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Experimental Study on Retrofitting Using FRP Laminates

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Abstract-Retrofitting is the modification of existing structure to improve the performance and durability of the structure. The concrete structure need retrofitting due to various factors like corrosion of detailing and failure of bonding etc. In retrofitting, fiber reinforced polymer (FRP) is relatively new technique to strengthening and repair damage of the structure. In this project the application of FRP in concrete structure is being investigated for its effectiveness in enhancing structure performance in terms of strength. The RC structure made are tested with compressive testing machine (CTM)

Index Terms— Fiber Reinforced polymer (FRP) laminates, retrofitting, loading frame

1.INTRODUCTION

Structural retrofitting, the process of strengthening existing infrastructure to meet modern demands, has become increasingly important in ensuring the safety and longevity of buildings, bridges, and other civil structures. Among the various retrofitting techniques available, the use of Fiber Reinforced Polymer (FRP) laminates has emerged as a versatile and effective solution. FRP laminates, consisting of high-strength fibers such as carbon, glass, or aramid embedded in a polymer matrix, offer unique advantages in terms of strength, durability, and ease of application. This paper explores the principles, benefits, and applications of retrofitting with FRP laminates, highlighting its significance in modern engineering practices.

Principles of FRP Retrofitting:

The process of retrofitting with FRP laminates involves the application of fiber-reinforced composite materials to the surface of existing structures. This technique aims to enhance the structural capacity of the elements, such as beams, columns, slabs, or walls, by providing additional reinforcement and confinement. The key principles of FRP retrofitting include surface preparation, adhesive bonding, and proper installation of FRP laminates. Surface preparation involves cleaning, roughening, and priming the substrate to ensure optimal bonding between the FRP and the existing surface. Adhesive bonding, typically achieved using epoxy resins, facilitates the transfer of loads between the FRP laminate and the substrate, ensuring effective reinforcement. Proper installation techniques, such as wet layup, vacuum bagging, or pultrusion, are employed to ensure the integrity and durability of the retrofitting system.

Benefits of FRP Retrofitting:

Retrofitting with FRP laminates offers numerous benefits compared to traditional strengthening methods. Firstly, FRP materials have a high strength-to-weight ratio, allowing for significant increases in structural capacity without adding excessive weight to the existing structure. This is particularly advantageous in retrofitting projects where structural elements are sensitive to additional loads. Secondly, FRP laminates exhibit excellent corrosion resistance, making them ideal for reinforcing structures in harsh environments or corrosive conditions. Additionally, FRP retrofitting is non-destructive and minimally invasive, reducing downtime and disruption to occupants during the strengthening process. Furthermore, FRP materials can be tailored to meet specific engineering requirements, offering flexibility in design and application.

Applications of FRP Retrofitting:

FRP retrofitting finds wide-ranging applications across various sectors of civil engineering. In the building industry, FRP laminates are used to strengthen and stiffen concrete structures, such as beams, columns, and slabs, to meet updated building codes or accommodate changes in occupancy loads. Similarly, in bridge engineering, FRP retrofitting is employed to enhance the load-carrying capacity of aging bridges, extend their service life, and improve their resilience to seismic events or extreme weather conditions. Moreover, FRP materials are utilized in retrofitting historical structures to preserve their architectural integrity while ensuring structural safety and stability. Other applications include the strengthening of industrial facilities, marine structures, and transportation infrastructure. Retrofitting with Fiber Reinforced Polymer (FRP) laminates represents a valuable strategy for enhancing the structural capacity and resilience of existing infrastructure. By leveraging the unique properties of FRP materials, engineers can effectively strengthen aging structures, mitigate deterioration, and prolong service life. The versatility, durability, and non-destructive nature of FRP retrofitting make it a preferred choice in modern engineering practices. As the demand for sustainable and resilient infrastructure continues to grow, the adoption of FRP retrofitting is expected to increase, contributing to safer, more durable, and environmentally friendly built environments.

2. LITERATURE REVIEW

Fiber Reinforced Polymer (FRP) retrofitting stands as a cornerstone in the improvement of Reinforced Concrete (RC) structures, particularly in seismic regions like Kerala. Its effectiveness in enhancing strength, notably in seismic areas, is well-documented. Beyond beams, FRP retrofitting exhibits versatility in addressing columns, floors, and walls, crucial elements for seismic resilience.

The significance of FRP retrofitting lies in its ability to upgrade existing structures to meet updated seismic codes, thereby ensuring safety and mitigating earthquake risks. Technical considerations, alongside cost-effectiveness and performance-based methodologies, underscore its efficacy in enhancing structural integrity.

In conclusion, FRP retrofitting offers a cost-effective solution for bolstering structural resilience. Ongoing research endeavors are focused on refining techniques for broader application and increased durability, thereby further enhancing the effectiveness of FRP retrofitting in ensuring the safety and longevity of structures in seismic-prone regions.

3. MATERIAL USED

3.1 Coarse aggregate

Crushed basalt rock coarse aggregate, adhering to IS: 383 standards and sized at 20mm, was utilized, ensuring flakiness and elongation indices remained below 15%.

3.2 Fine Aggregate

The utilized manufactured sand, with a specific gravity of 2.55, meets the IS: 383 specifications range of 2.5 to 2.9.

3.3 Ordinary Portland Cement (OPC)

The employed Ordinary Portland cement, graded at 43, possesses a specific gravity of 3.15, aligning with the specifications outlined in IS 8112-1989 (3.10-3.15).

3.4 Water

Achieving the desired strength in concrete heavily relies on the quality and quantity of water. A water-to-cement ratio of 0.45 is employed for M-20 grade concrete.

3.5 Fiber Reinforced Polymer (FRP) laminates

The FRP laminate depicted in Figure 1, utilized for retrofitting, incorporates 1mm and 2mm thick sheets with tensile strengths of 600MPa and elastic moduli of 26.1GPa.

Figure 1 FRP Laminates

3.6 Epoxy resin

Epoxy resin with a specific gravity of 1.17 is employed, meeting the requirements outlined in ASTM D-792.

Mix design

According to IS: 10262:2009, M-25 grade was designed and utilized to create the test samples, with the quantities specified in Table 1.

Table 1 Properties and quantities

CONSTITUENTS	PROPERTIES
Cement-OPC 43	Specific gravity=3.15
Fine Aggregate-M Sand	Specific gravity=2.55
Coarse Aggregate-20mm	Specific gravity=2.51

4. PROPERTIES OF MATERIALS USED

Cement

- Fineness = 6%
- Normal consistency = 32%

- Initial setting time = 44 min 55 sec
- Final setting time = 9 hrs 36 min
- Soundness of cement = 3.5 mm
- Density of cement = 3.08g/cc

Fine Aggregate

- Fineness modulus = 3.018
- Specific gravity = 2.67

Coarse aggregate

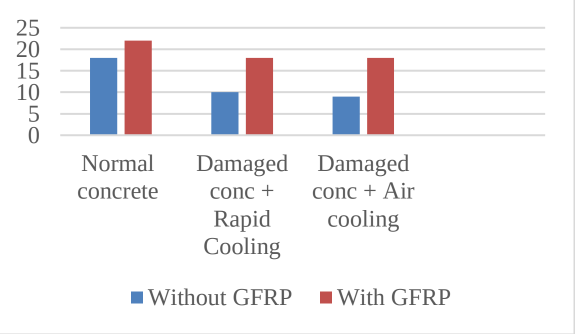
- Finess modulus = 7.2
- Specific gravity = 2.7

5.RESULT AND DISCUSSION

5.1 CTM Test Results

Table No. 2:7-Day Compressive Strength

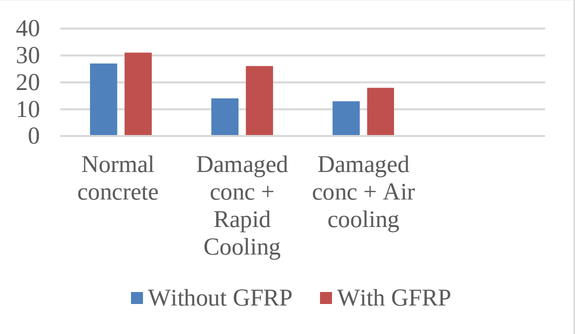
SL.NO	Description	Weight of sample (Kg)	Density (Kg/m^3)	Load of failure (KN)	Cube Compressive Strength (N/mm^2)
1	Normal concrete	12.908	2482	325	18.4
2	Normal conc.+ FRP	13.102	2519.6	380	21.51
3	Damaged conc.+ Rapid cooling	12.685	2439.42	180	10.19
4	Damaged conc.+ Rapid cooling+FRP	12.69	2440.38	320	18.117
5	Damaged conc.+Air cooled	12.33	2371.15	160	9.05
6	Damaged conc.+ Air cooled+ FRP	12.99	2498.07	315	17.83



Graph 1: 7 -Day Compressive Strength

Table No. 3:14-Day Compressive Strength

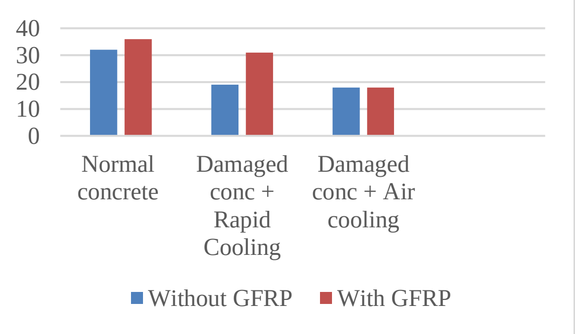
S.No	Description	Weight of sample (Kg)	Density (Kg/m^3)	Load of failure (KN)	Cube Compressive Strength (N/mm^2)
1	Normal concrete	12.845	2470.19	468	26.49
2	Normal conc.+FRP	13.029	2505.57	540	30.57
3	Damaged conc.+Rapid cooling	12.485	2400.96	252	14.26
4	Damaged conc.+Rapid cooling+FRP	12.59	242.15	460	26.04
5	Damaged conc.+Air cooled	12.21	2348.07	220	12.45
6	Damaged conc.+ Air cooled+FRP	12.82	2465.38	451	25.53



Graph 1: 14 -Day Compressive Strength

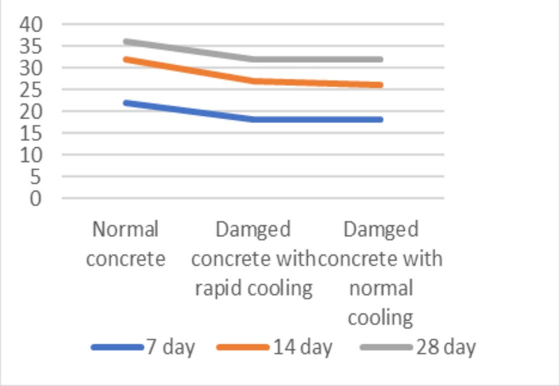
Table No. 4:28-Day Compressive Strength

S.No	Description	Weight of sample (Kg)	Density (Kg/m^3)	Load of failure (KN)	Cube Compressive Strength (N/mm^2)
1	Normal concrete	12.798	2461.15	558	31.59
2	Normal conc.+FRP	13.102	2519.6	638	36.12
3	Damaged conc.+Rapid cooling	12.491	2402.11	344	19.47
4	Damaged conc.+Rapid cooling+FRP	12.71	2444.23	546	30.91
5	Damaged conc.+Air cooled	12.31	2367.31	310	17.55
6	Damaged conc.+ Air cooled+FRP	13.02	2503.84	541	30.63-



Graph 1: 28 -Day Compressive Strength

Graph 4: Compressive Strength of Samples without FRP



Graph 5: Compressive Strength of Samples with FRP

6. CONCLUSION

During the initial phases or in the event of seepage conditions, there's a higher presence of pore water within concrete structural members. When a fire occurs in such conditions, the pore water attempts to escape as vapors, creating pressure within the concrete. Unable to escape due to strong bonding, this pressure can exceed the concrete's bond strength, leading to cracks and subsequent spalling. Spalling in concrete typically exhibits lower strength compared to unaffected samples, necessitating repairs with mortar and subsequent wrapping with FRP to enhance load-bearing capacity.

After repair and retrofitting, it was noted that the lost strength of the concrete due to fire damage could be restored to approximately 98% of normal concrete strength with two layers of wrapping. Further increases in strength are achievable by adding more layers of wrapping.

Additionally, it was observed that concrete samples subjected to rapid water cooling after fire exposure exhibited less strength loss compared to those cooled in air. Air-cooled samples endure prolonged thermal stresses, resulting in greater strength deterioration. Thus, it's concluded that rapid cooling methods are essential for minimizing structural damage during fires.

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