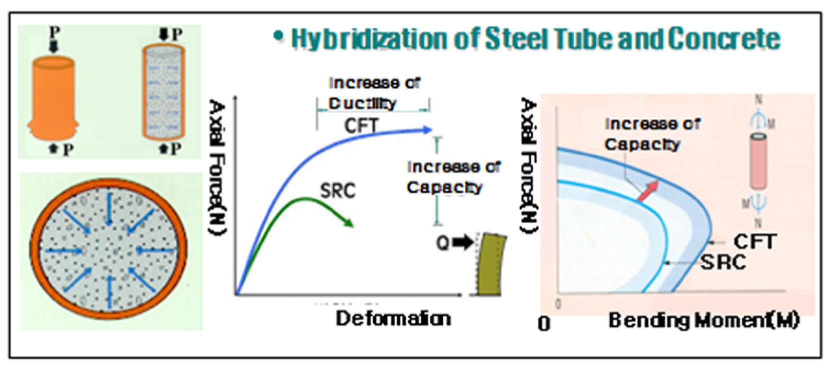
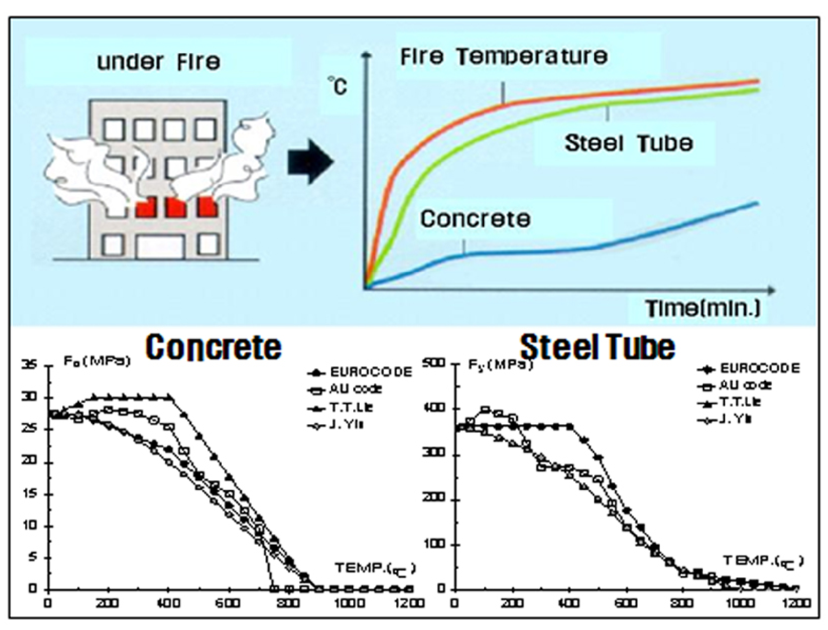
FIRE RESISTANCE OF BAR-REINFORCED CONCRETE-FILLED STEEL TUBE COLUMNS

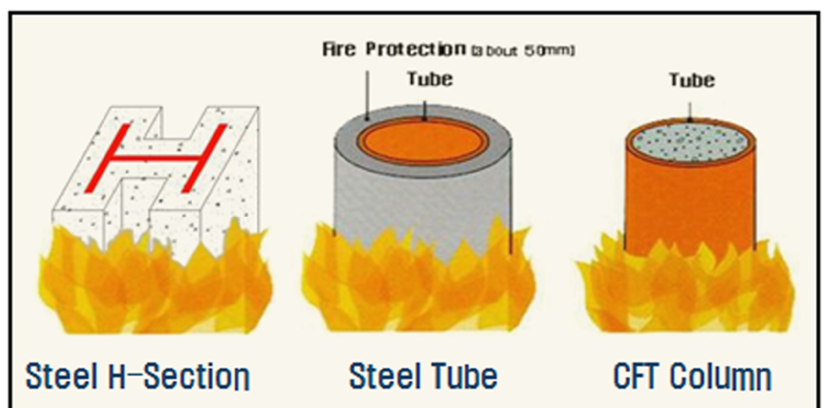
SU-Hee Park[a] Kyung-Chul Song[a] Kyung-Soo Chung[b] Byung-Yeol Min[c] Sung-Mo Choi[a]

[a] Department of Architectural Engineering, University of Seoul, Korea
[b] Researh Institute of Industrial Science &Technology Steel Structure Research Laboratory, Korea
[c] Korea Institute of Construction Technology, Kyungkido, Korea

Research Background







- Fire Resistance of CFT Column
↓
- Absence of the fire protection
↓
- Reduction of the column size
↓
- Simplification of Materials
- Reduction of the number of works

Domestic Research

Park. S.H. et al(2007)
A proposal to predict formulas with a limited range for the fire resistance capacity of non-reinforced CFT square steel columns.
Chung K.S et al(2008)
Material characteristics of non-reinforced CFT square steel columns exposed to fire.

Identification of fire resistance capacity of two hours or less under constant axial Load.

Domestic Standard

For high-rise buildings with more than 12 floors,the required fire resistance capacity is three hours.

Proposal to add measures to increase fire resistance capacity.

Objective and Scope

CFT Columns
Identification of fire resistance capacity of two hours or less under constant axial load.

Proposal to add measures to increase fire resistance capacity.

Evaluation of the fire resistance capacity of bar-reinforced unprotected CFT square columns using a real-scale fire-resistance test under a load.

Gather data from experiments conducted in Korea, and use as a basis for the proposal of a domestic fire resistance design formula.

Design of Specimens

Table 1 . Material Characteristics of Steel and Concrete

Concrete		Steel			
Age (day)	compressive strength (MPa)	thickness (mm)	grade	Yield Strength (Mpa)	Tensile strength
28	36.1	6	SS400	240	422
28	56.8	9	SS400	237	410

Table 2. Specimen Parameter

Name	size (mm)	Concrete strength f_{ck} (Mpa)	Steel strength F_y (Mpa)	Axial force ratio N_a/N_c	Effective length KL (mm)	Reinforcement ratio (%)	Fire resistance time FR (min) Test time
APL1	□-360×9	36.1	240	0.4	2902	-	99
ARL1		36.1	237	0.4		2%	171
BRL1	□-280×6	36.1	237	0.4			158
BRL2		36.1	237	0.6			80
BRH1		56.8	237	0.4			146

D×t (mm)		Reinforcement (concrete)		f_{ck} (MPa)	
A	B	P	R	H	L
360×9	280×6	Plain	Bar-reinforced	High	Low

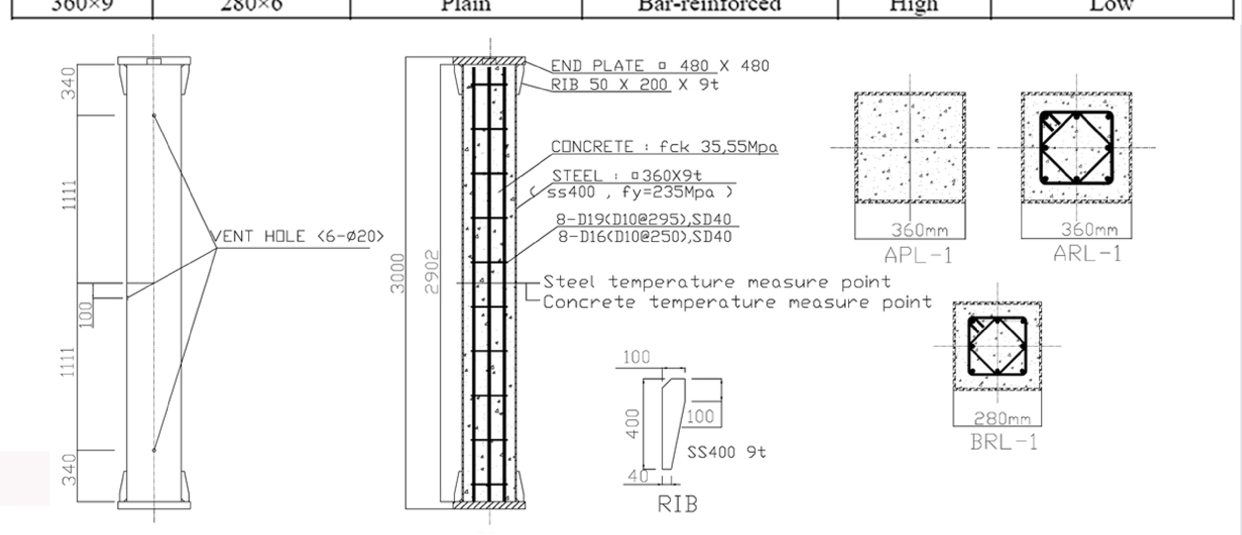


Fig 1. Section and Size of Column Specimens

Design of Specimens

- Cross-section diameter : 280, 360 mm
- Column length : 2900mm
- Thickness of a steel tube : 6, 9mm
- endplate : 50mm
- Bar reinforcing concrete cover : 50mm

Specimen details

- Vent hole :
A paired hole piercing with these dimensions: height of 340mm, 1311mm and 1011mm (measured from the lower end-plate).
- Rib :
A total of four ribs installation at the edges (as shown in the figure 1.).

Parameter

- Presence or absence of CFT column bar reinforcement;
in the presence of reinforcement, cross-section diameter, axial force ratio and concrete strength set as parameters.

Experiment Method

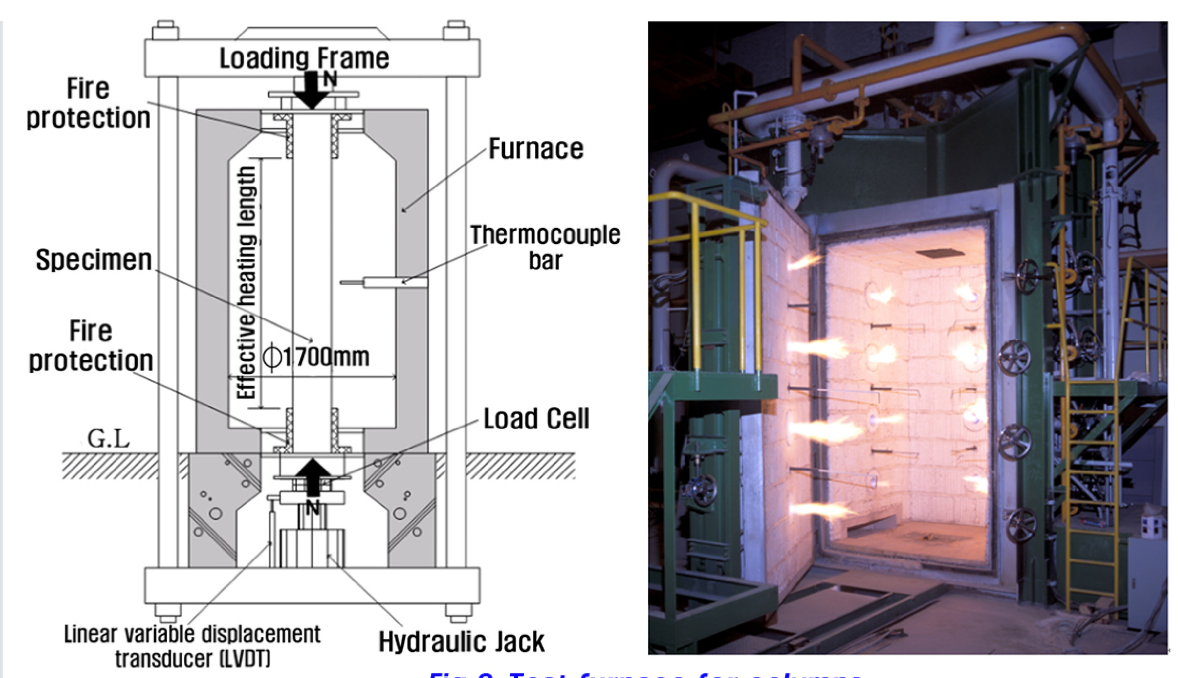


Fig 2. Test furnace for columns

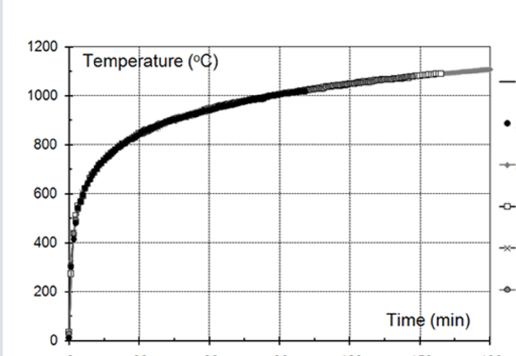


Fig 3. Comparison of ISO Standard Fire Curve and test Curve

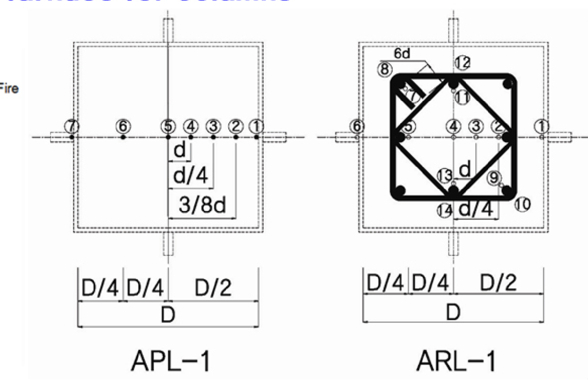


Fig 4. Temperature Measurement point

Experiment Equipment

- Loading specimens from top to bottom.
- A compression tester installment with a capacity of 3000kN.
- Loading at the lower column.

Temperature Measurement

- Items : Items for temperature measurementwere Fig. 4.

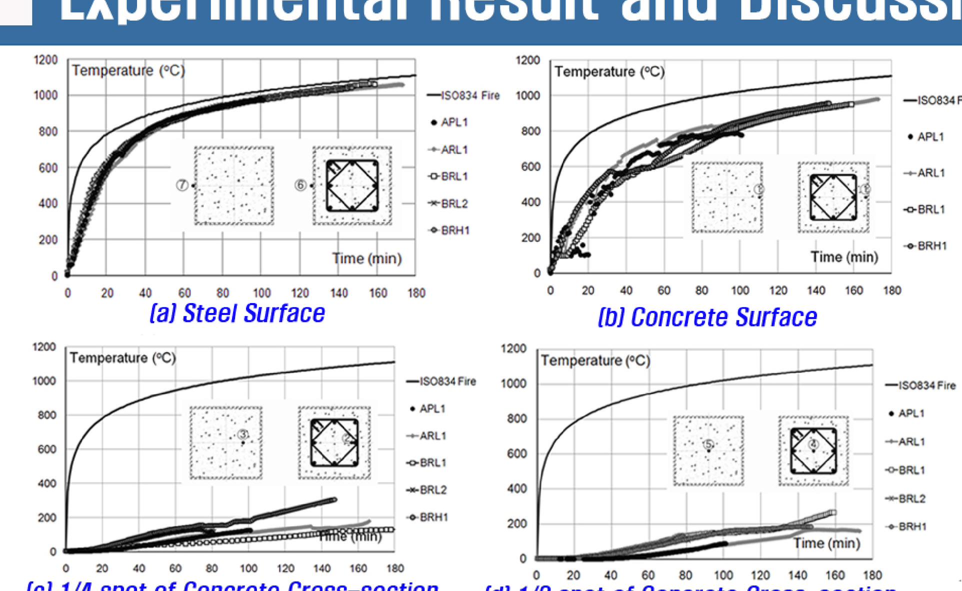
Heating Temperature Comparison

- In experimentation, the test furnace temperature is an almost perfect match to ISO 834 heating curve

Procedures

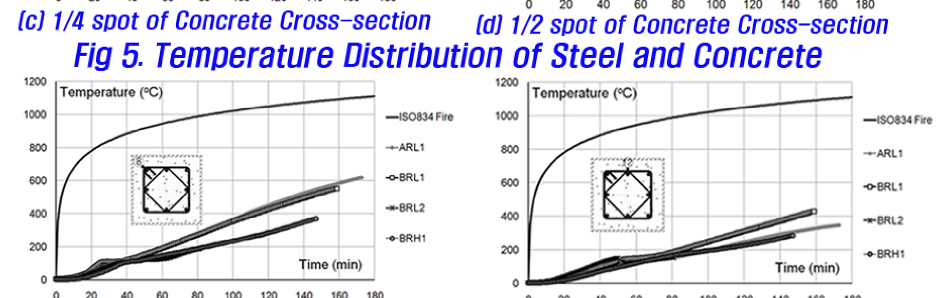
1. Set up CFT columns in the test furnace.
2. Introduce compressive force 15 minutes before heating.
3. Heat, under load, according to the ISO 834 heating curve.
4. End when shrinkage reaches L/100 or more, or when meeting government standards for fire resistance time.

Experimental Result and Discussion



(a) Steel Surface (b) Concrete Surface (c) 1/4 spot of Concrete Cross-section (d) 1/2 spot of Concrete Cross-section

Fig 5. Temperature Distribution of Steel and Concrete



(a) The Concrete Direction Boundary (b) The Concrete Central Direction Boundary

Fig 6. The Temperature Distribution of Internal and External Boundary of Bar

Temperature Distribution

- Specimen comparison at the surface of the steel tube, the center of concrete cross-section, 1/4 point, the surface and the inner and outer parts of the tube.

Steel Tube and Concrete

- A drastic increase in temperature distribution of BRH1 specimen after 30 minutes of heating or more due to the spalling effect at the 1/4 of concrete cross-section.

Internal and External Bar

- A small difference in the temperature distribution in the internal and external bar with concrete due to high thermal conductivity of steel.

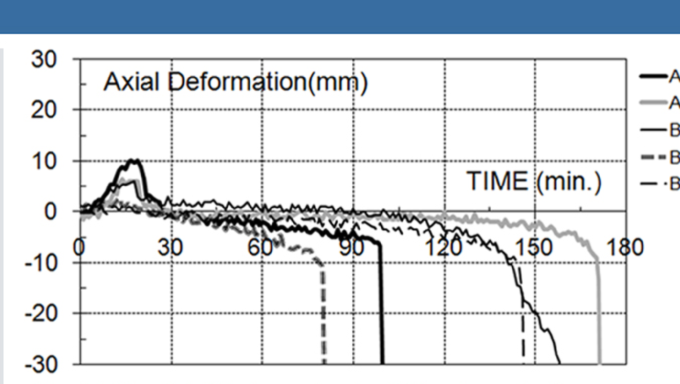


Fig 7. The Axial Deformaion by CFT column in fire resistance under load

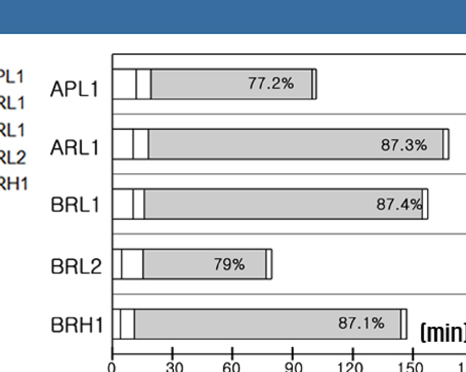
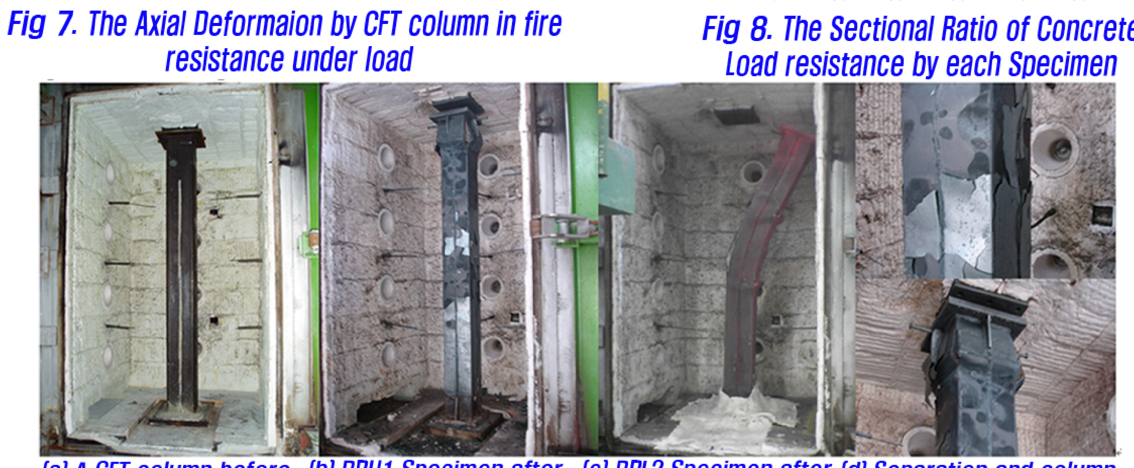


Fig 8. The Sectional Ratio of Concrete Load resistance by each Specimen



(a) A CFT column before the Experiment (b) BRH1 Specimen after the Experiment (c) BRL2 Specimen after the Experiment (d) Separation and column Fracture of BRH1 Specimen

Fig 9. A CFT Colum Before and After the Experiment

Axial Deformation

- Comparative analysis on the rate (%) by each specimen following the collection of concrete core resistance section in time-axial deformation relations.
- The bar-reinforced ARL1 specimen showed a 10% increase compared to the non-reinforced APL1 specimen.
- Identical rates were observed in the 280mm cross-section BRL1 specimen and the 360mm cross-section ARL1 specimen.
- The BRL2 specimen with the axial force ratio of 0.6 showed an 8% decrease in the section rate compared to the 0.4-axial force ratio BRL1 specimen.

Failure Mode

-The 0.6-axial force ratio BRL2 specimen showed global buckling.
-The BRH1 specimen, reinforced with a high-strength concrete, showed a steel tube fracture at the local buckling location.

Analysis of Factors Influencing Fire Resistance Capacity

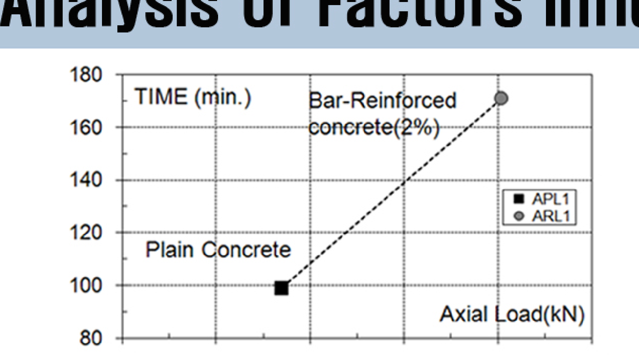


Fig 10. The Effect of Concrete Reinforcement

Impact according to the presence or absence of steel reinforcement

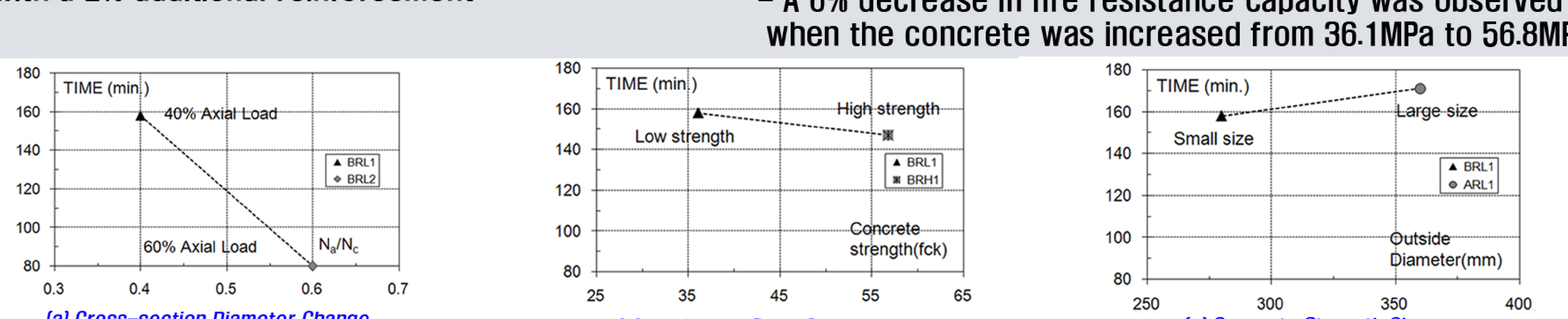
- 70% significant increase in fire resistance capacity with a 2% additional reinforcement

Factors Influencing Fire-Resistance Capacity

(a) the presence or absence of the bar reinforcement of CFT columns;
(b) effective reinforcement in the cross-section diameter;
(c) axial force ratio, and (d) high-strength concrete application

Impact according to Parameters in Bar Reinforcement Application

- A 65% increase in cross-section diameter led to an 8% increase in fire resistance capacity.
- A 50% decrease in fire resistance capacity was noted when the axial force ratio increased from 0.4 to 0.6.
- A 6% decrease in fire resistance capacity was observed when the concrete was increased from 36.1MPa to 56.8MPa



(a) Cross-section Diameter Change (b) Axial Force Ratio Change (c) Concrete Strength Change

Fig 11. The Effect of Influencing Factors in Steel Reinforcement

Conclusion

Following the analysis of the axial deformation behavior of the columns according to the time under fire:

the rate of the concrete resistance section in the entire section of the fire resistance time showed an approximately 10% increase and decrease depending on the presence or absence of reinforcement and on the variant axial force ratio (0.4→0.6). Moreover, when a 2% reinforcement rate was applied, there was an almost perfect match (about 87%) irrespective of the cross-section diameter and the concrete strength.

The following results were obtained from the analysis of the effects of the factors influencing the fire resistance capacity of the CFT columns:

1) The 2% reinforcement rate caused an approximately 70% significant increase in the fire resistance capacity of the columns.
2) When the axial force ratio increased to 0.6 from 0.4, an approximately 50% significant decrease in the fire resistance capacity of the columns was shown.
3) Under the same axial force ratio, the columns' fire resistance capacity increased as the cross-section diameter increased. Conversely, it decreased to 10% or less as the concrete strength increased.
4) It was determined in the study that bar reinforcement could secure the required three-hour fire resistance capacity of the columns for high-rise buildings.