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Performance of Reinforced Concrete beam after Exposed to Fire

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Abstract: Reinforced concrete beams play a crucial role in structural systems, but their strength and durability can be severely affected when exposed to fire. This study explores what happens to these beams after fire damage and how we can effectively bring them back to life through retrofitting. After exposing concrete beam specimens to high temperatures, different retrofitting methods—such as fibre-reinforced polymer (FRP) wrapping and cement-based jacketing—were applied to assess their ability to restore structural performance. We then tested the beams to understand how much of their strength, stiffness, and load-bearing capacity could be recovered. The findings showed that retrofitting significantly improved the condition of fire-damaged beams, with FRP techniques standing out for their efficiency and simplicity. This research highlights how timely intervention and the right repair techniques can extend the life of fire-affected concrete structures, ensuring safety and stability.

I. INTRODUCTION

Reinforced Concrete (RCC) structures Reinforced concrete (RC) remains a cornerstone of modern infrastructure due to its robustness, adaptability, and cost-effectiveness. However, when exposed to fire, RC elements—particularly beams—can undergo significant structural degradation. Elevated temperatures affect the concrete's microstructure, leading to spalling, cracking, and loss of compressive strength, while also compromising the yield strength and bond of embedded reinforcement. These changes can critically reduce the load-bearing capacity and overall stability of a structure.

In the aftermath of fire incidents, replacing damaged members is often costly, time-consuming, and environmentally taxing. Retrofitting offers a sustainable and practical alternative by restoring or enhancing the structural performance of fire-affected elements. This study investigates the residual behaviour of RC beams after fire exposure and evaluates the effectiveness of selected retrofitting techniques such as fibre-reinforced polymer (FRP) wrapping and cementitious jacketing. These methods are analysed in terms of strength recovery, failure modes, and practicality in real-world applications.

By combining experimental insights with structural performance analysis, this research aims to provide reliable solutions for post-fire rehabilitation. The broader goal is to contribute toward resilient infrastructure practices that prioritize safety, resource efficiency, and longevity—ensuring that fire-damaged structures are not prematurely discarded but effectively revived.

Figno.1FireDamageBeam

II. LITERATUREREVIEW

1) Riyaz J. Mulla, Vinit T. Avdut, Shivraj D. Bagal, Mohammad Fazal Bashir Dongare, Shubham D. Sarvade RC structures exposed to high temperatures experience severe cracking and reduced load-bearing capacity, making retrofitting essential. The research investigates the effectiveness of Glass Fiber Reinforced Polymer (GFRP) in restoring the structural integrity of such elements due to its superior strength-to-weight ratio, corrosion resistance, and ease of application. In the experiment, RC beams were subjected to controlled fire exposure based on the ISO 834 standard, with temperature increments from 100°C to 700°C, each maintained for three hours. Post-exposure, the beams were retrofitted using two different materials and cured for 21 days. Non-Destructive Testing (NDT) was used to evaluate damage levels, followed by flexural testing. Results revealed that retrofitted beams exhibited significant improvements in load-deflection behavior compared to untreated beams. Both materials used in retrofitting enhanced strength and ductility, with hybrid retrofitting techniques showing the best performance. The study concludes that GFRP-based retrofitting is a highly effective method for strengthening fire-damaged RC structures and emphasizes its potential in modern construction practices for enhanced durability and safety.
2) G.R. Abirami, Dr. M. Murugan ; Government College of Engineering, Tirunelveli, Tamil Nadu, India . Reinforced concrete (RC) structures often require retrofitting and strengthening due to damage from fires, earthquakes, and other external factors. Fibre Reinforced Polymer (FRP) composites, particularly Glass Fibre Reinforced Polymer (GFRP) , are widely used in construction for rehabilitation due to their high strength-to-weight ratio, corrosion resistance, and ease of application.
3) Amol Suresh Satpute, Dr. Mahavir Balmukund Varma , Maharashtra Institute of Technology, Aurangabad, and Government College of Engineering, Aurangabad, Maharashtra, India. Retrofitting of reinforced concrete (RC) beams is crucial for enhancing their shear strength, loadbearing capacity, and durability, especially in structures subjected to increased loads and environmental deterioration. Among various strengthening methods, Glass Fiber Reinforced Polymer (GFRP) wraps have gained significant attention due to their high strength-to-weight ratio, corrosion resistance, and ease of application. This study investigates the effectiveness of externally bonded GFRP wraps applied in single, double, and triple layers in strengthening RC beams.
4) Brightson Poul Sebastin, Joe M Adams, Maria A Rajesh & Shalin Prince , This review paper by Shrikant M. Harle highlights the growing relevance of Natural Fibre Reinforced Polymer (NFRP) composites in civil engineering. It emphasizes the environmental benefits of using natural fibers like jute, sisal, coir, and hemp due to their biodegradability, low cost, and sustainability. Harle discusses the challenges such as moisture absorption, compatibility issues between fiber and polymer matrix, and the need for surface treatments to improve interfacial bonding. The paper also compares NFRPs with synthetic fiber composites, showing that while NFRPs may be slightly inferior in strength, they are significantly advantageous in terms of cost and environmental impact. Applications in automotive, construction, and packaging industries are explored. The study concludes with suggestions for improving performance through hybridization and chemical treatment, stressing the need for more research in durability and long-term behavior under various environmental conditions.
5) Kodur and Sultan's (2003) paper, Effect of Fire on Concrete and Concrete Structures. "Effect of Strength and Fiber Reinforcement on Fire Resistance of High-Strength Concrete Columns"provides a comprehensive review of the thermal and mechanical behavior of reinforced concrete (RC) elements when exposed to fire. The authors emphasize that fire exposure induces significant thermal stresses and alters the material properties of both concrete and steel reinforcement, leading to a reduction in structural integrity. Concrete undergoes dehydration, spalling, and loss of compressive strength at elevated temperatures, while steel reinforcement experiences yield strength degradation and creep. The paper highlights the importance of understanding the temperature-dependent properties of concrete, such as thermal conductivity, specific heat, and modulus of elasticity, which are critical for predicting structural performance during and after fire events.

III. SYSTEM DEVELOPMENT

1) Retrofitting reinforced concrete (RC) beams exposed to fire is essential to restore their structural integrity, which is often compromised due to high temperatures. Fire can cause concrete spalling, cracking, delamination, and a significant reduction in the strength of both concrete and steel reinforcement. As concrete loses compressive strength and steel loses yield strength and ductility under elevated temperatures, the load-carrying capacity of beams is greatly affected. Accurate assessment through visual inspection and non-destructive testing (such as ultrasonic and rebound hammer tests) is critical to evaluate damage levels.
2) This experimental study involves the preparation and testing of ten RC beam specimens, each measuring 600 mm × 100 mm × 150 mm, cast using M20 grade concrete.

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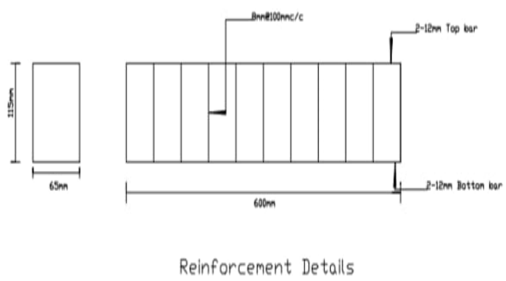
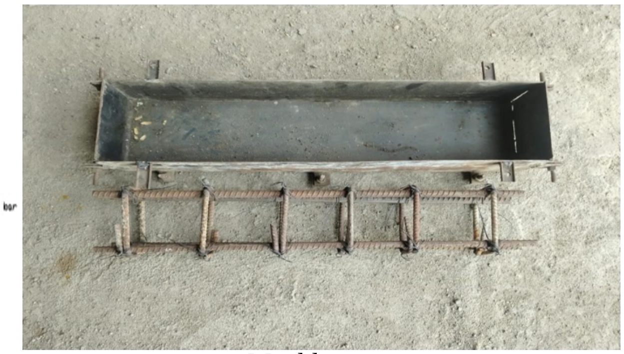
The beams were cured for 21 days and then exposed to fire for two hours at various temperatures (300°C to 700°C). The reinforcement used includes 12 mm main bars (top and bottom) and 8 mm stirrups at 100 mm center-to-center spacing with a clear cover of 12.5 mm.

3) Materials used include M20 cement, river sand (as fine aggregate), and 20 mm coarse aggregates to ensure strength and durability. Steel moulds were used for casting, allowing precise placement of reinforcement and ensuring uniformity for effective fire damage evaluation and subsequent retrofitting.



Reinforcement details



Mould

4) Two-Point Loading: A two-point load is applied to beams of 1m length and a cross-sectional dimension of 75mm × 150mm to evaluate their flexural behavior under bending. This method helps analyze the deflection characteristics and failure patterns. The beam is designed with a clear cover of 25mm and a depth-to-width ratio of 2, ensuring realistic structural conditions. Reinforced concrete beams used in this test are categorized as under reinforced members to study their ductile failure properties.

Two point load Refrence Beam Specimen

5) NDT Test

Effects of Temperature after exposed to fire :

Rebound Hammer Test Result:

Sr no	Specimen	Location 1	Location 2	Location 3	verage	Compressive Strength	Quality of Specimen
1	RS1	36	32	31	33	25	Good
2	B1-300	24	26	23	24.33	19.05	Fair
3	B1-400	20	21	20	20.33	15.05	Fair
4	B1-500	14	18	16	17.66	10	Poor
5	B1-600	19	12	13	13	8	Poor
6	B1-700	12	13	9	11.33	5	Poor

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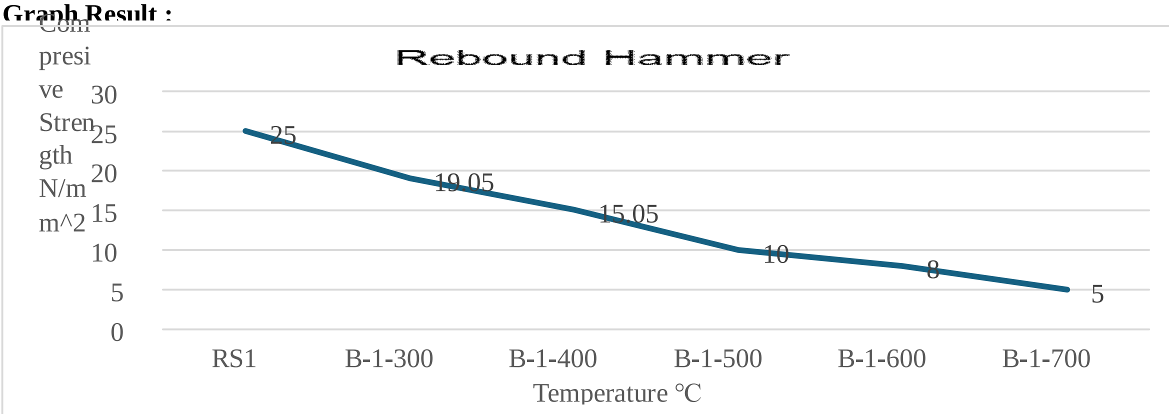
Graph Result :



Rebound Hammer Graph

Description:

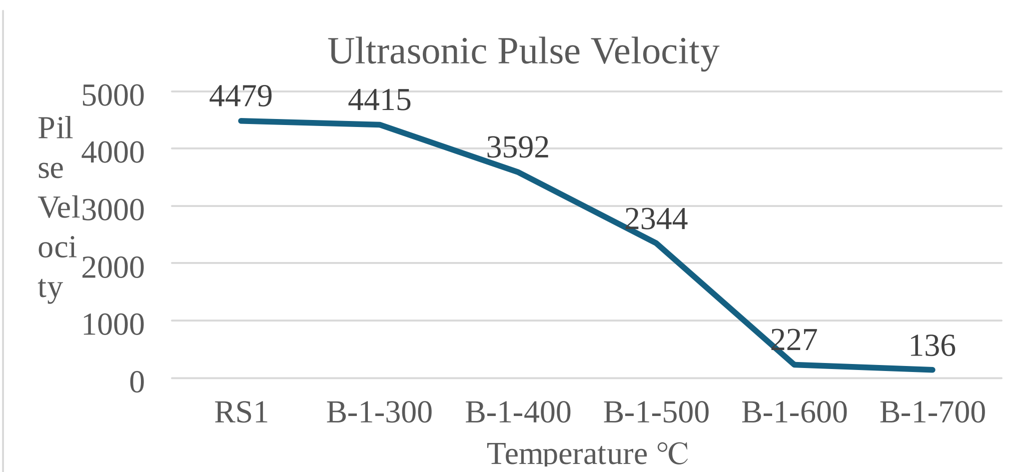
- The compressive strength of concrete drops significantly with rising temperature.
- At 700°C, it retains only 20% of its original strength, indicating a major loss in structural integrity.

Ultra sonic Pulse Velocity

Ultrasonic Pulse Velocity Test Result :

SR	SPECIMEANS	DIRECT	QUALITY
1	RS1	4479	GOOD
2	B1-300	4415	GOOD
3	B1-400	3592	GOOD
4	B1-500	2344	DOUBTFUL
5	B1-600	227	DOUBTFUL
6	B1-700	136	DOUBTFUL

Graph Results:



Ultrasonic Pulse Velocity Graph

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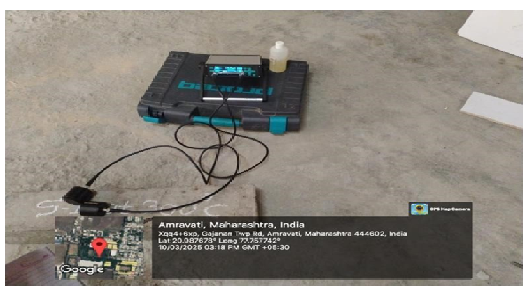
Description:
- Ultrasonic Pulse Velocity decreases with increasing temperature.
- Up to 400°C, the quality remains Good, with velocity above 3500 m/s.
- A sharp drop is observed after 400°C, with values falling below 2500 m/s, classifying the concrete quality as Doubtful.
- At 700°C, the pulse velocity drops to just 3% of the original value, indicating severe internal damage.

Pulse Velocity (km/second)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful



IV. CONCLUSION

1) As the temperature rises, loss of strength is observed.
2) From the performance of above test on the beams it concludes that there is no major temperature effect up to 300°C to 400°C. From the performance of above test on the beams it conclude that there is no major temperature effect up to 300 to 400 °C.
3) Rebound number and compressive strength decreases with increase in temperature.
4) Range from 300 to 400 the compressive strength decreases 20 to 80 with the increase in temperature.
5) Maximum compressive strength decreases 80 at 700 C.
6) From the UPV test it can be concluded that there is significant degradation of concrete with rise in temperature.

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