EFFECT OF FIRE ON FLEXURAL STRENGTH OF REINFORCED CONCRETE BEAM

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Abstract

Going vertical is the order of the day. Most of us in metropolitan cities invariably end up living in a high-rise apartment complex. Tier-2 cities too are not far behind, for a significant number of new developments are multi-storey apartment complexes. With habitat becoming increasingly dense, one needs to ask: "Are the high-rise buildings that are the future of the urban landscape equipped to deal with emergencies?" One such emergency is fire, from which no structure, however well-built, is immune. This work also gives an insight in to behavior of RCC structures in fire. The experimentation has been done to find out the effect of fire on flexural strength of reinforced concrete beams. After heating, these specimens were allowed to cool at room temperature & some samples were quenched with water for rapid cooling and then tested for flexural strength. Simultaneously, theoretical investigation of various parameters in relation to fire was carried out.

Index terms *— Reinforced Concrete, Beams, Fire resistance, Flexural strength, Spalling , C25-Beam with clear cover 25mm, C30-Beam with clear cover 30mm*

1. Introduction

We are all aware of the damage that fire can cause in terms of loss of life, homes and livelihoods. A study of 16 industrialized nations (13 in Europe plus the USA, Canada and Japan) found that, in a typical year, the number of people killed by fires was 1 to 2 per 100,000 inhabitants and the total cost of fire damage amounted to 0.2% to 0.3% of GNP. UK statistics suggest that of the half a million fires per annum attended by firefighters, about one third occur in occupied buildings and these result in around 600 fatalities (almost all of which happen in dwellings). The loss of business resulting from fires in commercial and office buildings runs into millions of pounds each year. The extent of such damage depends on a number of factors such as building design and use, structural performance, fire extinguishing devices and evacuation procedures. Although fire safety standards are written with this express purpose, it is understandably the safety of people that assumes the greater importance. Appropriate design and choice of materials is crucial in ensuring fire safe construction. Codes and regulations on fire safety are updated continually, usually as a result of research and development.

Most local and overseas studies on concrete under elevated temperatures have not consider the effects of water quenching during firefighting operations. Though concrete and steel reinforcing bars are non-combustible, both have been shown to degrade in strength during and after exposure to the high temperatures of a fire. However, there appears to be little data available in respect of the effects of water quenching on the fire performance of high strength concrete in a building fire.

The aim of this dissertation was to increase the awareness of the structural engineering field to the concepts behind structural design for fire safety. The development of simplified design tools that predict the fire performance of structural elements is of utmost importance to practicing structural engineers. These tools address structural fire performance from an applied design approach similar to those which exist for the effects of wind and earthquake loads. Extensive research has been published on the performance of structural steel in fire conditions, and simplified design tools already exist to describe its behavior. However, such tools do not exist for reinforced concrete structures where research has been focused on the material properties of concrete in fire conditions rather than structural performance.

2. Experimental Work

The specimens for testing were RCC beams. Forty two RCC beams were cast with similar cross-sectional details, length and grade of concrete and clear cover provided to reinforcement. Six specimens were tested for the Flexural strength using UTM before heating at normal temperature and the result were tabulated. Twelve specimens (6 specimen of 25mm clear cover & 6 specimen of 30mm clear cover) each were heated in the electrical furnace at 550°C for 1 hour and 2 hour respectively without any disturbance. Same procedure was repeated for 12 specimens each for

750°C and 950°C. After heating, specimen were kept aside for normal cooling at atmospheric temperature. Three more samples of clear cover 25mm were heated for 2 hours at 750°C but were quenched with water & rapidly cooled. The beams of size 150x150x700(all dimensions in mm) were kept on the UTM with setup to check for flexural strength. Point load was applied at a constant rate for all the specimens.

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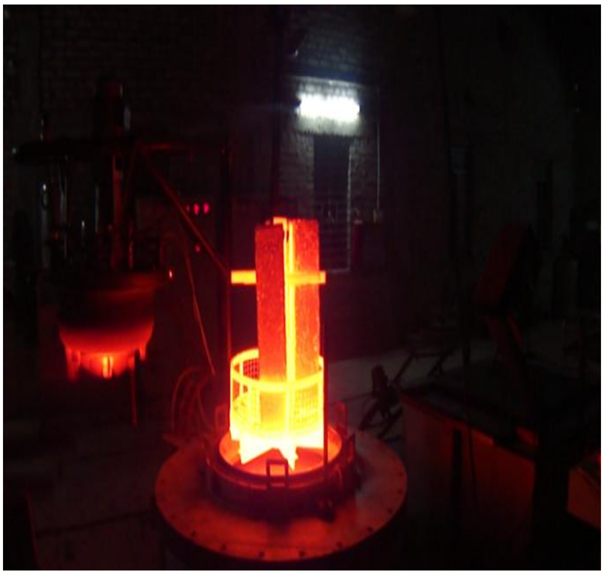

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Őĕ Results & Discussions

Thermogravimetric Analysis (TGA)

Thermo gravimetric analysis consists of finding change in weight of a material with increase in temperature. This plot is called a Thermogram.. This technique allows to find out the temperature range in which a material will remain stable and the temperature at which it would undergo decomposition.

TEMP °C	Identifi-cation of Specimen	Wt. Before Placing in furnace Kg.	Wt. after Placing in furnace Kg.	Percentage Loss %ge
room temp	C25 1hr	41	41	100
room temp	C30 1hr	41.13	41.13	100
room temp	C25 2hr	41	41	100
room temp	C30 2hr	41.13	41.13	100
550	C25 1hr	41	38.56	94.04
550	C30 1hr	41.13	39.06	94.96
550	C25 2hr	41	38.53	93.97
550	C30 2hr	41.13	38.76	94.23
750	C25 1hr	41	38.5	93.90
750	C30 1hr	41.13	38.67	94.01
750	C25 2hr	41	38.4	93.65
750	C30 2hr	41.13	38.6	93.84
950	C25 1hr	41	37.4	91.21
950	C30 1hr	41.13	37.53	91.24
950	C25 2hr	41	36	87.80
950	C30 2hr	41.13	36.33	88.32

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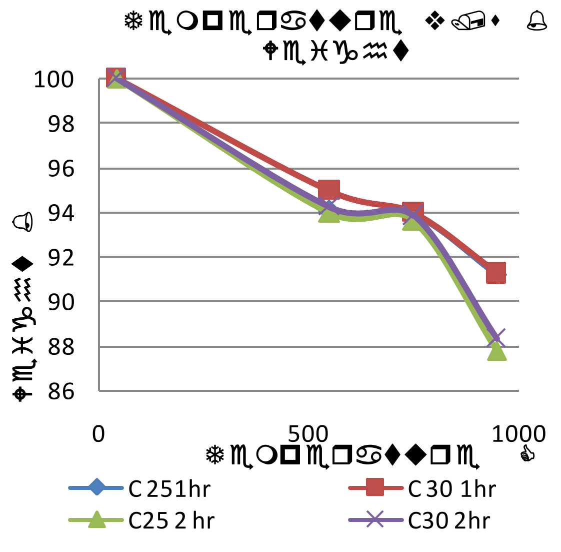
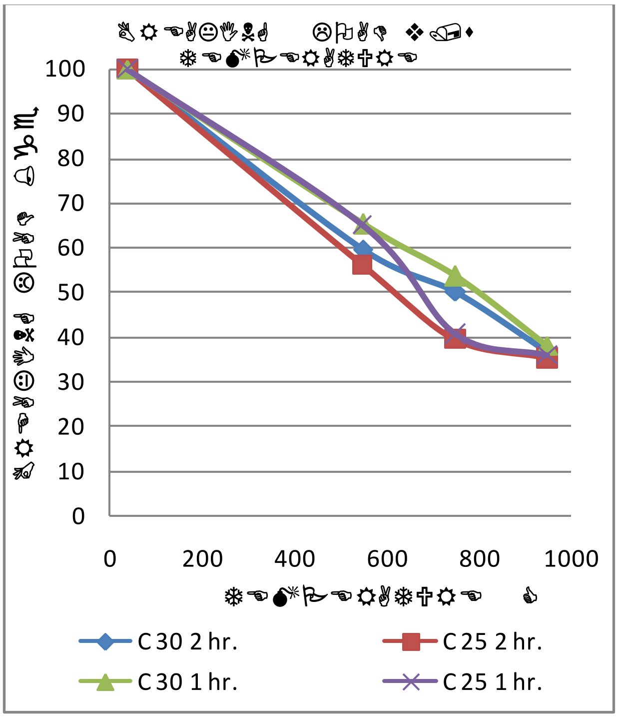


Flexural strength testing on UTM

TEMP °C	1 hour C25 LOAD KN	1hour C30 LOAD KN	2 hour C25 LOAD KN	2 hour C25 LOAD KN
room	69.66	73.66	69.66	73.66
550	45.33	48	39	44
750	28.33	39.5	27.5	36.91
950	25	28	24.5	27.08

Temp.	Percentage decrease in strength			
	1hour C25	1 hour C30	2 hour C25	2hour C30
°C	LOAD	LOAD	LOAD	LOAD
Room Temp.	100	100	100	100
550	65.07	65.16	55.98	59.73
750	40.66	53.62	39.47	50.10
950	35.88	38.01	35.17	36.76



Effects of Water Quenching on Reinforced Concrete Structures under Fire

750°C 2 hours C25	LOAD KN
NORMAL	69.66
w/o QUENCHING	27.5
QUENCHING	31.83

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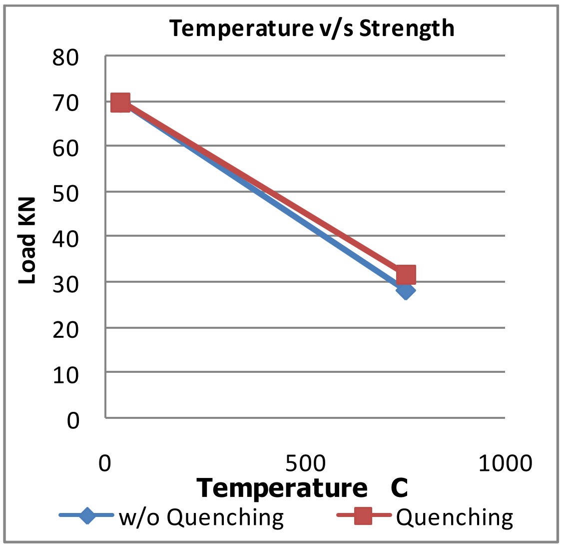

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Simultaneously, theoretical investigation of various parameters in relation to fire will be carried out.

	Room Temp.	550°C	750°C	950°C
Cracks	No	No	Moderate	Major
Color	Normal	Blackish Grey	Whitish Grey with pink spots	Buff (Yellowish)
Spalling	Unaffected	Minor	Localized to corners	All surfaces spalled
Distortion	None	No	Slight but insignific-ant	Severe & signific-ant
Scaling	No	No	No	Yes

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Effect of duration after heating beam at 950°C

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4. Conclusion

Based on the results of this experimental work the following conclusions can be drawn:

High temperature is one of the most important physical deterioration processes that influence the durability of concrete structures and may result in undesirable structural failures.

When exposed to high temperature, the physical structure of the Reinforced concrete beams change considerably.

The general conclusion is that majority of fire damaged RCC structures are repairable. But the effect of elevated temperature above 900°C on the reinforced concrete beams was observed that there is significant reduction in flexural strength.

The effect of fire on the reinforced concrete beams heated at 750°C cooled rapidly by quenching in water and normally cooled in the atmospheric temperature were studied and it is observed that the strength of rapidly cooled beams is high.

The flexural strength for beams exposed to fire at 550°C & 750°C for 60 and 120 minutes were less than that for the reference beam by about 34.84% and 44.37% respectively. But for 950°C there is significant decrease in flexural strength by about 61.99% and 64.24% respectively.

The reductions in strength for beams exposed to fire with a cover thickness of 25mm & 30mm is almost same at 550°C say 35% less than that for the reference beam ,but 60% and 47% less than that for the reference beam at 750°C and for 950°C it is 64% and 61% respectively.

By heating the reinforced concrete beams, weight loss is negligible say 4% till 750°C but there is a significant weight loss say 12% at 950°C.

Some spalling of concrete was observed in the beam exposed to fire for 2hr at 950°C at the time of removal from furnace, which increased with time under normal weathering conditions.

To sum up, up to 550°C, the weight loss for RCC is negligible & the flexural strength reduces by 1/3rd. No cracking, spalling or scaling is observed up to this stage. The fire affected structure up to this point only requires rapid cooling & repairs. At @ 750°C, there is a further drop in weight & flexural strength, cracks do appear but there is hardly any spalling or scaling. The fire affected structure at this point requires rapid cooling & retrofitting. Factor of safety will come down but the structure will be serviceable. Beyond this stage, all the parameters drop alarmingly. Weight loss at 950°C exceeds 10%, flexural strength comes down by 2/3rd, major cracking, spalling & scaling could be observed. The fire affected portion at this stage may require major retrofitting or replacement & can't be relied

upon. Greater cover & faster cooling provide relief.

5. Future Scope

Due to the paucity of funds, the experimentation had its limitations. To increase the database size, similar dissertation work can be taken up in future for temperatures of 650°C, 850°C & 1050°C. If charts are prepared by combining the two works, they will be more representative in nature & will help in predicting the drop in flexural strength for intermediate temperature values.

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