International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 07 | July 2022 www.irjet.net p-ISSN: 2395-0072

# EXPERIMENTAL STUDY ON F.R.P.S. STRENGTHENING REINFORCED CONCRETE BEAMS AT ELEVATED TEMPERATURE

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**Abstract –** *Concrete with steel reinforcement is the perfect combination for any construction. So, to enhance its properties different fibers are used. Basalt Fiber Reinforced Polymer (BFRP) and Glass Fiber Reinforced Polymer (GFRP) are used in this work to improve its fire resisting properties under elevated temperature. Basalt fiber and glass fiber increases the strength of concrete but if we put the concrete under fire, its strength decreases. So, several experimental studies are done in this work to improve its fire resisting properties with minimum decrease in strength or we can also say with lesser decrease in strength*

***Key Words***: BFRP, GFRP, Fire resisting, HR Aluminium Paint 500$^{0}$C, RC Beams

## 1. INTRODUCTION

In the recent years, there was a strong need to repair/strengthen concrete structures due to material deterioration, environmental effects, misuse or overloading. As an alternative to traditional strengthening techniques, Fiber-Reinforced Polymers (FRP) is being increasingly used due to their desirable attributes. Although FRP strengthening proved efficiency in practice, there are increasing concerns related to their performance in case of fire. Polymer materials exhibit a change in mechanical properties when exposed to temperature higher than 80–120$^{0}$C, referred to as the glass transition temperature (Tg). This causes serious damage to the bond between the FRP and the concrete surface and consequently the structural integrity and effectiveness of the FRP strengthening will be severely threatened or may be some design codes such as ACI 440-2008] do not recommend the use of FRP internal or external reinforcements for structures in which fire resistance is essential[1]

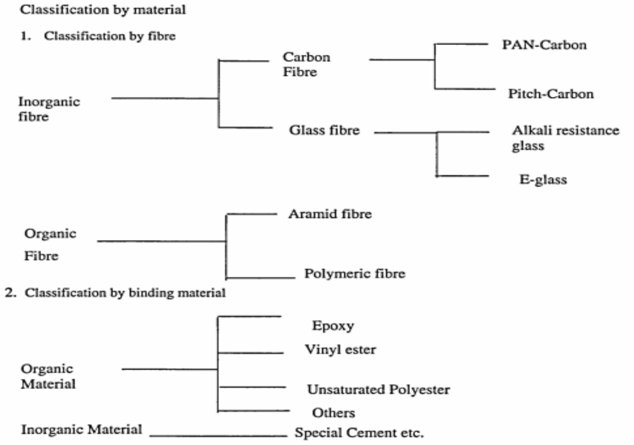
Other codes limit strengthening by externally bonded FRP to only 40% of the capacity, for the un strengthened concrete element to be sufficient to resist the service loads .Elevated temperature conditions occurring in case of fire have damaging effects on concrete structures.

### 1.1 TYPES OF THE FRP BARS

Surface geometries of the FRP reinforcements commercially available include ribbed, sand coated then wrapped and sand coated again.[2] The physical characteristics of the surface of the FRP rebar's are an important property for mechanical bonding to concrete. There is no standardized classification of surface deformation patterns 3 . The nominal diameter of a deformed FRP bar is equivalent to that of a plain round bar having the same area as the deformed bar. When the FRP bar is not of the conventional solid round shape (that is, rectangular or hollow), the outside diameter of the bar or the maximum outside dimension of the bar will be provided in addition to the equivalent nominal diameter.

FRP bars made of continuous fibres (aramid, carbon, glass, or any combination) should conform to quality standards. FRP reinforcing bars are available in different grades of tensile strength and modulus of elasticity. The tensile strength grades are based on the tensile strength of the bar with the lowest grade being 414 MPa (grade F60) and the highest strength of 2,069 MPa (grade F300)[3]. For the modulus of elasticity grade the minimum value is prescribed depending on the fibre type. For design purposes, the engineer can select the minimum modulus of elasticity grade that corresponds to the chosen fibre type for the member or project. For example, an FRP bar specified with a modulus grade of E5.7 indicates that the modulus of the bar should be at least 39.3GPa

FRP materials are highly combustible and burn when exposed to fire. A large amount of combustible gases, ignite, release heat and propagate flame are generated during burning of FRP.[5] The emitted smoke, which affects visibility, hinders ability of the occupants to escape and poses difficulties for fire fighters to conduct evacuation operations and suppress the fire.



### 1.2 Glass Fiber Reinforced Polymer

Glass fiber reinforced Polymer (GFRP) is a type of concrete which basically consists of a cementitious matrix composed of cement ,sand, coarse aggregate, water, polymer and admixtures, in which short length glass fibers are dispersed. In general, fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between the fibers and protecting them from environmental damage. In fact, the fibers provide reinforcement for the matrix and other useful functions in fiber-reinforced composite materials. Glass fibers can be incorporated into a matrix either in continuous or discontinuous (chopped) lengths.

## 2. MATERIALS AND ITS PROPERTIES

### A. Concrete

Concrete has been used as construction material for hundreds of years. The information on variation of thermal properties of concrete with temperatures is well established, based on extensive experimental and theoretical studies. Since normal strength concrete is usually used in FRP strengthened concrete members.

### B. Reinforcing steel

Although steel reinforcement forms only a small portion of cross sectional area in concrete members, high temperature properties of steel reinforcement, especially mechanical properties, has significant influence on the fire response of reinforced concrete members. This section reviews some notable studies on the behavior of reinforcing steel at elevated temperatures.

### C. Mix Proportion

a) Grade designation = M30

b) Type of cement = OPC 43 grade

c) Maximum nominal size of aggregate = 20 mm

d) Minimum cement content = 300 kg/m$^3$ (IS 456:2000)

e) Workability = 75 mm (slump)

f) Exposure condition = mild (for reinforced concrete)

g) Degree of supervision = Good

h) Type of aggregate = Crushed angular aggregate

i) Maximum cement content = 450 Kg/m$^3$

Cement = 435.40 kg/m$^3$
Water = 191.58 kg/m$^3$
Fine aggregate = 614.02 kg/m$^3$
Coarse aggregate = 1098.678 kg/m$^3$
Water-cement ratio = 0.44

**Design Mix is 1 : 1.39 : 2.49**

## 3. CASTING, MIXING AND TESTING OF CONCRETE

Once the mix design and all the required tests on ingredients of concrete are done and their suitability is found satisfactory, the task of casting of beam having size 150x150x700mm is carried out.

**1. Ultimate load and mid span deflection (Controlled Beam)**

| Item | S.No. | Pu (KN) | δ mm | Avg Pu (KN) | Avg δ mm |
|---|---|---|---|---|---|
| BFRP | 1 | 94.90 | 25.00 | 94.00 | 24.67 |
| | 2 | 93.00 | 24.00 | | |
| | 3 | 94.10 | 25.00 | | |
| GFRP | 1 | 82.60 | 21.00 | 82.23 | 20.33 |
| | 2 | 81.80 | 20.00 | | |
| | 3 | 82.30 | 20.00 | | |

Fig 1: Heating of Beam at 500$^0$C

The tests which were done were its flexural strength test and deflection test. Three samples were tested with BFRP mixed under controlled temperature and three samples were tested with GFRP mixed under controlled temperature. Here, controlled temperature means at room temperature. Next mix was tested above 500⁰C with a cover of 20mm and after that again the mix was tested above 500⁰C but this time the cover was increased to 40mm. At last HR Aluminium Paint was used to increase its fire resisting property. Two test were performed i.e. Flexural strength test and Deflection test.

**2. Ultimate load and mid span deflection (After 500⁰C) (Cover 20mm)**

| Item | S.No. | Pu (KN) | δ mm | Avg Pu (KN) | Avg δ mm |
|---|---|---|---|---|---|
| BFRP | 1 | 85.00 | 21.00 | 84.64 | 20.34 |
| | 2 | 84.80 | 20.00 | | |
| | 3 | 84.10 | 20.00 | | |
| GFRP | 1 | 68.50 | 16.00 | 67.67 | 16.34 |
| | 2 | 67.00 | 17.00 | | |
| | 3 | 67.50 | 16.00 | | |

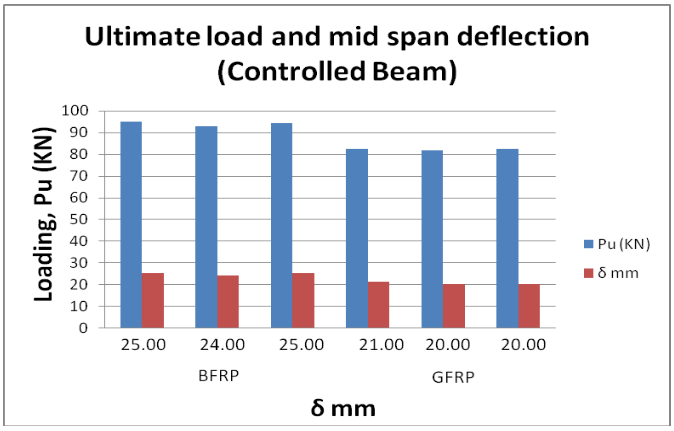
**3. Ultimate load and mid span deflection (After 500⁰C) (Cover 40mm)**

| Item | S.No. | Pu (KN) | δ mm | Avg Pu (KN) | Avg δ mm |
|---|---|---|---|---|---|
| BFRP | 1 | 89.50 | 22.00 | 89.06 | 22.00 |
| | 2 | 88.90 | 23.00 | | |
| | 3 | 88.80 | 21.00 | | |
| GFRP | 1 | 75.00 | 18.00 | 75.00 | 17.33 |
| | 2 | 75.10 | 17.00 | | |
| | 3 | 74.90 | 17.00 | | |

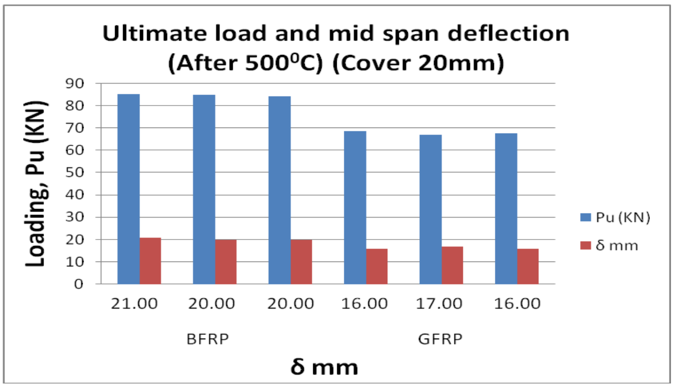
**4. Protection using Aluminium Paint (After 500⁰C)**

| Item | S.No. | Pu (KN) | δ mm | Avg Pu (KN) | Avg δ mm |
|---|---|---|---|---|---|
| BFRP | 1 | 90.50 | 24.00 | 90.80 | 23.67 |
| | 2 | 91.10 | 25.00 | | |
| | 3 | 90.80 | 24.00 | | |
| GFRP | 1 | 78.90 | 18.00 | 78.74 | 17.67 |
| | 2 | 78.80 | 17.00 | | |
| | 3 | 78.50 | 18.00 | | |

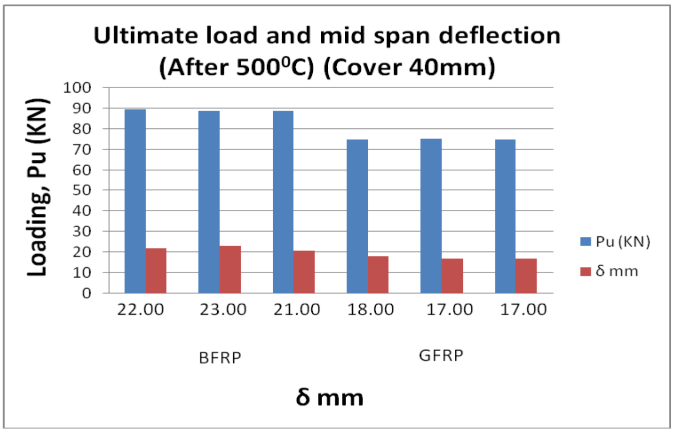
## 4. RESULT THROUGH GRAPH



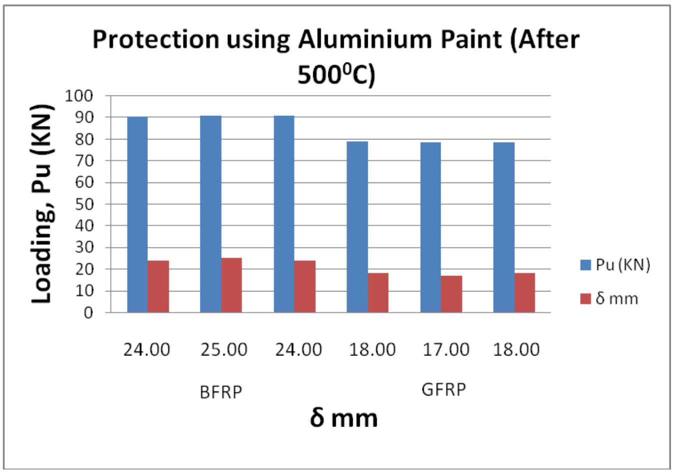

Graph 1 Shows : Left 3 Samples BFRP Mixed and Right 3 Samples GFRP Mixed, Blue Line in indicating Failure Load and Red Line is indicating Deflection at failure. (Controlled Temperature)




Graph 2 Shows : Left 3 Samples BFRP Mixed and Right 3 Samples GFRP Mixed, Blue Line in indicating Failure Load and Red Line is indicating Deflection at failure. (After 500⁰C and Cover of 20mm)




Graph 3 Shows : Left 3 Samples BFRP Mixed and Right 3 Samples GFRP Mixed, Blue Line in indicating Failure Load and Red Line is indicating Deflection at failure. (After 500⁰C and Cover of 40mm)




Graph 4 Shows : Left 3 Samples BFRP Mixed and Right 3 Samples GFRP Mixed, Blue Line in indicating Failure Load and Red Line is indicating Deflection at failure. (Protection using Aluminium Paint after 500$^0$C)

## 5. CONCLUSIONS

Finally, we are on the conclusion that when we are testing the beam at increased temperature, its flexural strength is decreasing and also the deflection is decreasing which is good but reduction in strength makes this project incomplete. So, to increase its strength we are increasing the effective cover from 20mm to 40mm then we can see increase in strength and deflection has increased slightly but still under the acceptable limit. Finally, we have used HR Aluminium Paint and we can see increase in strength close to the ideal one as shown in Graph 1 which gives a new result for the Durability criteria.

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