Fire tests of loadbearing light gauge steel frame (LSF) walls: One-sided vs. two-sided fire exposure

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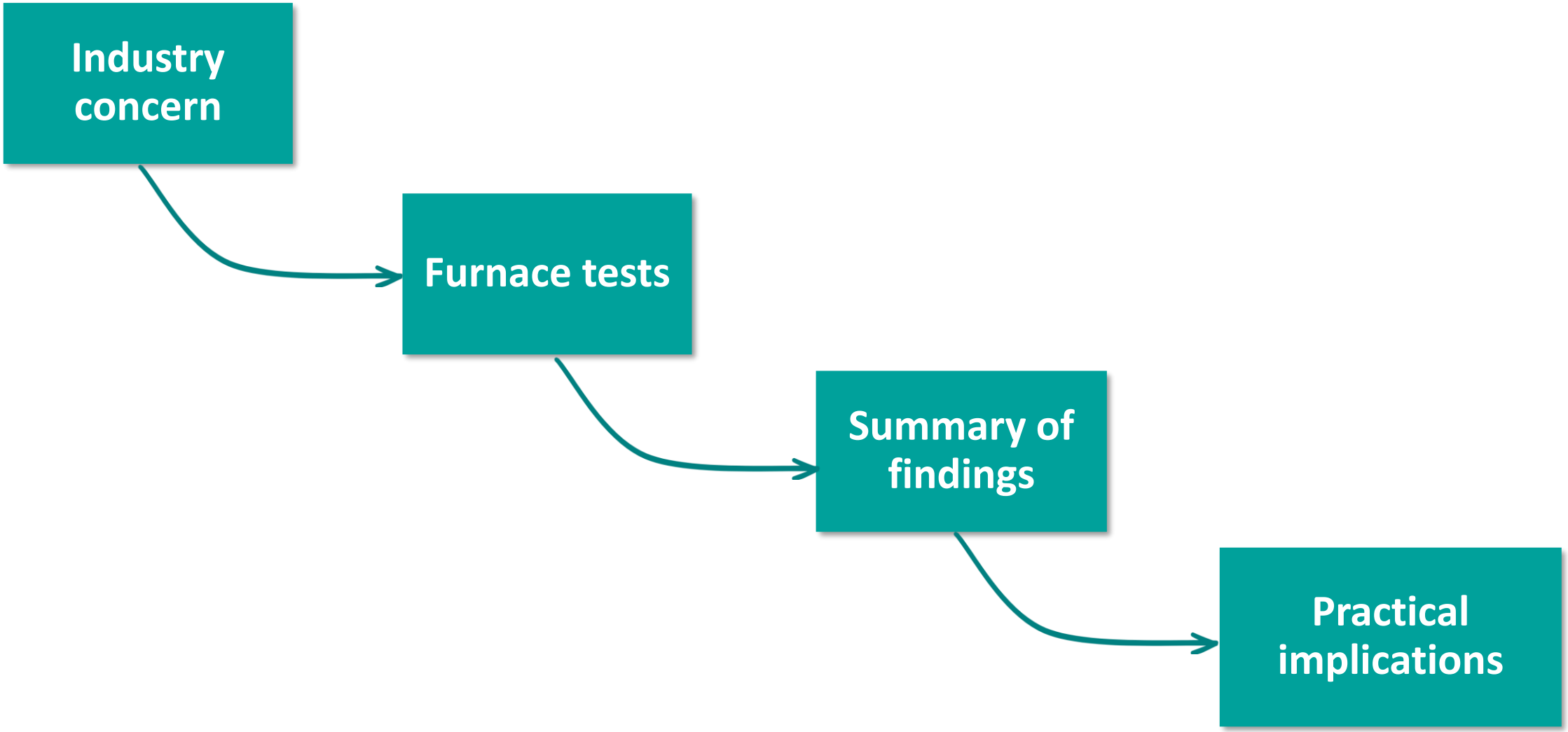
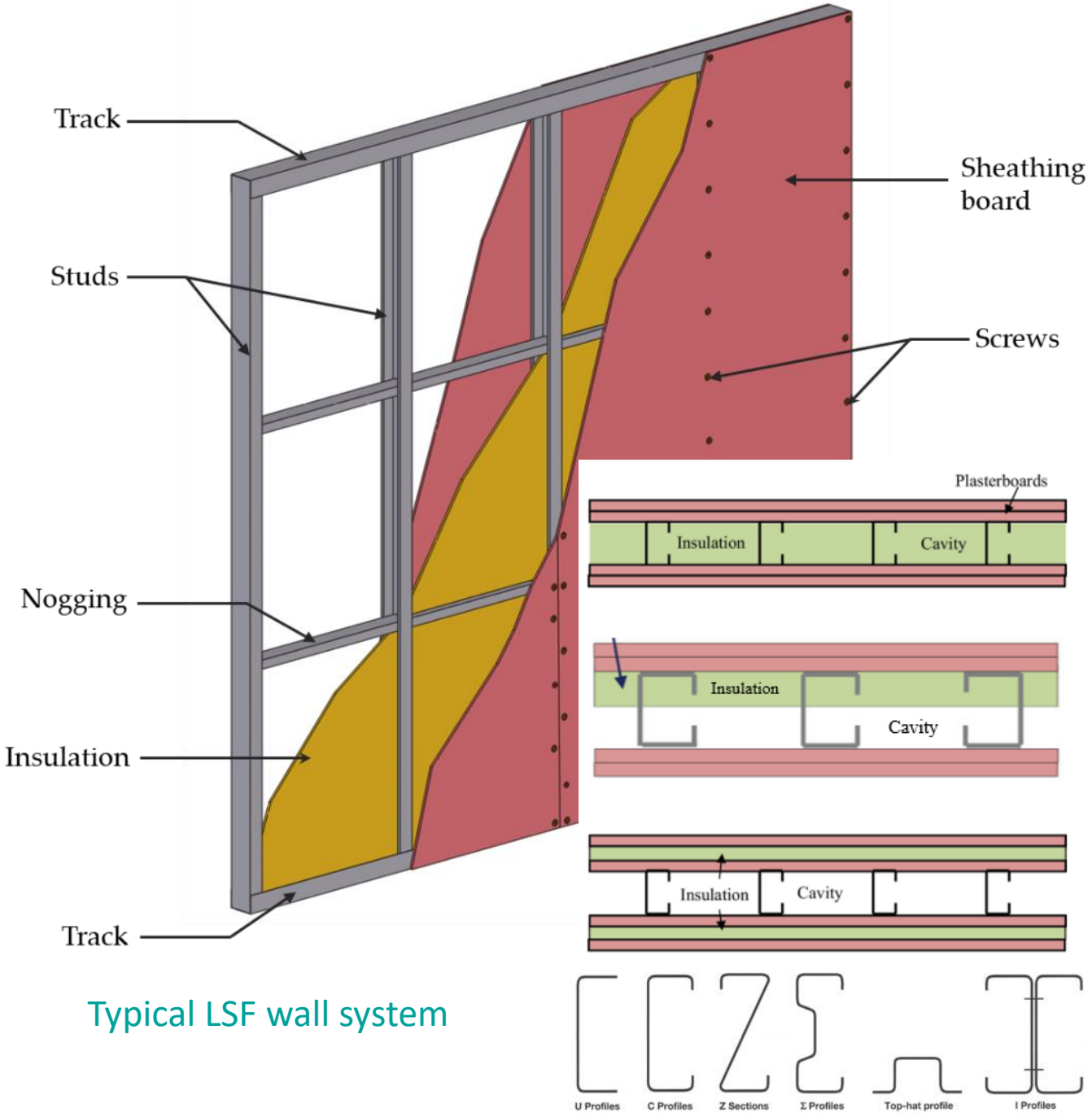
27th September 2024

Presentation Outline



Industry Concern



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 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.

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

Report 1116

CROSS Safety Report

Fire protection to structure by cavity barriers

Report ID: 1231 Published: 20 November 2023 Region: CROSS-UK

Overview

A reporter is concerned about a potential misconception in the construction industry regarding the role of cavity barriers and the impact their design and installation can have on the structural performance of a building.

Key Learning Outcomes

Fire and structural engineers/designers:

- As cavity barriers have a role in protecting the structure as well as inhibiting the spread of fire and smoke, they should be specified carefully, in particular when they have a role in protecting the structure

Report 1231

CROSS UK

CROSS Safety Report

Use of Table B3 of Approved Document B for loadbearing external walls

Report ID: 1264 Published: 21 May 2024 Region: CROSS-UK

Overview

A reporter is concerned about the apparent selective reading of Table B3 of Approved Document B (ADB) by some designers.

Key Learning Outcomes

For designers and engineers:

- Loadbearing walls, whatever their location or use should have the most onerous fire resistance guidance applied from Approved Document B Table 3
- When considering the guidance of Table B3, the user should always consider their particular building situation, including the type of construction and associated sensitivity to heat exposure
- The potential type of fire exposure a construction may face must also be considered

For building control bodies:

- Ensure the guidance in Table B3 is only applied within its scope and in situations where it can be demonstrated that the overall functional requirements of the building regulations will be met, and stability will be maintained for the required period in ADB Appendix B

Report 1264

Responding to industry concerns

Table B3 Specific provisions of the test for fire resistance of elements of structure, etc.

Part of building	Minimum provisions when tested to the relevant European standard (minutes)[1]	Alternative minimum provisions when tested to the relevant part of **BS 476**[2] (minutes)			Type of exposure
		Loadbearing capacity[3]	Integrity	Insulation	
Structural frame, beam or column.	R see Table B4	See Table B4	Not applicable	Not applicable	Exposed faces
2. **Loadbearing wall** (for a wall which is also described in any of the following items, the more onerous guidance should be applied).	R see Table B4	See Table B4	Not applicable	Not applicable	Each side separately
3. **Floors**[4]					
a. between a shop and flat above	REI 60 or see Table B4 (whichever is greater)	60 min or see Table B4 (whichever is greater)	60 min or see Table B4 (whichever is greater)	60 min or see Table B4 (whichever is greater)	From underside[5]
b. in upper storey of two storey dwellinghouse (but not over garage or basement)	R 30 and EI 15	30 min	15 min	15 min	From underside[5]
c. any other floor – including compartment floors.	REI see Table B4	See Table B4	See Table B4	See Table B4	From underside[5]

Table B3 Continued

Part of building	Minimum provisions when tested to the relevant European standard (minutes)[1]	Alternative minimum provisions when tested to the relevant part of **BS 476**[2] (minutes)			Type of exposure
		Loadbearing capacity[3]	Integrity	Insulation	
4. **Roofs**					
a. any part forming an escape route	REI 30	30 min	30 min	30 min	From underside[5]
b. any roof that performs the function of a floor.	REI see Table B4	See Table B4	See Table B4	See Table B4	From underside[5]
5. **External walls**					
a. any part a maximum of 1000mm from any point on the relevant boundary[6]	REI see Table B4	See Table B4	See Table B4	See Table B4	Each side separately
b. any part a minimum of 1000mm from the relevant boundary[6]	RE see Table B4 and I 15	See Table B4	See Table B4	15 min	From inside the building
c. any part beside an external escape route (Section 2 Diagram 2.7 of Approved Document B Volume 1 and Section 3, Diagram 3.4).	RE 30	30 min	30 min	No provision[7] [8]	From inside the building
6. **Compartment walls** Separating either:					
a. a flat from any other part of the building (see paragraph 7.1 of Approved Document B Volume 1)	REI 60 or see Table B4 (whichever is less)	60 min or see Table B4 (whichever is less)	60 min or see Table B4 (whichever is less)	60 min or see Table B4 (whichever is less)	Each side separately
b. occupancies.	REI 60 or see Table B4 (whichever is less)	60 min or see Table B4 (whichever is less)	60 min or see Table B4 (whichever is less)	60 min or see Table B4 (whichever is less)	Each side separately
7. **Compartment walls** (other than in item 6 or item 10).	REI see Table B4	See Table B4	See Table B4	See Table B4	Each side separately

A

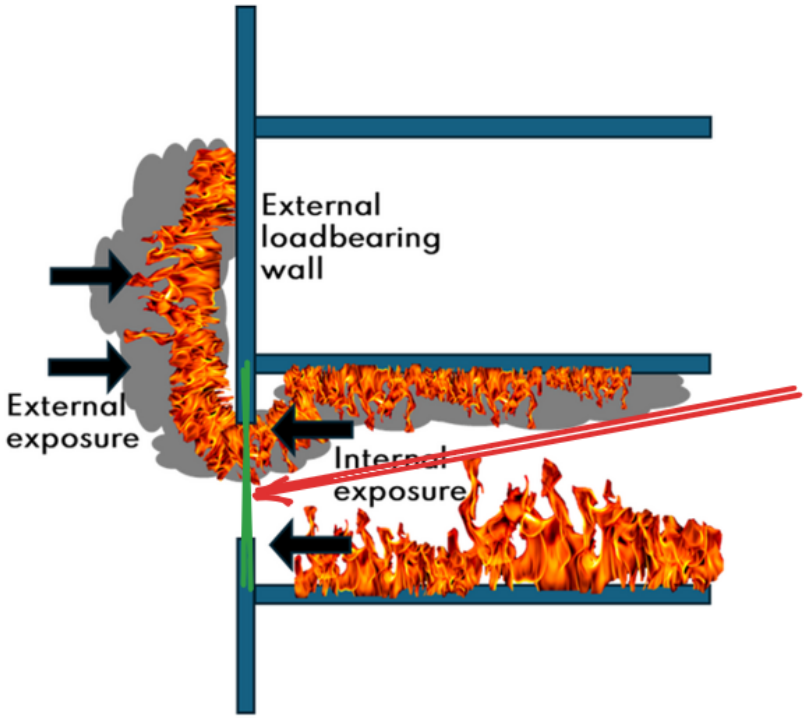
B

C

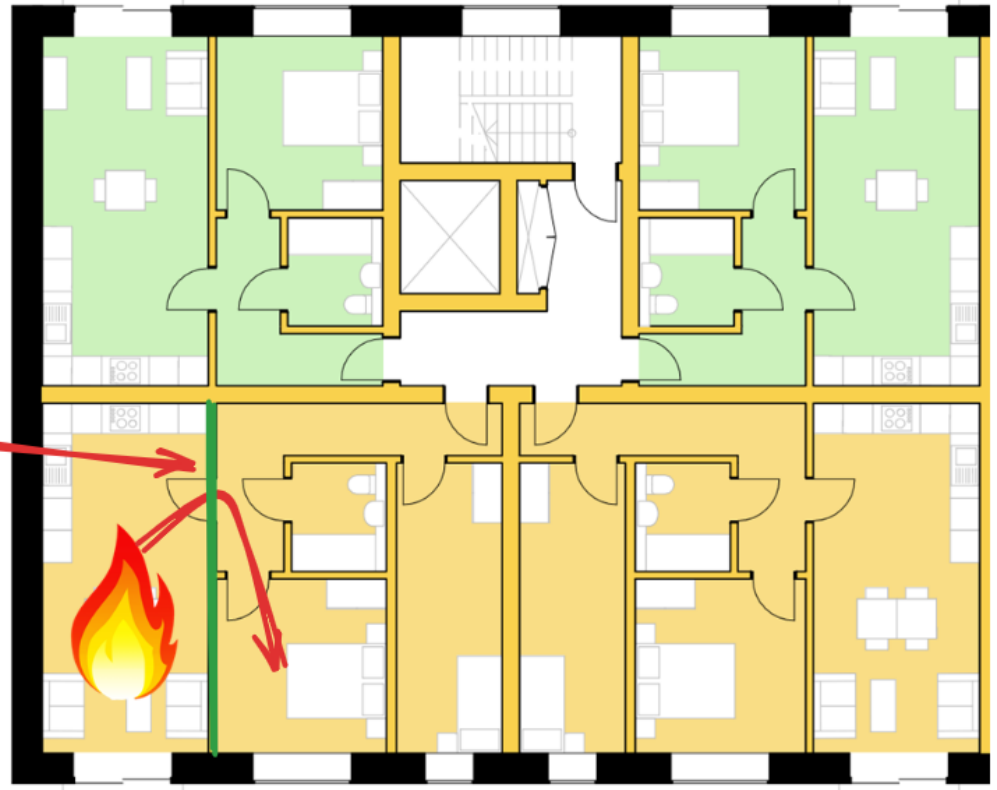
A **"Exposed faces"**

B **"Each side separately"**

C **"From inside the building"**



Wall exposed on BOTH SIDES simultaneously



EXTERNAL FIRE SPREAD

INTERNAL FIRE SPREAD

*From: CROSS-UK (2024)**

* CROSS-UK, 2024, Use of Table B3 of Approved Document B for loadbearing external walls, 1264, CROSS-UK. [Online]. Available: https://www.cross-safety.org/uk/safety-information/cross-safety-report/use-table-b3-approved-document-b-loadbearing-1264. [Accessed: 21-Sep-2024]

Guidance

Approved Document B: Fire safety - frequently asked questions

Answers to frequently asked questions on Approved Document B including 2020 and 2022 amendments.

From: Department for Levelling Up, Housing and Communities and Health and Safety Executive

Published 23 August 2022

Last updated 14 March 2024 — See all updates

13. Are the exposure conditions recommended in Table B3 applicable to all situations?

14. My building element could be described by several of the items in Table B3. Which one should I apply?

https://www.gov.uk/guidance/approved-document-b-fire-safety-frequently-asked-questions

CROSS Safety Report

Fire protection to light gauge steel frame walls

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

Expert Panel Comments

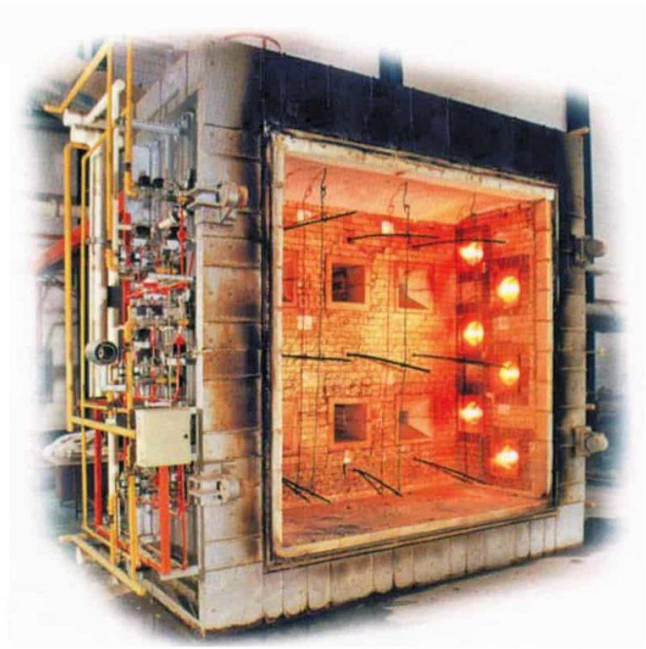
The panel agrees that these internal loadbearing walls could be exposed on both sides simultaneously and should be designed as such because exposure to both sides by fire is possible. Avoiding such confusion is even more crucial when the structural (resistance) requirements are higher than the separating requirements (insulation and integrity).

BS 476-21:1987

A.6 Walls

A.6.1 ***General***

Some walls, used in practice, act as wide columns which are not designed to provide fire separation, but are required for their loadbearing capacity. In such cases the methods specified in clause 8 may be used but normally the criteria for integrity and thermal insulation are not required. Owing to modern building design, situations can develop in a building, due to open plan design or the provision of doors that are not inherently fire resisting, where a wall that acts as a wide column can be exposed either partially or fully to fire on both faces simultaneously. Very few facilities are capable of exposing a realistic length of walling to fire exposure on both faces simultaneously. However, where the facility does exist, the basic methodology used in evaluating the single face exposure is appropriate for such situations.



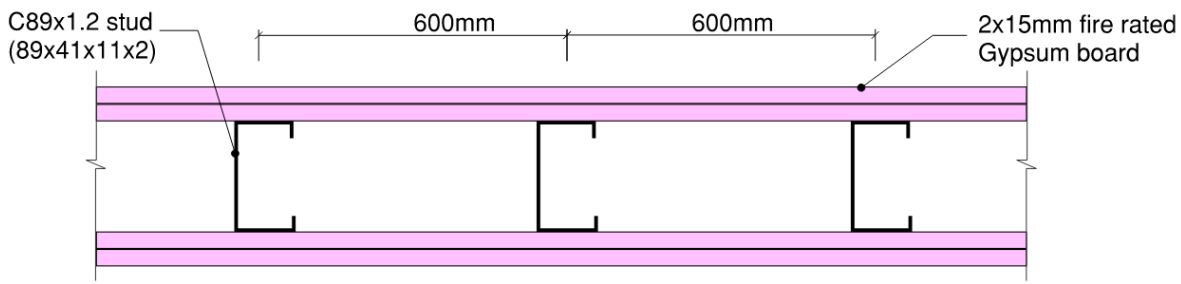
Literature Review

- There is lack of test data for two-sided exposure of LSF walls. This justifies the need for two-sided exposure testing to be carried out.
- Experimental and numerical modelling data for one-sided fire exposure of LSF walls show that the insulation between the studs has a significant impact. Therefore, this is a variable that should be considered.
- Evidence from other materials (i.e., masonry and concrete) suggests that the difference between one-sided and two-sided exposure is more significant at higher fire resistance demands.
- Current design guidance in England (Table B3 of Approved Document B) does not explicitly identify a need to test for two-sided exposure.

Furnace Tests

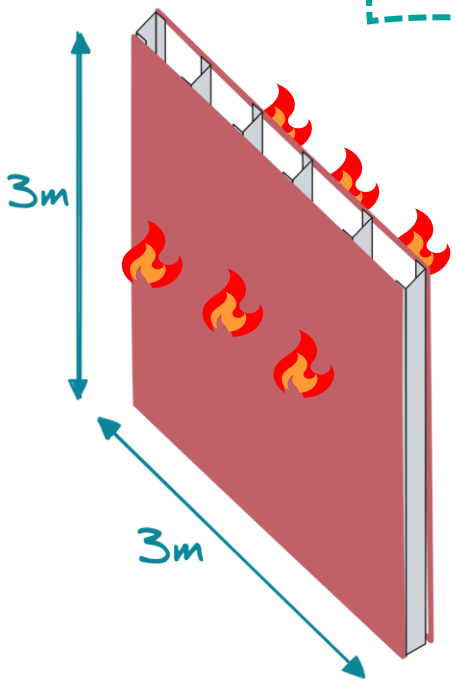
Test programme

ISO fire

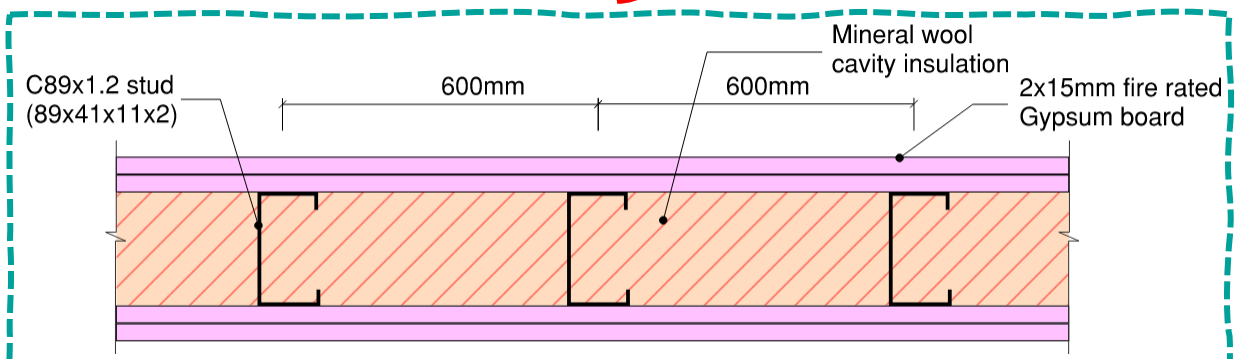


ISO fire

	Fire exposure condition	Cavity insulation
1	Two-sided	No
2	One-sided	
3	Two-sided	Yes
4	One-sided	



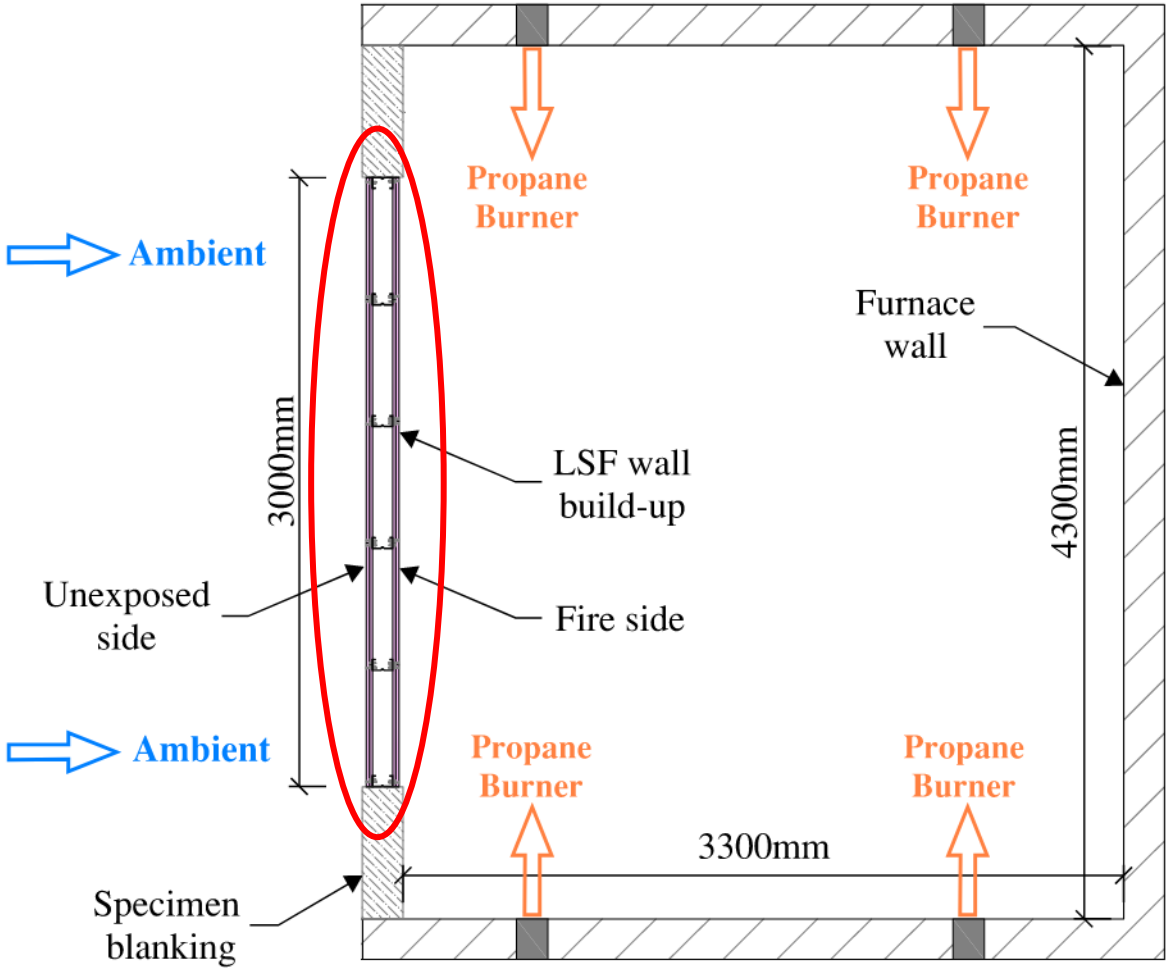
ISO fire

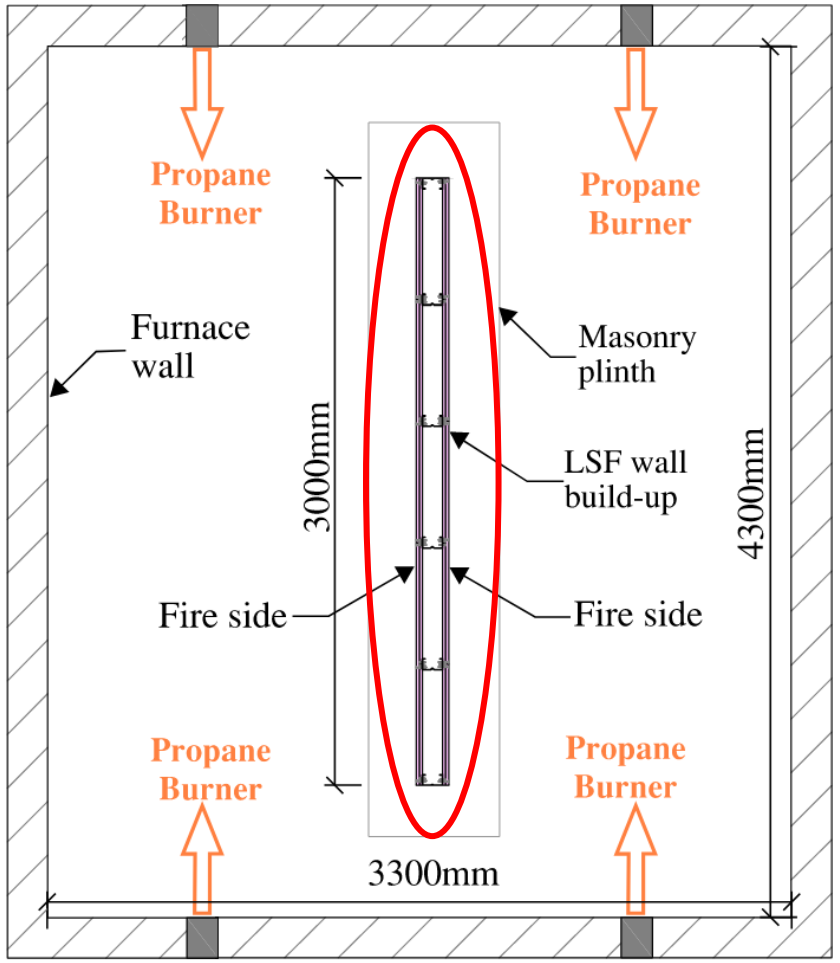


ISO fire

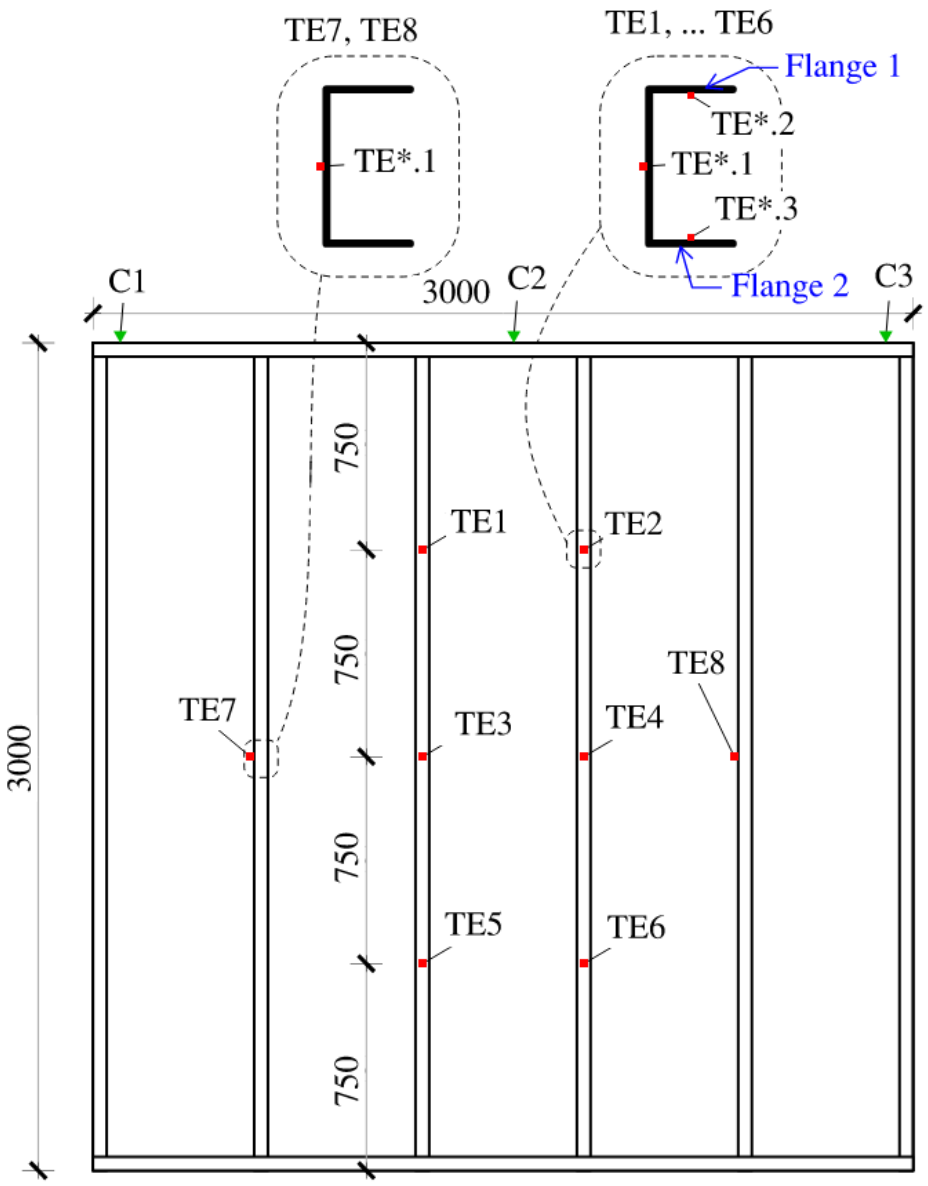
REI 90

Test setup

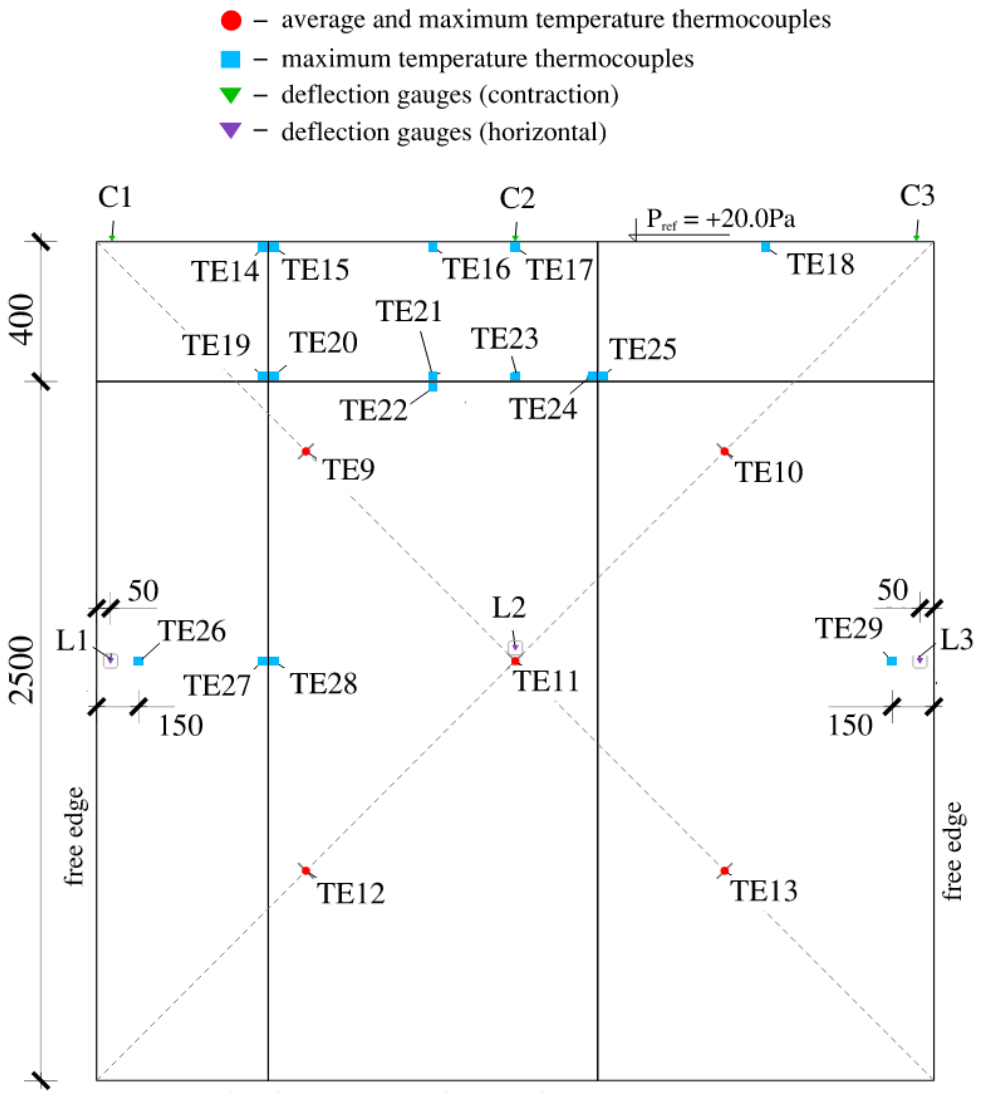

Ambient
Propane Burner
Propane Burner
Furnace wall
LSF wall build-up
3000mm
4300mm
Unexposed side
Fire side
Ambient
Propane Burner
Propane Burner
3300mm
Specimen blanking


Propane Burner
Propane Burner
Furnace wall
Masonry plinth
3000mm
LSF wall build-up
4300mm
Fire side
Fire side
Propane Burner
Propane Burner
3300mm

Instrumentation



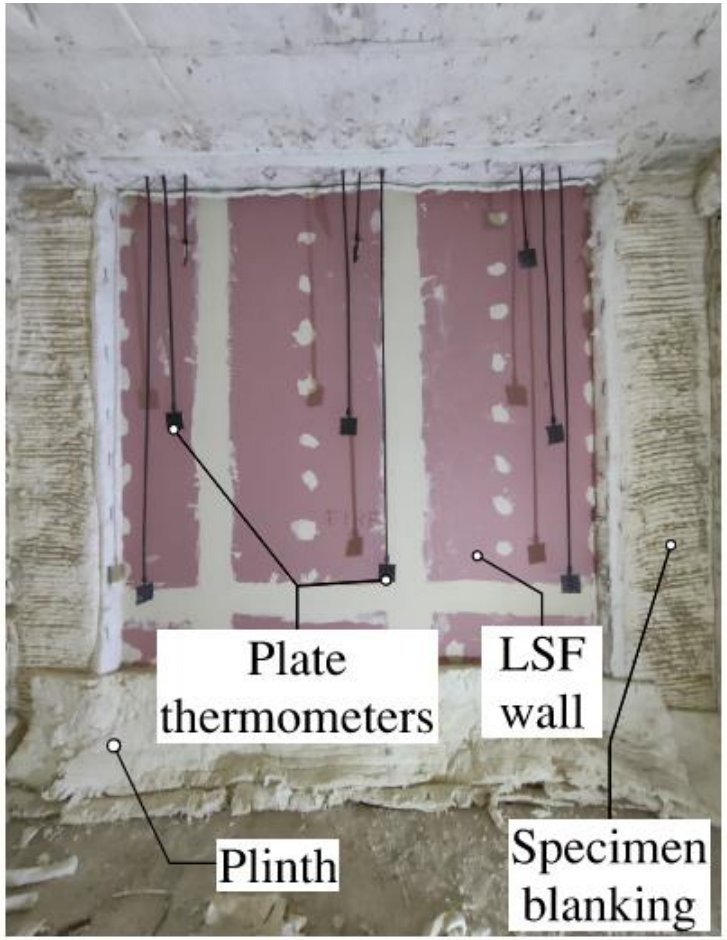
INTERNAL THERMOCOUPLES



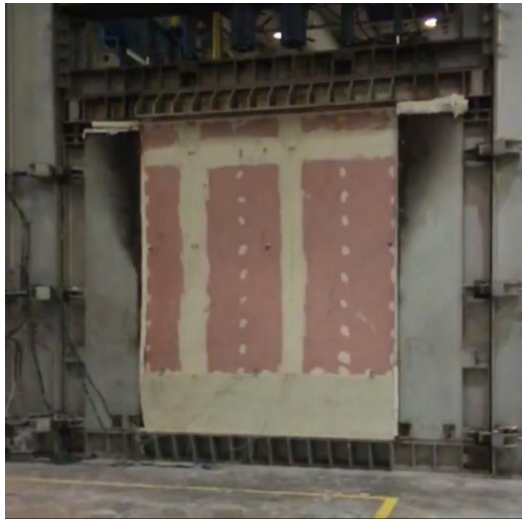
EXTERNAL THERMOCOUPLES

TWO-SIDED FIRE EXPOSURE

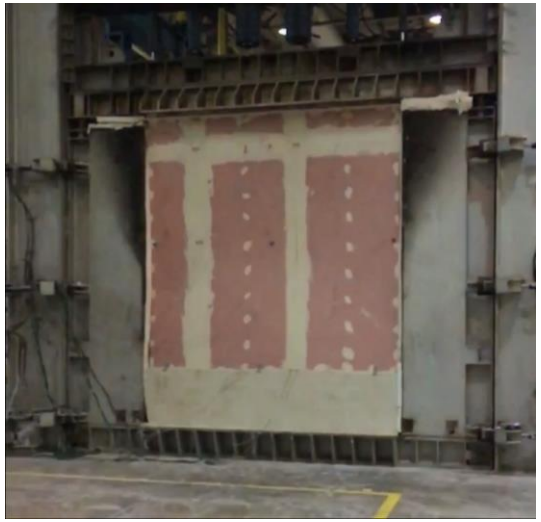
ONE-SIDED FIRE EXPOSURE



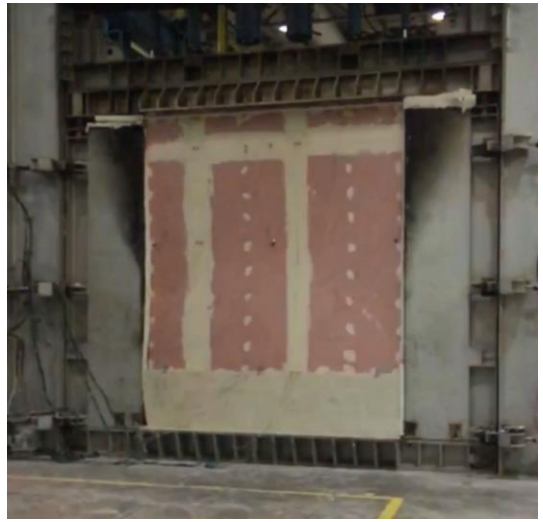
Time-lapse image of LSF wall performance during fire test (one-sided, no insulation)



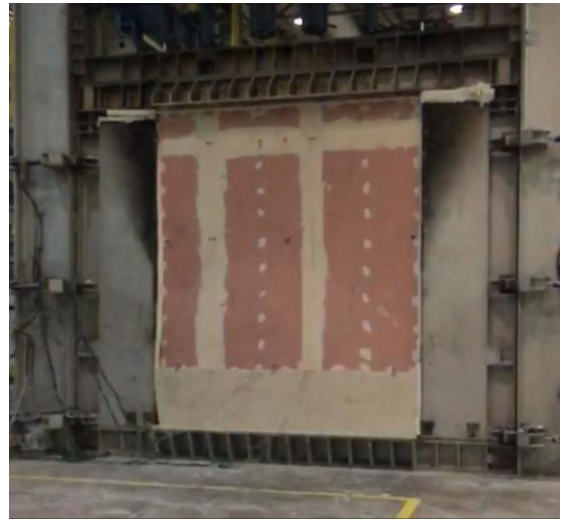
0 min



30 min



60 min



90 min

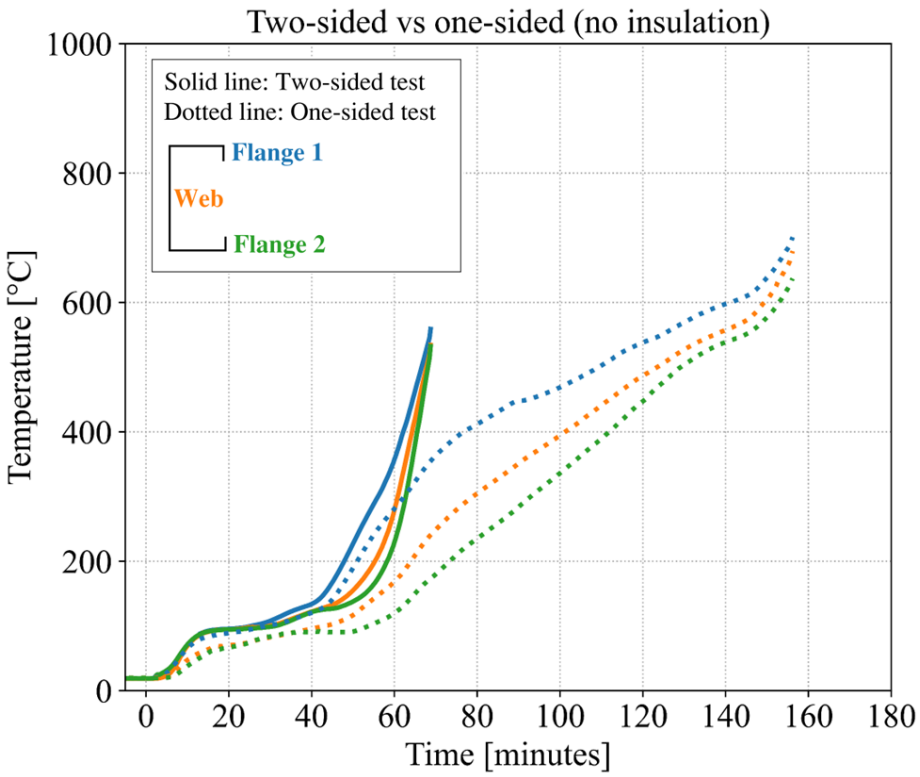
120 min

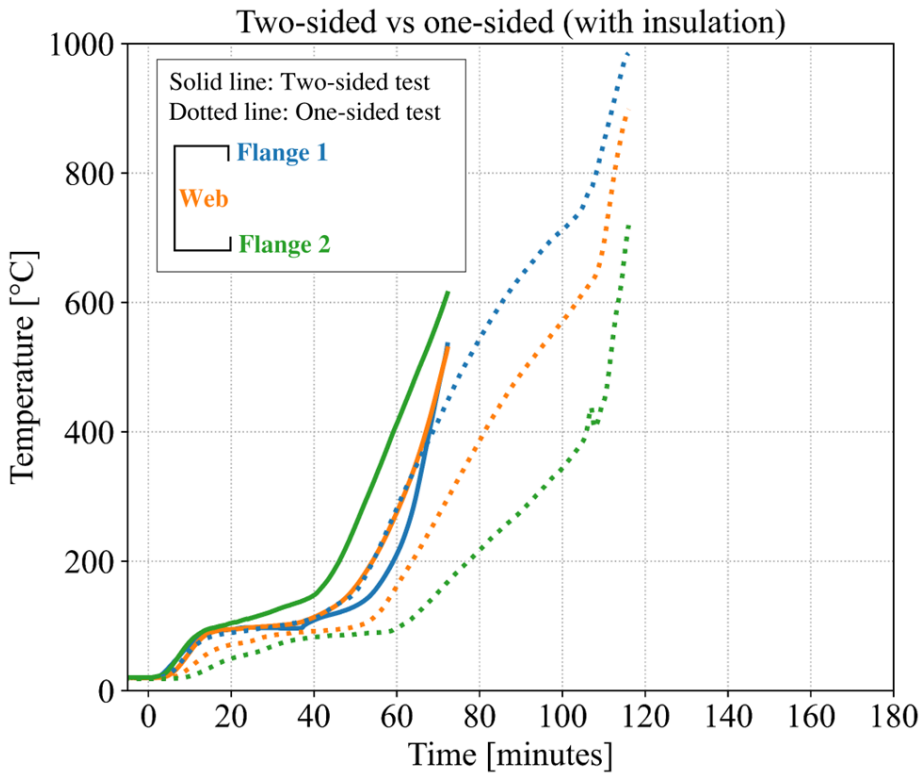
156 min

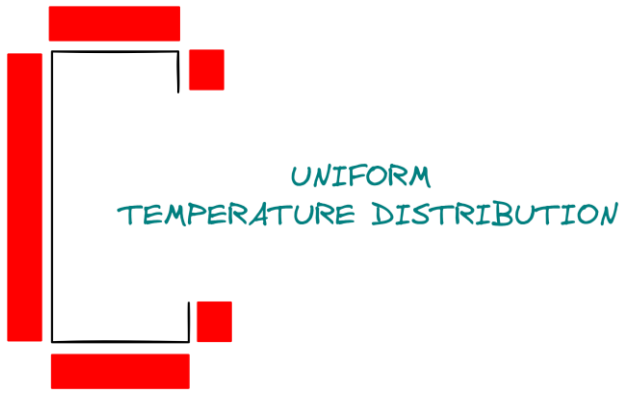
156 min: 8 sec

156 min: 18 sec

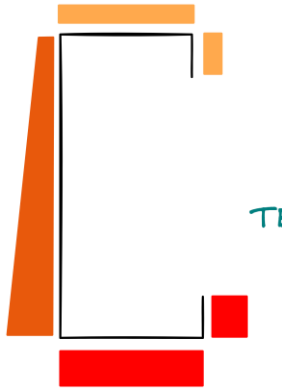
Steel stud temperature distribution





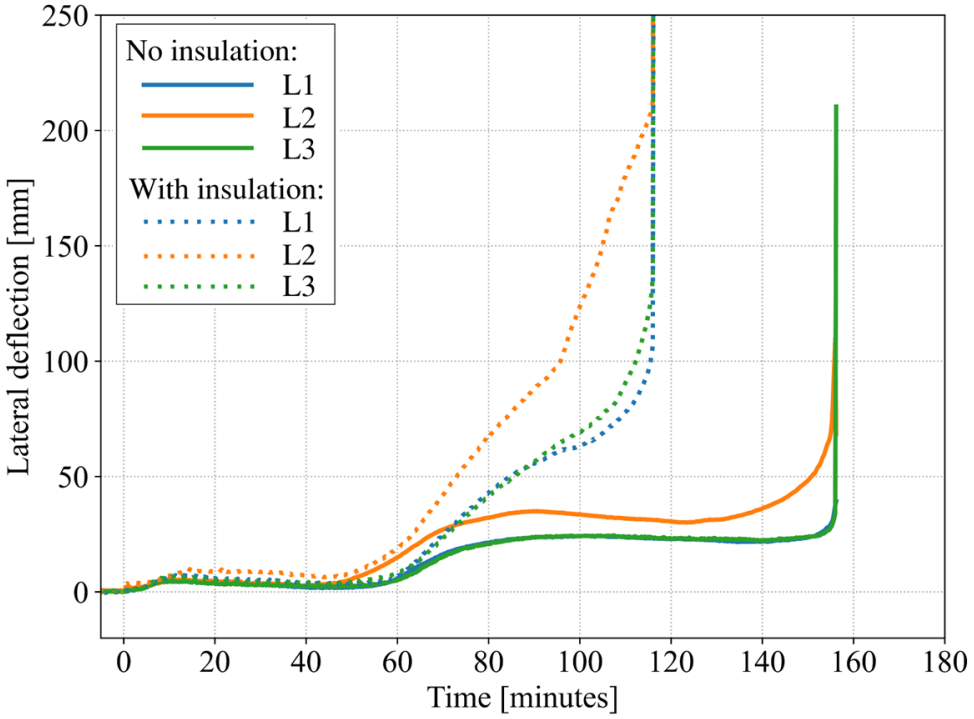


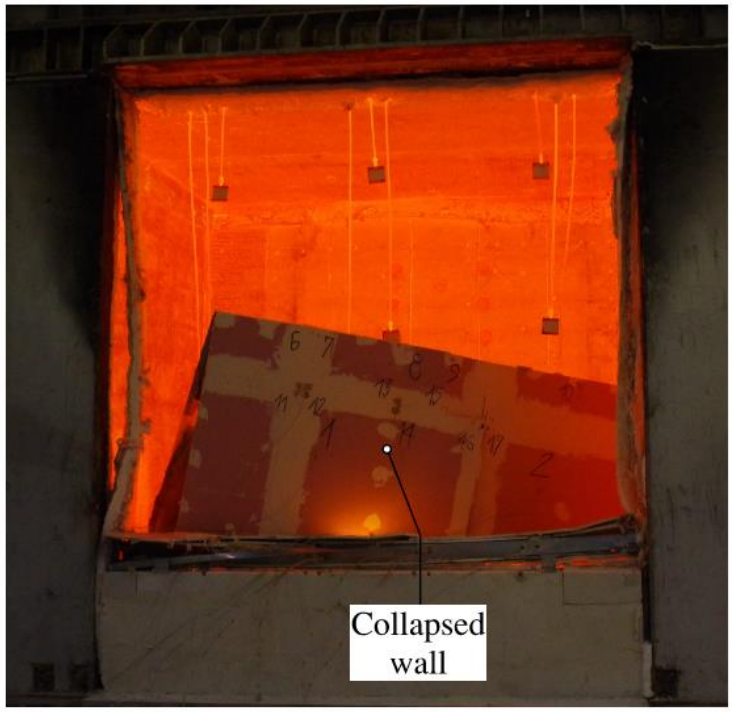
UNIFORM
TEMPERATURE DISTRIBUTION



NON-UNIFORM
TEMPERATURE DISTRIBUTION

Lateral deflection of wall specimen





Effect of the insulation

Fire exposure condition	Cavity insulation	Time to failure [minutes]	Ratio of two-sided to one-sided
Two-sided	No	68	0.44
One-sided		156	
Two-sided	Yes	72	0.62
One-sided		116	

Effect of the insulation

Fire exposure condition	Cavity insulation	Time to failure [minutes]	Ratio of two-sided to one-sided
Two-sided	No	68	0.44
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Two-sided	Yes	72	0.62
One-sided		116	

Effect of no. of fire exposed sides

Fire exposure condition	Cavity insulation	Time to failure [minutes]	Ratio of two-sided to one-sided
Two-sided	No	68	0.44
One-sided		156	
Two-sided	Yes	72	0.62
One-sided		116	

Effect of no. of fire exposed sides

Fire exposure condition	Cavity insulation	Time to failure [minutes]	Ratio of two-sided to one-sided
Two-sided	No	68	0.44
One-sided		156	
Two-sided	Yes	72	0.62
One-sided		116	

More info and data in the paper

SiF 2024 – The 13th International Conference on Structures in Fire
University of Coimbra, Portugal, 19 to 21 June 2024

EXPERIMENTAL STUDY OF THE LOADBEARING PERFORMANCE OF LIGHT GAUGE STEEL FRAME (LSF) WALLS EXPOSED TO FIRE ON TWO SIDES

Iziengbe Inerhunwa[1], Danny Hopkin[2], Grzegorz Kimbar[3], Michael Spearpoint[4], Georgios Kanellopoulos[5], Piotr Turkowski[6]

ABSTRACT

Concerns have been raised by UK industry regarding the expected fire performance of buildings that employ light gauge steel frame (LSF) walls as a solution for their structural loadbearing system. There is a level of uncertainty arising from the potential exposure of internal and external loadbearing walls to heating conditions on both sides. This study investigated the performance of loadbearing LSF walls exposed to fire on two sides to determine whether their loadbearing performance is likely affected by the number of faces simultaneously exposed to fire. A total of four wall specimens were tested, two each (with and without cavity insulation) for one- and two-sided fire exposure conditions under the ISO 834 heating regime. The main findings from the experiments are that exposure of LSF walls to fire on two sides markedly intensifies heating compared to one-sided exposure, evidenced by higher stud temperatures and accelerated rates of increase particularly at higher fire resistance periods. The loadbearing capacity of LSF walls is considerably reduced under two-sided fire, dropping to 44% for non-insulated walls and 62% for cavity-insulated walls, relative to one-sided exposure. While cavity insulation precipitates a notable temperature gradient and subsequent early failure in one-sided exposure, its impact is negligible in two-sided scenarios. Furthermore, the results showed that fire resistance classifications for single-sided exposure should not be extrapolated to two-sided exposure.

Keywords: Light gauge steel frame (LSF); loadbearing walls, two-sided exposure; standard fire test

1 INTRODUCTION

Light gauge steel frame (LSF) walls are commonly used in modern building construction [1], consisting of cold-formed steel studs, sheathing material, and may include insulation [2]. LSF walls may be used as fire-separating walls to mitigate fire and smoke spread from one compartment to another and limit temperature

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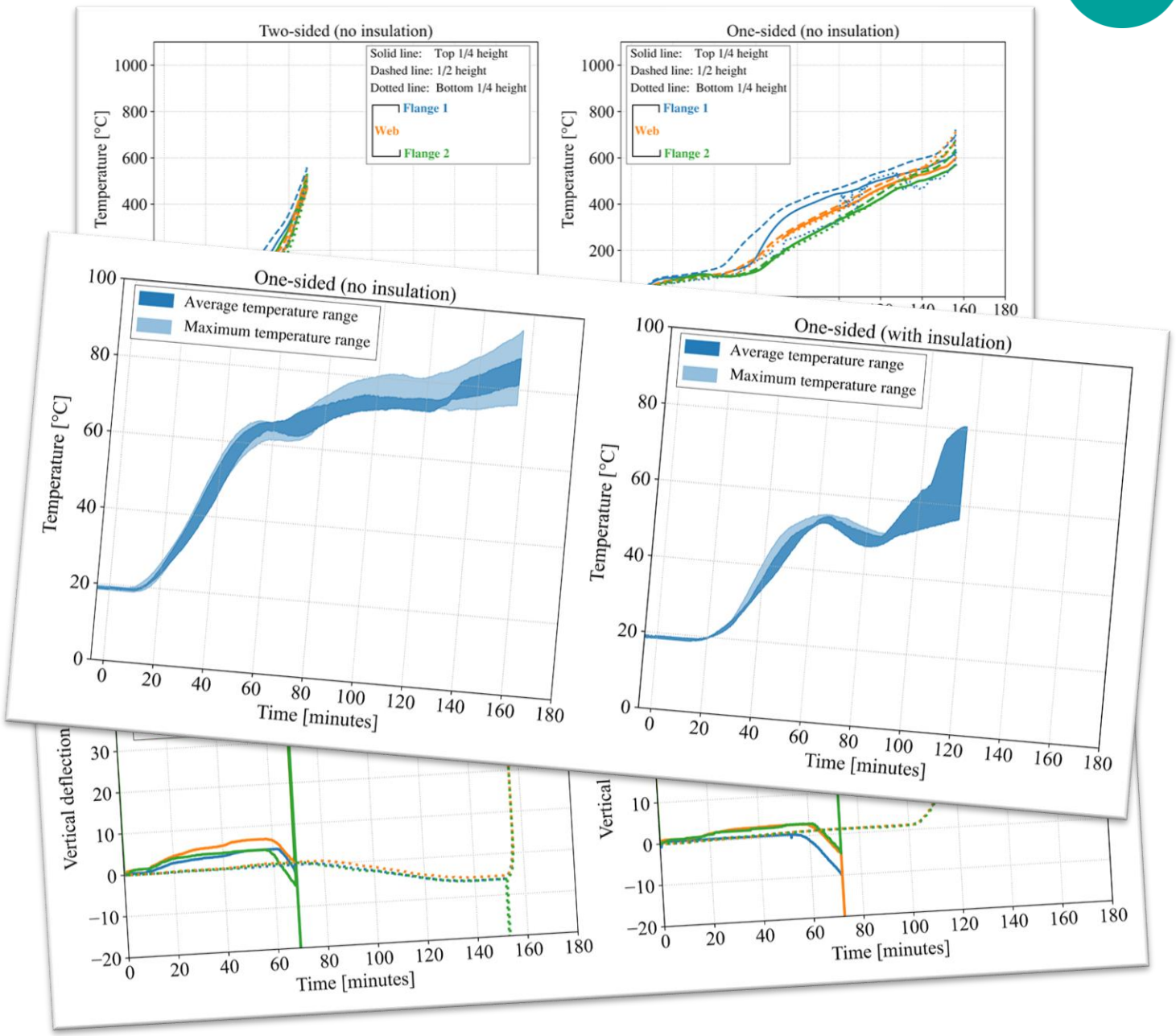
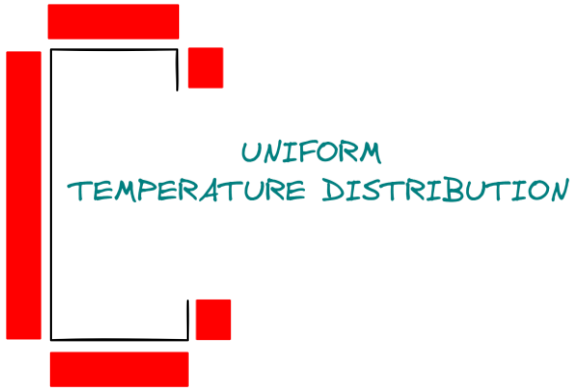


Summary of Findings

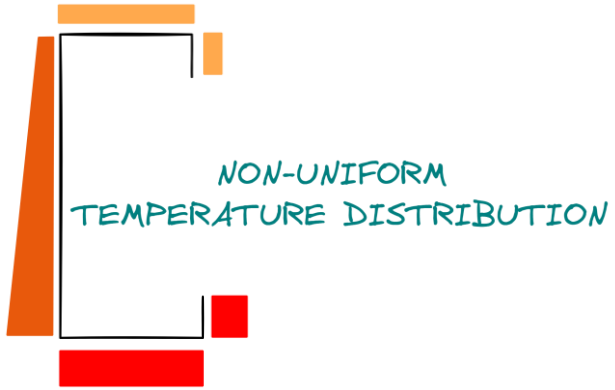
Summary of findings from test

- The loadbearing capacity of LSF walls decreased significantly when exposed to two-sided fire: down to **44% for non-insulated walls** and **62% for insulated walls**.

- One-sided fire exposure leads to a significant thermal gradient and non-uniform heating within the stud section, especially when insulation is present. In contrast, two-sided exposure generally promotes a more even temperature distribution across the stud section.



- Temperature gradient due to cavity insulation in one-sided fire exposure leads to thermal bowing and earlier structural failure compared to non-insulated walls. For two-sided fire exposure, the influence of cavity insulation on the performance was not significant versus non-insulated walls.



- The temperature gradient due to presence of insulation for one-sided fire exposure typically results in reduced load-bearing fire resistance. However, the reduction due to two-sided heating is greater.

- Fire resistance classifications for one-sided exposure should not be extrapolated to two-sided exposure.

Practical Implications

Key Learning Outcomes

For designers and engineers:

- Loadbearing walls, whatever their location or use should have the most onerous fire resistance guidance applied from Approved Document B Table 3
- When considering the guidance of Table B3, the user should always consider their particular building situation, including the type of construction and associated sensitivity to heat exposure
- The potential type of fire exposure a construction may face must also be considered

For building control bodies:

- Ensure the guidance in Table B3 is only applied within its scope and in situations where it can be demonstrated that the overall functional requirements of the building regulations will be met, and stability will be maintained for the required period in ADB Appendix B

From the CROSS expert panel

13. Are the exposure conditions recommended in Table B3 applicable to all situations?

Table B3 in Approved Document B (ADB) sets out the type of exposure relevant for parts of buildings in common situations. This includes the structural frame, internal walls, external walls and floors. Cases may arise where parts of buildings, for example internal floors within multi-level flats, load-bearing walls internal to a flat, or parts of external load-bearing walls above openings, may be subject to fire exposures, through the course of a fire event, that would not normally be covered in single sided exposures in standard fire resistance testing. Also in some building situations, the type and form of construction may be particularly sensitive to exposure conditions and therefore will be relevant to additional exposure types, for example, due to asymmetrical cross sections or reliance on passive fire protection. Designers should consider the relevance of the exposure conditions advised in ADB to their particular design, construction type/form, and potential fire scenarios.

From the ADB FAQs

From our experiments

Fire exposure condition	Cavity insulation	Time to failure [minutes]
Two-sided	No	68
One-sided		156
Two-sided	Yes	72
One-sided		116

- The test samples are considered to be representative of common LSF construction practices and, therefore, it is probable that the findings are broadly applicable to the technology.
- Where there is the potential for two-sided exposure, there is a sufficient reduction in load bearing performance that elements should be specifically designed to address such an exposure condition.

Thank you!

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