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Impact of Fire on Steel Reinforcement of R.C.C Structures

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Abstract:

With the increased incidents of major fires in buildings; assessment, repairs and rehabilitation of fire damaged structures has become a topical interest. This is a specialized field involves expertise in many areas like concrete technology, material science and testing, structural engineering, repair materials and techniques etc. Research and developmental efforts are being carried out in this area and other related disciplines. In this topic the experience of real life problems are presented which add immense value to this. The experimentation has been done to find out the impact of the fire on reinforcement steel bars by heating the bars to 100°,300°,600°,900° centigrade of 6 samples each. The heated samples are rapidly cooled by quenching in water and normally by air cooling. The change in the mechanical properties are studied using universal testing machine (UTM) and the microscopic study of grain size and grain structure is studied by scanning electron microscope (SEM).

1.Introduction:

With the increased incidents of major fires and fire accidents in buildings; assessment, repair and rehabilitation of fire damaged structures has become a topical interest. This specialized field involves expertise in many areas like concrete technology, material science and testing, structural engineering, repair materials and techniques etc. Research and development efforts are being carried out in these related disciplines. Any structure can undergo fire accident, but because of this the structure cannot be denied neither abandoned. To make a structure functionally viable after the damage due to fire has become a challenge for the civil engineering community. The problem is where to start and how to proceed.

It is vitally important that we create buildings and structures that protect both people and property as effectively as possible. Annual statistics on losses caused by fires in homes and elsewhere make for some unpleasant readings and sadly through these events we learn more about fire safety design.

1.1 EXPERIENCE OF FIRES:

Fig 1.1: fire damaged slab

Fig 1.2: concreting of fire damaged slab

1. Most of the structures were repaired. Of those that were not, many could have been but were demolished for reasons other than the damage sustained.
2. Almost without exception, the structures performed well during and after the fire.

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1.2 WHAT HAPPENS TO CONCRETE IN A FIRE:

Fires are caused by accident, energy sources or natural means, but the majority of fires in buildings are caused by human error. Once a fire starts and the contents and/or materials in a building are burning, then the fire spreads via radiation, convection or conduction with flames reaching temperatures of between 600°C and 1200°C. Harm is caused by a combination of the effects of smoke and gases, which are emitted from burning materials, and the effects of flames and high air temperatures.

2. EXPERIMENTAL WORK:

2.1 INTRODUCTION:

The specimens for testing were Sri TMT bar of 12mm diameter. 54 bars were cut to 40 cm size. 6 Specimens were tested for the mechanical properties using UTM before heating at normal temperature and the properties were tabulated. 12 specimens each were heated in the electrical furnace at 100°, 300°, 600° and 900°C for an hour without any disturbance. After heating, out of 12 specimens for each temperature 6 samples were quenched in water for rapid cooling and the other 6 were kept aside for normal cooling at atmospheric temperature. These specimens later were tested for mechanical properties with UTM and microstructure study using SEM.

2.2 EQUIPMENT:

i. Universal Testing Machine
ii. Scanning Electron Microscope
iii. Electrical Furnace

2.3 UTM TESTING:

The 12mm steel bar is cut to a length of 40 cm and gave a gauge length of 60mm. The specimen is fixed on the machine and the required data on the computer is given. Test is conducted at a load rate of 300 kg/min for all the specimens. An extensometer is fixed to the specimen during the test to read the elongation. The data of the test is noted in computer during the test by default s it is setup.

The graph of load versus deformation and load versus elongation is drawn on the computer. After the test all the other parameters like ultimate load, maximum extension in mm, area in mm^2, ultimate stress, elongation in percent, reduction in in area, young's modulus, yield stress, .1% and .2% proff stress and many other parameters can be observed.

Fig 2.1: UTM testing setup

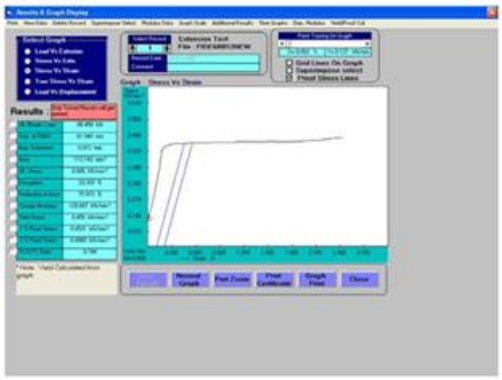

Fig 2.2: Screenshot of the result of tensile test using UTM

2.4: Tensile testing:

Tensile testing is performed in accordance with ASTM D-638 as well as ISO 527 combined tensile and flexural procedure. Tensile properties are the most important single indication of strength in a material.

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The force needed to pull the specimen apart is determined, along with how much the material stretches before it breaks. The tensile modulus is the ratio of stress to strain below the proportional limit of the material. This is the most useful tensile data as parts should be designed to accommodate stresses to a degree well below it.

2.5: SEM:

Scanning Electron Microscopy has done by JSM-6480LV at magnification of 5 microns (x5000) and 10 microns (x1000). The specimens are made in a size of 12mm diameter and 10mm length. Before testing the specimens are to be finely polished in all the edges and neatly cleaned with acetone for the clear view of the gain size and grain structure.

Fig 2.3: Setup of SEM

Fig 2.4:Inner view of SEM

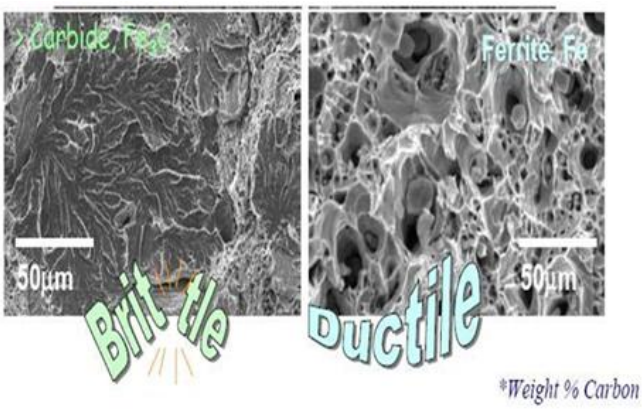

Fig 2.5: SEM properties of steel bar

2.6 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 a 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.

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Fig 2.6: Electric furnace

3. RESULTS AND DISCUSSIONS:

Results from computerized UTM:

s.no	Temperature in ° C	Ultimate load (kN)	Ultimate stress (kN/mm^2)	Yield stress (kN/mm^2)	Max. extension (mm)	Elongation (%)	.2% proof stress
1	Room temp 27	67.1	0.583	0.466	1.63	28.3	0.465
2	100	66.1	0.584	0.469	1.66	15	0.461
3	300	65.5	0.582	0.451	1.422	30	0.44
4	600	68.4	0.606	0.453	0.972	23.3	0.456
5	900	78.3	0.692	0.469	0.206	11.6	0.534

Table 3.1: Properties for rapid cooing conditions

s.no	Temperature in ° C	Ultimate load (kN)	Ultimate stress (kN/mm^2)	Yield stress (kN/mm^2)	Max. extension (mm)	Elongation (%)	.2% proof stress (kN/mm^2)
1	27	67.1	0.593	0.466	1.63	28.3	0.465
2	100	66.5	0.588	0.448	1.139	30.2	0.455
3	300	63.7	0.571	0.436	1.12	28.3	0.429
4	600	64.3	0.574	0.484	0.76	27.45	0.449
5	900	65.5	0.585	0.465	0.62	26.6	0.437

Table 3.2: Properties for ordinary cooing conditions

For Rapid cooling conditions from table 3.1:

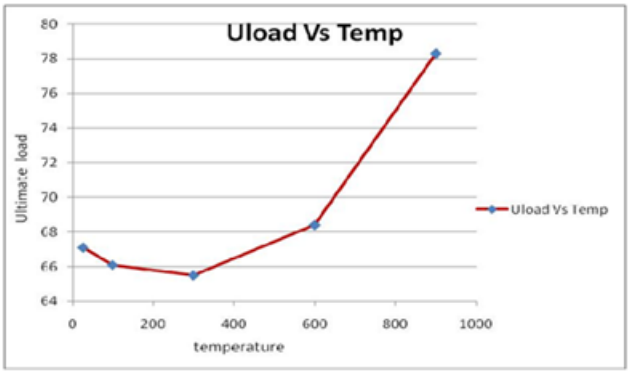

Fig 3.1: Temperature vs ultimate load

From the graph it can be observed that the ultimate load initially decreases from and then gradually increases , this happens due to the microstructure of the bar. For high temperatures the grain size decereases.

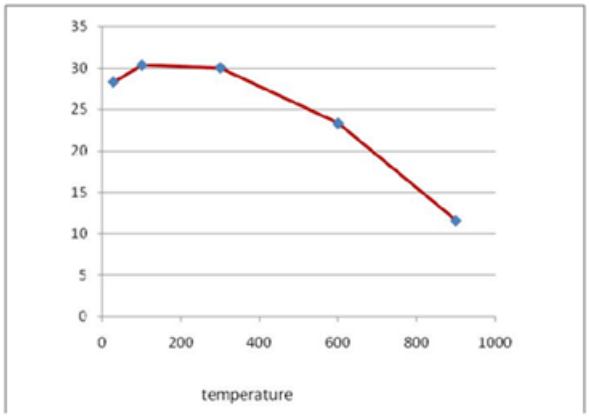

Fig 3.2: Temperature vs% elongation

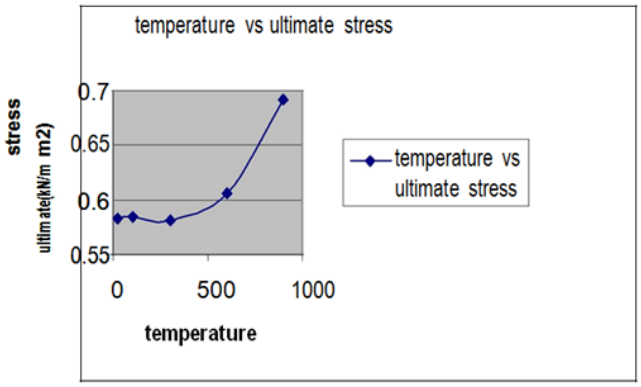

Fig 3.3: Temperature vs Ultimate stress

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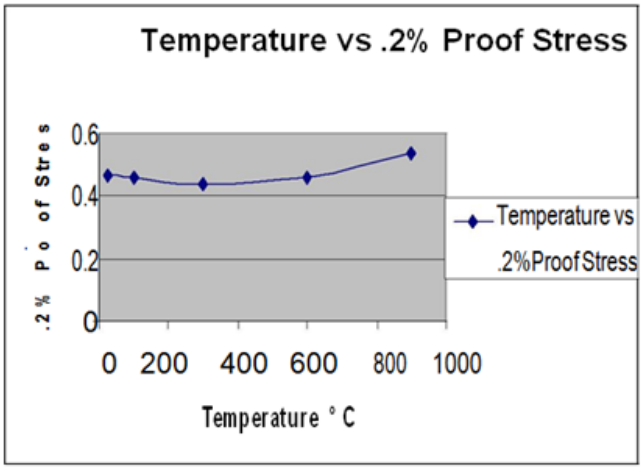

Fig 3.4: .2%Proff stress vs temperature

For ordinary cooling conditions from table 3.2:

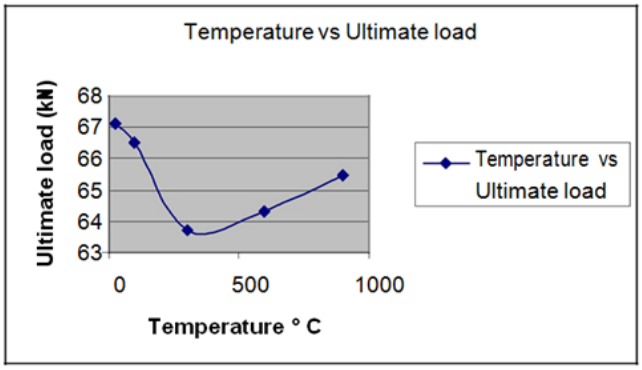

Fig 3.5: Temperature vs Ultimate load

From the Fig 3.5, the ultimate load carrying ot the specimen was reduced drom the specimen before heating.

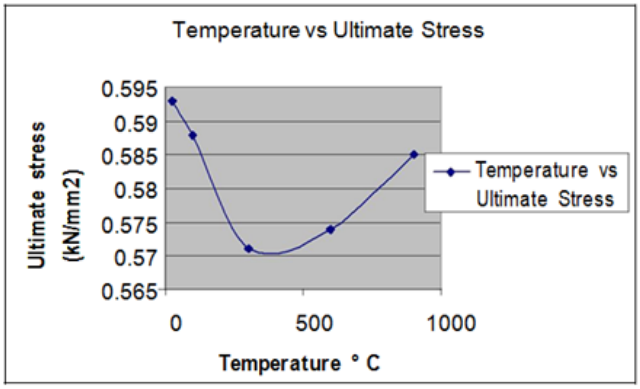

Fig 3.6: Temperature vs Ultimate stress

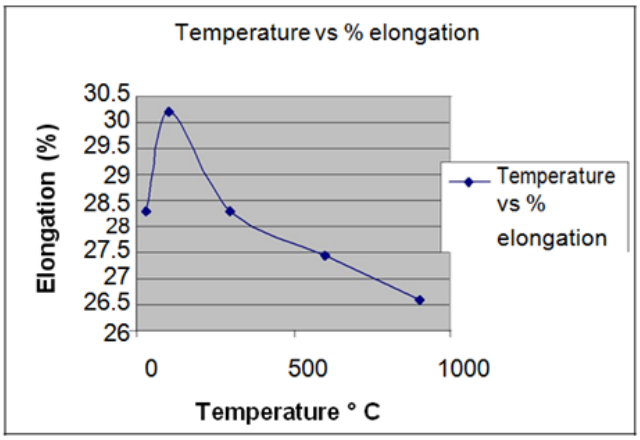

Fig 3.7: temperature vs elongation

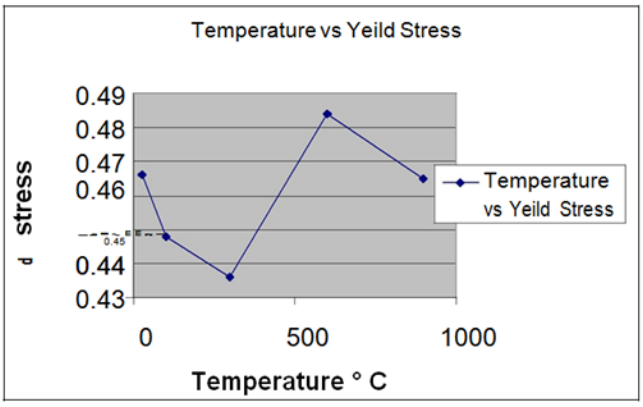

Fig 3.8: Temperature vs yeild Stress

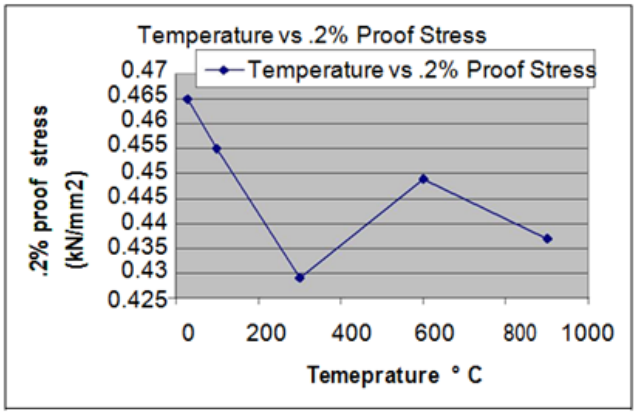

Fig.3.9: Temperature vs .2% Proof stress

SEM Analyses:

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

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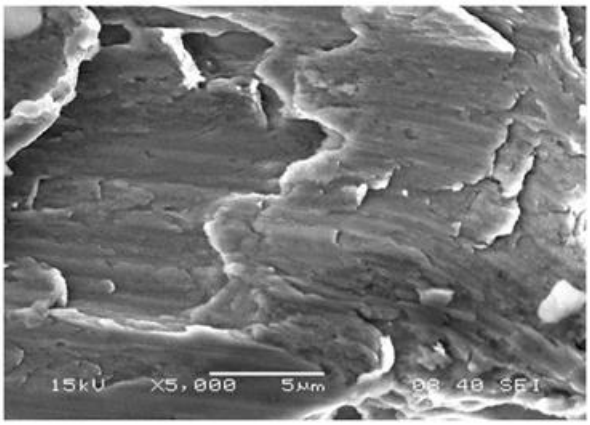

Fig 3.10: 100° C Ordinary cooling at magnification of 5 microns

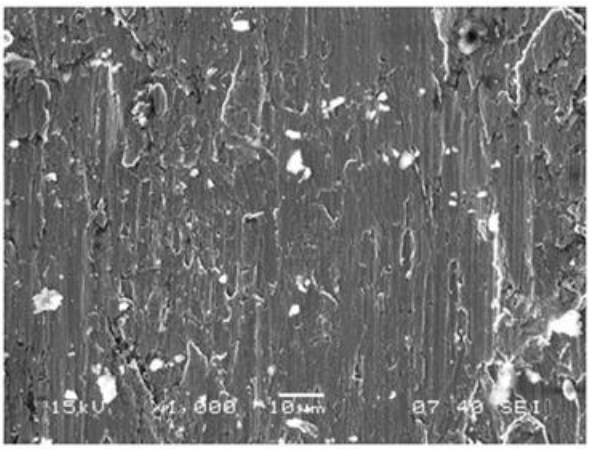

Fig 3.11: 100° C Ordinary cooling at magnification of 10 microns

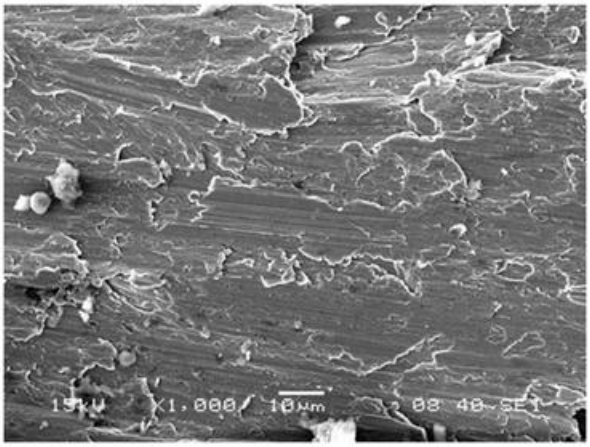

Fig 3.12: 300° C Ordinary cooling at magnification of 10 microns

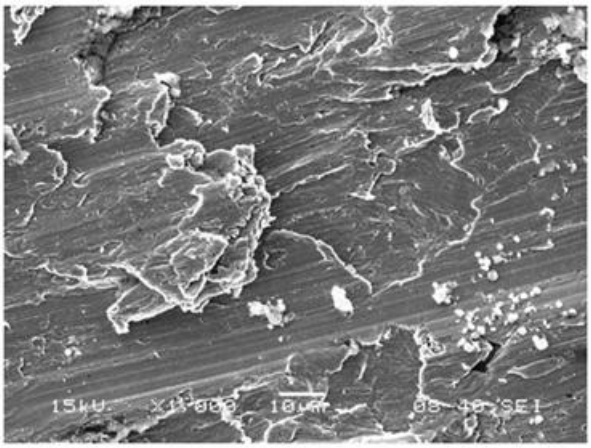

Fig 3.14: 300° C Rapid cooling at magnification of 10 microns

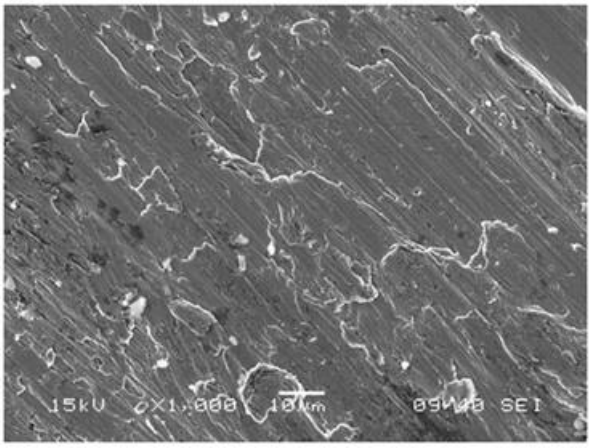

Fig 3.14: 900° C ordinary cooling at 10 micron

4.CONCLUSION:

i. The impact of fire on the reinforcement bars heated at various temperatures of 100° C, 300° C, 600° C, 900° C, cooled rapidly by quenching in water and normally cooled in the atmospheric temperature were studied and it is observed that the ductility of rapidly cooled bars after heating to high temperature to 900 ° C.

ii.Studying the characteristic changes in the mechanical properties of the bars by Tensile strength testing using Universal Testing Machine shows that the increase in ultimate load and decrease in percentage elongation of the specimen which mean that there is significant decrease in ductility of the specimen.

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iii. Study of micro structure of the bars using Scanning Electron Microscope (SEM) also shows that the microstructure of highly heated specimens varies without varying the chemical composition which would have negative impact on the structure.

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Specimen failed on UTM

Failed specimen

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Shear failure of specimen

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