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The thermal characteristics of roofs: policy, installation and performance

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Abstract

This paper investigates the in-situ performance of UK cold pitched roof structures through a case study dwelling of typical construction using site survey, and estimation of U-values through simple calculation and from measured heat flow data. Significant increases of U-values resulted from under- and un-insulated areas due to installation issues, whilst a higher than expected estimated thermal resistance of the roof space and structure was also noted, potentially associated with heat gains. Both issues are expected to be observed more widely in the stock and contribute to a performance gap for roof insulation.

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Keywords: U-value; thermal resistance; roof; performance gap; in-situ

1. Introduction

Improving the thermal efficiency of the housing stock is central to many governments' policies to deliver the significant reductions in carbon emissions required to curtail global temperature rises [1]. For example, policies to realise the UK commitment to reduce carbon emissions by 80% from 1990 levels [2] identify improved thermal efficiency of dwellings as an important cost-effective measure [3]. It has been estimated that 87% of current UK buildings are still expected to be standing in 2050 [4], and consequently improvements in the performance of the existing stock are central to such policies. Certain types of retrofitted insulation have been identified as "*easy wins*"

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with "*all practicable cavity walls and lofts having been insulated by 2020*" [3]. However, the in situ performance of loft insulation in UK dwellings has not been extensively studied.

A significant performance gap between expected and actual energy use for energy efficiency interventions has been identified across a wide range of measures[5]. Recently, the performance gap associated with the thermal performance of walls has received considerable interest [6]. However, although loft insulation is one of the most common energy efficiency measures in the UK [7], there are few recent studies of its in situ performance.

This paper discusses the thermal performance of cold pitched roofs, which comprise approximately 80% of domestic roofs in the UK [8]. It identifies mechanisms that may lead to potentially systematic discrepancies between measured and expected U-values for dwellings.

1.1. The potential for a performance gap in roofs

Insulation of cold pitched roofs in the UK is typically rolled mineral wool quilt, installed between and across ceiling joists to meet target maximum U-values of 0.16 and 0.20 $Wm^{-2}K^{-1}$ for existing and new dwellings respectively [9], [10]. New dwellings typically exceed this as roof insulation is a cost effective measure to meet Target Fabric Energy Efficiency rates. Where loft insulation is retrofitted in existing dwellings, a total depth of 250 mm is usually fitted [9].

The thermal performance of loft insulation has been characterized in experiments using test cells, suggesting good agreement between literature U-values and those estimated from measurements in controlled environments [11]–[13]. Whilst increasing airflow over the insulation surface has been shown to result in decreasing performance, the experimental wind speeds were likely higher than those in typical loft spaces; therefore the effect of wind speed in situ is expected to be small [11], [12]. Studies on the impact of a 5% uninsulated area [11] and gaps between insulation rolls [14] suggest a significant effect on measured U-values: an increase of 57.5% for the former and approximately a factor of two in the latter. Both defects were found to have a higher measured impact than expected from simple calculation. However, these studies were carried out in purpose-built structures; the thermal performance of roofs in real UK dwellings has not been widely reported.

Differences between the expected and actual thermal performance of roofs may derive from issues associated with the materials, installation, usage factors and characterization of heat flow through the loft space. These defects can result in cold bridges that may be prone to condensation, and subsequent mould growth [15], such issues have been reported in UK and other Northern European countries and may lead to health impacts. Specific examples may include:

- gaps between insulation rolls [16];
- imperfections in coverage around service penetrations [17];
- practical challenges of finishing insulation around loft features, such as trusses and wall/roof junctions [17];
- reduced insulation thickness around the eaves to ensure adequate ventilation through soffit vents [17] or due to challenges of installation in a confined space, as discussed below;
- degradation of insulation materials due to age, dust/debris accumulation, water or damage from pests;
- thermal bridging and reduced insulation thickness under loft-boarding;
- reduced or missing insulation beneath water tanks and loft hatches [18].

Additionally, roof spaces are complex and challenging to represent in simple estimates of thermal performance or building simulation models. Ventilation from roof, eaves and wall vents depends on installation and specification, plus local wind speeds, whilst the flow of air and heat through partial-fill or unfilled cavity walls, partition walls and service penetrations is difficult to characterise and represent in models.

No recent studies have investigated the impact of installation in houses, degradation of materials and in use factors as outlined above. Results from one case study indicate good performance of loft insulation compared to literature estimates [19], but the loft conditions were not reported and required insulation levels have increased substantially in subsequent years. With the emphasis on improvement of the thermal performance of the stock to support the UK's decarbonisation strategy, there is a need to investigate the in-situ performance of cold pitched roofs.