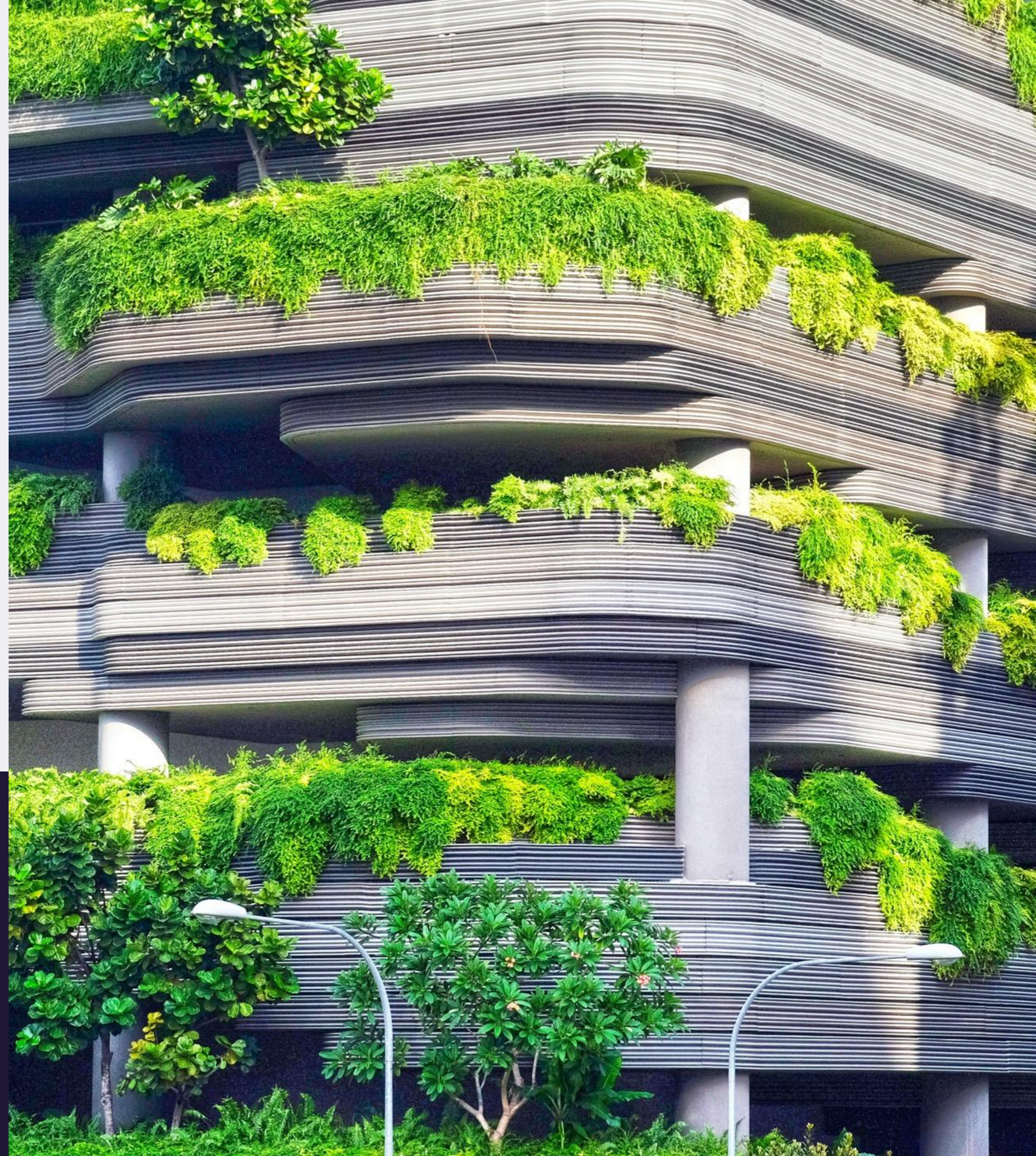




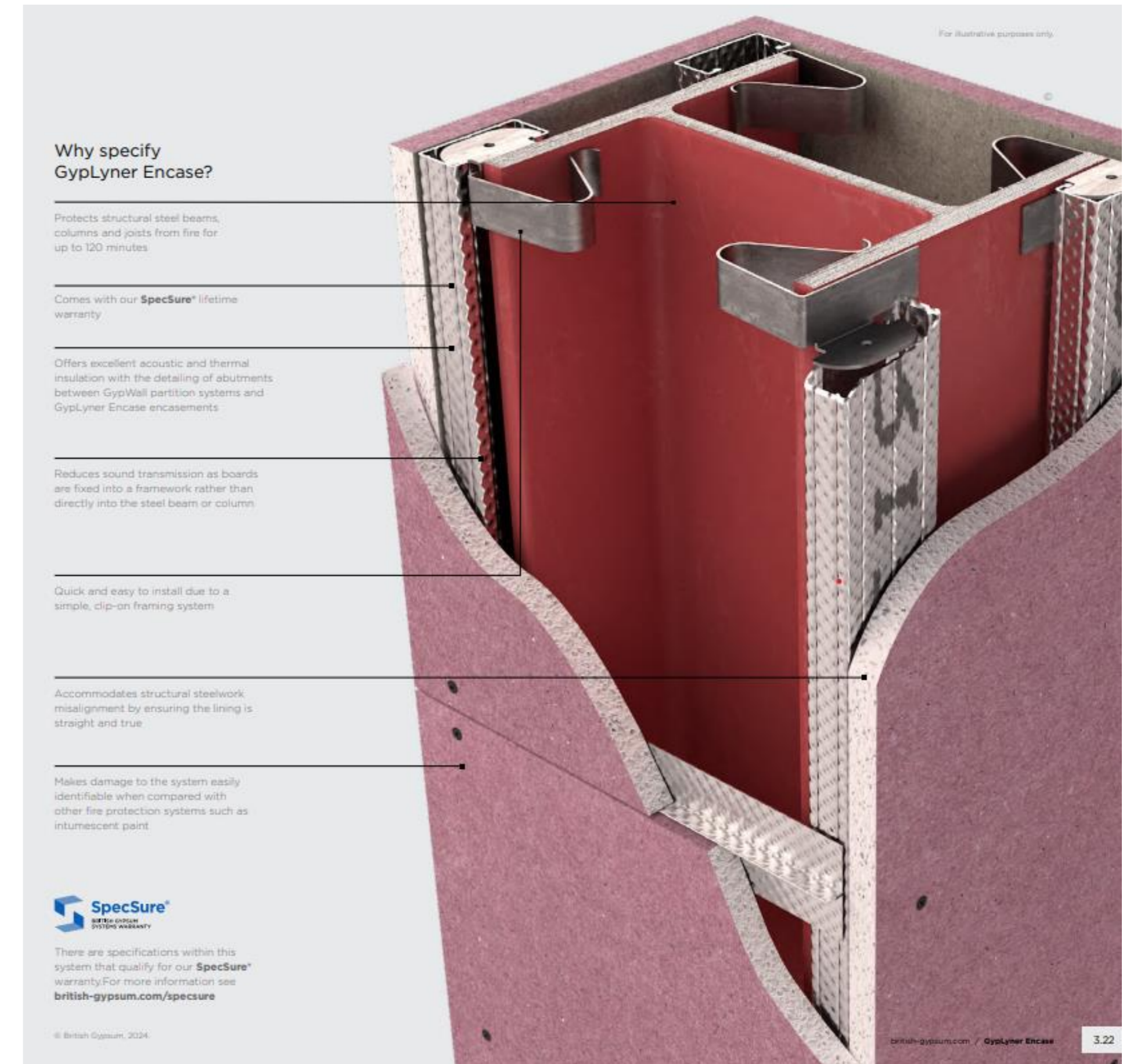
# Fire Resistance Tests and Analysis of Plasterboard-Encased Steel Columns under Standard Conditions

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PhD, CEng, MIFireE



# Overview

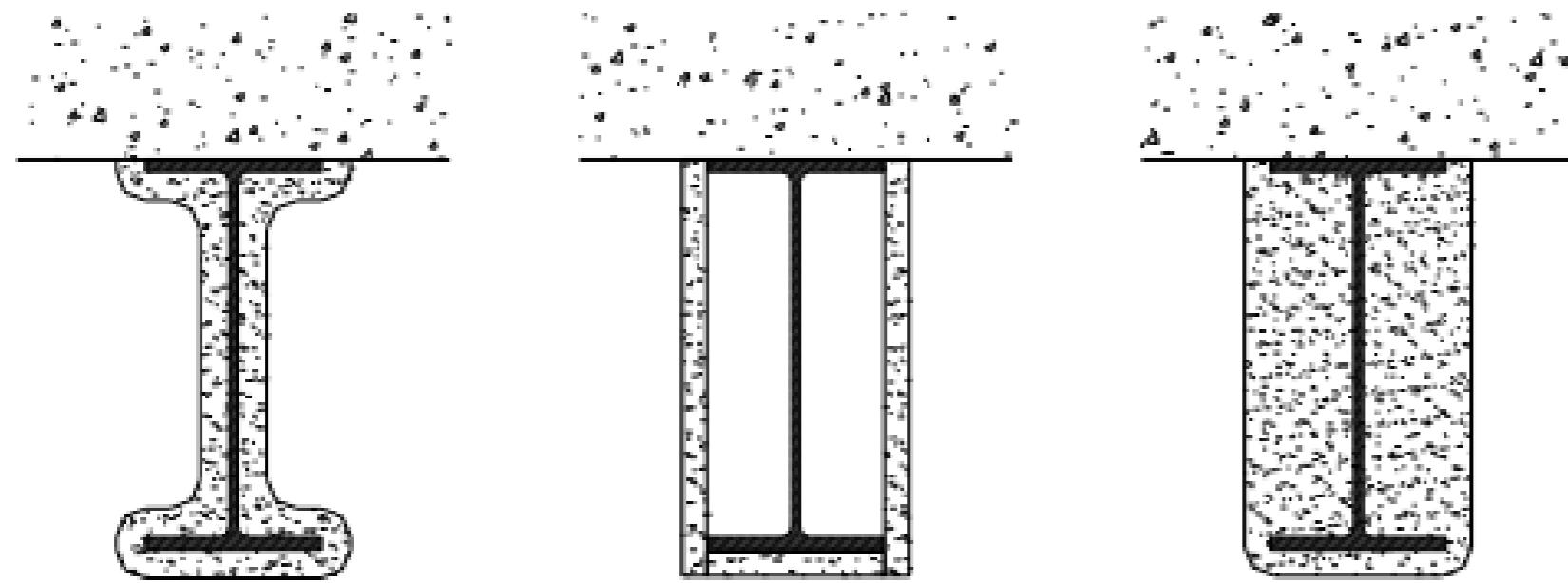
- Introduction to fire protection methods
- Fire resistance testing of steel columns
- 60 minutes solutions
- 120 minutes solutions
- Fall-off temperature of type F plasterboard
- Future research directions
- Conclusions



Plasterboard encasement of a steel column – White book GypLyner Encase

# Introduction to fire protection methods

## Protection methods for beams



**Profile**

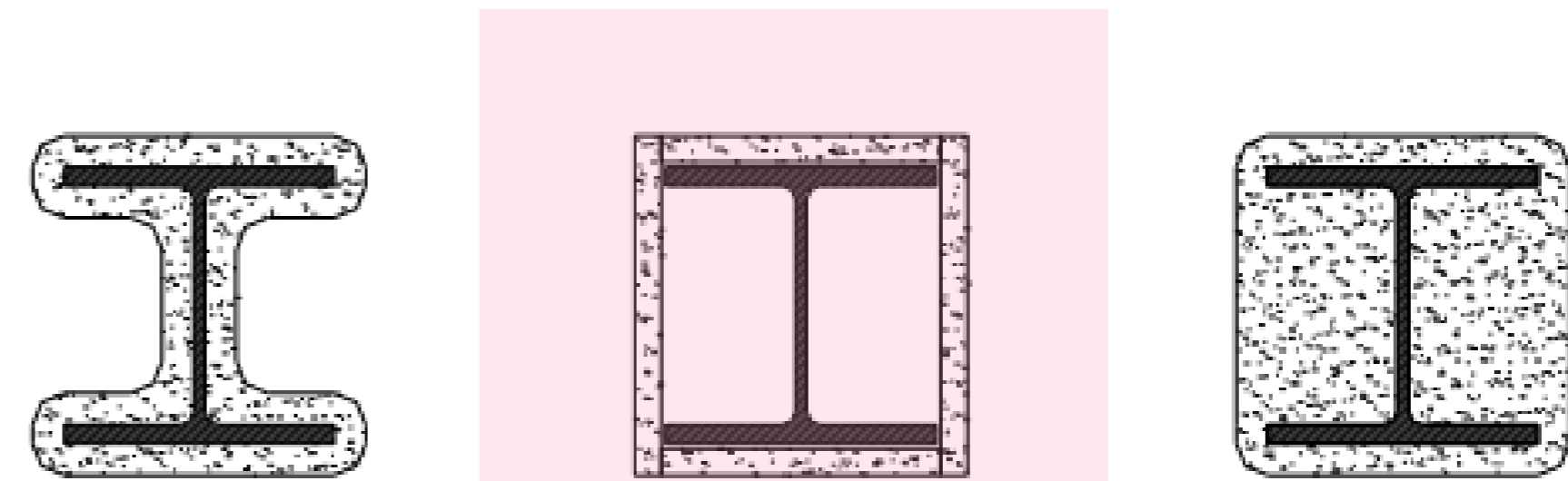
**Box**

**Solid**

(with or without gap over flanges)

**Figure 2 - Protection technique for three-sided protection**

## Protection methods for columns



**Profile**

**Box**

**Solid**

(with or without gap over flanges)

**Figure 3 - Protection technique for four-sided protection**

# Introduction to fire protection methods

## Fire resistance tests for tension members

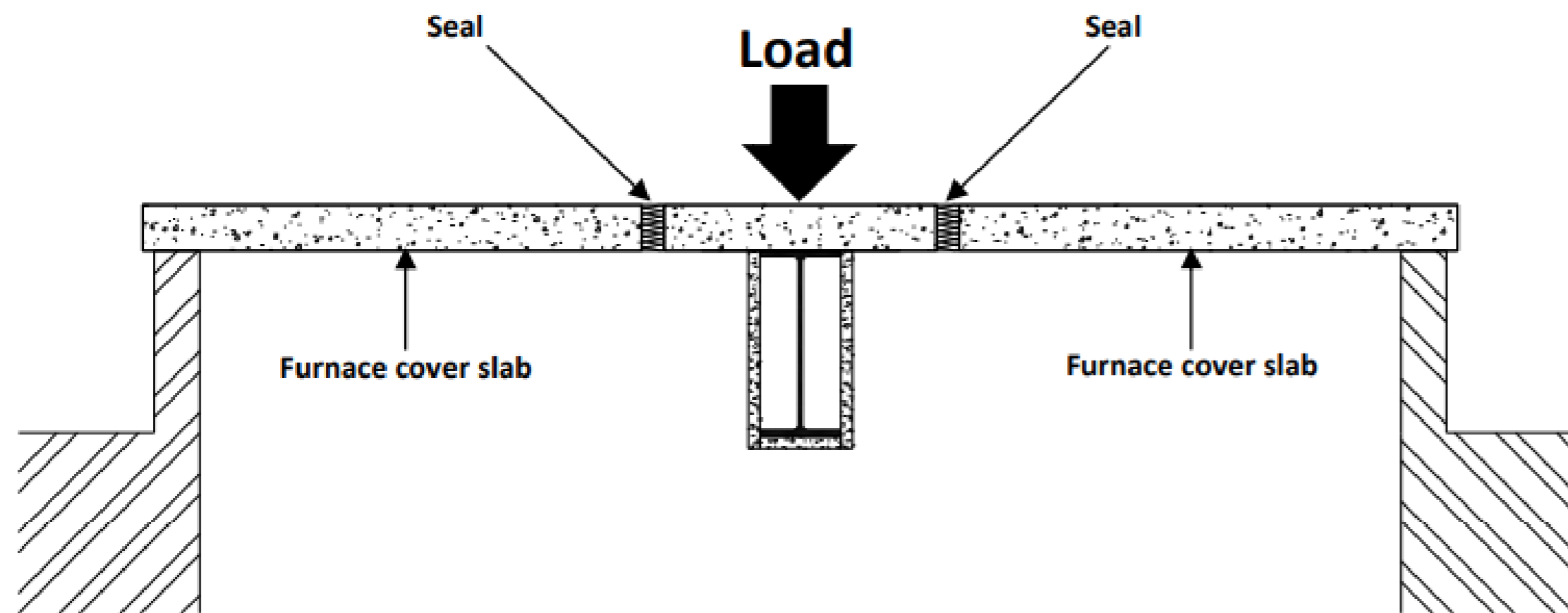


Figure 4 - General arrangement for fire tests on beams (in this instance protected with a board)

- Loadbearing capacity (R) is deemed to be maintained as long as the structural member continues to sustain the load applied in the test without exceeding defined limits of deflection, rate of deflection, instability or collapse.

## Fire resistance tests for compression members

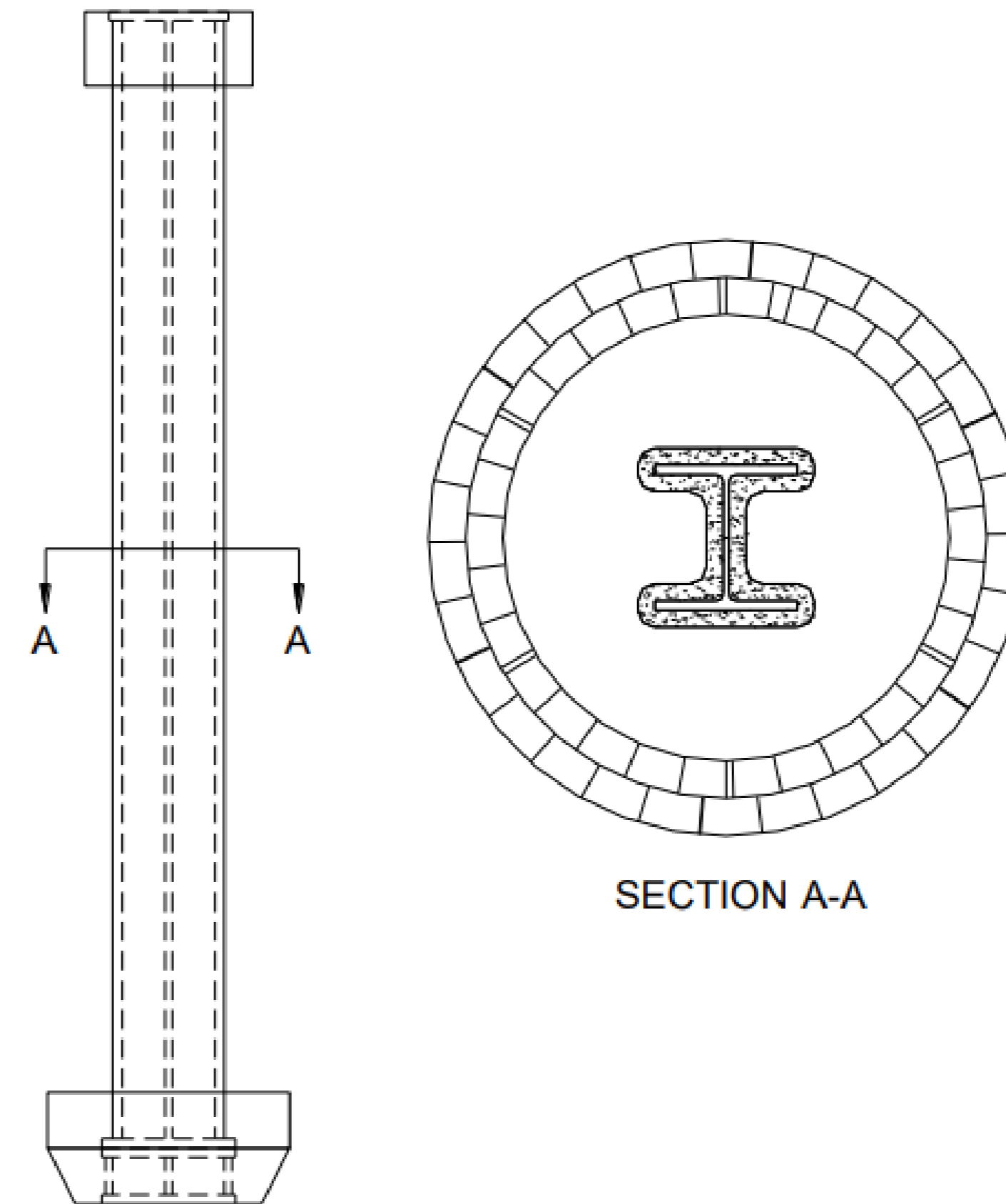


Figure 5 - General arrangement for fire tests on loaded columns

# Introduction to fire protection methods

## Section factor for profile protection

Steel section	Profile protection				
Universal beams, universal columns and joists (plain and castellated)  $H_p$	4 sides	3 sides	3 sides Partially exposed	2 sides	1 side Partially exposed
	$2B + 2D + 2(B - t) = 4B + 2D - 2t$	$B + 2D + 2(B - t) = 3B + 2D - 2t$	$B + 2d + (B - t) = 2B + 2d - t$	$B + D + 2(B - t)/2 = 2B + D - t$	$B$

## Section factor for box protection

Steel section	Box and solid protection				
Universal beams, universal columns and joists (plain and castellated) $H_p$	4 sides	3 sides	3 sides Partially exposed	2 sides	1 side Partially exposed
	$2B + 2D$	$B + 2D$	$B + 2d$	$B + D$	$B$

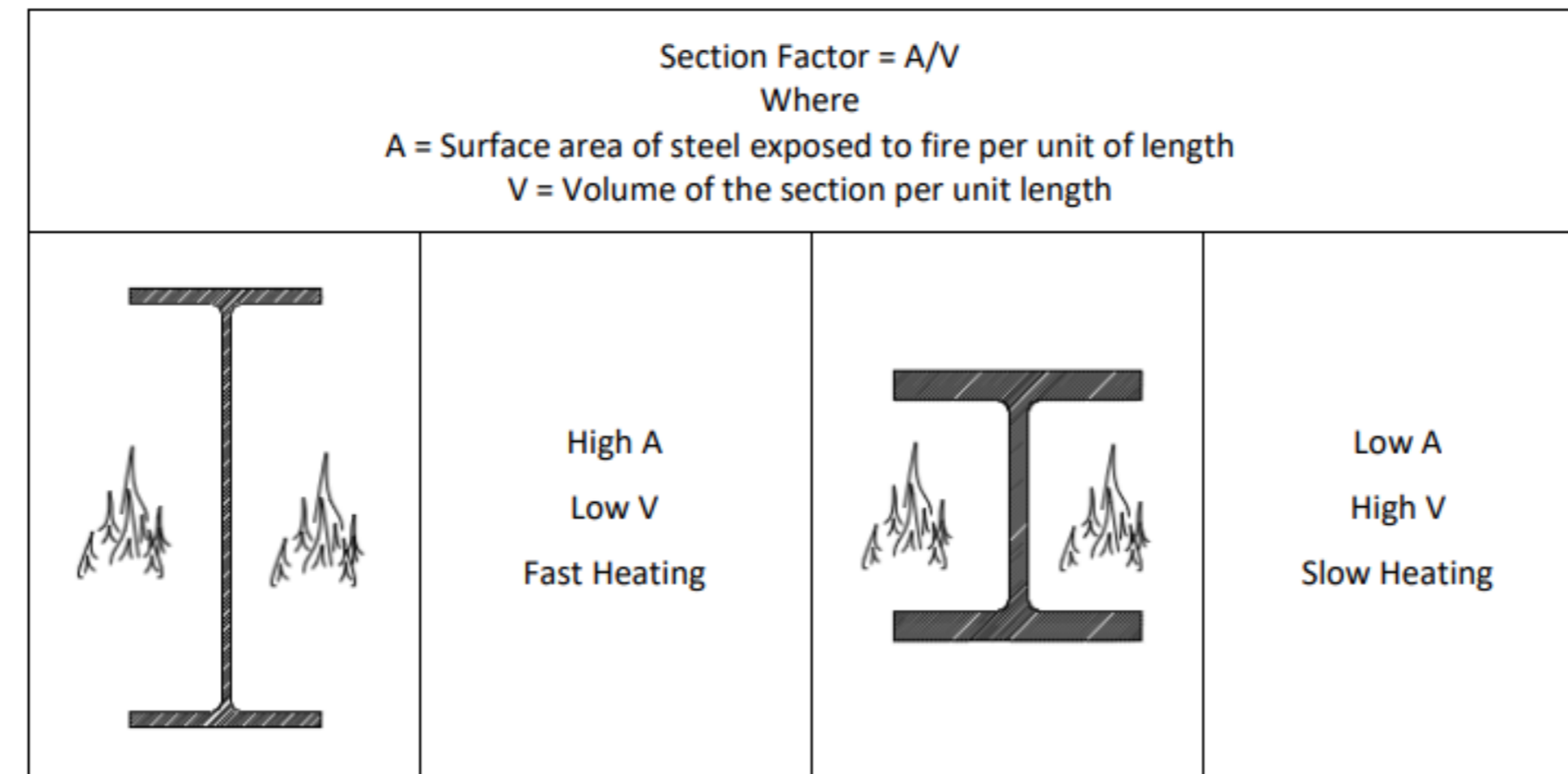
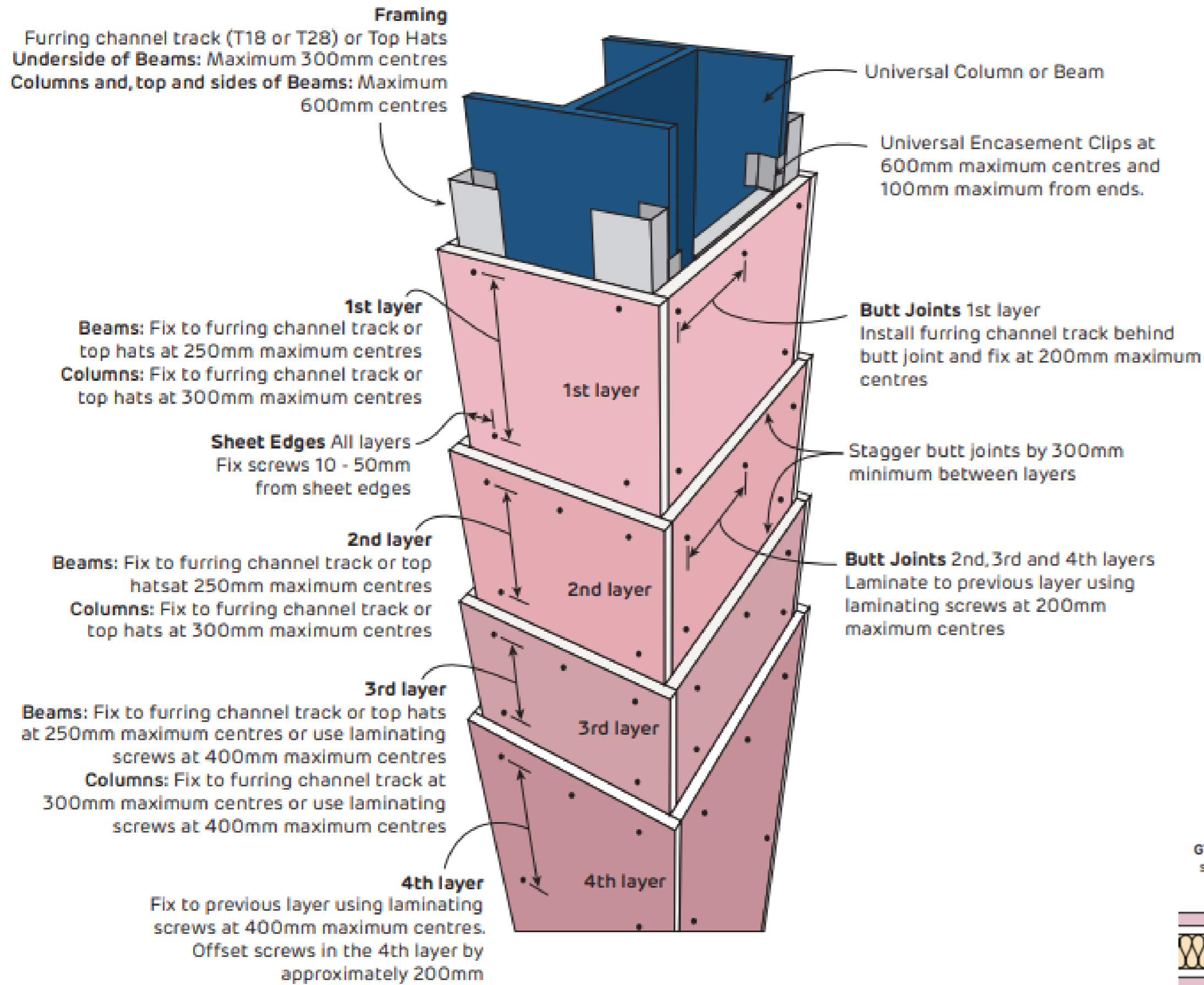


Figure A.1 – Concept of section factor

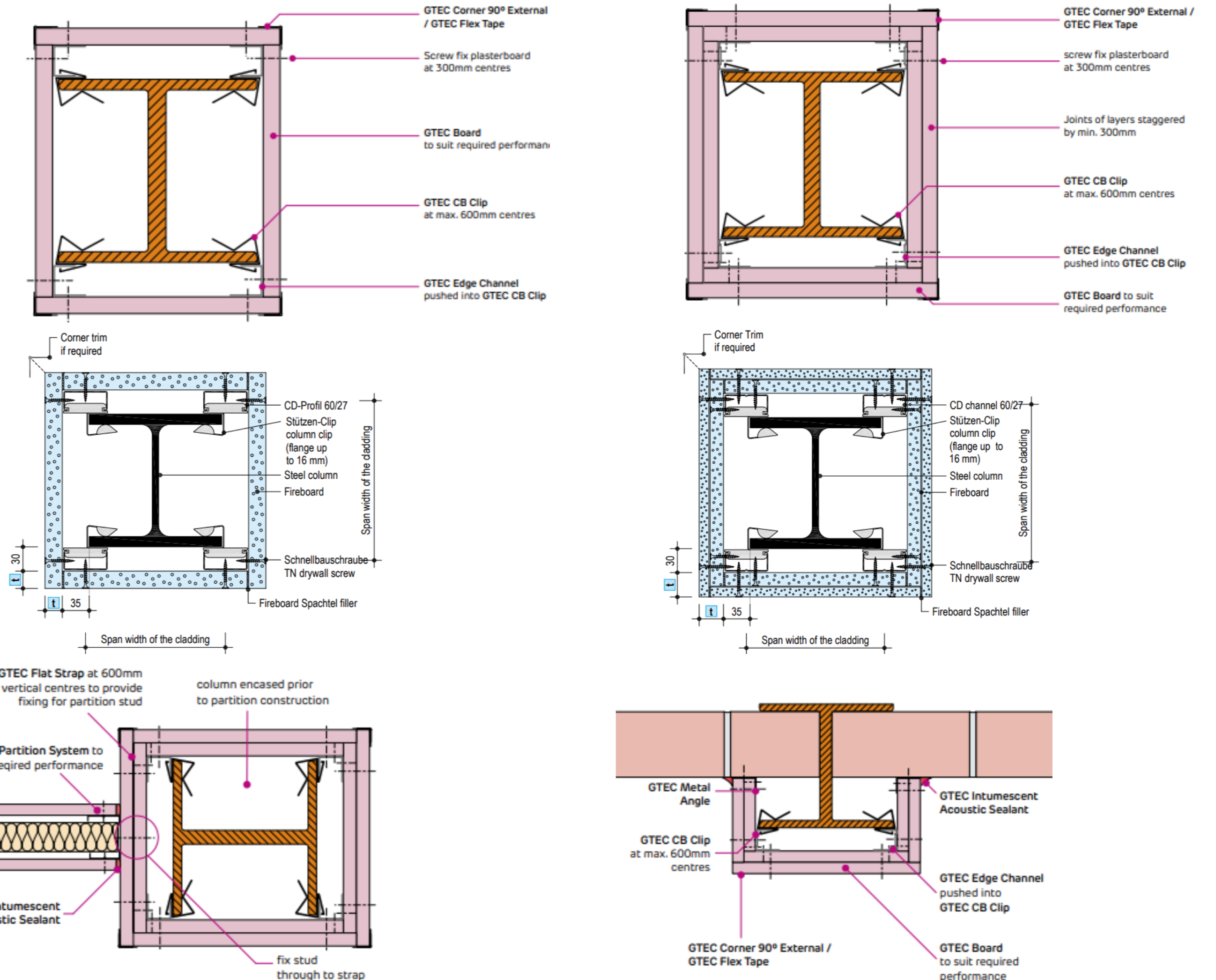
- High  $A/V$  – fast heating;
- Low  $A/V$  – slow heating;
- Unprotected steel sections with low  $A/V$  and low load ratios can achieve 15-30 minutes fire resistance;

# Introduction to fire protection methods

## Box protection to a steel column



## Section through a boxed protection using one or two layers of type F plasterboard



Reference:

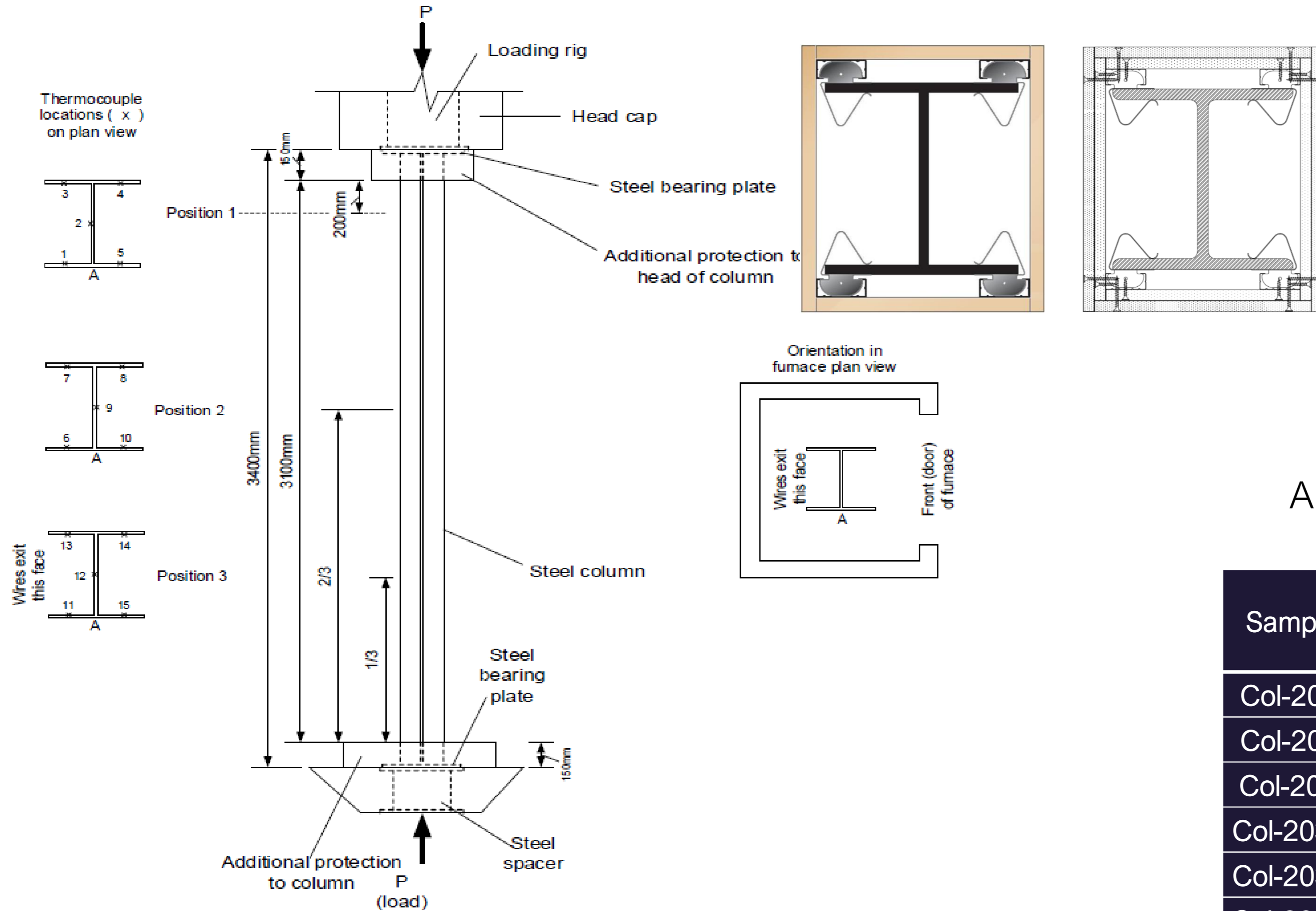
SINIAT Blueprint v3\_2022 March Section 6.4 Column and Beam Fire Protection  
 White Book – GypLyner Encase

# Fire resistance testing of steel columns

Column furnace

1 x 15mm and 2 x 15mm Type F

Fire resistance test parameters



Sample Ref.	Moisture content (%)	Dry weight (kg/m <sup>2</sup> )	Density (kg/m <sup>3</sup> )
Sample 60A	0.50	12.87	858
Sample 60B	0.49	12.90	860
Sample 60C	0.56	11.87	791.3
Sample 120A	0.40	12.66	844
Sample 120B	0.44	12.78	850
Sample 120C	0.40	12.95	863

Applied load and protection to the steel columns

Sample Ref.	Column capacity N <sub>Rd,fi</sub> (kN)	Load Ratio μ <sub>fi</sub> (-)	Applied Load N <sub>Ed,fi</sub> (kN)	Protection (mm)
Col-203-60A	1890.9	0.66	1248	15
Col-203-60B	1847	0.60	1108	15
Col-203-60C	1847	0.60	1108	15
Col-203-120A	1890.9	0.66	1248	2×15
Col-203-120B	1847	0.60	1108	2×15
Col-203-120C	1847	0.60	1108	2×15

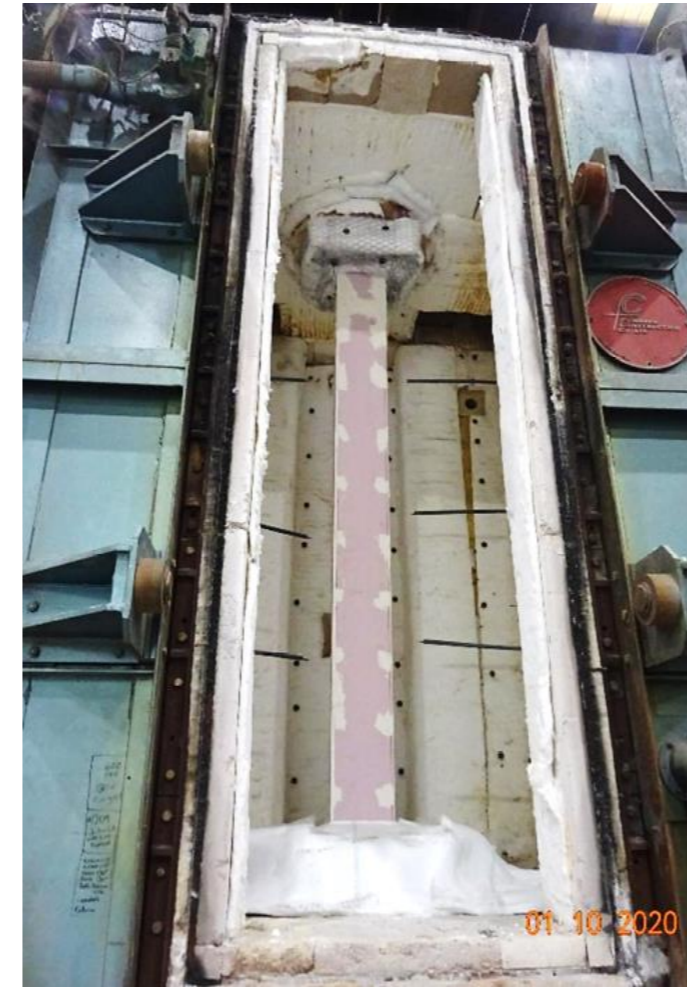
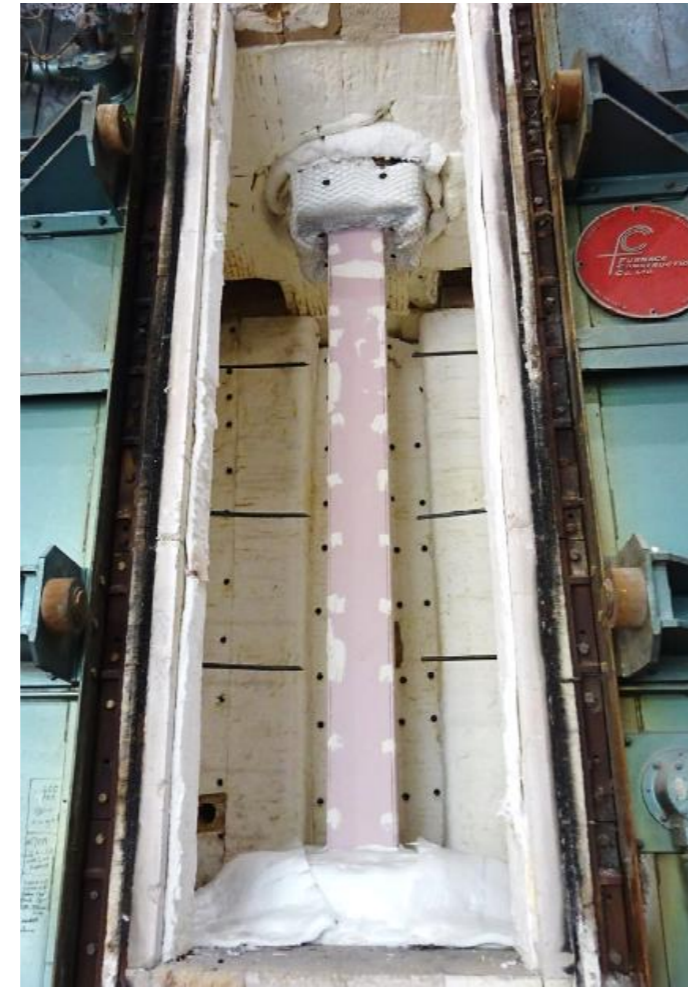
# Fire resistance testing of 60 minutes solutions

Sample 60A

Sample 60B

Sample 60C

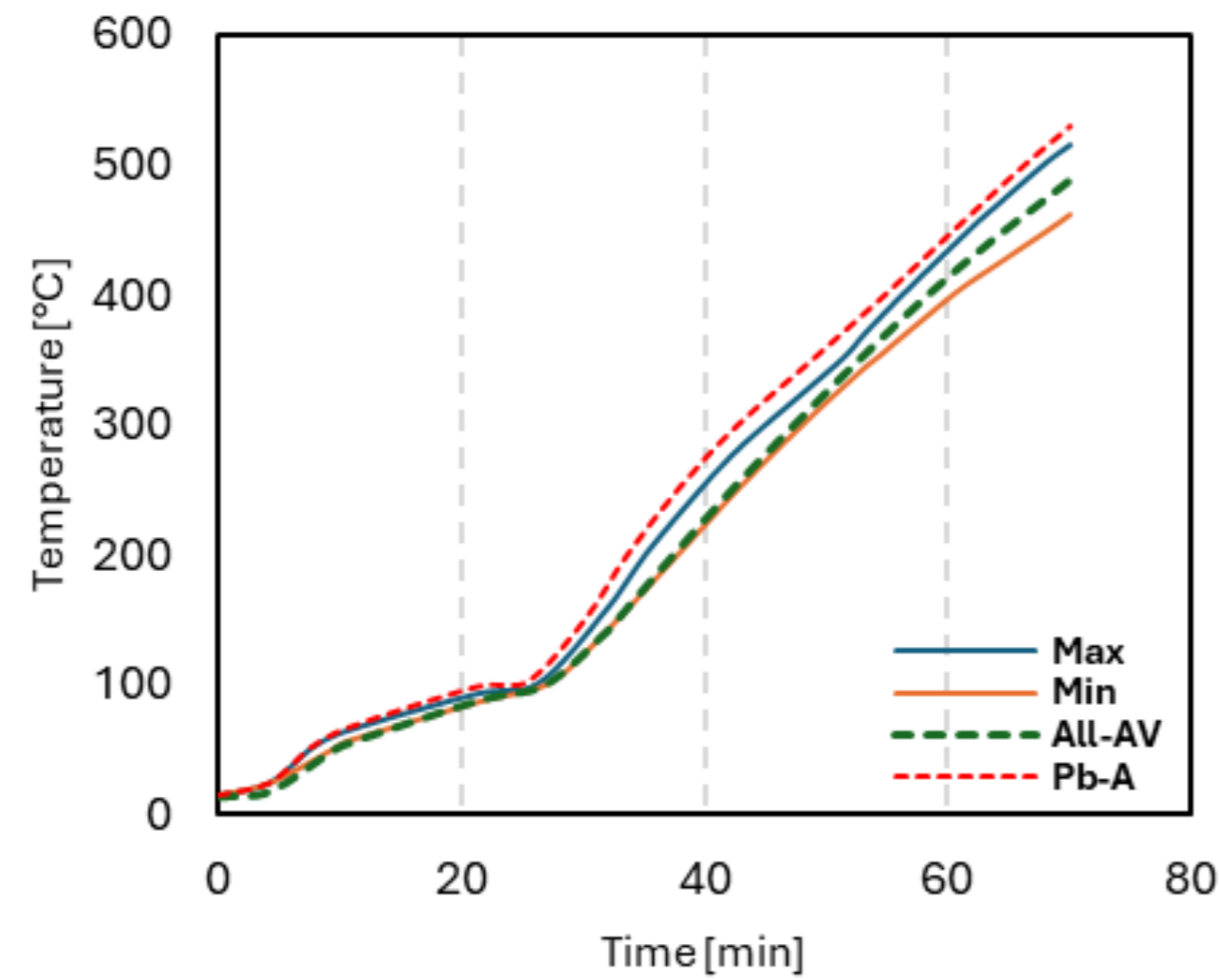
Failure time and mechanisms



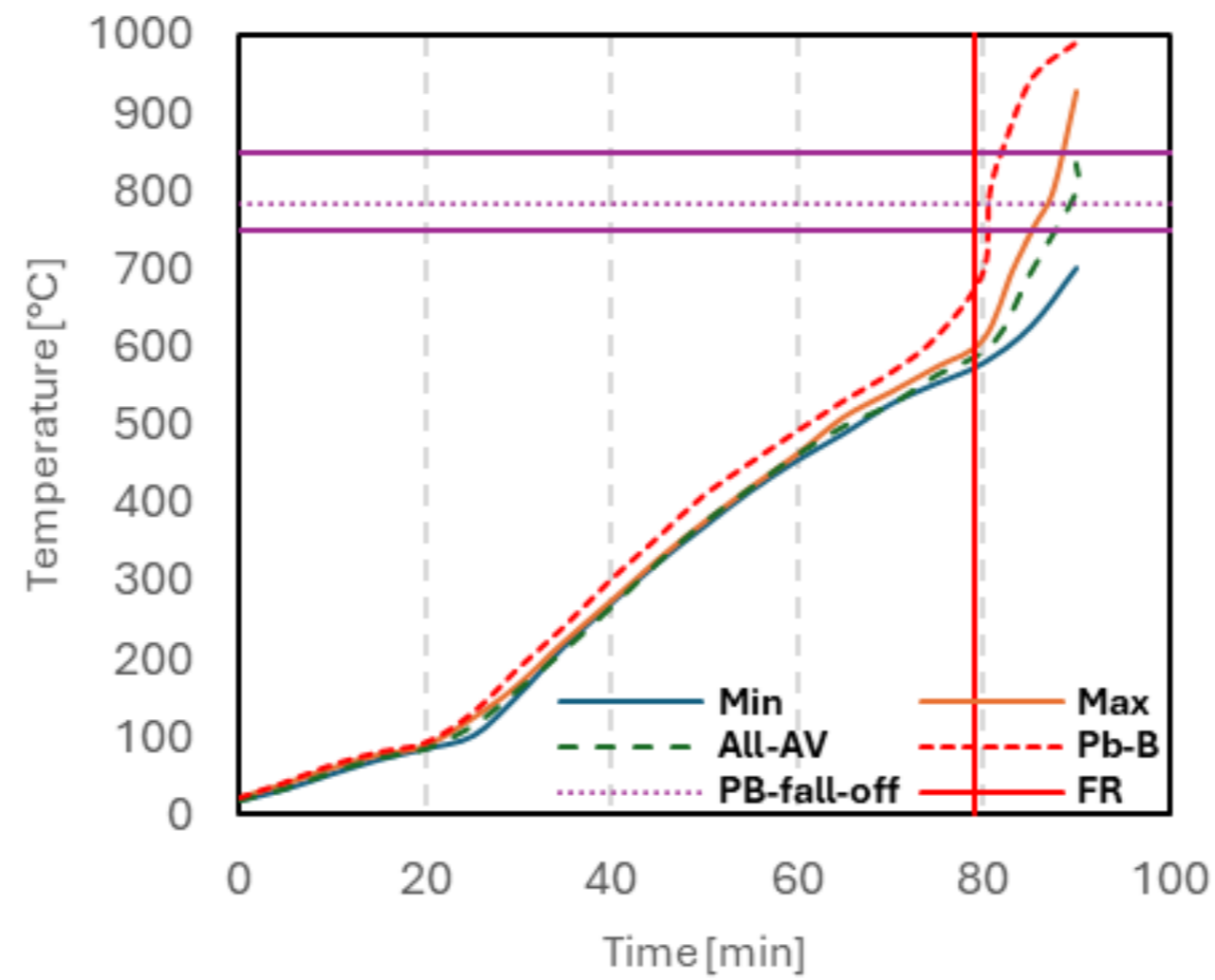
Sample	Fire exposure (min)	Failure time (min)	Failure mechanism
Col-203-60A	66	-	No failure – test stopped
Col-203-60B	91	79	Combination of flexural and distortional buckling
Col-203-60C	101	77	Flexural buckling

# Results for 60 minutes solutions

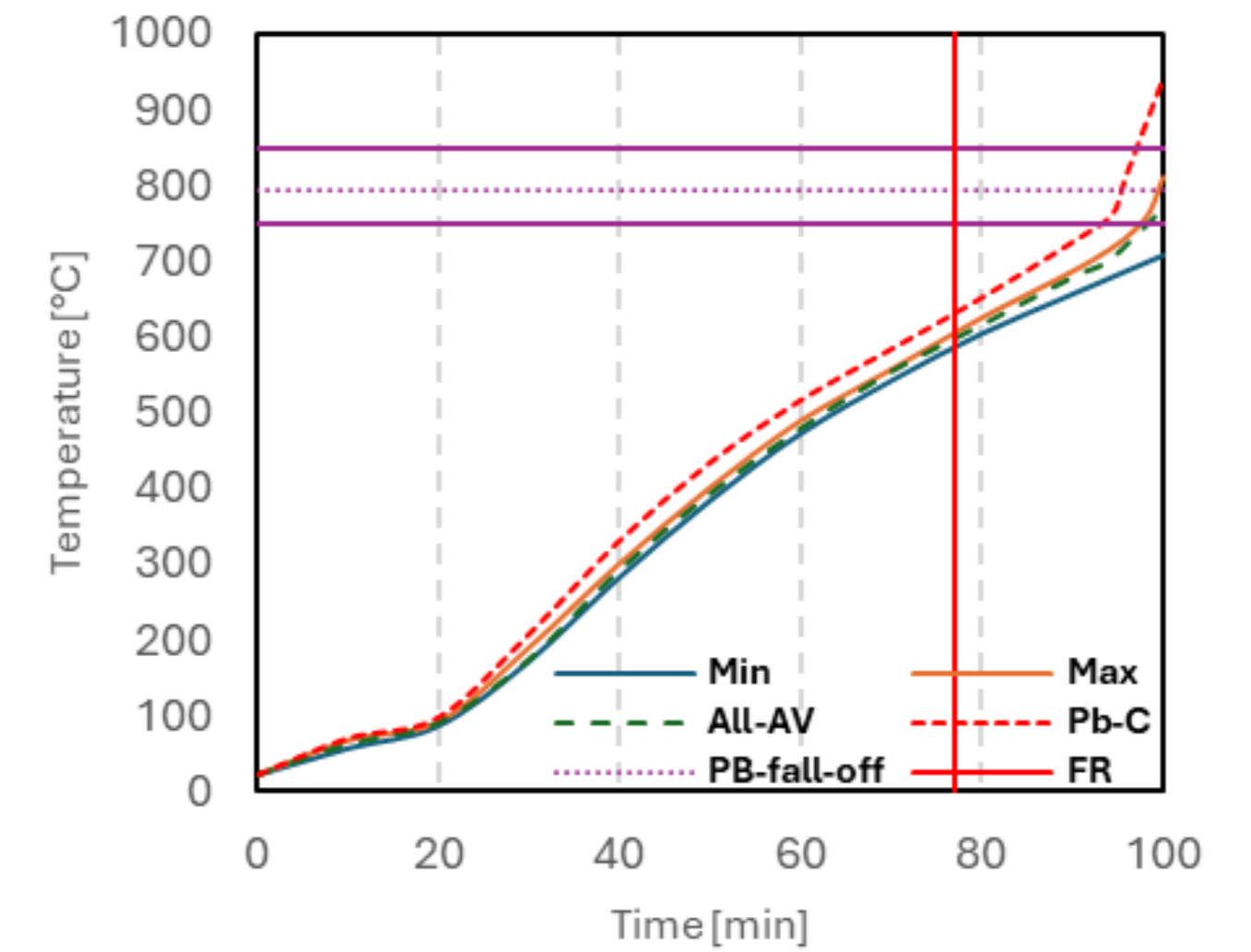
Sample 60A



Sample 60B



Sample 60C



Sample	R-fail (min)	PB-failure time (min)	PB-fail temp. (°C)
Col-203-60A	No failure	-	-
Col-203-60B	79	81	785
Col-203-60C	77	94	795

# Fire resistance testing of 120 minutes solutions

Sample 120A

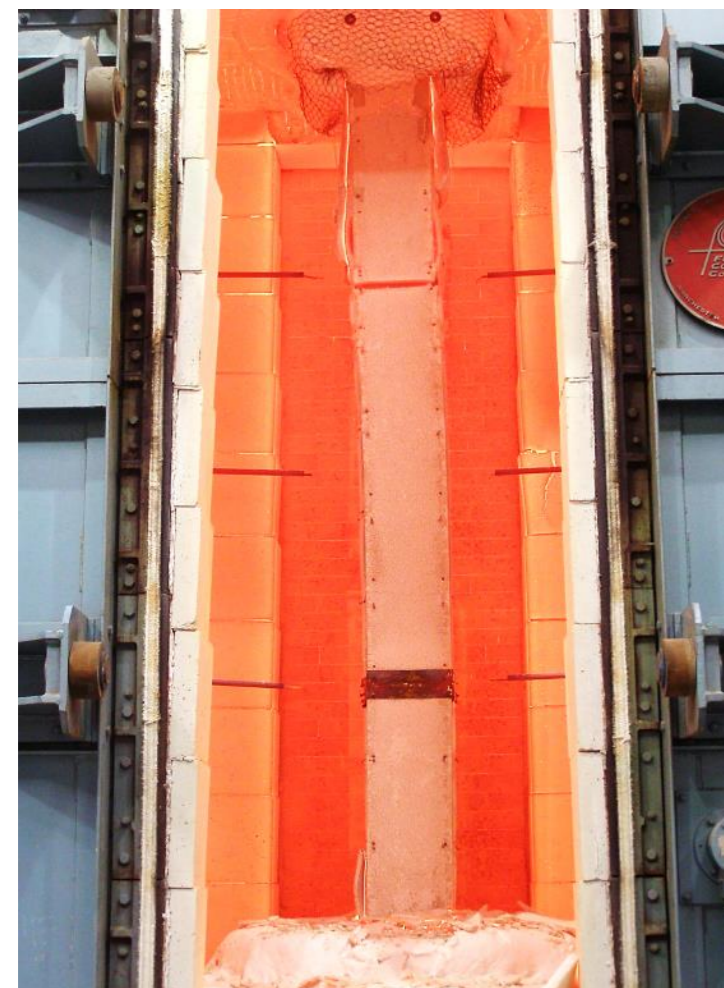
Sample 120B

Sample 120C

Failure time and mechanisms

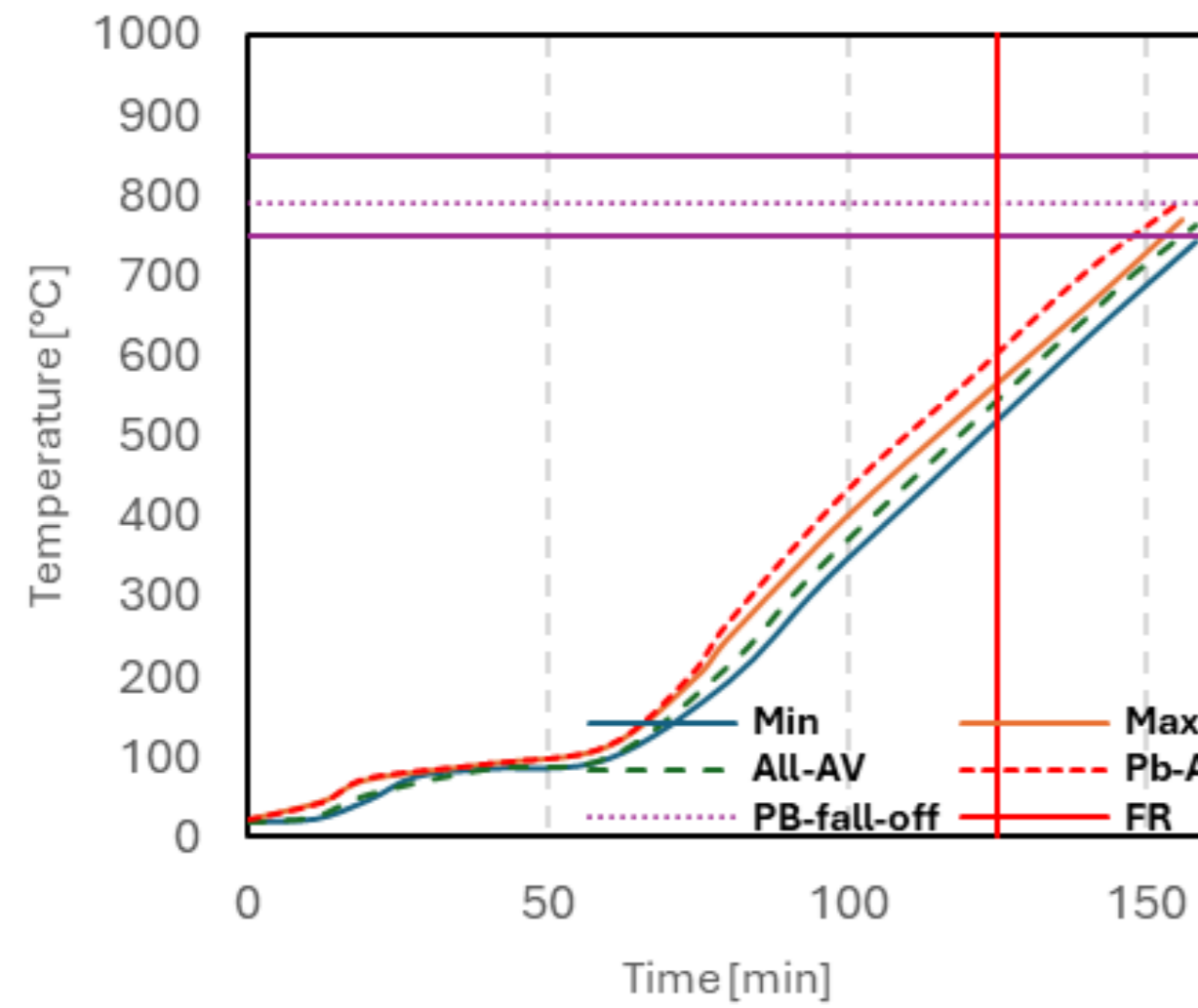


Sample	Fire exposure (min)	Failure time (min)	Failure mechanism
Col-203-120A	158	126	Flexural buckling
Col-203-120B	150	131	Combination of local and flexural buckling
Col-203-120C	150	136	Flexural buckling

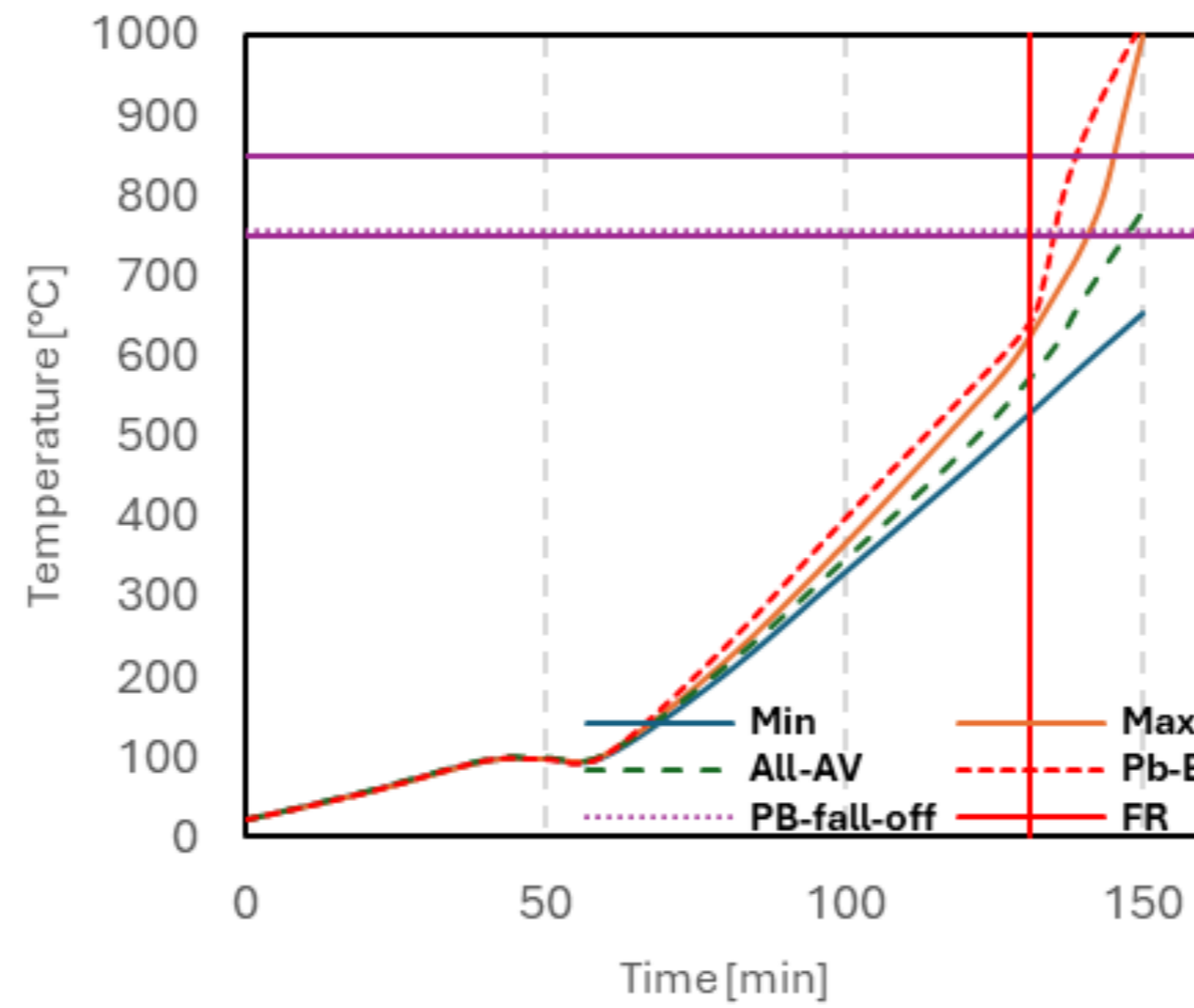


# Results for 120 minutes solutions

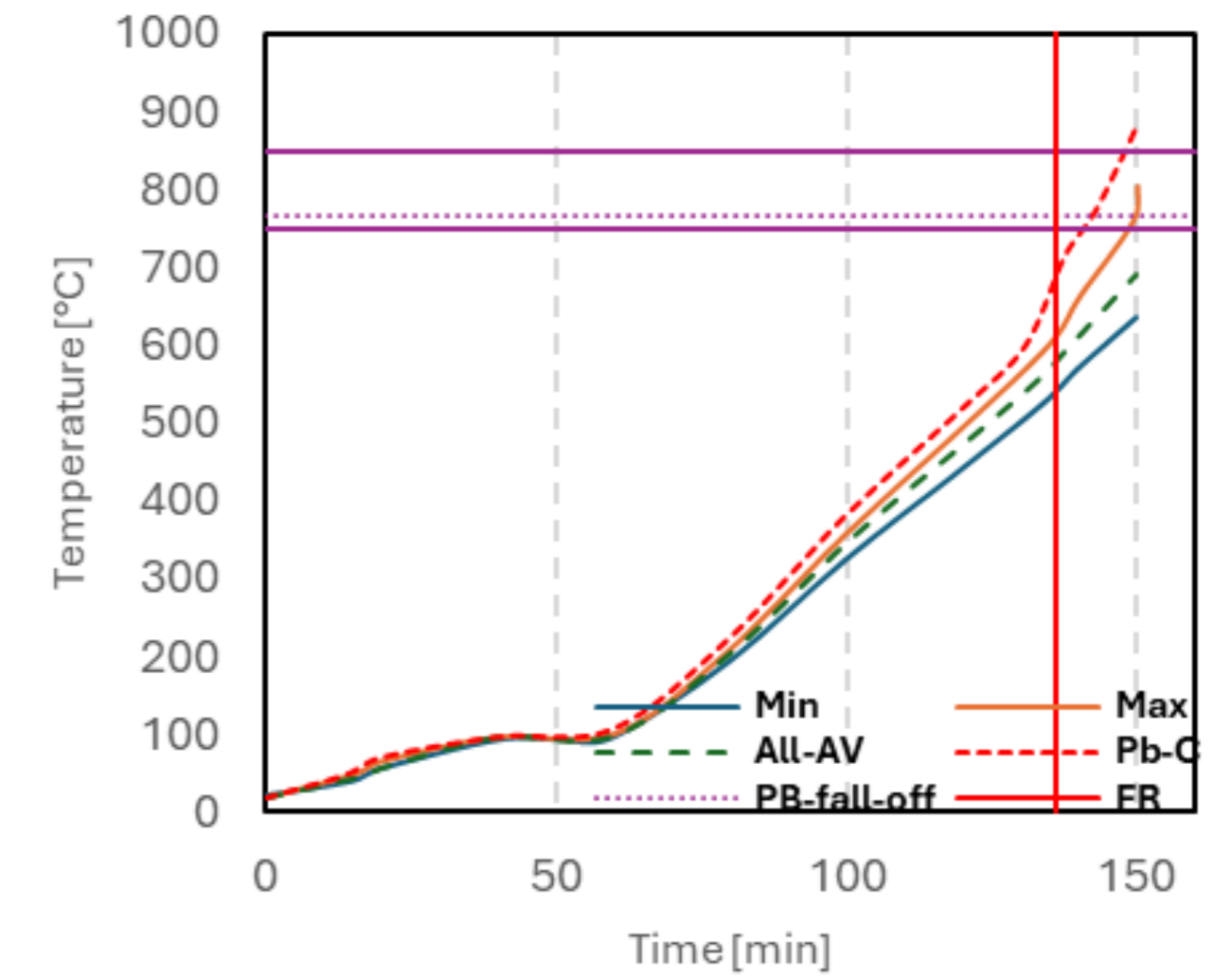
Sample 120A



Sample 120B



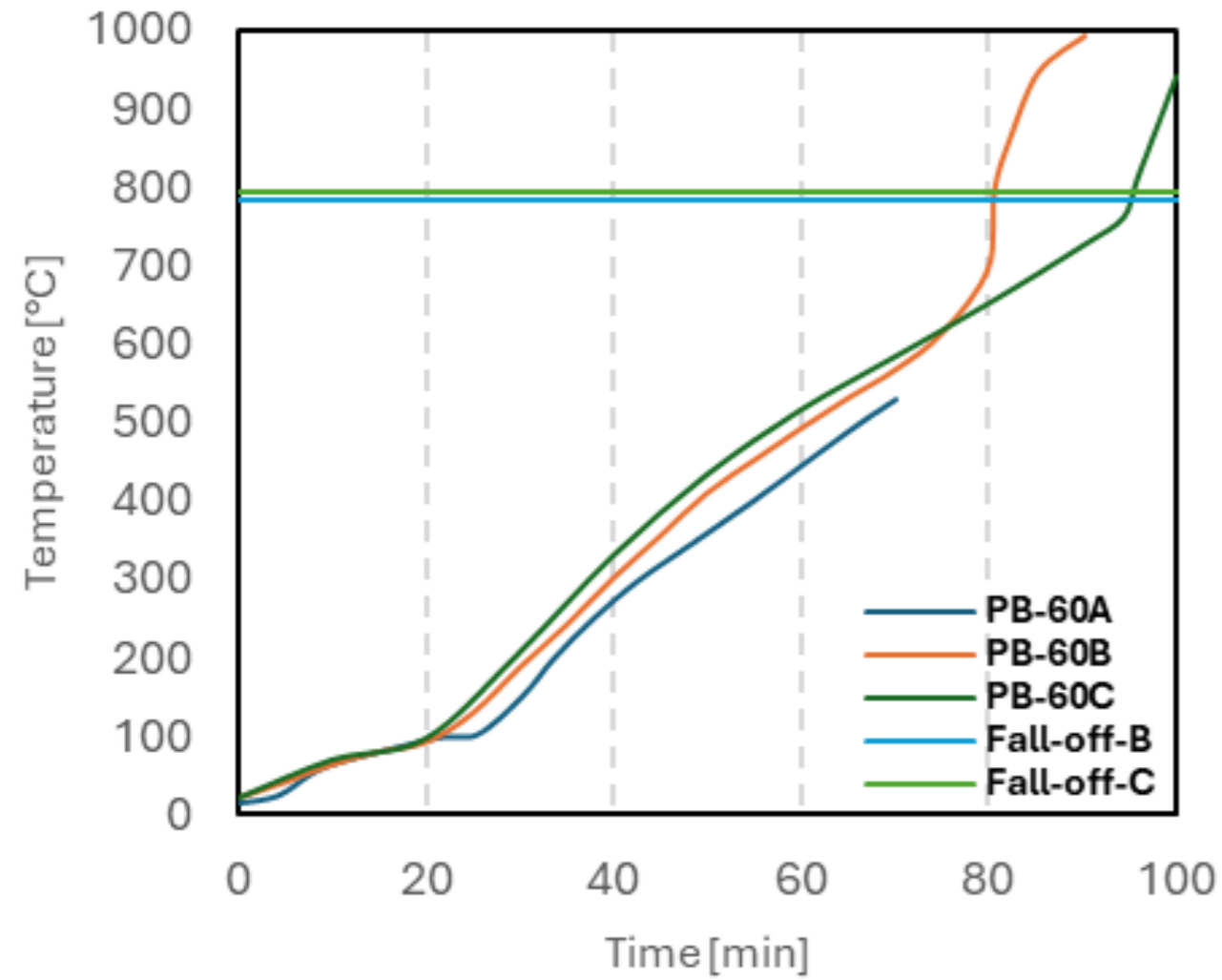
Sample 120C



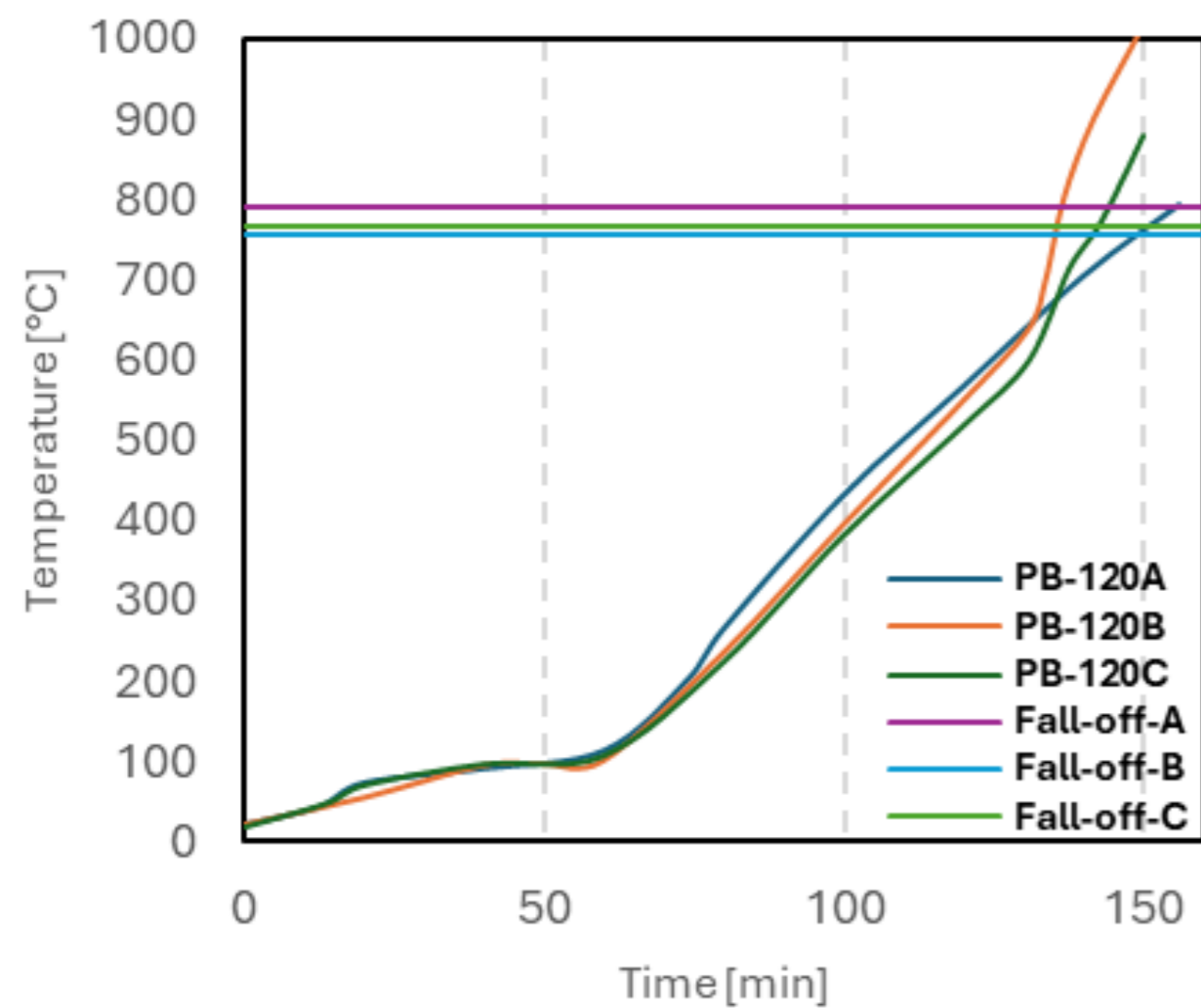
Sample	R-fail (min)	PB-failure time (min)	PB-fail temp. (°C)
Col-203-120A	126	155	790
Col-203-120B	131	135	755
Col-203-120C	136	139	765

# Fall-off temperature

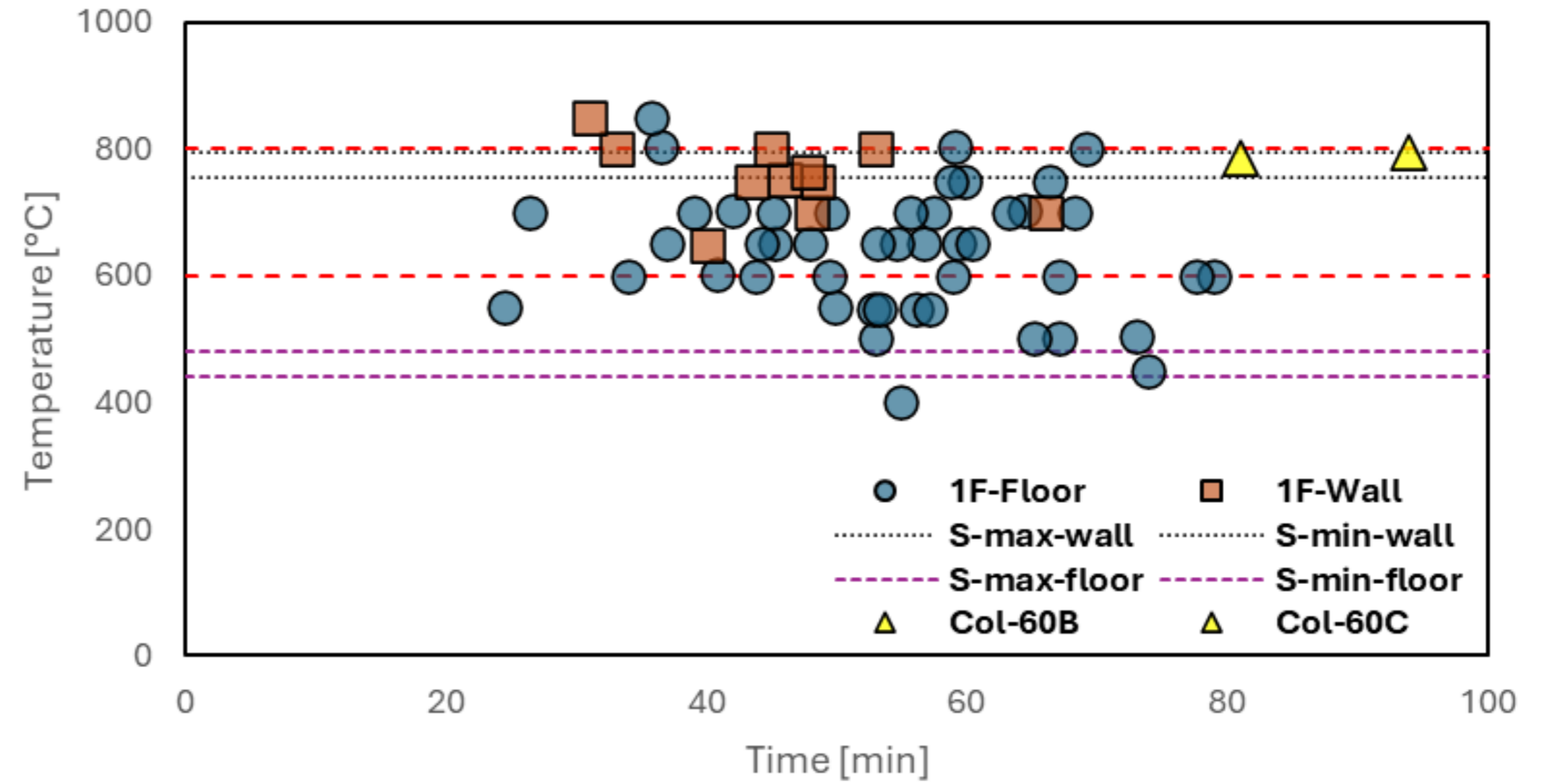
60 minutes



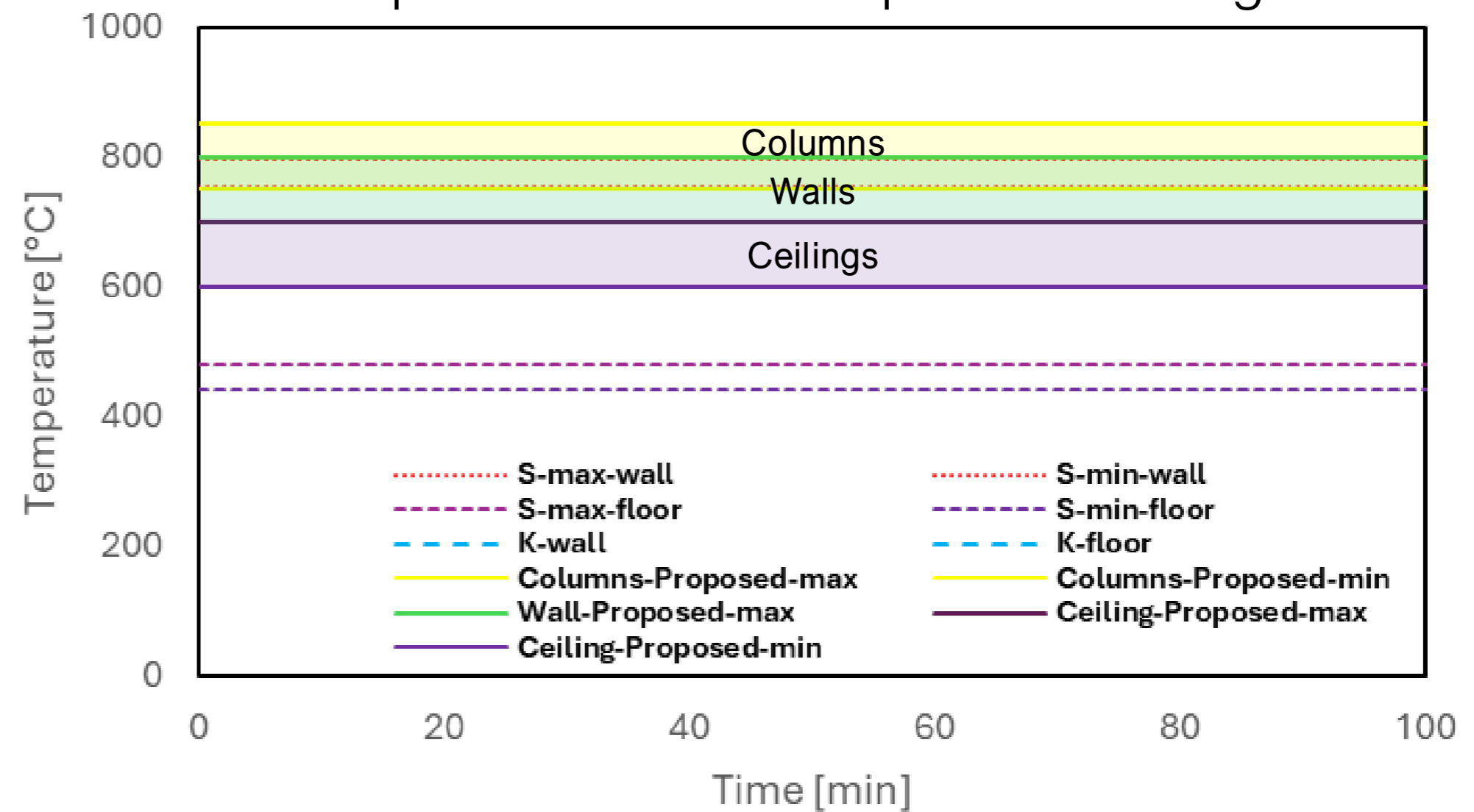
120 minutes



Fall-off temperature for ceilings, walls and columns (1F)

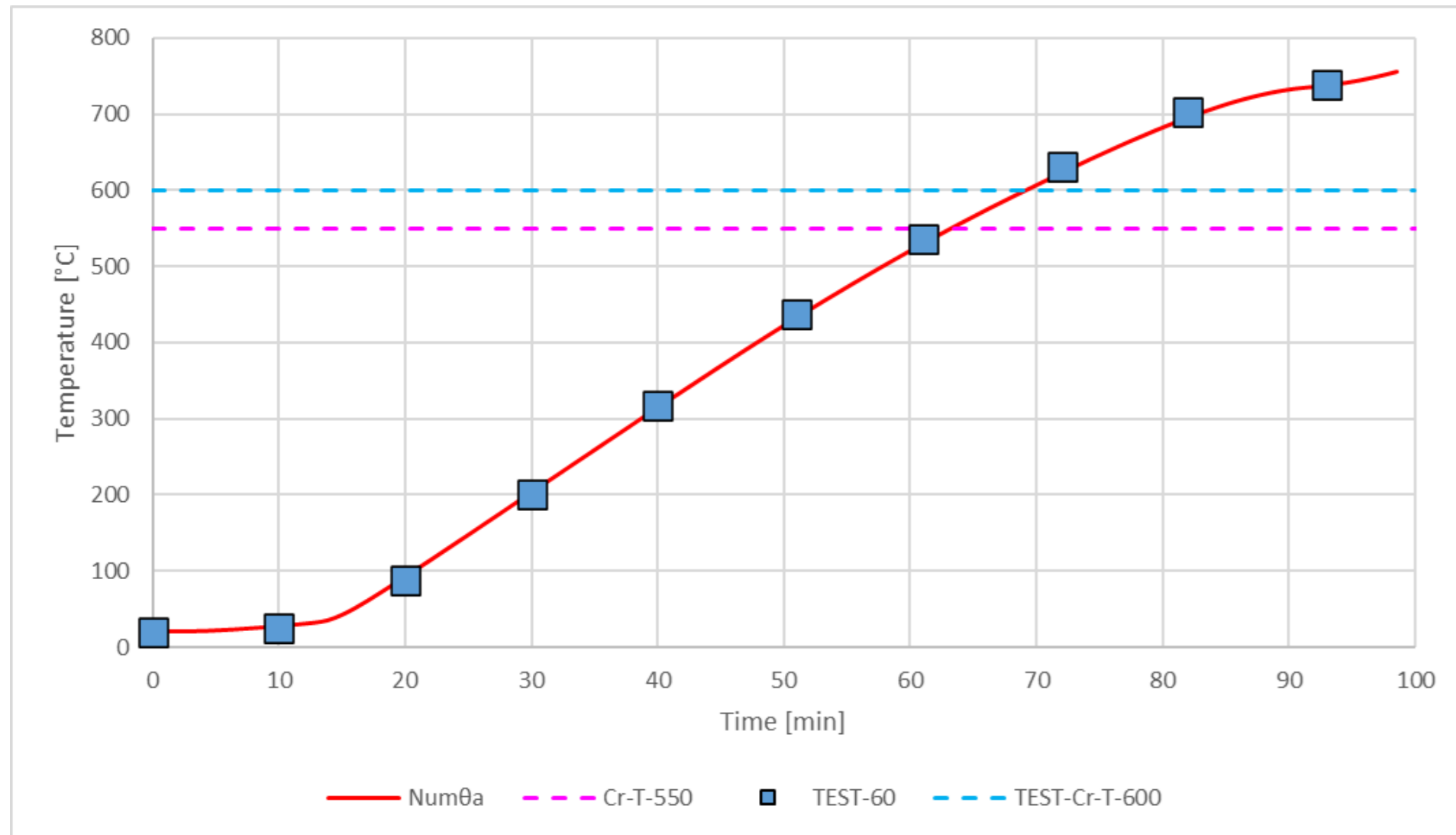


Proposed fall-off temperature ranges

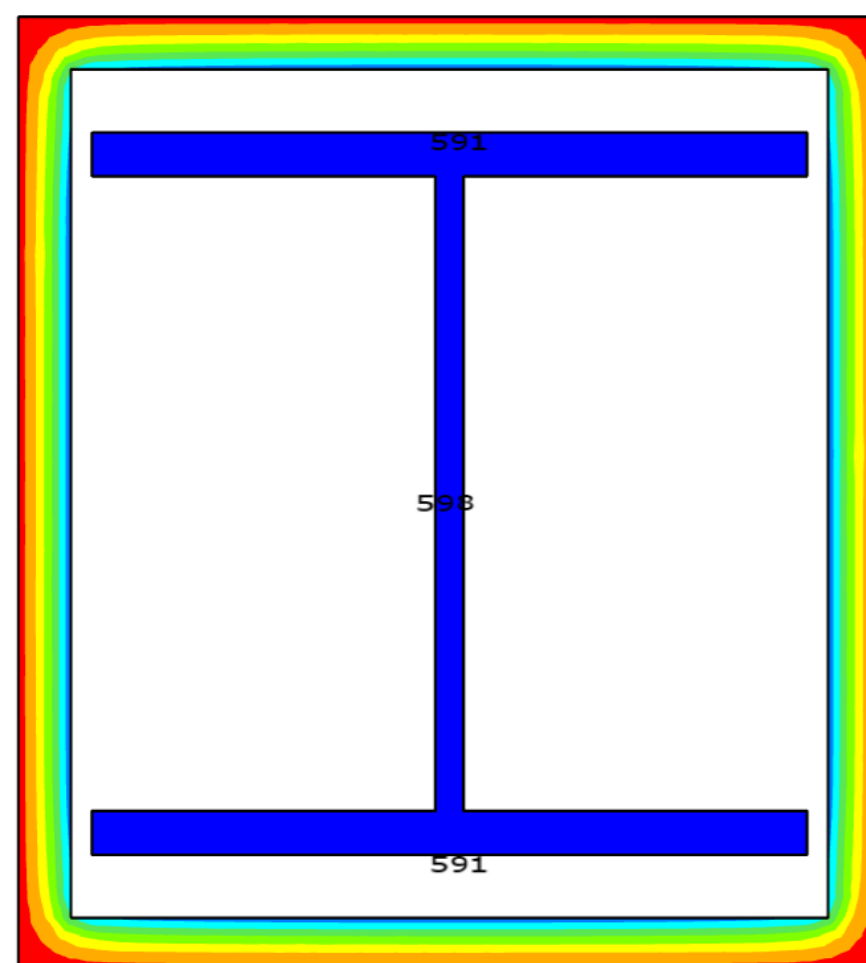
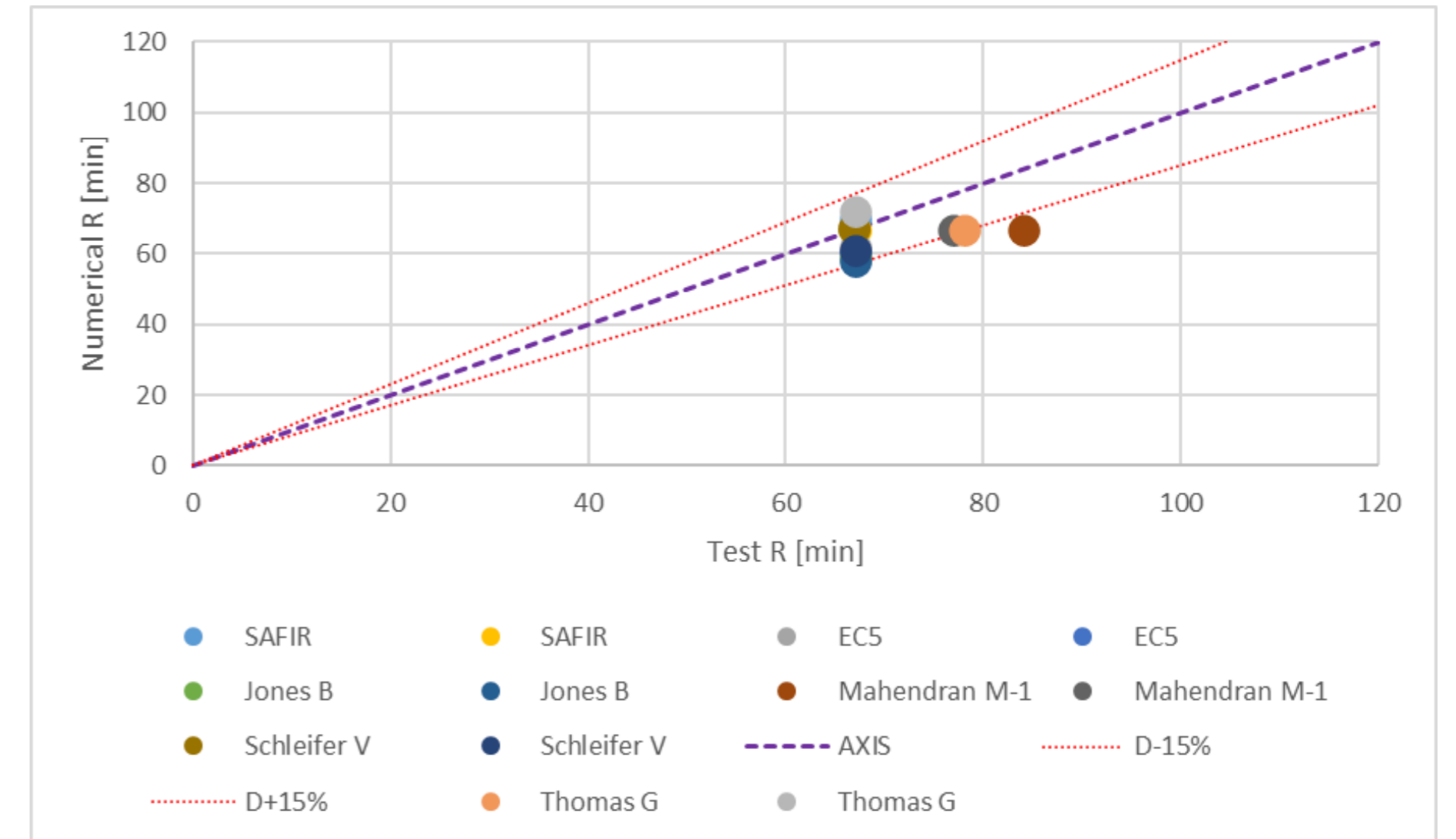


# Future research

## Heat transfer analysis



## Mechanical analysis



**Diamond 2016 for SAFIR**  
 FILE : 203Col\_1F  
 NODES : 903  
 SOLIDS : 1280

**CONTOUR PLOT  
 TEMPERATURE PLOT**

TIME : 4140 sec

**TEMPERATURE :**

- 920°C to 967°C
- 873°C to 920°C
- 825.9°C to 873°C
- 778.9°C to 825.9°C
- 731.8°C to 778.9°C
- 684.8°C to 731.8°C
- 637.7°C to 684.8°C
- 590.7°C to 637.7°C



# Conclusions

- 1x15mm type F plasterboard can provide 60 minutes R
- 2x15mm type F plasterboard can provide 120 minutes R
- Applicable for section factors  $A/V < 124 \text{ m}^{-1}$
- Fall-off temperature for plasterboard encased columns is in the range of  $800 \pm 50 \text{ }^\circ\text{C}$
- Plasterboard fall-off occurs after the mechanical failure of the steel columns (valid for  $A/V < 124 \text{ m}^{-1}$ )
- The use of fall-off temperatures for walls can be conservative
- The use of fall-off times for type F plasterboard provided in EC5 are conservative (44 min for 1x15F and 82 min for 2x15F) ???
- Plasterboard encased protection to steel beams should be investigated
- The aim is to develop equivalent thermal properties of type F plasterboard protection for steel columns



Local buckling failure of the steel column – Sample 120B

Questions?

Thank four your attention!

