Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 62 (2014) 299 – 308
Energy Procedia

6th International Conference on Sustainability in Energy and Buildings, SEB-14

Impact of current steel lintels on the thermal performance of cavity wall buildings under the elemental recipe of Part L1A 2013

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Abstract

This study investigates the impact of current steel lintels on the CO_2 emissions of a notional building when trying to comply with the new PART L1A 2013 of the Building Regulations of England and Wales. For this purpose different families of lintels were assessed under SAP2009 using 12 different cavity walls with U-value under 0.18W/m^{2}K. Any of the current steel lintels without base plate studied in this research were found to be useable under PART L1A 2013. Their impact, depending also upon the construction detail used, could vary from 3% to 0.7% of the DFEES and from 1.6 to 0.4% of the DER of the notional building here studied.

Selection and peer-review under responsibility of KES International

Keywords: thermal bridges, low carbon building design, steel lintel.

1. Introduction

Concerns about global warming have driven the implementation of energy-saving policies in the UK to limit the CO_2 emissions from housing stock. Part of them, are based on thermal performance standards expressed on limitations for the U-values of the plane elements of the buildings and recommendations for the Ψ-values of their junctions [1].

A U-value measures the one-dimensional heat flow passing through the uniform layers of the plane elements of the building envelope, such as walls, windows, ceilings etc.. It is expressed as [W/m^{2}K] [2]. Progressively, the heat

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Selection and peer-review under responsibility of KES International
doi:10.1016/j.egypro.2014.12.391

flow turns two and even three dimensional close to discontinuities and junctions of these plane elements. A Ψ-value measures the extra heat loss due to two-dimensional flows in these areas that are not accounted for in the U-value of the flanking plane elements containing a linear thermal bridge [3]. It is expressed as Watts per meter run of the junction [W/mK] [4]. A thermal bridge offers an area of least resistance to the heat flux through the building envelope. One of the largest thermal bridges is located at the heads of openings, due to the sudden change in geometry and the common use of steel lintels [5].

The Standard Assessment Procedure [SAP] is the methodology adopted in the UK to assess the energy performance of new dwellings. Two of the indicators of energy performance generated during the assessment by SAP are used for the purposes of compliance with building regulations, these are: Fabric Energy Efficiency [FEE] and Dwelling CO_2 Emission Rate [DER] [2].

The Dwelling Fabric Energy Efficiency [DFEE] is measured in kWh/m²/yr and is affected by the U-values of the building fabric, Ψ-values of the thermal bridges, airtightness, thermal mass of the building and features affecting lighting and solar gains [6]. The Dwelling CO_2 Emission Rate [DER] is expressed in kg/m²/yr and represents the annual CO_2 emissions per unit floor area for space heating, water heating, ventilation and lighting, deducting the emissions saved by renewable technologies included in the dwelling [2].

PART L1A 2013, "Conservation of fuel and power in new dwellings" [7] establishes a mandatory Target Fabric Energy Efficiency [TFEE]. Different combinations of fabric specification can achieve the same TFEE [6], but always under limited fabric parameters of U-values and Air Permeability [2]. SAP 2012 provides an 'elemental recipe' based on a set of fabric and services specifications of a notional building that guarantee compliance as a starting point for designers to create their own solution. Then, the Fabric Energy Efficiency [FEE] of the building is calculated and increased by 15% to set up the TFEE for this type of dwelling [2]. It is accepted and noted that the "elemental recipe" is not the only way to comply [7].

PART L1A 2013, also establishes a Target CO_2 Emission Rate [TER] ($kgCO_2/m^2/yr$) [7] which reduces the PART L1A 2010 [8] Target Emission Rates [TER] of CO_2 by 6% for England [7] and 8% for Wales [9].

The cavity wall, which is the main method of building walls in England and Wales [10], has evolved to achieve better energy efficiency in the last couple of decades. The latest milestone in this evolution was the 100mm cavity partially or fully filled with insulation to comply with PART L1A 2010 [8]. Therefore, wider and better insulated cavities are extremely likely to be required to comply with PART L1A 2013 [7].

Previous research, [3] and [12], has demonstrated that for a given thermal bridge, a reduction of the thermal conductivity of its flanking elements will increase the heat loss through it. PART L1A 2010 [8] had a default Ψ-value of 0.300 W/mK for the head of the openings and a minimum U-value for the external walls of 0.30 W/m^2K. The new elemental recipe [2] suggests a Ψ-value of 0.050 W/mK for the lintel area and a U-value of 0.18 W/m^2K for the walls. It has been demonstrated that the early stages of building design are one of the most influential phases in which to save energy in construction [13]. Therefore, the new legislation represents a considerable challenge for designers and extra care will need to be taken when designing these junctions in order to reduce the thermal bridging.

This research investigates possible design solutions for cavity walls with U-values under or equal to 0.18 W/m^2K when joining the head of a window. It analyses the impact of the current steel lintels and the construction details used on the thermal performance of a notional building. Based on that, this research assesses and suggests possible design enhancements of the construction details. Finally, it establishes a benchmark of thermal performance scenarios.

This research could help designers to make more informed decisions to comply with the new PART L1A 2013 [7] and to realise the significance of these solutions. Selecting the adequate construction detail can be of real advantage to designers seeking to meet the strict carbon emission targets of the current and future PART L1A.

2. Methodology

In order to evaluate the impact of current steel lintels on the new cavity walls to comply with PART L1A 2013 this research explores and assesses some of the possible design solutions which designers could apply. This section presents the research design, data collection, and data presentation of the investigation.

2.1. Theory of heat loss calculations for the lintel area

The lintel area of a dwelling represents a linear thermal bridge and is defined by its Ψ-value [4]. The heat loss of the building fabric due to thermal bridging can be inputted into SAP2012 [2] in two different ways:

- The transmission heat loss coefficient [H_{TB}], measured as Watts per degree Kelvin [W/K] [2] is calculated using Equation 1 below. Here *l* is the length of the thermal bridge, in meters, through which *Ψ* applies.

$$H_{TB} = \psi_j \cdot l_i \tag{1}$$

- The y-value is obtained by the sum of heat loss through all of the thermal bridges divided by the total heat loss area of the building, measured in [W/m^2K] [14].

$$\text{y - value} = \frac{\sum(\psi_j \cdot l_i)}{\sum A_{exp}} \tag{2}$$

2.2. General methodology

The general methodology used in this research is as follows:

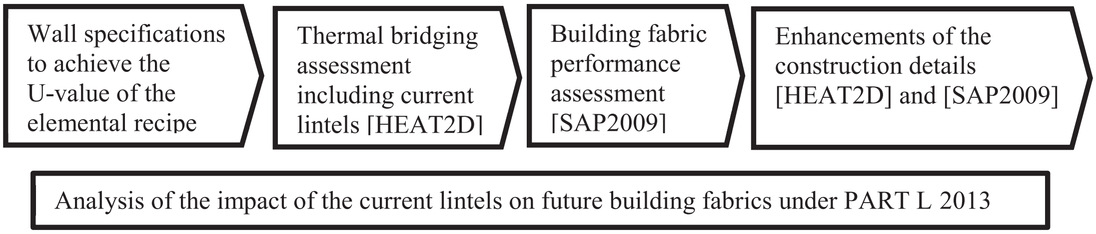

Fig. 1. Flow diagram of general methodology.

2.3. Data collection and presentation

The heat loss through the head of the openings changes depending on the cavity wall, its corresponding allocated lintel and the configuration of the construction detail. It is possible to use numerical analysis to predict "what if" scenarios and how all these factors will affect the heat loss [Ψ-value] around the area when trying to achieve the new elemental recipe. For this purpose 12 different models of cavity wall with U-value under or equal to 0.18 W/m^2K were set up to comply with PART L1A 2013 [7] as represented in Table 1. The U-value calculations were carried out using the U-value STROMA tool [15]. They were divided into four different groups depending on the cavity gap thickness of 100mm/120mm/140mm/150mm, because of saving cost/space implications. These examples could be possible solutions which a designer could apply in the future. Designers should also be aware that Building Control could point out the incompatibility of some of these cavities with the local weather.

Table 1. Characteristics of the walls to comply with PART L1A 2013 standard [7].

Case	Cavity/Wall (*mm*)	U-value (W/m^2K)	Specification from inside to outside - Thickness *(mm)* / Thermal conductivity (*W/mK*)
1	100/330	0.167	27.5mm P.O.D (0.19) / 100mm Concrete block (0.11) / 100mm PIR insulation with 5mm HIPS skin (0.021) / 102.5mm Brick (0.77)
2	100/346.5	0.170	27.5mm P.O.D (0.19) / 100mm Concrete block (0.11) / 75mm PIR(0.021) + 25mm air gap (0.056) / 100mm Concrete block (0.11) / 19mm Render (0.57)
3	100/360	0.177	12.5mm Board (0.21) / 35mm PIR (0.021) / 10mm dabs (0.09) / 100mm Concrete block (0.11) / 50mm PIR (0.021) + 50mm air gap (0.114) / 102.5mm Brick (0.77)
4	120/365	0.170	12.5mm Board (0.21) / 20mm PIR (0.023) / 10mm dabs (0.09) /100mm Concrete block (0.11) / 70mm PIR (0.021) + 50mm air gap (0.114) / 102.5mm Brick (0.77)
5	120/366.5	0.178	27.5mm POD (0.19) / 100mm Concrete block (0.11) / 70mm PIR (0.021) + 50mm air (0.114) / 100mm block (0.11) / 19mm Render (0.57)
6	120/366.5	0.179	27.5mm POD (0.19) / 100mm Concrete block (0.11) / 120mm Glass wool (0.032) / 100mm Concrete block (0.11) / 19mm Render (0.57)
7	140/386.5	0.161	27.5mm POD (0.19) / 100mm Concrete block (0.11) / 140mm Glass wool (0.032) / 100mm Concrete block (0.11) / 19mm Render (0.57)
8	140/370	0.168	27.5mm POD (0.19) / 100mm Concrete block (0.11) / 90mm PIR (0.021) + 50mm air gap (0.114) / 102.5mm Brick (0.77)
9	140/370	0.179	27.5mm POD (0.19) / 100mm Concrete block (0.11) / 140 Glass wool (0.032) / 102.5mm Brick (0.77)
10	150/380	0.156	27.5mm POD (0.19) / 100mm Concrete block (0.11) / 100mm PIR (0.021) + 50mm air gap (0.114) / 102.5mm Brick (0.77)
11	150/380	0.170	27.5mm POD (0.19) / 100mm Concrete block (0.11) / 150mm Glass wool (0.032) / 102.5mm Brick (0.77)
12	150/396.5	0.179	27.5mm POD (0.19) / 100mm Concrete block (0.11) / 150mm Wool (0.040) / 100 Concrete block (0.11) / 19mm Render (0.57)

Twelve construction details were set up based on the walls described above by incorporating two different families of standard-duty lintels. Conventional CG steel lintels without steel base plate [16] used for this analysis represent the common practice in dwelling construction under PART L1A 2010 [8]. On the other hand the HT/S hybrid lintel [17] is a solution mixing galvanized steel and glass-reinforced polymer [GRP] at a higher cost. 24 case studies were modelled and assessed using HEAT2D software [18] following the standard conventions covered in BR497 [19] to obtain their corresponding Ψ-values. The results are shown in Table 4. The designer should also be aware of the structural advantages and weaknesses of every lintel here studied to avoid structural incompatibility of use depending on what loads needs to be taken by the lintel.

Next, a notional building represented in Table 2 was set up to carry out a SAP assessment using STROMA FSAP 2009 software [15] to obtain the target indicators TER and TFEE for the case studies. The Ψ-values which were input into SAP for this calculation were default ones and taken from the elemental recipe [6] as shown in Table 3. After that, every one of the calculated Ψ-values (Column 6 of the Table 4) were also input into the previous SAP file instead of the default Ψ-value for the lintel area, obtaining the DER and DFEE values for each case. The results are shown in Table 4. Therefore, the impact of every variation of the construction detail could be weighed in terms of the variations of the DER and DFEE with respect to the TFEE and TER of the notional dwelling.

In all the cases analysed, the internal perimeter, the U-value of the wall and Ψ-value of the construction detail around the lintel were varied. That was responsible of changes in the TER. At the time of writing, a consultation version of SAP2012 was not available, hence the potential impacts on the TFEE values or DFEE specifications were not assessed. The calculations were carried out using SAP2009. The case studies presented in this paper were theoretical. At the time of writing, built models were not available for test and hence cannot be compared with the theoretical outputs obtained.

Table 2. Characteristics of the notional dwelling used to comply with PART L1A 2013 standards [7].

Typology	Semi-detached, 3 bedroom.	**Location**	Cardiff	**Internal area**	75.04m^2
Thermal mass	Medium	**Orientation**	East	**Internal Perimeter[m]**	4.82x7.78
H_{TB}	10.566 W/K			**Floor area**	37.52 m^2
Thermal bridging	y ~ 0.050 W/m^{2}K	**Fabric U-values (W/m^{2}K)**		**Roof area**	37.52 m^2
Lintels length	**10.58m**	**Walls**	0.18	**Living area**	19.74m^2
Heating	Gas Boiler - 89.5% SEDBUK	**Floors**	0.13	**External wall**	88.89m^2
Infiltration	5 m^3/hr/m^2@50Pa	**Roofs**	0.13	**Party wall**	39.68m^2
Photovoltaic	NO	**Glazing**	1.4	**Openings**	15.48m^2
Ventilation	Natural (extract fans)	**Doors**	1.0	**Ground floor h**	2.40m
TER	**19.31 kgCO$_2$/m^2/yr**			**First floor h**	2.70m
FEES	47.56 * 1.15 = **54.69 kWh/m^2.yr**	**DER < TER and general requirements complaint = PASS**			

Table 3. Thermal bridging values based on SAP2012 standards used in the notional building [2].

	Ref	Junction detail	Recipe 2013 Ψ (W/m·K)	length (m)	Total (ΨxL) (W/m^2·K)
Junctions with an external wall	E2	Other lintels (including other steel lintels)	0.050	10.58	**0.529**
	E3	Sill	0.050	8.325	**0.416**
	E4	Jamb	0.050	29.6	**1.480**
	E5	Ground floor (normal)	0.160	17.4	**2.784**
	E6	Intermediate floor within a dwelling	0.070	17.4	**1.218**
	E10	Eaves (insulation at ceiling level)	0.060	9.634	**0.578**
	E12	Gable (insulation at ceiling level)	0.060	7.68	**0.460**
	E16	Corner (normal)	0.090	10.2	**0.918**
	E18	Party wall between dwellings	0.060	10.2	**0.612**
Junctions with a party wall	P1	Ground floor	0.080	7.68	**0.614**
	P4	Roof (insulation at ceiling level)	0.120	7.68	**0.921**

Table 4: Variations on DER and DFEES depending on the lintel and cavity wall used to achieve the elemental recipe.

CASE	LINTEL	Cavity/Wall [mm]	Internal perimeter [m]	U-value [W/m^{2}K]	Ψ-value [W/mK]	TER -- DER [kgCO$_2$/m^2/yr]		TFEES -- DFEES [kWh/m^2/yr]	
PART L1A 2013		100/330	4.817x7.768	0.18	0.050	19.31	18.58	54.69	47.56
	Default	100/330	4.817x7.768	0.18	1.000	19.31	20.13	54.69	54.87
	Base	100/330	4.817x7.768	0.18	0.500	19.31	19.32	54.69	51.03
	No base	100/330	4.817x7.768	0.18	0.300	19.31	18.99	54.69	49.49
1	CG 100	100/330	4.817x7.768	0.167	0.177	19.31	18.64	54.69	47.84
2	CG 100	100/346.5	4.792x7.735	0.170	0.139	19.37	18.68	54.69	47.85
3	CG 100	100/360	4.772x7.708	0.177	0.111	19.42	18.77	54.69	48.12
4	CG 110	120/365	4.765x7.698	0.170	0.121	19.44	18.72	54.69	47.86
5	CG 110	120/366.5	4.765x7.698	0.178	0.137	19.44	18.84	54.69	48.42
6	CG 110	120/366.5	4.765x7.698	0.179	0.136	19.44	18.85	54.69	48.46
7	CG 130	140/386.5	4.732x7.655	0.161	0.138	19.52	18.73	54.69	47.68
8	CG 130	140/370	4.757x7.688	0.168	0.175	19.46	18.81	54.69	48.22
9	CG 130	140/370	4.757x7.688	0.179	0.173	19.46	18.93	54.69	48.80
10	CG 150	150/380	4.742x7.668	0.156	0.180	19.49	18.72	54.69	47.69
11	CG 150	150/380	4.742x7.668	0.170	0.177	19.49	18.88	54.69	48.43
12	CG 150	150/396.5	4.717x7.635	0.179	0.137	19.56	18.98	54.69	48.75
13	HS/T 100	100/330	4.817x7.768	0.167	0.069	19.31	18.47	54.69	47.00

CASE	LINTEL	Cavity/Wall [mm]	Internal perimeter [m]	U-value [W/m^{2}K]	Ψ-value [W/mK]	TER -- DER [kgCO_2/m^2/yr]		TFEES -- DFEES [kWh/m^2/yr]	
14	HS/T 100	100/346.5	4.792x7.735	0.170	0.043	19.37	18.52	54.69	47.10
15	HS/T 100	100/360	4.772x7.708	0.177	0.053	19.42	18.67	54.69	47.66
16	HS/T 110	120/365	4.765x7.698	0.170	0.054	19.44	18.61	54.69	47.33
17	HS/T 110	120/366.5	4.765x7.698	0.178	0.046	19.44	18.69	54.69	47.70
18	HS/T 110	120/366.5	4.765x7.698	0.179	0.044	19.44	18.70	54.69	47.74
19	HS/T 130	140/386.5	4.732x7.655	0.161	0.048	19.52	18.58	54.69	46.97
20	HS/T 130	140/370	4.757x7.688	0.168	0.078	19.46	18.65	54.69	47.45
21	HS/T 130	140/370	4.757x7.688	0.179	0.075	19.46	18.77	54.69	48.03
22	HS/T 150	150/380	4.742x7.668	0.156	0.081	19.49	18.55	54.69	46.91
23	HS/T 150	150/380	4.742x7.668	0.170	0.075	19.49	18.70	54.69	47.62
24	HS/T 150	150/396.5	4.717x7.635	0.179	0.046	19.56	18.83	54.69	48.03

2.4. Potential design modifications

Most of the previous 24 case studies listed in Table 4 did not achieve the suggested Ψ-value of 0.050 (W/mK). CASE 10 was the worst-case scenario of them. The thermal performance of a construction detail could be increased if the different elements are assembled in the right way to minimise the heat loss. Three possible actions were selected and tested following a "what if" methodology to determine their impact on the Ψ–value of CASE 10.

- Insulate the soffit: It has been demonstrated [20] that is possible to achieve a clear reduction of the Ψ-value when the inner angle of the lintel is insulated. A strip of PIR insulation is added to the bottom of the lintel. For aesthetic reasons the maximum applied in this study is of 20mm thickness. The effect of the enhancements is shown below in Table 5.

Table 5. Variations on Ψ–value when insulating the soffit.

CASE	LINTEL	Cavity/Wall [mm]	U-value [W/m^{2}K]	Ψ-value [W/mK]
Not Insulated	CG 150	150/380	0.157	0.180
15mm PIR strip [0.023 W/mK]	CG 150	150/380	0.157	0.151
20mm PIR strip [0.023 W/mK]	CG 150	150/380	0.157	0.143

- Location of the fenestration: The Ψ-value changes when the adiabatic boundary which represents the fenestration shifts position. The best thermal performance is obtained when the frame and insulation are aligned [21]. The location of the window inside the cavity, however, will lead to an increase in building costs. The effect of the change of location is shown below in Table 6.

Table 6. Variations on Ψ–value when changing the position of the fenestration.

CASE	LINTEL	Cavity/Wall [mm]	U-value [W/m^{2}K]	Ψ-value [W/mK]
30mm overlapping the cavity	CG 150	150/380	0.157	0.180
70mm overlapping the cavity	CG 150	150/380	0.157	0.173
Aligned with the insulation	CG 150	150/380	0.157	0.159

- Insulate the top of the lintel: Since 2002 the Building Research Establishment [BRE] [22] recommends cutting the insulation of the cavity to match the slope of the lintel profile. The effect of this variation is shown below in Table 7.

Table 7. Variations on Ψ–value when insulating the top of the lintel.

CASE	LINTEL	Cavity/Wall [mm]	U-value [W/m^{2}K]	Ψ-value [W/mK]
Not Insulated	CG 150	150/380	0.157	0.180
PIR [0.021 W/mK]	CG 150	150/380	0.157	0.156

Three key solutions were found to enhance any lintel area with a Ψ-value over 0.050W/mK whilst not representing a significant increase in building costs, and requiring only simple changes to standard building methods. It has been demonstrated that by adding 20mm of insulation in the soffit area, recessing the window 40mm and extending the insulation of the cavity to match the slope of the lintel could significantly reduce thermal bridging. Therefore, the 17 cases out of 24 that were over 0.050W/mK were enhanced and the effect is shown in Table 8. Case 10 presented a reduction of the Ψ-value from 0.180 to 0.122 W/mK. The Ψ-value of the different enhanced cases was reduced between 0.025 and 0.065 W/mK. In average the Ψ-value of the construction details could be reduced by 0.040W/mK.

Table 8. Variations on DER and DFEES depending on the enhanced detail used to achieve the elemental recipe.

CASE	LINTEL	Cavity/Wall [mm]	Internal perimeter [m]	U-value [W/m^{2}K]	Ψ-value [W/mK]	TER -- DER [kgCO_2/m^2/yr]		TFEES -- DFEES [kWh/m^2/yr]	
PART L1A 2013		100/330	4.817x7.768	0.18	0.050	19.31	18.58	54.69	47.56
1	CG 100	100/330	4.817x7.768	0.167	0.114	19.31	18.54	54.69	47.35
2	CG 100	100/346.5	4.792x7.735	0.170	0.106	19.37	18.62	54.69	47.59
3	CG 100	100/360	4.772x7.708	0.177	0.084	19.42	18.72	54.69	47.91
4	CG 110	120/365	4.765x7.698	0.170	0.095	19.44	18.68	54.69	47.65
5	CG 110	120/366.5	4.765x7.698	0.178	0.104	19.44	18.79	54.69	48.16
6	CG 110	120/366.5	4.765x7.698	0.179	0.103	19.44	18.80	54.69	48.20
7	CG 130	140/386.5	4.732x7.655	0.161	0.105	19.52	18.67	54.69	47.43
8	CG 130	140/370	4.757x7.688	0.168	0.115	19.46	18.71	54.69	47.75
9	CG 130	140/370	4.757x7.688	0.179	0.109	19.46	18.83	54.69	48.29
10	CG 150	150/380	4.742x7.668	0.156	0.122	19.49	18.62	54.69	47.23
11	CG 150	150/380	4.742x7.668	0.170	0.116	19.49	18.77	54.69	47.95
12	CG 150	150/396.5	4.717x7.635	0.179	0.105	19.56	18.93	54.69	48.50
13	HS/T 100	100/330	4.817x7.768	0.167	0.020	19.31	18.38	54.69	46.62
20	HS/T 130	140/370	4.757x7.688	0.168	0.054	19.46	18.61	54.69	47.27
21	HS/T 130	140/370	4.757x7.688	0.179	0.028	19.46	18.69	54.69	47.66
22	HS/T 150	150/380	4.742x7.668	0.156	0.059	19.49	18.51	54.69	46.73
23	HS/T 150	150/380	4.742x7.668	0.170	0.035	19.49	18.64	54.69	47.3

3. Analysis and discussion

Based on the results gathered from Table 4 and 8, Figure 2 shows a comparative diagram of the Ψ-values and DFEES depending on the lintel and the 12 different construction details studied, revealing this result:

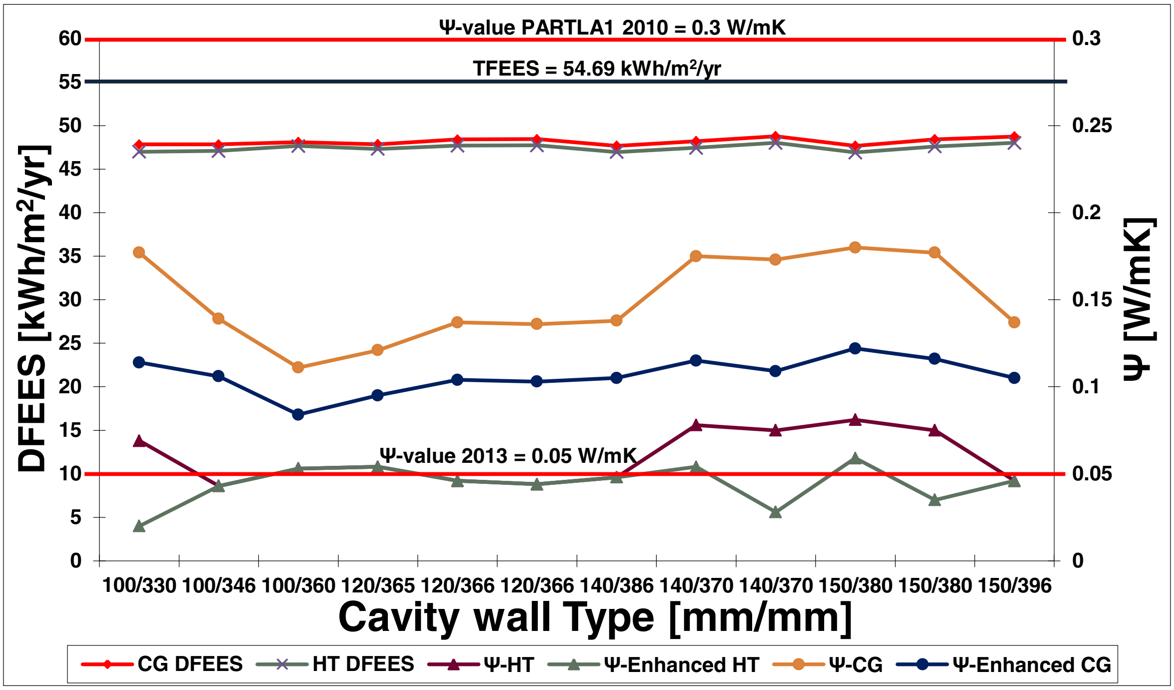

Fig. 2. Variation of Ψ-value depending on the lintel and cavity wall.

- The hybrid lintels offer a better thermal performance than conventional lintels. However, the use of hybrid lintels does not ensure the achievement of the suggested Ψ-value of 0.050 W/mK. 7 out of 12 cases were over 0.050 W/mK. Furthermore, viewed as part of the overall DFEES the impact of using one or another is limited as seen in Figure 2.
- The common practice to comply with PART L1A 2010 [8] was 100mm cavities, wider cavities are expected to be used under PART L1A 2013 [7]. Therefore, in this study, the examples of cavities over 120mm in width reproduced the classic 100mm cavities with just extra insulation. None of these case studies achieved the recommended Ψ-value = 0.050 W/mK. As was pointed in the introduction, a reduction of the U-value of the wall will increase the heat loss through the window-wall junction [3].
- The previous point demonstrates that the Ψ-value corresponds to the construction detail itself as well as to the type of lintel used. Therefore, it will be desirable to assess the junctions of the actual dwelling rather than considering the default Ψ-values or the ones given by the lintel manufacturers. As the National Measurement Network recommends [22]: “It is pointless to try to improve building energy models if the data fed into them is not accurate”. This is one of the causes of the gap between “as designed” and “as built”.
- In the cases 2,5,6,7 and 12 where the external leaf had lower thermal conductivity because of the use of light concrete blocks instead of bricks the Ψ-values of these junctions were reduced. In these cases the external angle of the lintels were also covered with 19mm of render reducing the heat loss.
- Even better Ψ-values were achieved for cases 3 and 4, where internal insulation was added to the walls which also covered the internal angle of the lintel.

- Finally it has been also demonstrated that the implementation of three simple design enhancements of the construction details could produce a clear reduction of the Ψ-values. Once the conventional lintels are enhanced, if the reduction of the heat loss is translated into CO_2 savings, the difference between families of lintels could be around 0.1 $kgCO_2/m^2/yr$.
- Every case assessed complied with the TFEE and TER of the notional building as shown in Table 4. Therefore, both families of lintels studied in this research could be used under PART L1A 2013. Conventional steel lintels could account for on average 2.4% of the DFEES and 1.3% of the DER. On the other hand hybrid lintels could account for on average 1% for the DFEES and 0.6% of the DER. Both these figures could be further reduced, as shown in Table 9, if the construction details were enhanced.

Table 9. Impact in percentage, of every family of lintels on SAP calculations, over DER and DFEES rates.

LINTEL	DER [$kgCO_2/m^2/yr$]	DFEES [$kWh/m^2/yr$]	DER [$kgCO_2/m^2/yr$]	DFEES [$kWh/m^2/yr$]
Notional	0.4%	0.8%	0.4%	0.8%
Conventional	1-1.65%	1.8-3%	Enhanced 0.75-1. %	Enhanced 1.37-2.1%
Hybrid	0.37-0.75%	0.72-1.4%	Enhanced 0.16-0.54%	Enhanced 0.35-1.0%

- The CO_2 savings associated with the use of the hybrid lintels varies from 0.18 to 0.1$kgCO_2/m^2/yr$ on SAP calculations for the DER when compared with conventional lintels. These figures could be reduced when the construction details of the conventional lintels were enhanced. Accordingly, the CO_2 savings were reduced to an average of 0.1$kgCO_2/m^2/yr$ based on the outputs of Tables 4 and 8.

4. Conclusion

This research investigated the potential impact of the current steel lintels on the thermal performance of a building when trying to achieve the "elemental recipe" proposed in PARTL1A 2013. The results shown that their impact depending on the cavity wall width, construction detail, and type of lintel used could vary from 3% to 0.7% of the DFEES and from 1.6 to 0.4% of the DER of the notional building here studied.

It was concluded that, any of the lintels and construction details studied in this research could be used under PART L1A 2013, proving that the suggested Ψ-value of 0.050 W/mK is not compulsory. However, for good practice it was suggested to design and enhance the construction details to reduce their impact in the DER and DFEE of the building, which was the main purpose of PART L1A 2013.

It was found that in few cases the recommended Ψ-value by the elemental recipe could be achieved, even when hybrid lintels were used. Although hybrid lintels demonstrated to have a better thermal performance than conventional lintels, this study shown that its use does not guarantee a Ψ-value ≤ 0.050 W/mK when $U_{wall} \leq 0.18W/m^2K$.

In the future when wider cavities will be expected to comply with energy standards, the designer will be expected to face higher Ψ-values for the thermal bridges. Some easy actions to reduce the heat loss of the thermal bridge were pointed out and tested: external leafs of lower thermal conductivity than brick and with the external angle of the lintel covered; internal angle of the lintel insulated; window recessed to approximate the insulation layer; and insulation of the cavity cut to match the slope of the lintel. It was demonstrated that the implementation of three simple design enhancements could produce a clear reduction of the Ψ-value. In average the Ψ-value of the construction details could be reduced by 0.040W/mK. Furthermore, in terms of CO_2 savings the difference between families of lintels could then be reduced to an average of 0.1$kgCO_2/m^2/yr$.

Finally, designers should consider each building individually, and while they may use the elemental recipe as a starting point, it should be the responsibility of each designer to consider issues of cost, space, time, weather or structural weakness of the lintel, when deciding upon which type of cavity wall and lintel would be appropriate. It was accepted and noted that the "elemental recipe" is not the only way to comply. Furthermore, it was also found that to reduce the gap between "as designed" and "as built" designers should assess the element of the actual dwelling rather than using the default Ψ-values or the ones given by the lintel manufacturers. This research produced a benchmark of Ψ-value choices to help designers to make more informed decisions.

Acknowledgements

This work forms part of a project for which financial support was provided by the Knowledge Economy Skills Scholarships [KESS] from European Social Funds [ESF].

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