# Performance of thermal break strips in lightweight steel framed walls

Telmo Ribeiro*[1], Paulo Santos[1] and Diogo Mateus[1]

[1] ISISE, Department of Civil Engineering, University of Coimbra, Pólo II, Rua Luís Reis Santos, 3030-788 Coimbra, Portugal
*telmo.ribeiro@dec.uc.pt

**Abstract.** An accurate thermal characterization of the envelope components is essential to achieve a reliable evaluation of thermal behaviour and energy efficiency of buildings. In lightweight steel-framed (LSF) building components, the major thermal performance concern is related to the unwanted significant thermal bridge effects originated by the high thermal conductivity of steel. The application of thermal break (TB) strips in the steel stud flanges is one of the most currently used thermal bridge mitigation strategies. In this paper the thermal performance of ten interior LSF walls configurations are measured, using the heat flow meter (HFM) method under laboratory-controlled conditions. Three TB strips materials and three TB locations (inner, outer and both sides of steel stud) are assessed and a comparison with the thermal performance of a reference wall without TB strips is made. Regarding the TB strips materials, it was found that the best thermal performance is achieved by aerogel, which is the material that presents the lowest thermal conductivity. Considering the TB strips location, the application on both sides of steel stud shows a relative significant thermal performance increase comparatively to the application on inner or outer side, presenting these last two configurations very similar performances.

**Keywords:** Lightweight steel frame, LSF walls, Partition walls, Thermal resistance, Thermal break strips, Experimental measurements.

## 1 Introduction

The thermal comfort and energy efficiency in buildings are strongly influenced by the characteristics of the envelope. In the specific case of LSF walls, the high thermal conductivity of steel frames can lead to significant thermal bridges, that should be predicted and treated appropriately. One of the most used strategy to mitigate steel studs thermal bridge effect is the application of thermal break (TB) strips along stud flanges, being this the main focus of the research project Tyre4BuildIns – "*Recycled tyre rubber resin-bonded for building insulation systems towards energy efficiency*" [1]. The TB strips, usually made of thermal insulating materials, allow to increase the thermal resistance of the LSF walls, by reducing the heat losses due to steel stud thermal bridges [2]. Nowadays, there are available in the market several TB strips materials, which were specifically developed for this purpose, or could easily be adopted for this use.

In this work, with the aim of evaluating the thermal break (TB) strips performance for the mitigation of thermal bridges originated by the steel studs, the overall surface-to-surface thermal resistance (*R*-value) of ten different configurations of interior partition LSF walls were measured in controlled laboratory conditions. The laboratorial tests were performed using a mini hot box apparatus with a set of two climatic chambers, being the thermal performance of the LSF walls measured using the heat flux meter (HFM) method [3]. For each wall, three tests were performed, applying the sensors at different high positions (top, middle and bottom) within the LSF wall test-sample surfaces, totalizing thirty lab tests. The TB strip materials tested were recycled rubber (MS-R1), extruded polystyrene (XPS) and aerogel (AG), and three different configurations for the localization of the TB strips were considered, along the: inner; outer, and; both steel stud flanges. Furthermore, in order to perform a verification of the experimental values, all the LSF wall measurements results (overall conductive *R*-values) were compared with bi-dimensional finite element numerical simulations.

# 2 Materials and methods

## 2.1 Characterization of LSF Walls

In this section the characterization regarding materials, geometry, dimensions and thermal properties of the LSF reference wall and the thermal break (TB) strips are performed.

The cross-section of the reference LSF interior wall is illustrated in Fig. 1. The vertical steel studs (C90x37x15x0.6 mm) are spaced 400 mm apart and the steel sheet is 0.6 mm thick. The outer and inner sheathing surfaces are constituted by two gypsum plasterboards (GPB) on each side (2x12.5 mm thick). The cavity, with a total thickness of 90 mm, is totally filled with mineral wool (MW) batt insulation.

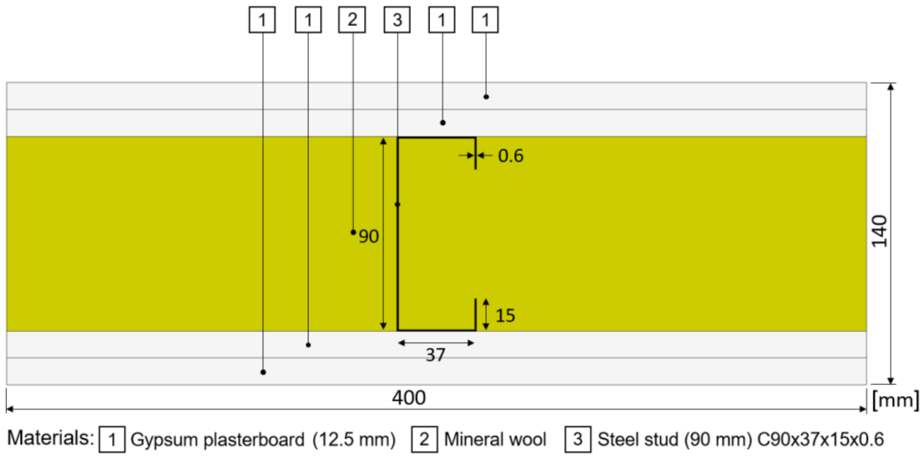


**Fig. 1.** Horizontal cross-section of the reference interior LSF wall: geometry, dimensions and materials.

The thickness of each layer and the thermal conductivities of the materials are presented in Table 1.

**Table 1.** Thickness (*d*) and thermal conductivities ($\lambda$) values of the LSF interior wall constituent materials [4].

| **Material** | $d$ [mm] | $\lambda$ [W/(m·K)] |
|---|---|---|
| GPB[1] (2 x 12.5 mm) | 25 | 0.175 |
| MW[2] | 90 | 0.035 |
| Steel Stud (C90 x 37 x 15 x 0.6 mm) | --- | 50.000 |
| GPB[1] (2 x 12.5 mm) | 25 | 0.175 |
| **Total Thickness** | 140 | --- |

[1]GPB - Gypsum Plaster Board (Standard A: GyptecIberica); [2]MW - Mineral Wool (AlphaRolo: Volcalis®).

The thermal break (TB) strips tested are 50 mm wide and 10 mm thick, and the materials used were recycled rubber (MS-R1), extruded polystyrene (XPS), and CBS aerogel (AG) (Fig. 2), with thermal conductivities ranging from 0.122 W/(m·K) to 0.015 W/(m·K), as presented in Table 2. The three configurations considered for the localization of the TB strips, along the: inner, outer, and on both steel stud flanges, are illustrated in Fig. 3.

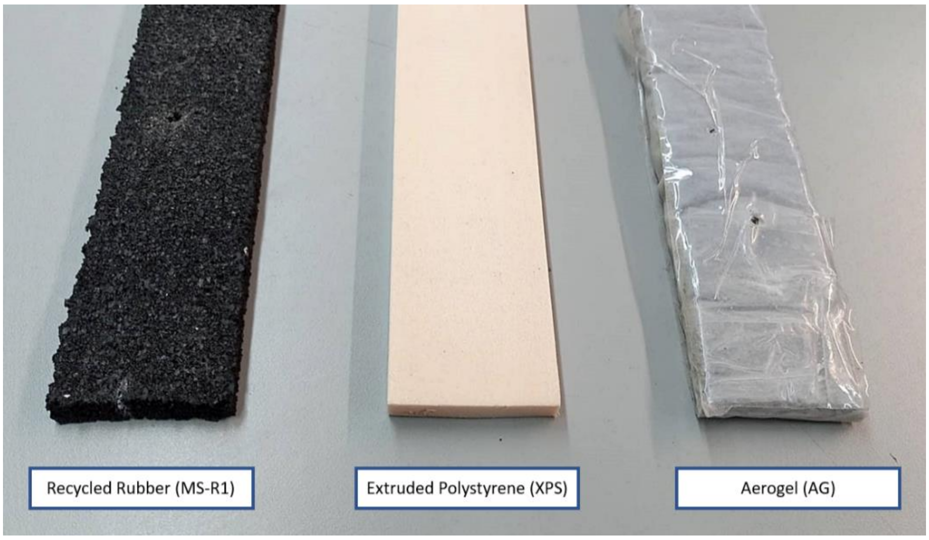


**Fig. 2.** Thermal break strips materials used on the experimental tests.

**Table 2.** Materials and thermal conductivity ($\lambda$) of the thermal break strips [2].

| **Material** (abreviation) | $\lambda$ [W/(m·K)] |
|---|---|
| Recycled Rubber (MS-R1) | 0.122 |
| Extruded Polystyrene (XPS) | 0.034 |
| CBS[1] Aerogel (AG) | 0.015 |

[1]CBS - Cold Break Strip

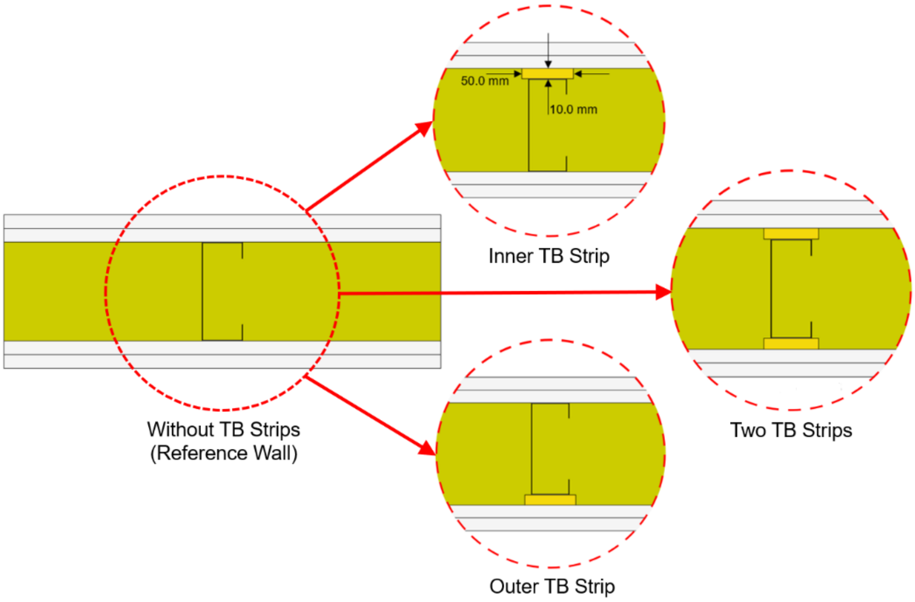


**Fig. 3.** Geometry and location of the thermal break (TB) strips.

## 2.2 Experimental Lab Tests

The laboratorial tests were performed using a mini hot box apparatus, in which the wall sample is placed between two climatic chambers (hot box and cold box), as illustrated in Fig. 4a. The LSF wall test samples used in the measurements have 1030 mm height and 1060 mm width, and are composed by three vertical steel studs spaced 400 mm, being the middle one centered. The measurement of the thermal performance of the LSF walls was obtained using the heat flux meter (HFM) method [3], adapted to have two HFM sensors [5]. Four heat flux meters were used to measure the heat flux through the LSF wall, being two of them on the hot surface and the other two on the cold wall surface. In order to measure the two distinct thermal behavior zones (steel stud zone and cavity zone) within the LSF wall sample, in both wall surfaces, one HFM was placed in the zone of the central vertical stud, and the another one in the middle of the insulation cavity. Temperature measurements were performed using 12 Type K PFA insulated thermocouples (TCs), being half of them in the cold side, and another half in the hot side. In each side (cold and hot), two of the six TCs measured the environment air temperature inside the chamber, another two measured the wall temperature near the wall surface, and the remaining two measured the wall surface temperatures.

The hot and cold boxes were programmed to maintain a temperature of 40ºC and 5ºC, respectively, being the measurements performed in a quasi-steady-state heat transfer condition. Furthermore, in order to ensure the repeatability of the experimental measurements, for each wall, three tests were performed corresponding to three high locations: top, middle and bottom (Fig. 4b). The considered measured overall conductive *R*-value of the LSF walls was the average of these three tests.

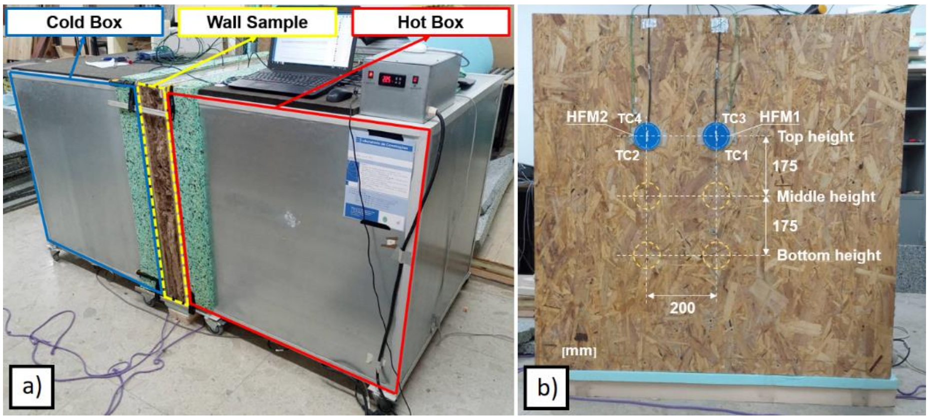


**Fig. 4.** Laboratorial tests: a) mini hot box apparatus; b) tested LSF wall sample and sensors localization.

## 2.3 Numerical Simulations

The 2D numerical simulations of the LSF walls were performed using the finite element method (FEM) software THERM® (version 7.6.1). Being a bi-dimensional FEM numerical simulation, the models created consider only a 2D representative part of the walls cross-section (400 mm width), as previously illustrated in Fig. 1 for the reference LSF wall. Regarding the thermal properties of the materials, the values used in these simulations were previously presented in Section 2.1 (Table 1 and 2).

In order to apply the boundary conditions to the models, the environment air temperatures and surface thermal resistances were defined. The air temperatures of the warm and cold environments were set equal to the temperature values defined for hot and cold climatic boxes in lab measurements, i.e., 40ºC and 5ºC, respectively. The modelling of the surface thermal resistances was performed using the average values measured for each test and for each LSF wall surface, considering the difference between the air and surface temperatures.

## 3 Results and Discussion

The values measured in laboratory and the values predicted by THERM software 2D FEM models for the conductive thermal resistances of the LSF walls assessed, as well as the absolute and percentage differences between them, are displayed in Table 3. The results presented in that table are organized into four parts: the first composed by the reference LSF wall ($W_{ref}$); the second, by the LSF walls with an inner TB strip ($W_{int}$); the third, by the LSF walls with an outer TB strip ($W_{out}$), and; the fourth, by the LSF walls with two TB strips ($W_{x2}$), inner and outer.

**Table 3.** Predicted (THERM) and measured thermal resistances (conductive *R*-values).

| **Wall Code**<br>Layer Description **(mm)** | ***R*-value**<br>**THERM**<br>[(m²·K)/W] | <br>**Measured**<br>[(m²·K)/W] | **Difference**<br>**Absolute**<br>[(m²·K)/W] | <br>**Percentage**<br>[%] |
|---|---|---|---|---|
| **$W_{ref}$**<br>2GPB(12.5)+[C90+MW(90)]+2GPB(12.5) | 1.719 | 1.752 | +0.033 | +2% |
| **$W_{MS-R1in}$**<br>2GPB(12.5)+[C90+MW(90)+**R1(10)**]+2GPB(12.5) | 1.932 | 1.964 | +0.032 | +2% |
| **$W_{XPSin}$**<br>2GPB(12.5)+[C90+MW(90)+**XPS(10)**]+2GPB(12.5) | 2.162 | 2.195 | +0.033 | +2% |
| **$W_{AGin}$**<br>2GPB(12.5)+[C90+MW(90)+**AG(10)**]+2GPB(12.5) | 2.359 | 2.404 | +0.045 | +2% |
| **$W_{MS-R1out}$**<br>2GPB(12.5)+[**R1(10)**+C90+MW(90)]+2GPB(12.5) | 1.932 | 1.931 | -0.001 | 0% |
| **$W_{XPSout}$**<br>2GPB(12.5)+[**XPS(10)**+C90+MW(90)]+2GPB(12.5) | 2.162 | 2.211 | +0.050 | +2% |
| **$W_{AGout}$**<br>2GPB(12.5)+[**AG(10)**+C90+MW(90)]+2GPB(12.5) | 2.359 | 2.414 | +0.055 | +2% |
| **$W_{MS-R1x2}$**<br>2GPB(12.5)+[**R1(10)**+C90+MW(90)+**R1(10)**]+2GPB(12.5) | 2.147 | 2.142 | -0.005 | 0% |
| **$W_{XPSx2}$**<br>2GPB(12.5)+[**XPS(10)**+C90+MW(90)+**XPS(10)**]+2GPB(12.5) | 2.574 | 2.627 | +0.053 | +2% |
| **$W_{AGx2}$**<br>2GPB(12.5)+[**AG(10)**+C90+MW(90)+**AG(10)**]+2GPB(12.5) | 2.892 | 2.885 | -0.007 | 0% |

GPB – Gypsum plasterboard; C90 – Steel stud type and web dimension in mm; MW – Mineral wool; OSB – Oriented strand board; MS-R1 – Recycled rubber thermal break strip; AG – Aerogel thermal break strip.

Analyzing the results obtained, it is possible to verify that the measured and predicted *R*-values are very similar (percentage differences between 0% and +2%), thus ensuring the reliability of these values. Furthermore, the results presented show that the *R*-value increase depends mainly on two factors: (1) the number of thermal break (TB) strips (single TB strip on inner or outer flange, or TB strips on both flanges), and; (2) the thermal conductivity of the TB strips materials. For a better visualization and comparison, in Fig. 5, the measured *R*-values are graphically displayed, being indicated, additionally, the *R*-value obtained by THERM for the reference wall without steel studs.

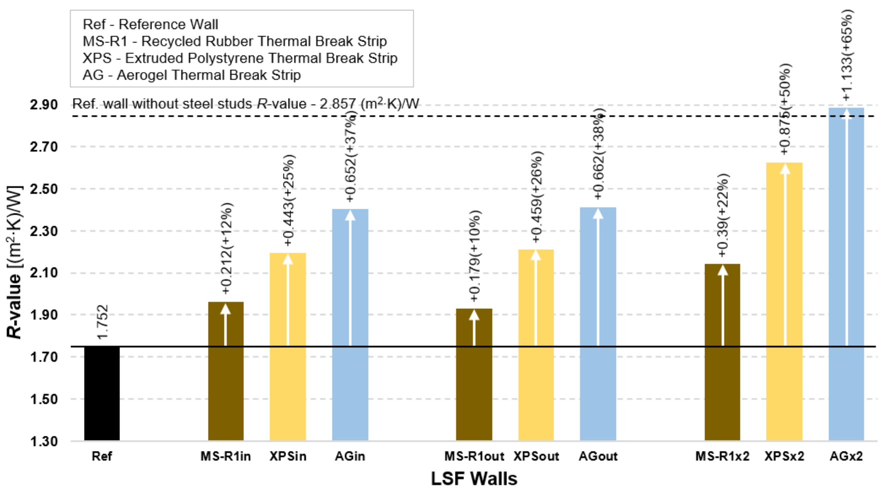


**Fig. 5.** Measured thermal resistances (conductive *R*-values).

As expected, the heat loss reduction due to mitigation of the steel thermal bridges provided by the application of TB strips allows to increase the *R*-value of the LSF walls. The application of TB strips on the steel studs has led to a thermal resistance increase ranging from 10% (for outer recycled rubber TB strip) up to 65% (for two aerogel TB strips).

Regarding TB strip materials, aerogel exhibited the largest thermal performance improvement: +37% and +38% for inner and outer TB strips, respectively, and; 65% for TB strips at both flanges. The lower *R*-value increase was measured in the recycled rubber TB strips (material with the highest thermal conductivity), while the extruded polystyrene TB strips registered intermediate values. Taking in account the localization of the TB strips on the steel studs, the results demonstrate that, for each material, the application at both flanges achieves the highest thermal performance improvements, increasing significantly the *R*-value comparatively with a single TB strip. Furthermore, the comparison between a single inner and outer TB strip shows that the *R*-values obtained are very similar for each one of the tested materials, as expected given the wall's symmetry.

Among the tested LSF walls configurations, only the two aerogel TB strips solution is able to reach the *R*-value provided by the reference wall without steel studs (2.857 $m^2 \cdot K/W$), fully mitigating the steel frame thermal bridge effect.

## 4 Conclusions

In this work the thermal performance of lightweight steel frame (LSF) partition walls with thermal break strips was assessed experimentally in laboratory-controlled conditions. Three TB strips materials (recycled rubber, extruded polystyrene and aerogel) were tested, and three configurations for the localization of the TB strips were considered: inner, outer and on both steel stud flanges.

The main conclusions of this study are presented as follows:

(1) The thermal performance achieved when a single TB strip is applied on inner or outer steel stud flanges is very similar, as expected.

(2) The application of TB strips on both steel stud flanges provides a significant thermal resistance increase, compared to the application of single TB strips.

(3) Aerogel was the TB strip material with the best thermal performance, while the recycled rubber exhibited the worst results. The extruded polystyrene presented an *R*-value increase between the other two materials.

(4) The application of aerogel TB strips on both steel stud flanges was the only configuration able to reach the *R*-value provided for the reference wall without steel studs, fully mitigating the steel frame thermal bridge effect.

## Funding

This research was funded by FEDER funds through the Competitivity Factors Operational Programme – COMPETE and by national funds through FCT – Foundation for Science and Technology, within the scope of the project POCI-01-0145-FEDER 032061.

Cofinanciado por: POCI-01-0145-FEDER-032061

## Acknowledgments

The authors also want to thank the support provided by the following companies: Pertecno, Gyptec Ibéria, Volcalis, Sotinco, Kronospan, Hulkseflux, Hilti and Metabo.

## References

1. Tyre4BuildIns, Research project Tyre4BuildIns - 'Recycled tyre rubber resin-bonded for building insulation systems towards energy efficiency', University of Coimbra, PT, www.tyre4buildins.dec.uc.pt, last accessed 2021/01/29.
2. Santos, P., Mateus, D.: Experimental assessment of thermal break strips performance in load-bearing and non-load-bearing LSF walls. Journal of Building Engineering 32, p. 101693 (2020).
3. ISO 9869-1, "Thermal insulation – Building elements - In-situ measurement of thermal resistance and thermal transmittance. Part 1: Heat flow meter method." ISO - International Organization for Standardization, Geneva, Switzerland, 2014.
4. Santos, P., Lemes, G., Mateus, D.: Thermal Transmittance of Internal Partition and External Facade LSF Walls: A Parametric Study. Energies 12(14), pp. 2671-2690 (2019).
5. Soares, N., Martins, C., Gonçalves, M., Santos, P., Simões da Silva, L., Costa, J. J.: Laboratory and in-situ non-destructive methods to evaluate the thermal transmittance and behaviour of walls, windows, and construction elements with innovative materials: a review. Energy and Buildings (182), pp. 88-110 (2019).