

Fig. 6 Cross section

The geometries are given in Fig. 5 and Fig. 6. The compressive strength of concrete was 30 MPa and the yield stress of steel was 435 MPa with the value of  $2 \times 10^5$  MPa for the modulus of elasticity at normal temperature. The beam was exposed to high temperature from bottom and two sides of section according to ASTM E119 time-temperature relationship. Emissivity and the convection coefficient are assumed to be 0.2~0.3 and 30 W/mK, respectively. Fig. 7 shows the average temperature of steel in B-B section, which results were used for nonlinear analysis. The result of numerical analysis is mostly same with the experimental result. The displacements from numerical analysis are well compatible with the experiment as can be seen in Fig. 8.

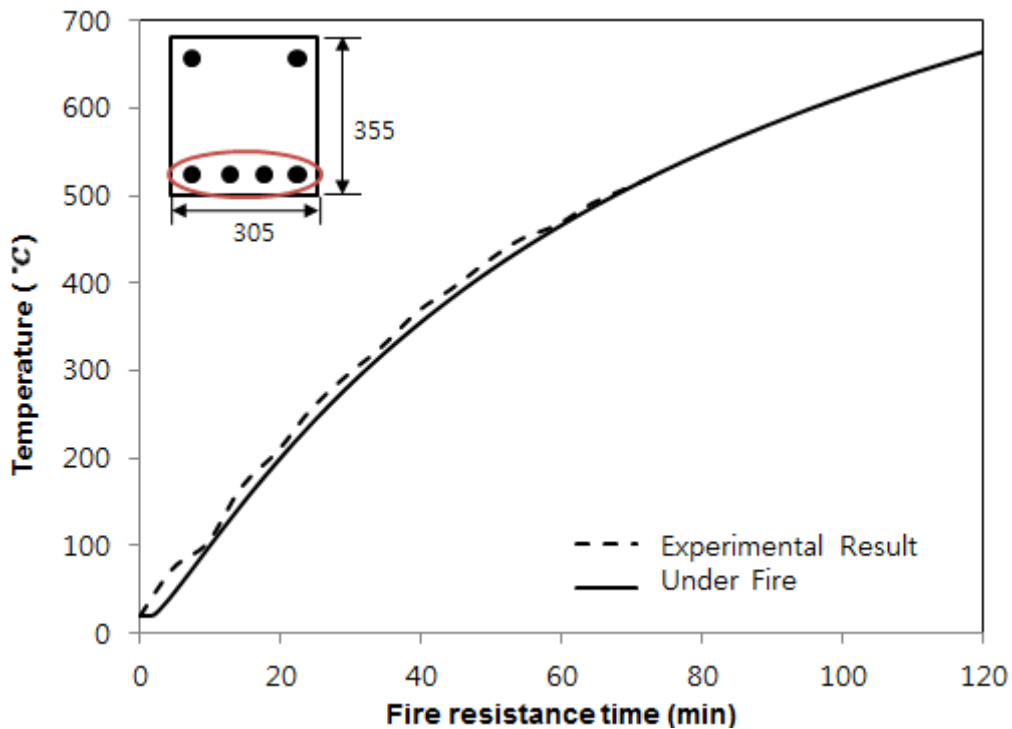


Fig. 7 Average temperature of steel in B-B section

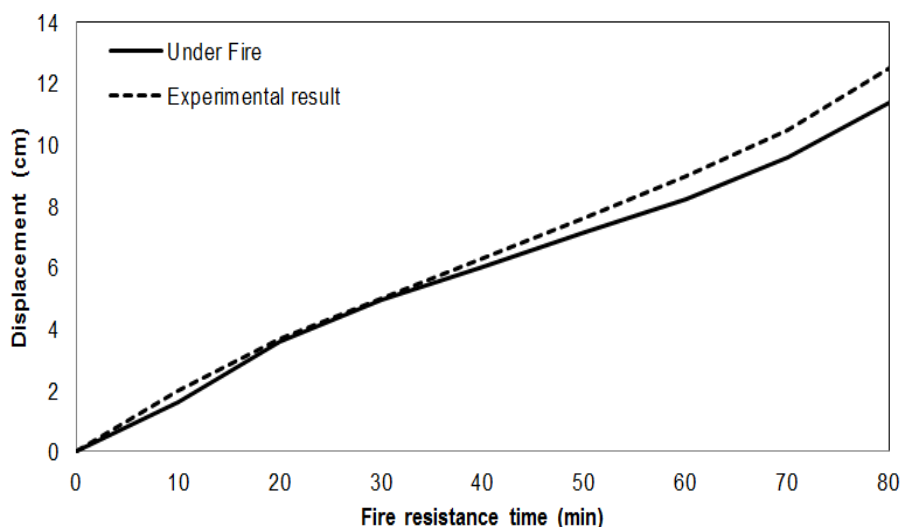


Fig. 8 Predicted and measured displacements at center of beam

Beginning of the fire, strain of analysis shows almost same with the experimental result. Time between 30 min. to 60 min., slope of the graph is slightly decreased because rate of increase for the fire temperature is smaller than the early time. After the 70 min. creep of steel caused from high temperature makes rate of strain higher again. Other minor differences between two curves seem to be due to the experimental limitation of several environmental and material variables such as mixing ratio, water content and kinds of aggregates.

## 6. AFTER-COOLING ANALYSIS

Several studies reported that the strength of concrete decreases during the cool-down phase because of micro defects caused by high temperature, which were supported from the some experiments data (Nassif 2006, Chang 2006). Fig. 9 from the ACI Committee report shows that the residual compressive strength of after-cooling status is lower than under-fire status.

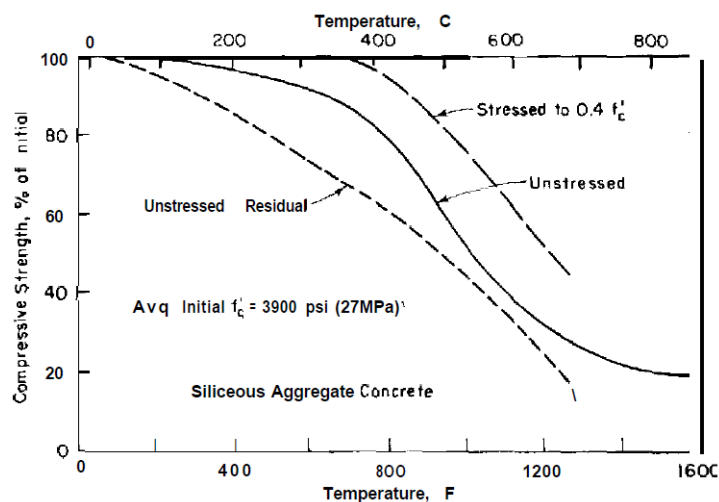


Fig. 9 Compressive strength of concrete at high temperature and after cooling (ACI)

This study therefore attempted the after-cooling analysis of fire-damaged concrete based on the comparison with proposed concrete models and experimental results at high temperature. This study expects to show that the safety side design of RC structures against fire. From the experimental data, the concrete model for after-cooling status can be suggested. In all temperature range, the maximum strength is lower than the strength of concrete in high temperature, and strain is also smaller.

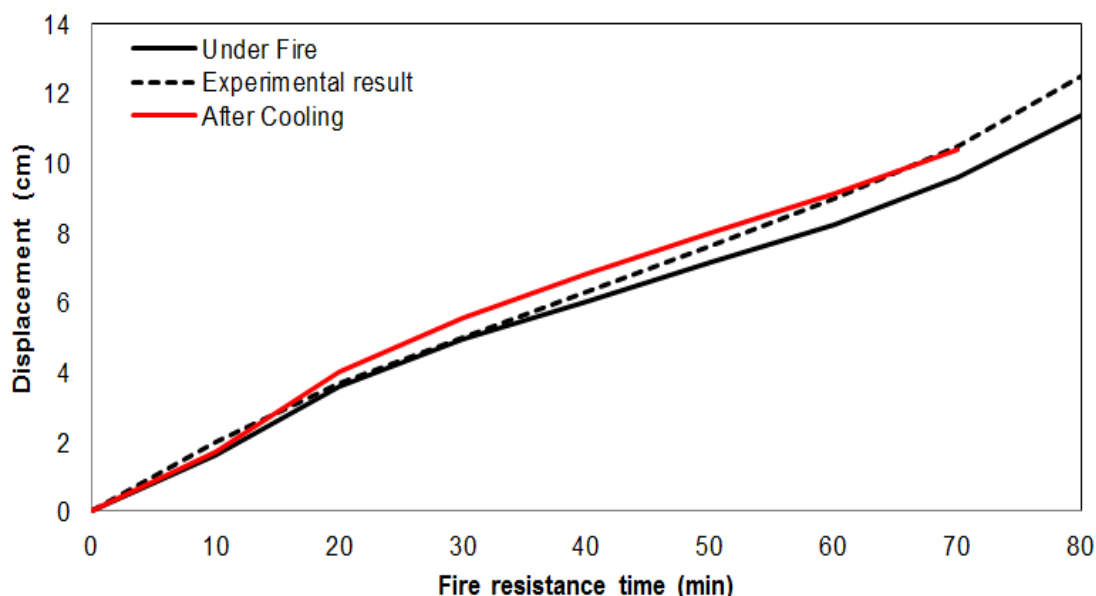


Fig. 10 Displacement by after-cooling analysis

Fig. 10 is the result of after cooling analysis applying to the example above mentioned. Beam from under-fire collapse at 80 min of fire resistance time, but after-cooling beam collapse earlier than that, at 70 min of fire resistance time.

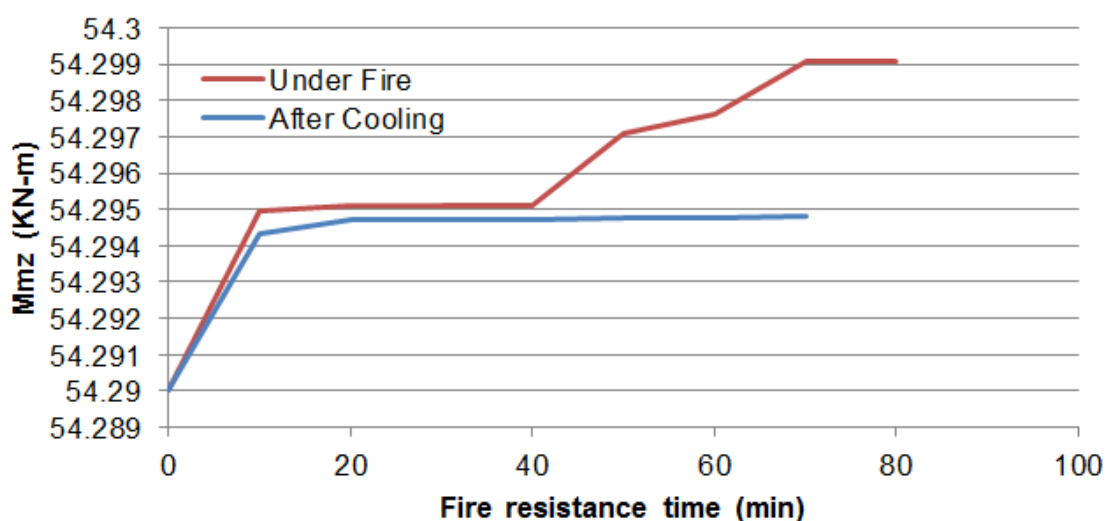


Fig. 11 Moment at the mid-span



But moment at the mid-span is not that different as shown in Fig. 11. Failure caused from moment is controlled by the steel failure but after-cooling analysis is applied to concrete only. So the difference of maximum moment between under-fire and after-cooling is small.

The model still needs to verify under the different load conditions because it has low strength to collapse. The advanced study will be reported in further study.

## **7. CONCLUSIONS**

This paper introduced a numerical approach for the RC structures exposed to high temperature and suggested new material model, which is after-cooling analysis. The proposed numerical approach was validated by comparing its analysis results with the data from fire test on beam, the after-cooling analysis was proposed with comparison of experiment data. For the future study, nonlinear analysis needs to verify comparison with design codes, and after-cooling analysis needs to be verified under the several load condition such as moment load combined with axial force. Also, new model for steel is needed to be applied to after-cooling analysis.

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