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Investigation on Effects and Properties of Concrete Structure after Exposed to Fire

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***Abstract:** The integrity and strength of the materials used in reinforced concrete structures are highly influenced by their exposure environment. Exposing the building materials to high temperature changes their performance. The change in the performance is a result of the change in the material properties. When subjecting a building material to fire, the occurring damage depends on the severity of the fire in terms ofthe fire temperature and time of exposure.*

This study investigates the effects of fireexposure on the set of RC beams. Through controlled experiments, varyingtemperatures from 300^{0}C to 700^{0}C areapplied to RC beams, analyzing changes in compressive strength, spalling, andmicrostructure by using rebound hammer, UPV meter and applying two-point loading in UTM. Results indicate a significantreduction in compressive strength with increasing fire temperature, attributed to thermal degradation of cement paste and aggregate. Additionally, changes inmicrostructure, such as pore structure alterations and formation of cracks, are observed. Also, few of RC beams were strengthened using GFRP sheets as a U- shaped wrapping to entire beam and U- shaped wrapping at certain intervals. The strengthened specimens are again tested in UTM for two-point loading, the results of the tests showed the feasibility of rehabilitating RC beams exposed to fire using GFRP plates.U-shaped wrapping to entire beam showed the good performance.

***Keywords:** concrete, compressive strength, high temperature, fire temperature, residual strength, heat accumulation factor.*

I. INTRODUCTION

Reinforced Concrete (RCC) structures serveas the backbone of modern infrastructure, providing strength, durability, and stability. However, when exposed to fire, these structures face significant challenges that cancompromise their 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 behaviour. High temperatures during a fire can led to thedeterioration 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 RCCbeams. Fiber-Reinforced Polymer (FRP)composites have emerged as a popular choice due to their high strength-to-weight ratio, corrosion resistance, and ease ofapplication. Studies have shown thatexternally bonded FRP sheets or wraps can effectively restore the flexural and shear capacities of fire-damaged beams, providingan 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.

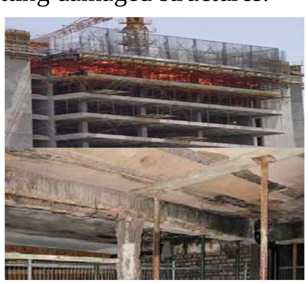
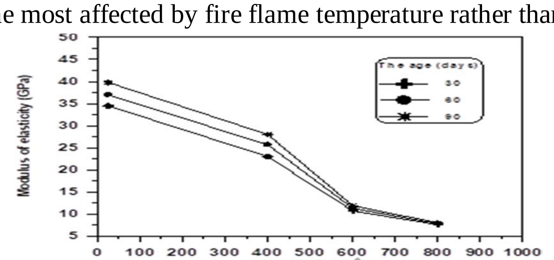


Fig no. 1 Fire Damage Beam

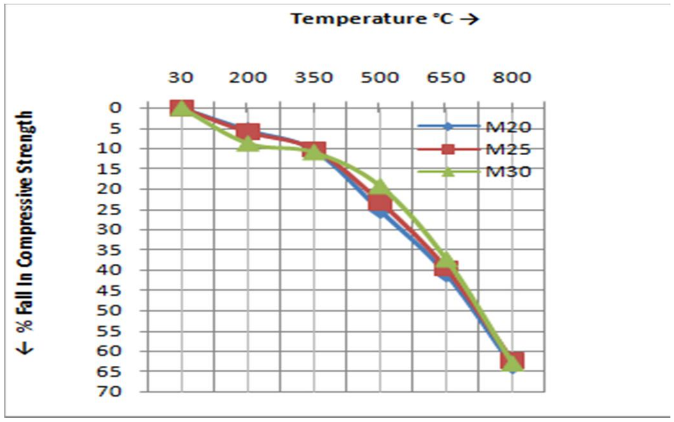
II. LITERATURE REVIEW

1) 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 fora considerable period of time. Therefore,this study was carried out to generateexperimental 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 hightemperatures by furnace in which rate ofheating 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 andagain 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 withrepair materials 1 and 2. Thereafter, thesetest specimens were tested by NDTfollowed by flexure test. The load deflection behaviour of RC beams repaired with repair material 1 and 2 have been studied and presented.
2) E. Bhargayi, N. Girl Bahu and V. Sowjana vani Generally during fire accidents in buildings, columnsand beamsare exposed to fire and these structures are expected to perform well during such extreme conditions. This shows the importance of the study of concretestructures 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 this objective previous investigations done by various researchers are summarized.
3) 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 concludedthat size effect is more pronounced in specimens exhibiting brittle mode offailure.
4) Mohammed Mansour Kadhum et.al In this paper, the authors discussed a study in which some mechanical properties and deflection behavior of rectangularreinforced 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 specimensand 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 of 2.0 hours. Authors found that,

- The residual compressive strengthranged 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.

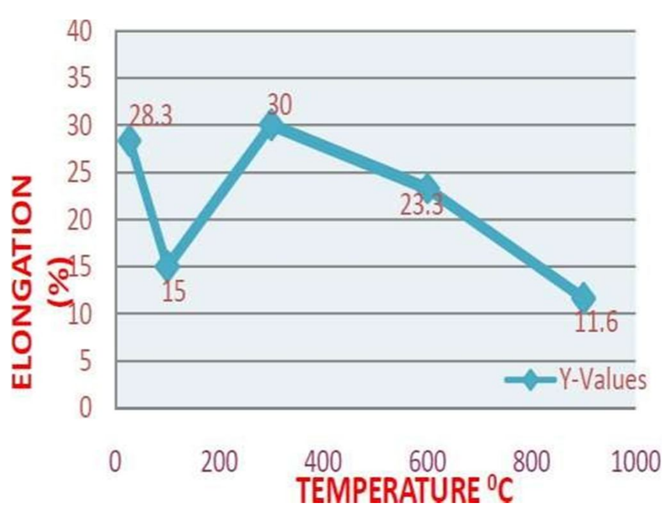


5) Ashok R. Mundhada, Arun D. Phophale et.al In this paper the author studied the effect of high temperatures on compressive strength of concrete. 90concrete cubes of 150 mm size divided equally over three different grades of design mix concrete viz. M 30, M 25 & M20 were cast. After 28 days' curing & 24 hours' air drying, the cubes were subjected to different temperatures in the range of 200°C to 800°C, for two differentexposure times viz. 1 hour & 2 hours in anelectric 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. Theconclusions of the test were,



6) **Dattatreya, B. Balkrishna Barathea** In this paper the author did research work on studying the impact of fire on reinforcement provided in R.C.C structuresof various types of buildings which areunder blast or fire. The Behavior of Steel Reinforcement at various elevatedtemperatures from 100° C to 1000°C wasstudied. The specimens for testing wereTMT bars of 12mm diameter. 20 bars werecut to 30 cm size. Then the specimens weretested for mechanical properties using UTMbefore heating at normal room temperatureand the properties were tabulated. 10specimens each were heated in theelectric furnace at 100°, 300°, 600°, 900°C and 1000°C for an hour without anyinterference. After heating, out of 10 specimens for each temperature 5 sampleswere quenched in cold water for rapidcooling and the other 5 were kept aside fornormal cooling at atmospheric temperature.These specimens later were tested formechanical properties with UTM. Theauthors concluded that,

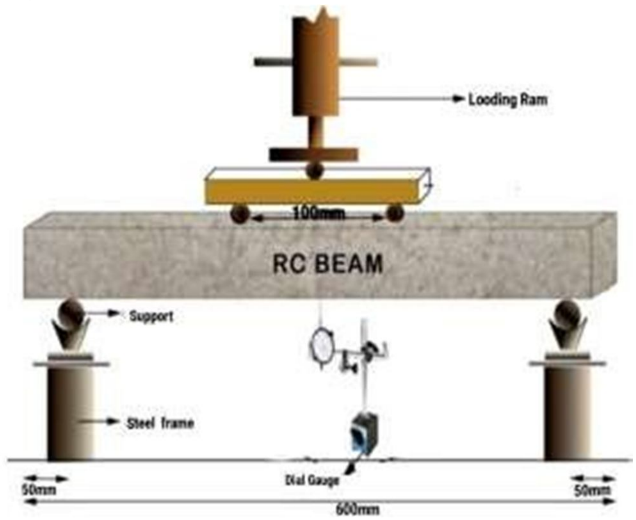
- Ductility of quickly cooled reinforced bars after heating to high temperature of1000°C decreased which could bedangerous for a structure.
- Significant change in ductility was observed at high temperatures & near ultimate load.
- A major problem caused by high temperatures was the spelling of concrete i.e. separation of concrete mass from concrete element which resulted in the exposure of steel reinforcement directly to high temperatures.
- If the duration and the intensity of fire are higher, the load bearing decreases to the extent of the applied load resulting in collapse of structure.



III. METHODOLOGY

A. *Test on Fired Beam by usingof (UTM)*

1) *Arrangement Of Two Point Loading*



4.1 Two Point Loading

- Prepare the sample: Ensure the sampleis 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 placeto 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 testing standards.
- Position the 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 analyze the sample's mechanical 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 thetest.

2) *Apply Load On (RS1)*

Apply Load On (RS1)

3) Apply Load On (RS2)

Apply Load On (RS2)

4) Apply Load On (RS3)

Apply Load On (RS3)

5) Testing On beam Expose To Fire

Reference Specimen One (RS1)

This Reference specimen is use as reference point of view. This Reference specimen compare with the fired beam. Remaining beam are fire provided is different by using muffle Furnace after the testing of that beam all results compare RS1.

4.1.1 Reference Specimen one

B. Temperature Specimen One (TS1Fired At 300°c):

Exposing a specimen to a temperature of300°C would likely have severeconsequences, including heat stroke, burns, and damage to equipment. Spacesuits are designed to withstand extreme temperatures, but 300°C is beyond their operational limits. Elevated temperatures cause severe damage to reinforced concrete (RC) structures, such as RC beams. RC beams have been reportedto lose strength and stiffness with relatively large permanent deformations because of exposure to high temperature.

Damage to Equipment: The extreme heatcould also damage the spaceman's equipment, including their spacesuit,electronics, and any other gear they are carrying. Components may melt or malfunction, compromising the spaceman's ability to function safely in space.

Temperature Specimen One

1) Temperature Specimen two (TS2 Fired At 400°c)

In a muffle furnace, setting the temperature to 400 degrees Celsius means that the furnacewill generate heat up to that temperature. It'simportant to ensure that the furnace is properly calibrated and that you follow safetyprotocols when operating it at such high temperatures.

Immediate Thermal Burns: At 400°C, the spaceman's skin and any exposed tissues would suffer rapid and extensive thermal burns upon contact with surfaces at this temperature. These burns would penetrate deep into the skin layers, causing significant tissue damage.

Heat Shock: The rapid increase in temperaturecould induce heat shock, a condition where the body's thermoregulatory mechanisms fail to cope with the extreme heat, leading to physiological stress and potential organ damage. Equipment Failure: The spaceman's spacesuit and any equipment they are carryingwould likely malfunction or even melt at suchhigh temperatures, compromising their abilityto survive and operate effectively in space. Dehydration and Electrolyte Imbalance: The intense heat would lead to rapid dehydration and electrolyte imbalance in the spaceman's body, increasing the risk of heat-related illnesses such as heat exhaustion and heatstroke.

Respiratory Distress: Inhaling air at 400°C would cause severe damage to the respiratorysystem, potentially leading to respiratory distress, lung damage, and difficulty breathing.

Loss of Consciousness: The extreme heat andphysiological stress could lead to loss of consciousness, further exacerbating the spaceman's vulnerability in the hostile space environment.Fatal Outcome: Without immediate intervention and rescue, exposure to 400°C temperatures would likely result in fatal injuries and irreversible damage to the spaceman's body.

In summary, exposure to temperatures as highas 400°C would pose an existential threat to the spaceman, causing severe thermal burns, organ damage, equipment failure, andultimately, death withoutprompt intervention.

Temperature Specimen Two

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2) Temperature Specimen three (TS3Fired At 500°c)

Exposing a spaceman to a temperature of500°C would lead to catastrophic effects: Instantaneous Burns: Contact with surfaces at 500°C would cause immediate and severeburns to the spaceman's skin and any exposedtissues, resulting in extensive tissue damageand likely ignition of clothing or equipment.

Heat-induced Trauma: The rapid increase intemperature would induce shock and traumato the body's systems, potentially leading to organ failure, especially as the body struggles to regulate its internal temperature.

Equipment Failure: Spacesuits andequipment would quickly degrade and melt at such extreme temperatures, rendering them useless and leaving the spaceman vulnerable to the harsh conditions of space. Rapid Dehydration: The intense heat would cause rapid dehydration as the body loses fluids through sweating, leading to electrolyte imbalances and increasing the risk of heat-related illnesses. Respiratory Damage: Inhaling air at 500°C would cause severe damage to the respiratory system, potentially resulting in respiratory distress, lung damage, and difficulty breathing. Loss of Consciousness: The combination of extreme heat and physiological stress wouldlikely lead to loss of consciousness, further exacerbating the spaceman's perilous situation. Immediate Fatality: Without immediate rescue and medical intervention, exposure to 500°C temperatures would almost certainly result in fatal injuries and irreversible damage to the spaceman's body.

In essence, exposure to temperatures as high as 500°C would be utterly catastrophic for a spaceman, causing severe burns, organ damage, equipment failure, and ultimately, death within moments of exposure.

Temperature Specimen Three

(a) Fired Process on Beam At (500◌°)

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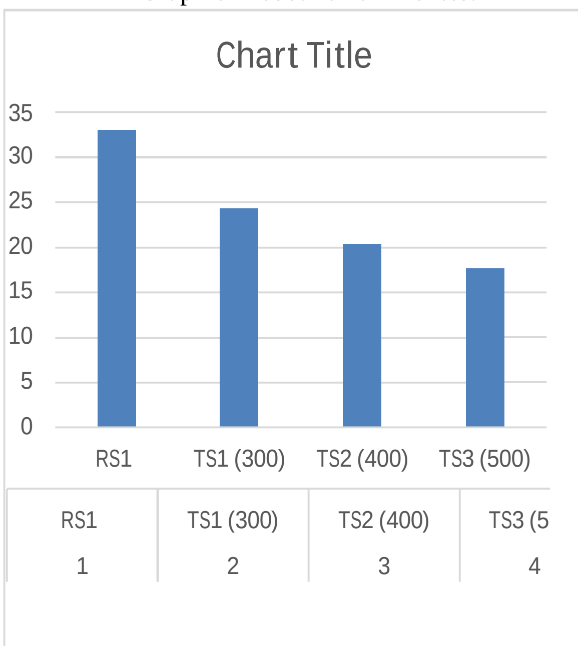
C. Result and Discussion

Rebound Hammer Test Result

REBOUND NO					
Location-1	Location-2	Location-3	Average	Compressive strength	
36	32	31	33	25	Good
24	26	23	24.33333333	19.05	Fair
20	21	20	20.33333333	15.05	Fair

Graph of Rebound hammer test



Ultra Sonic Pulse Velocity TestResult of Ultra Sonic pulse

	TEMPRATURE COMPARISION					
	UITRASONIC VELOCITY TEST					
SR	SPECUMEANS	TEMP	INDIRECT	SEMI DIRECT	DIRECT	(DIRECT) TIME Sec
1	RS1	0	6329m/sec	6157m/sec	1136m/sec	27.01
2	TS1	300	3267m/sec	4789m/sec	818m/sec	29
3	TS2	400	3274m/sec	4052m/sec	9677m/sec	32.02
4	TS3	500	108.6m/sec	802.3m/sec	187.2m/sec	34.8

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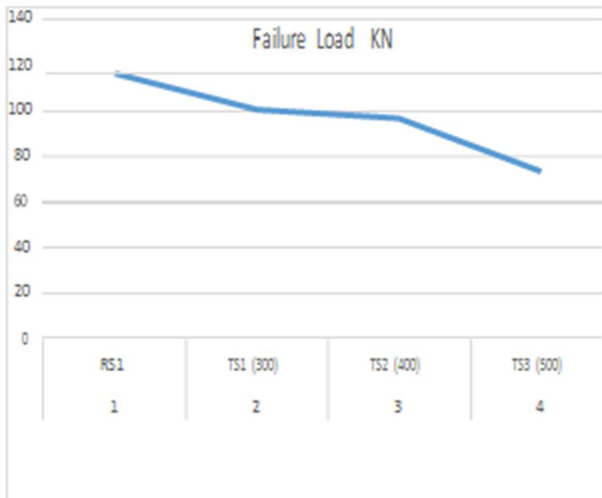
Pulse Velocity (km/second)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

Result of Ultra Sonic pulse

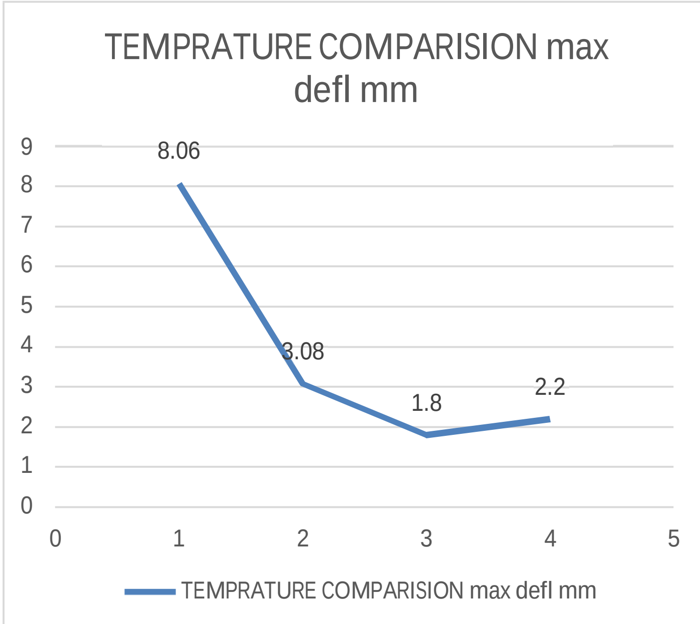
Graph of Ultra sonic Pulse velocity test



Load Test Result

	TEMPRATURE COMPARISION	
Sr. No.	SPECUMEANS	Failure Load KN
1	RS1	116.4
2	TS1 (300)	100.5
3	TS2 (400)	96.64
4	TS3 (500)	73.5

Graph Result



Deflection Graph Result

Strengthening Result

	STRENGTHENING COMPARISION				
SR	SPECUMEANS	max defl mm			
1	STR-0 (600)	1.5			
2	STR-1 (600)	0.9	GFRP wrapping at bottom face only		
3	STR-2 (600)	0.8	GFRP wrapping at three face		
SR	SPECUMEANS	Failure Load KN			
1	STR-0 (600)	69.4			
2	STR-1 (600)	81.9	GFRP wrapping at bottom face only		
3	STR-2 (600)	95.7	GFRP wrapping at three face		

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Deflection Test Result

	TEMPRATURE COMPARISION	
SR	SPECUMEANS	max defl mm
1	RS1	8.06
2	TS1 (300)	3.08
3	TS2 (400)	1.8
4	TS3 (500)	2.2

IV. CONCLUSION

1) From the performance of above test on the beams it concludes that there is no major temperature effect up to 300℃ to 400℃.
2) At 500℃ colour beam changes and thereis no spalling.
3) As a temperature rises at 600℃ minor spalling occur and cracks are form attemperature 700℃, and the colour of beam changes into light brown and majorcracks are found on beams.
4) Rebound number and compressive strength decreases with increase in temperature.
5) Range from 300℃ to 400℃ the compressive strength decreases 20% to 80% with the increase in temperature.
6) Maximum compressive strength decreases 80% at 700℃.
7) The type of concrete observed from UTMtest i.e concrete deteriorate,
8) As compare with the reference beam failure load decreases by 48% at 700℃ as the failure load decreases with increase in temperature.
9) Varying in temperature deflection increases and maximum deflection reduced at 700℃
10) Regarding to strengthening technique U-shape wrapping to entire beam the failureload increases by 37%as compare to U- shape wrapping at intervals.

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