Fire resistance of loadbearing light gauge steel frame (LSF) walls exposed to fire on both sides: A systematic review and numerical study

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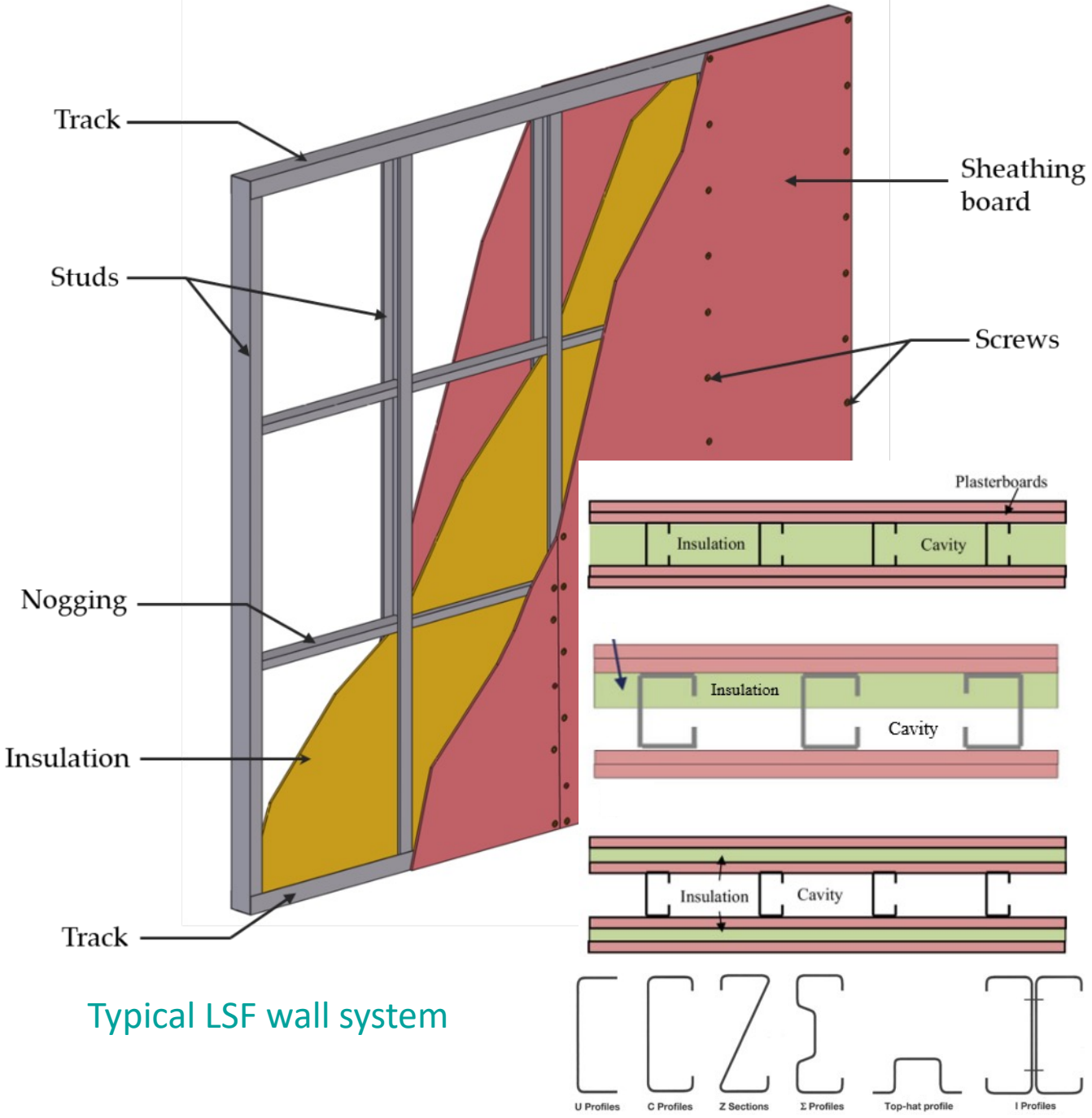
OFR Consultants Ltd

29th September 2023

Introduction



Typical LSF wall system

Terminologies:

- ✓ Light gauge steel frame (LSF) walls
- ✓ Lightweight steel frame/framing
- ✓ Cold-formed steel (CFS) walls
- ✓ Thin-walled steel elements

Applications:

- ✓ Utilised in residential, office, and industrial buildings
- ✓ Fire-separating or non-fire separating
- ✓ Loadbearing walls or non-loadbearing elements
- ✓ Increasing usage in the building industry

CROSS UK

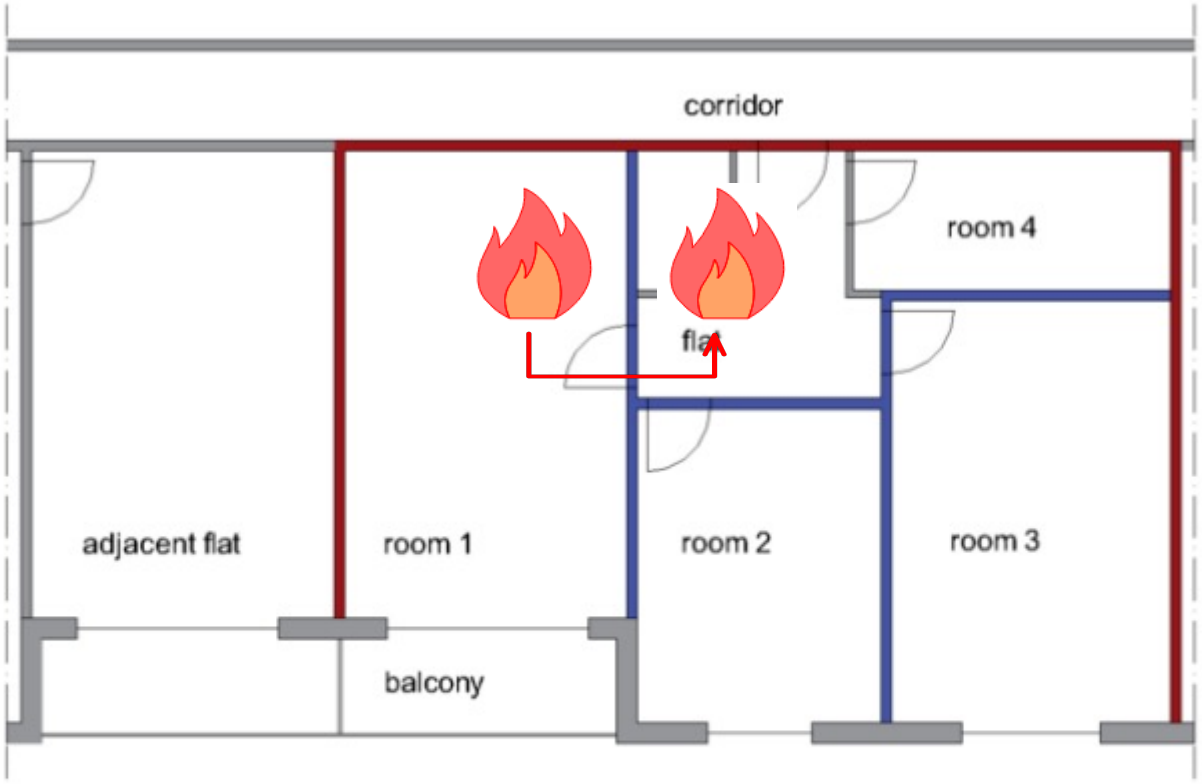
CROSS Safety Report

Fire protection to light gauge steel frame walls

Report ID: 1116 Published: 21 June 2022 Region: CROSS-UK

Overview

A disagreement between fire engineers and manufacturers on testing for the loadbearing performance of light gauge steel frame walls in case of fire has been reported.



Light Gauge Steel (LGS) frame would be exposed to fire on one side only - test evidence for these separating walls evidences fire resistance performance with exposure to fire from one side only

Light Gauge Steel (LGS) frame would be exposed to fire on more than one side simultaneously. No testing of LGS appears to have been undertaken with exposure to fire from more than one side - fire resistance performance not evidenced.

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Overview

A disagreement between fire engineers and manufacturers on testing for the loadbearing performance of light gauge steel frame walls in case of fire has been reported.

Key Learning Outcomes

For Light Gauge Steel Frame manufacturers and suppliers:

- Provide relevant information to help ensure that designers and builders provide adequate protection to all elements of a structure, including walls that are not separating compartment walls
- Internal loadbearing walls could be exposed to fire on both sides simultaneously and should therefore provide the required loadbearing fire resistance for such exposure

For designers:

- Panelised light gauge steel frame construction is considered a modern method of construction, according to an MHCLG Joint Industry Working Group.
- Approved documents may not provide appropriate guidance for some buildings that are not considered as "common buildings situations" and incorporate modern construction methods, according to the MHCLG's Manual to the Building Regulations
- Any design should be tested against the functional requirements of the relevant building regulations, and not only against the provisions of technical guidance
- Internal walls that may not need to be fire-resisting for means of escape purposes (i.e. not separating walls) may need additional fire protection if they form part of the structure
- Light gauge steel frame elements may need additional measures to ensure they remain structurally stable in order to perform their intended function

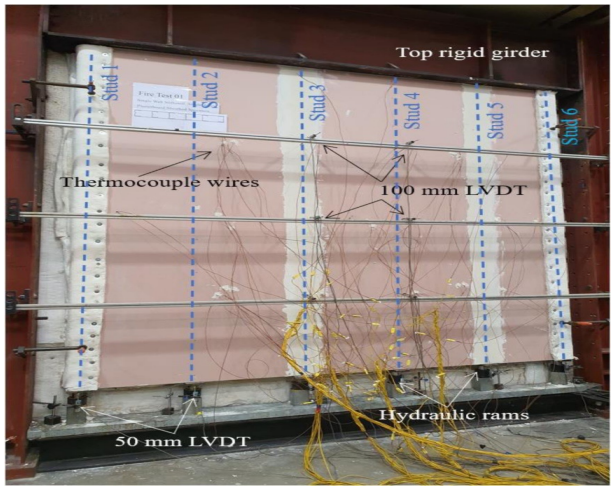
For fire and rescue services:

- Light gauge steel frame structures that do not have all-round fire-resisting protection may be vulnerable in a fire situation, potentially leading to the progressive collapse of the whole structure

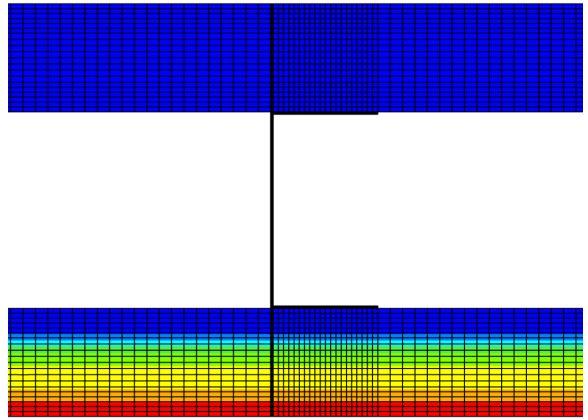
OFR

Scope

1 **Systematic literature review**



2 **Benchmark furnace tests**



3 **Numerical modelling study**

Systematic literature review

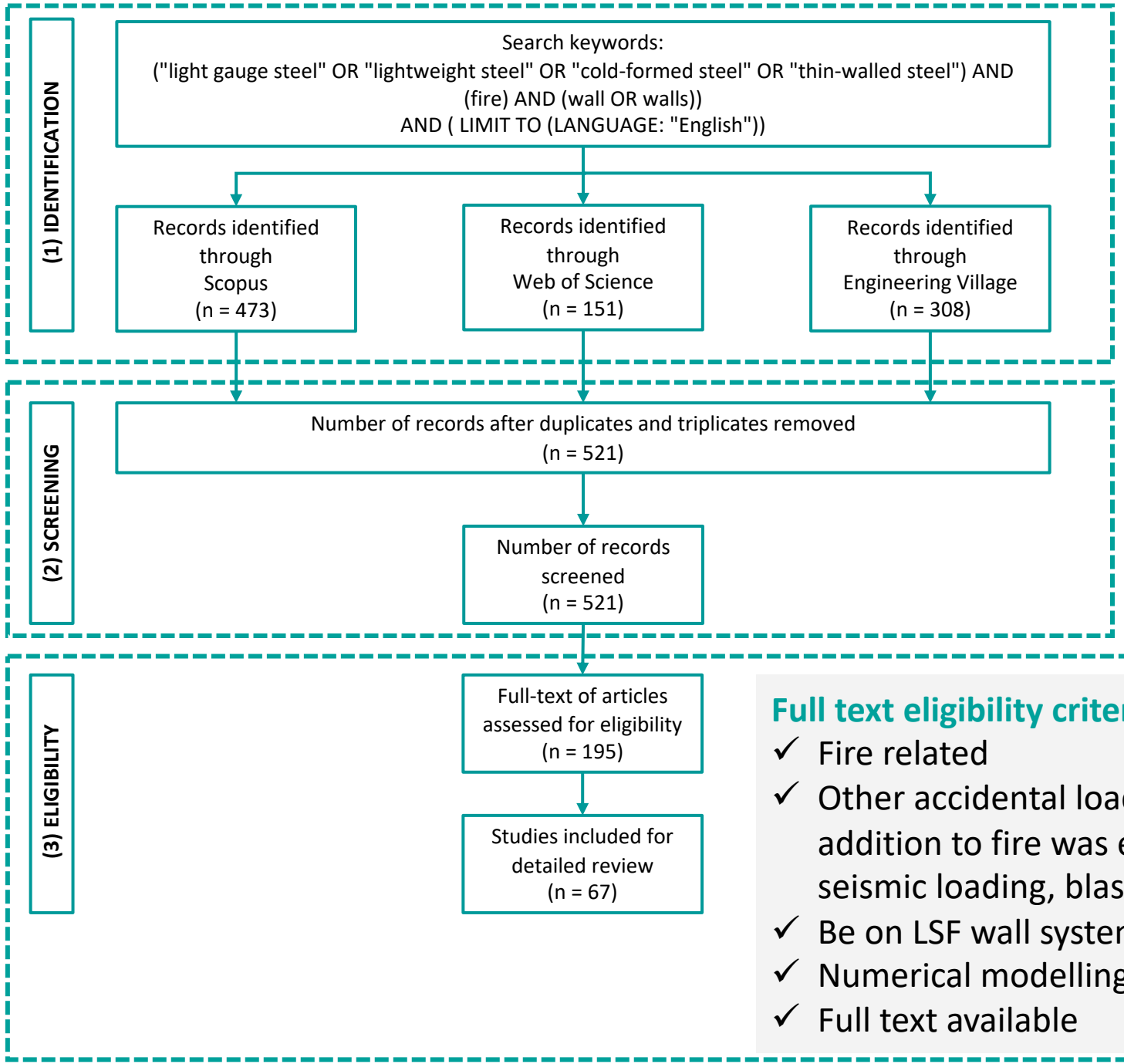
Aim of literature review study

- ✓ To understand current strategies used in numerical modelling of LSF walls exposed to fire.
- ✓ To examine how various design conditions, including fire exposure condition, the number of exposed faces to fire, loading conditions, component characteristics, and configurations, impact the structural performance of LSF walls in fire.

Research questions

- ✓ What are the best practices for modelling the performance of LSF walls in fire?
- ✓ How does the number of faces exposed to fire and other design parameters affect the fire resistance rating and structural performance of LSF walls?

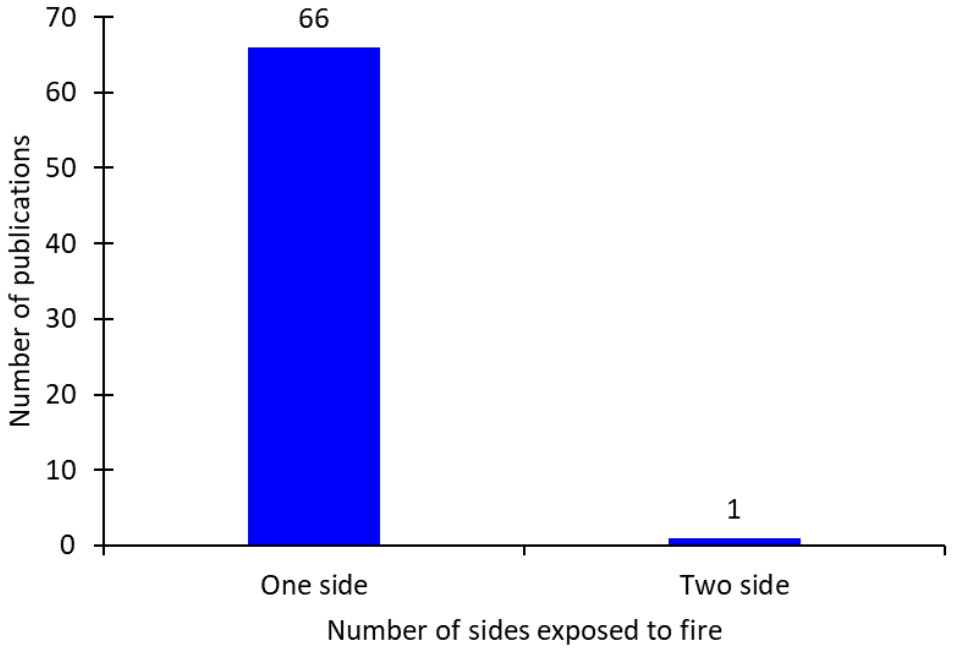
Systematic review design (PRISMA)

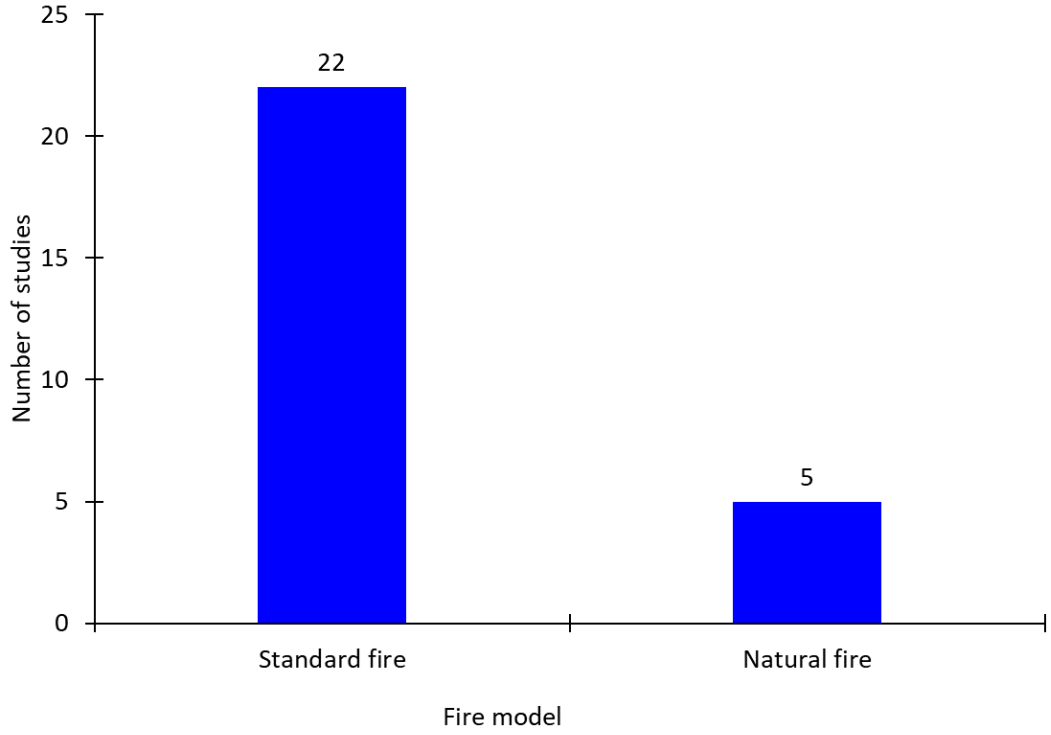


Full text eligibility criteria:

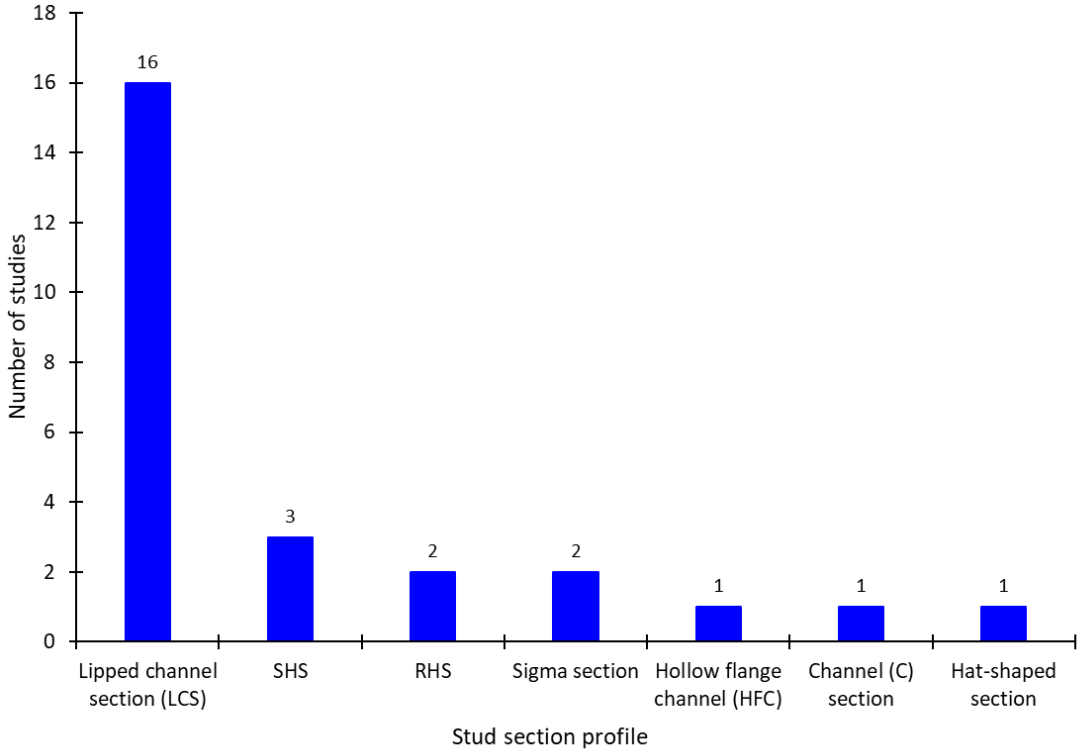
- ✓ Fire related
- ✓ Other accidental loadings in addition to fire was excluded (e.g., seismic loading, blast loading, etc.)
- ✓ Be on LSF wall systems
- ✓ Numerical modelling
- ✓ Full text available

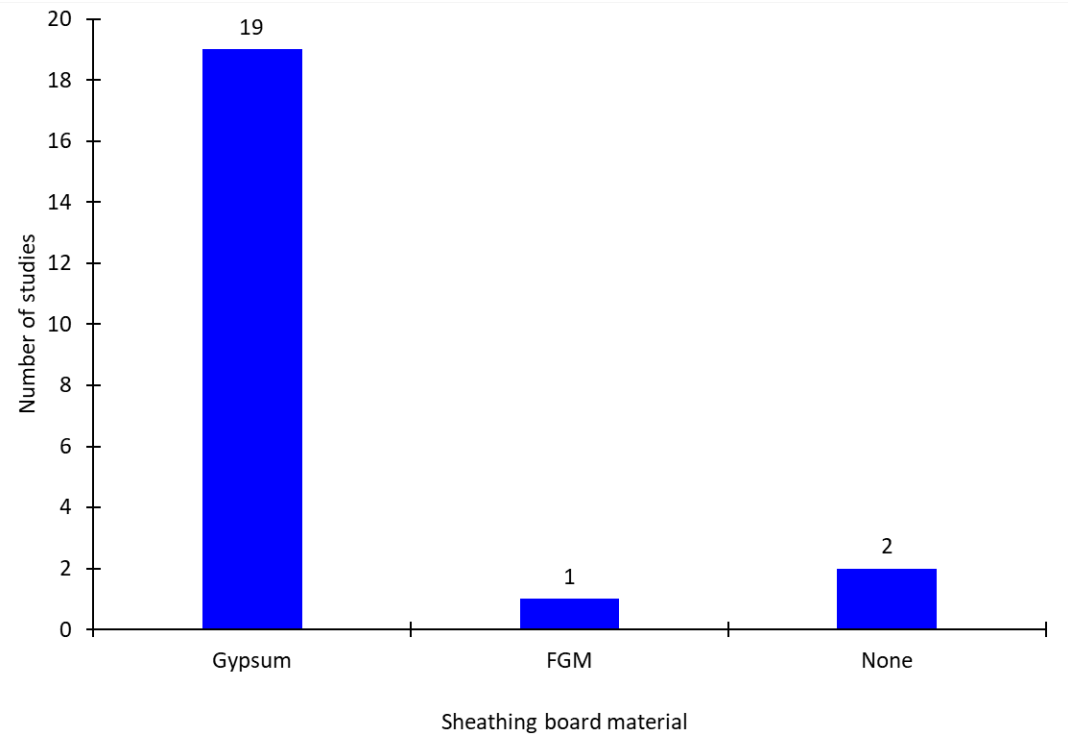
Review results – Modelling parameters



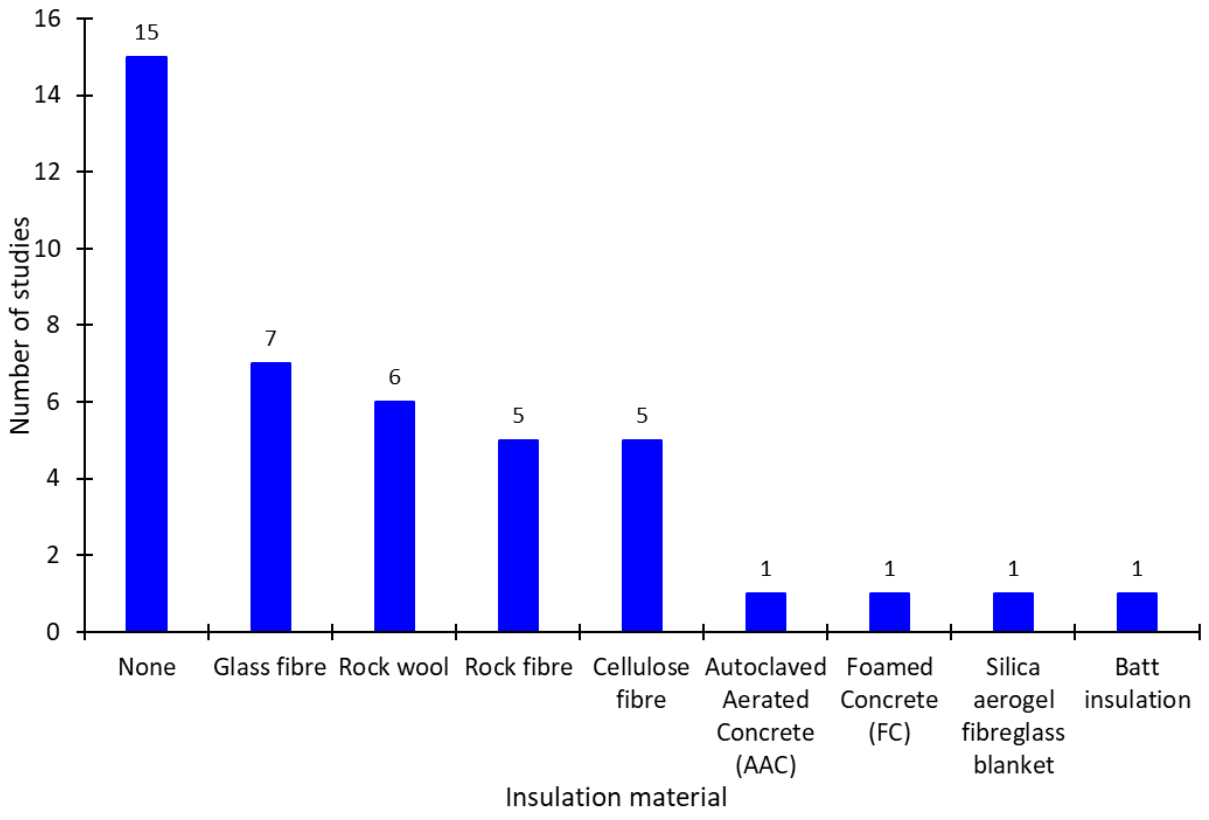


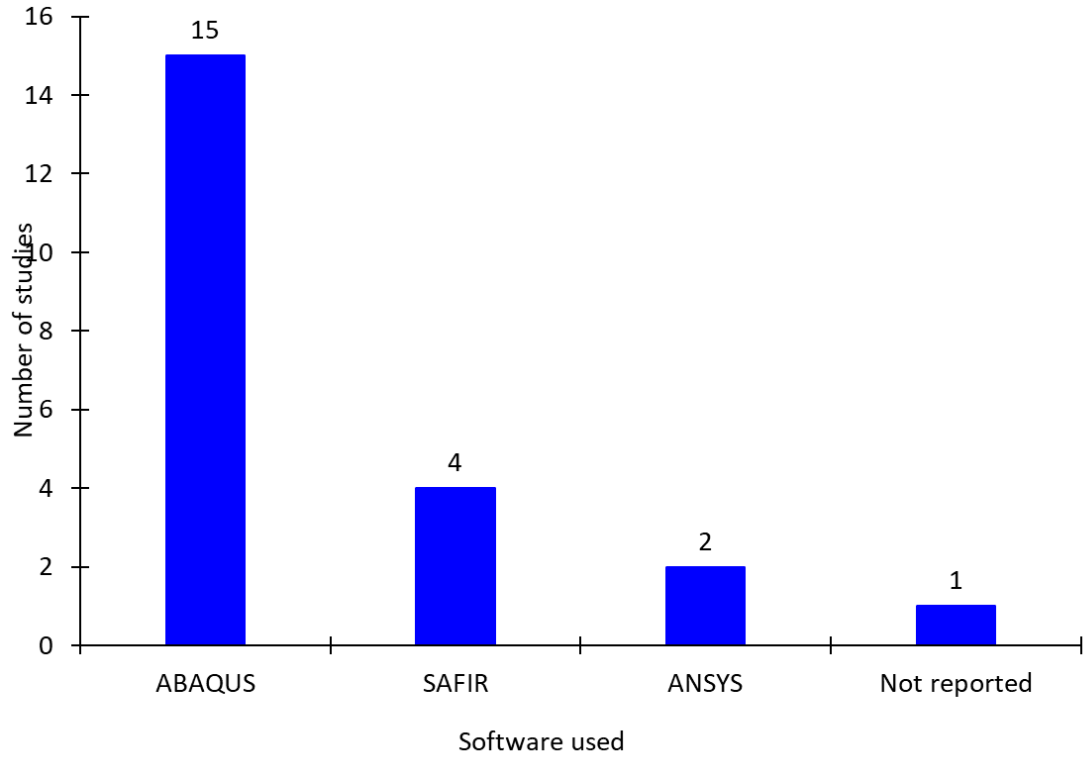
Review results – Modelling parameters



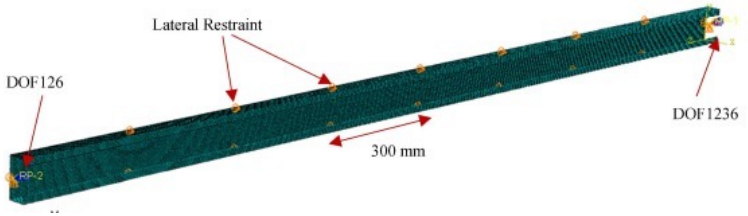


Review results – Modelling parameters

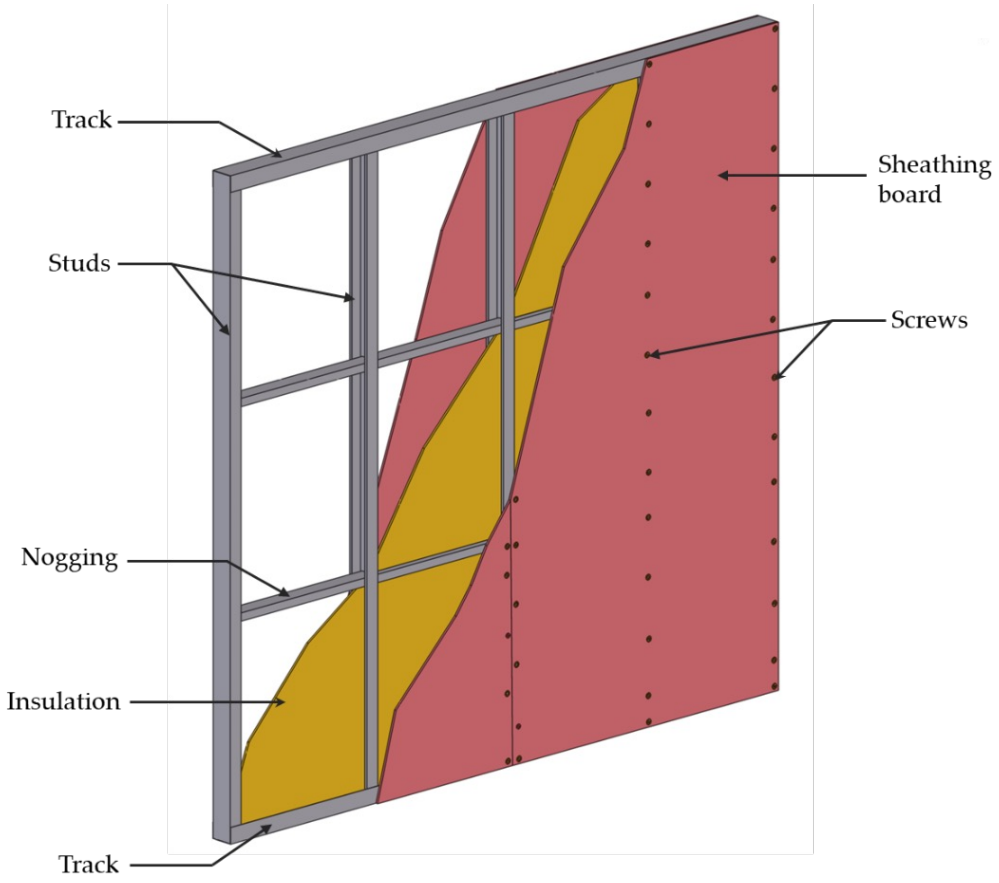


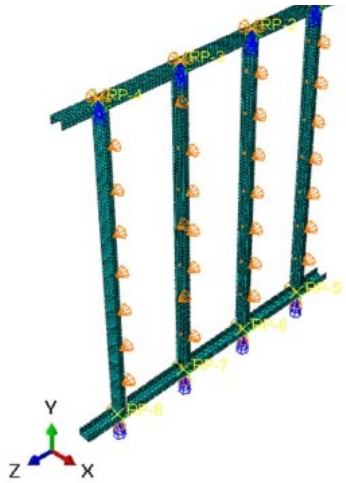


Modelling Idealization

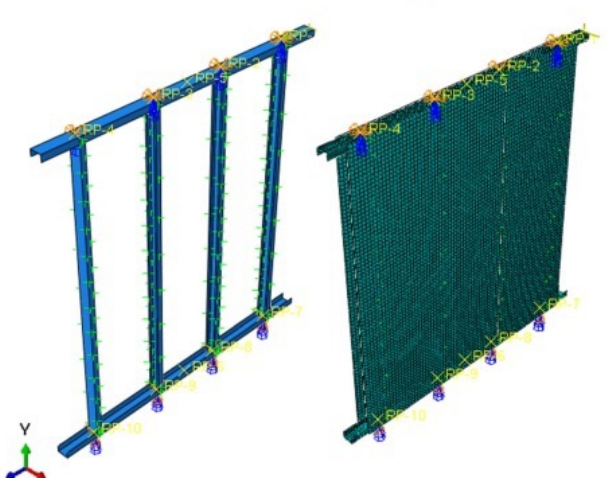


Single stud model





Steel frame with lateral restraint

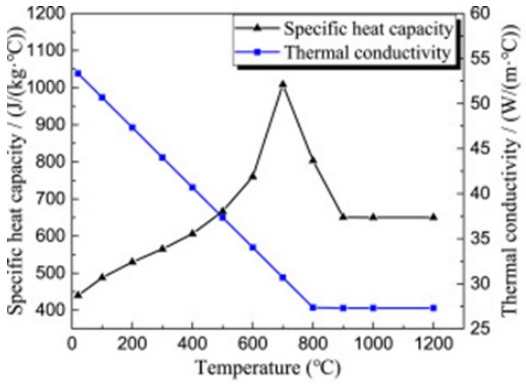


Complete wall

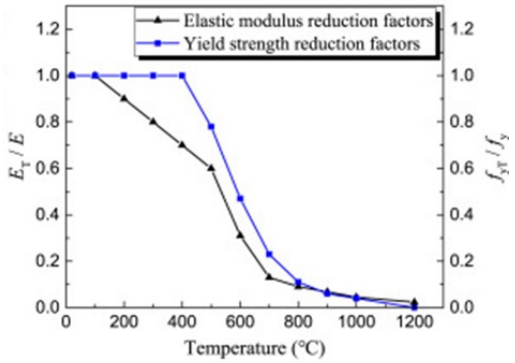
Review results – Modelling parameters

❑ Temperature dependent properties:

- Density
- Specific heat capacity
- Thermal conductivity
- Mechanical properties

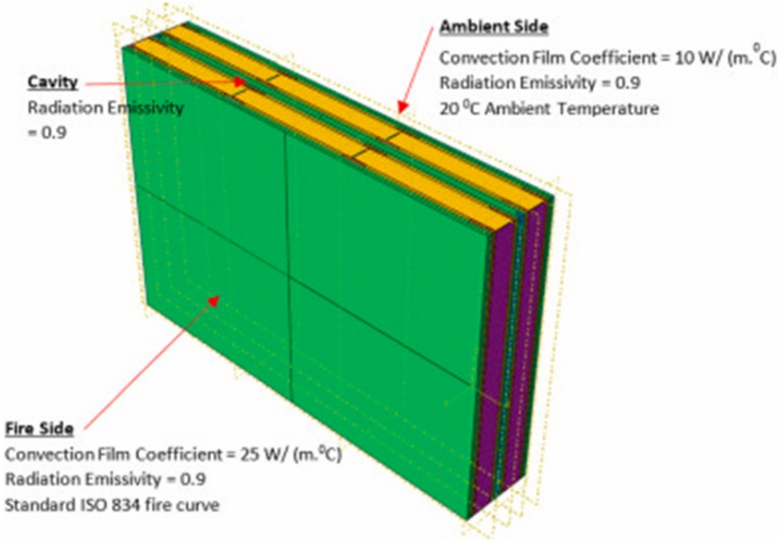


(a) Thermal property of steel

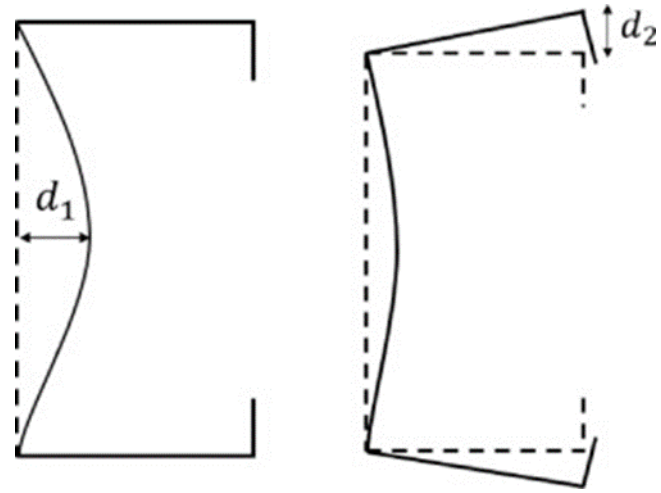


(b) Mechanical property of steel

❑ Boundary condition

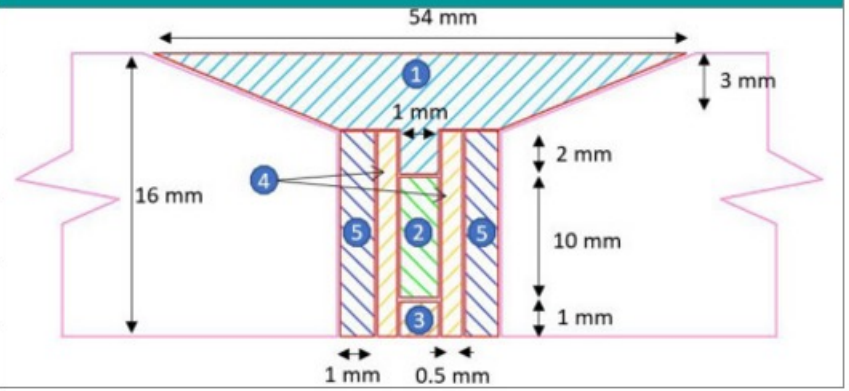


❑ Initial Geometric imperfections



❑ Sheathing material fall-off

Step	Function	Total time [min]	Element blocks
1	No element deletion	–	
2	Delete element block 1	17	
3	Delete element block 2	20	
4	Delete element block 3	25	
5	Delete element block 4	30	
6	Delete element block 5	35	



Review results – Factors influencing performance of LSF walls

Fire exposure condition

- Type of fire time-temperature curve.
- Realistic design fires cause more damage compared to standard fires.
- It is important to investigate the influence of two-sided exposure on the temperature distribution within LSF wall components and ultimately its fire performance.

Load ratio

- Load ratio has a significant impact on the fire performance of load-bearing and non-load bearing LSF walls
- Load ratios for load-bearing LSF walls typically ranging between 0.2 and 0.7

Steel section details

- The geometry of steel stud sections has minimal impact on LSF wall stud performance under fire conditions, however, using hollow section (SHS/RHS) studs in cavity-insulated walls has an advantage in increasing FR.
- Increasing the aspect ratio of LSF walls marginally improved fire behaviour, while increasing the stud web depth led to an increased FR.
- Increasing steel thickness and grade results in an increase in FR.

Insulation and sheathing board

- Cavity insulation can enhance the insulation fire resistance level of non-loadbearing LSF walls but reduces the fire resistance level of load-bearing LSF walls
- Number of sheathing board layers and insulation location

Sheathing material fall-off

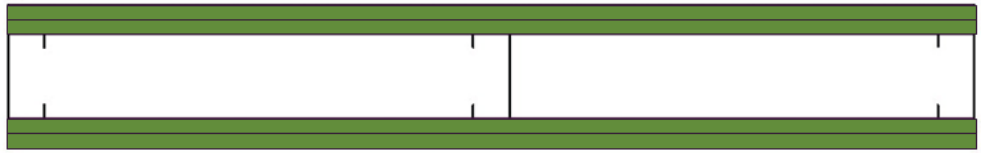
- Sheathing board fall-off lead to increase in the rate of temperature rise, significantly reducing the fire resistance of LSF walls.

Preliminary Numerical Study (Thermal FE Analysis - SAFIR)

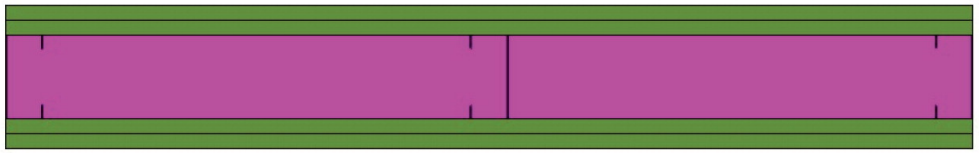
Modelling scenarios

- ✓ Based on proposed testing programme
  - ➢ Two layers of sheathing board (15 mm each) – Gypsum plasterboard
  - ➢ With and without insulation
  - ➢ Steel stud - 100SN12 (100x53x14x1.2)
  - ➢ Stud spacing = 600 mm
  - ➢ Standard fire

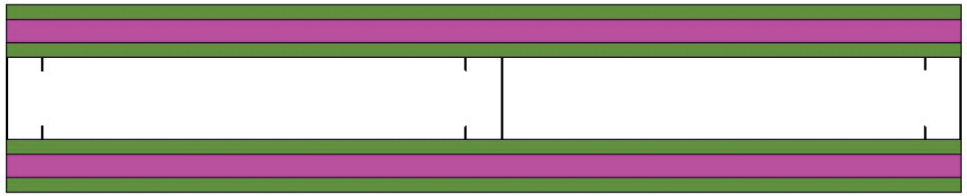
- ✓ Three LSF wall configurations
  - ➢ No insulation
  - ➢ Cavity insulation
  - ➢ External insulation



No insulation



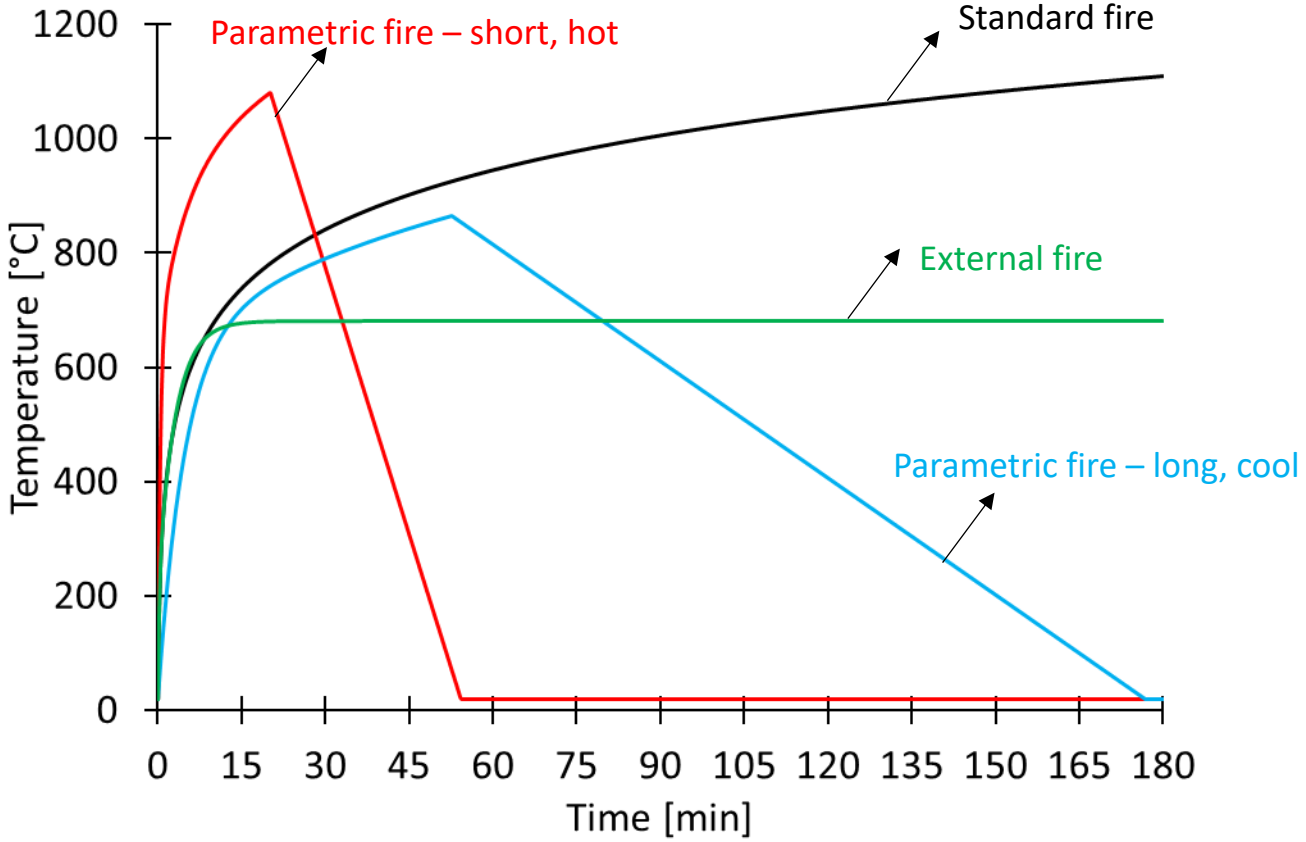
Cavity insulation (Cold frame system)

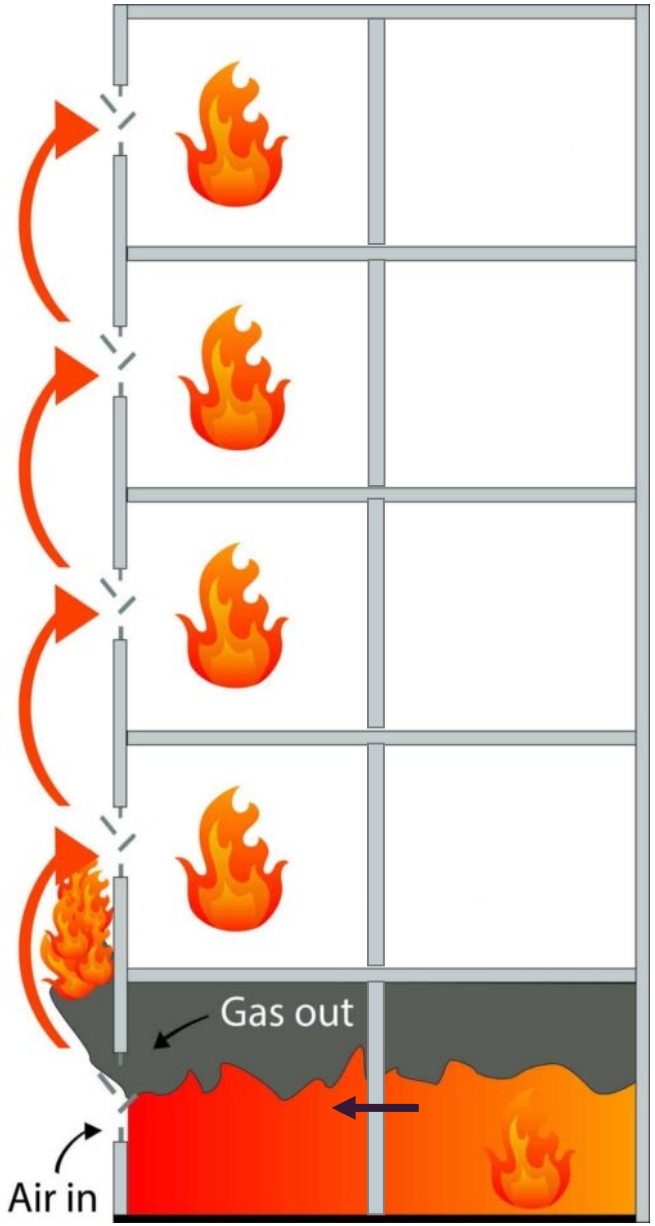


External insulation (Warm frame system)

Modelling scenarios

- ✓ Four fire models
  - ➢ Standard ISO fire
  - ➢ EC 1 parametric fire – short, hot
  - ➢ EC1 parametric fire – long, cool
  - ➢ EC1 external fire
- ✓ Fire exposure on one side only
- ✓ Fire exposure on both sides
  - ➢ Time lags: 5 min, 10 min & 20 min

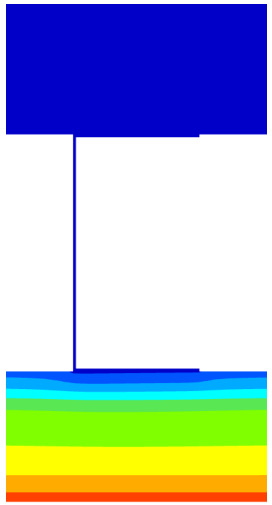




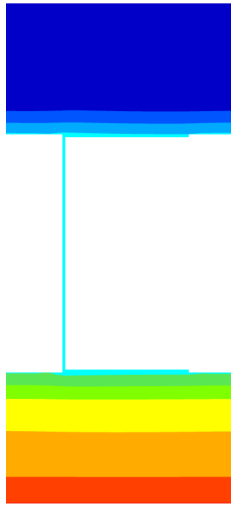
Selected Modelling Results

Fire condition: ISO Insulation type: External insulation

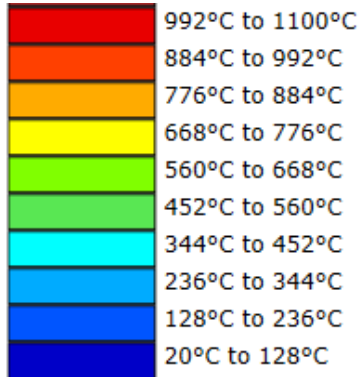
One- sided exposure

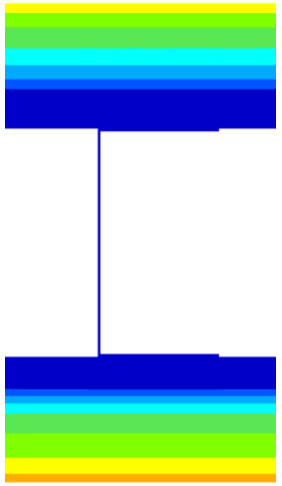


One- sided exposure



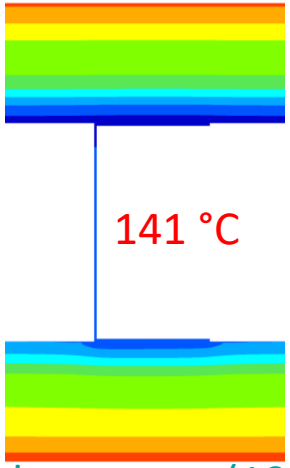
One- sided exposure





Two - sided exposure (10 min lag)

30 min



Two - sided exposure (10 min lag)

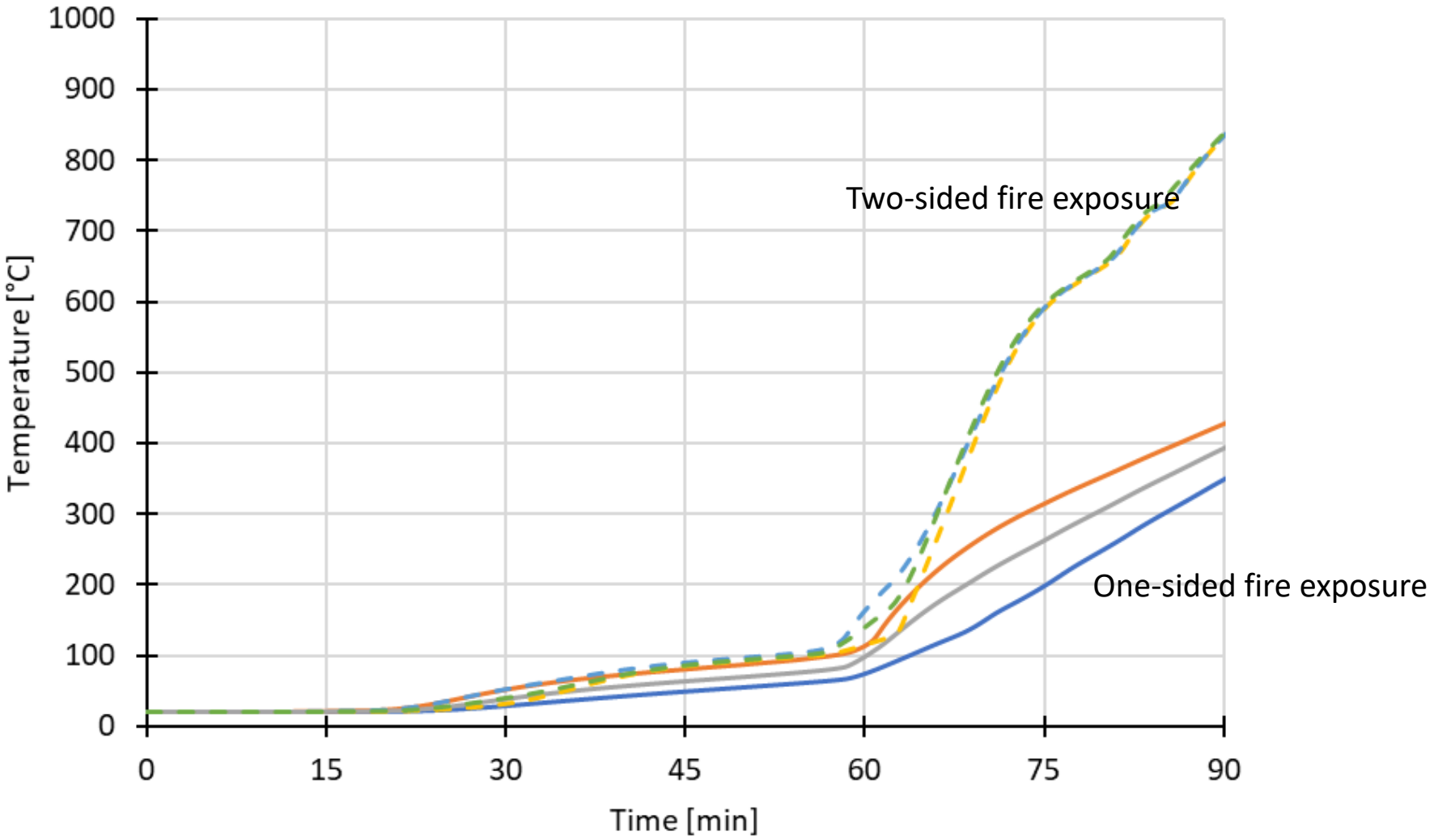
60 min

Two - sided exposure (10 min lag)

90 min

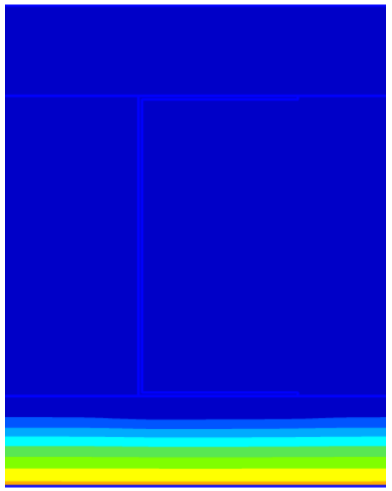
Selected Modelling Results

Fire condition: ISO Insulation type: External insulation

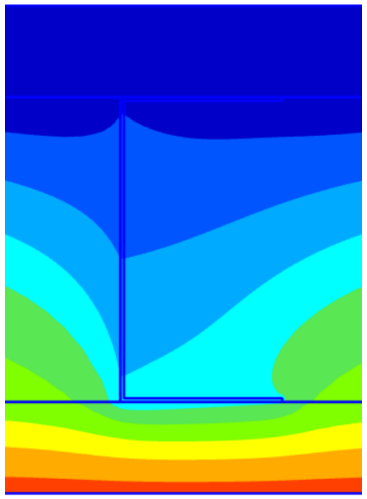


Selected Modelling Results

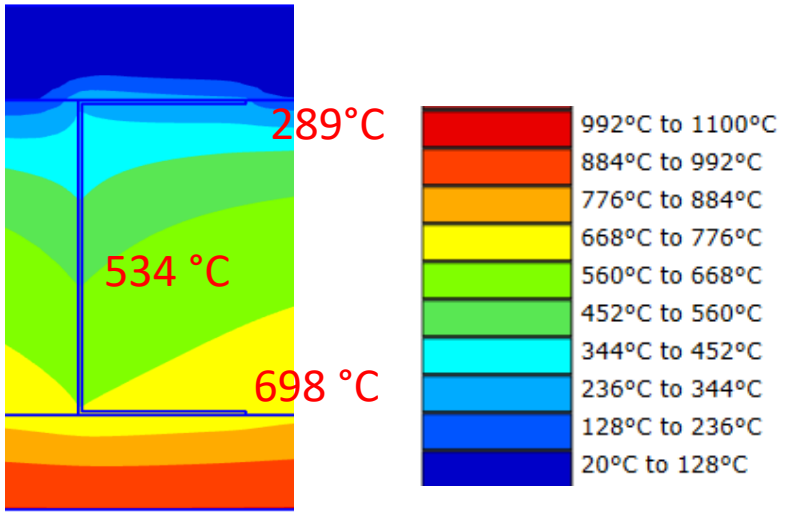
Fire condition: ISO Insulation type: Cavity insulation



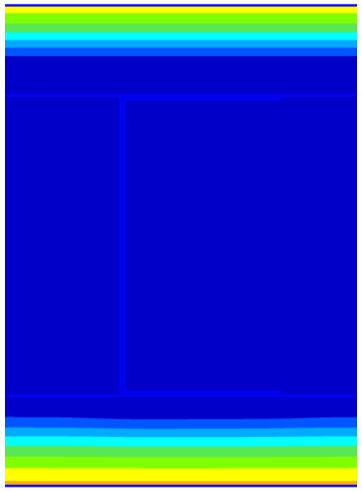
One- sided exposure



One- sided exposure

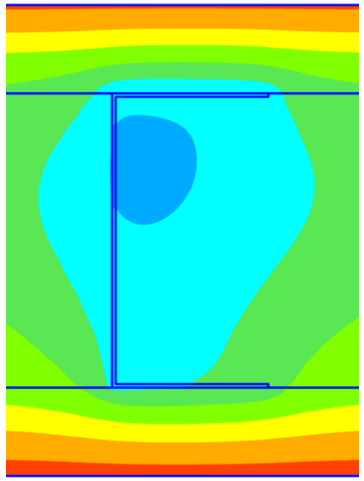


One- sided exposure



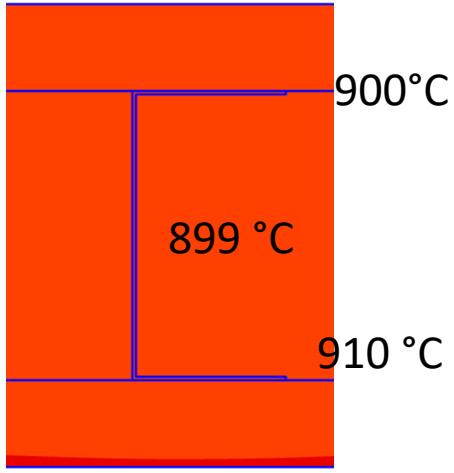
Two - sided exposure (10 min lag)

30 min



Two - sided exposure (10 min lag)

60 min

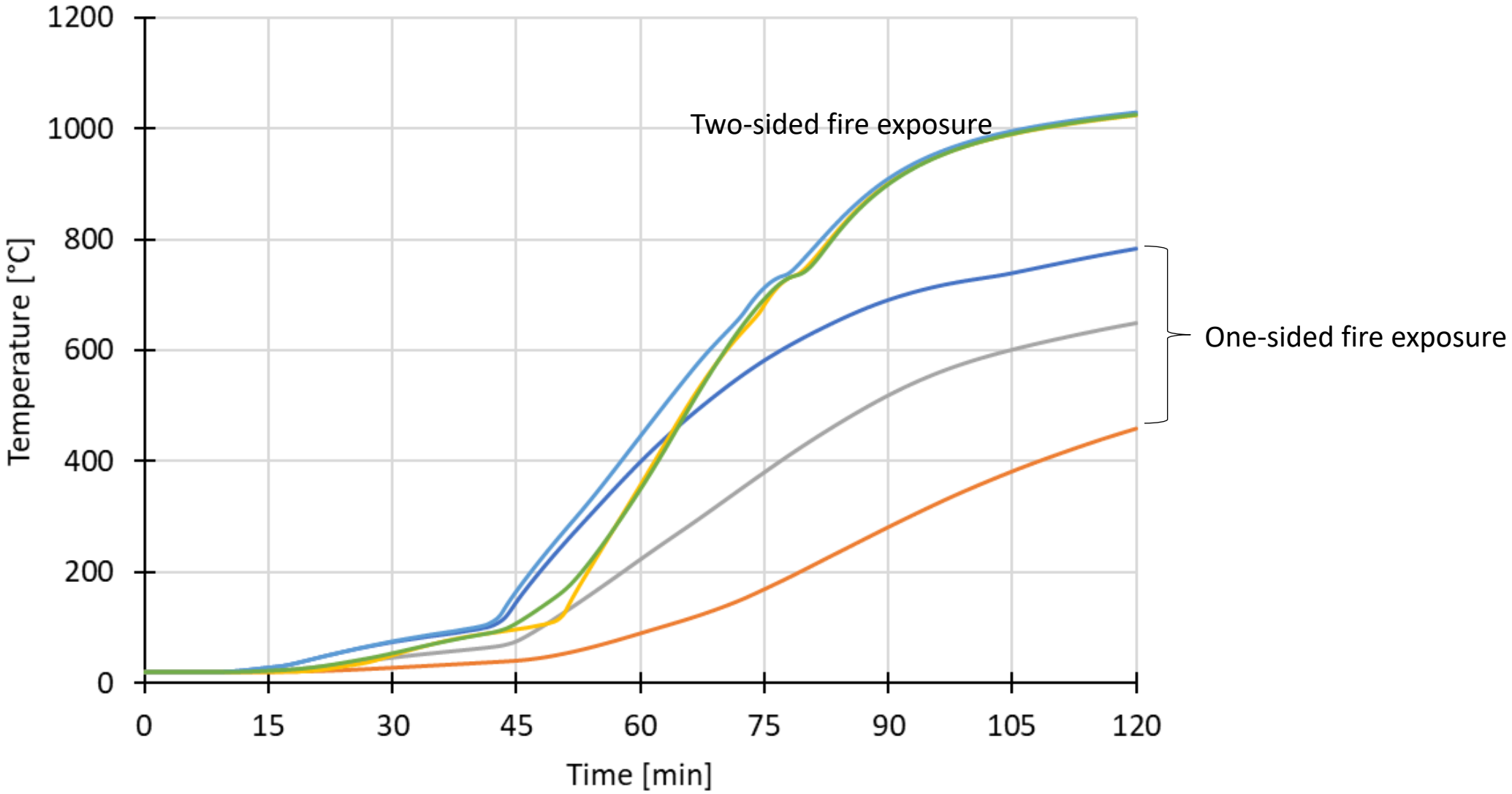


Two - sided exposure (10 min lag)

90 min

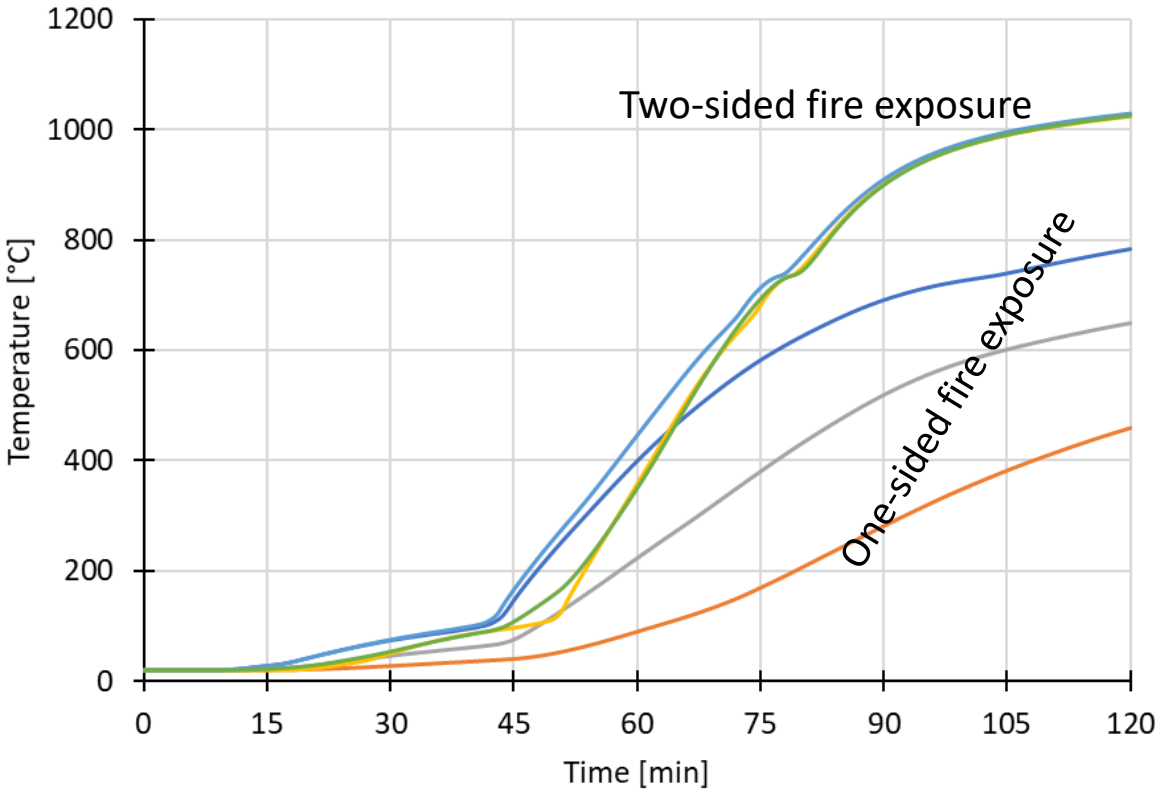
Selected Modelling Results

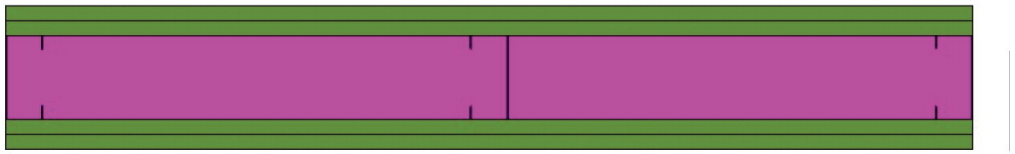
Fire condition: ISO Insulation type: Cavity insulation



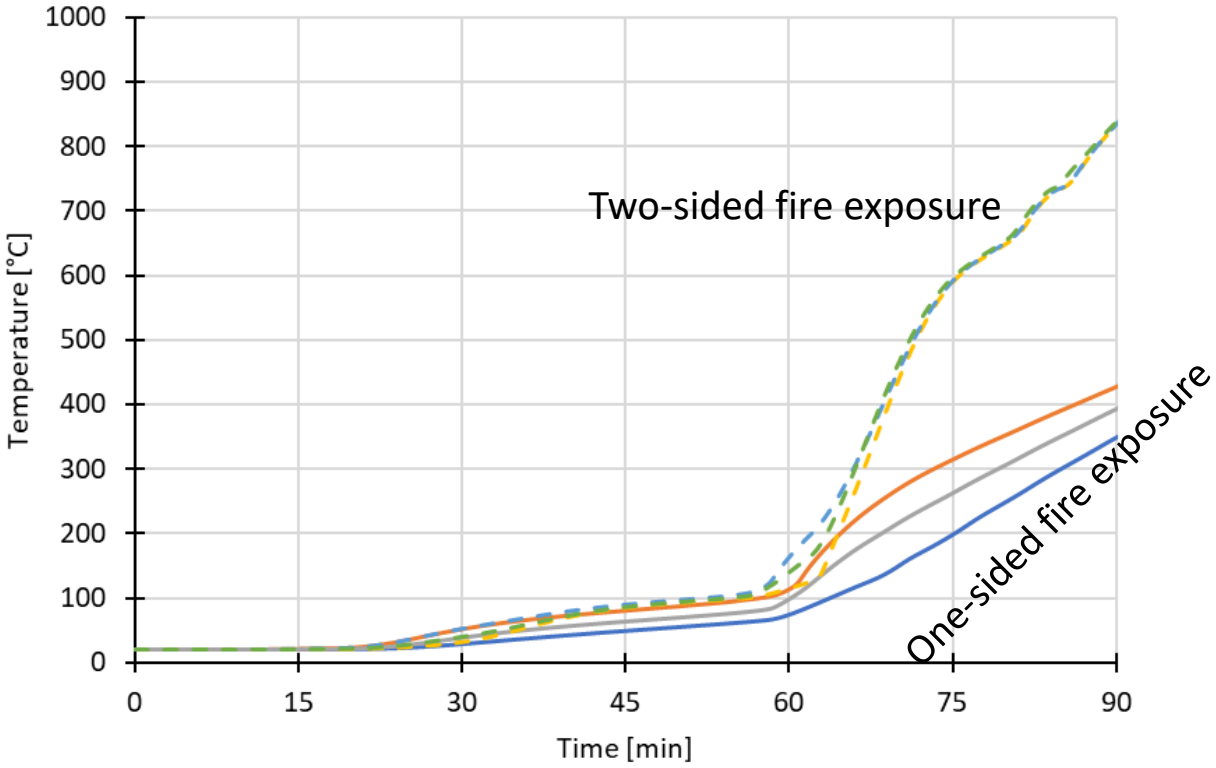
Selected Modelling Results

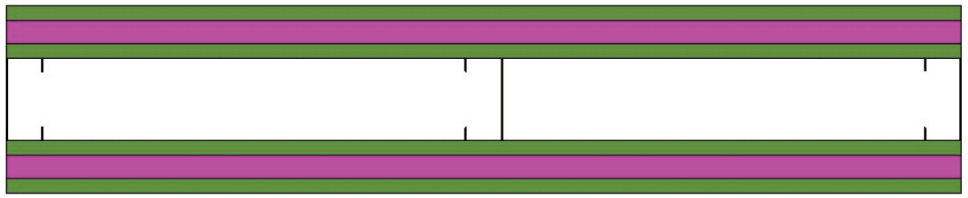
Fire condition: ISO





Insulation type: Cavity insulation





Insulation type: External insulation

Summary

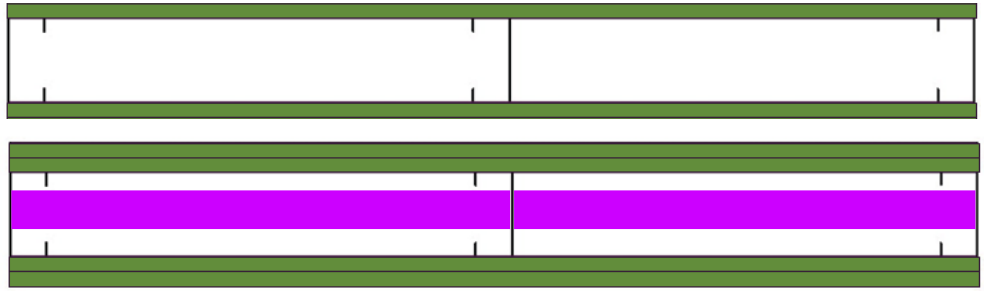
Summary

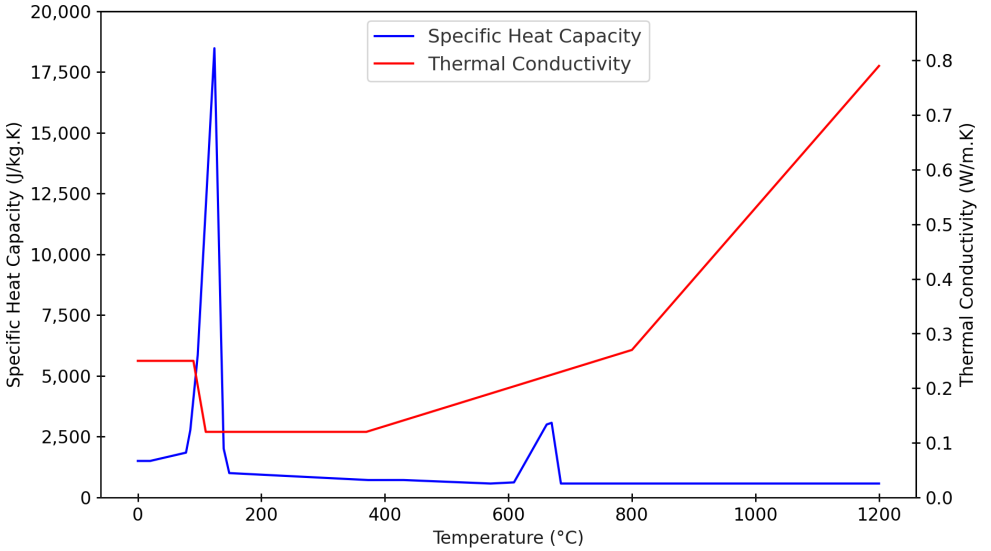
- The effect of double-sided exposure could have implications for the fire resistance of LSF walls exposed to fire.
- There is lack of test data and numerical studies for two-sided exposure of LSF walls.
- Results of numerical studies on LSF walls subjected to fire on one side can be used to define factors that can potentially influence the performance of LSF walls in fire to form a basis for future parametric studies of LSF walls exposed to fire on two sides.
- Preliminary numerical simulation indicate that Insulation between the studs has a significant impact and, therefore, this is a variable that should be considered.
- Results further suggests that two-sided exposure is more significant at higher fire resistance demands.

Further Studies

Further numerical studies

- ✓ Validation of numerical models with experiments.
- ✓ Further parametric studies:
  - ✓ Influence of different section types
  - ✓ Influence of number of sheathing board
  - ✓ Influence of cavity insulation thickness
  - ✓ More time lags
  - ✓ Thermo-mechanical analysis
  - ✓ Reversible and irreversible thermal properties
  - ✓ Influence of thermal and mechanical properties during the cooling phase
- ✓ Analysis to ascertain whether existing design equations/methods can be used or modified to account for double-sided fire exposure





Acknowledgement

Funding

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Questions?