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FIRE EFFECT ON STEEL OF RCC STRUCTURES

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Abstract

Effect of fire on reinforcement steel provided in RCC structures of various types of buildings which are under blast or fire. The behaviour of steel reinforcement at various temperatures from 100° C to 1000° C is studied. After the attack upon the World Trade Center of United States in Newyork in sept 2011, interest in the design of building protect from fire greatly increased. Fire has become one of the major and greatest dangers to buildings. The increased incidents of major fires in structures, repairs and rehabilitation of fire damaged structures has become a topical interest.

This experiment has been done to find out the effect of fire on reinforcement steel by heating the bars to 100°,300°,600°,900° C. The heated samples are rapidly cooled by quenching in water and normal by air cooling. The change in the mechanical properties in steel are observed by universal testing machine and microscopic study of grain size and structure is observed by scanning electron microscope. This project's conclusion is the majority of fire damaged RCC structures are repairable. If reinforcement bars are rapidly cooled by quenching and impact of elevated temperature above 900°C on bar then observed that there is significant reduction in ductility. and bars cooled in normal air conditions the impact of temperature on ductility of bar is not high. when a bar is heated Mechanical property of reinforced bar is changed without varying its chemical composition.

Keywords: *Concrete, Construction Material, Reinforcement, UTM Machine, SEM.*

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1. Introduction

Now a days there are incidents of fires in buildings are often heard which are increasing day by day and also the repair and rehabilitation of fire damaged structures has become an area for study and research. Many efforts are been laid down to carry out research in these related fields. To build a structure usable again after fire damage is a discipline of great concern by civil engineering com-munity. We totally recognize that fire cause damage in terms of deprivation of life, families and livelihoods. Structural design for fire safety is chiefly based upon

"Authoritative Approach." The Authoritative Approach involves fire resistance rating of structures & was developed almost 100 years back.

1.1 Experience of fire

Concrete during the high temperature event has a complex behaviour due to the differences in coefficient of thermal expansion of each composition. Proportioning of con- create mixtures to achieve high effectiveness and maintaining durability requirements during service live led to production of dense concrete mixtures with less water-cementitious material ratio (w/cm). Consequently, mechanical properties of HSC at elevated temperature are different from that of conventional concrete in two principal areas: first, strength loss in the intermediate temperature ranges 100°C to 400°C and second the occurrence of explosive spalling of the HSC. Strength loss should be considered by incorporating the code and design specifications during the invention phase. In addition, explosive spalling of the HSC and loss of the concrete cover during fire leads to direct exposure of the steel reinforcement to heat leading to a loss of overall structural capacity Therefore, high strength concrete (HSC) and normal strength concrete (NSC) will cause a substantial difference in fire performance. Various genes that bear upon the fire resistance of concrete are concreate strength, moisture content, concrete density, and aggregate type.

Figure 1. Fire damaged slab

Figure 2. Concreting of fire damaged slab

Take strength and modulus of elasticity of steel are re-decade by nearly 12% to 14% when exposed to 482°C temperatures, beyond this temperature a rapid reduction in both properties will occur. In increase, the reduction in yield strength and modulus of elasticity at high temperature is also regarded by the carbon percentage and stress level of the steel member. Steel reinforcement if protected by the minimum cover specified by the code it is expected that the consequence of high temperature on the reinforcement bars will be trifling. However, distortion due to thermal expansion and loss.

1.2 Objective

Study the fire effect on steel reinforcement heated at various temperatures to 100°,300°,600°,900° C and cooled rapidly by quenching in water and normal cooling in atmospheric temperature and their comparison. To Study the behaviour changes in the mechanical properties of the steel bars by Tensile strength test using Universal Testing Machine. By using Scanning Electron Microscope (SEM) study the micro structure of steel bars.

2. Experimental Study

The specimens for testing were Sri TMT bar of 12mm diameter. the bars were cut to 30 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.

Equipment

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

Universal Testing Machine:

The 12mm steel bar is cut to a length of 30 cm and gave a gauge length of 50mm. 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 mm2, 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.

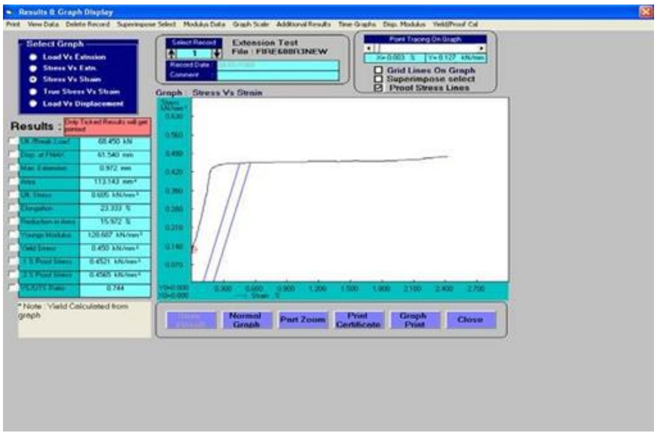

Figure 3. Result of tensile strength test

Tensile Test:

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. The force needed to pull the specimen apart is deter-mined, 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.

Scanning Electron Microscopy:

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 15mm 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.

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 door closing tightly so that no air enters 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.

3. Results and Discussions

Results from computerized UTM:

Table 1. Properties for rapid cooling conditions

S.no	Temperature in ° C	Ultimate load (kN)	Ultimate stress (kN/mm2)	Yield stress (kN/mm2)	Max. extension (mm)	Elongation (%)	.2% proof stress
1	27	67.2	0.594	0.456	1.65	28.2	0.461
2	100	66.4	0.587	0.464	1.61	15.1	0.452
3	300	65.2	0.576	0.451	1.44	30.1	0.448
4	600	68.8	0.608	0.468	0.94	23.2	0.466
5	900	74.2	0.656	0.492	0.24	11.5	0.515

Table 2. Properties for ordinary cooing conditions

S.no	Temperature in ° C	Ultimate load (kN)	Ultimate stress (kN/mm2)	Yield stress (kN/mm2)	Max. extension (mm)	Elongation (%)	.2% proof stress (kN/mm 2)
1	27	67.1	0.593	0.466	1.6	28.2	0.465
2	100	66.8	0.591	0.465	1.14	30.3	0.432
3	300	67.5	0.597	0.478	1.1	28.3	0.435
4	600	68.6	0.607	0.494	0.8	27.4	0.449
5	900	68.8	0.608	0.496	0.65	26.5	0.457

For Rapid cooling conditions:

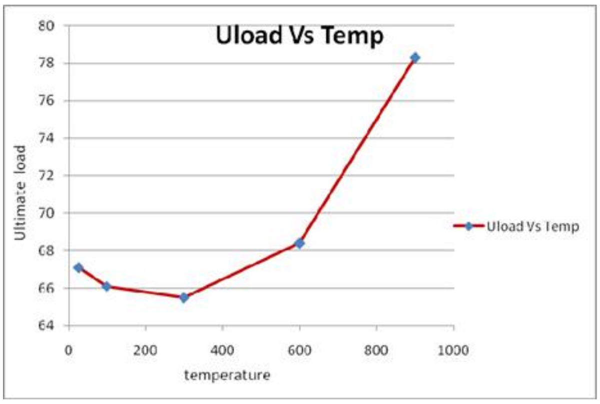

Figure 4. Temperature vs ultimate load

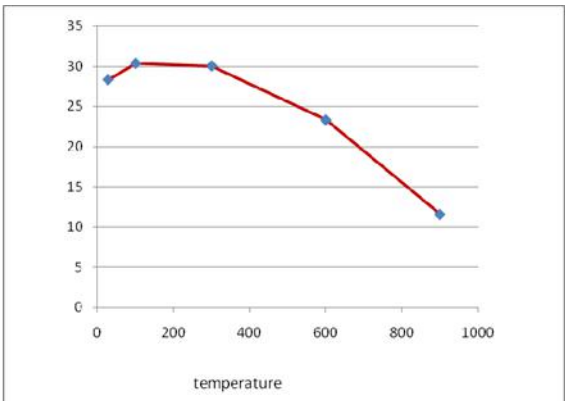

Figure 5. Temperature vs% elongation

Graph shows the ultimate load initially decreases from and then gradually increases due to the microstructure of the bar. Grain size decreases for high temperature.

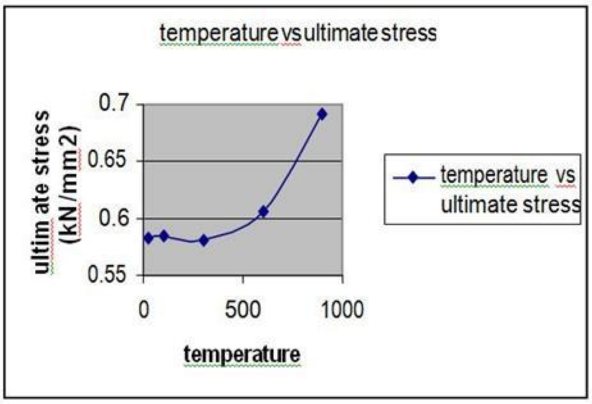

Figure 5. Temperature vs Ultimate stress

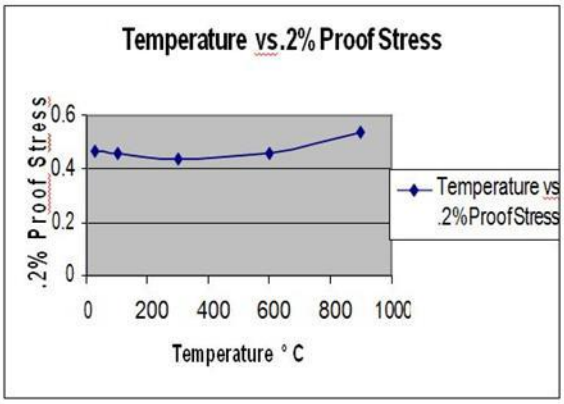

Figure 5. 0.2%Proff stress vs temperature

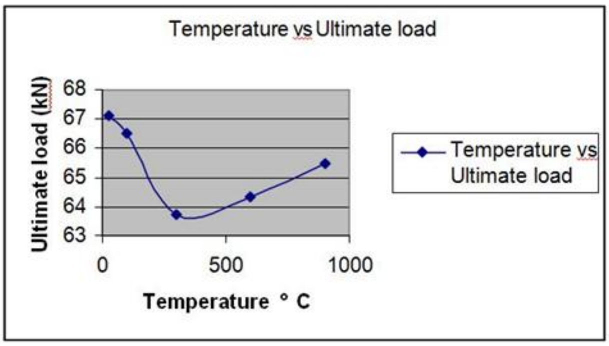

Figure 7. Temperature vs ultimate load

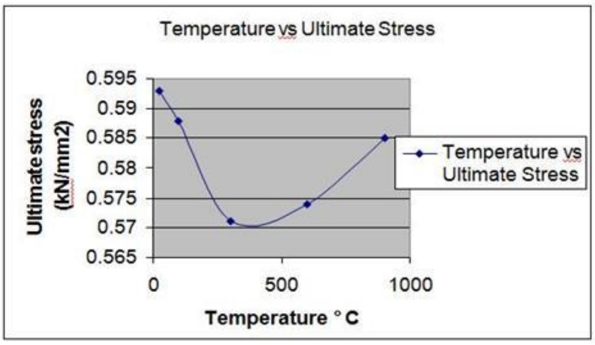

Figure 8. Temperature vs Ultimate stress

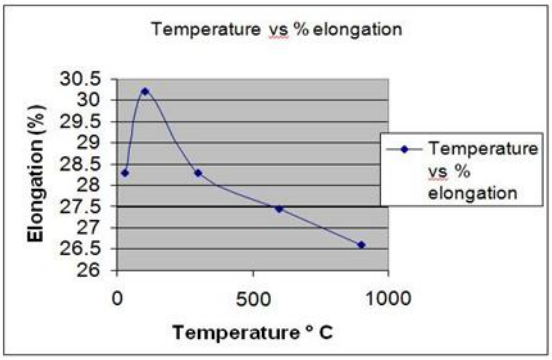

Figure 9. Temperature vs elongation

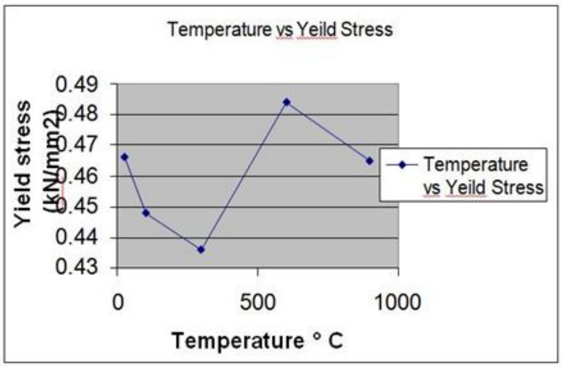

Figure 10. Temperature. vs yield Stress

Fig. shows the ultimate load carrying out the specimen was reduced before heating of specimen.

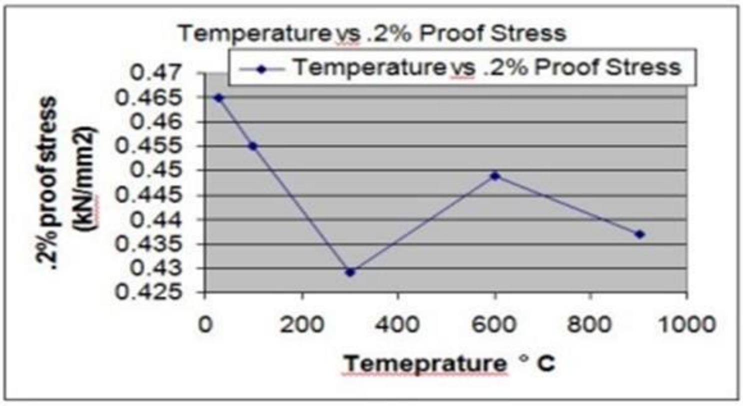

Figure 11. Temperature vs .2% Proof stress

SEM Analyses:

Microscopic images are taken at the magnification of 5 microns and 10 microns.

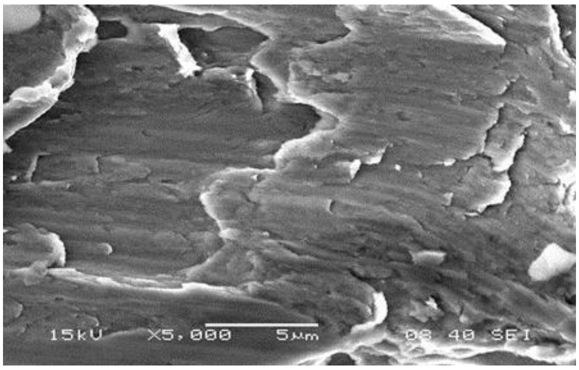

Figure 12. Normal cooling of 100° C at magnification of 5 microns

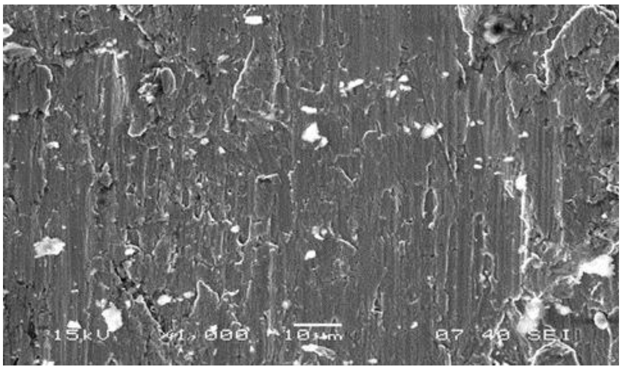

Figure 13. 100° C rapid cooling at magnification of 10 micron

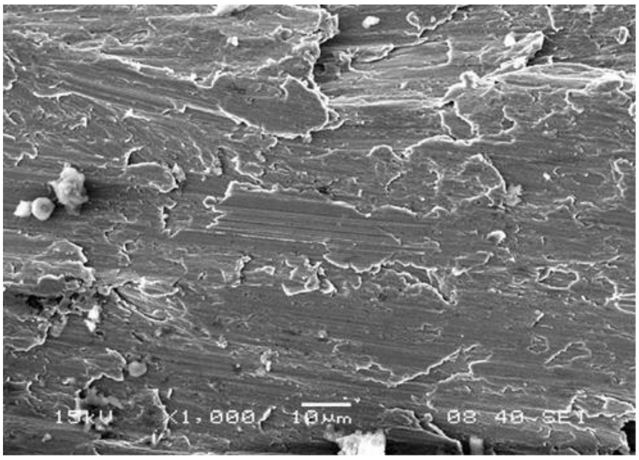

Figure 14. 300° C Normal cooling at magnification of 10 microns

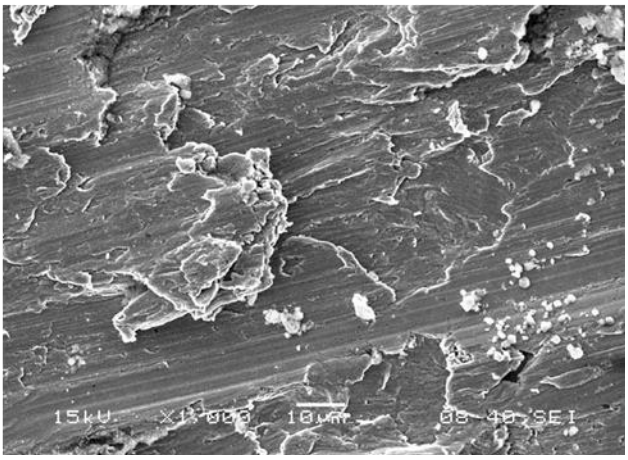

Figure 15. Rapid cooling of 600° C at magnification of 10 microns

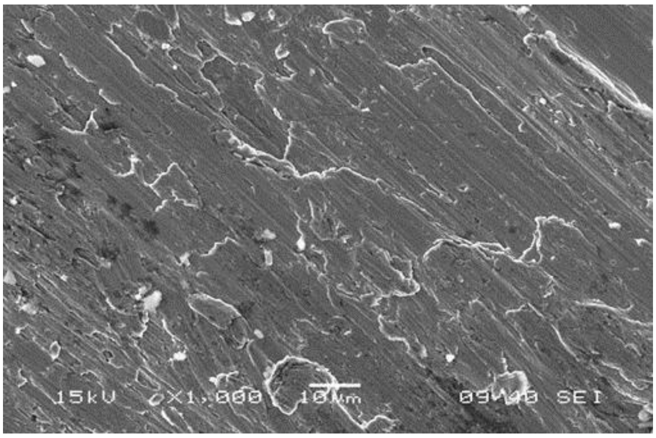

Figure 16. Normal cooling of 900° C at 10 microns

4. Conclusion

- The effect of fire on the reinforcement steel 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 reduced by rapidly cooled bars after heating to high temperature to 900 °
- There is a detailed Study of the characteristic changes in the mechanical properties of the bars by Tensile strength testing using Universal Testing Machine readings and the graphs which are produced from the readings, shows that there is an increase in ultimate load and decrease in percentage elongation of the specimen which means that there is a significant change in ductility or we can say that ductility is decreasing as the ultimate load on the bars is increasing.
- 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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