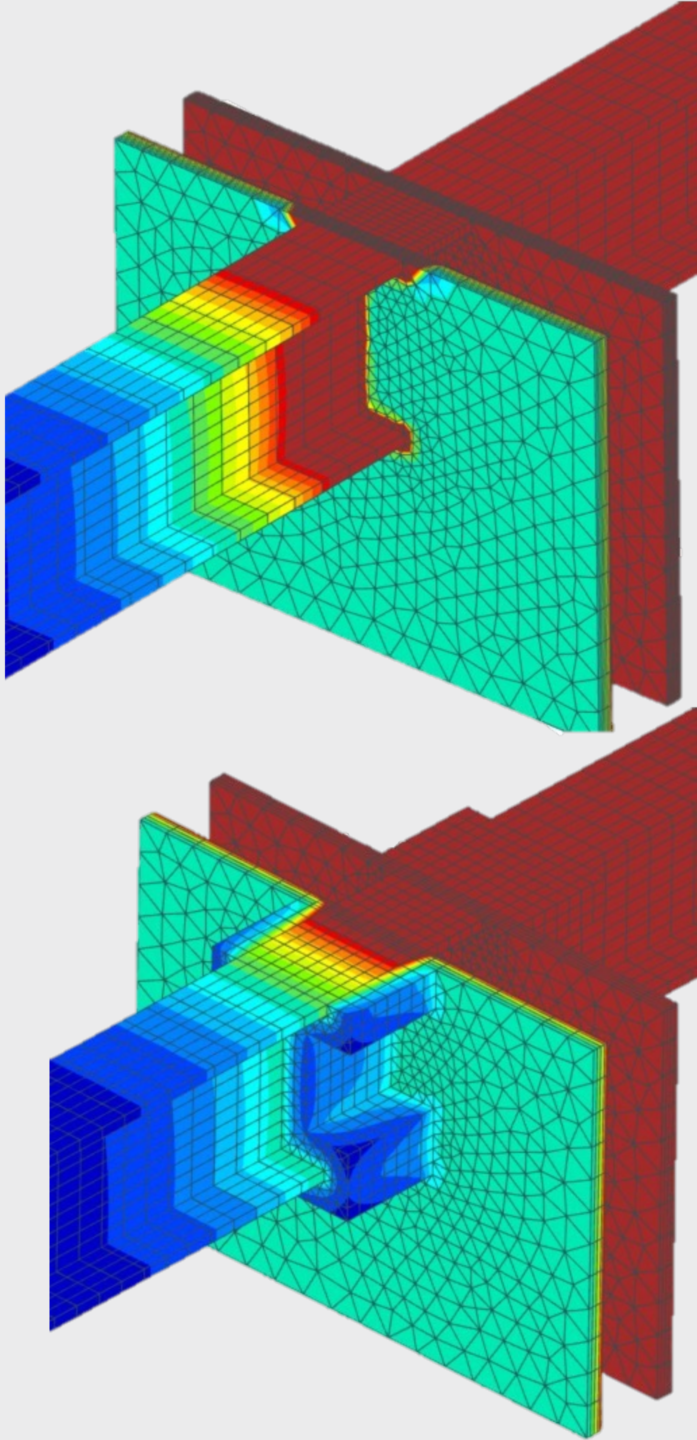
Researching the insulation criteria for a steel beam penetrating compartment wall



Edwin Ayala, Mark Davison, Cristian Maluk

27th September 2023
Structures in Fire Forum (London)

Semper

Background of the 'problem'

- Steel beam passing through a fire rated compartment wall
- Wall + beam 'system' may fail to provide adequate fire compartmentation
- <u>Options:</u> full or partial insulation of steel beams
- <u>Needs:</u> $$, construction time, additional trades on-site, space limitations (for services)

Tfire technical manual

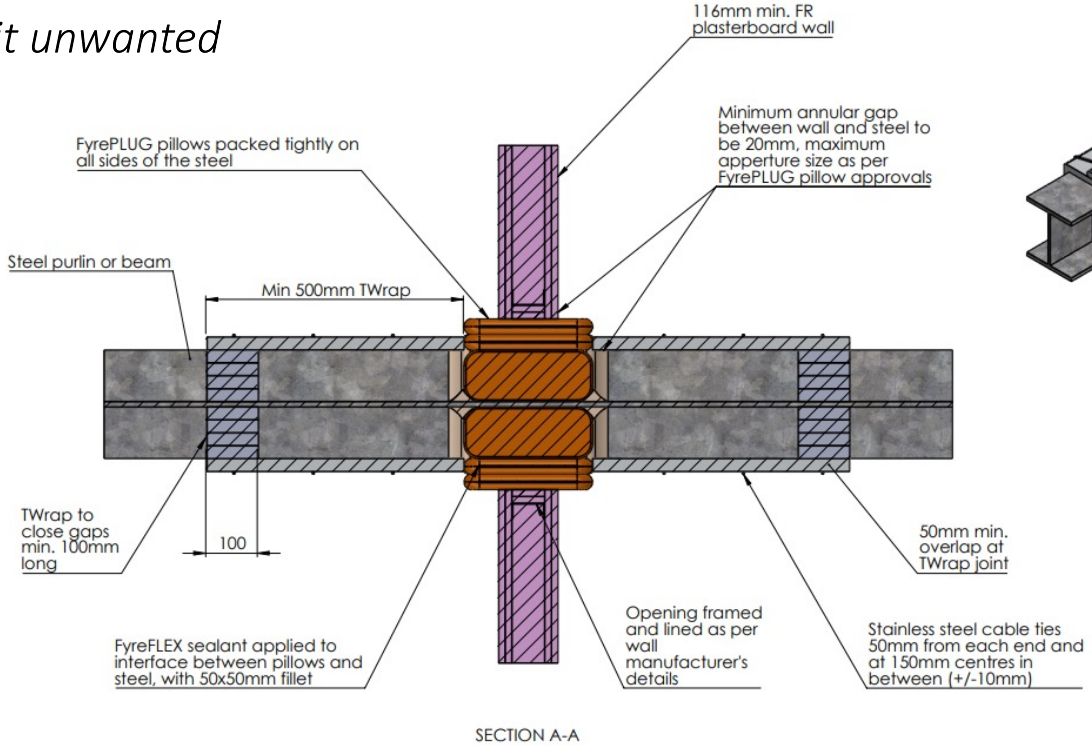
Fire stop centre – New Zealand

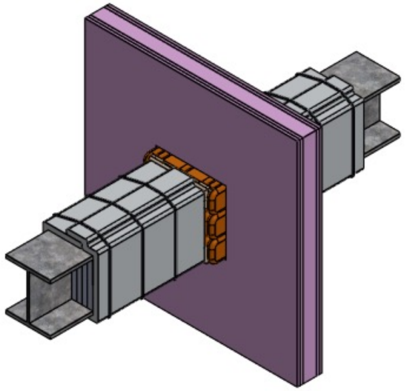
Steel beams protected with thin intumescent paint

Status-quo – *off-the-shelf solution*

ASFP recommendations

- *”The potential for heat transfer from unprotected structural steel into protected structural steel must be considered. It is normally considered good practice to protect the adjoining 500mm of ‘unprotected’ structural steel to limit unwanted heat transfer.”*





Tfire technical manual

Aims of this presentation

1. Layout the first principles of the 'problem'

2. Describe a method of analysis based on computational modelling

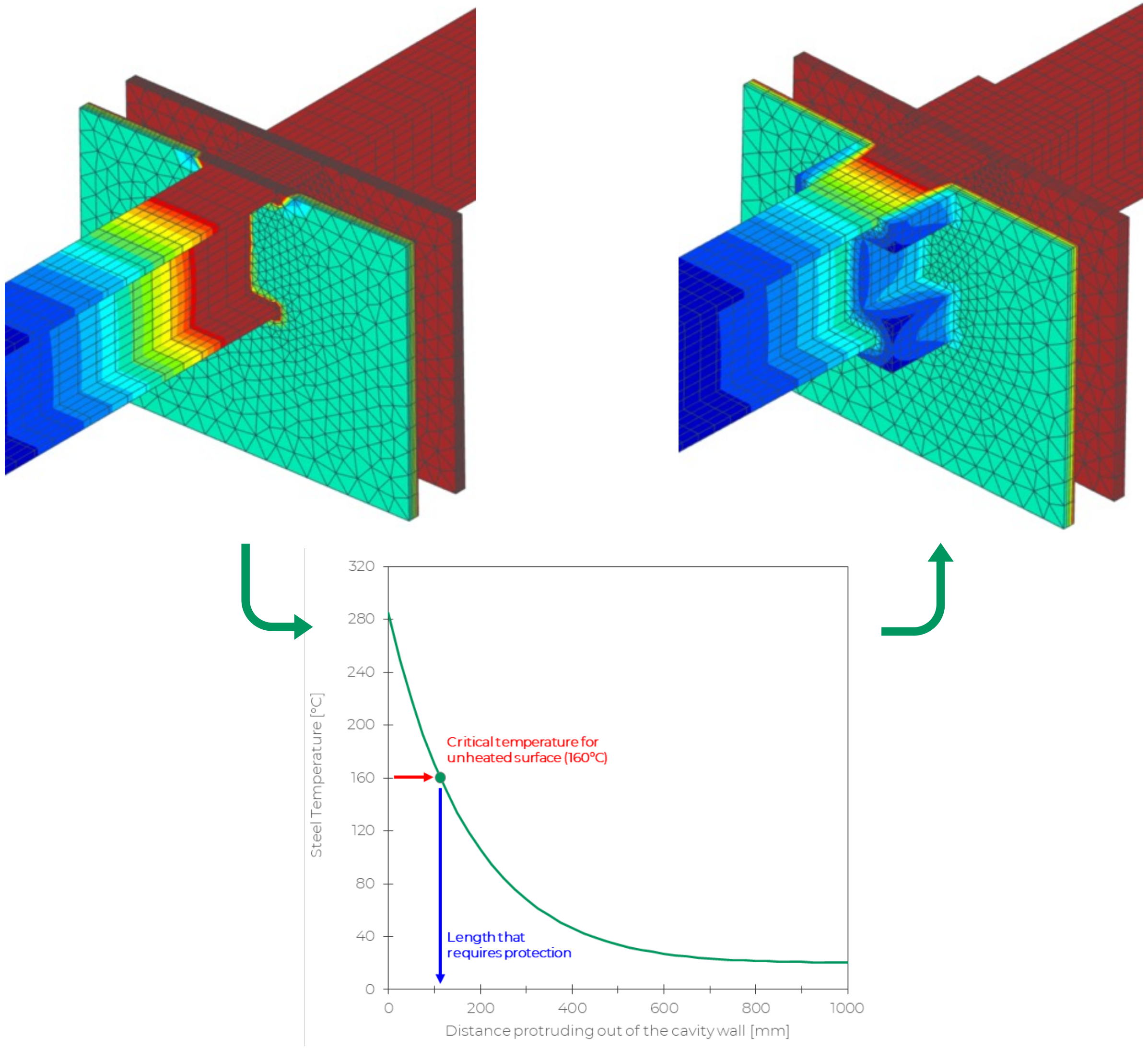
3. Show the outcomes of this approach for different wall types and steel protections

Proposed approach

Fire Engineering approach

Finite Element Modelling

- Run the model for the unprotected beam
- Identify the length of the unexposed beam with a temperature above the failure criteria at the fire-resisting time of the compartment wall
- Protect the identified length employing plasterboard on both sides.
- Verify temperatures of the unexposed beam



Fire Engineering approach (cont.)

Failure Criteria (BS 476-20:1987)

Failure shall be deemed to have occurred when one of the following occurs if:

- *The mean unexposed face temperature increases by more than 140 °C above its initial value;*
- *The temperature recorded at any position on the unexposed face is in excess of 180 °C above the initial mean unexposed face temperature;*
- *When integrity failures occur.*

Architects journal The Regs: How to make buildings fire-safe with cavity barrier / 3June 2021 / by Geoff Wilkinsons

Scenarios

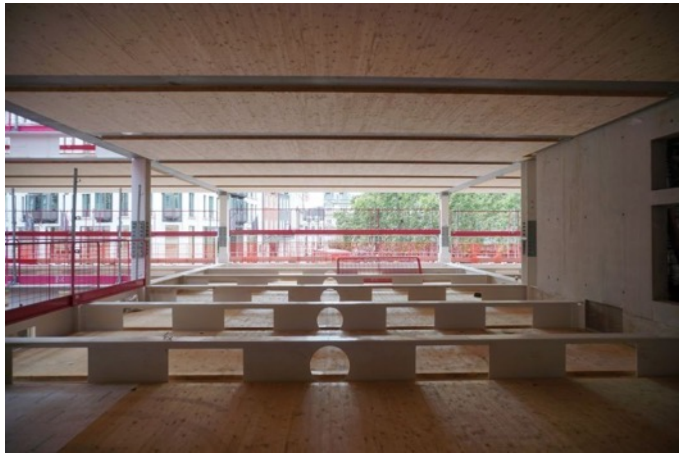
Compartment wall material

- Brick Masonry
- Timber
- Plasterboard cavity walls

Type of protection

- Unprotected
- Boarded

The Journal of Light Construction – Opening Up a Masonry Wall

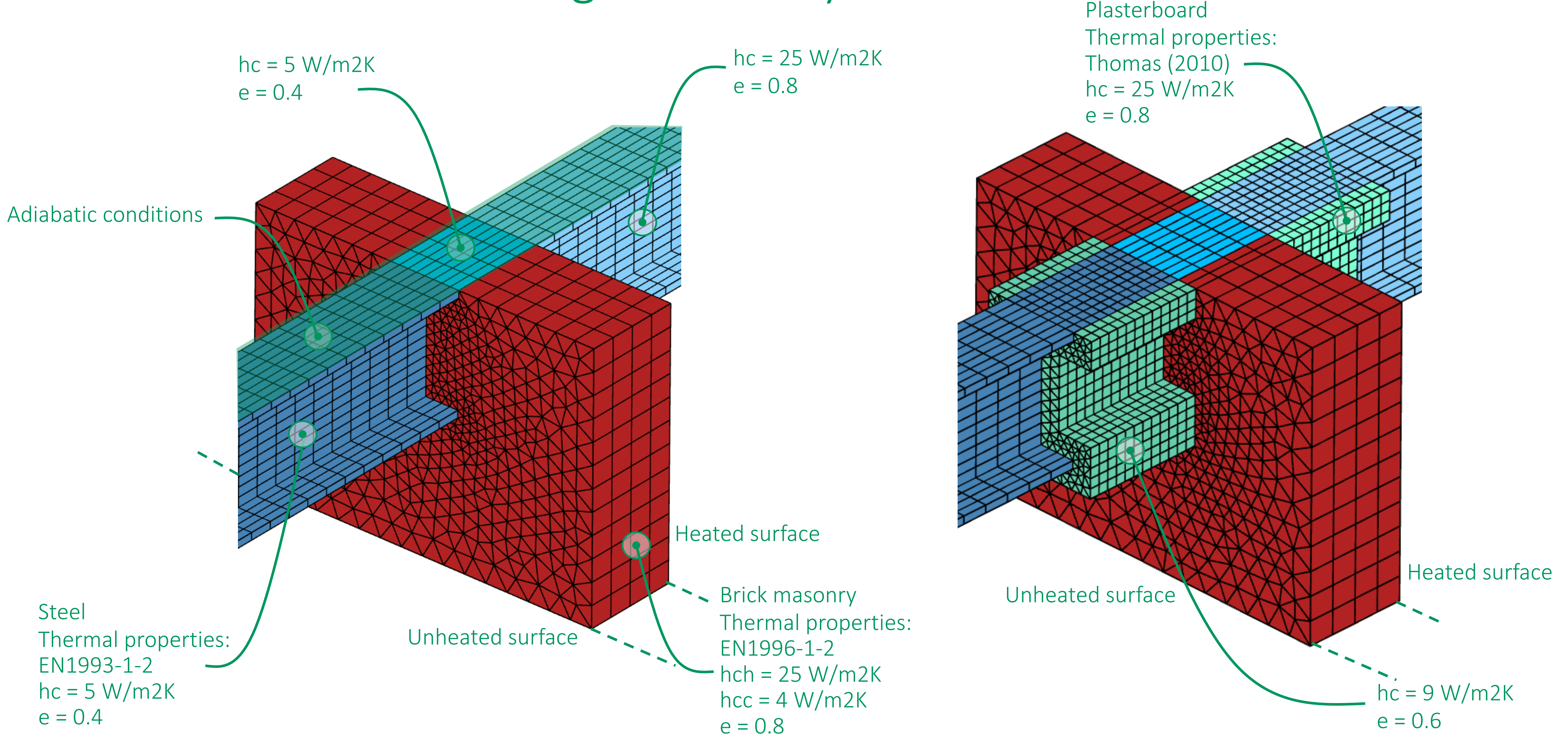


38 Berkeley Sq

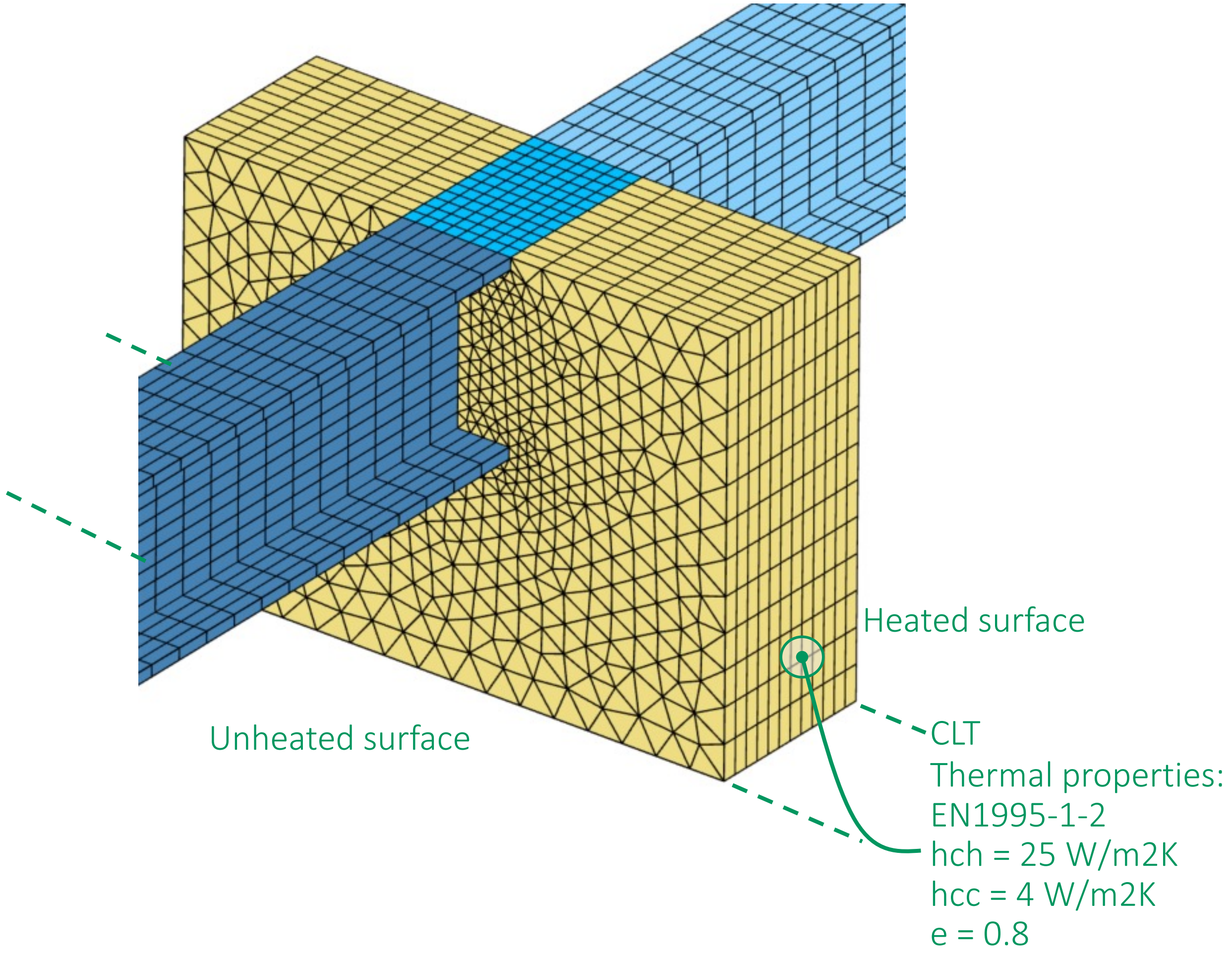
Fire stop centre – New Zealand

Finite element modelling

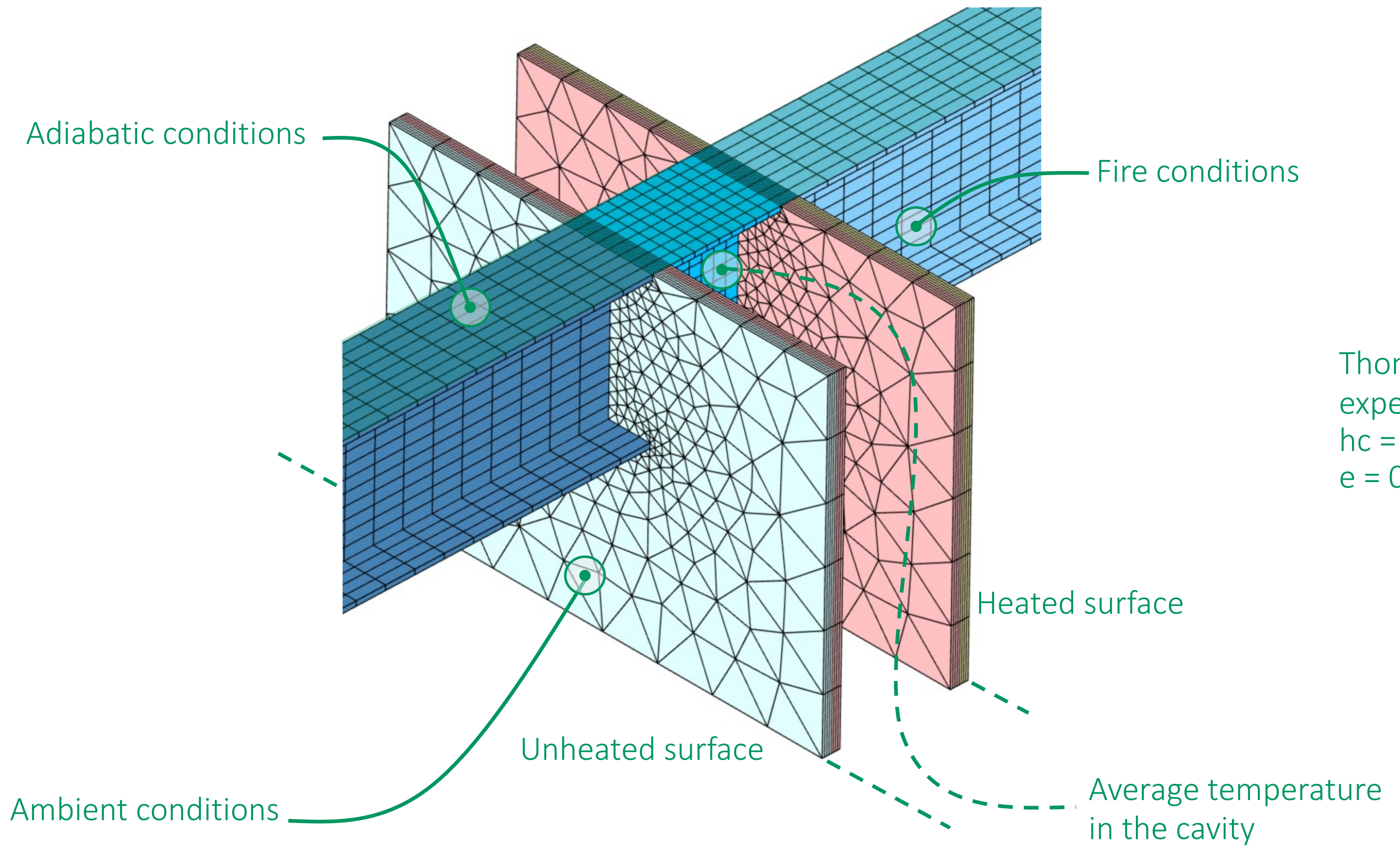
Finite Element Modelling – Masonry Wall

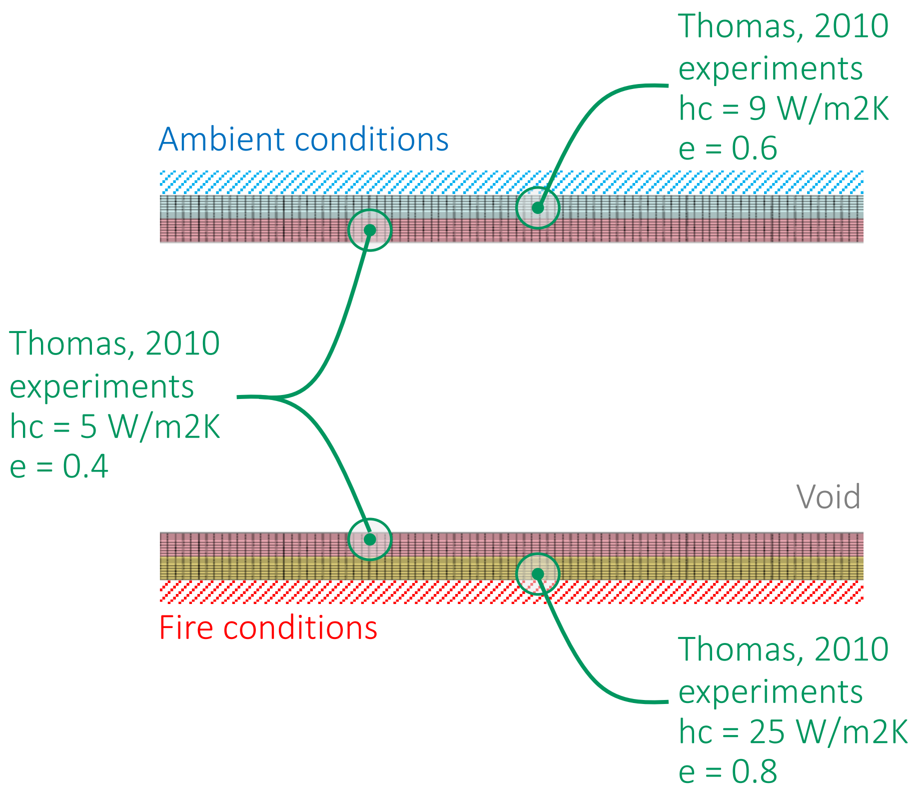


Finite Element Modelling – CLT Wall



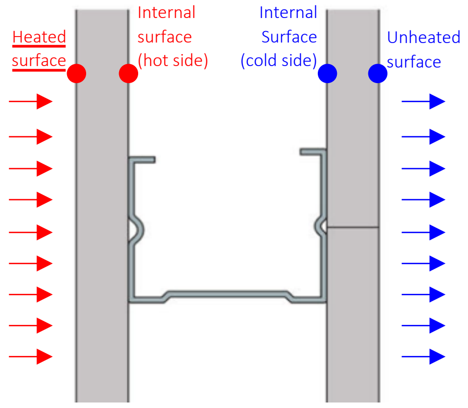
Finite Element Modelling – Cavity wall





Empirical validation

Validation – heat transfer inside the cavity

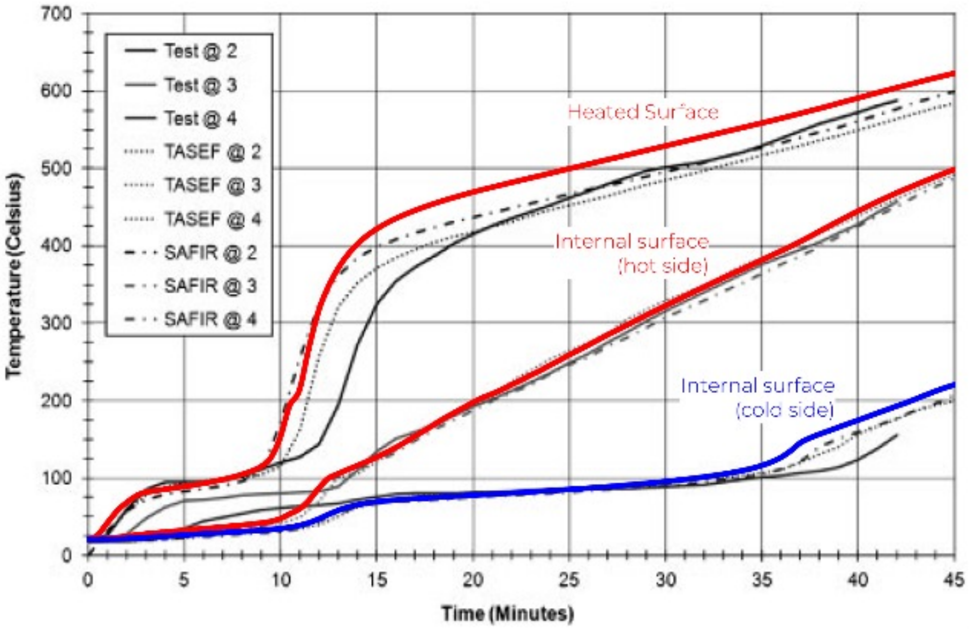


Empirical data

- Thomas, 2010

Key assumptions

- **The air temperature** inside the cavity is assumed be the **average temperature** of all surfaces inside the cavity
- The hot surfaces inside the cavity **radiate heat** to colder surfaces inside the cavity (**considering the view factors**)
- When **more than one plasterboard** is used on one surface, **perfect adhesion** is assumed in heat conduction calculations



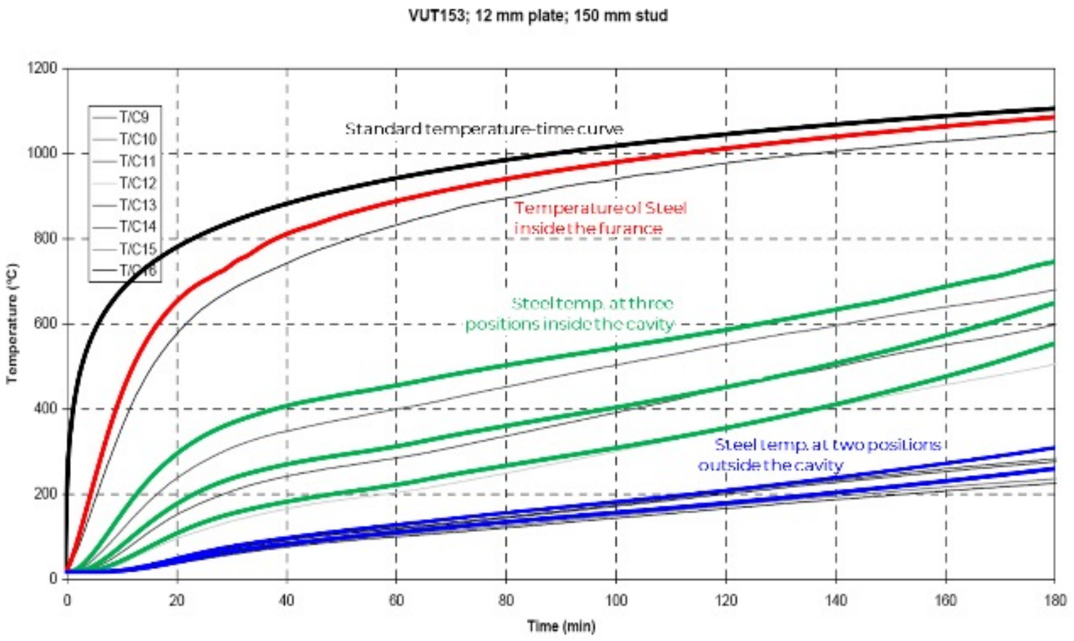
Validation – steel temperature

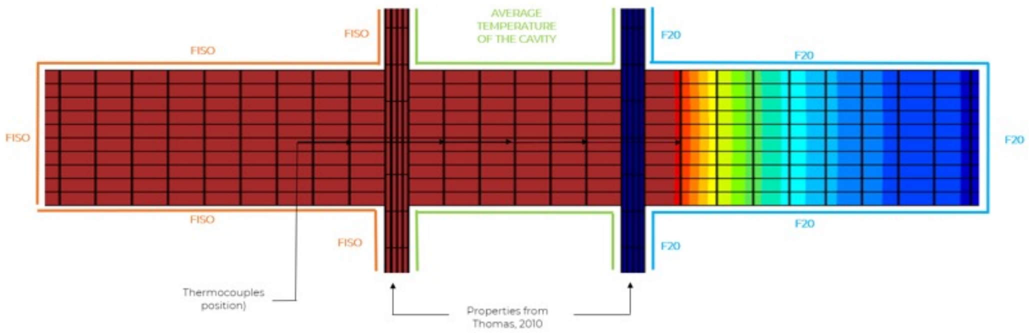
Empirical data

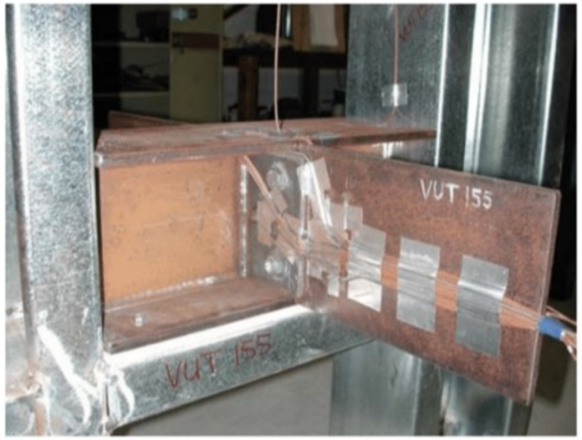
- Bennetts and Moinuddin, 2006

Key assumptions

- The thermal boundary conditions of the steel beam in the cavity are calculated assuming that the convective and radiative temperature is equivalent to the average temperature of the internal surfaces calculated using the 2D HT model for the cavity wall
- The top surface of the beam's top flange is assumed to have adiabatic conditions due to the presence of a slab







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Outcomes of the modelling study

Outcomes of the model

Without boarding

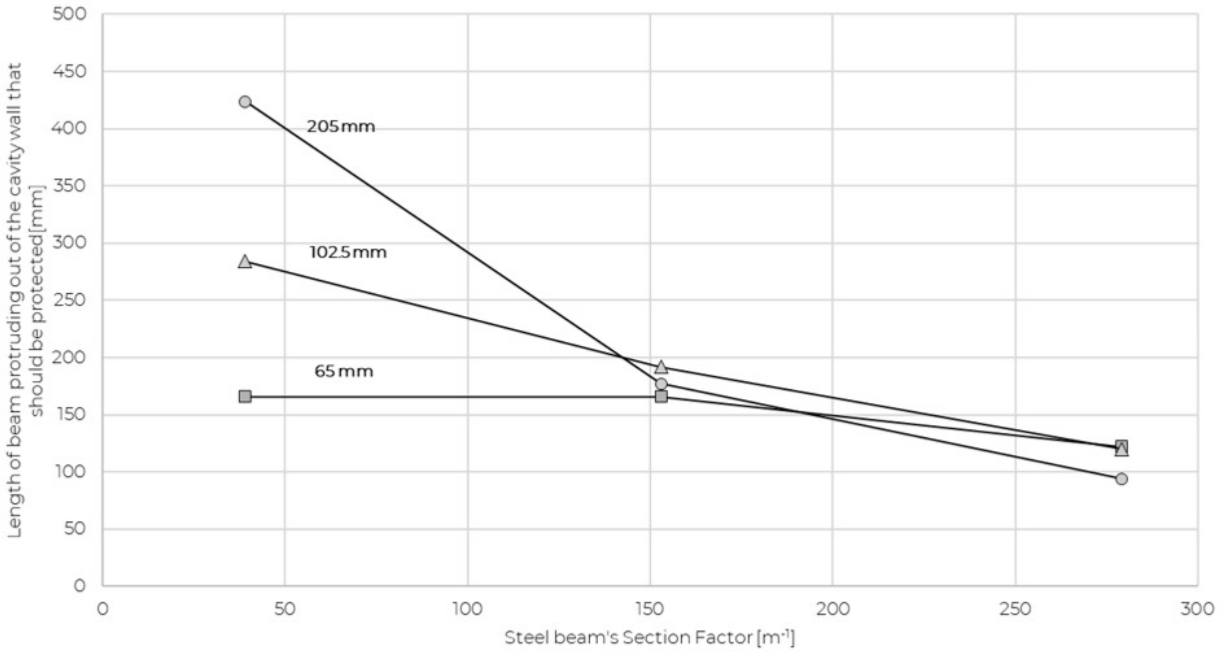
With boarding

Masonry Wall – Outcomes of the model (cont.)

Minimum length of beam protruding out that should be protected at both sides of the of the masonry wall [mm] †					
			Masonry Wall		
	Cross-section serial size [3]	Total depth of the wall [9] [mm] / Section Factor (A/V) * [m^{-1}]	65 60min	102.5 120 min	205 420 min
Steel beam	UB 127x76x13	279	122	120	94
	UB 457x191x74	153	166	192	177
	UB 1016x305x584	39	166	284	424

† This length is calculated based on modelling done on the length of unprotected beam above the temperature threshold and verified with the modelling of a protected beam considering such length.

* Heating on three sides, leaving the top surface of the top flange insulated.

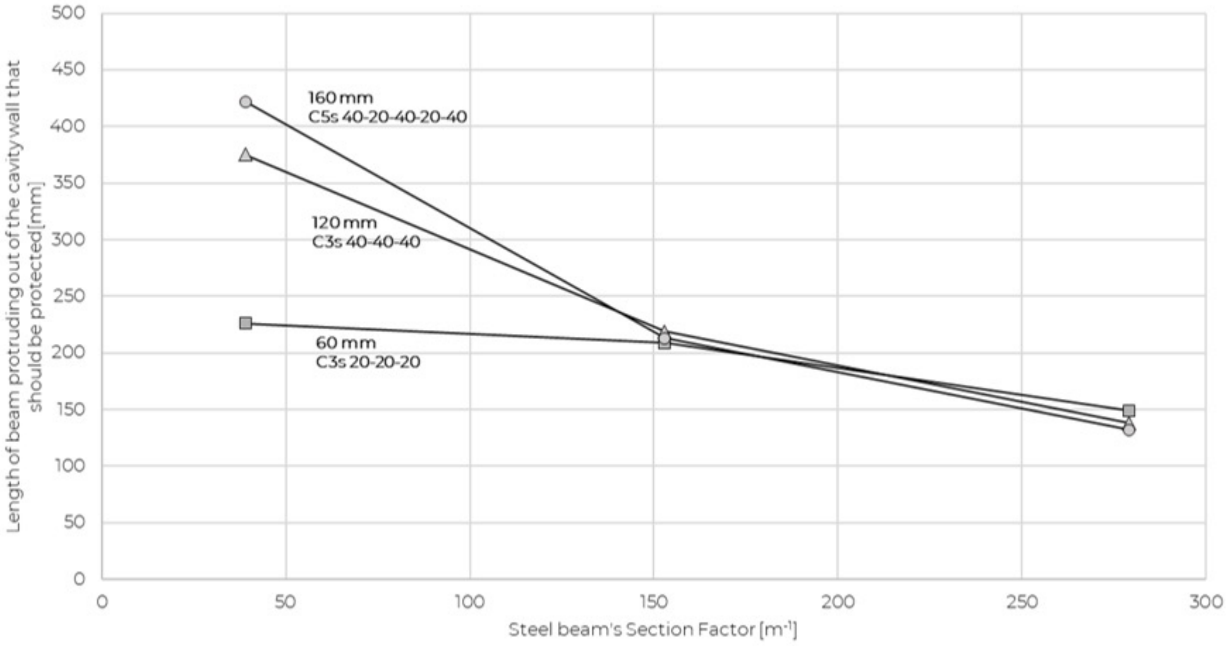


CLT Wall – Outcomes of the model (cont.)

Minimum length of beam protruding out that should be protected at both sides of the of the CLT wall [mm] †					
			CLT Wall		
	Cross-section serial size[3]	Total depth of the wall[12] [mm] / Section Factor (A/V)* [m^{-1}]	60 90min	120 210 min	160 300min
Steel beam	UB 127x76x13	279	149	138	132
	UB 457x191x74	153	209	219	213
	UB 1016x305x584	39	226	375	422

† This length is calculated based on modelling done on the length of unprotected beam above the temperature threshold and verified with the modelling of a protected beam considering such length.

* Heating on three sides, leaving the top surface of the top flange insulated.



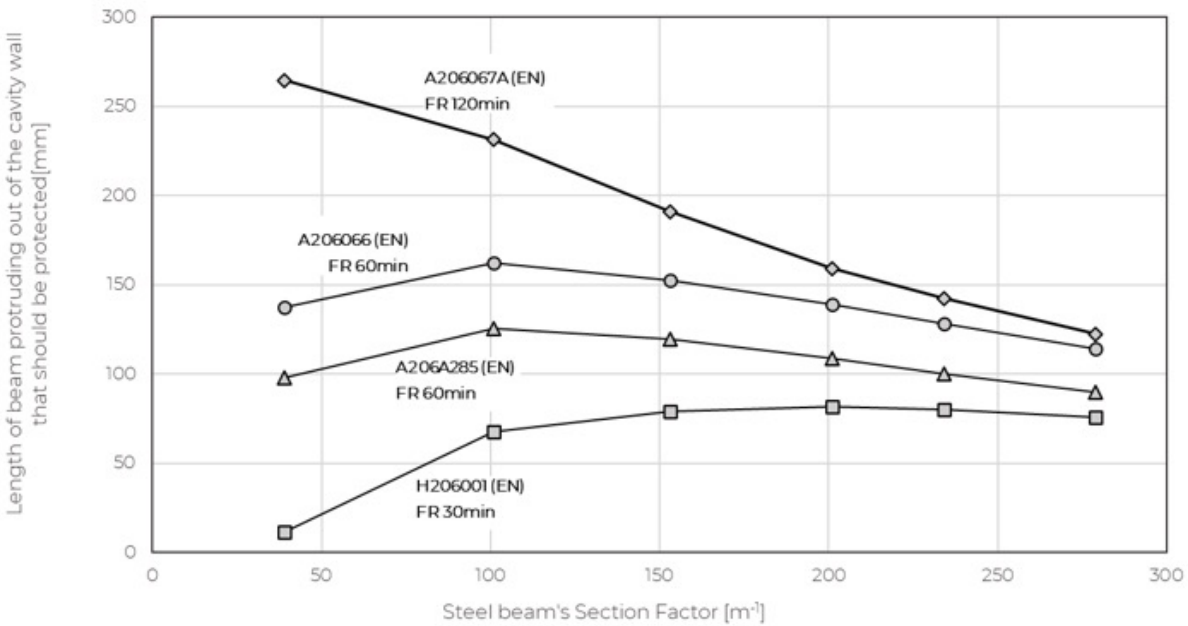
Cavity Wall – Outcomes of the model (cont.)

Minimum length of beam protruding out that should be protected at both sides of the of the cavity wall [mm] †								
			Cavity Wall					
		Fire Resistance	30	60	60	90	120	180
		Cavity Wall Product[2]	H206001 (EN)	A206066 (EN)	A206A285 (EN)	A206A091F (B) (EN)	A206067A (EN)	A206256 (EN)
		Board type	Glasroc H TileBacker	Gyproc FireLine	Gyproc FireLine	Gyproc FireLine	Gyproc FireLine	Gyproc FireLine
		Total depth of gypsum board(s) [mm]	12.5	15.0	25 (2×12.5)	25 (2×12.5)	25 (2×12.5)	45 (3×15.0)
	Cross-section serial size[3]	Total depth of the cavity wall [mm] / Section Factor (A/V)* [m⁻¹]	75	80	124	198	100	238
Steel beam	UB 127x76x13	279	76	114	90	57	122	49
	UB 203x102x23	234	80	128	100	68	142	64
	UB 305x127x37	201	82	139	109	77	159	76
	UB 457x191x74	153	79**	153	120	94	191	104
	UB 838x292x194	101	67**	162	125	113	231	149
	UB 1016x305x584	39	11**	138**	98**	111**	265	220

† This length is calculated based on modelling done on the length of unprotected beam above the temperature threshold and verified with the modelling of a protected beam considering such length.

* Heating on three sides, leaving the top surface of the top flange insulated.

** These values calculated for the "length of beam protruding out of the cavity wall that should be protected" are lower than those for higher section factors because larger cross-sections of steel beams take longer to heat up at the heated side.



Thin intumescent paint

Thin intumescent paint

- There is ample empirical data which demonstrates that thin intumescent paints used for protecting steel structures swell when the surface temperature of the paint is between 350 and 500°C.
- Therefore, for a steel beam protected using thin intumescent paint and passing through a compartment wall, it is irrelevant whether the paint will swell or not at an adjacent compartment.

Steel Beam protected with intumescent coating

Concluding remarks

- Steel beams with a section factor above 150 m-1 penetrating a solid wall (i,e, brick or timber) present a required protection length independent of the wall thickness.
- Every scenario modelled showed a required protection length lower than 500 mm (prescribed recommendation)
- Generally, the required protection length is inversely proportional to the section factor of the penetrating beam.
- The protection of the beam with intumescent paint does not guarantee the insulation of the compartment wall

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