INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

IJARIIT

ISSN: 2454-132X
Impact factor: 6.078
(Volume 6, Issue 3)
Available online at: www.ijariit.com

Retrofitting of concrete member subjected to fire

Sipendra Kumar Goit
ksipendra69@gmail.com
RajaRajeshwari College of Engineering, Bangalore, Karnataka

Sanjeevkiran M.
sankiran1996@gmail.com
RajaRajeshwari College of Engineering, Bangalore, Karnataka

Sangmeshwar
sangmesh.kanta888@gmail.com
RajaRajeshwari College of Engineering, Bangalore, Karnataka

Shivaraj R.
shivarajgun12@gmail.com
RajaRajeshwari College of Engineering, Bangalore, Karnataka

Dr. V. Ramesh
professor.vramesh@gmail.com
RajaRajeshwari College of Engineering, Bangalore, Karnataka

ABSTRACT

This paper presents an experimental investigation for evaluating the effects of fire exposure on properties of structural elements retrofitted by fiber–reinforced polymers (FRPs). Mechanical properties of FRP-strengthened reinforced concrete (RC) members, protected with secondary insulation, were investigated, before and after (residual) direct fire exposure. Direct fire contact resulted in a reduction in capacity of 9% to 20% for FRP-strengthened RC beams and 15% to 34% for FRP-strengthened RC columns. Furthermore, a similitude analysis was developed for a heat transfer relationship between full-scale and small-scale specimens, allowing a one-fourth exposure time reduction for the latter. Results from the experimental investigations demonstrated the benefits of employing secondary fire protection to FRP-strengthened structures, despite the glass transition temperature being exceeded in the early stages of the elevated-temperature exposure. Therefore, it is suggested that fire protection is necessary for a FRP-strengthened structure to retain integrity throughout the duration of the fire exposure and on return to ambient temperature. Retrofitting RC structures with adequate fire resistance by contributing to the missing information for fire protection requirements not available in codes of p. Apart from the test data, relations defining the variation of strength and elastic modulus of CFRP and GFRP with temperature are available in literature. These relations are proposed by [8][9][10][11]33,35,39,40]; for FRP. Majority of these relations define the temperature dependent variation in strength properties of CFRP, while relatively few relations define the variation in strength properties of GFRP. Additionally, most of these relations are in form of semi-empirical equations and express the variation of strength and stiffness of FRP up to 800 �C, whereas some relations are in the form of reduction factors providing percentage degradation in ambient temperature strength and stiffness of FRP at different temperature level. Saafi [40] proposed linear/bilinear relations for expressing degradation of strength and stiffness of GFRP and BFRP at elevated temperature. These relations are based on the tests carried out on GFRP and BFRP rebars reported by Blontrock et al.

Keywords— *CFRP, GFRP, BFRP, Epoxy Resin*

1. INTRODUCTION

Demolishing and reconstructing a structure was considered to be an uneconomical and time-consuming process. Hence strengthening of new and existing structures had become popular in the construction field [1]. One of the most commonly used methods for repair and rehabilitation of structures is Retrofitting. Retrofitting is the modification of the existing structure by the addition of a new component for restoring the original capacities in the structure [2]. Strengthening old structures is necessary as old structures were constructed with old design codes that do not consider the post elastic behavior of the structure [3, 4]. Other reasons to strengthen a structure include faulty design or execution, aging of structure, various environmental conditions like corrosion, change in climate, inadequate maintenance, natural calamities like earthquakes and so on [1]. Jacketing is one of the easiest and effective techniques in retrofitting of structures. There is various type of jacketing is available to enhance the strength in structures such as Concrete jacketing, Steel jacketing, Ferro cement jacketing and Fiber Reinforced Polymer (FRP) jacketing [2]. Concrete jacketing is the first method to strengthen the damaged structures. A new layer of reinforced concrete is constructed around the existing concrete for achieving strength. Steel connectors, roughening of the surface and applying epoxy resin are used to make the bond between existing and new concrete material [2]. Steel jacket helps to restore the strength, ductility, and energy absorption capacity of columns thus it seems to be effective in retrofitting columns [5].

The FRP helps to increase the flexural strength and ductile behavior of the lap-spliced column thus increasing the lateral performance of columns [81]. The FRP helps to increase the performance of RC structures in the seismic region effectively.

The FRP is also to protected by corrosion. Ferro cement is a low cost thin composite material, easily manufactured, easily adaptable and durable. Hence requires no fire and corrosion protection. With the addition to expanded steel mesh, it is used to strengthen the shear deficient columns [3]. One of the most commonly used methods for retrofitting is Fiber Reinforced Polymer (FRP). FRP is widely used for its properties such as high strength to weight ratio, stiffness, good impact properties, high resistance to corrosion in harsh environmental and chemical condition, and also it causes only a minimum alteration to the geometry of structural elements than other methods [1, 9, 10]. In this paper behavior of FRP strengthened structures concrete structure were discussed.

2. LITERATURE REVIEW

Balasubramanaian et al (2007), evaluated the performance of the CFRP/GFRP wraps used for retrofitting of the beams and columns and concluded that, the performance of the RC beams was found to have improved after retrofitting using FRP wrapping. But the performance of both CFRP and GFRP were almost similar. In case of the shear strengthening, the RC beams provided with CFRP wrap along the entire span was found to be better among the various methods of carbon fibre wrap that were investigated. 19 For RC columns retrofitted with single layer of CFRP/GFRP wrap, peak load, maximum strains as well as ductility index were higher than the control RC columns for both the lateral tie spacing.

Sing-ping Chiew et al (2007), presented an experimental and numerical study for flexural behaviour of RCC beams strengthened with GFRP and concluded that by bonding GFRP laminates to the tension face of flexural RC beams; both strength and stiffness of the beams can be increased. The strengthening ratio increases linearly with the increase of the axial rigidity of the external GFRP laminates. The interfacial shear stress concentration due to the cut off effect is less significant than that caused by flexural cracking. Debonding failure occur when the interfacial bond in the shear span is fully utilized. All the strengthened beams fail by de-bonding of GFRP laminates.

Maria Antonietta Aiello et al (2002) analyses to study the structural behaviour of concrete beams reinforced with hybrid fibre-reinforced polymer (FRP)-steel reinforcements. They observed from the experiment that the increase of stiffness is more evident for beams reinforced with FRP rebars 21 placed near the outer surface of the tensile zone and steel rebars placed at the inner level of the tensile zone.

3. MATERIAL USED

This chapter includes various laboratory tests are carried out to determine the physical properties of different materials of concrete with respect to their codes of practice. Those tests carried out for various ingredients of concrete are tabulated. Materials used up as ingredients of concrete are as shown below:

1. Cement: OPC 53 (Birla A1)
2. Mineral additives: GGBS
3. Coarse aggregate I: 20mm crushed stone
4. Fine aggregate: M sand
5. Water: Portable
6. Admixture: Super plasticizer (ECMAS HP890)

3.1 Behaviour of materials during fire

Concrete member are consisting of construction materials that vary in nature from one another. The very nature of each material is specific to its physical properties, chemical properties and behaviour of material, when exposed to fire. The most important materials found in the concrete buildings is obviously concrete and structural steel but even in them, we have variations depending upon the manufacturing process and ingredient mix.

Other materials like glass, aluminium, thermal insulations, wood, plastics etc. are also part of building. Investigate of the damage occurred to the building, requires the understanding of these materials especially those which are part of the structural elements. Now, we will discuss the behaviour of basic structural materials (concrete and steel).

Fig. 1: Behaviour of materials during fire

4. RETROFITTING

Retrofitting is the technique used to re-strengthen the concrete members which are damaged or failed. Repairing and strengthening of old structures using advanced materials are a contemporary research in structural engineering field. The traditional method is by steel jacketing, thin layers of heavily reinforced concrete or pre-tensioned steel cables covered with thin layer of concrete. These methods are difficult to implement and high cost. Then, fiber-reinforced plastic (FRP) has come into market.

Generally, structures are subjected to geo physical and man-made loads during their service life. When the magnitude of these loads exceeds the capacity or strength of the structures, they are likely to be damaged. Sometimes, the strength of the structure is reduced because of the use of sub-standard materials in the construction. Strength also decreases due to the application of additional loads because of the change in functioning. These situations are the reason for strengthening and up-gradation of the structure to carry the enhanced loading. Instead of putting up a new structure in place, a decision to repair is essential.

FRP composites are now increasingly used in the construction industry and offer considerable potential for greater use in buildings, including large primary structures. In recent years more complex applications have been developed to satisfy the desire for more features in building design. FRP composites have numerous advantages in construction industry such as offsite fabrication, modular constructions, reduced mass, improved thermal insulation.

There are many methods of retrofitting among them which we used for this process are as follows,

- GFRP (Glass fibre reinforced polymer) and,
- BFRP (Basalt fibre reinforced polymer).

4.1 Glass Fibre Reinforced Polymer (GFRP)

First developed in the mid 1930's, Glass Fiber Reinforced Plastic (GFRP) has become a staple in the building industry. Originally used merely for the construction of parts, in 1967, the architectural advantages were discovered with the attempted destruction of Disneyland's "House of the Future." Built in 1956-7, the futuristic house was built entirely of fiberglass, and when the attraction was no longer deemed necessary, it was scheduled to be destroyed in 1967. Amazingly, the wrecking ball merely bounced off the structure, and the possibilities for GFRP were recognized and began to grow. By 1994, nearly 600 million pounds of composite materials were used in the building industry. Today, Stromberg Architectural provides a variety of products in GFRP to fit your building needs and aesthetic vision. These Glass fiber reinforced polymer (GFRP) are initially developed in the middle 1930's. Uses of Glass fiber reinforced polymer are growing rapidly in construction industry.

These Glass fiber reinforced polymer are widely considered for the following reasons:

(a) High strength: Use of Glass fiber reinforced polymer shows very good and high strength to weight ratio.

(b) Light weight: Glass fiber reinforced polymer has a low weight which reads about 2 to 4 lbs per square foot which results in 3 advantages that is,
    i) Installation will be faster and greater,
    ii) Structural framing will be less and
    iii) Shipping costs will be low.

(c) Resistance:
    i) Resistance to salt water,
    ii) Resistance to chemicals and
    iii) Resistance acid rain.

(d) Seamless construction: Using Glass fiber reinforced polymer water tight structures cab be made.

(e) Easy shapes: Using Glass fibre reinforced polymer complex shapes can be moulded in to required shapes. Virtually any shape or form can be molded

(f) Low maintenance: Using of Glass fibre reinforced polymer requires low maintenance. Research shows no loss of laminate properties after 30 years.

(g) Durability: Stromberg GFRP stood up to category 5 hurricane Floyd with no damage, while nearby structures were destroyed.

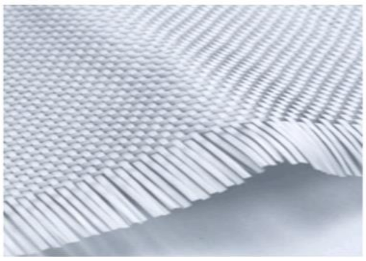

Fig. 2: Glass fibre reinforced polymer(BFRP)

4.2 Basalt Fibre Reinforced Polymer (BFRP)

Basalt fibre reinforced polymer are manufactured from very fine layers of basalt generally in brown colour and it shows many more advantages then glass fibre reinforced polymer. Even though basalt fibre is a new invention than glass fibre it has many advantages than glass fibre and has a high characteristic strength, corrosion resistance, greater resistance towards oxidation, high resistance towards radiation and higher shear strength.

Fig. 3: Basalt Fibre Reinforced Polymer (BFRP)

5. CLEANING

Just after the fire concrete members is in filthy condition, depending upon the size, nature and duration of fire. It is better to clean the concrete members. It will minimize the impact of damage and make it easier and cost efficient to recover the building and belongings. Water or fire extinguishing foam is used to extinguish the fire. Therefore, the only worrying point is not fire and smoke damage but possible water damage as well. This measure must be taken preferably just after the fire even before assessment and evaluation and decision making phase. This will not allow the soot and smoke deposits or penetrate inside and further damage will be prevented as the acidic fumes and particles in smoke and soot will not be granted enough time to inflict damage. In the beginning all water accumulated in the concrete members must be removed by the help of pumps and manual equipment. Fire extinguishing foam is removed as well from the concrete members. It is very important to dry the wet surface as it will otherwise generates the problem of mold. Professional cleaners are required for cleaning job in case of heavy fires. Heavy soot will be deposited on the accessories and the concrete members. It is important to deal with it properly and remove it from the surface otherwise it will deteriorate them and the smoke smell will become a permanent stay in the facility. Inspection of concrete members services like HVAC is important. If soot is not properly removed from the surface of walls and ceiling then the smell of fire wouldn't go away.

6. REMOVAL OF SMOKE ODOUR

Smoke penetrates the concrete members in the event of fire. The smoke is very problematic in case of fire. Smoke penetrates virtually through very other material present in the concrete members. It persists in the concrete members if not properly removed. Records recovered from 1906 San Francisco fire that are currently stored in National Achieves of USA, still have very strong odour of smoke. It can give the idea that how critical this problem is to understand the gravity of the problem first it is necessary to understand smoke and its composition. Smoke is the combination of gases, liquid and solid fumes that emits from the fuel. They are considered as the unburnt part of the fuel and they may contains toxic and carcinogenic particles. The size of these particles is less than 10 microns in diameter, mostly they are less than 1 micron. Hence it is critical to get rid of smoke particles as they pose serious health issue and sometimes acidic fumes that may contain corrodes and damages the property and structure like wise.

7. WRAPING

Fibre reinforced polymer wrapping method is resistance to seismic movements can be improved. The fibre reinforced polymer has significantly enhanced the strength and ductility of concrete by forming perfect adhesive bond between concrete and the wrapping material.

Fig. 4: Wrapping

Fig. 5: UTM

8. TEST AND RESULT

8.1 Glass fibre reinforced polymer

8.1.1 Cube test

Table 1: Compression test of 7 day

Mix	Weight (Kg)	Compressive strength after fire (N/mm²)	Compressive strength after retrofitting (N/mm²)
Normal	8.09	10.14	12.56
10%GGBS +90%OPC	8.7	17.22	25.56
20%GGBS +80%OPC	8.25	22.67	26.22
30%GGBS +70%OPC	8.15	13.5	15.56

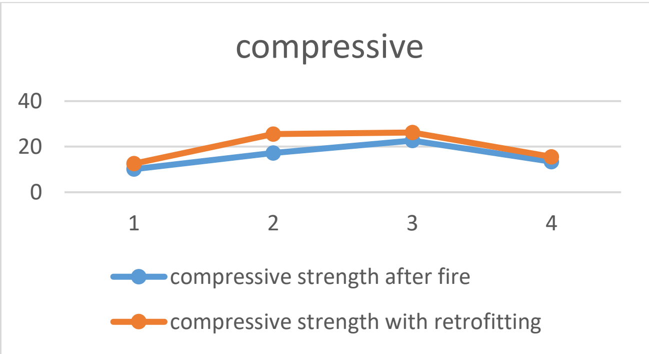

Fig. 6: Compression

8.1.2 Cylinder test

Table 2: Tensile test of 7 day

Mix	Weight (Kg)	Tensile strength after fire(N/mm²)	Tensile strength after retrofitting (N/mm²)
Normal	12.32	1.69	2.44
10%GGBS +90%OPC	12.97	1.52	2.67
20%GGBS +80%OPC	12.99	1.74	3.88
30%GGBS +70%OPC	13.12	1.84	3.55

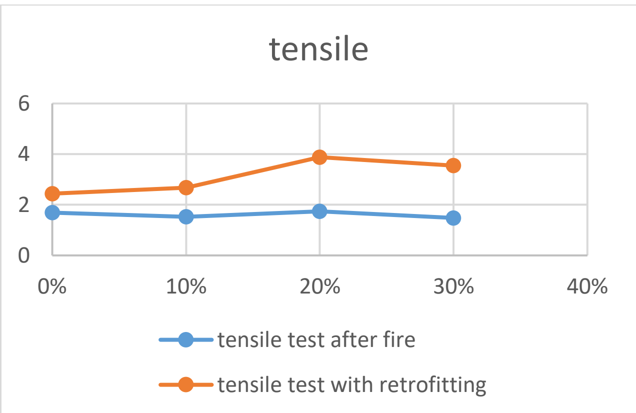

Fig. 7: Tensile

8.1.3 Prism test

Table 3: Flexural test of 7 day

Mix	Weight (Kg)	Flexural strength after fire(N/mm²)	Flexural strength after retrofitting(N/mm²)
Normal	12.92	1.9	3
10%GGBS+90%OPC	12.52	1.52	2.8
20%GGBS +80%OPC	12.84	2.1	3.88
30%GGBS+70%OPC	12.25	1.82	3.55

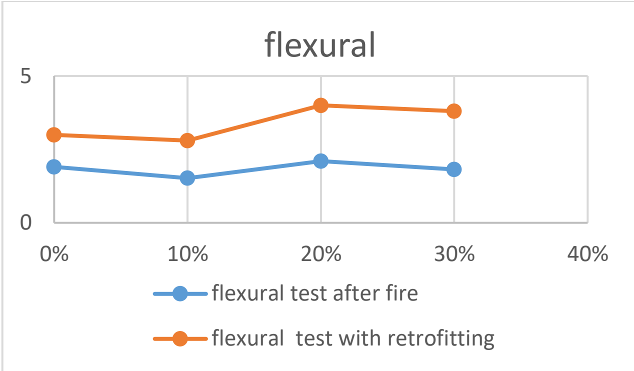

Fig. 8: Flexural

8.2 Basalt Fiber Reinforced Polymer (BFRP)

8.2.1 Cube test

Table 4: Compression test of 7 day

Mix	Weight (Kg)	Compressive strength after fire(N/mm²)	Compressive strength after retrofitting(N/mm²)
Normal	8.33	10.14	14.44
10%GGBS+90 %OPC	8.26	13.22	15.55
20%GGBS +80%OPC	8.81	22.67	23.77
30%GGBS+70 %OPC	8.60	13.5	15.8

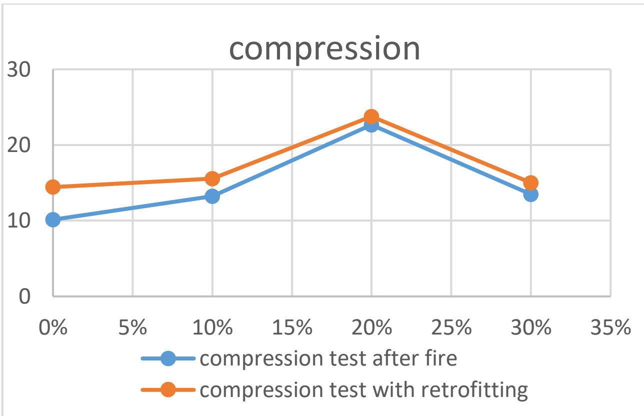

Fig. 9: Compression

8.2.2 Cylinder test

Table 5: Tensile test of 7 day

Mix	Weight (Kg)	tensile strength after fire(N/mm²)	tensile strength after retrofitting(N/mm²)
Normal	12.67	1.69	3
10%GGBS +90%OPC	12.71	1.52	3.33
20%GGBS +80%OPC	13.11	1.74	4.22
30%GGBS +70%OPC	12.89	1.48	3.88

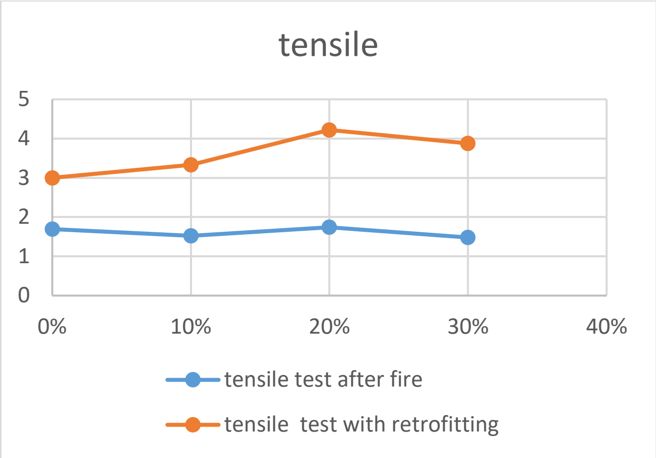

Fig. 10: Tensile

8.2.3 Prism test

Table 6: Flexural test of 7 day

Mix	Weight	Flexural strength after fire(N/mm²)	Flexural strength after retrofitting (N/mm²)
Normal	12.92	1.9	3
10%GGBS+90%OPC	12.52	1.52	2.8
20%GGBS +80%OPC	12.84	2.1	3.88
30%GGBS+70%OPC	12.25	1.82	3.55

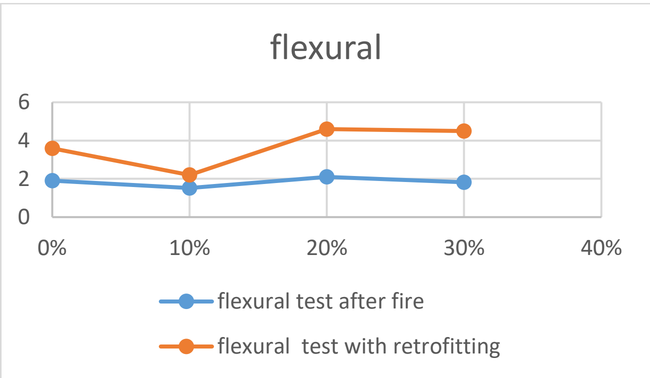

Fig. 11: Flexural

8.3 Advantage

(a) It increases the tensile strength of the concrete.
(b) It is a great material for restoration of old buildings and is used for the exterior of the buildings. It is also being used extensively for walls and ceilings. Landscape artists have come on board and discovered the versatility of FRP
(c) It reduces the air voids and water voids the inherent porosity of gel.
(d) FRP is lightweight and is about 75% lighter than traditional concrete.
(e) FRP is very adaptable in that it can be poured or sprayed.

8.4 Disadvantage

(a) It is expensive.
(b) Ductility is a solid material's ability to deform under stress
(c) The cost of FRP is higher than traditional concrete.
(d) Due to the fiberglass being inside the concrete and the addition of additives and acrylic co-polymer the price is steeper
(e) FRC is difficult to self-mix.

9. FUTURE STUDY

Further investigations may include the strengthening of the beam using the laminates bonding using both rivets and epoxy and to determine the bonding of the laminate with the beam and determination of the ultimate load carrying capacity of the strengthened concrete member.

10. CONCLUSION

- The experimental results clearly conclude that GFRP wrapping can enhance the strength of concrete columns under axial loading.
- Confinement by GFRP enhances the performance of rectangular concrete columns. GFRP wrapping is more effective for aspect ratio 1 than aspect ratio 1.5, i.e. for M30 grade of concrete, percentage increased in strength are 43.12% and 36.98% respectively for column with single layer of GFRP
- As the aspect ratio increases from 1 to 1.5, the strength gain in confined concrete columns decreases.
- Compressive Strength of the Concrete Columns increases with increase in the number of layer of GFRP. For M30 grade of concrete, percentage increase in strength from single layer to double layer of GFRP are 22.86% and 21.44% for aspect ratio 1 and 1.5 respectively.

It is concluded that the retrofitting columns will have significantly better performance compared with the unwrapped columns, i.e. for M30 grade, retrofitted specimens have taken 14.19% and 14.73% more load than control specimens for aspect ratio 1 and

11. REFERENCES

[1] Shrikant M. Harle, "The Performance of Natural Fibre Reinforced Polymer Composites: Review", International Journal of Civil Engineering Research, 2014, Volume 5, PP. 285-288.

[2] Burgoyne Chris, "Fibre Reinforced Polymers-Strengths, Weaknesses, Opportunities and Threats" Department of Engineering, University of Cambridge, UK, 2009.

[3] S. Shivakumar and Guggari G.S, "Literature Review of Fibre Reinforced Polymer Composites", International Journal of Advances in Engineering; Technology, 2011, Vol. 1, PP. 218-226.

[4] Miguel Cerezo Jesus, "Fibre Reinforced Polymer (FRP): A New Material Used in Façades of Tall Buildings", Global Interchanges: Resurgence of the Skyscraper City, 2015.

[5] Ashik K.P and Sharma S. Ramesh, "Natural Fibre Reinforced Hybrid Polymer Composites", Journal of Minerals and Materials Characterization and Engineering, 2015, Vol.3, PP. 420-426.