Study on Behaviour of Reinforcing Bars and Concrete of a RCC Structure Exposed to Fire

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Abstract— In this modern era, most of the buildings all over the world are made up of RCC. The increasing incidents of fire in buildings have increased the importance of assessment; repairs and rehabilitation of such buildings as these buildings are very costly. This field needs special expertise in many areas viz. concrete technology, structural engineering, material testing, and repairs and maintenance etc. A continuous effort through research and development programmes all over the world is being made in this specialized field. This topic gives us immense pleasure as we deal with the real life problems in this research. In this research, we gain the knowledge which is being used as a strategy for the rehabilitation of fire damaged buildings and by conducting proper assessment procedures by non-destructive techniques. In this research, we did various experiments so as to find out the effect of fire on the reinforcing bars in RCC buildings by taking 6 samples at 110°, 310°,610°,900° each for 3 hours. After heating the samples, they are cooled quickly by quenching in water and normally by air cooling. It is seen that there is a change in the mechanical properties of samples which are studied under universal testing machine (UTM) and for close look at reinforcing bars in a fire damaged structure, scanning electron microscope (SEM) is used. From conclusions, it is seen that most of the fire damaged RCC are restorable. The mechanical properties of all common building materials decrease with the elevation of temperature. The behavior of a RCC in fire conditions is governed by properties of constituent materials, concrete and steel at high temperature. Both concrete and steel undergo considerable change in their strength, physical properties, and stiffness by the effects of heating. It is also seen that above 900°C some of these changes are not recoverable after subsequent cooling.

Keywords: Reinforcing Bars, RCC

I. Introduction

In this modern era, most of the buildings all over the world are made up of RCC. The increasing incidents of fire in buildings have increased the importance of assessment; repairs and rehabilitation of such buildings as these buildings are very costly. This field needs special expertise in many areas viz. concrete technology, structural engineering, material testing, and repairs and maintenance etc. A continuous effort through research and development programmes all over the world is being made in this specialized field. As there can be fire in any type of structure but because of this, such type of structures cannot be ignored. For rehabilitation of such type of structures after fire to make them structurally functional, it has given civil engineers a tough challenge. Firstly civil engineers have to find the amount of damage caused to the structure by the fire. The difficulty starts from where to start the rehabilitation work and how to work on such type of structures. It is, therefore, important to build such type of structures that are efficient enough to prevent the loss of life as well as property. Annual statics regarding fire showing loss in residential buildings, offices, industries etc can be used for the development of fire safety design.

As we know that damages due to fire can lead to loss of human life, property and livelihood. As per the World Fire Statistics 2018, a survey of 14 industrialized countries (12 in Europe, USA, Canada and Japan) found that, the human lives lost due to fire in a typical year amounted to about 1.5% to 2.6% per 1,00,000 inhabitants and the total damage of property amounted to 0.3% to 0.4% of Gross National Income (GNI). As per the National Fire Protection Association (NFPA's) statistical data about USA for the year 2017 showed that United States fire departments responded to an estimated 1,219,500 fires in 2017.These fires resulted in 3,350 civilian fire fatalities, 13,670 civilian fire injuries and an estimated $22 billion in direct property loss. Fire Fatalities UK showed that fire deaths in England increased sharply last year. There were 335 fire deaths in England (including 71 at Grenfell). This is the worst year for fire deaths since 2010-2011. Fire-related fatalities in England rose by a quarter between 2016-17 and 2017-18 from 260 to 330.The amount of damage caused by fire in a RCC structure depends on a number of factors such as structural design and performance aspects, firefighting equipments and evacuation plans provided in a building. Fire safety standards like working fire alarms, fire extinguishers, proper ingress and egress, hazardous materials, flammable material storage and maximum occupancy are important for the safety of people in case of fire in a building. They assume greater importance. For the fire safety construction, it is necessary to have proper design and choice of materials. Codes and Regulations on fire safety in buildings should be updated from time to time through conducting proper research and development.

Pietro Croce (2001) developed a method which is illustrated for assessing the fire damage occurred to the RCC buildings. For close look of reinforcing bars in a fire damaged structure is investigated by Wei Lin (2006) by using Scanning Electron Microscope (SEM) and Stereoscopic or Dissecting microscope for concrete by heating it to a temperature of about 950°C to get good visualization of concrete to understand the behaviour of concrete in fire which would have been impossible with the naked eye. Post fire curing effect on the strength and durability recovery was investigated by Chi Sun Poon (2001). M.A.Riley from Sir William Halerow and Partners (1991) has given "Possible new methods for assessment of fire damaged buildings". Assessment of fire damaged structures by using colour image analysis by N.R. Short. The effects of rapid cooling by water quenching on the stiffness properties of fire-damaged concrete was studied by A. Y Nassif of London University in the year 1999.

II. CHANGES DUE TO FIRE IN RCC STRUCTURES.

The various changes which arises due to fire in a RCC structures are given below

Among all fire damaged structures, most of them were repairable and remaining which are not repairable were demolished for their unsafe reason for people.

Most of the structures performed well during and after the fire except few structures.

It gives rise to various problems in a RCC structure like

Damage in structural members.

Excessive loading.

Seismic damage.

Structural cracks

Error in design or construction

Fig1.1: Fire Damaged Slab

Fig 1.2: Concreting of Fire Damaged Slab

III. RESULTS AND DISCUSSIONS:

Following results interpreted from computerized UTM for rapid cooling of specimen by quenching and for normal cooling at atmospheric temperature.

S.no	Temperature in ° C	Applied load (kN)	Ultimate stress (kN/mm^2)	Yield stress (kN/mm^2)	Max. extension (mm)	Elongation (%)	0.3% Proof stress
1	27	67.1	0.585	0.456	1.63	28.3	0.465
2	110	65.8	0.583	0.459	1.65	17	0.451
3	310	65.1	0.581	0.441	1.42	32	0.43
4	610	68.0	0.601	0.443	0.96	25.3	0.446
5	910	79.3	0.698	0.459	0.25	13.6	0.524

Table 4.1: Properties for Rapid Cooing Conditions.

S.no	Temperature in ° C	Applied load (kN)	Ultimate stress (kN/mm^2)	Yield stress (kN/mm^2)	Max. extension (mm)	Elongation (%)	0.3% proof stress
1	27	67.1	0.593	0.456	1.63	27.3	0.465
2	110	65.5	0.578	0.438	1.13	29.2	0.445
3	310	62.7	0.561	0.426	1.12	27.3	0.419
4	610	63.3	0.564	0.474	0.66	26.45	0.439
5	910	64.5	0.575	0.455	0.52	25.6	0.427

Table 4.2: Properties for Ordinary Cooling Conditions.

For rapid cooling conditions from table 4.1:

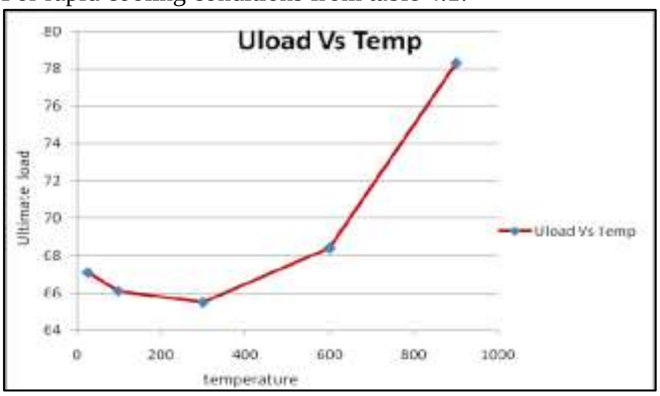

Fig. 4.1: Temperature Vs Ultimate Load

From the graph it can be seen that the ultimate load initially decreases with the increase in temperature up to certain temperature limit and then starts gradually increasing, this happens due to the microstructure of the bar. For high temperatures, the grain size decreases.

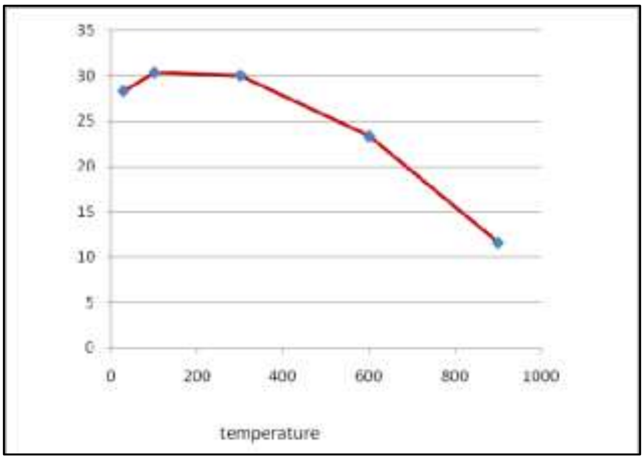

Fig. 4.2: Temperature Vs % Elongation

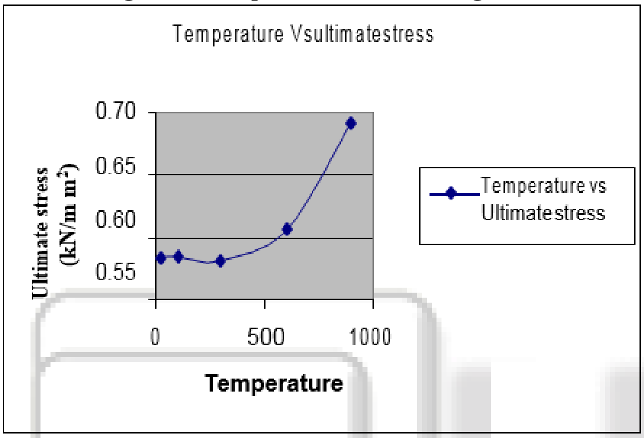

Fig. 4.3: Temperature Vs Ultimate stress

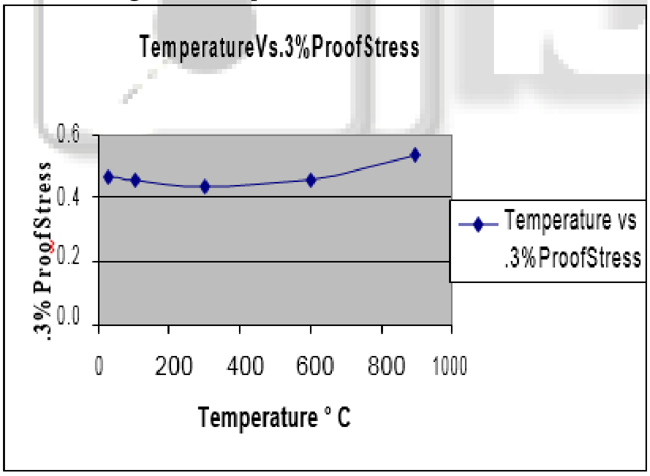

Fig. 4.4: .3% Proof Stress Vs Temperature

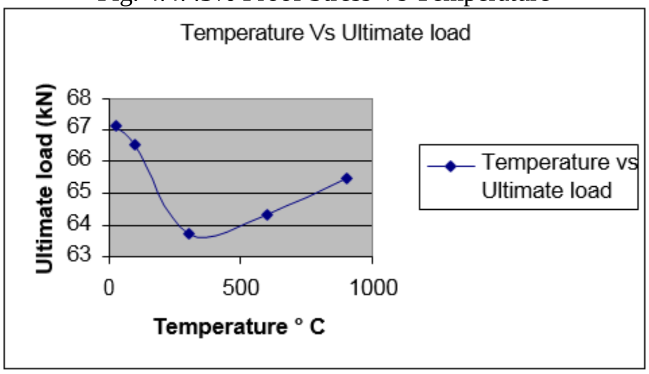

Fig. 4.5: Temperature Vs Ultimate load

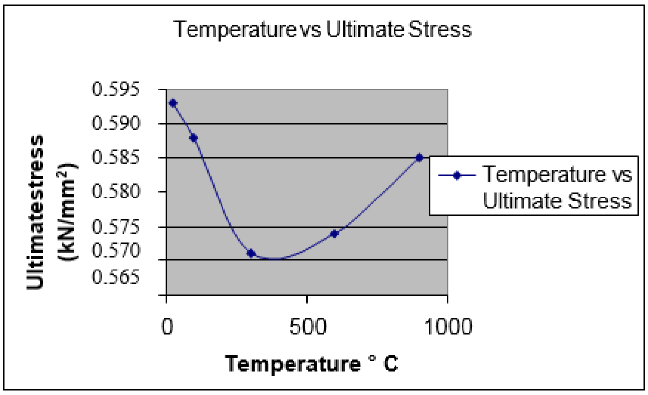

Fig. 4.6: Temperature Vs Ultimate Stress

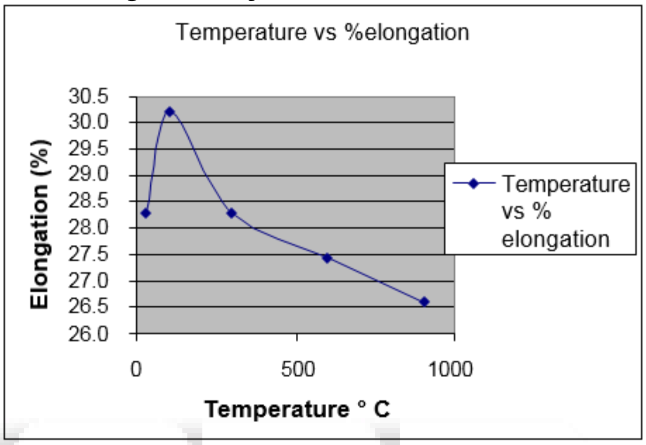

Fig. 4.7: Temperature Vs %Elongation

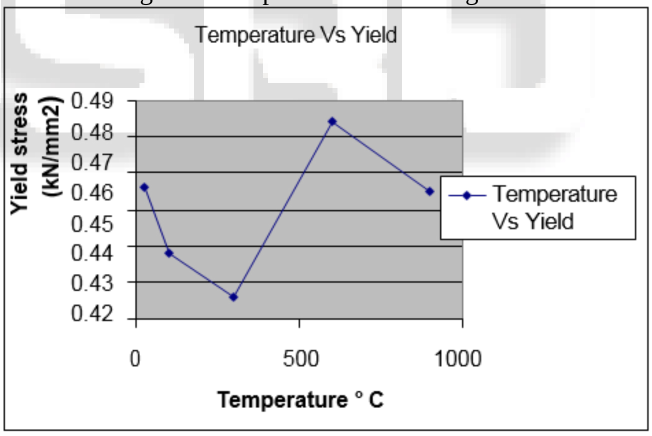

Fig. 4.8: Temperature Vs Yield Stress

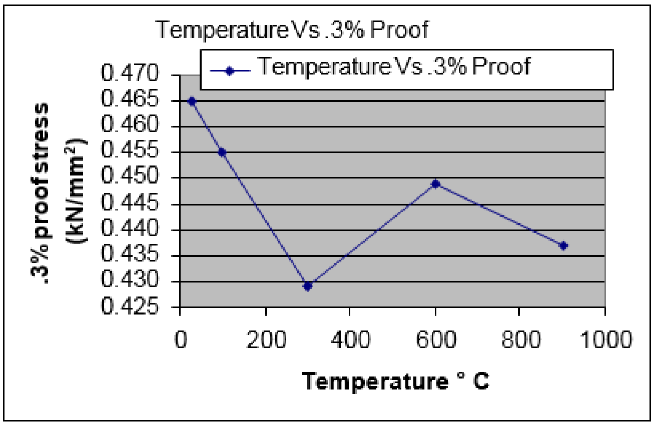

Fig. 4.9: Temperature Vs .3% Proof Stress

Fig. 4.10: Failed specimen

Fig. 4.11: Shear Failure of a Specimen

Fig. 4.12: Specimen failed on UTM.

Fig. 4.13: UTM under working condition.

IV. SEM ANALYSES (MICROSCOPIC STUDY):

Pictures are taken at the magnification of 10 microns and 5 microns.

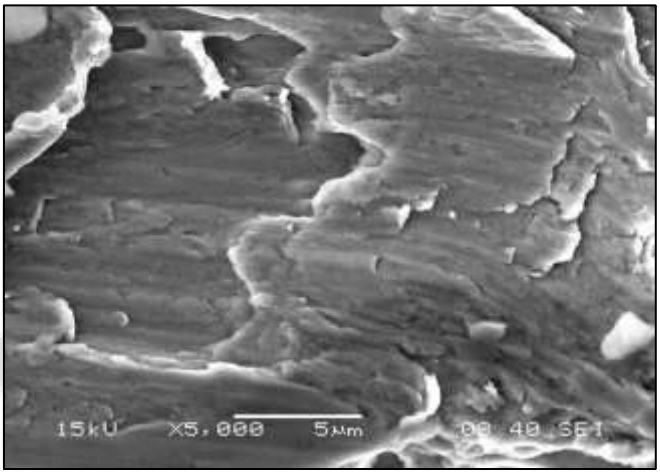

Fig. 4.14: 100° C Ordinary Cooling at Magnification of 5 Microns

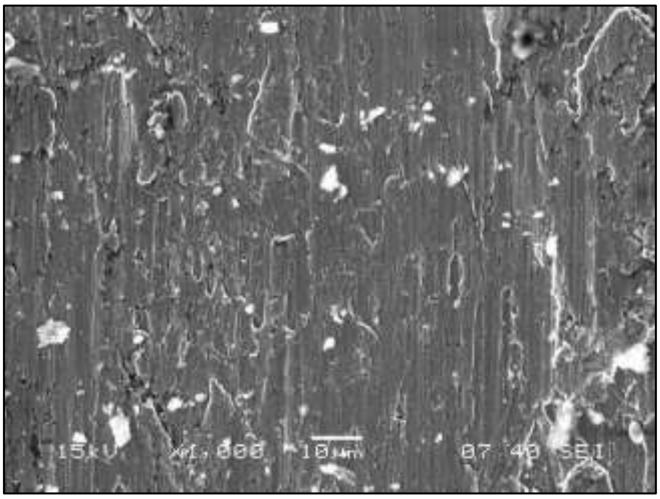

Fig. 4.15: 100° C Ordinary Cooling at Magnification of 10 Microns

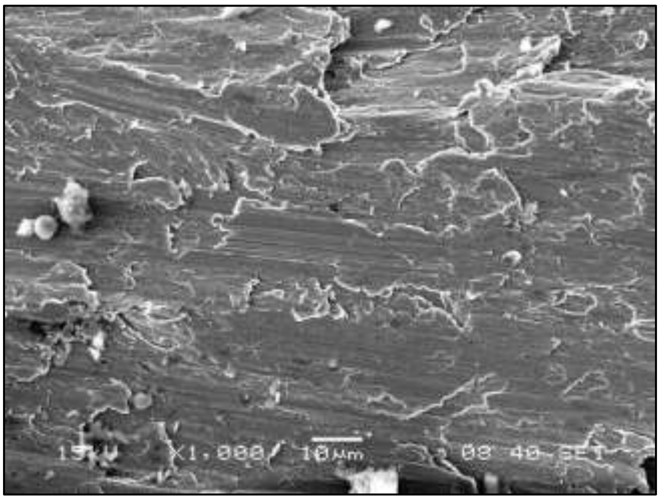

Fig. 4.16: 300° C Ordinary Cooling at Magnification of 10 Microns

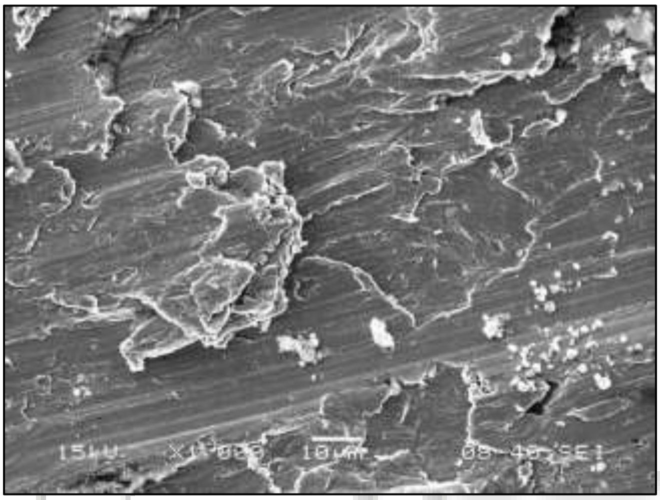

Fig. 4.17: 300° C Rapid Cooling at Magnification of 10 Microns

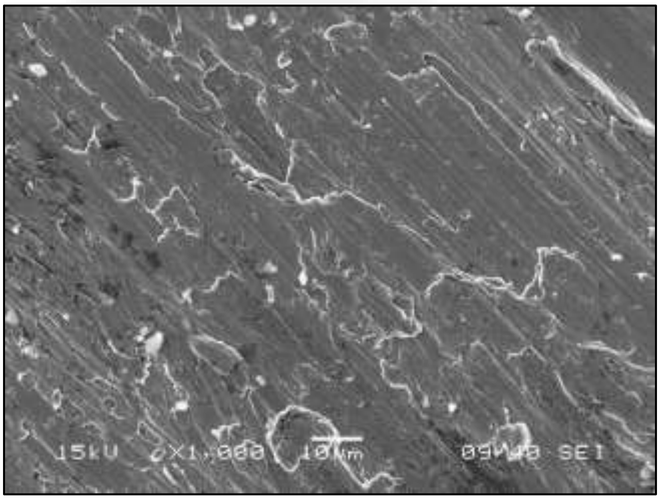

Fig. 4.18: 900° C Ordinary Cooling at Magnification of 10 Micron

V. CONCLUSION

Based on the above study, the following observations are made regarding behavior of reinforcing bars and concrete in a RCC structure when exposed to fire:

– The effect of fire when reinforcing bars and concrete in a RCC structure are exposed to temperatures of 120°C, 320°C,620°C and 920°C when cooled rapidly by quenching in water and normally cooled in atmospheric temperature shows that ductility reduces when rapidly cooled by quenching in water after heating to a temperature of 920°C.
– It is also observed that there is change the mechanical properties of the bars studied by tensile strength testing under UTM shows there in increase in ultimate strength and decrease in percentage elongation of the specimen implies there is significant decrease in ductility of the reinforcing bars.
– By studying the microstructure of the bars by Scanning Electron Microscope (SCM) shows that there is no change in the chemical composition of the microstructure when exposed to high temperatures.

VI. FUTURE SCOPE

Following are the various recommendations for future scope:

– After proper study of the above results, we can modify the properties of the reinforcing bars.
– By proper rehabilitation of structures, we can make the structures suitable for living as it involves less cost in repairing than constructing a new structure.
– By using above results, we can also increase the tensile strength of the structures at the time of manufacture.
– We can build RCC structures fire proof by adopting proper insulating materials.

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