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Improving the energy performance in a dwelling built before 1919 in the UK: Insulation application to the envelope

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Abstract

The UK possesses the oldest dwelling stock in the developed world with 8.5 million properties over 60 years old. Statistics have shown that the largest existing housing stock corresponds to dwellings built before 1919, which also represents the poorest energy performance stock. In order to meet the cutting CO_2 emissions fixed by the government (80% by 2050), refurbishment measures should be undertaken in existing dwellings. This paper focuses on the study of refurbishment measures for dwellings built before 1919 in the UK, especially in the application of insulation to the envelope (as a passive strategy). Research on the topic, a survey and simulations of a real case study was undertaken. The insulation of the dwelling envelope (walls, floor and roof) improved its SAP rating from band F to band D. The thicknesses needed for EPS insulation were far thicker than for VIP insulation. Nevertheless, the cost using VIP was over three times more expensive than using EPS.

Keywords: Energy performance, refurbishing dwellings, envelope insulation, cost

1 Introduction

According to statistics from the Department of Energy and Climate Change, in the UK, buildings are responsible for 44% of CO_2 emissions, with 27% produced by twenty-six million homes and 17% by two million non-residential buildings. The housing sector is, therefore, responsible for more than a quarter of CO_2 emissions (DECC, 2012).

The UK government has defined energy policies in recent decades following commitments to the Kyoto Protocol. Emissions are to be reduced by 80% in 2050, with a target of approximately 34% before 2020, based on 1990 emissions levels (DECC, 2009).

The European Parliament and the Council of the European Union signed a recast on the energy performance of buildings on 19 May 2010 (EPBDrecast, 2010). Building Regulations Part L - Conservation of fuel and power has been adapted accordingly (Part L1B, 2010). In consonance with the EPBD directive, the UK government set up the Energy Performance Certificate (EPC), which is a document that rates the energy performance of a building and their environmental impact. This is mandatory for all dwellings sold and rented.

The EPC document is an estimation of the levels of energy use per square meter of floor area, energy efficiency based on fuel costs and environmental impact based on CO_2 emissions. This document also presents recommendations to improve the energy performance of the building. The EPC ranking goes from A to G, A being the highest ranking and G the lowest.

Other incentives and mechanisms, for instance Feed-in Tariffs and The Green Deal, were created to promote the improvement of energy efficiency and carbon savings of the existing stock. However, only a reduced number of dwellings have benefited from these schemes. It is, thus, important to present cases studies and provide findings that can help similar scenarios.

A review of recent refurbishment measures applied to case studies dated pre-1919, with data from the National Refurbishment Centre (NRC, 2012), highlighted that fabric insulation measures should be considered in retrofitting before service upgrades or installing renewable energies, as they are more cost effective. Moreover, effective passive measures should be applied beforehand to minimize the heating/cooling demand and, therefore, reduce the use of active systems. These systems should adopt renewable resources as much as possible to reduce the CO_2 emissions.

The energy performance of a representative case study was assessed, using SAP 2009 simulations, with different insulation applications to the envelope.

2 Envelope energy performance of existing dwellings

The largest existing housing stock corresponds to dwellings built before 1919. Most of them are poorly insulated and often very drafty. For example, loft insulation needs to be improved in existing dwellings: approximately only 50% of the existing stock is loft insulated (EHS, 2012a). The characteristics that make loft insulation more problematic and/or expensive are: the presence of a loft fully boarded across the joists, the presence of a room in roof and flat or shallow pitched roof (EHS, 2012b).

Recent refurbished projects may have contributed to improving the energy efficiency of the dwelling stock dated before 1919. However, these dwellings still have a mean SAP rating of 47 (band E) compared with a mean of 66 (band D) for homes built after 1990. These figures show the need to further improve the energy performance of this specific stock (EHS, 2012b).

An initial assessment identified that the insulation of the dwelling should be the first steep, which is also the most cost effective system. Often insulation is applied to the air cavity or to the interior of the wall; however, immediate disadvantages are the loss of space or the aggravation of thermal bridges.

In case of dwellings with solid walls, it may be advantageous to apply insulation to the exterior of the wall. External insulation allows the application of a continuous insulation layer; therefore, thermal bridges are avoided. Other advantages of external insulation are: minimizing the risk of interstitial condensation, damp and mould growth, improving the air-tightness of the construction, reducing draughts and heat loss. Conversely, external wall insulation tends to be much more expensive than other solutions and may be refused in conservation areas/listed buildings. The type and conditions of the existing wall finish and the presence of projections such as conservatories, porches or bays have a relevant impact on the cost of external insulation (EHS, 2012b).

Recent retrofitting works applied to dwellings built before 1919 have shown that great carbon reductions and a higher energy efficiency band involve major works and often high capital costs. When retrofitting existing dwellings, every case study is different with different constraints and limitations. Quite often problems appear when the dwelling is opened up, therefore flexible timelines should be considered and should be kept in mind that cost increases may occur (NRC, 2012).

3 Case Study: A Victorian house

A Victorian house located in North-West London was chosen as a case study. Dwellings in the UK mainly have heating loads. Overheating is only addressed by regulations as simplified criteria (Part L1B, 2010). Therefore, particular emphasis was given to the envelope performance of the case study to reduce heat losses.

The dwelling had solid walls with brick 200mm width and U-value=2.40 W/m2K. An in-situ assessment was made with a thermal imaging camera to identify where heat losses occurred and needed to be addressed. Thermal images showed linear bridges at ground floor, between floor and façade, and lack of insulation at corners between different facades and at the joists between facade and roof (see fig 1).

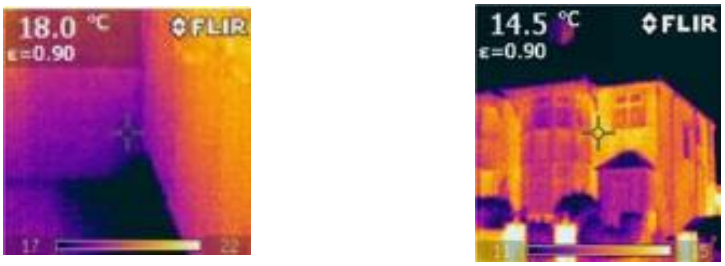

Fig 1: Kitchen floor and main facade, thermal images taken on 14th June 2013.

3.1 Overall Energy Performance: SAP Band and Environmental Impact Band

The dwelling was assessed with SAP 2009. The existing performance of the house was really poor, obtaining 14.53 points for the SAP rating and 14.47 points for the Environmental Impact rating, and a band G for both (see fig 2). These results were significantly worse than the average band for similarly-dated dwellings.

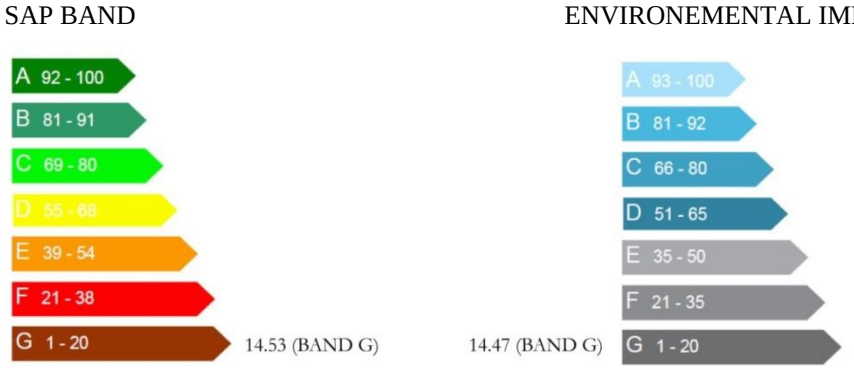

Fig 2: SAP results for existing energy performance of the case study, bands.

3.2 Heat Lost Parameter

The heat lost parameter (HLP) is a parameter that forms part of the SAP calculation. This value is basically based on the external surface area of the dwelling (envelope: windows, walls, floor and roof), taking into account thermal bridges and air-tightness (ventilation) of the dwelling (BRE, 2011).

The HLP was used to compare and derive effective refurbishment measures for the case study. This parameter was utilized to identify which part of the envelope was performing worse and, therefore, had to be insulated first. Walls had the largest impact on the performance of the existing dwelling; followed by the floor, windows and roof (see fig 3).

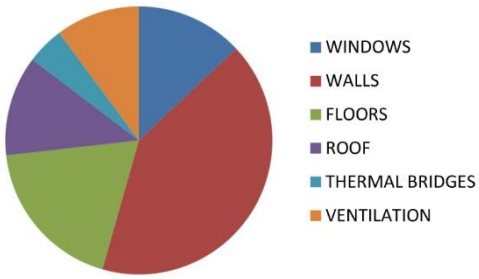

Fig 3: Pie chart with the breakdown of the parameters that affect to HLP of the existing performance of the case study.

3.3 Proposed insulation of the envelope to improve the current energy performance of the case study

The strategy used was to enhance the energy efficiency of the case study through the application of insulation as a passive strategy. The ideal scenario would be to achieve a continuous insulation layer through all the envelope to avoid thermal bridges and minimise heat losses. This would involve the application of insulation to walls, floor and roof, as well as improvements in windows (glass thickness, air gap and thermal break frames).

Insulating materials were selected from ´The Green Guide´, based on their environmental credentials (BRE, 2012), as well as from the table listing insulating materials adopted in refurbishments undertaken by Energy Saving Trust (EST, 2010c). Recently, innovative high performance materials such as aerogel and vacuum insulated panels are becoming more attractive due to their very low thermal conductivity and, therefore, thin thicknesses are required to achieve low U-values. However, most of these new materials are not environmentally rated by the green guide or any other accredited organization yet. This can be an impediment to its adoption and wide dissemination.

The materials chosen for the study were: expanded polystyrene (EPS) (A rated by the Green Guide) and a high performance material, vacuum insulated panels (VIP).

Refurbishment measures studied were applied to parts of the envelope in different steps. The first solution adressed external wall insulation; the second included external wall and floor insulation; and the third refurbishment solution added roof insulation to the previous solutions. These proposed refusbishment solutions depend on the budget accessible.

Refurbishment solution 1: external wall insulation

For the external wall insulation, only 30mm of VIP was required to meet the U-value of 0.30W/m2K (recommended by Part L1B). External wall insulation using EPS needed 150mm thickness to achieve a similar U-value. Required VIP thickness was far thinner than EPS thickness due to their lower conductivity: λ= 0.008 W/m2K against λ= 0.045 W/m2K. This may be of particular importance as a thicker insulation is often a complicate application, specially in the surroundings of windows and doors. In addition, the net area is reduced.

The ratings obtained using VIP were slightly higher than using EPS, 36.49 points against 35.45 points for SAP rating and 33.12 points against 32.23 points for Environmental Impact rating. This is a result of the slightly better U-value for VIP versus EPS. Both insulation solutions achieved a band F for SAP and Environmental

Impact bands. This means a one band improvement from the existing scenario (see table 1).

Table 1 : SAP results for refurnishment solution 1, external wall insulation.

REFURBISHMENT SOLUTION 1	THICKNESS (MM)	SAP RATING	ENV. IMP. RATING	SAP BAND	ENV.IMP. BAND
EXT. WALL INSULATION VIP	30	36.49	33.12	F	F
EXT. WALL INSULATION EPS	150	35.45	32.23	F	F

Refurbishment solution 2: external wall and floor insulation

The application of insulation over slab implies a rise in floor level. Therefore, lower thicknesses are advised in order to comply with Building Regulations (accessibility and room height ceiling) as well as to minimise the effect on interior fittings (doors and frames height). In order to meet the U-value 0.25W/m2K (recommended by Part L1B), a thickness of only 30mm VIP was needed to insulate the floor. This does not affect significantly the height of the room on the ground floor. For the solution using EPS, 50mm thickness was applied to the floor. Thicker EPS thicknesses could not be adopted due to room height constraints and, consequently, this solution did not comply with Part L1B.

For the solution combining external wall and floor insulation, the SAP and Environmental Impact ratings obtained using VIP were 49.08 points and 44.16 points respectively; and for EPS, 45.23 points and 40.75 points. Both, VIP and EPS obtained a band E for SAP and Environmental Impact bands. This shows an improvement of two bands from the existing dwelling performance (see table 2).

Table 2 : SAP results for refurnishment solution 2, external wall and floor insulation.

REFURBISHMENT SOLUTION 2	THICKNESS (MM)	SAP RATING	ENV. IMP. RATING	SAP BAND	ENV.IMP. BAND
EXT. WALL AND FLOOR INSULATION VIP	30+30	49.08	44.16	E	E
EXT. WALL AND FLOOR INSULATION EPS	150+50	45.23	40.75	E	E

Refurbishment solution 3: external wall, floor and roof insulation

In the Victorian house, the space below the roof was not habitable. Roof insulation was applied above the first ceiling, which is the easier and cheaper way to insulate roofs when there is no a habitable room. For roof insulation, a thickness of only 45mm VIP was needed to meet the U-value 0.16W/m2K (recommended by Part L1B), which is a very low figure against 250mm thickness needed using EPS.

Ratings obtained using VIP were 59.47 points for SAP rating and 54.89 points for Environmental Impact rating, against 55.09 points (SAP rating) and 49.97 points (Environmental Impact rating) for EPS. Both, VIP and EPS insulation application obtained a band D in SAP. However, VIP achieved a higher band D for the Environmental Impact band, whereas EPS remained with a band E (see table 3).

Table 3 : SAP results for refurnishment solution 3, external wall, floor and roof insulation.

REFURBISHMENT SOLUTION 3	THICKNESS (MM)	SAP RATING	ENV. IMP. RATING	SAP BAND	ENV.IMP. BAND
EXT. WALL, FLOOR AND ROOF INSULATION VIP	30+30+45	59.47	54.89	D	D
EXT. WALL, FLOOR AND ROOF INSULATION EPS	150+50+250	55.09	49.97	D	E

3.4 Cost analysis

The cost of external wall insulation using VIP was over three times more expensive than using EPS, £13,334 against £4,165. External wall and floor insulation using VIP was also over three times more expensive than using EPS, £18,871 against £5,783. External wall, floor and roof insulation using VIP was 3.5 times more expensive than EPS insulation, £26,544 against £7,130.

4 Conclusions

The UK possesses the oldest dwelling stock in the developed world with 8.5 million properties over 60 years old. Serious actions need to be undertaken if the UK has to meet CO_2 emissions reduction imposed in signed commitments.

Insulation refurbishment measures have been acknowledged as the first steep to improve the performance of the dwellings. Innovative insulating materials are becoming more commonly adopted given size and technological constraints in refurbishments.

In the case study, the energy performance of the dwelling was better with VIP insulation than EPS, as a result of a better condutivity of VIP, which meant lower thicknesses and easier applicability. However its high cost is still only justifiable under very specific conditions; this will hopefully change as this material becomes more adopted.

For this reason, a combination of VIP and EPS insulation applied to the Victorian House may be the best refurbishment solution. This solution would give a figure half cheap than an insulation solution using only VIP. Overall the energy performance of the dwelling would change from band F to band D and every part of the envelope insulated would comply with the current Part L1B. Further improvements in terms of lower infiltration rates, more energy efficient systems and possibly the use of renewable energy are expected to lead to zero carbon dwellings.

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