iJRASET
International Journal For Research in
Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 10 **Issue:** VI **Month of publication:** June 2022

**DOI:** https://doi.org/10.22214/ijraset.2022.44123

# Performance of Glass Fiber, Basalt Fiber: Subjected to Fire

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***Abstract— Over the decades, there was a widespread increase in the use of fiber in concrete for improving its properties such as tensile strength and ductility. The fiber reinforced concrete is also used in retrofitting existing concrete structures. Dispersed fiber reinforcement of concrete improves specific properties and one of them is fire resistance. In numerous research was proven that glass fiber and basalt fiber can inhibit or partly prevent concrete from explosive spalling. New kind of fiber may be be used as dispersed reinforcement are chopped basalt fiber (BF) and glass fiber with ability to improve not only physical and mechanical properties of concrete but also to resist fire . Basalt is rock with suitable properties for resistance to high temperatures, as low coefficient of thermal expansion and stability up to 600 °C to 700 °C. Glass fiber has benefits of getting higher tensile strength and fire resistant properties, thus reducing the loss of damage during fire accident of concrete structures. Concrete mixes with various doses of cement and chopped basalt fiber and glass fiber had been investigated in this study. Properties of fresh and hardened concrete had been examined and evaluated temperatures.Due to large damages of concrete structure it was not possible to measure changes of porous system evaluated by spacing factor after thermal load. Compressive strength was examined before and after thermal load. Special thermal regimes with maximum temperature 200 °C, 300 °C,400˚C and 500 °C were applied. Results showed that chopped basalt fiber and glass fiber have positive impact not only on mechanical properties of concrete but also on its fire resistance. Two specific doses of chopped basalt fiber and glass fiber were tested but further research is in progress. Many studies are under way in this modern world in construction fields and seen that use of fiber reinforced concrete can lead to more effective and efficient construction material.***
***Keywords— Chopped basalt fiber (BF), Glass fiber, Thermal load, fire resistance, spacing factor.***

## I. INTRODUCTION

This Generally, concrete is strong in compression and weak in tension. Concrete is brittle and will crack with the application of additional compressive force. Once concrete cracks it cannot carry tensile loads and compression loads. In order to make concrete capable of carrying compressive load it is essential to increase the compressive strength. To increase the compressive strength, fibers are introduced in concrete. The addition of fibers in concrete will result in a composite material that has properties different from those of un-reinforced concrete. The extent of this variation depends not only on the type of fibers, but also on the percentage addition of thr fiber. The incorporation of fibers into a brittle concrete can have the effect of controlling the growth and propagation of micro cracks as the compressive strength in the concrete increases. Care is needed in the usage of fiber as additive in concrete. The use of fibers in concrete has elevated with the improvement of fast-track construction. In fact, nearly 65 per cent of the fibers produced worldwide is presently utilized in concrete. It offers increasing toughness and ductility, tighter crack control and improved load-carrying capacity. Different sorts of fibers are available in the market for reinforcing concrete and they are: basalt, steel, glass, acrylic, aramid, carbon, nylon, polyester, polyethylene, glass, etc. Besides, natural fibers like sisal, wood cellulose, banana, jute, etc., have also been used. From the above mentioned fibers, glass fiber and basalt fiber is more advantageous on the basis of strength and fire resistant characteristics.

The freshest and thinnest fibers are more ductile. The more the surface is scratched, the less the resulting tenacity. Because glass has an amorphous structure, its properties are the same the fiber and throughout the fiber.

Properties of concrete can by modified by addition of dispersed reinforcement. Most common materials for fiber reinforcement are basalt, steel, glass, glass or carbon fibers. New sort of fibers which is more used as high temperature insolation or textile applications for fire protection are basalt fibers. This fibers are produced by melting basalt rock in temperature among 1460 °C to 1500 °C and rowing the filament on spools. The resulting monofilament can be chopped into short fibers and used as a dispersed reinforcement in concrete. Reviewed literature targeted on chopped basalt fiber reinforced concrete is presenting promising results, however there's still not enough research done on concrete with chopped basalt fibers which have high chemical resistance and long life cycle. One of the advantage of basalt fibers is resistance to alkaline environment as it can withstand pH up to 13 - 14 but they are less stable in strong acids.

*A. Significance of study*

The objective of this study is to generate experimental data base for compressive strength, of standard concrete, basalt fiber and glass fiber. Fiber reinforced standard concrete which are exposed to elevated temperatures of 200C to 500C for 3 hours. The tests have been conducted immediately on specimens in hot condition after taking out of oven.

*B. Aim and Objective*

*1)* To study Behaviour of Basalt Fiber Reinforced Concrete Exposed to Elevated Temperatures.
*2)* To study Glass Fiber Concrete Exposed to Elevated Temperatures.
*3)* Comparative study of Normal concrete and Fiber reinforced concrete at elevated temperatures.

*C. Scope of Work*

Basalt Fiber Reinforced Concrete and Glass Fiber Concrete will be compared to concrete by different compressive loads to draw the increase in compressive strength of concrete subjected to elevated temperatures.

## II. MATERIAL COLLECTION AND PROPERTIES

*A. Cement*

After reviewing all above requirements Portland Pozzolana Cement (PPC) of grade 53 is used be throughout the experimental work. All properties of cement are tested by referring IS 12269-1987. Cement is tested in laboratory and is as follows:

TABLE I

Properties of Cement.

| Sr. No | Description of Test | As per IS 12629-1989 | Results |
|---|---|---|---|
| 01 | Fineness of cement(residue on IS sieve No.9) | 10% | 2% |
| 02 | Specific gravity | 3.15 | 3.15 |
| 03 | Standard consistency of cement | 35 mm from top | 35 mm from top |
| 04 | Setting time of cement<br>a)Initial setting time<br>b)Final setting time | 30 minutes<br>600minutes | 105 min 305 min |
| 05 | Soundness test of cement (with Le chatelier's mould) | 10.0 Max | 3 mm |

*B. Aggregate*

TABLE II

Specific gravity of fine aggregate

| Sr.no. | Particulars | As per IS Specification | Sample 1 |
|---|---|---|---|
| 1. | Specific gravity | 2.6-2.8 | 2.48 |

TABLE III

Specific gravity of coarse aggregate

| Sr.no. | Particulars | As per IS Specification | Sample 1 |
|---|---|---|---|
| 1. | Specific gravity | 2.5-3.0 | 2.91 |

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

*C. Sand*

TABLE IV
Physical properties of sand

| Sr. No. | Property | As per IS Specification | Result |
|---|---|---|---|
| 1 | Particle shape and size | Rounded, below 4.75mm | Rounded, below 4.75mm |
| 2 | Silt content | Up to5% | Nil |
| 3 | Specific gravity | 2.6-2.8 | 2.48 |
| 4 | Surface moisture | 5% | Nil |

*D. Water*

Water plays an active role in the chemical process of hydration and in curing concrete. It is important ingredient of concrete as it actively participates in the mix design consideration. The strength of concrete is mainly due to binding action of heat of hydrated cement gel. The requirement of water should be reduced to that required for chemical reaction of heat of hydration and required for workability. The excess water form undesirable voids and / or capillary cavities in the hardened cement paste in concrete.

*E. Basalt Fiber*

TABLE V
Physical and mechanical properties of basalt fibers.

| Name: Characteristics: | Basaltex BCS17-25.4-KV13 |
|---|---|
| Diameter [µm] | 17 |
| Length [mm] | 12 |
| Density [kg/m3 ] | 2670 |
| Degradation temperature (°C ) | 300-600 |
| Melting point [°C] | 1250 |
| Tensile strength [N/mm2 ] | 2,800 - 4,800 |
| Elastic modulus [kN/mm2 ] | 86-90 |

*F. Glass Fiber*

TABLE IV
Physical properties of sand

| Name: Characteristics: | Glass Fibers |
|---|---|
| Diameter [µm] | 13 |
| Length [mm] | 12 |
| Density [kg/m3 ] | 2600 |
| Degradation temperature ( ) | 300-500 |
| Melting point [°C] | 1135 |
| Tensile strength [N/mm2 ] | 1700 |
| Elastic modulus [kN/mm2 ] | 72 |

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## III. MIX PROPORTIONS

TABLE V

| Cement(KG) | F.A (KG) | C.A (KG) | Water |
|---|---|---|---|
| 5.55 | 9 | 15.318 | 2.5 |

## IV. EXPERIMENTAL PART

Several types of basalt fiber and polypropylene fiber strengthened concrete mixes had been designed and examined inside experimental part.Selection of materials substances with appropriate fire resistance properties took place prior to mix design. 144 various mixes were designed with different cement content and basalt fiber and polypropylene fiber content. All this mixes had been tested in fresh and hardened state with focus on air void characteristic. Fire testing was performed according self-designed fire testing curves with maximum temperature 400 °C, 600 °C and 800 °C. Fire resistance was evaluated by decrease of compressive strength due to thermal load Degradation of samples and fibers within side the cement paste had been additionally inspected with the aid of using microscope with most magnification of 220 times.

### *A. Fire Resistance Testing*

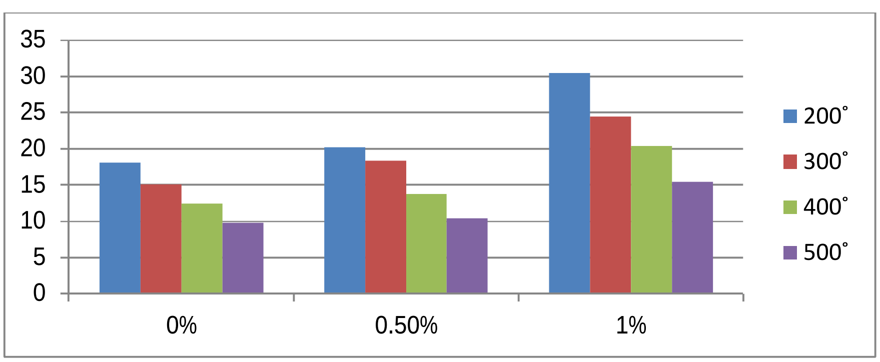
1) *For Basalt Fiber:* Samples for fire testing trying out had been organized and examined in accordance to self-designed temperature. Temperature ramp and maximum temperatures were selected based on previous experiences and reviewed literature. Temperature ramp was set up at 5 °C/min and temperature dwell after reaching the maximum temperature was 2 hours. Cooling of samples was turned into by natural way. Maximum temperatures were 200 °C, 300 °C, 400 and 500 °C. Fire resistance evaluation was based on compressive strength loss and visual inspection.
2) *For Glass Fiber:* The concrete cubes had been subjected to extended toelevated temperature of 200°C, 300 °C, 400 and 500 °C Afterwards they were tested under Compression Testing Machine to determine their residual strength as, generally, the compressive strength of the concrete will be reduced after it is heated. The objective of this study here is to determine whether the glass fiber concrete is highly resistant to fire as compared to conventional concrete.

## V. COMPRESSIVE STRENGTH OF TESTED MIXES AFTER THERMAL LOAD

### *A. For Basalt Fiber*

*Table VI*

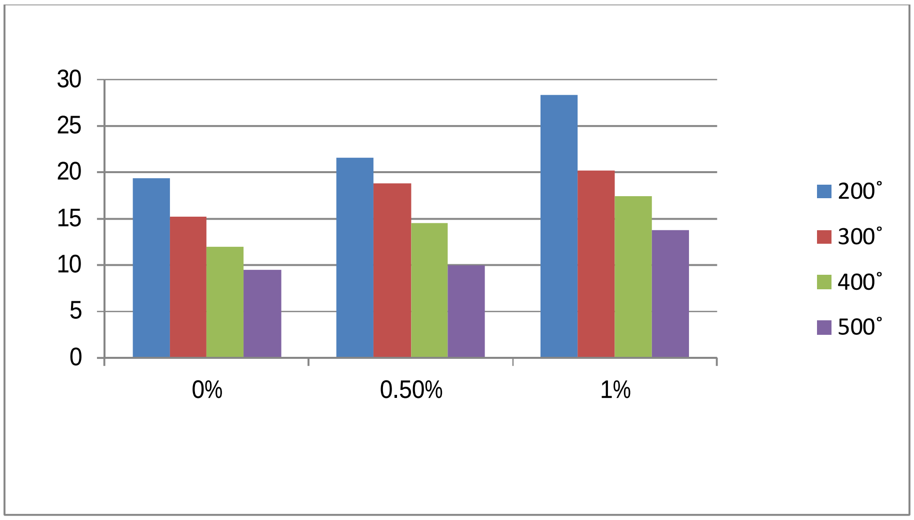
| **Name** | **Compressive strength** | **Compressive strength** | **200˚ C** | **200˚ C** | **200˚C** | **200˚ C** |
|---|---|---|---|---|---|---|
| *Avg 0.0%* | *32.6* | *36.8* | *18.1* | *15.1* | *12.4* | *9.8* |
| *Avg 0.5%* | *38.8* | *42.6* | *20.2* | *18.4* | *13.7* | *10.4* |
| *Avg 1.0%* | *40.7* | *45.5* | *30.4* | *24.4* | *20.4* | *15.4* |



*B. For Glass fiber*

TABLE VII

| Name | Compressive strength | Compressive strength | 200˚ C | 200˚C | 200˚ C | 200˚C |
|---|---|---|---|---|---|---|
| *Avg 0.0%* | *35.89* | *38.65* | *19.4* | *15.2* | *11.9* | *9.5* |
| *Avg 0.5%* | *40.56* | *44.20* | *21.5* | *18.7* | *14.5* | *10.0* |
| *Avg 1.0%* | *43.67* | *47.38* | *28.3* | *20.2* | *17.4* | *13.7* |




## VI. RESULTS AND DISSCUSSION

By comparing and analysing the test results, the research group made the following findings concerning the possible changes of ultra-high-performance concrete in case of fire temperature to which the test pieces were heated has been a main factor in ultra-high-performance concrete changes. This particularly applied to basic test piece, which cracked many times and more severely at 300◦C than at 200◦C and eventually exploded at 500◦C, forcing the test to get aborted.

At 300◦C, reinforced concrete test pieces were more vulnerable to heat than others. Basic test pieces suffered moderate flake-away while reinforced concrete ones broke into pieces.

Certain amount of Basalt fiber would noticeably enhance ultra high-performance concrete’s fire resistance. Heated to 200~300◦C, test pieces with fiber hardly showed changes; test pieces with 2 kg/m2 fiber stayed intact at moderately high temperature, even at 400~500◦C, they only chapped a little.

This can be explained this way: the Polypropylene fiber mixed into concrete test piece melts in the heat, creating steam vessels throughout the whole test piece. These vessels not only help drain or ventilate the liquid and vapour within the body, but also make room for thermal expansion, which reduces its chance of cracking and exploding.

This finding coincides with the popular vapour pressure theory in the explanation of high-performance concrete’s cracking and exploding. According to vapour pressure theory, the water in concrete turns into vapour when the temperature goes up (e.g., in fire), if the vapour cannot escape in time, pressure will be created inside the concrete body, when the internal pressure accumulates to some degree, explosion happens Polypropylene fibers melt in the heat, providing ventilation for liquid and vapour thus, they prevent concrete from cracking and exploding.

Visual inspection of thermally loaded samples showed the change in colour from grey to brown/light orange. Network of micro cracks was formed on all samples but in case of the samples heated to 400 °C degree the network was very little. Placement of basalt fibers in cement paste and none degradation in colour or any signs of decomposition are visible. High formation of micro cracks with thickness up to 52 µm are created on sample surface after exposure to 500 °C.

## VII. CONCLUSION

High-performance concrete is an artificially synthesized material low in water-cement ratio and high in strength, density, impermeability, and brittleness. These traits make it easy to crack in case of fire, which results reduction in strength. Adding polypropylene and basalt fibers not only helps enhance concrete's strength and elasticity, but also provides ventilating vessels when the surrounding temperature rises. With these merits, high-performance concrete with fibers is able to tolerate heat and pressure for a relatively long time without getting seriously damaged, thus making time for fire-fighters to save people's lives and their properties.

The followings are the conclusions drawn from the study on addition of basalt fiber and glass fiber in concrete. With 0.5 per cent addition of fiber, the increase in the compressive strength is of 38 Mpa and 35 Mpa respectively. With 1 per cent addition of fiber, the increase in the compressive strength is 40 Mpa and 43 Mpa respectively .

The fire resistant test results show that there is a reduction in the compressive strength, after heating the concrete at 200˚C for 2 hours. Without the addition of fiber, the decrease in the compressive strength of 18.11 Mpa and 19.43 Mpa. For 0.5% addition of fiber, the decrease in the compressive strength of 20.25 Mpa and 21.14 Mpa respectively. Similarly, with 1 per cent addition of fiber, the decrease in the compressive of 30.44 Mpa and 28.45 Mpa respectively. This investigation shows a higher of fiber reinforced concrete to fire when compared to normal concrete. So, glass fiber concrete has a better fire resistant characteristics.

The test results shows that there is increase in compressive strength compressive strength with addition of 1 percent basalt and glass fiber compared to normal concrete when subjected to different elevated temperatures .Thus addition of fibers in concrete results in increase to fire resistance compared to normal concrete**.**

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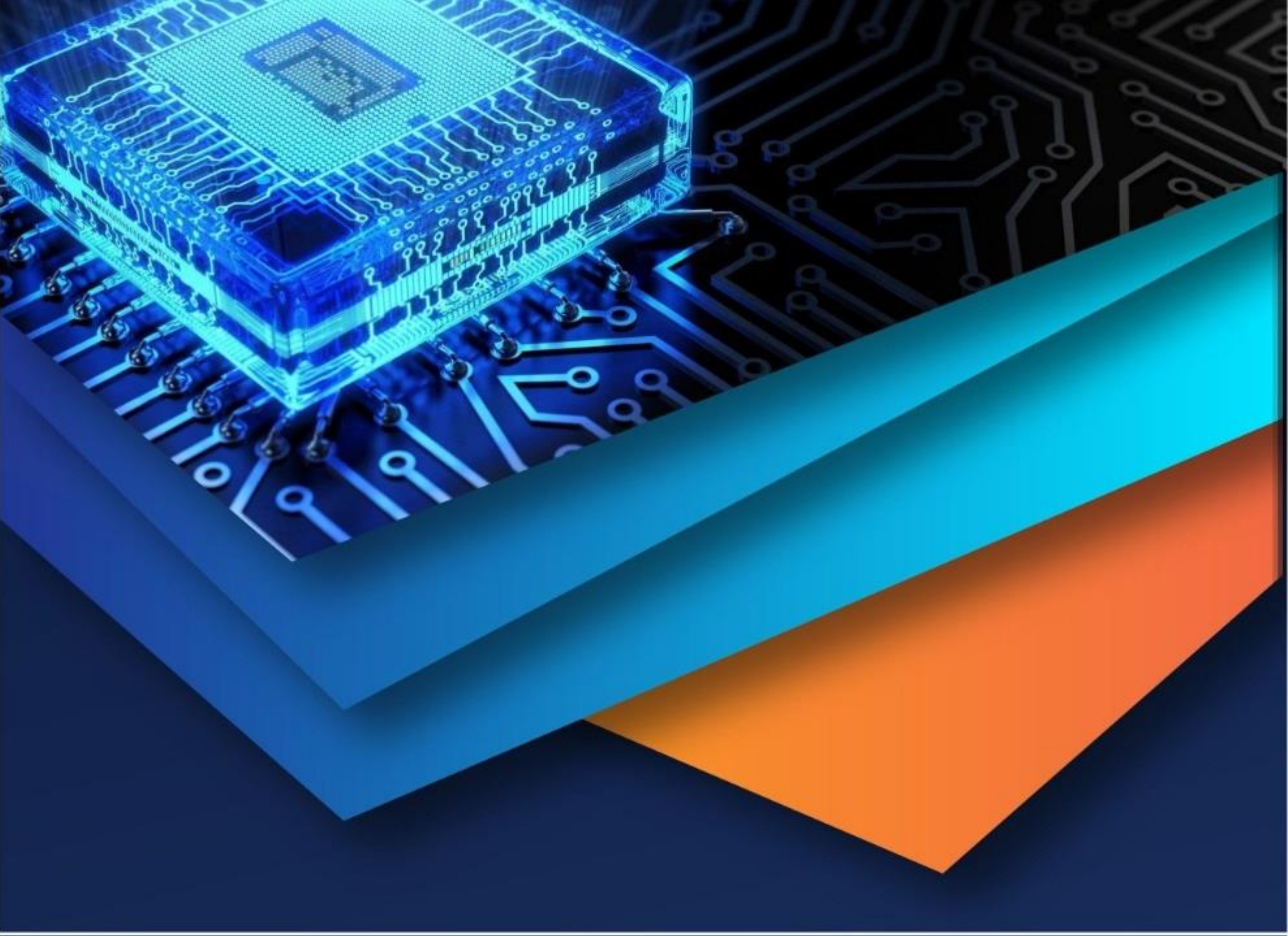


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