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# Study the Effect of Elevated Temperature on Reinforced concrete columns Strengthed Using Fibres

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## ملخص البحث

**يقدم هذا البحث دراسة عن الخرسانة المسلحة المدعمة بالالياف الكربون والزجاج لتقليل الفقد فى اجهاد الخرسانة الناتج عن تعرض الخرسانة للحريق والتي تعتبر طريقة جديدة لتحسين سلوك الخرسانة المسلحة وذلك للحصول على المزيد من الخصائص المرغوبة ، وتحسين العناصر الخرسانية لتحمل أحمال أكبر ولتعزيز أو تحويل السلوك الكلي إلى أكثر ليونة وقوة محسنة للخرسانة عند تعرضها للحريق. و سيتم مناقشة سلوك الاعمدة الخرسانية المسلحة المعرضة للحريق مع إضافة الألياف الكاربون والزجاج عن طريق صب 8 عينات مقسمة إلى مجموعتين،المجموعة الاولى تتكون من عينتين تم تصنيعهم دون إضافة ألياف الكربون والزجاج يتم تعرض عينة واحده فقط للحريق ،المجموعة الثانية تتكون من ست عينات تم إضافة ألياف الكربون والزجاج الى (عينتين بنسبة 0.6% وعينتين بنسبة 0.9% وعينتين بنسبة 1.2%) من الحجم الكلى للعينة يتم تعرض عينة واحدة فقط من كل نسبة للحريق لمدة ساعتين وعند درجة حرارة 400 درجة مئوية. تمت دراسة المتغيرات الحادثة علي سلوك الخرسانة باضافة النسب المذكورة من ألياف الكاربون والزجاج .تم تسجيل العديد من النتائج: أحمال الشروخ الابتدائيه ، نمط الشروخ ، منحنيات انحراف الحمل ، الصلابة وأحمال الانهيار لكل عينة. واستنتج من هذه الدراسة إلى أن استخدام ألياف ألياف الكاربون والزجاج بنسبة (0.6%-0.9%-1.2%) من الحجم له تأثير إيجابي على سلوك الخرسانة المسلحة عند تعرضها للحريق.**

## ABSTRACT

This paper present a study on reinforced concrete strengthed with carbon and glass fibre to reduce the losses in concrete strength results from fire exposure, to gain more desired properties, confine the concrete members to sustain larger loads and to enhance or may convert the total behavior of the member into more ductile one and enhanced the character of concrete when exposed to fire. The behavior of reinforced concrete columns exposed to fire will be discussed with the addition of carbon and glass fibers by prepare 8 samples divided into two groups. The first group consists of two samples that were manufactured without adding carbon and glass fibers. Only one sample is exposed to fire. The second group consists of six samples. Carbon and glass fibers to (two samples 0.6%, two samples 0.9% and two samples 1.2%) of the total sample size. Only one sample of each percentage is exposed to a fire for two hours and at a temperature of 400 degrees Celsius. The variables occurring on the behavior of concrete were studied by adding the aforementioned percentages of carbon and glass fibers. Many results were recorded: crack loads, crack pattern Curves of load deflection, stiffness and failure loads for each sample. It was concluded from this study that the use of carbon and glass fibers at a percentage (0.6% -0.9% and 1.2%) of the volume has a positive effect on the behavior of reinforced concrete when exposed to fire.

**Keywords:** Concrete; Circular columns; fire; Axial load; carbon fiber; glass fiber.

## Introduction

Reinforced concrete columns are critical members for the performance of structures and the safety as that transfer axial compressive loads to the foundation, the behavior of RC columns during and after a fire is still a vital issue due to safety and structural resistance implications, concrete usually performs well in building fires at starts but when it is subjected to prolonged fire exposures, concrete can suffer significant strength losses, the behavior of these structures and their failure modes are extensively studied, the behavior of concrete columns exposed to fire depends on its mix composition and determined by complex interactions during heating process, the modes of concrete failure under fire exposure vary according to the nature of fire, loading system and types of structure moreover, the failure could happen due to different reasons such as a reduction of bending, loss of compressive strength, and more. In the past decade, several experimental and theoretical studies have been carried out on the degradation of column concrete strength due to the short term exposure to fire . In this research study the effect of fire on concrete by using carbon and glass fiber to concrete mix to improve its characteristics against fire by casting eight columns and exposed some of them to fire and recheck it by loading and examine stresses on them and find difference by examine control columns without any additives. This research includes also the effect of different variables on crack loads, crack patterns, failure modes, loads axial deflection curves, measurement of ductility and energy absorption on all columns.

## Previous Research

**J Novák1 and A Kohoutková1 (2017)[1]** Although concrete when subject to fire performs very well, its behavior and properties change dramatically under high temperature due to damaged microstructure and mesostructure. As fiber reinforced concrete (FRC) represents a complex material composed of various components with different response to high temperature, to determine its behavior and mechanical properties in fire is a demanding task. **Josef Nováka; Alena Kohoutkováa (2016) [2],** both the tensile and compressive strength of hybrid fiber reinforced concrete decrease with increasing temperature. The peak compressive strength at 400°C and 600°C represent 60% and 35%, respectively, of the initial strength, The peak tensile strength were 60% and 30%, respectively. The fall is mainly caused by the specimen structure damaged by cracks and increased porosity. All the obtained strengths, more or less, do not correspond to those stated in valid European standards. As the temperature increases, the presence of fiber-reinforced materials no longer affects the residual tensile strength of the material. **Chandramouli, Srinivasa Rao, Pannirselvam, Seshadri Sekhar and Sravana(2010) [3]** FRC is a relatively new material, this is a composite material consisting of a matrix containing a random distribution or dispersion of small fibers, either natural or artificial, having a high tensile strength, due to the presence of these uniformly dispersed fibers, the cracking strength of concrete is increased and the fibers act as crack arresters, fibers suitable of reinforcing concrete have been produced from steel, glass and organic polymers, many of the current applications of FRC involve the use of fibers ranging around 1-5%, by volume of concrete the followings are the conclusions drawn from the study on addition of glass fiber in concrete with 0.5 percent addition of fiber, the increase in the compressive strength is 13 per cent, the increase in flexural strength was 42 per cent and the increase in split tensile strength is 20 percent over conventional concrete. Concrete with 1 percent addition of fiber, the increase in the compressive strength was 35 percent, the increase in flexural strength is 75 percent and the increase in tensile strength is 37 percent, therefore reinforcing with glass fiber contributes immensely in enhancing the compressive strength of concrete and the increase was 1.78 times that of normal concrete. from the test results, it was found that the glass fiber possesses the high flexural strength the fire resistant test results show that there is a reduction in the compressive strength, After heating the concrete at 300C for 2 hours without the addition of fiber, the decrease in The compressive strength was 32 per cent over its original strength, for 0.5% addition of fiber, The decrease in the compressive strength was 25 percent over its original strength. Similarly, with 1 per cent addition of fiber, the decrease in the compressive strength was showed 10 per cent over its original strength This investigation show a higher resistance of fiber reinforced concrete to fire when compared to normal concrete so, glass fiber concrete has a better fire resistant characteristics.

## Experimental Programme

## Materials Characteristics

The materials used to cast the specimens were (sand, dolomite, ordinary Portland cement and drinking water). Concrete mix designed to get target cubic compressive strength of 25 kN/m$^2$ after 28 days.

**Fibres:** The carbon and glass fibers used was purchased from "sika" Company with properties as listed in Table 1.

Table (1): Properties of Chopped Basalt Fibre.

| | Glass | Carbon |
|---|---|---|
| tensile strength | 3400 N/mm2 | 4100 N/mm2 |
| Modulus of elasticity | 72 GPa | 231000 N/mm2 |
| Density | 2 g/cm³ | 1.6 g/cm³ |
| length | 10 mm | 14 mm |

**Coarse Aggregate:** Dolomite used from natural sources with nominal maximum size of 10 mm. This nominal size was chosen taking into consideration the dimension of the tested beams as well as the spacing between the reinforcing bars. Batches used were all of good quality, clean and free from organic material.

**Fine Aggregates:** Natural sand composed of siliceous materials, clean and free from impurities.

**Cement:** Locally produced high quality ordinary Portland cement (CEM I 42.5 R).

**Mixing Water:** Drinking water used for mixing and curing for all specimens

**Reinforcement Steel:** Different reinforcement diameters and types used in this study. High tensile deformed steel bars of 10 mm diameter were used as top and bottom reinforcement for beams and denoted by (Y), While mild smooth steel 8 mm diameter was used as spiral stirrups in all columns and denoted by (Φ).

## Mixing

The quantities and proportions of fibers by weight. Of fibers were listed in the Table2.

Each specimen's code was identified with letter and numbers, in this Table name of additions take the designation name consists of one or two letters. The letter "C" refers to carbon fiber and letter "G" refers to glass. The letter "c" refers to control sample without fire, and letter "f" refers to control sample with fire. Sand, coarse aggregate and half amount of fibres added to the mechanical mixer and mixed for about one minute. Cement and the rest amount of fibres were added without adding of water for another one minute to insure better dispersion of the fibers throughout the mix, then water was added gradually to the mixer. It was observed that mixes with different fibres content was less workable than those without fibres. This may be due to the absorption of certain amount of moisture by the fibres.

Table (2): Quantities and proportions of fibers.

| G. no | | Type of frb | Total percentage of frb | percentage of glass fiber | percentage of carbon fiber | weight of the first additions | weight of the second additions |
|---|---|---|---|---|---|---|---|
| G1 | c1 | -- | -- | -- | -- | -- | -- |
| | f2 | -- | -- | -- | -- | -- | -- |
| G2 | GC3 | G + C | 0.6% from the total volume of the sample | 40% From additives | 60% From additives | 70gm | 132gm |
| | GC4 | G + C | 0.6% from the total volume of the sample | 40% From additives | 60% From additives | 70gm | 132gm |
| | GC5 | G + C | 0.9% from the total volume of the sample | 40% From additives | 60% From additives | 105gm | 197gm |
| | GC6 | G + C | 0.9% from the total volume of the sample | 40% From additives | 60% From additives | 105gm | 197gm |
| | GC7 | G + C | 1.2 from the total volume of the sample | 40% From additives | 60% From additives | 140gm | 263gm |
| | GC8 | G + C | 1.2% from the total volume of the sample | 40% From additives | 60% From additives | 140gm | 263gm |

## Test Specimens

In this study, eight circular RC columns were prepared and tested under concentric axial load according to the purpose of the study. They included two RC columns as control sample without additives reinforced with 5#10 bars and Φ 8 spiral stirrups spaced at 50 mm. Fig. 1 shows the dimensions, various configurations, and reinforcement details of the test specimens. Each column was vertically supported a total length of 1,000 mm, 20mm cover , 300mm concrete cover at head and bottom of column , a diameter of columns 150 mm. The equivalent effective depths were 940 mm. control column f2 exposed to fire and one column from each proportion exposed to fire (GC4, GC6 and GC8). Then put out with air and loaded.

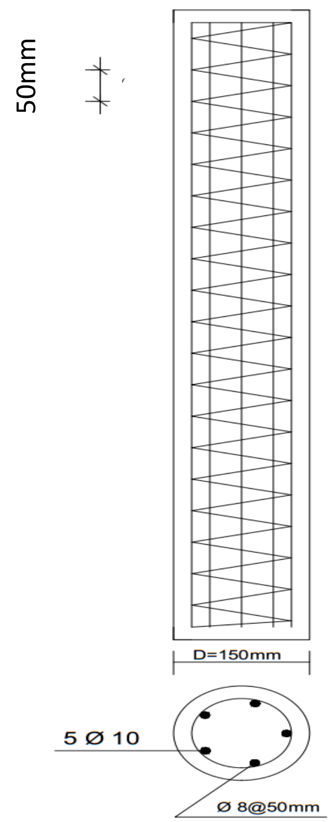


Fig. (1): Details of tested columns

## TEST SETUP

Samples were placed inside oven at 400 c for two hours. Once asample has been burned, it is tested. As shown in Fig. 2. For concentric loading, steel plates were used to transfer the loads effectively to the desired regions through a calibrated vertical hydraulic jack 1500 kN capacity. Square load plates of size 250 x 250 mm to 40 mm thickness were used. The load was applied to each column in the form of a vertical concentrated load, under essentially pin–ended conditions with a constant rate of increase in increment of 5 kN where the deflection values were recorded. The load then continued up to failure. A special 3D steel frame setup for testing the columns was constructed (Mataria Faculty of Engineering, Helwan University). The setup consisted of the load cell to read the value of the load, Head to fix the specimen, and LVDT to measure vertical and horizontal displacement of the specimen during testing in material testing laboratory of the faculty of engineering Material Helwan University was used for testing. The frame consisted mainly of Horizontal I-beam fixed to two vertical columns I-beam by angles and bolts. The I-beam column was rested on floor. Two horizontal angles fixed at mid of column to Rest dial gage. The details of testing machine is shown in details Fig. 3.

## 4. RESULTS OF EXPERMENTAL PROGREM

Test values for columns are summarized in Table 3 and will be discussed below.

Fig. (2): An oven for burning samples.

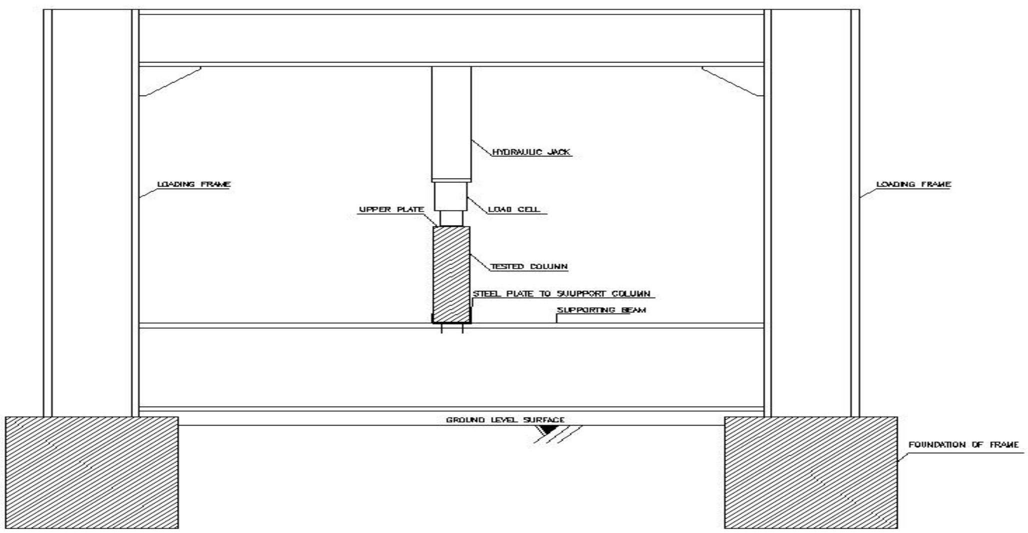


Fig. (3): Details of testing machine.

### 4.1. Results of tests

### 4.1.1 First Crack and Crack patterns

Fig. 3 and Fig. 4 shows cracking patterns for tested specimens, the failure load, maximum Axial and horizontal displacement for the entire tested columns are as shown In Table 3, from which the following observations are listed:

- First group consisted of two columns. In control columns (c1) not exposed to fire showed that the first crack appear at load level nearly 70% of column failure load. The first crack appear at the top level of the column. Cracking pattern of tested column were generally vertical cracks, without inclination cracks as shown in Fig. 3. Control column (f2) exposed to fire showed that the first crack appear at load level nearly 60% of column failure load. The failure load is about 76% from the failure load of sample (c1), The first crack appear at the top level of the column, Cracking patterns of tested column were generally vertical cracks, with horizontal cracks at the bottom of the column. As shown in Fig. 3. Second group consisted of six columns: - column (GC3) not exposed to fire showed that the first crack appeared at load level nearly 96% of column failure load. The failure load improved from failure load of control sample (c1) by 7.6% The first crack appeared at the top quarter of The column, cracking patterns of tested column were generally vertical cracks, with horizontal crack appeared at failure load as shown in Fig. 4. Column (GC4) exposed to fire showed that the first crack appeared at load level nearly 98% of column failure load. The failure load was about 77% from the failure load of sample (GC3). The first crack appeared at the top level of the column, Cracking patterns of tested column were generally vertical cracks, without horizontal or inclinaed cracks. As shown in Fig. 4. Column (GC5) not exposed to fire showed that the first crack appear at load level nearly 89% of column failure load. The failure load improved from failure load of control sample (c1) by 11.7%. The first crack appear at the top level of the column, cracking patterns of tested column were generally vertical cracks, with horizontal cracks at top and bottom quarters of the column as shown in Fig. 4. Column (GC6) exposed to fire showed that the first crack appeared at load level nearly 90% of column failure load. The failure load was 80.5% from the failure load of sample (GC5), the first crack appeared at the top level of the column and Cracking patterns of tested column were generally vertical cracks at the top and bottom of the column, without horizontal cracks. As shown in Fig. 4. Column (GC7) not exposed to fire showed that the first crack appeared at load level nearly 87% of column failure load. . The failure load improved from failure load of control sample (c1) by 15.7%. the first crack appeared at the top level of the column, cracking patterns of tested column were generally vertical cracks, without horizontal cracks as shown in Fig. 4. Column (GC8) exposed to fire showed that the first crack appear at load level nearly 88% from column failure load. The failure load is 84% from the failure load of sample (GC7), the first crack appeared at the top level of the column and cracking patterns of tested column were generally vertical cracks at the top and bottom of the column, without horizontal or inclined cracks. As shown in Fig. 4.

Fig. 3. Tested specimens of first group.


Fig. 4. Tested specimens of second group.

Table 3: Results of Tested Specimens

| Group no | Specimen designation | Max axial displacement (mm) | Failure load (KN) |
|---|---|---|---|
| **G1** | c1 | 11 | 460 |
| | f2 | 7.85 | 372 |
| **G2** | GC3 | 16.88 | 495 |
| | GC4 | 13.22 | 401 |
| | GC5 | 21.2 | 514 |
| | GC6 | 16.65 | 430 |
| | GC7 | 19.1 | 532 |
| | GC8 | 14.9 | 458 |

### 4.1.2 Load – axial displacement Curve

The deflection of all columns increased proportional to the load increase until the first crack occur. The deflection then continued to increase in a linear way with the increase of the load. Then the rate of increase in load decreased until reaching the failure load. Then the curve begin to drop. The relation between the applied load and axial displacement are as shown in Fig. 5. And Fig. 6 (a-c).

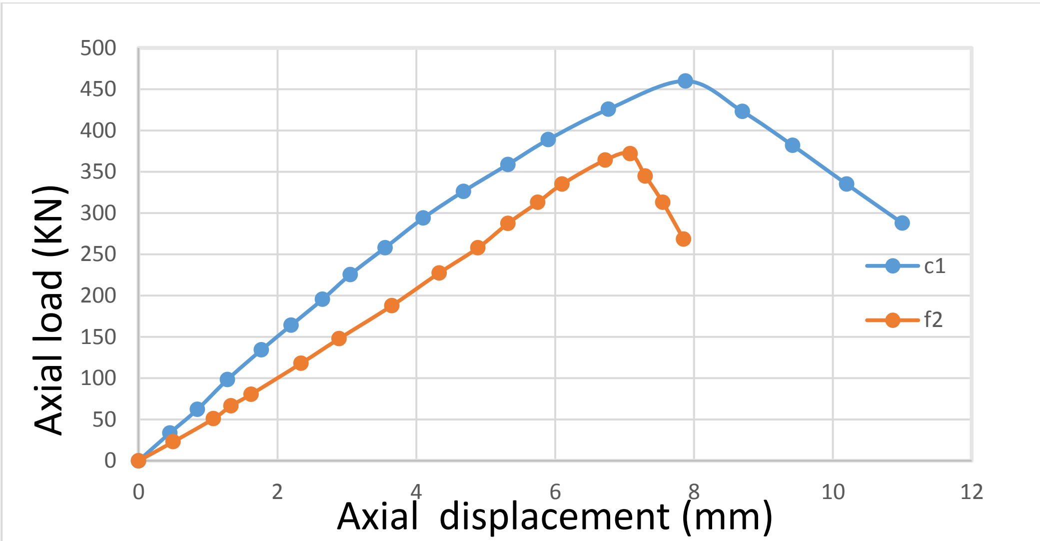


Fig. 5: Load–vertical displacement relationship of C1and f2.

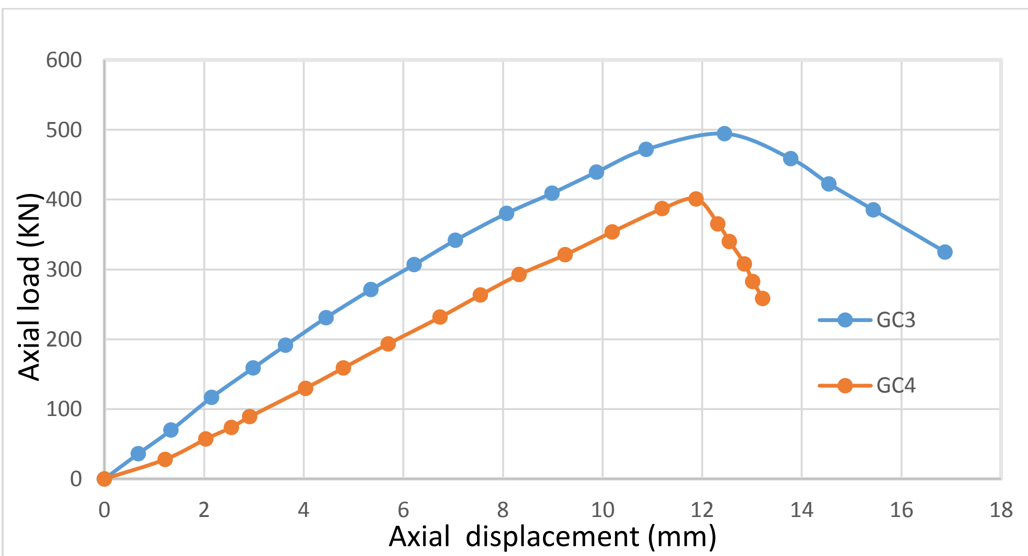


Fig. 6 (a): Load–vertical displacement relationship of GC3and GC4.

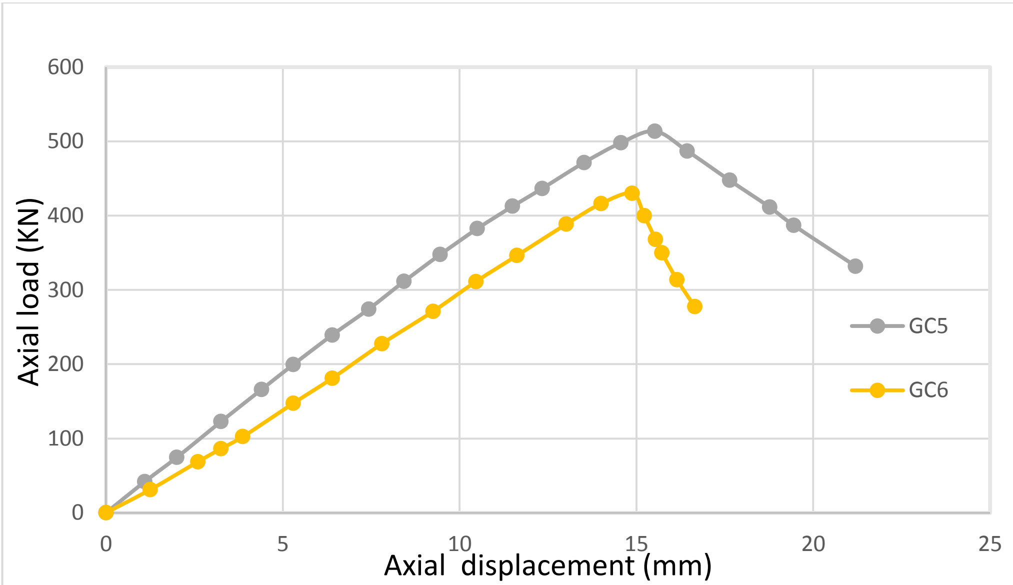


Fig. 6 (b): Load–vertical displacement relationship of GC5and GC6.

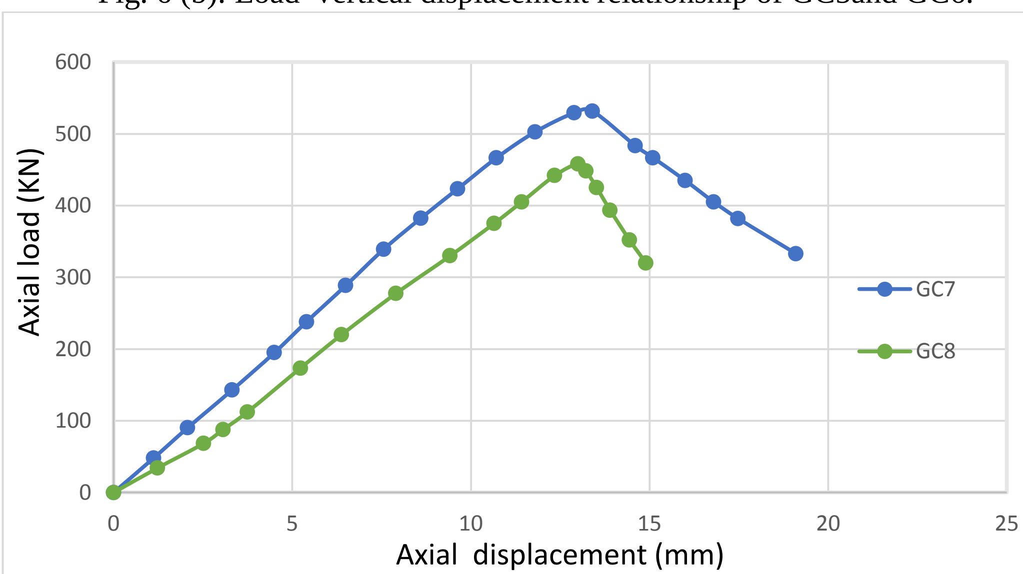


Fig. 6 (c): Load–vertical displacement relationship of GC7and GC8.

### 4.1.3 Effect of Carbon and polypropylene Fibre on Failure load

-Column GC3 increased the column failure load by nearly 7.6% from control column (c1). Column GC5 increased the column failure load by nearly 11.7% from control column (c1). Column GC7 increased the column failure load by nearly 15.7% from control column (c1).

### 4.1.4 Effect of Carbon and polypropylene Fibre on column exposed to fire

- f2 losses 24% from load capacity after two hours fire exposure at 400 □c, GC4 losses 23 % from GC3 after fire exposure . GC6 losses 19 % from GC5 after fire exposure. GC8 losses 16 % from GC5 after fire exposure.

## 5 .CONCLUSION

1-The test results indicate that the control column without carbon and glass fiber f2 exposed to fire at (400 _C) for two hours decreased axial load capacity 24% from control column c1, which had the same spiral- and longitudinal-reinforcement ratios.

2- The test results indicate that the columns strengthed with carbon and glass fiber, exhibited higher axial load capacity and comparable performance to that of the control columns without fiber, which had the same spiral- and longitudinal-reinforcement ratios.

3- Vertical displacement decreased by exposed concrete column to fire.

4- The test results indicate that the columns strengthed with carbon and glass fiber, increase Vertical displacement of the column.

## 6 REFRENCES


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(3) Chandramouli, Srinivasa Rao, Pannirselvam, Seshadri Sekhar and Sravana. [2010]. — STRENGTH PROPERTIES OF GLASS FIBRE CONCRETE. 1Priyadrashini Institute of Technology for Women, Tenali, Guntur, Andhra Pradesh, India 2JNTU College of Engineering, Hyderabad, Andhra Pradesh, India. 4Samual George Institute of Technology, Markapur, Prakasam District, Andhra Pradesh, India3VIT University, Vellore, India.