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 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 structures 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* – Scanning Electron Microscope (SEM), Universal Testing Machine (UTM), Mechanical Properties.**

I. INTRODUCTION

As we know 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.

Pietro Croce *at el* [22] 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 *et al*** [8] 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 *et al*** [5]. **M.A.Riley** [4] 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 *et al*** [2]. The effects of rapid cooling by water quenching on the stiffness properties of fire-damaged concrete was studied by **A. Y Nassif *et al*** [13] of London University in the year 1999.

- **CHANGES DUE TO FIRE IN RCC STRUCTURES**

1. Among all fire damaged structures, most of them were repairable and remaining which are not repairable were demolished for their unsafe reason for people.
2. Most of the structures performed well during and after the fire except few structures.

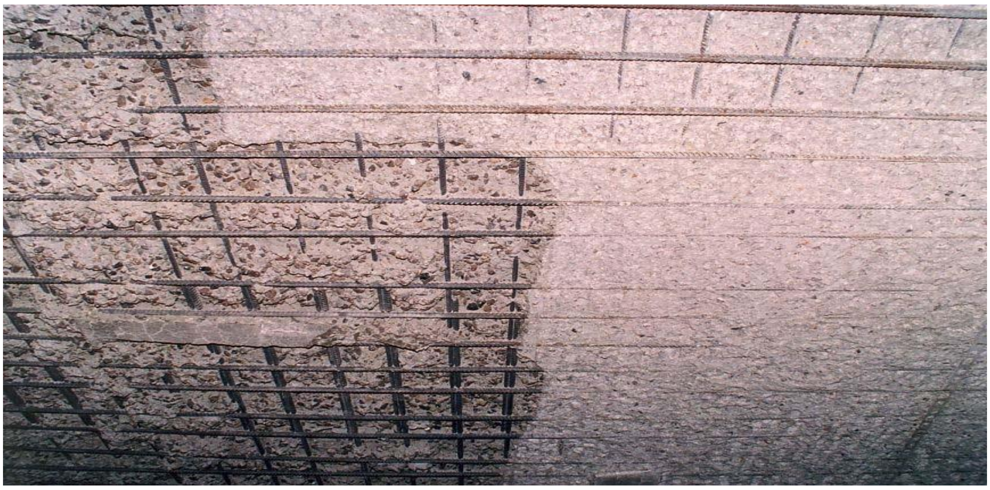

Fig.1 Fire Damaged Slab

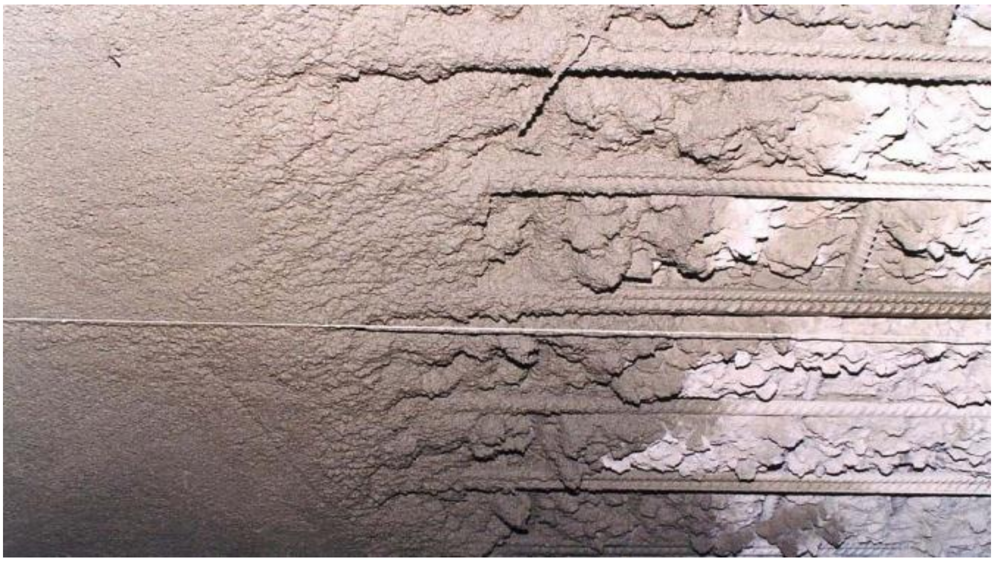

Fig.2 Concreting Of Fire Damaged Slab

II. RESEARCH METHODOLOGY

EQUIPMENTS

- Universal Testing Machine.
- Scanning Electron Microscope.
- Electrical Furnace.

Universal Testing Machine (UTM):

Earlier UTM was known as Tensometer. It is also known as Universal Tester or Material Testing Machine or Material Test Frame. A UTM is a machine used to find the tensile strength and compressive strength of materials. As the 'Universal' suggests that it can be used for many standard tensile tests, compressive tests, pull-out tests, bending tests etc. The various materials to be tested by UTM are concrete, steel, cables, springs, steel wires, steel ropes etc. By using UTM, we can draw stress-strain graph. For that UTM gives the value of load applied vs their respective displacement. From the observed values, a load deflection graph is obtained. X-axis represents displacement and Y-axis represents load applied. From load-deflection graph, we can determine stress-strain relationship, modulus of Elasticity, yield strength of the material.

The PRIMEGOLD TMT bar of 12mm diameter is cut to a length of 45cm and providing a gauge length of 70mm is to be fixed to an UTM and the required data on the computer is provided. Then load is to be applied on the specimen at a rate of 400kg/min for all the specimens. Elongation of the specimen is read with the help of an extensometer fixed to the specimen. The computer notes down the required data of the test. Then by default, a graph of load vs deformation and load vs elongation is shown on the computer screen. After conducting the test, other parameters like maximum extension in mm, area in mm^2, ultimate load, ultimate stress, elongation in percentage, reduction in area, Young's Modulus, yield stress, 0.2% and 0.3% proof stress etc can be observed.

Scanning Electron Microscope (SEM): Scanning Electron Microscope is a type of electron microscope that uses a focused beam of electrons to produce images of a sample. These beams of electrons interact with atoms of sample to produce various signals that inform us about composition and surface topography.

Fig.3 UTM under Working Condition

Fig.4 setup of SEM

Scanning Electron Microscopy has been done by using a Hitachi S-3400 SEM. In this, sample size of specimen up to 100mm in diameter and 60mm in height can be magnified from 4x to 2,50,000x. The materials to be analyzed through SEM can be solid inorganic material including metals and polymers. In most SEM applications, selected area is to be taken of the surface of the sample and data for the same is collected. From the data collected produces a 2D image that shows spatial variations in properties like chemical composition, texture and orientation of materials. SEM can be used for the analysis of selected point locations on the sample. This analysis is very useful especially in qualitatively or semi-quantitatively in determining chemical composition, texture and orientation of material.

Electric Furnace:

The electric furnace is used to heat the specimens. The maximum temperature attained in this furnace is 1000°C. The inner depth of the furnace is 45mm. initially the furnace is heated to the required temperature by switching on it and when the required temperature is attained then 6 specimens put inside with the doo closing tightly so that no air enter inside. The specimens are kept for duration of 1 hour inside the furnace and later 3 specimens are quenched in water for rapid cooling and the other 3 are kept aside for atmospheric time. The 3 specimens which are quenched in water are removed after 15 minutes. Each time 6 bars are kept at temperatures of 100°C, 300°C, 600°C, 900°C and the same is repeated.

Fig.5 Electric Furnace

III. RESULTS AND DISCUSSION

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

TABLE 1: PROPERTIES FOR RAPID COOLING 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	Room tempt 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	0.430
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 2: PROPERTIES FOR ORDINARY COOLING 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

For rapid cooling conditions from table 1:

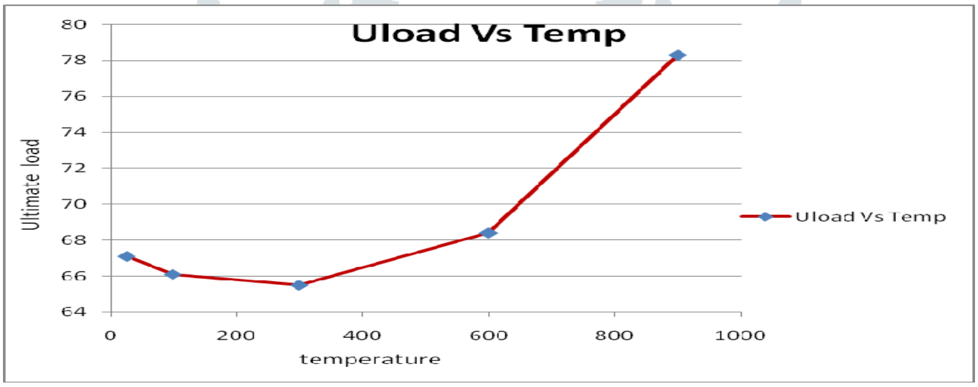

Fig 6: Temperature Vs Ultimate Load

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.

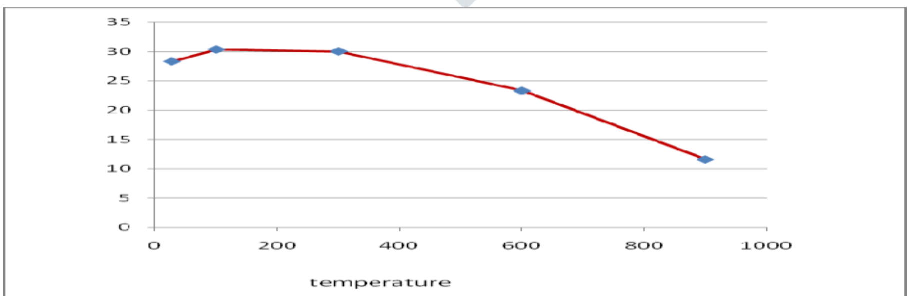

Fig.7: temperature vs % elongation

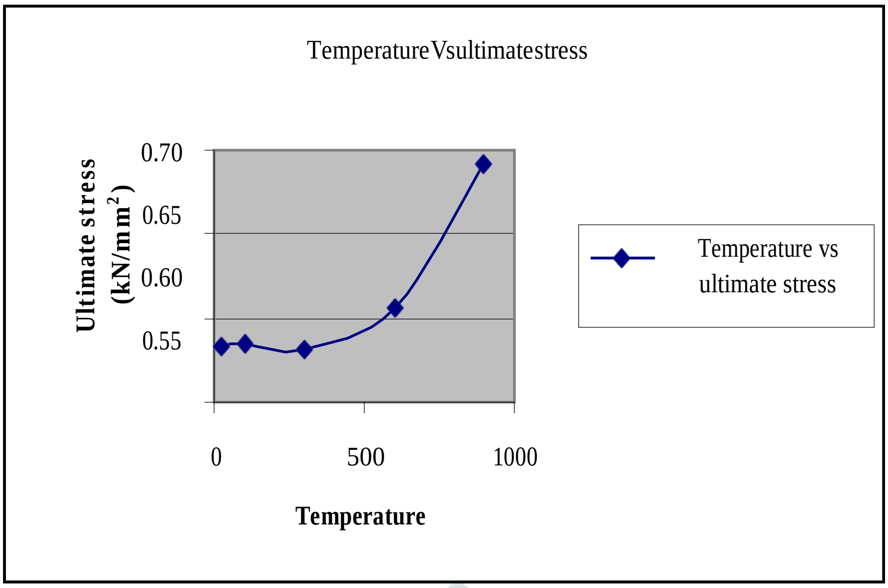

Fig 8: Temperature Vs Ultimate stress

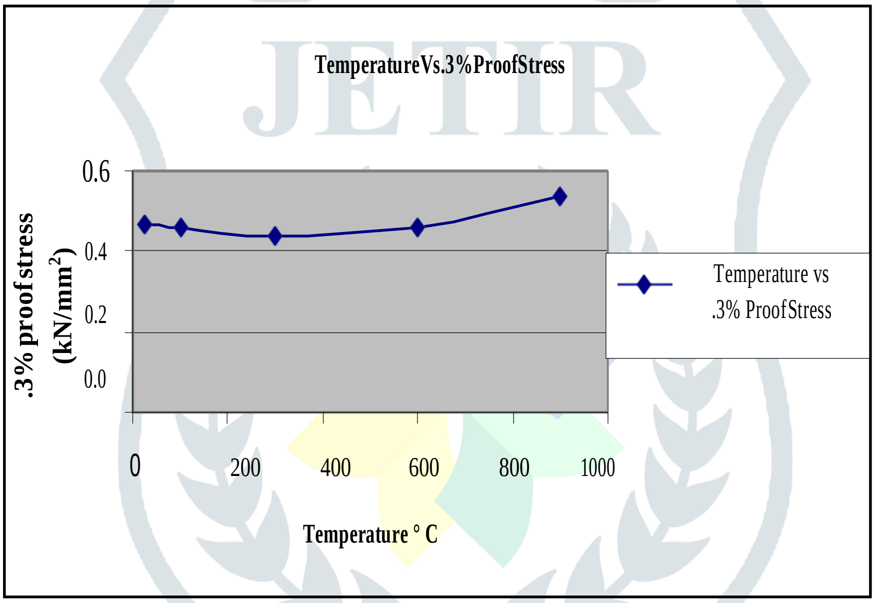

Fig 9: .3% Proof Stress Vs Temperature

For ordinary cooling conditions from table 2:

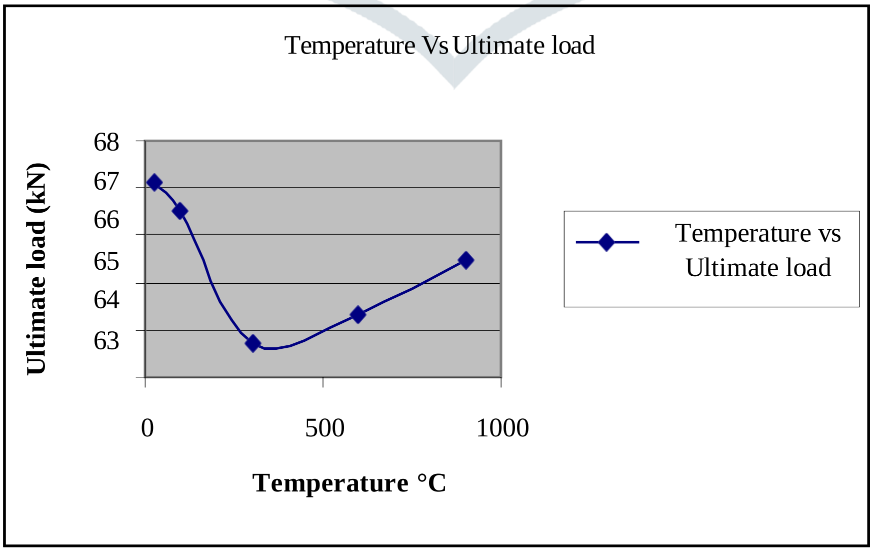

Fig 10: Temperature Vs Ultimate load

From the Fig 4.5, the ultimate load carrying by the specimen was reduced from the specimen before heating

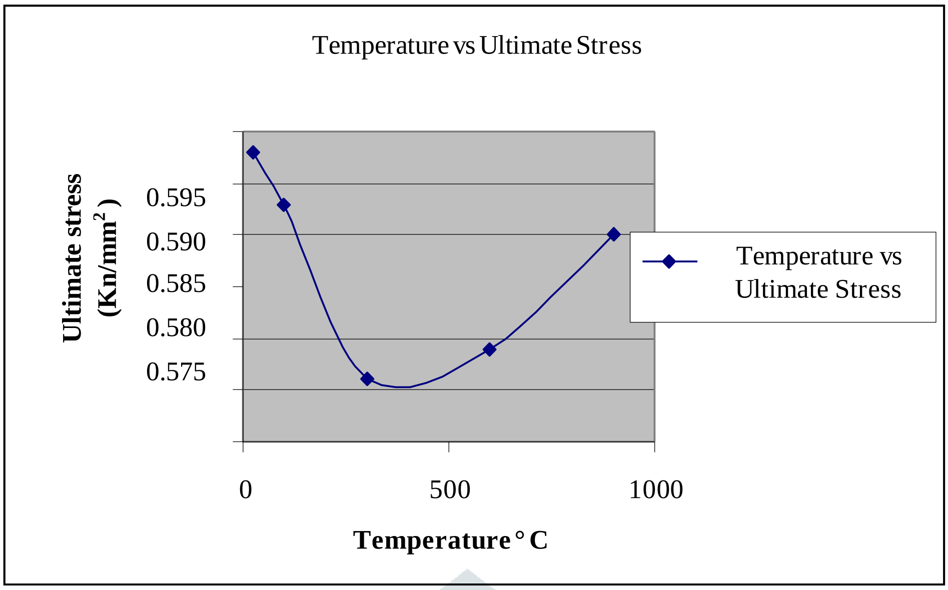

Fig 11: Temperature Vs Ultimate Stress

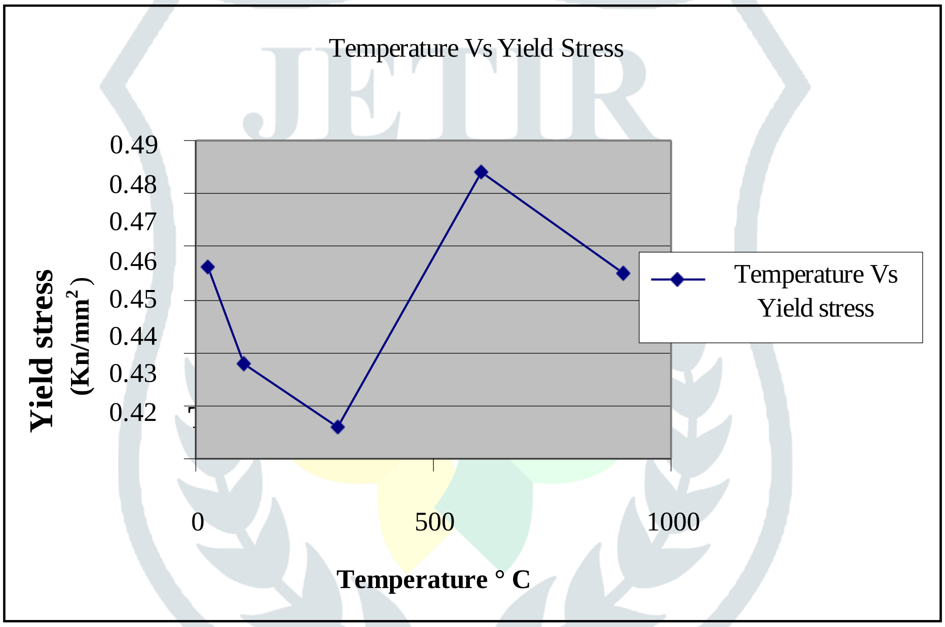

Fig 12: Temperature Vs Yield Stress

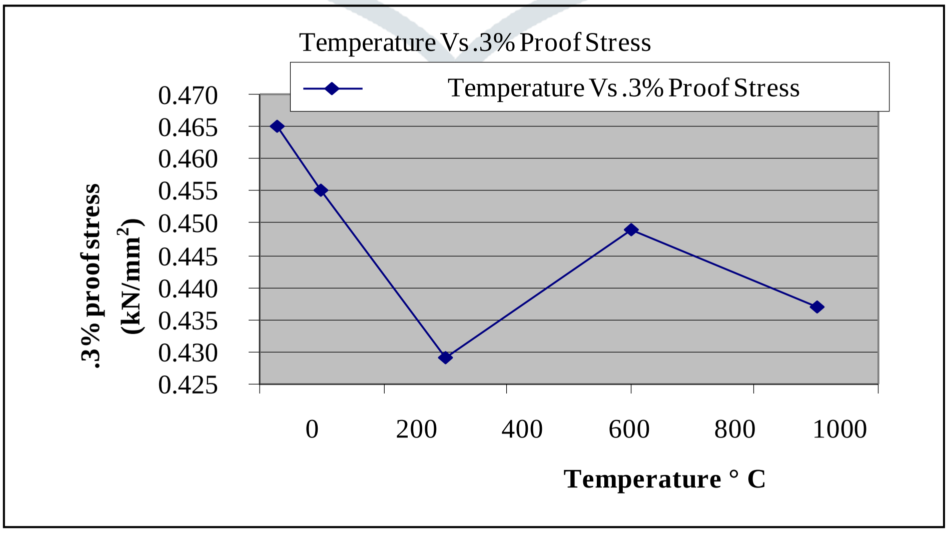

Fig.13: Temperature Vs .3% Proof Stress

IV. 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.

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