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# Use of Fiber Glass (FG) in concrete mix to resist fires in installations (A case study on the columns)

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**Abstract:** High temperature and Fires has become one of the biggest threats to buildings. Concrete is a primary building material and its properties of concrete to high temperatures have gained a lot of attention. But there is a fundamental problem caused by high temperatures that is the separation of concrete masses from the concrete block "separation phenomenon ". Separation of concrete leads to a decrease in the cross section area of the concrete column and so reduction the resistances to axial loads; also reinforcement steel bars become exposed directly to high temperatures, with the growing of incidents from major fires in buildings. Several samples of reinforced concrete columns with Fiber Glass have been used. Tow mixes of concrete been prepared using different contents of Fiber Glass (0.5 kg/m³ and 1.0 kg/m³). Reinforced concrete columns dimensions are (150 mm x150 mm x500 mm). The samples are heated for 1, 3 and 6 hours at 200 C°, 400 C° and 700°C and tested for compressive strength. Also, the behavior of reinforcement steel bars at high temperatures is investigated. Reinforcement steel bars are embedded into the concrete samples with 2 cm and 2.5 cm concrete covers, after heating at 700°C for 6 hours. The reinforcement steel bars are then extracted and tested for yield stress and maximum elongation ratio. The analysis of results obtained from the experimental program showed that, the best amount of Fiber Glass to be used is 1.0 kg/m³, where the residual compressive strength is 25 % higher than of that when no Fiber Glass are used at 400 C for 6 hours.

**Keywords:** Fiber Glass, resist fires, compressive strength, separation phenomenon, yield stress.

## 1. Introduction

High temperature and Fire still of the serious potential risks to most buildings and structures, the widespread use of concrete as a structural material has led to the need to fully understand the effect of fire on concrete. The behavior of reinforced concrete columns under high temperature is influenced mainly by the strength of the concrete [1]. High temperature and Fire affects reinforced concrete members by raising the temperature of the concrete block [2]. This increase in temperature shortens largely the mechanical properties of concrete and steel. In addition to, the fire temperatures induce new varieties, thermal, and temporary creep. Fire is a global catastrophe in the sense that it impedes the normal human activities and leaves behind its scars for some time to come, however, when it's subjected to prolonged fire exposure or unusually high temperatures, concrete can suffer significant distress. Because concrete's pre-fire compressive strength often exceeds design requirements, a modest strength reduction can be tolerated. But large temperatures can reduce the compressive strength of concrete so much that the material retains no useful structural strength [3]. A study of RC columns is important because these are primary load bearing members, and a column could be crucial for the stability of the entire structure [4]. Access to fire-resistant concrete, especially main structural elements such as concrete columns through the following:

- Study the effect of concrete cover on enhancing fire resistance of reinforced concrete columns.
- Determine the best amount of Fiber Glass to be used in the concrete mix for improving fire resistance of RC columns to compression loads.
- Study the effect of elevated temperature and duration on the mechanical properties and elongation of the reinforcement steel bars and the effect of concrete covers of 2 cm and 2.5 cm.

## 2. Experimental Program and materials

Experimental program consists of high temperature endurance tests. These tests will examine the effect of high temperatures on reinforced concrete columns and testing their compressive strength. The program consist of three types of small scale reinforced concrete columns (150 mm x 150 mm x 500 mm) ,one type of specimens is free from Fiber

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Glass and the other type contain 0.5 kg/m³ and 1.0 kg/m³ of Fiber Glass, samples of this group have the same concrete cover (2.0 cm). The samples will be tested at (ambient temperature, 200 C°, 400 C° and 700 C°) at (1, 3 and 6 hours) exposure. The other groups have a concrete cover of 2.5 cm and will be tested at 700 C° for 6 hours to determine the behavior of RC column with deferent concrete covers at high temperatures.

### 2.1-Materials and Their Quality Tests:

It is important to know the properties of constituent materials of concrete, as we know, concrete is a composite material made up of several different materials such as gravel, sand, water, cement and admixture. These materials have properties such as "dry density, water content and Specific gravity. Therefore, we must work out necessary tests on these components, and that to know the different characteristics and their effects on the strength of concrete. The tests are conducted in the laboratory of soil in the Faculty of engineering, South Valley University and Helwan University.

### 2.1.1. Unit Weight of Aggregate:

Density(γ) is thus a measurement and is also known as bulk density, but this alternative term is similar to bulk specific gravity, which is quite a different quantity, and perhaps is not a good choice. The sample shall be in oven dry condition and the capacity of measures is shown in Table (1).

Table: (1): Capacity of Measures

| Aggregate Size (mm) | Capacity (Liter) |
|---|---|
| 11.9 | 2.65 |
| 24.5 | 9.25 |
| 38.2 | 14.75 |
| 73.75 | 27.35 |

### 2.1.1.1- Moisture content of Aggregate:

Since aggregates are porous, they can absorb moisture. However, this is a concern for Portland cement concrete because aggregate is generally not dry and therefore the aggregate moisture content will affect the water content and thus the water-cement ratio also of the produced Portland cement concrete and the water content also affects aggregate proportioning . The moisture content values of coarse and fine aggregate are (2.60%, 1.2%) respectively.

### 2.1.1.2- Specific Gravity of Aggregate:

Specific gravity ($G_S$) expresses the density of the solid part of the aggregate in concrete mixes as well as to determine the volume of pores in the mix. Since densities are determined by displacement in water, specific gravities are naturally and easily calculated and can be used with any system of units [5].

### 2.1.1.3-_Fiber Glass

Polyester resin was invented in 1935 [6]. Its potential was recognized, but finding a suitable reinforcing material proved elusive – even palm fronds were tried. Fiber Glass has been used in a number of applications, most notably as fiber for carpeting and upholstery for furniture and car seats [7]. Then, glass fibers which had been invented in the early 1930's by Russel Games Slaytor and used for glass wool home insulation, were successfully combined with the resin to make a durable composite. Although it was not the first modern composite material (Bakelite - cloth reinforced phenol resin was the first), glass reinforced plastic ('GRP') quickly grew into a worldwide industry [8]. Fiber Glass has also make an industrial revolution with the plastics industry, providing an inexpensive material that can be used to create all sorts of plastic products for the home and office, recently become widely used in the construction industry, in order to enhance fire resistance concrete [9]. The mechanical and physical properties of Fiber Glass resin is shown in Table 2.

Table 2: mechanical and physical properties of Fiber Glass

| properties | giber glass |
|---|---|
| Density (Kg/m$^3$) | 2540 |
| Tensile strength (MPa) | 2000 |
| Tensile modulus (GPa) | 75 |
| Passion ratio | 0.23 |
| In plane shear modulus | 31 |

### 2.2- Mix Proportions

Since the process of concrete formation is a unidirectional chemical hydration, concrete obtain its different properties all together. In this study, three mixes for different contents of (F.G) (0 kg/m³, 0.5 kg/m³ and 1.0 kg/m³) were used. Design Requirements

1- Characteristic cube concrete strength (cube) *fc'* 300 kg/cm²
2- Max water cement ratio (w/c) 0.56
3- Minimum cement content 350 kg/m³
4- Aggregate Size 3/4" (20mm) crushed limestone aggregate

The following table (3) illustrates the mix design of the column samples.

Table :(3): mix design of the concrete column samples

| Weight per one cubic meter kg/m3 | | | |
|---|---|---|---|
| Materials | **Mix 1** | **Mix 1** | **Mix 1** |
| Gravel | 1080 | 1080 | 1080 |
| Sand | 740 | 740 | 740 |
| Cement | 350 | 350 | 350 |
| Water | 196 | 196 | 196 |
| Fiber Glass FG | 0.0kg | 0.5kg | 0.75 kg |

### 2.3-Sample Categories:

The main reinforcement steel bars are 4Φ12 mm, 45 cm in length, and 3 stirrups Φ 8 mm in diameter. The samples are 150 mm x 150 mm, and 500 mm in dimensions Fig (1). The total number of reinforced concrete samples will be 50 samples.

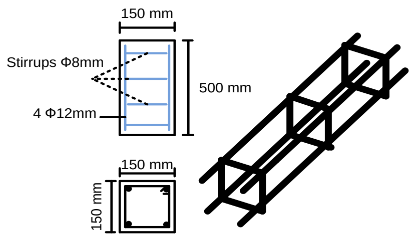


Fig (1): Dimension of Samples

The total number of concrete columns samples was 50 samples, and the samples were categorized and distributed according to the following factors:
1- A mount of Fiber Glass FG (0 kg/m³, 0.5 kg/m³ and 1.0 kg/m³).
2- According to concrete cover thickness (2 cm, 2.5cm)
3- According to time of heating (0, 1, 3 and 6 hours).
4- According to degree of temperature (0, 200, 400 and 700 C°).

**2.4-Compressive and Tensile Strength Tests:**
For each group of reinforced concrete columns, 3 samples were prepared and tested it in order to obtain averaged value and then the results are taken and analyzed. Reinforced concrete columns are tested for axial load capacity after the all concrete samples were exposed to high temperatures

**2.5- Reinforcing Steel Tests:**
The reinforcement bars were extracted from the columns samples after exposure of the reinforcement steel bars to elevated temperature (600 C°) for 6 hours.

**3. Results and analysis**
The results of the tests that were performed on the reinforced concrete and steel bars samples. After the completion of the heating process of samples according to the experimental program, the samples were transferred to the materials and soil laboratory at the Faculty of Engineering, South Valley University and Helwan University for compression test for concrete columns and tensile strength for steel reinforcement bars.

**3.1-Effect of Fiber Glass content**

The Fiber Glass were used in the reinforced concrete columns to prevent Spelling process, different amounts of Fiber Glass were used (0.0 kg/m³, 0.50 kg/m³ and 1.0 kg/m³),shown in figures (2 , 3 , 4 ).

**3.1.1- Unheated Columns**

For unheated columns (2 cm concrete cover), the load capacity for 0.5 kg/m³ and 1.0 kg/m³of Fiber Glass are 5 % and 8 %, respectively higher than those for columns without Fiber Glass. For unheated columns (2.5 cm concrete cover ), the load capacity for 0.5 kg/m³ and 1.0 kg/m³of Fiber Glass are 6 % and 9 % , respectively higher than those for columns without Fiber Glass .

**3.1.2- Heated Columns**

Table (4), shows the results of the compressive strength tests for reinforced concrete columns at different degrees of temperature (Ambient Temp, 200 C°, 400 C° and 700 C°) and heating durations of 0, 1, 3 and 6 hours, and 2 cm concrete cover .

Table (4): The axial load capacity test results for the columns samples with Fiber Glass

| Degree of Heating, 200 C° , with 2 cm concrete cover | | | | | |
|---|---|---|---|---|---|
| Axial load capacity , kn | | | | | |
| Time (hrs) | 0.0 kg/m³ FG | 0.5 kg/m³ FG | Difference % | 1.0 kg/m³ FG | Difference % |
| 0 | 40 | 42 | 7 | 47 | 10 |
| 1 | 26 | 33 | 22 | 38 | 27 |
| 3 | 18 | 23 | 25 | 31 | 36 |
| 6 | 17 | 21 | 18 | 29 | 34 |
| Degree of Heating, 400 C° , with 2 cm concrete cover | | | | | |
| 0 | 40 | 42 | 7 | 47 | 10 |
| 1 | 18 | 20 | 12 | 22 | 21 |
| 3 | 16 | 18 | 13.5 | 21 | 23 |
| 6 | 15 | 17 | 12 | 19 | 19 |
| Degree of Heating, 700 C° , with 2 cm concrete cover | | | | | |
| 0 | 40 | 42 | 7 | 47 | 10 |
| 1 | 10 | 11 | 13 | 17 | 29 |
| 3 | 9 | 10 | 10 | 14 | 20 |
| 6 | 8 | 9 | 14 | 13 | 28 |

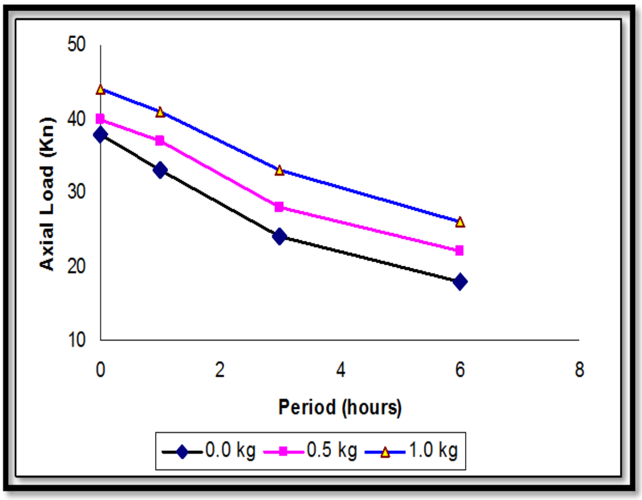

Fig.(2) : correlation between axial load capacity and heating duration at 200 C° for different contents of FG.

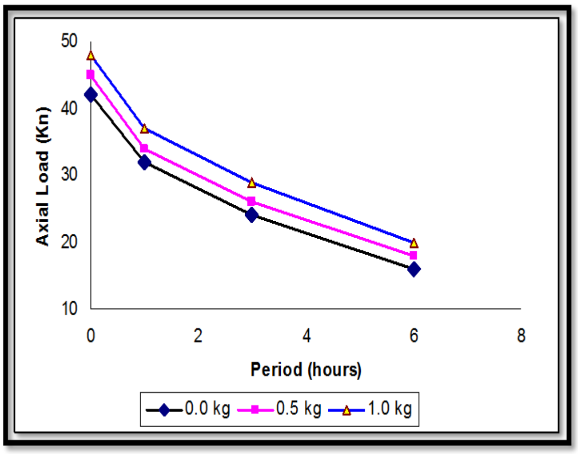


Fig.(3) : correlation between axial load capacity and heating duration at 400 C° for different Contents of FG.

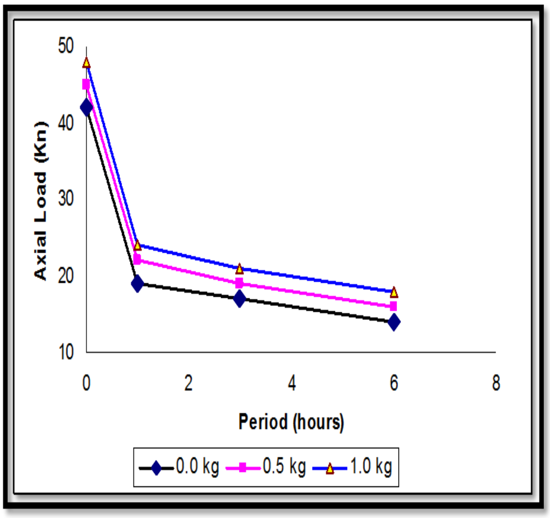


Fig.(4) : correlation between axial load capacity and heating duration at 700 C° for different contents of FG.

Then the increase of axial load capacity for samples with 0.5 kg/m³ is 2.5 %, and for the samples with 1.0 kg/m³ is 6 % higher than the samples free from FG. So that the use of 1.0 kg/m³ FG in the concrete mix increases the resistance of the axial load capacity the of reinforced concrete columns. . concrete cubes( 150 x 150 x 150 mm) at 0.5% FG ,by volume reserve more than 80% of their initial residual strength at 400 C° and 6 hours. On the other hand 0.0%

**3.2-Effect of concrete cover**

The increase in concrete cover thickness in improving the fire resistance of reinforced concrete columns was also studied for concrete covers 2 cm and 2.5 cm and heating durations of (1, 3 and 6) hours for 700 C°, shown in fig(5).

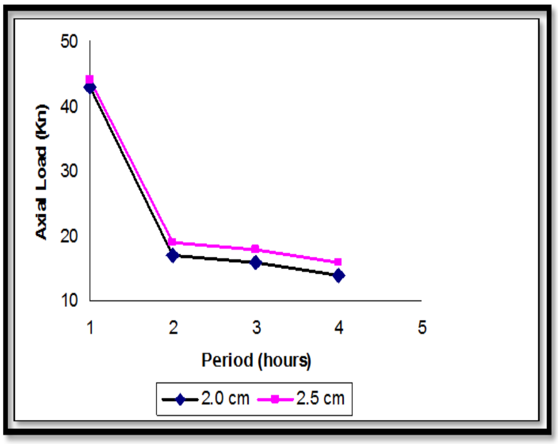


Fig.(5) : correlation between axial load capacity and heating duration at 700 C° for different concrete covers.

## 4. Conclusion

Percentage of FG to be used in improving fire resistance of reinforced concrete columns is about 1.0 kg/m³ of the concrete mix. For a temperature of 200 C° sustained for 6 hours, the residual axial load capacity is 20 % higher than of that when no FG are used. Fiber Glass has a positive impact on axial load capacity of unheated concrete columns. At 0.5 kg/m³, there is about 5 % increase in axial load capacity, and at 1.0 kg/m³, the increase is about 8 % than that with no FG are used. The concrete cover has a clear influence on axial capacity of concrete columns load capacity, where the residual axial load capacity for the column samples with 2.5 cm cover 5 % higher than the column samples with 2 cm concrete cover at 6 hours and 400 C°. For the reinforcement steel bars at high temperatures, the yield stress of steel reinforcement is significant. The concrete cover has a good contribution in protection the steel bars at high temperatures, where the loss in the yield stress at 2.5 cm concrete cover 20 % smaller than that of the reference sample, and for the reinforcement steel bars with 2 cm the loss was 40 % smaller than that of the reference sample.

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