Experimental Study on Mechanical Properties of Concrete under Varying Temperature Using Different Aspect Ratios of Basalt Fiber

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Abstract: The impact of basalt fiber on the mechanical characteristics of concrete at different temperatures is the subject of this experimental study. For comparison, various aspect ratios of basalt fiber (25, 50, 75) and various temperatures (300 °C, 500 °C, 700 °C) is taken. Compressive, Tensile and Flexural strength test is carried out on test specimen at 56 days. Testing specimen (150×150×150 mm cube and 150ø×300 mm cylinder And Flexural Beam 500×100×100 mm) were prepared using high strength concrete with basalt fiber at dosage 0.75% then subjected to elevated temperature at 300°C, 500 °C, 700 °C (± 10 °C). Basalt fiber has superior properties to minimize damage under elevated temperature. According to test results, the inclusion of basalt fiber increases the compressive and tensile strength and also increases the flexural strength of concrete, while decreasing its strength at increased temperatures of 500 °C and 700 °C.

Keywords: Chopped basalt fiber, Aspect ratios, Elevated Temperature, Compressive, tensile, strength

I. INTRODUCTION

Concrete is an important man-made material that is used globally second after water. In civil engineering, concrete is used all over the world because of its superior properties like structural strength, impermeability, durability etc. but it has some bitter properties like brittleness, low tensile strength causing cracking, lower fire resistance etc. To improve some properties of concrete additional ingredients like fibers are widely used in concrete in recent days. FRC is a composite material in which fibers are spread in an ordinary manner or randomly distributed manner. In concrete propagation of micro and macro cracks causes water and other environmental factors to corrode reinforcement, freezing and thawing and result in a decrease in strength and durability of concrete. It was reported that about 40 per cent of failure of RCC due to corrosion of reinforcement.

In industry, various fibers are available abundantly with various parameters like Steel fiber, Glass fiber, Natural fiber, PET fiber, Polypropylene fiber, Carbon fiber, etc. Several researches are carried out on various fibers recently. Steel fiber will make concrete heavier structurally and create a balling effect during mixing, which will make the concrete less workable. Glass fiber reacts strongly to alkaline environments. Aside from being stiffer and chemically inert, carbon fiber possesses anisotropy and a high cost. Low elastic modulus, low melting temperature, and weak interfacial interaction with the inorganic matrix are typical characteristics of synthetic fibers, primarily polymeric fibers. Globally, basalt fiber is **becoming** increasingly popular among all types of fiber. The amount of study that has been done on basalt fiber is rather small.

Basalt fiber is obtained from basalt rock that is first crushed, then washed & transferred into melting baths in gas-heated furnaces beneath temperatures of 1400 °C - 1500 °C. BF is extruded from basalt rock that are melted at 1400 °C without any application of additives, which makes it cost-efficient.

The concrete industry always trying to find new, beneficial to the industry. For this purpose, rectification in conventional cement concrete has become mandatory. An effective way to improve the properties of concrete by adding various types of fibers but among all the fiber available BF proves beneficial because it is naturally occurring

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and one of the most abundant materials on earth. In addition, it is environmentally safe, non-toxic, non-corrosive, non-magnetic and insulating characteristics. BF is obtained at high temperature of about 1400°C resulting in high heat stability.

The study conducted by M. HassaniNiaki, A. Fereidoon M. Ghorbanzadeh Ahangari [3] examined the mechanical and thermal properties of basalt fiber and nanoclay-reinforced polymer concrete. The findings indicate that while adding nano clay to BFRP improves some mechanical properties, it does not significantly increase the thermal stability of plain concrete.

However, FRP materials like glass, steel fiber exhibit poor performance at high temperatures, therefore in case of heat resistivity use of such fiber is limited. Thus, various studies were carried out on plain concrete and FRP at elevated temperatures.

The impact of higher temperatures at room temperature, 40 °C, 80 °C, 120 °C, 160 °C, and 200 °C on the mechanical characteristics of basalt fiber and BFRP plates was investigated by Zhongyu Lu, Guijun Xian, and Hui Li [5]. Glass fiber and GFRP plates were employed as a means of comparison. According to the findings, BFRP specimens have superior tensile behavior and barely show any decrease in mechanical characteristics at temperatures as high as 200 °C when compared to GFRP and glass fiber. The limited understanding of the impact of high raised temperatures and different aspect ratios of BF on the mechanical characteristics of concrete is derived from existing research papers.

In this study, the influence of rise in temperature from 300 °C, 500 °C and 700 °C on traditional concrete and BFRC having various aspect ratios of 25, 50,75 of BF is studied. The result can be analyzed to estimate the heat-resisting behavior of controlled concrete and BFRC. The properties investigated for this purpose include compressive and tensile strength and the effect of the addition of BF to traditional concrete can be judged at elevated temperatures.

II. PROBLEM DECLARATION

Corrosion of the steel reinforcing bars is one of the most common issues with reinforced concrete. The concrete has many tiny fissures and is weak in tension. When the load is applied, micro-cracks start to spread throughout the matrix. The reinforcing steel becomes vulnerable to environmental damage due to the propagation of micro and macro fractures. The life and longevity of concrete buildings are significantly impacted by the permeability of the concrete caused by cracks, which also allows reinforcement to corrode. Adding basalt fiber to concrete is one of the greatest ways to get over this problem, which is crucial for the construction to last for many years.

III. OBJECTIVES & SCOPE

Objectives of Work:

- Adding chopped basalt fiber to normal concrete to improve its performance
- Examine and determine the issues with standard, plain concrete and use chopped basalt fiber for rectification to enhance overall performance.
- Compare the effects of different aspect ratios and fiber contents on the ability of different grades of concrete (M25, M35, and M45) to withstand heat.
- Compare the performance of chopped BF of different lengths (6 mm, 12 mm, and 18 mm) at fiber doses (0.75%) at different temperature conditions (300 °C, 500 °C, and 700 °C) owing to fire (compressive and split tensile and flexural strength of BFRC specimens).
- Find the ideal chopped basalt fiber aspect ratio needed to increase the BFRC with thermal stability's split tensile and compressive strengths relative to plain concrete.
- Additionally, contrast plain concrete and BFRC.

Scope of Work:

- Analysis and Issue Recognizing standard concrete in its simple form.
- A thorough analysis and evaluation of the literature.
- Select chopped basalt fiber with varying aspect ratios and content from the literature review to add to plain concrete.
- Carry out the required analysis, testing, and inspections.
- Create the mix design for the M25, M35, and M45 grade plain concrete control mix.
- Making cube and cylinder examples of basalt fiber reinforced concrete.
- Seven days of curing test specimens.
- Following curing, the cube and cylinder specimens were exposed to fire temperatures of 300°C, 500°C, and 700°C.
- Using the necessary data collection systems and apparatus to test the specimens.
- Examining the test findings
- Examine the differences between standard concrete and concrete reinforced with basalt fibers.
- Determine optimum Aspect Ratio of chopped basalt fiber which improves the thermal stability and mechanical properties of plain concrete than others.

IV. LITERATURE REVIEW

TABLE: 1
LITERATURE PAPER: 1

Sr. No	Title of Paper	Author	Source & Publication Year
1	Use of basalt fibers for concrete structures	Cory High, Hatem M.Seliem, AdelEl - Safty, SamiH. Rizkalla	Elsevier 2015
Data Related to Paper	• In this paper, a comparative study is carried out by them related to the use of basalt fiber bars and chopped basalt fiber in concrete. Use of basalt fiber in concrete focusing fiber length effect.		
Test conducted	• Bond strength Test on bar specimen • Compressive strength and Flexural strength test on chopped basalt fiber specimen		
Conclusion	• Results show that chopped basalt fibers how to increase in compressive strength at 28 days. • Short bond lengths show gradual slip prior to failure and specimens with long bond lengths exhibited sudden failure due to rupture of BFRC bars.		

TABLE: II
LITERATURE PAPER: 2

Sr. No	Title of Paper	Author	Source & Publication Year
2	Evaluation of heat-resisting behavior of basalt fiber in forced FGtiles	Anuja Narayan and Prabhavathy Shanmugasundaram	Elsevier 2018
Data Related to Paper	• In this paper, investigations are carried out to predict the heat-resisting behavior of leash- based geo polymer(FG) tile intended for thermal application in buildings.		
Test conducted	Steady-state temperature, Flame Test, Furnace heat resistance, Opentosky, Heat dissipation, Thermal shock resistance, Compressive strength test		
Conclusion	• The end of the research conclusion is FG tiles prepared with 0.5% basalt fiber and 0.5% TiO2 to the mass of flesh give a higher compressive strength of 33.10 MPa with the dry density1961Kg/m^3. • Various temperature drop and times is taken by the specimen to regain its original form Specimen with Tio2 and Basalt fiber increases temperature drop of 25.38%and4.78% • Compressive strength is higher than normal and additive mixes of about 30.89% and 28.11% because of the higher oxidizing property of TiO2 and high temperature with the standing ability of basalt fiber. • In to sky test higher drop value of 12.72% at 11.00 am.		

TABLE III:
LITERATURE PAPER: 3

Sr.No	Title of Paper	Author	Source & Publication Year
3	Experimental study on the mechanical and thermal properties of basalt fiber and Nanoclay reinforced Polymer concrete.	M HassaniNiaki, A.Fereidoon, M.Ghorbanzadesh Ahangari	Elsevier 21 February 2018
Data Related to Paper	• Researchers investigate the effect of chopped basalt fiber on the Compressive, Flexural, and Split tensile strength test as well as the effect of different temperatures (up to 250°C) • In a second step, the effect of Nano clay particles under high temperatures on mechanical properties was also studied in the same way and compared.		
Test conducted	• Steady-state temperature, Flame Test, Furnace heat • resistance, Open to sky, Heat dissipation, Thermal shock resistance, Compressive strength test		
Conclusion	• Basalt Fiber caused an improvement of 35% in splitting tensile strength compared to plain concrete. • Nanoclaycauseddecreaseofsplittensilestrengthfrom15.95Mpato 11.54Mpa • Due to the addition of basalt fiber increased in compressive strength 10%, Flexural strength 4.8%, and split tensile strength upto 35%while due to Nanoclay increased compressive Strength by upto 7% and flexural strength27%.		

V. EXPERIMENTAL PROGRAMMED

1. Material:

1.1 Cement:

The whole project employed OPC (53 grade), which verifies IS - 12269:2013 and IS - 456:2000, both of which are readily accessible locally and have a specific gravity of 3.15.

1.2 Aggregate:

It is confirmed that IS – 383:2016 and IS – 2386 were employed throughout the job using locally accessible fine and coarse aggregate. Uses include coarse aggregate with a maximum size of 20 mm and a specific gravity of 2.74, as well as river sand, which verifies Zone II and has a maximum size of 3 mm and a specific gravity of 2.62.

1.3 Admixture:

FOSROCCONPLASTSP430 is available commercially used in making concrete which is brown in color and in liquid form having specific gravity1.18@ 25 °C.

1.4 Basalt Fibers:

Three different lengths of chopped basalt fiber 6 mm,12 mm and 18 mm used in this study. The fiber was supplied by GoGreen Products, India. Melting pure basalt rock that occurs naturally is the first step in the one-stage process used to create basalt fibers. Dark brown to black, hard, and volcanic igneous rock in its native state is called basalt. It is the most prevalent kind in the crust of the world. Because of its exceptional strength and durability, basalt is a perfect material for structural and other construction-related applications.

Fig. 1 Basalt fiber

Basalt Fiber Properties:

- **Color:** Golden Brown.
- **Diameter:** 0.24 mm.
- **Length:** 6, 12, 18 mm.
- **Density:** 2.67g/cm^3.
- **Coefficient of friction:** 0.42 to 0.50.

- Basalts are stable in strong alkalis.
- Weight loss in boiling water, Alkali, and acid is also considerably lower.
- Basalt fibers have very good resistance against alkaline environments and withstand pH up to 13 to 14.
- It also has good acid and salt resistance.

2.2 Mixing and Curing:

BF (0.75%) was added to the mix after cement was put to the dry mixture that had first been combined with coarse and fine aggregate. Water was lastly added to the mixture gradually. New concrete was individually poured into a 150×150×150 mm cubic mold for compressive strength testing, a 150ø × 300 mm cylindrical mold for split tensile strength testing, and a 500×100×100 mm flexural beam. Specimens were deposited in the tank to cure after casting.

2.3 Elevated Temperature Condition:

Before testing, a specimen was placed to an elevated temperature of 300°C, 500 °C, 700 °C (±10°C). The temperature was controlled by an electrical furnace. After 2h of subjecting to elevated temperature specimens were allowed to cool down to room temperature and then tested.

2.4 Mechanical Test:

All of the mechanical tests were conducted using a compressive strength testing apparatus. Testing for compressive strength was done in accordance with IS-516, while testing for split tensile strength was done in accordance with IS-5816. For the split tensile strength test on a cylinder specimen measuring 150ø × 300 mm, the compression test will be conducted on a cube specimen measuring 150×150×150 mm, and the flexural beam will be tested at 500×100×100 mm. The equipment utilized to assess compressive strength was provided by EIE Instruments Pvt. Ltd. After being made and tested, three distinct mixes, designated Mix-1, Mix-2, and Mix-3, were found to have the following mean values for tensile and compressive strength after 28 days.

TABLE IV:
MEAN STRENGTH AT 28 DAYS

Mix	Mean compressive strength At 28 days (N/mm^2)	Mean Split tensile strength At 28 days (N/mm^2)	Flexural Strength At 28 days (Mpa)
1	28.35	3.63	3.5
2	40.63	4.29	4.14
3	49.41	4.7	4.69

Fig. 2 Compressive Strength test

Fig. 3 Split Tensile Strength test

VI. RESULT AND DISCUSSION

1. Compressive Strength:

- Findings for several mixtures are displayed in Table 1-3, It is evident that adding 0.75% of BF to concrete mixtures boosts their strength. Strengthened concrete with BF added can be increased by 4–20% over plain concrete.
- At a high elevated temperature of 500 °C, In PC, there is a reduction of strength up to 15-18 % but in the case of BF having an Aspect Ratio 25, Strength reduction up to 8%, Aspect Ratio 50, Strength reduction up to 5%andAspectRatio75, Strength reduction upto 5-6%.At700°CtemperatureStrengthreductionupto30%in PC, while in the case of BF, strength reduction is limited to 20-22 % due to AR-25, 16 % due to AR-50, and17-18% strength reduction due to AR-75.
- From the Fig, it can be seen that as the Aspect Ratio of BF increases strength of concrete increases.

TABLE V:
COMPRESSIVE STRENGTH (MIX-1)

MIX–1Compressive Strength (56Days)				
M-25	0 °C	300 °C	500 °C	700 °C
PCC	29.48	28.09	24.17	20.68
AR25	30.87	30.01	28.4	24.07
AR50	33.6	33.54	31.58	27.55
AR75	34.03	33.8	31.98	28.18

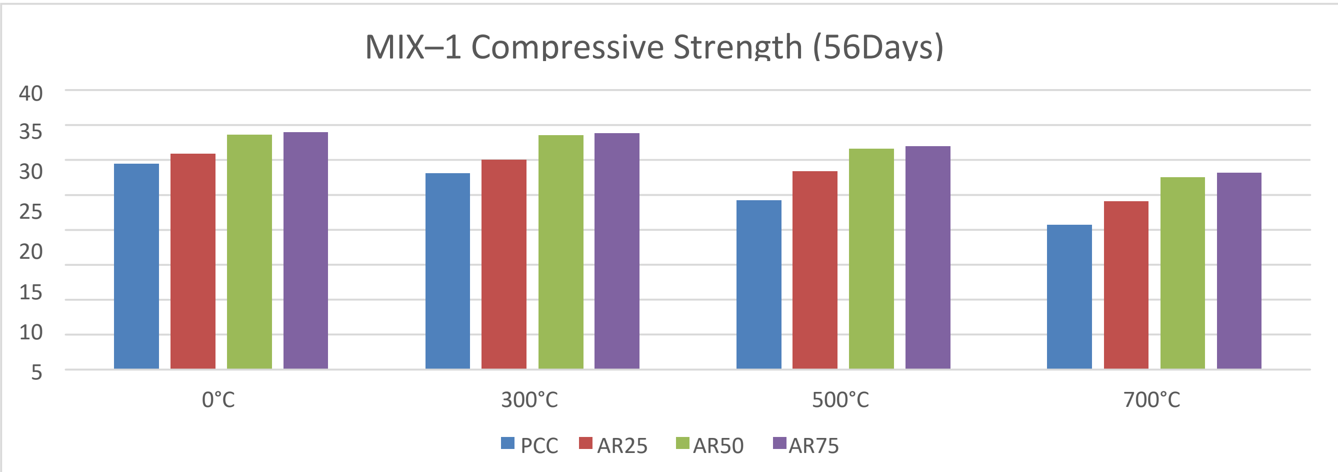

Fig. 4 Compressive Strength (MIX-1)

TABLE VI:
COMPRESSIVE STRENGTH (MIX-2)

MIX–2 Compressive Strength(56Days)				
M-35	0 °C	300 °C	500 °C	700 °C
PCC	42.5	41.02	36.25	31.34
AR25	45.18	44.4	42.06	36.09
AR50	49.48	49.45	47.11	41.56
AR75	50.33	50.12	47.8	42.04

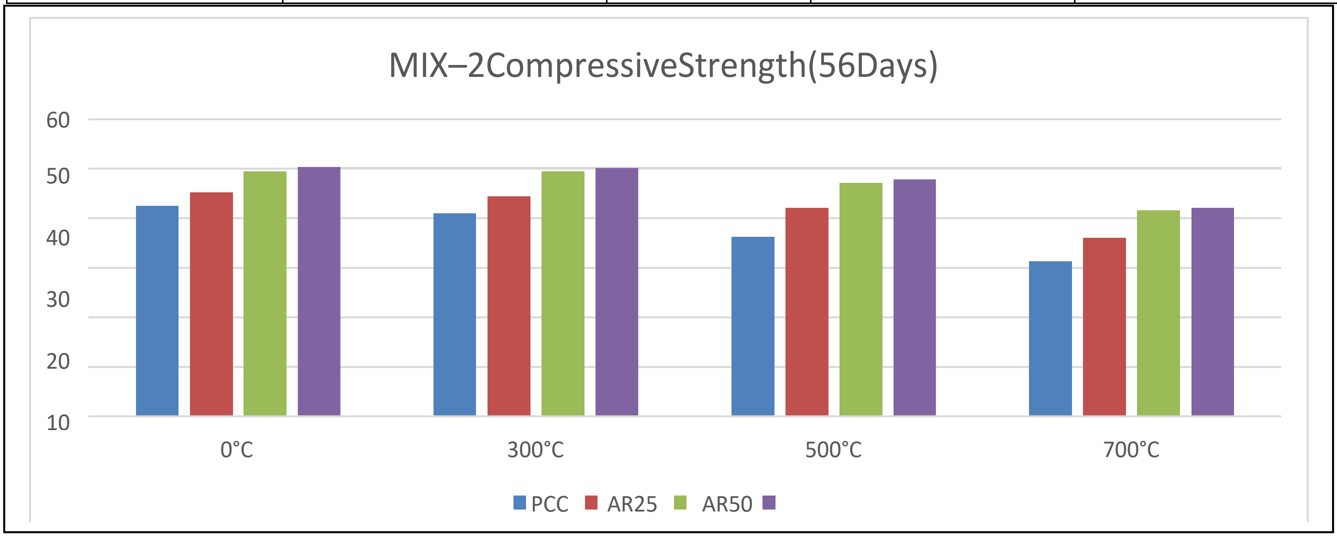

Fig. 5 Compressive Strength (MIX-2)

TABLE: VII
COMPRESSIVE STRENGTH (MIX-3)

MIX–3 Compressive Strength(56Days)				
M-45	0 °C	300 °C	500 °C	700 °C
PCC	51.4	48.98	42.65	37.22
AR25	54.22	53.69	50.42	42.57
AR50	58.9	58.88	55.89	49.18
AR75	59.32	59.19	56.17	49.38

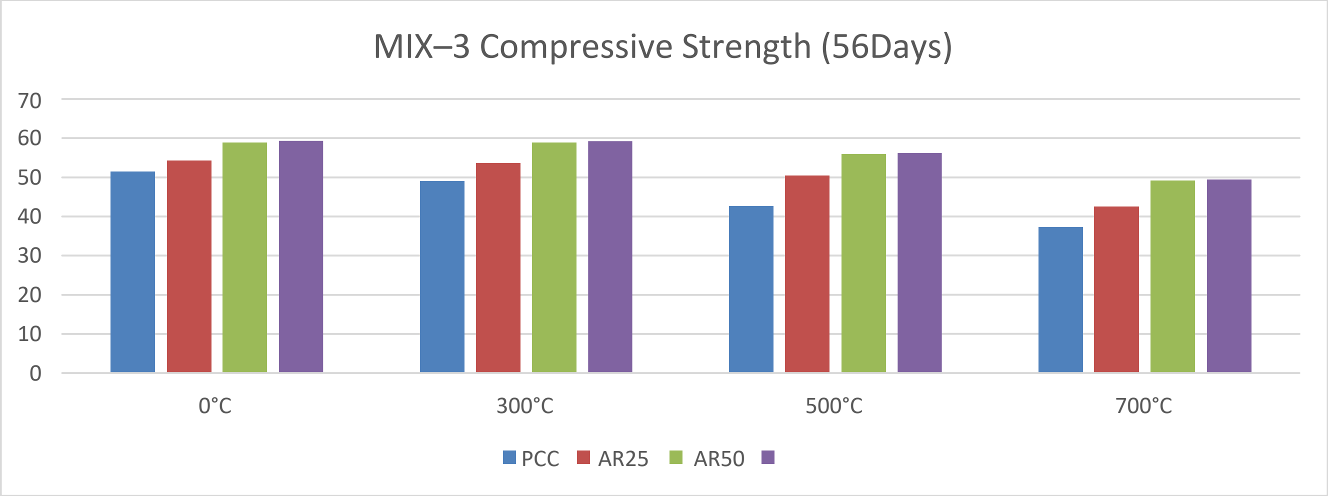

Fig. 6: Compressive Strength (MIX-3)

2. Split tensile strength test:

- Results for the different combinations' tensile strengths are displayed in Table 4-6. As can be observed, adding BF to PC increases split tensile strength by up to 34%.
- At an elevated temperature of 500°Cand 700 °C, the Strength of PC was reduced by up to 11 % and 25% correspondingly. While BF having AR-25 cause a reduction in strength up to 10 % (At 500 °C) and 22 % (At700°C).BF having AR-50causereductioninstrengthupto6-7%(At500°C)andupto19%(At700
- °C).BF having AR-75cause reduction in strength up to 8% (At500°C) and up to 20 % (At 700°C).
- It can be seen that as the aspect ratio of basalt fiber increases strength of concrete increases.

TABLE VIII:
TENSILE STRENGTH (MIX-1)

MIX–1 Tensile Strength(56 Days)				
M-25	0 °C	300 °C	500 °C	700 °C
PCC	3.8	3.66	3.38	2.85
AR25	4.2	4.05	3.81	3.28
AR50	4.88	4.84	4.5	3.95
AR75	5.05	4.92	4.65	4.04

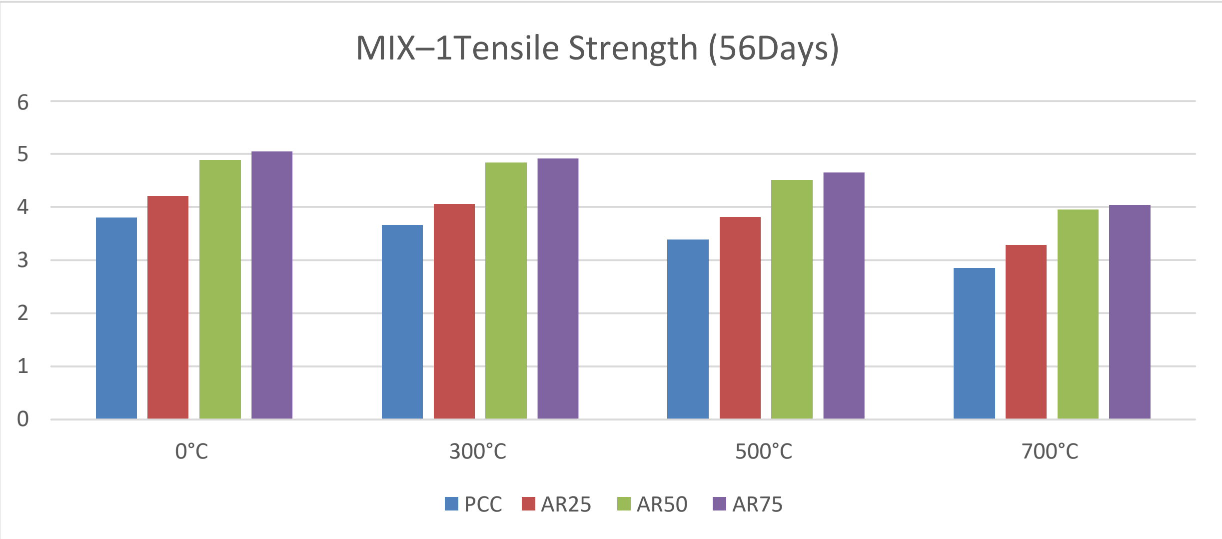

Fig. 7 Tensile Strength (MIX-1)

TABLE IX:
TENSILE STRENGTH (MIX-2)

MIX–2 Tensile Strength(56 Days)				
M-35	0 °C	300 °C	500 °C	700 °C
PCC	4.42	4.27	3.97	3.35
AR25	4.9	4.76	4.48	3.82
AR50	5.67	5.65	5.33	4.58
AR75	5.97	5.79	5.39	4.75

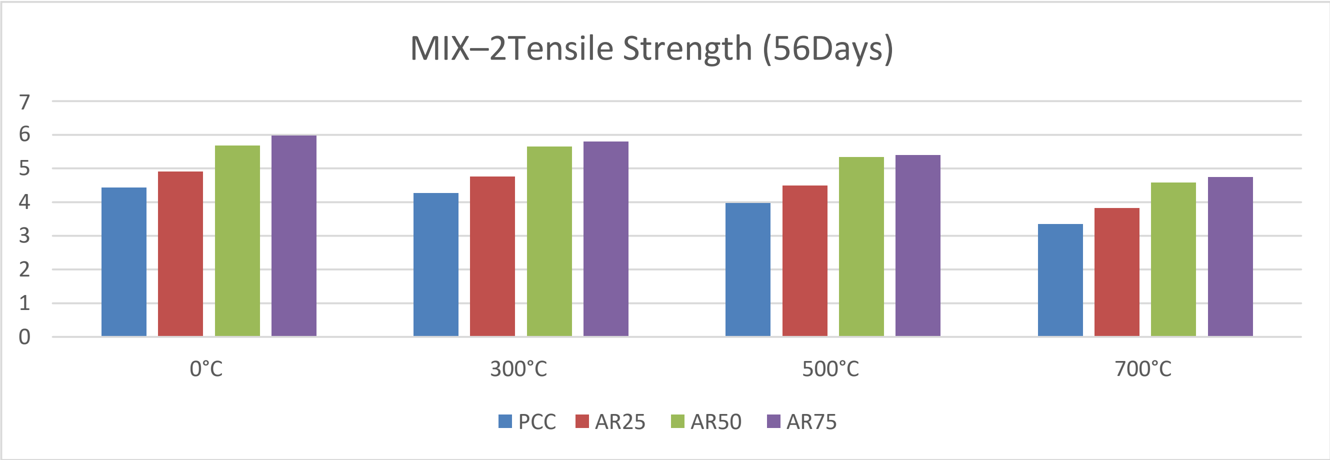

Fig. 8: Tensile Strength (MIX - 2)

TABLE X:
TENSILE STRENGTH (MIX-3)

MIX–3 Tensile Strength(56 Days)				
M-45	0 °C	300 °C	500 °C	700 °C
PCC	4.85	4.67	4.34	3.64
AR25	5.29	5.13	4.81	4.12
AR50	6.21	6.2	5.82	5.03
AR75	6.47	6.38	5.95	5.21

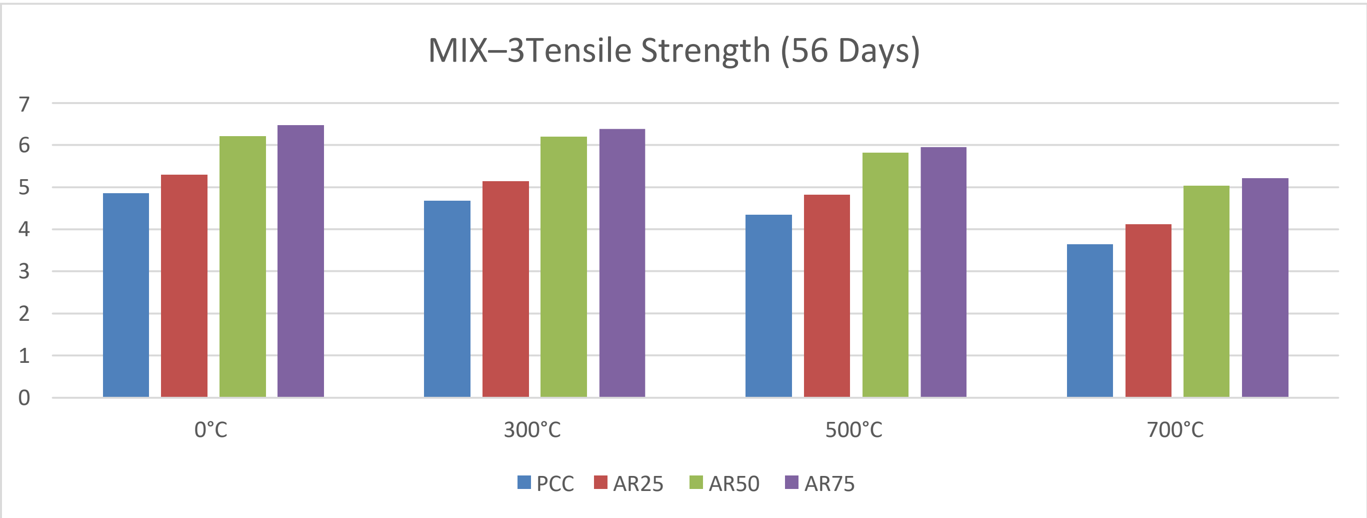

Fig. 9 Tensile Strength (MIX-3)

2. Flexural Strength Test

- Results for the Flexural strength of various mixes are shown in Table 8-10. It can be seen that the addition of BF to PC causes an increase in Flexural strength by up to 31%.
- At elevated temperatures of 500°Cand 700°C, the Strength of PC reduced upto12% and 24% correspondingly. While BF having AR-25 cause a reduction in strength up to 10 % (At 500 °C) and 22 % (At700 °C). BF having AR-50 causes a reduction in strength up to 5-6 % (At 500 °C) and up to 18 % (At 700 °C). BFhavingAR-75cause reduction in strength upto7% (At500°C) and up to 20% (At 700 °C).
- It can be seen that as the aspect ratio of basalt fiber increases strength of concrete increases.

TABLE XI:
FLEXURAL STRENGTH (MIX-1)

MIX–1Flexural Strength(56Days)				
M-25	0°C	300°C	500°C	700°C
PCC	3.68	3.54	3.27	2.76
AR25	4.00	3.85	3.56	3.00
AR50	4.56	4.39	4.05	3.42
AR75	4.69	4.52	4.18	3.52

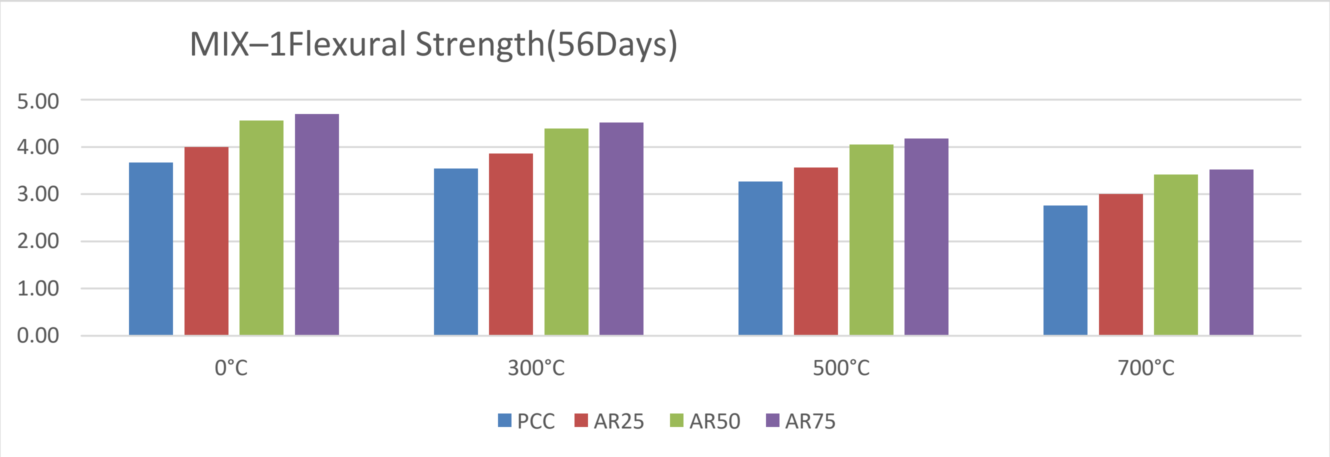

Fig. 10 Flexural Strength (MIX-1)

TABLE: XII:
FLEXURAL STRENGTH (MIX-2)

MIX–2Flexural Strength(56Days)				
M-35	0°C	300°C	500°C	700°C
PCC	4.35	4.19	3.87	3.26
AR25	4.70	4.52	4.18	3.52
AR50	5.31	5.12	4.72	3.98
AR75	5.46	5.26	4.85	4.09

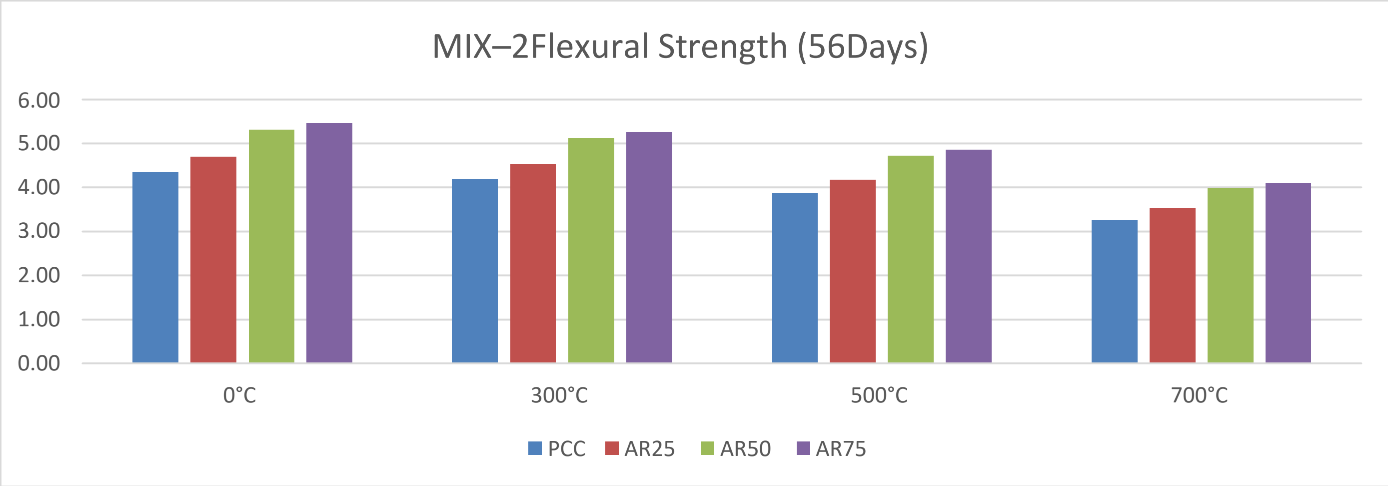

Fig. 11 Flexural Strength (MIX-2)

TABLE: XIII
FLEXURAL STRENGTH (MIX–3)

MIX–3 Flexural Strength(56Days)				
M-45	0°C	300°C	500°C	700°C
PCC	4.92	4.74	4.38	3.69
AR25	5.31	5.12	4.73	3.99
AR50	5.97	5.75	5.31	4.47
AR75	6.13	5.90	5.45	4.60

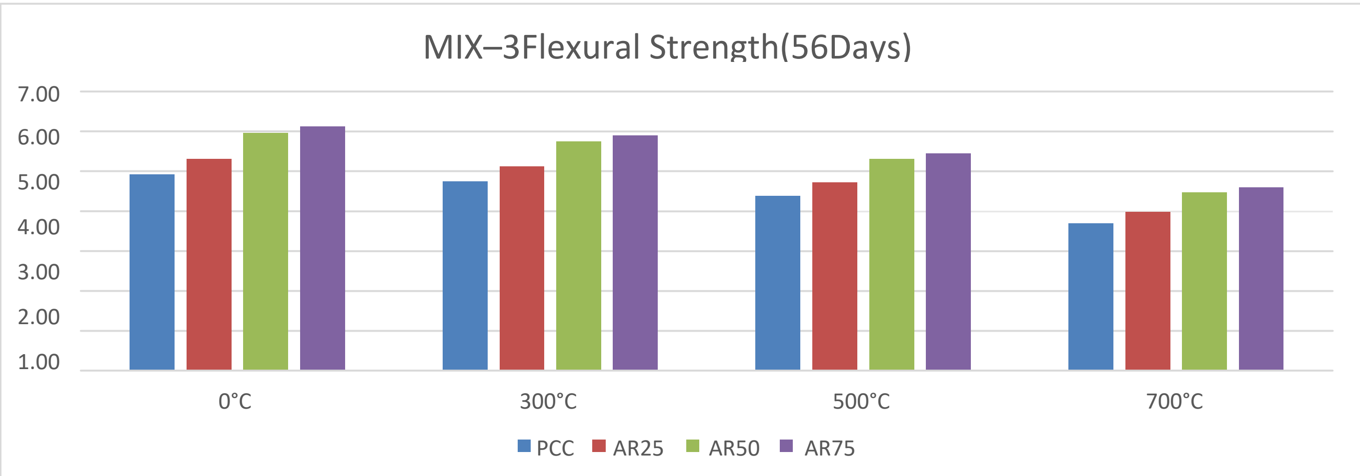

Fig.12 Flexural Strength (MIX–3)

VII. CONCLUSION

The findings indicate that the inclusion of BF results in an increase in the plain concrete's tensile, compressive, and flexural strengths. The workability of concrete is reduced as the length of fiber increases.

Temperature Effect:

- Up to 300°C, BFRC remains almost unaffected in appearance and strength effect.
- At elevated temperatures of 500°Cand700°C, a Reduction in a certain amount of strength is observed in BFRC. In the case of PC higher amount of strength reduction below residual strength is observed.

Aspect Ratio Effect:

- The investigation leads to the conclusion that adding BF to plain concrete increases its strength.
- Concrete gains strength as the BF Aspect Ratio rises.
- At AR-50, the strength of concrete shows a maximum increase beyond it at AR-75 slight increase in the strength of concrete.

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