CrossFire
Advanced Structural Fire Engineering at Intersections Among Disciplines
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Fire Resistance Design Equation for Rectangular CFT Columns in According to AISC 360-22

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1. Introduction

- The current AISC 360-22 [1] desgin equation may overestimate the fire resistacne of rectangular CFT columns.
- Rectangular sections have a high surface-area-to-volume ratio, leading to rapid heat transfer and reduced fire resistance.
- A lack of experimental data for rectangular CFT columns limits the reliabilty of current design methods.
- A conservative and practical fire design equation is needed to account for diverse geometries and conditions

2. FE model and Validation

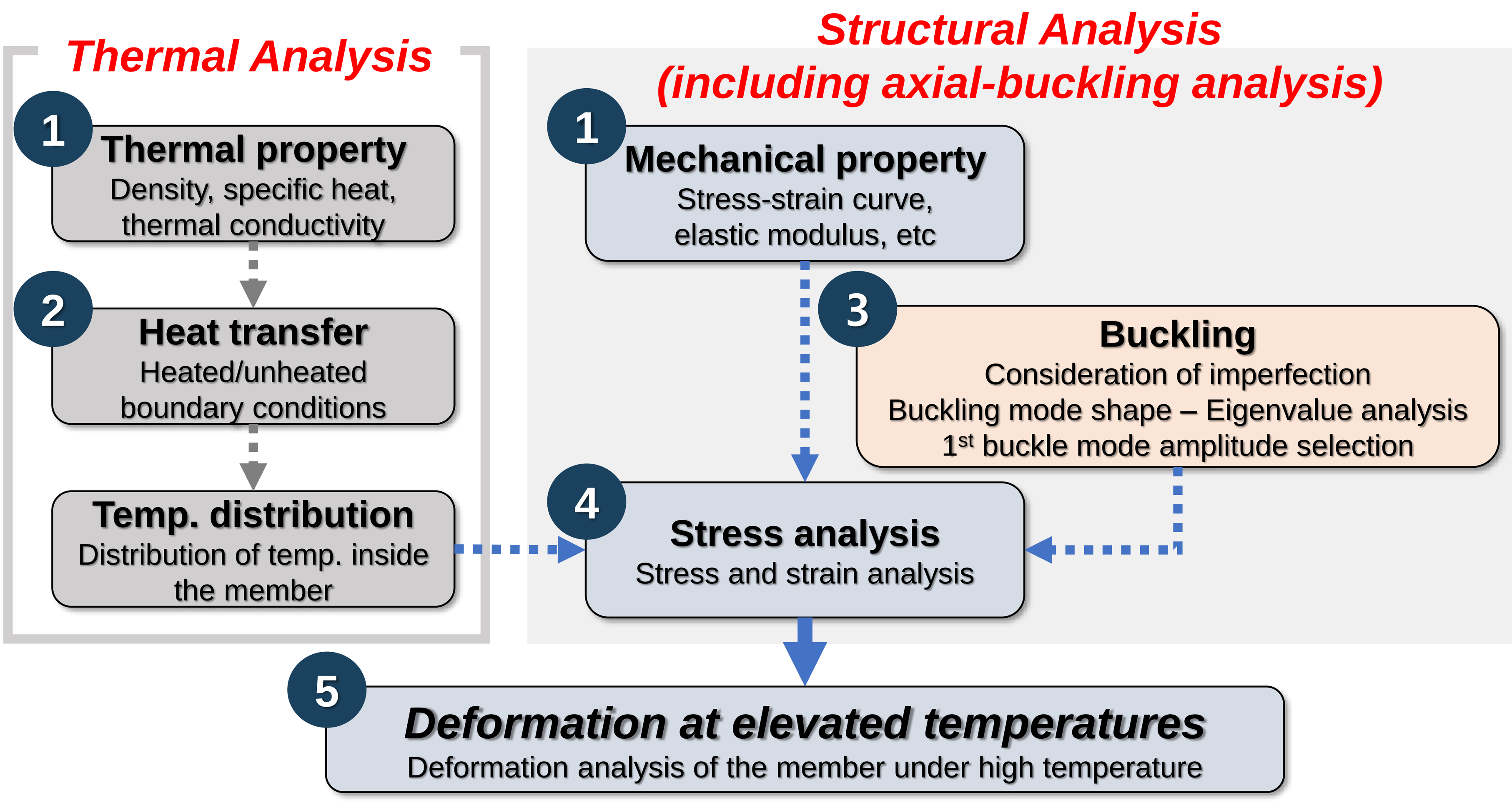
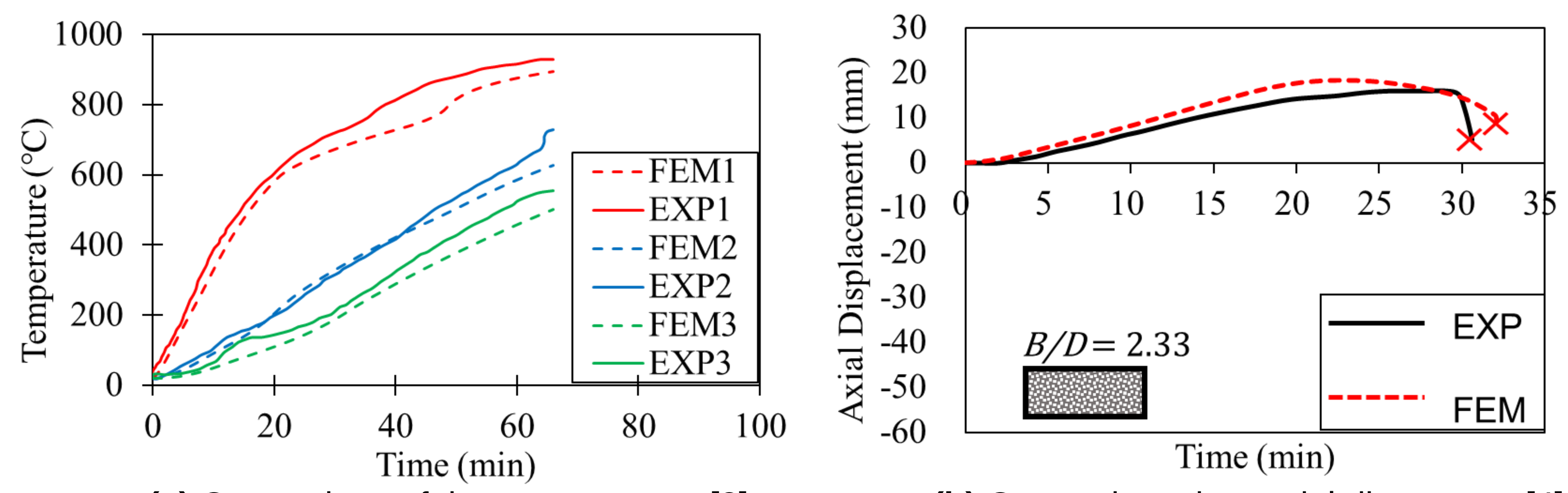


Figure 1. Thermo-mechanical coupled analysis process

- Rectangular CFT columns were modeled and subjected to thermo-mechanical coupled analyses to evaluate their fire performance.
- As shown in Figure 2, the reliability of the finite element analysis was verified by referencing and comparing with temperature and axial displacement curves from previous experimental results. [1-4]



(a) Comparison of time-temp. curve [2] **(b)** Comparison time-axial disp. curve [4]

Figure 2. Partial validation: comparison between experimental (EXP) and Numerical(FEM) results

3. Parametric studies

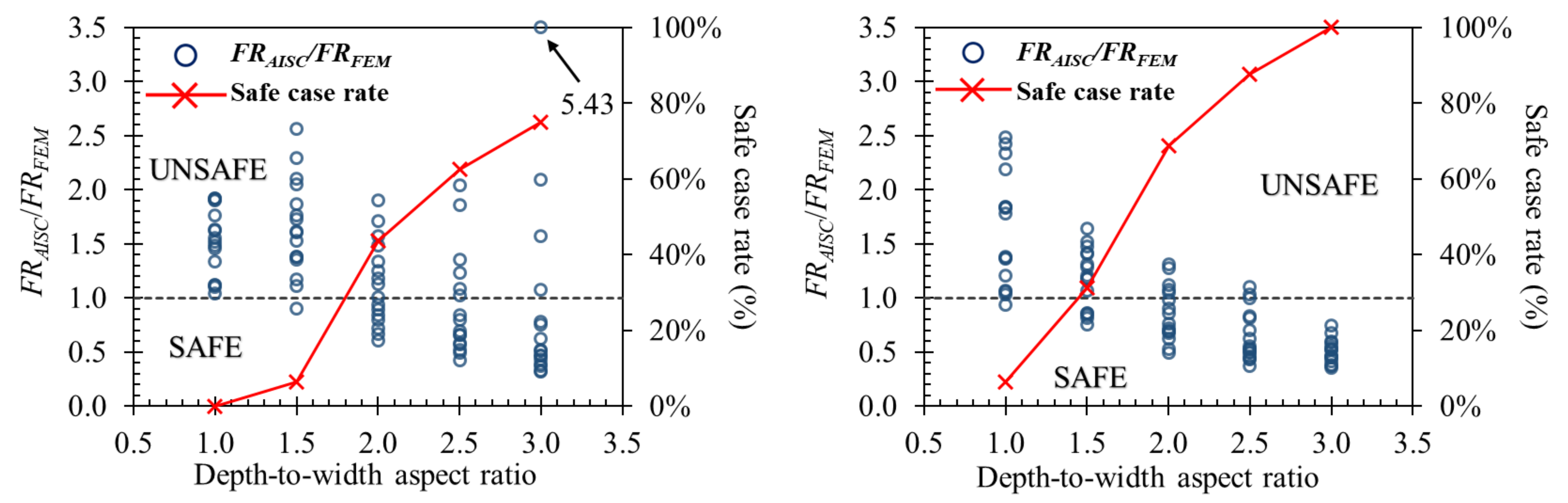
Table 1. Summary or parameters for rectangular CFT columns

Parameters	Symbol	Unit	Range	Description
Depth	B	mm	300 / 400	Long side of rectangular section
Column length	L	mm	3800	Total height of column
Width	D	mm	100~300 / 150~450	Short side of rectangular section
Depth-to-width aspect ratio	B/D	-	1.0~3.0	Sectional aspect ratio (step 0.5)
Thickness of steel tube	t	mm	7 / 10.5	Set to keep the same B/t ratio
Yield strength of steel	f_y	MPa	355	Fixed
Concrete strength	f_c'	MPa	30~60	Compressive strength (step 10 MPa)
Load ratio	n	-	0.3~0.75	Axial load ratio (step 0.15)

- A total of 160 rectangular CFT columns were simulated by varying key parameters such as depth, depth-to-width aspect ratio, concrete strength, and load ratio

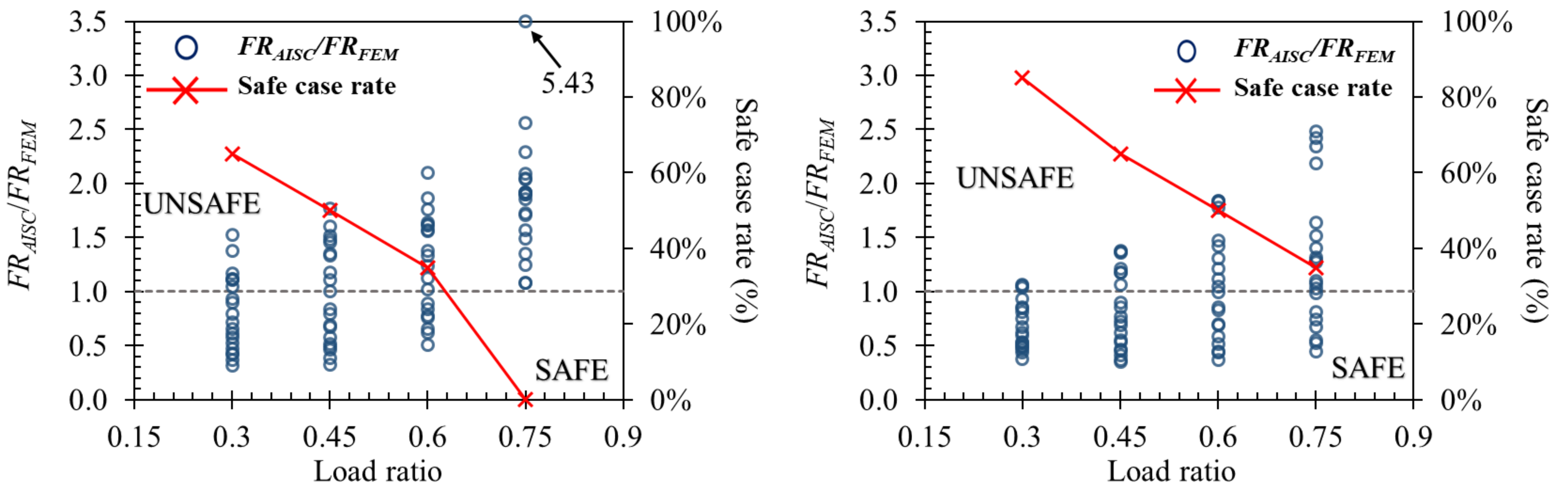
Reference

[1] [2] AISC; Specification for structural steel buildings. American Institute of Steel Construction (AISC): Chicago, IL, USA. 2022;360–22.
[2] Lie TT, Chabot M. Experimental studies on the fire resistance of hollow steel columns filled with plain concrete. NRC-CNRC Internal Report No. 611. Canada; 1992.
[3] Espinos A, Romero ML, Serra E, Hospitaler A. Experimental investigation on the fire behaviour of rectangular and elliptical slender concrete-filled tubular columns. Thin Walled Struct. 2015;93:137–48.
[4] Han LH, Yang YF, Xu L. An experimental study and calculation on the fire resistance of concrete-filled SHS and RHS columns. J Constr. Steel Res. 2003;59:427–52.
[5] Yang H, Liu F, Gardner L. Performance of concrete-filled RHS columns exposed to fire on 3 sides. Eng. Struct. 2013;56:1986–2004.



(a) B: 300 mm **(b)** B: 450 mm

Figure 3. Comparison between FR_{FEM} and FR_{AISC} according to the influence of B/D



(a) B: 300 mm **(b)** B: 450 mm

Figure 4. Comparison between FR_{FEM} and FR_{AISC} according to the influence of n

- Among the four types of parameters considered, B/D and n had the most significant influence on the FR of rectangular CFT columns

4. Proposed equation vaildation

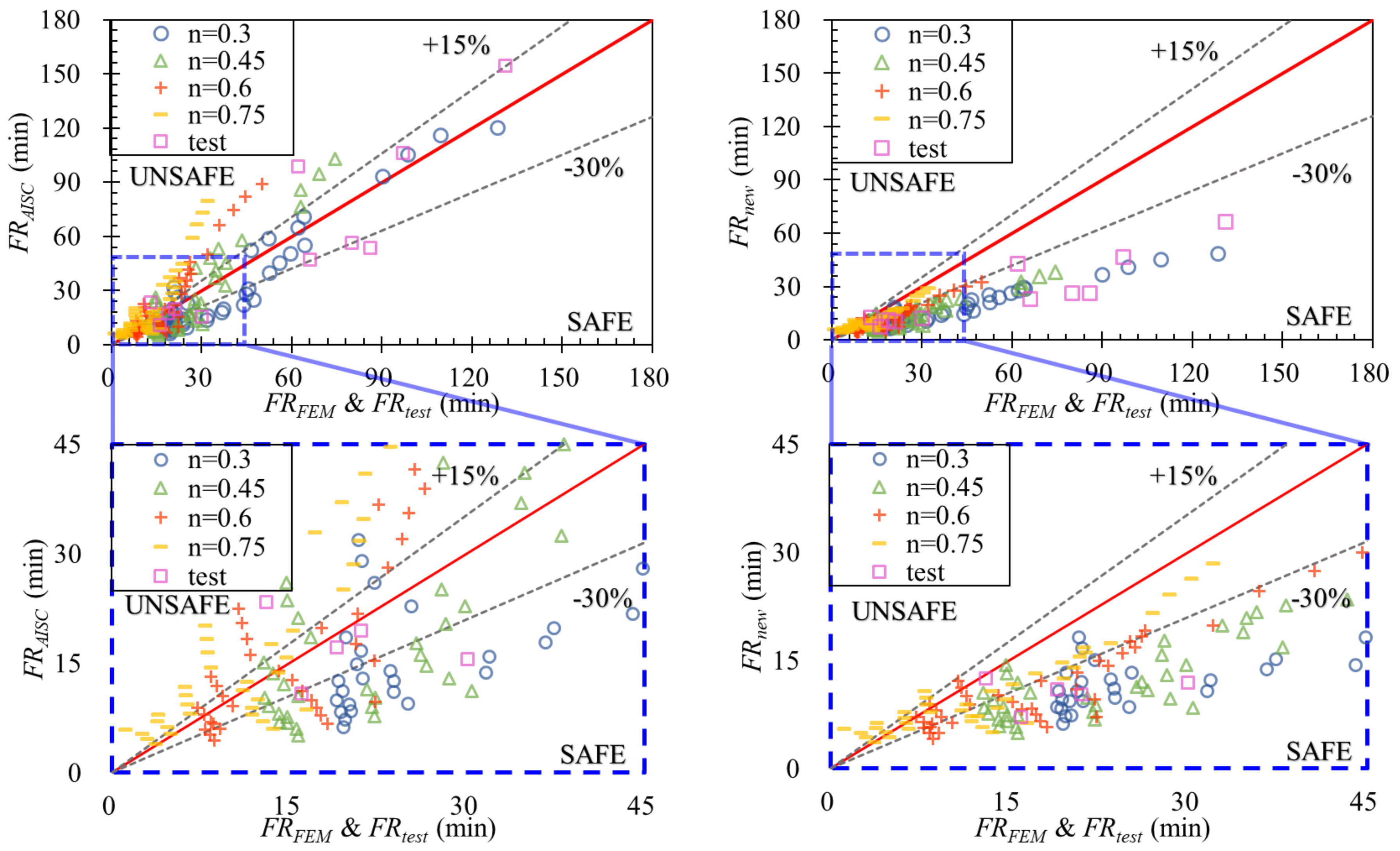
$$FR_{AISC} = \frac{a(f'_c+20)D^2\left(\frac{D}{C}\right)^{0.5}}{60(L_c-1000)} \quad \text{Eq. (1)}$$

$$FR_{new} = \frac{a(f'_c+20)D'}{60(L_c-1000)C^{0.58}} \quad \text{Eq. (2)}$$

$$D' = B^{0.63}\times D^{1.82} \quad \text{Eq. (3)}$$

FR_{AISC} = Fire resistance using AISC 360-22
FR_{new} = Fire resistance using Proposed equation
C = compressive force due to unfactored dead and live load (kN)
D = outside width of the column (mm)
L_c = column effective length (mm)
a = accounts for the type of aggregate mixed (carbonate or siliceous), percentage of reinforcement, the thickness of the concrete cover, and shape of the steel tube (circular or square)
f'_c = Compressive strength of concrete (MPa)
D' = Equivalent cross-sectional dimension
B = outside depth of the column (mm)

- Eq. (2) and (3) were proposed by incorporating the effects of load ratio and depth-to-width aspect ratio



(a) Using the AISC Eq. (1) **(b)** Using the proposed Eq. (2-3)

Figure 5. Comparison between FR and FR_{FEM} & FR_{test}

- Based on the red line criterion, the safe case rate was 49% for Eq. (1) and 90% for Eq. (2), indicating that the proposed equation evaluates the fire resistance performance of rectangular CFT columns more conservatively and reliably than the AISC equation.

5. Conclusion

- The results of the thermo-mechanical coupled analysis confirmed that the FEM model proposed in this study is reliable.
- The parametric studies showed that B/D and n had a significant influence on the fire resistance of rectangular CFT columns.
- The proposed equation provides more conservative and consistent fire resistance predictions compared to the AISC equation.