INVESTIGATION ON PROPERTIES OF CONCRETE CASTED WITH TREATED EFFLUENT

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# Abstract

# concrete structures are frequently exposed to fire incidents, posing significant challenges to their structural integrity and overall performance. Understanding the behavior of concrete under fire conditions is crucial for ensuring the safety and resilience of such structures. This paper provides a comprehensive review of the performance of concrete structures after exposure to fire, focusing on key aspects such as material properties, structural behavior, and post-fire assessment techniques.

# The first part of the review examines the fundamental properties of concrete that influence its response to fire, including thermal conductivity, specific heat capacity, and thermal expansion. The effects of elevated temperatures on the mechanical properties of concrete, such as compressive strength, modulus of elasticity, and tensilestrength, are also discussed. Furthermore, the influence of various factors, including concrete mix design, aggregate type, and curing conditions, on the fire resistance of concrete is explored.

# The second part of the review investigates the structural behavior of concrete elements under fire loading, including beams, columns, slabs, and connections. Emphasis is placed on the mechanisms of thermal degradation, such as spalling, cracking, and loss of stiffness, and their impact on the load-carrying capacity and deformation capacity of concrete structures. The effectiveness of different fire protection measures, such as passive fire protection coatings and concrete additives, in enhancing the fire resistance of concrete elements is critically assessed.

# Finally, the review discusses post assessment techniques for evaluating the residual strength and serviceability of concrete structures after exposure to fire. This includes non-destructive testing methods, such as ultrasonic pulse velocity testing and infrared thermography, as well as destructive testing methods, such as core sampling and mechanical testing. The importance of considering both structural and non-structural elements in the post-fire assessment process is highlighted, along with the need for reliable predictive models for estimating the residual capacity of fire-damaged concrete structures.

# Overall, this review provides valuable insights into the performance of concrete structures after exposure to fire, highlighting the importance of holistic approaches to fire safety design, construction, and maintenance.

# Keywords Concrete structure, Fire exposure, Performance evaluation, Fire resistance, Material, properties Structural behavior, Post-fire assessment

# Introduction

# Reinforced Concrete (RCC) structure

# serve as the backbone of modern

# infrastructure, providing strength, durability,

# and stability. However,

# challenges that can compromise

# integrity and safety. The post-fire strengthening and retrofitting of RCC beams are critical processes aimed at restoring their structural capacity and ensuring continued functionality. This thesis investigates these processes through a comprehensive review of existing literature, aiming to provide insights into effective methodologies, challenges, and future directions in this field.

# Fire-induced damage to RCC beams arises from a combination of thermal effects and material behavior. High temperatures during a fire can lead to the deterioration of concrete properties, including strength and modulus of elasticity, as well as the degradation of steel reinforcement. Literature reveals that the severity of damage depends on various factors such as fire duration, temperature, and the structural configuration of the beams.

# In response to fire-induced damage, researchers and engineers have developed numerous strengthening and retrofitting techniques to enhance the resilience of RCC beams. Fiber-Reinforced Polymer (FRP) composites have emerged as a popular choice due to their high strength-to-weight ratio, corrosion resistance, and ease of application. Studies have shown that externally bonded FRP sheets or wraps can effectively restore the flexural and shear capacities of fire-damaged beams, providing an efficient solution for rehabilitation.

# Steel plate bonding is another commonly employed method for strengthening fire-damaged RCC beams. Literature indicates that bonding steel plates to the surface of the beams can significantly increase their load-carrying capacity, particularly in enhancing flexural strength. Moreover, steel plates offer advantages such as cost-effectiveness and versatility in application, making them a viable option for retrofitting damaged structures.

**Literature review**

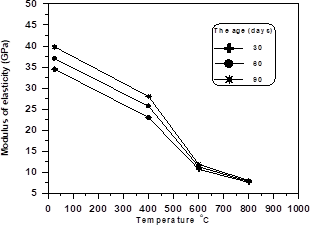
**Sesha P. Ratnam , Srinivasa K. Rao** Research Scholar, Department of Civil Engineering, Andhra University, Visakhapatnam, Andhra Pradesh- 530 003, India Exposure of reinforced concrete (RC) buildings to an accidental fire may result in cracking and loss in the bearing capacity of major components like columns, beams and slabs. It is challenging for structural engineers to develop efficient repair and rehabilitation techniques that enable RC members to restore their structural integrity after being exposed to intense temperatures for a considerable period of time. Therefore, this study was carried out to generate experimental data on repair techniques and performance of heat affected RC beams after repair. Data is presented from tests conducted on RC beams. Initially RC beams were exposed to high temperatures by furnace in which rate of heating is as per standard ISO 834 furnace and repaired using two different repair materials 1 and 2. Non-destructive tests (NDT) were conducted for all the beams after a curing period of 28 days and again after temperature exposure of 100 to 700°C with increments of 100°C each for 3 h duration. After heating, the fire affected beams were repaired with repair materials 1 and 2. Thereafter, these test specimens were tested by NDT followed by flexure test. The load deflection behaviour of RC beams repaired with repair material 1 and 2 have been studied and presented.

**E. Bhargayi, N. Girl Bahu and Sowjavani** Generally during fire accidents in buildings, columns and beams are exposed to fire and these structures are expected to perform well during such extreme conditions. This shows the importance of the study of concrete structures when they are exposed to fire. The objective of this limited study is to provide an overview of the effects of size and fire on columns and beams. In meeting these objective previous investigations done by various researchers are summarized.

**Salim Barbhuiya and Abdul Munim Choudhury** (2015) Studied the size effect of RC beam column connections under cyclic loading. Ordinary Portland cement of 53 Grade is used. Reinforcing steel of diameters 20 mm, 12 mm and 8 mm are used, considering three types of beams–column connections with some specific deficiencies. Cyclic load is applied with displacement-controlled load. Parameters studied are energy dissipation. From the study it is concluded that size effect is more pronounced in specimens exhibiting brittle mode of failure.

**• Mohammed Mansour Kadhum et.al** In this paper, the authors discussed a study in which some mechanical properties and deflection behavior of rectangular reinforced concrete beams under the effect of fire flame exposure is presented. The properties investigated were compressive strength and load-deflection behavior of rectangular reinforced concrete beams under the effect of fire flame exposure. The concrete specimens and beams were subjected to fire flame temperatures ranging from (25-800) °C at different ages of 30, 60 and 90 days, three temperature levels of 400, 600 and 800°C were chosen for exposure duration o2.0 hours. Authors found that, The residual compressive strength ranged between (62 – 72 %) at 400 °C,(52 – 62%) at 600 °C and (38 – 49 %)at 800 °C. Large proportion of drop in compressive strength occurs at the first 1.0-hour period of exposure. Based on the results obtained, it was found that the shrinkage values increase with temperature increase. The temperature distribution through the thickness of beam that was found in this investigation is similar for all the beams which have the same thickness and exposed period to fire flame. After the beams were subjected to fire flame, two types of cracks developed. The first was thermal cracks, which appeared in honeycomb fashion all over the surface. The second crack originated at mid-span region due to bending from the applied load and called flexural cracks. It was noticed that the load deflection relations to specimens exposed to fire flame are flat, representing softer load- deflection behavior than of the control beams. This can be attributed to the early cracks and lower modulus of elasticity. At temperature of (400°C), both burning and subsequent cooling did not affect the mechanical properties of steel reinforcement; the effect was observed at 600 and 800°C. The residual yield tensile stress and residual ultimate stress was (90.6%, 78.8% and 89.8%, 81.4%)

respectively. Modulus of elasticity of concrete is the most affected by fire flame temperature rather than compressive strength.



**Ashok R. Mundhada, Arun D. Phophale et.al**

In this paper the author studied the effect of high temperatures on compressive strength of concrete. 90 concrete cubes of 150 mm size divided equally over three different grades of design mix concrete viz. M 30, M 25 & M 20 were cast. After 28 days’ curing & 24 hours’ air drying, the cubes were subjected to different temperatures in the range of 200°C to 800°C, for two different exposure times viz. 1 hour & 2 hours in an electric furnace. The heated cubes were cooled at room temperature for 24 hours & then subjected to cube compressive strength test. Mix design was carried out using the Ambuja method of design. The conclusions of the test were,

**Dattatreya, B. Balkrishna Barathea** In this paper the author did research work on studying the impact of fire reinforcement provided in R.C.C structures of various types of buildings which are under blast or fire. The Behaviour of Steel Reinforcement at various elevated temperatures from 100° C to 1000°C was studied. The specimens for testing were TMT bars of 12mm diameter. 20 bars were cut to 30 cm size. Then the specimens were tested for mechanical properties using UTM before heating at normal room temperature and the properties were tabulated. 10specimens each were heated in the electric furnace at 100°, 300°, 600°, 900°C and 1000°C for an hour without any interference. After heating, out of 10 specimens for each temperature 5 samples were quenched in cold water for rapid cooling and the other 5 were kept aside for normal cooling at atmospheric temperature. These specimens later were tested for mechanical properties with UTM. The authors concluded that, Ductility of quickly cooled reinforced bars after heating to high temperature of 1000°C decreased which could be dangerous for a structure.

Significant change in  ductility  was

**Methodology**

**Reinforcement Details:**

Casting: Casting a beam typically involves pouring concrete into a Two number of Mold that defines the shape and dimensions of the beam is 60cmx10cmx15c. The process includes preparing the mould for a size of beam, placing any necessary reinforcement such as steel bars its use main bar is 12mm diameter and stirrup is use as 10mm diameter.

**Curing:** The curing process on a beam typically involves allowing the concrete to harden and attain its full strength. This can take several **28 days** of each beam, depending on factors like the type of concrete mix, ambient temperature, and humidity levels. During curing, it's important to keep the concrete moist to prevent cracking and ensure proper hydration.

The curing process is to be completed by using **gunny bag** on a beam typically involves allowing the concrete to harden and attain its full strength. This can take se 28 day

**Fire beam:** The effect of temperature on a beam can be significant and complex. Changes in temperature can cause thermal expansion or contraction in the beam material, leading to stress and deformation. This phenomenon is known as thermal loading. Thermal Expansion: When a beam is subjected to temperature changes, its material will expand or contract. Different materials have different coefficients of thermal expansion, meaning they expand or contract at different rates. This non-uniform expansion or contraction can induce internal stresses within the beam

**UTM (universal testing machine):** A Universes Testing Machine (UTM) is a hypothetical concept often discussed in philosophical and scientific circles, particularly within discussions about the nature of reality and the possibility of multiple universes. The idea revolves around a theoretical apparatus capable of testing and interacting with different universes or realities. It's often used as a thought experiment to explore the implications of theories like the multiverse hypothesis, where multiple universes with different physical laws and constants may exist. While purely speculative, the concept sparks philosophical debates about the nature of existence, perception, and the boundaries of scientific inquiry.

**Result:**

3.6.1. Rebound Hammer Test Result

3.6.1Ultra Sonic pulse velocity Results

Load Test Results

Deflection Test Results

**Strengthening techniques Results**

**Fire-Induced Damage Mechanisms:**

Fire damage can escalate quickly, with temperature playing a crucial role in determining its severity. Up to 700°C (1292°F), the damage can range from structural weakening of materials like wood, weakening of metals, and potential ignition of flammable materials like paper or fabric. At this temperature, plastics and synthetic materials can melt, releasing toxic fumes. Heat can also cause expansion, leading to structural deformations and compromising integrity. Additionally, electronics may malfunction or be destroyed at these temperatures. Overall, the effects depend on factors like duration of exposure, proximity to the source, and the materials involved.

**Strengthening Techniques:**

Strengthening techniques for glass fiber reinforced polymer (GFRP) typically involve optimizing the fiber orientation, adding additional layers, using hybrid composites, or incorporating nanoparticles for enhanced mechanical properties.

**Temperature Specimen Four (TS4 Fired At 600°c):**

Exposing a spaceman to a temperature of 600°C would indeed lead to catastrophic effects:

Instantaneous Burns: Contact with surfaces at 600°C would cause immediate and severe burns to the spaceman's skin and any exposed tissues, resulting in extensive tissue damage and potential ignition of clothing or equipment.

Rapid Thermal Decomposition: At such extreme temperatures, materials composing the spacesuit and equipment would rapidly decompose, leading to structural failure and rendering them ineffective in protecting the spaceman from the harsh environment of space. Organ Failure: The intense heat would induce shock and trauma to the body, leading to rapid organ failure as the body's physiological systems struggle to cope with the extreme conditions.

Complete Dehydration: The spaceman would experience rapid and severe dehydration due to intense sweating and fluid loss, leading to electrolyte imbalances and exacerbating the risk of heat-related illnesses .Severe Respiratory Damage: Inhaling air at 600°C would cause immediate and severe damage to the respiratory system, leading to respiratory distress, lung damage, and potentially suffocation .Loss of Consciousness: The combination of extreme heat and physiological stress would likely result in rapid loss of consciousness, leaving the spaceman incapacitated and unable to take any protective measures .Immediate Fatality: Without immediate rescue and medical intervention, exposure to 600°C temperatures would inevitably result in fatal injuries and irreversible damage to the spaceman's body, leading to death within moments of exposure. In summary, exposure to temperatures as high as 600°C would lead to catastrophic and survivable consequences for a spaceman, causing severe burns, organ failure, equipment breakdown, and ultimately, death.

A blue box with a red light inside

Description automatically generated

**Fired Process on Beam At (600°)**

A close up of a stone

Description automatically generated

**Temperature Specimen Four**

**4.1.6 Temperature Specimen Five (TS5 Fired At 700°c):**

Exposing a spaceman to a temperature of 700°C would undoubtedly result in catastrophic effects Immediate and Severe Burns: Contact with surfaces at 700°C would cause instantaneous and severe burns to the spaceman's skin and any exposed tissues, leading to extensive tissue damage and potential ignition of clothing or equipment. Rapid and Complete Equipment Failure: The extreme heat would cause rapid decomposition and melting of the spacesuit and equipment, rendering them ineffective in protecting the spaceman from the harsh conditions of space.

Organ Destruction: The intense heat would induce shock and trauma to the body, resulting in rapid and catastrophic organ failure as the body's systems are overwhelmed by the extreme temperatures. Extreme Dehydration: The spaceman would experience rapid and severe dehydration due to intense sweating and fluid loss, leading to electrolyte imbalances and exacerbating the risk of heat-related illnesses.

Severe Respiratory Damage: Inhaling air at 700°C would cause immediate and severe damage to the respiratory system, resulting in respiratory distress, lung damage,

A concrete surface with white chalk writing

Description automatically generated

**Temperature Specimen five**

**3.6 TEST ON FIRED BEAM BY USING OF (UTM):**

**3.6.1 Arrangement Of Two Point Loading:**

**Diagram of a beam

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**6.1. Two Point Loading**

**Prepare the sample:** Ensure the sample is properly prepared and positioned on the testing machine's bed or fixture. The sample should be aligned with the machine's axis and securely held in place to prevent movement during testing**.**

**Set the distance:** Determine the distance between the two point loads based on the specifications of your testing procedure or the properties you want to measure. This distance will vary depending on factors such as sample size, material properties, and

**load points:** Adjust the grips or fixtures of the testing machine to position the two point loads at the specified distance apart along the length of the sample. Ensure that the loads are applied symmetrically to avoid introducing any bending or twisting forces that could affect the test results.

**Calibrate the machine:** Before applying any loads, calibrate the testing machine to ensure accurate measurement and control of the applied forces. This may involve zeroing the load cell, verifying the displacement measurement system, and checking the alignment of the load points.

**Apply the loads:** Once the machine is calibrated and the sample is properly positioned, gradually apply the desired loads to the sample using the testing machine's controls. Monitor the applied force and any resulting deformation or displacement of the sample throughout the testing process.

**Record data:** During the test, record relevant data such as applied force, deformation, and any other parameters specified by your testing procedure. This data will be used to analmechanical properties and performance.

**Evaluate results:** After completing the test, analyze the recorded data to evaluate the sample's response to the applied loads. This may involve calculating mechanical properties such as tensile strength, elastic modulus, or fracture toughness, depending on the nature of the test.

**Results & Discussion:**

**4.2.1 Rebound Hammer Test Result :**

When a concrete beam is exposed to fire, it can undergo changes in its material properties, particularly affecting its strength and durability. The rebound hammer test is a common method used to assess the strength of concrete. Here's how the rebound hammer test might be applied after a concrete beam has been exposed to fire:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| REBOUND NO |  |  |  |  |  |
| Location-1 | Location-2 | Location-3 | Average | Compressive strength |  |
| 14 | 12 | 13 | 13 | 8 | fair |
| 12 | 13 | 9 | 11.33 | 5 | fair |

**Graph result:**

**Rebound Hammer graph**

**Ultra Sonic Pulse Velocity Test Result :**

When an RCC (Reinforced Concrete) beam is exposed to fire, its properties can be significantly altered, particularly in terms of its strength and integrity. Ultrasonic pulse velocity (UPV) testing after exposure to fire can provide valuable insights into the condition of the beam. Here's how the test results might be interpreted

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SPECUMEANS | TEMP | INDIRECT | SEMI DIRECT | DIRECT | (DIRECT) TIME Sec | pulse velocity | compression strength |
| TS4 | 600 | 1409m/sec | 544m/sec | 177m/sec | 26.3 | 3.8 | 25 |
| TS5 | 700 | 832m/sec | 438m/sec | 168m/sec | 25.1 | 3.98 | 30 |

**Temperature comparision**

|  |  |
| --- | --- |
| SPECUMEANS | max defl mm |
| TS4 (600) | 1.5 |
| TS5 (700) | 3.72 |

**Strengthening comparision**

|  |  |  |
| --- | --- | --- |
| SPECUMEANS | max defl mm |  |
| STR-0 (600) | 1.5 |  |
| STR-1 (600) | 0.9 | GFRP wrapping at bottom face only |
| STR-2 (600) | 0.8 | GFRP wrapping at three face |

|  |  |  |
| --- | --- | --- |
| SPECUMEANS | Failure Load KN |  |
| STR-0 (600) | 69.4 |  |
| STR-1 (600) | 81.9 | GFRP wrapping at bottom face only |
| STR-2 (600) | 95.7 | GFRP wrapping at three face |

**5.3 DISCUSSION**

From the result and tests performed earlier, it is clear that the treated sewage waste water and industrial treated water can be used to prepare cement mortar as the impurities are under permissible limits according to the tests. It was observed that under normal conditions this water gives comparatively the same compressive strength hence it is economical to use the treated sewage waste water and industrial treated waste water for curing and preparing cement mortar. On the other hand, while testing the performance of the same water for the preparation of cement concrete. The result obtained was more than normal water. Thus, the treated sewage water and industrial treated waste water can also be used for the preparation of cement concrete. So, it is clear that the treated wastewater can be used for construction works and thus, the commercial use of treated sewage water and industrial treated waste water will encourage many more industries to install more sewage treatment plants resulting in the reuse of water. The idea of sustainable development can be achieved by the use of treated sewage water and industrial treated waste water

1. **CONCLUSION**

From the research carried out to use of treated waste water and potable water in concrete construction, following conclusion are made:

* Impurities present in treated waste water from domestic treatment plant and industrial treated water having almost nearby same and hence, we can say that it is in within permissible range.
* The compressive strength of cement cube casted by potable water for 7-day, 14 day, 28 days of M20 grade of concrete is 17.77 N/mm², 20.77 N/mm² & 22.53 N/mm²and for M25 grade of concrete is 18.25N/mm², 22.05 N/mm² & 25.95 N/mm²

The compressive strength of cement cube casted by domestic treated water for 7 day, 14 day, 28 days of M20 grade of concrete is 14.45 N/mm², 17.55 N/mm² & 21.23 N/mm² and for M25 grade of concrete is 15.56 N/mm². 22.76 N/mm² & 25.01 N/mm²

The compressive strength of cement cube casted by industrial treated water for 7 day, 14 day, 28 days of M20 grade of concrete is 13.95 N/mm², 16.74 N/mm²& 20.93 N/mm² and for M25 grade of concrete is 20.85 N/mm² 22.5 N/mm² & 24.95 N/mm²

* After studying effect of treated water on concrete property it is observed that we can use treated water in plain cement concrete in nearby construction of treatment plant to achieve economy and it help for sustainable development.

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