forth. At the point when the small scale breaks are framed in the solid, these are captured by the filaments. Thus improving strength and ductility, and under loading reinforced fibers will stretch more than concrete. The properties of concrete are influenced by numerous variables like properties of cement, fine total and coarse total, such large consumption of natural aggregates will cause destruction of the environment. Therefore there is a critical need to discover and supply elective substitutes for regular totals by investigating the likelihood of use of mechanical side-effects like copper slag and waste materials in making high strength concrete. This will prompt practical solid plan and greener condition

1.1 High strength concrete

High quality cement (HSC) is generally utilized in the development of superior structures, for example, skyscraper strengthened and pre-focused on solid structures, long range solid extensions, etc. Therefore, it should be designed to have higher workability, higher mechanical properties and greater durability than those of conventional concrete. The definition of HSC continues to change as advances in state of the art concrete technology make it easier to achieve increasingly higher strength and greater workability using traditional construction practices. A review of the ongoing examination demonstrated that it is conceivable to use mechanical results and in addition other waste materials in the creation of typical cement and HSC when utilized as halfway as well as full substitution of bond or totals or as admixtures. Different types of fibers, such as those used in HSC composite materials have been introduced into the concrete mixture to increase its toughness, or ability to resist crack growth.

1.2 Copper slag

Copper Slag, is a black glassy and granular in nature and has a similar particle size range like sand. It is an industrial by-product obtained during the smelting of copper. CS used in the production of high strength concrete supplied and added in the powdered form, in present study it is partial replacement of sand. So as to enhance the workability of high strength concrete, super plasticizer, Sika ViscoCrete-20 HE was used in the concrete mix with various dosages.

Fig 1.1: Copper slag

1.2 Basalt fiber

Basalt fiber is an inorganic material produced from volcanic rock called Basalt. It is the most widely recognized rock in the earth covering. Basalt rock qualities change from the wellspring of magma, cooling rate and past exposure to the element. The quality of high class fiber formation depends on basalt stores with uniform synthetic makeup. Basalt fiber is nontoxic material and which can be produced like to that of glass fiber. Crushed basalt rock is only raw material which required for manufacturing the fiber of basalt rock. It is a continuous fiber that produced through igneous basalt rock which melts temperature at about 1350 - 1650^{0}C. Basalt fiber used as fiber reinforced polymer (FRP) and structural composites that has high potential and is drawn lot of attention because of its high temperature and scraped area obstruction.

Fig 1.2 Basalt fiber

2. MATERIALS

The properties of materials used in concrete are determined in laboratory as per relevant code of practice. Different materials used in the present study were cement, two types of coarse aggregates that are 10mm and 20mm, fine aggregate, copper slag, superplasticiser and water.

Copper Slag

It used in this work was brought from Taj Abrasive Industries located in Sikar, Rajasthan, India. CS is a polished granular material with high explicit gravity. Molecule sizes are of the request of sand and have a potential for use as fine total in cement

Superplasticizer

A super plasticizer, Sika ViscoCrete-20 HE was used in the concrete mix with various dosages. It was designed to provide high usefulness maintenance where fast functionality misfortune is caused by high encompassing temperatures or to make up for postpones transportation.

Basalt fiber

Basalt fibers obtained from igneous rock in which molten mass is solidify over the earth surface and is a resin epoxy binder. They are non-corrosive and nontoxic. In the present experimental investigation, chopped basalt fiber strands of 24 mm length and 6 µm diameter procured from HDM Company Private Limited Noida, NCR- Delhi were used. The properties of basalt fiber are shown in table.

Table2.1 basalt fiber

Properties	**Chopped basalt fiber**
Density	2.65
Fiber length (mm)	24
Diameter (µm)	6
Breaking strength (MPa)	3000-4800
Modulus of elasticity (GPa)	79.3-93.1
Water content (%)	<0.10 %
Breaking extension (%)	3.1
Temperature withstand	-260 to +1100

Mix proportion

In the present study the influence of combined application of copper slag and basalt fiber as partial replacement of sand & cement on 1:1.2:2.24 ratio grade concrete is studied with suitable dosages of superplasticizer.

Table 2.2 Mix proportions per m^3

Mix	Fibers %	Water Kg/m^3	Cement Kg/m^3	Fine aggregates Kg/m^3	Coarse aggregates		CS %	SP %	W/C
					20mm	10mm			
M1	0	150	477.27	543.91	808.03	258.64	0	0.8%	0.27
M2	0.05	150	477.27	543.91	808.03	258.64	0	1%	0.27
M3	0.1	150	477.27	543.91	808.03	258.64	0	1.2%	0.27
M4	0.3	150	477.27	543.91	808.03	258.64	0	1.4%	0.27
M5	0.5	150	477.27	543.91	808.03	258.64	0	1.6%	0.27
M6	0	150	477.27	543.91	808.03	258.64	50	0.8%	0.27
M7	0.05	150	477.27	543.91	808.03	258.64	50	1%	0.27
M8	0.1	150	477.27	543.91	808.03	258.64	50	1.2%	0.27
M9	0.3	150	477.27	543.91	808.03	258.64	50	1.4%	0.27
M10	0.5	150	477.27	543.91	808.03	258.64	50	1.6%	0.27

3. RESULTS AND DISCUSSIONS

3.1 Workability of concrete mixes

The workability of concrete mixes was found out by slump test, Water cement ratio was kept constant at 0.27 for all the concrete mixes. Super-plasticizer was used to maintain for required slump. Dosage of superplasticizer was asserted 0.8 to 2% by weight of cement on all mix. The lowest value of slump was obtained with mix 50% FA+50% CS+0% BF, and highest value of slump obtained 0% CS+0.05 BF%. Slump value for all the mix is between 23 to 28mm which was sufficient for satisfactory compaction by use of table vibrator.

3.2 Compressive strength test results

The compressive strength test was conducted at curing ages of 7, 28 and 56 days of specimen size 100 X 100 X 100 mm. Variation of compressive strength of all the mixes cured at 7, 28 and 56 days are also shown in figures.

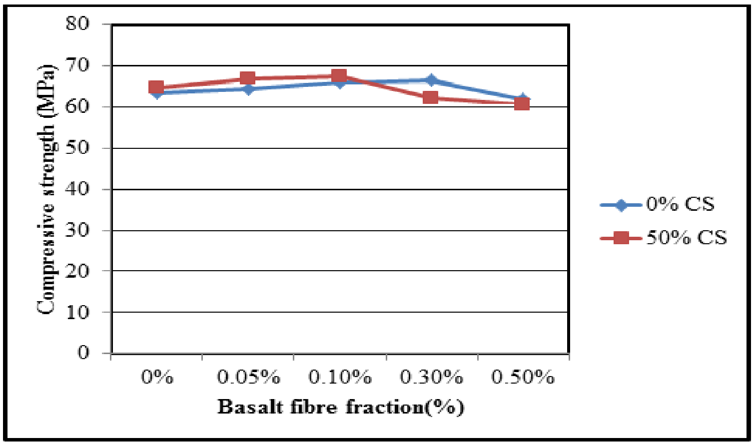

Fig 3.1 Compressive strength with fiber fraction and copper slag at 7 days

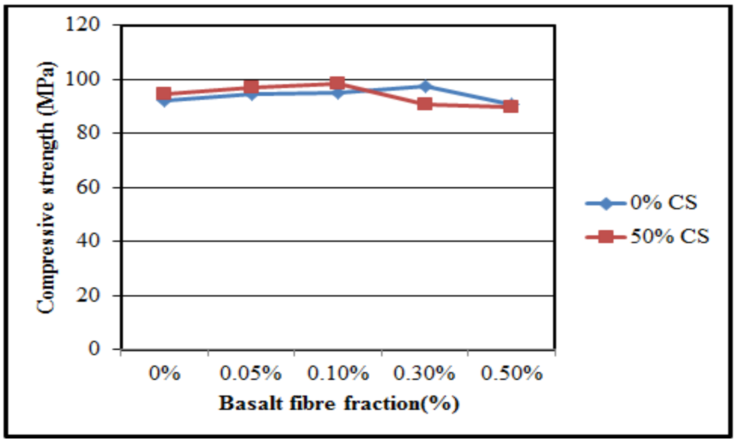

Fig 3.2 Compressive strength with fiber fraction and copper slag at 28 days

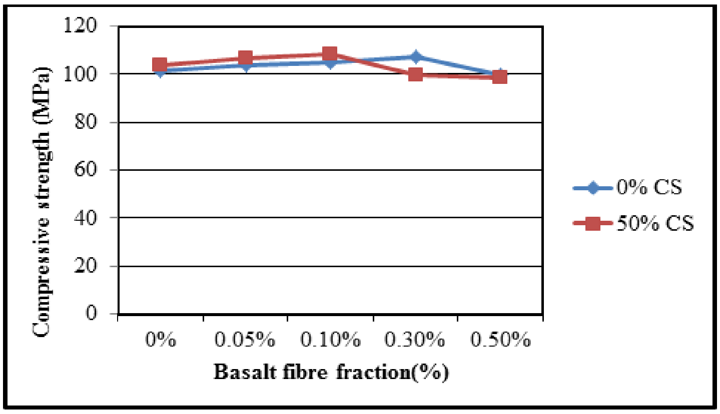

Fig 3.3 Compressive strength with fiber fraction and copper slag at 56 days

Fig 3.1, 3.2 and 3.3 that the compressive strength of copper slag and basalt fiber concrete displays more than the control concrete up to 0% copper Slag and 0.4% basalt fiber and with further increase in basalt fiber the strength decreases for the given basalt fiber content, because the reason might be that the more drawn out fiber has a more grounded spanning impact and hauling out obstruction, which adds to the quality advancement. However, with the increase of fiber length, it is more difficult for fiber to distribute uniformly in cementitious composites, which is decrease the development of strength. Likewise adding 50% CS and 50% BF in concrete mix, observed that the compressive strength of copper slag and basalt fiber concrete demonstrates more than the control concrete up to 50% CS +50% FA+ 0.4% basalt fiber and with further inclusion of basalt fiber the strength decreases for the given basalt fiber content, because more fiber content do not distribute properly in concrete hence structure form honeycomb structure and accordingly strength will decreased.

3.3 Split tensile strength test results

The after effects of the part elasticity tests directed on HSC examples of various blends restored at various ages are introduced and talked about in this segment. The part rigidity test was led at restoring ages of 7, 28 and 56 days. Variety of part elasticity of all blends cured at 7, 28 and 56 days is also shown in fig. 3.4 to 3.6.

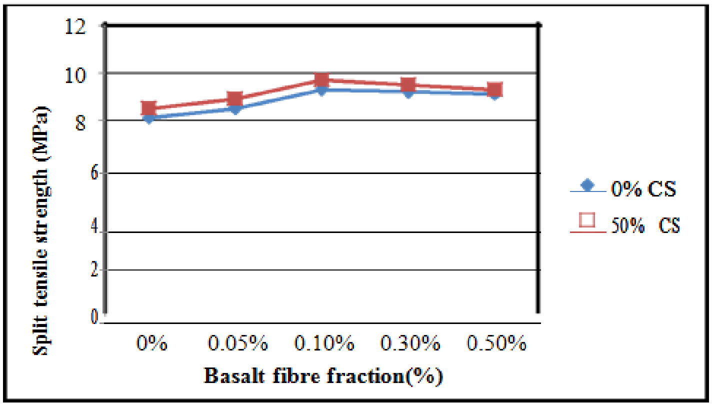

Fig 3.4. split tensile test with basalt fiber and CS at 7 days

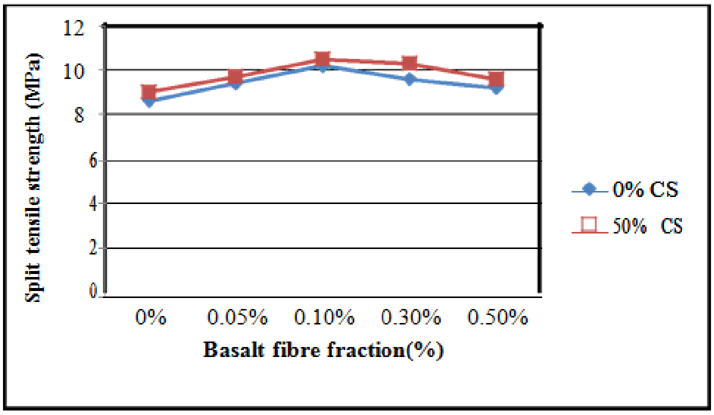

Fig 3.5. split tensile test with basalt fiber and CS at 28 days

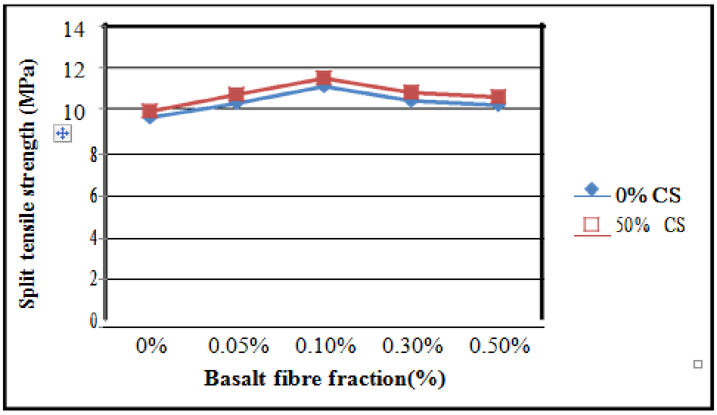

Fig 3.6. split tensile test with basalt fiber and CS at 56 days

Fig 3.4, 3.5 and 3.6 depicts that the split tensile strength of copper slag and basalt fiber concrete exhibits more than the control concrete up to 0% copper Slag and 0.1% basalt fiber and with further increase in basalt fiber the split tensile strength decreases for the given basalt fiber content, because more fiber content do not distribute properly with coper slag due to glassy material in concrete hence structure formed honeycomb and dryness therefore strength will decreased. Likewise adding 50% CS and 50% BF in concrete mix, observed that the split tensile strength of copper slag and basalt fiber concrete evidences more than the control concrete up to 50% CS +50% FA+ 0.1% basalt fiber and with further inclusion of basalt fiber the strength decreases for the given basalt fiber content.

3.4 Flexural strength test

The results of the flexural strength tests carried on HSC specimens of various blends restored at various ages are introduced and talked about in this area. The flexural quality test was led at restoring ages of 7, 28 and 56 days. Variation of flexural strength of all mixes cured at 7, 28 and 56 days is also shown in fig. 3.7 and 3.8.

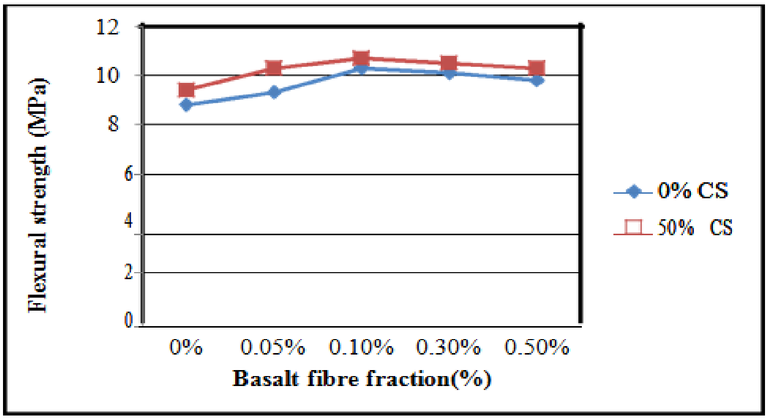

Fig 3.7 flexural strength test with basalt fiber and CS at 28 days

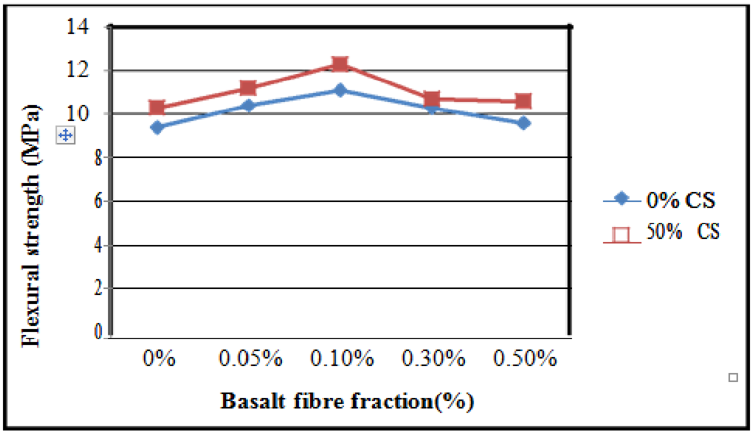

Fig 3.8 flexural strength test with basalt fiber and CS at 56 days

Fig 3.7 and 3.8 shows that the flexural strength of copper slag and basalt fiber concrete exhibits more than the control concrete up to 0% copper Slag and 0.1% basalt fiber and with further increase in basalt fiber the flexural strength decreases for the given basalt fiber content, because it may be due to the difficulty in dispersion of basalt fiber with copper slag due to glassy material in concrete hence structure formed honeycomb and dryness, therefore strength will decreased. Likewise adding 50% CS and 50% BF in concrete mix, observed that the flexural strength of copper slag and basalt fiber concrete demonstrates more than the control concrete up to 50% CS +50% FA+ 0.1% basalt fiber and with further inclusion of basalt fiber the strength decreases for the given basalt fiber content.

3.5 UPV test results

The results of the UPV tests carried on HSC specimens of different mixes cured at different ages are presented and discussed in this section. The UPV test was conducted at curing ages of 28 and 56 days. The UPV test results of all the mixes at different curing ages are depicted in table 3.5 and 3.6.

Table 3.5UPV test results for 28 days

Mix	Description	SP	Distance mm	Transit time µsec	Average pulse velocity (km/sec)	Quality of concrete
M1	0% CS+0% BF	0.8%	100	25.4	3.95	Good
M2	0% CS+0.05% BF	1%	100	26.5	3.52	Good
M3	0% CS+0.1% BF	1.2%	100	27.6	3.73	Good
M4	0% CS+0.3% BF	1.4%	100	28.5	3.63	Good
M5	0% CS+0.5% BF	1.6%	100	28.2	3.54	Good
M6	50% FA+50% CS+0% BF	0.8%	100	26.4	3.78	Good
M7	50% FA+50% CS+0.05% BF	1%	100	26.8	3.73	Good
M8	50% FA+50% CS+0.1% BF	1.2%	100	26.8	3.87	Good
M9	50% FA+50% CS+0.1% BF	1.4%	100	27.8	3.72	Good
M10	50% FA+50% CS+0.5% BF	1.6%	100	28.1	3.64	Good

Table 3.5 shows the UPV values at 28 days of curing. It was observed that concrete mix containing 0% CS+0% BF, showed highest value of UPV than all the values i.e. 3.95 (km/sec) at 28 days of curing. Concrete mix containing 0% CS+0.05% BF, showed lowest value of UPV value i.e. 3.54 (km/sec) at 28days. Similarly concrete mix containing 50% FA+50% CS+0.1% BF, showed highest value of UPV than all the values i.e.3.87 (km/sec) at 28 days. Concrete mix incorporating 50% FA+50% CS+0.5% BF, showed lowest value of UPV than all the values i.e.3.64 (km/sec) at 28 days. It was found that the interface bonding between cementitious composites and aggregate is improved by the addition of fiber with suitable dosage of superplasticizer.

Table 3.6 UPV test results for 56 days

Mix	Description	SP	Distance mm	Transit time µsec	Average pulse velocity (km/sec)	Quality of concrete
M1	0%CS+0% BF	0.8%	100	25.3	3.95	Good
M2	0%CS+0.05% BF	1%	100	25.7	3.89	Good
M3	0%CS+0.1% BF	1.2%	100	25.6	3.90	Good
M4	0%CS+0.3% BF	1.4%	100	25.6	3.90	Good
M5	0%CS+0.5% BF	1.6%	100	26.9	3.92	Good
M6	50%FA+50%CS+0% BF	0.8%	100	26.5	3.54	Good
M7	50%FA+50%CS+0.05% BF	1%	100	25.3	3.96	Good
M8	50%FA+50%CS+0.1% BF	1.2%	100	25.3	3.95	Good
M9	50%FA+50%CS+0.3% BF	1.4%	100	25.7	3.89	Good
M10	50%FA+50%CS+0.3% BF	1.6%	100	28.1	3.64	Good

Table 3.6 shows the UPV values at 56 days of curing. It was observed that concrete mix containing 0% CS+0% BF, showed highest value of UPV than all the values i.e. 3.95 (km/sec) at 56 days of curing. Concrete mix containing 0% CS+0.05% BF, showed lowest value of UPV value i.e. 3.89 (km/sec) at 56 days. Similarly concrete mix containing 50% FA+50% CS+0.05% BF, showed highest value of UPV than all the values i.e.3.87 (km/sec) at 56 days. Concrete mix incorporating 50% FA+50% CS+0% BF, showed lowest value of UPV than all the values i.e.3.64 (km/sec) at 56 days.

4. CONCLUSION

- Inclusion of basalt fiber fraction and 50% copper slag with suitable dosage of superplasticizer improved the compressive strength, split tensile strength and flexural strength.
- Addition of 0.3% basalt fiber and 0% copper slag improved the compressive strength 4.51%, 5.43% and 5.84% at 7, 28 and 56 days respectively compare to controlled mix. The reason may be that the longer fiber has a stronger bridging effect and pulling-out resistance, which contributes to the strength development.
- Similarly at 50% CS and fiber inclusion in the concrete mix, the following compressive strength results are depicts that the compressive strength obtained for 50% FA+50% CS+0.1% BF, mix was 4.74%, 3.86% and 3.86% at7, 28, 56 days respectively. The addition of fiber effectively slows down the propagation of crack, and thus improves the mechanical behavior of compressive strength.
- It has been found that the substitution of copper slag with basalt fiber in concrete mix, the percentage improvement value of splitting tensile strength obtained for 0%

CS+0.3% BF; mix was 12.9% at 7 days and 0% CS+0.1% BF, mix was 15.68%, 13.51% at 28 days and 56 days respectively when compared to controlled mix.

- Similarly replacement of 50% copper slag with basalt fiber inclusion significantly increases the splitting tensile strength were at 50% FA+50% CS+0.1% BF, mix were 12.37%, 14.28% and 13.91% at 7, 28 and 56 days respectively when compared to controlled mix. It was found that the interface bonding between cementitious composites and aggregate is improved by the addition of fiber and copper slag with suitable dosage of plasticizer. With longer length, it is more likely for fibers to stride across aggregate and to act on tiny bridges. Longer fibers demonstrate progressively evident spanning impact and more resistance, which would add to quality improvement. which would contribute to strength development.
- It has been observed that the flexural strength reached a maximum value obtained for 0%CS+0.1% BF, mix was 14.56% and 15.31% at 28 and 56 days respectively. In addition, it can be seen that FRC with 24 mm BF shows better flexural strength.
- Similarly the concrete containing 50%CS, 50% FA and fiber inclusion gives the flexural strength were at 50% CS+50% FA+0.1% BF, mix was 12.14% and 16.26% at 28 and 56 days respectively. The addition of fiber viably backs off the proliferation of crack, and in this manner enhances the mechanical conduct and durability of the specimen.

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