FIRE RESISTANCE PERFORMANCE OF GLASS FIBER REINFORCED CONCRETE COLUMNS

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Abstract

The behavior of the reinforced concrete (RC) material can be modified by adding a percentage of glass fibers which depend on their characteristics such as type, shape, volume, or weight content. These fibers are characterized by high tensile strength, perfect elasticity, high tightness, good thermal stability and thermal insulation. In this paper, the behavior of glass fiber reinforced concrete (GFRC) columns with varying glass fiber volume fraction (1% and 1.5%) under elevated temperatures and axial compressive loading is numerically studied in order to evaluate the effect of adding glass fibers on the behavior of RC columns under elevated temperatures. A RC column without fibers is used as a control sample. The study is carried out using the ANSYS software where the temperatures due to the fire are applied according to the standard ISO834 fire model. In evaluating the fire behavior of the columns, geometric and material nonlinearities are considered. The results show when glass fiber is added to reinforced column, the load carrying capacity and displacement of reinforced column increase. Adding glass fibers to RC columns provides better protection to rebar under elevated temperatures. The percentages of decreasing the ultimate load under elevated temperature were considerably less in GFRC columns compared to that in RC columns.

Introduction

Fire is considered one of the most severe environmental conditions that reinforced concrete structures accidently may be subjected to, causing huge material and human losses.

Under fire exposure, reinforced concrete (RC) members experience loss of strength and stiffness as a result of increased temperatures in reinforcing steel and concrete.

The behavior of the RC material can be modified by adding a percentage of glass fibers which depend on their characteristics such as type, shape, volume, or weight content. These fibers are characterized by high tensile strength, perfect elasticity, high tightness, good thermal stability and insulation.

Structural members must have adequate fire resistance rating as specified by design codes to avoid failure.

This work is done to study numerically the behavior of glass fiber reinforced concrete (GFRC) columns with varying glass fiber volume fraction (1% and 1.5%) under elevated temperatures and axial compressive loading.

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Case of study

This study aims to develop the finite element model by ANSYS software to evaluate the effect of adding glass fibers on the behavior of RC columns under high temperatures. The columns are exposed on the four sides, to the standard fire scenario ISO834. Two fiber volume fractions (Vf), 1 % and 1.5 %, were taken and are presented in table 1.

Table 1. Designation and configuration of columns.

Column designation	Vf (%)	Compressive strength of concrete at 28 days (MPa)
C-RC	0	39
C-GFRC1	1	47
C-GFRC1.5	1.5	54

The columns studied have a cross section 250 × 250 mm with 3 m high. Each column had four #10 bars as longitudinal reinforcement and #6 stirrups at 120 mm spacing, figure 1-a. The steel of the main reinforcing bars and stirrups had specified yield strength of 400 MPa and 215 MPa, respectively. The loading and boundary condition of the columns studied are shown in figure 1-b. The study is based on two stages:

- first stage is the transient thermal study consisting to the exposure of four longitudinal sides of the columns to standard fire model ISO834.
- Second stage is the mechanical study by applying increasing load at the top of the studied columns until failure at temperature of 20, 400 and 600 °C.

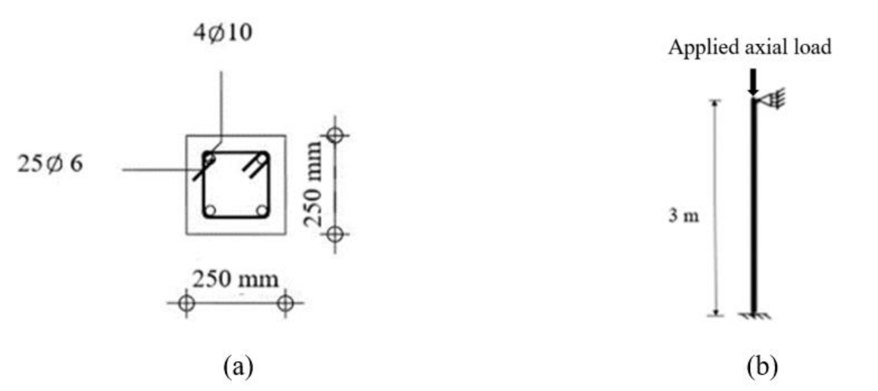

Fig. 1. Details of the studied columns (a) Cross-sectional details and (b) Boundary conditions and loading.

The evolution of the thermal and mechanical properties of materials as a function of temperature was taken from the experimental results of Wang et al [1], the equation proposed by Ezeldin et al.[2] and Eurocode 2 part 1-2 [3].

Results

Thermal analysis

Figure 2 shows the temperature evolution in the cross section of the columns studied for the rebar and the center of the section. It can be seen that by increasing the volume fraction of the glass fibers by 1 and 1.5%, the rate of temperature evolution is reduced by 2% and 11% respectively in the reinforcing bars and by 4% and 14% in the center of the section respectively. It can be concluded that adding glass fibers to RC column provides better protection to rebar under high. This is due to the low thermal conductivity caused by the addition of glass fibers to concrete.

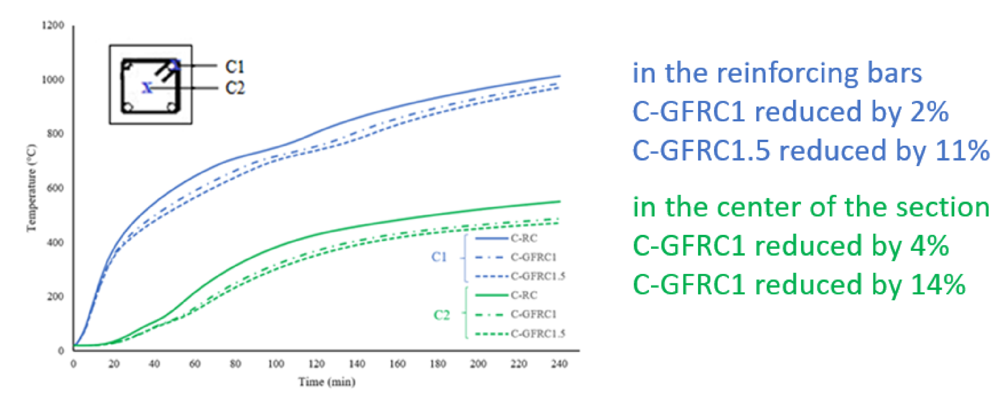

Fig. 2. Temperature evolution as a function of time in the cross section of the columns

Mechanical analysis

Figure 3 shows the load-displacement curves of the columns reinforced or not with the volume fraction of glass fibers at temperature of 20 °C, 400 °C and 600 °C. It can be observed that the ultimate load capacity decreased with temperature and was considerably less in GFRC columns compared to that in RC columns. It is due to the ductility and stiffness that glass fibers give to concrete.

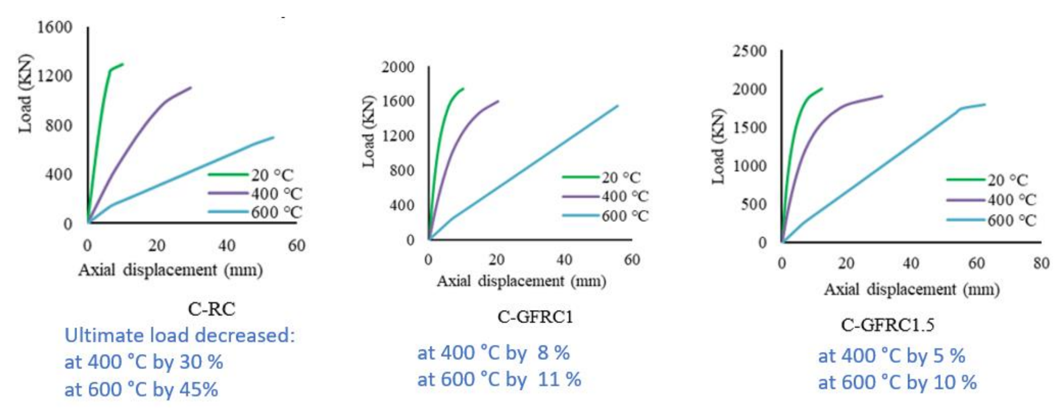

Fig. 3. Load–displacement RC column with Vf of 0, 1 and 1.5 % of glass fiber under elevated temperatures.

Conclusion

This paper predicted the behavior of glass fiber reinforced concrete columns with volume fractions of 1% and 1.5%, under the effect of high temperatures due to fire. This prediction was based on the development of finite element models using ANSYS software. The following conclusions were drawn:

– A reduction in the rate of temperature evolution under elevated temperatures observed in the reinforcement bars of RC column with the increase in the volume fraction of the glass fibers.

– The addition of glass fibers to the RC columns provides better protection of the rebars by reducing the temperature in the cross section under elevated temperatures.

– The decrease of the ultimate load was considerably less in GFRC columns compared to that in RC columns under elevated temperatures.

References

1. Wang, W.-C., et al., Effect of high temperature on the strength and thermal conductivity of glass fiber concrete. Construction and Building Materials, 2020. 245: p. 118387.
2. Ezeldin, A.S. and P.N. Balaguru, Normal-and high-strength fiber-reinforced concrete under compression. Journal of materials in civil engineering, 1992. 4(4): p. 415-429.
3. CEN, Eurocode 2. Design of Concrete Structures – Part 1-2: General Rules–Structural Fire Design, 2004.