The Effect of Glass Fiber on Concrete and Reinforced Concrete Beam under Elevated Temperature

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Abstract: Any service structures could suffer in unexpected time from one of the most serious accidents is fire accidents. A small source is sufficient for a fire accident to be ignited, but its shore is difficult to control. In Ethiopia, so many fire accidents took place that in the near past have taken lives and house damage. For example, Merkato area burnt down nearby shops at the Greater Anwar Mosque in Addis Ababa. The cause of the accident has been investigated and a great number of homes and lives have been demolished. A long fire period leads to structural failure, loss of valuable lives, etc. The use of advanced finite elements and structural analysis models to determine the fire growth within a compartment is currently undergoing good development to determine temperatures within the component through a heat transfer analysis. This study focussed more on the influence of fiberglass under high temperature on concrete and reinforced concrete beams. In this study, different fiber glass percentage, concrete temperature and fire exposure duration were discussed. Experimental tests on both conventional and fiber-powered concrete at high temperatures have been done and the compressive strength of the concrete cube is found to be reduced to 37.41% for two hours at a 3000°C temperature relative to initial concrete compression strength. Concrete cylinder tensile strength decreases up to 20 percent at 3,000 cm for two hours, relatively with initial concrete tensile strength, and the reinforced concrete beam's load-resisting capacity decreases to 21 percent with 3,000 cm held for two hours. But by adding 0.75% of the fiber on concrete, the compressive strength increases to 21% compared to normal cements. The concrete with 0.75% fiber increases the divided tensile strength by 29% over regular cement. The load resistance capacity for beams with 0.5% fiber at the same temperature exceeds 9.4%. Thus fiber glass concrete has a high resistance to load and a high fire resistance than conventional concrete.

Keywords: Fiber glass, Reinforced concrete, Elevated Temperature.

1. Introduction
Concrete is the most widely used man-made construction material in the world today. It is relatively inexpensive and simple to shape into any desired shape. Steel has been and continues to be the most common reinforcing material for concrete. Steel material has numerous advantages when used as reinforcing concrete; it is strong in tension and compression and has...
a high modulus of elasticity\cite{1}. It has the same thermal expansion as concrete and works well with it under load. However, using steel as reinforcing concrete has some drawbacks; it corrodes over time and has a low fire resistance. However, the main challenge for civil and structural engineers is to provide society with sustainable, environmentally friendly, and financially viable structures. Finding new materials that can meet these requirements is essential. However, most fiberized materials on the market today have at least one major drawback that prevents them from being widely used in structural applications. Fibers made primarily of carbon fiber, for example, have exceptional structural properties such as a high elastic modulus and a relatively high tensile strength\cite{2}. However, their performance in fire testing is less than desirable, and their cost makes them unsuitable for use in most applications. Fiber glass, a relatively new fiber, is generating interest in the construction industry as a raw material and fiber reinforcement polymer alternative to carbon fiber reinforced polymers. It is made of glass fibers that are extremely fine. It is a lightweight, extremely strong, and sturdy material. The most common synthetic fiber is glass fiber, which is chemically inert, hydrophobic, and lightweight. They are manufactured as continuous cylindrical monofilaments that can be cut to desired lengths. Glass fibers also help to reduce plastic shrinkage cracking and subsidence cracking when used in conjunction with steel reinforcement\cite{3}.

1.1. Statement of the Problems

The concrete structure under high temperatures (fire) results in a severe deterioration and a number of transformations and reactions, leading to gradual disintegration of the cement gel structure and reduced durability and increased drying shrinkage trend, structural cracking and related changes in colour. Betons lose strength at high temperatures from previous experiments, but the rate of reduction varies with the various construction materials used. Not only fire is now increasing rapidly (global warming) until the date of this research, but it also loses its strength at different altitudes, which require special attention in the construction industry\cite{4}. In fact it also increases quickly (global warming). There are no detailed and adequate provisions on the performance of various types of construction materials for high temperatures also in our country building code (fire). Limits, infrastructure growth and increasing security interest in our country, repetitive and continuous experiments and fire-resistance tests must be given considerable value in determining the characteristics of the various construction materials, construction methods and structural components.

Adding fibers is one way to enhance the resistance to fire and reduce spillage. Fiber application can moderate damaging effects of expanded steam. The polypropylene melting point lies at 100-200 degrees Celsius. Fiber evaporates from concrete at such temperatures and builds small cavities into concrete. The concrete structure becomes more pore and expanded vapor can escape without significant damage to the concrete microstructure \cite{5}. This effect limits the splitting and breakdown of the structure of the concrete. Fibers with a higher slimming ratio have been shown to be better suited. A porous concrete structure is then easier to escape from interconnected and expanded water steam without damaging the cement \cite{6}. Furthermore, the glass fiber contains a mixture of oxides with high heat and fire resistance and therefore cannot burn in the air or oxygen but can smooth, melt and melt at high temperatures (8500c – 9000c). The reason for this research is this situation. The key agenda for this research is therefore the identification of these effects on concrete and beam with and without glass fibers under high temperature.

1.2. Objective of the Study

Generally, this thesis investigates the resistance of the effect of adding glass fibers in concrete and reinforced beam under elevated temperature. To determine whether the fiberized concrete and RC concrete beam is highly resistance as compared with conventional one\cite{7}. To compare
the performance of concrete and axially un-restrained RC beam element under elevated temperature with and without fiber in terms of strength. To identify the different parameters (Temperature and duration) which affect the performance of concrete and axially un-restrained RC beam under elevated temperature with and without fiber.

1.3. Significance of the Study
The construction of wider infrastructures including high rise buildings in our country Ethiopia is increasing now and will be expected to grow further. The design of such complex structures will need not only good software but also other inputs of researches, studies and review of foreign Codes used in our country. As previous practices tells important findings and research results of important value comes from such type of fulfilment papers and the results of this experimental research will be useful. Since this construction industry is huge it will need huge number of inputs. Based on the output of this research will be used[8]. To evaluate concrete structure with and without fiber after fire accident. To justify the recommendations in other literatures used. For the design of concrete structure with fiber glass for fire. As a reference for further study.

2. Literature Review
David et al, 2008 Even though there is nothing in the world up to now that will assure the control of fire accident in service structures and buildings without causing significant damage, there exists variety of active firefighting mechanisms and other manual options[9]. There are different types of firefighting mechanisms some of them they are direct fighting systems others are alarming types for the people living inside prior to possible total damage or partial damage. Sprinkling system, fire detection and alarm system, fire Extinguishers, hose cabinet and stand pipes of water for firefighting vehicle could be mentioned as examples of firefighting mechanisms ACI216R-89, 1994 to compare the loss of life and resources during fire accident, whatever it costs the design of structures for fire safety and fire resistance of desired rating should be implemented[10]. The "safety factor" is contained in the fire resistance rating in the design for fire. Therefore, for a particular situation a member with a resistance of four hours should have a "safety factor" greater than one with a resistance rate of two hours

Beitragel & Wankiw, 2002. The impact of structural continuity on the global response of buildings at risk of fire has shown the real impact of large-scale experiments and real events such as the fire of Windsor Mtower in Madrid (Fletcher et al) and the World Trade Center collapse in New York (Beitel and Wankiv 2002). Since then much work, particularly steel and composite structures, has been done to understand the global fire response. The global behavior is still not fully understood in concrete structures, mainly due to the lack of reliable information on material properties at high temperatures.

3. Materials and Methods
The conventional method of testing any building construction and materials samples for fire performance is based in burning furnaces, which is well equipped with temperature measuring sensors thermocouples, controlled fueling mechanism for burning and simultaneous loading way during burning (ASTM E119, 2000). This type of methodology for testing the sample is realistic but it is very expensive to build it for individual research purpose. The way of testing fire for this research commonly used an oven dry machine[11]. The samples are burned in an oven for different specified concrete temperature and duration then allowed to cool at room temperature and they are tested for failure.
3.1. Material Investigation

Cement: The cement used shall be Portland or Portland-Pozzolana cement from dangote is used satisfying the requirements of the latest Ethiopian Standards on such cements (EBCS -2, 1995). For this research PPC cement from dangote is used.

3.2. Fine aggregate (sand)
River side from awash is used here for production of the test samples. Sieve analysis is carried out to determine its sizes and properties to confirm the ASTM standard and having specific gravity 2.5. Coarse aggregate: as per ASTM standards, sieve analysis carried out to find 20mm size confirming to having specific gravity 2.7 aggregate is selected for this mix design. Also its crushing value is checked. In this thesis, the crushed type of basaltic stone, available around Adam city which is classified as siliceous aggregate type. Actually the basaltic aggregate type is the most widely used coarse aggregate in our country for production of concrete.

3.3. Rebar
10mm deformed bar and 6mm bar is used. The reinforcement used for the sample production is made of Abyssinia steel factory, Ethiopia with steel grade S-520 and its ultimate tensile strength is 634 (MPa) from test results.

3.4. Water
Mixing water used to be clean and free from harmful matter. Potable water is used.

3.5. Chopped strand mat (CSM 450) glass fiber
This form of glass fiber from world fiber glass company, Addis Ababa is used and it is easily detached in to single piece with length 5mm and it diameter of 0.5mm. Different proportions of fiber (0.5, 0.75 and 1.0%) are taken for making specimens. The following table shows the trial percentage of glass fiber by weight of concrete and its aspect ratio.

| Percentage of glass fiber by weight of concrete | Aspect Ratio (l/d) |
|-----------------------------------------------|------------------|
| 0.5                                           | 100              |
| 0.75                                          | 100              |
| 1.0                                           | 100              |

Table 1: Percentage of glass fiber and its aspect ratio

| No. | Material        | Quantity 25 MPa | Material Quantity 25 MPa |
|-----|-----------------|-----------------|--------------------------|
|     |                 | Reinforced concrete beam | Concrete cylinder       |
| 1   | Cement (PPC)    | 393.72 Kg       | 393.72 Kg                |
| 2   | Fine Aggregate  | 677.33 Kg       | 677.33 Kg                |
| 3   | Course Aggregate| 1015.75 Kg      | 1015.75 Kg               |
| 4   | Water           | 0.19686 m³      | 0.216546 m³              |

Table-2: Standard mixing for ordinary concrete structure per 50Kg bag of cement (EBCS -2, 1995).
Table- 3: The mixing proportion for 1m$^3$

| Concrete grade (MPa) | Description |
|----------------------|-------------|
|                       | Nominal size of aggregate (mm) | 20 |
| C-25                 | Workability | High |
|                      | Limit of slump that may expect for normal (mm) | 50-100 |
|                      | Total aggregate(Kg) | 215 |
|                      | Fine Aggregate (%) | 35 - 45 |
|                      | Tot. vol. of concrete | 0.127m$^3$ |
|                      | Max. water cement ratio of beam for moderate exposure | 0.55 |
|                      | Max. Water cement ratio of concrete for moderate exposure | 0.60 |

4. Mix Proportioning

The basic mix proportion for C-25 grade of concrete is cement, fine aggregate, coarse aggregate and water with mixing ratio of 1:1.67:3.12. Mix 1 and mix 2 contains 0% glass fiber. Mix 3 and 4, mix 5 and 6, mix 7 and 8 contains 0.5%, 0.75% and 1.0% glass fiber by weight of concrete respectively. A total of 8 mixes were studied with water-cement ratio of 0.50 for both reinforced concrete beam and concrete cylinder to maintained C-25 MPa for all the concrete mixes. The workability of the concrete with and without fiber is also checked within the limit slump value according to the EBCS standard in using slump. The slump value lay under normal range of 50mm-100 mm. But the concrete with fiber affects the workability of the concrete; it needs another recommended water cement ratio or special adding techniques. Increasing the percentage beyond 0.75%, it reduce the workability of the concrete mix and it gives the formation of mat and balling which is difficult to separate by vibration. When as we increases the percentage of fiber beyond 1.0%, it may affects the workability of concrete mix.

![Slump test results for concrete with and without fiber](image)

**Figure 1:** Slump test results for concrete with and without fiber

4.1. Concrete Specimen for Compressive Strength

Compressive concrete specimen Three concrete cube samples were tested for strength testing to achieve a representative compressive strength value for various burning tempers and fire exposure times. First design and make the mixing ratio with and without glass fiber as mentioned above. The concrete sample is cast correctly with the L*W*D aspect ratio (150X150X150) and the Concrete compaction. The next day it was demolished and placed in portable water for 28 days after casting the concrete cube. The cube sample is subjected to room temperature (200c) of up to 3000c after 28 days. Then the cube sample is placed so that the load is applied without a shock and continuously increase at a rate. The load is then increased until the specimen is broken and the maximum load on the specimen is recorded during the test. Finally, the specimen shall record the maximum load and notice failure.
4.2. Testing Specimens
The cylindrical specimens of 150mm*300mm concrete were the specimen used in this test. Two groups of samples would be produced to study the performance of concrete tensile strength under fire. The first group consists of 3 and 18 fibre-free samples at normal and elevated temperatures to assume their tensile resistance. The second group includes 9 and 54 fiber samples at normal and high temperatures, to assume its tensile strength, respectively. Preparation of the concrete cylinder samples for the divided tensile strengths and loading conditions of conventional and fiberized concrete. Three beam samples are tested to achieve a representative force value for different burning temperatures and fire exposure duration. Premiere design and make the mixing ratio with and without glass fiber as mentioned above. Then cast beam samples with the aspect ratio of W by D da L (150 Tod150 by 750) and compact concrete with a lateral vibrator correctly. After casting the sample on the cement beam, remove the mold and put it in a 28-day water reservoir[12]. The fiber effect is shown in the oven at a different heat level after 28 days, by the room temperature up to a higher temperature from 1000 c - 3000 cm in the furnace. Then take the test from the oven and expose it 24 hours before testing at room temperature[13]. The beam specimen is placed in a bending machine so that the charge is applied without shock and continuously increased until the specimen is unsuccessful[14]. Finally, a specimen records the maximum load and notices the error.

![Figure 2: Reinforcement detail of sample RC beams](image)

4.3. Loading condition of sample beam
The reinforced concrete beam with and without fiber are loaded at the mid-span to get maximum moment and deflection shown in Figure below as per ASTM C293M. The following figure shows flexural machine, the cross section of the beam specimens with its loading condition. Beam Samples are subjected for desired temperature from 1000c up to 3000c and durations starting from one hour up to two hours in the oven and air cooled to room temperature, then tested for maximum concentrated load at the mid span. The mode of the failure of the beam samples are failed in shear. If the samples were tested in hot just at a time of heat conditions without cooled to room temperature, the results will be different from results recorded of this research. The reason is reinforcing steels (rebar) will be affected by the elevated temperature when they are tested during the fire but the reinforcing steel restores when cooled.

![Figure 3: Representation of loading test of sample beam and its cross section](image)
5. Results

5.1. Results of Concrete cube for compression
Concrete cube samples are tested for compressive strength stress with and without fiber glass in order to determine its toughness (the ability to absorb energy), relationship between concrete, fiber and fire are presented in the following table. The effect of fire on concrete structure is induces thermal expansion (tension stress) which causes spalling of concrete. Now adding fiber glass and checking fire resistance more effective to prevent this thermal stress because fiber glass used as crack arrester to reduce the expansion of concrete Martials. Finding tensile and bending stress of concrete and reinforced concrete under fire is more representative than determining the effect fiber on concrete for compression

| No. | Specimen ID | % of fiber | Compressive strength (MPa) |
|-----|-------------|-----------|---------------------------|
| 1   | NCC         | 0         | 29.6                      |
|     | NCC         |           | 24.71                     |
|     | NCC         |           | 26.78                     |
|     | Average     |           | 27.03                     |
| 2   | FCC/0.5     | 0.5       | 31.5                      |
|     | FCC/0.5     |           | 29.12                     |
|     | FCC/0.5     |           | 30.3                      |
|     | Average     |           | 30.31                     |
| 3   | FCC 0.75    | 0.75      | 33.40                     |
|     | FCC 0.75    |           | 30.60                     |
|     | FCC 0.75    |           | 34.00                     |
|     | Average     |           | 32.67                     |
| 4   | FCC 1.0     | 1.0       | 28.90                     |
|     | FCC 1.0     |           | 27.71                     |
|     | FCC 1.0     |           | 27.00                     |
|     | Average     |           | 27.87                     |

Table -4: The Result for compressive strength of concrete with and without fiber glass.

| % fiber weight concrete | Room Tem. | Elevated Tem.(°C) | Room Tem. | Elevated Tem.(°C) |
|-------------------------|-----------|-------------------|-----------|-------------------|
|                         | 1 hour    | 2 hour            | 1 hour    | 2 hour            |
| 20.5                    | 100       | 300               | 25        | 100               |
| 0.00                    | 27.03     | 23                | 26        | 22                |
| 0.50                    | 30.31     | 27                | 28        | 25                |
| 0.75                    | 32.67     | 28                | 30        | 27                |
| 1.00                    | 27.87     | 25                | 25        | 23                |

Table - 5: Summary of the result for compressive strength of concrete with and without fiber glass at elevated temperature.
Table 6: Percentage reduction of compressive strength of concrete with and without fiber exposed at 3000°C for 2 hours

| % fiber by weight of concrete | 1 hour | 2 hours |
|------------------------------|--------|---------|
| 0.00                         | 22.14  | 37.41   |
| 0.50                         | 21     | 30.87   |
| 0.75                         | 20     | 27.67   |
| 1.00                         | 16.66  | 27.33   |

The relationships between compressive strength of concrete, percentage of fiber, temperature and duration for elevated temperature of cube specimens with and without fire glass are shown in figure below. Concrete with and without fiber are presented in figure.

Figure 4: Variation of compressive strength of concrete with the addition of fiber glass

Figure 5: Stress and strain graph for concrete with and without fiber

Figure 5 shows typical strain curves for horns with fiberglass and without fiberglass with different strengths. These curves match tests on specimens which resemble the compressive pressure of the cube sample. The stress-strain curves on figure 5 all increase to a maximum stress.
of 0.0015 to 0.0022, with a descending branch. As discussed in section, the shape of this curve results from the gradual formation of micro-cracks within the concrete structure. Fiberglass concrete has a high capacity for caring than conventional concrete. Generally, the addition of glass fiber to 0.75% by weight of concrete is stronger and more load-bearing than conventional concrete. This shows that 0.75% of the concrete is more ductile than other materials.

![Image of failure mode of normal reinforced concrete beam](image)

**Figure – 6:** Failure mode of normal reinforced concrete beam

![Graph of variation of maximum load versus temperature for beam sample without fiber](graph)

**Figure-7:** Variation of maximum load versus temperature for beam sample without fiber

### 6. CONCLUSIONS

From this research, it was established that the fiber application in concrete reduces fresh concrete workability. The results of the workingability test obtained in the standard slump test demonstrated low workability. The conclusion was that the increased fiber weight in the concrete would reduce workability. High dosage weight above 0.75 percent showed the concrete to be considerably rigid and compact. However, blood and segregation in the concrete mixture have also been reduced. With increased fiber-dose levels up to 0.75 percent, the compressive strength of concrete increases, and then decreases. The optimal percentage of fibers found in the research was therefore 0.75 percent and a continuous decrease of strength was observed when the percentage of fiber dose increases. Split concrete tensile strength increases up to 0.75%, and then it begins to decrease. The ideal percentage of fiber found in the research is therefore 0.75 per cent and a continuous reduction in strength has been observed as the percentage of the fiber dosage increases.

Fiber concrete is more resistant to the load than the fiberless cement in normal condition. The heat lasts up to two hours, the tensile spillage strength of the normal concrete decreases by
20% and the strength of the conventional reinforced beam by 24.7% with high temperatures of 3000°C. Bitter with the recommended fiber (0.75%) percentage sustained for two hours at a high temperature of 3000°C, decreases the initial division strength of concrete to 12.12%. Duration of exposure to a fire up to two hours lowers conventional reinforced concrete beam's load-resistant capacity to up to 28.12% when burnt at 3000°C temperature. The load capacitance of the reinforced fibre-glass beam is approximately 9 percent higher than the normal reinforced beam at 3000°C for 2h with 0.5 percent. As can be seen in Figure 4.10, the strength of the tensile cylinder samples burnt for 2000°C is higher than the tensile strength of the cylinder samples burnt for 1000°C, this seems contrary to the results of the study because the fire temperatures increase the tensile strength of the concrete decreases. However, for beam samples, it is apparent that, due to quick drying of concrete past and porosity, the strength of concrete at a high temperature from 100-2000 cm increases and steel increases at that temp due to residual stress. More research is needed to verify the effect of tensile strength and fire performance variation in bending times. These generally show that fibre-glass concrete takes precedence over normal concrete at room temperature and at its highest value.

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