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Improving the airtightness in an existing UK dwelling: The challenges, the measures and their effectiveness

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ABSTRACT

Air infiltration, occurring through gaps in the building envelope, can contribute up to one third of total heat losses associated with older UK dwellings [1]. Therefore, reducing the rate of air leakage (i.e. improving air 'tightness') can have a positive effect in terms of decreasing space heating requirements.

This study presents an investigation of the effectiveness of airtightness measures applied in a retrofit context to a UK dwelling. A phased programme of refurbishment work was undertaken to a test dwelling at the University of Nottingham campus, UK. Evaluation techniques, including building energy modelling (SAP 2009), air pressurisation tests and thermal imaging, were performed. The study demonstrates that the use of conventional draught-proofing measures can achieve a reduction in air permeability of over 30% when compared with the house base case value of 15.57 $m^3/(h.m^2)$ @ 50 Pa. This reduction was only achievable with close attention to installation detail. Further measures of service penetration and floor sealing enabled the air permeability to be reduced to as low as 4.74 $m^3/(h\ m^2)$ @ 50 Pa.

Modelling of the test dwelling predicted an initial space heating supply energy requirement of 32,373 kWh, which was reduced to 23,197 kWh by a combination of the air tightness measures, insulation, and system (boiler and ventilation) improvements. Air tightness measures alone contributed to approximately 9% of the predicted total reduction, half of which was due to relatively straight-forward draught-proofing. Other more advanced air tightness measures were considerably more expensive, though cheaper approaches to their application could help reduce payback times.

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1. Introduction

The UK Government has set an ambitious target to achieve a reduction in national greenhouse gas emissions of 80% below 1990 levels by the year 2050, alongside a 20% reduction in energy consumption by 2020 [2]. Up to 75% of the total building stock that will exist in 2050 already exists today, and this presents a challenge and opportunity in terms of investigating measures to improve the energy and carbon performance of existing homes [3].

Buildings require an adequate level of ventilation in order to maintain the health, comfort and well-being of the occupants and this involves the supply of fresh air and the removal of stale air and indoor air pollutants. Uncontrolled ventilation, known as air infiltration or air leakage, can occur due to air permeability of the building fabric, via gaps and cracks. This may lead to occupant discomfort and a significant reduction in energy efficiency. Ventilation heat losses can contribute up to 20% of the total heat losses observed in existing buildings, and this value can increase by up to one-third in well insulated properties [1].

The implications of low levels of airtightness in buildings are well documented. The effects can include high infiltration rates, draughts caused by uncontrolled air leakage, a reduction in the effectiveness of mechanical ventilation systems, a possible increased risk of condensation and moisture accumulation, as well as increases in annual energy consumption [4]. Airtightness is therefore of critical importance in improving the energy performance of buildings [5], and is often central to Building Regulations compliance and energy efficiency refurbishment programmes.

The significance of airtightness was emphasised during the consultation process relating to the UK Building Regulations Part L in 2000 [6], with the proposal put forward for a maximum as-built 10 $m^3/(h.m^2)$ @ 50 Pa to be attained by all new domestic and non-

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domestic buildings. This limit for air leakage was subsequently implemented in the 2002 amendments to the UK Building Regulations Part L, and then again in the 2005 (interim), 2006 (full) and 2010 (full) editions.

The current UK residential building stock, consisting of approximately 25 million dwellings, is characterised by properties with a range of airtightness levels. The least airtight dwellings can be up to 10 times more permeable than those achieving the highest standards [5]. The Building Research Establishment (BRE) manages a database that contains information relating to 471 dwellings characterised by different age, size, type and construction. This sample indicates that a very wide range of air permeability levels exists within the UK housing stock, ranging from 2 to 29 $m^3/(h.m^2)$ @ 50 Pa [7,8].

When compared to properties in Europe and North America, UK dwellings are generally less airtight. Airtightness standards are utilised as a benchmark standard in many countries, such as Belgium, Canada, The Netherlands, Norway, Switzerland, and the USA, but the values derived may be based on different testing regimes and unequal criteria. Normalised maximum air leakage criteria for these countries are shown in Fig. 1 [8]. It is evident that the UK has less stringent compliance levels than several other nations, meaning that dwellings that qualify as being very airtight in the UK may often be classed as standard practice elsewhere in the world [5]. Pan [9] provides a detailed review of the air tightness requirements in an international context, demonstrating that the UK requirement of 10 $m^3/(h.m^2)$ @ 50 Pa is not as onerous as many other nations.

Montoya et al. [10] reported an assessment of the accuracy of air tightness measurements through comparison with modelled data for a sample of 483 single family dwellings in France. The work concluded that structure type, the floor area, the age of the building, the number of stories and the insulation type are the characteristics that have the most significant influence on building airtightness. This is in agreement with the work carried out by Sherman, who developed a technique to attempt to normalise blower door test data to account for such variances in dwellings [11,12].

With demolition rates at around 1% of total stock [13], and current target new-build construction rates forecast to provide only an additional 9 million homes over the next 15–20 years, it is estimated that approximately 75% of the total building stock that will exist in 2050 already exists today [3]. Therefore, refurbishment work relating to older properties presents a significant opportunity for the UK to reduce its carbon emissions, the RIBA [14] highlighting that improving energy efficiency in existing housing should not be underestimated in terms of importance. Improving the airtightness of a large proportion of the existing housing stock can contribute to this process.

Previous studies have shown that it is possible to reduce infiltration rates by up to 77% through utilisation of retrofit measures [5,15]. However, when compared with new build dwellings, achieving high levels of airtightness in existing buildings can be very challenging and complex. The air permeability of building fabric is affected by a number of factors, including age, number of storeys, size/complexity of the building structure, longevity, and seasonal variations/environmental conditions. Typical air leakage pathways within a dwelling are shown in Fig. 2.

The majority of observed air leakage is usually attributable to a combination of a number of cracks, joints and gaps rather than to a single element or component. Building type and structure are therefore found fundamental in the achievement of an airtight building envelope [5], with the contribution of several air leakage pathways quantified in Fig. 3, where the remainder refers to fabric and systems improvements.

To evaluate the contribution that can be made by improving airtightness, key questions that must be addressed include the following:

1. To what extent can the airtightness of a property be improved within a practical refurbishment context?
2. Which airtightness measures are the most effective?
3. What level and quality of airtightness refurbishment can be expected from a commercial installer?
4. What might be the implications for energy saving, costs of measures, payback, and environmental quality?

In order to develop a greater understanding of the challenges and constraints involved in the improvement of airtightness levels in existing dwellings, a detailed study was conducted as one component within the CALEBRE ('Consumer-Appealing Low Energy technologies for Building REtrofitting') Project. CALEBRE, an RCUK/E.ON-funded multi-partner research project of 4.5 years duration (2008–2013) involved a consortium of six UK Universities: Loughborough, Nottingham, Oxford, Warwick, Ulster and Heriot-Watt ([17,18]). Project CALEBRE's aim was to address some of the many challenges associated with the energy efficiency refurbishment of the UK's existing homes.

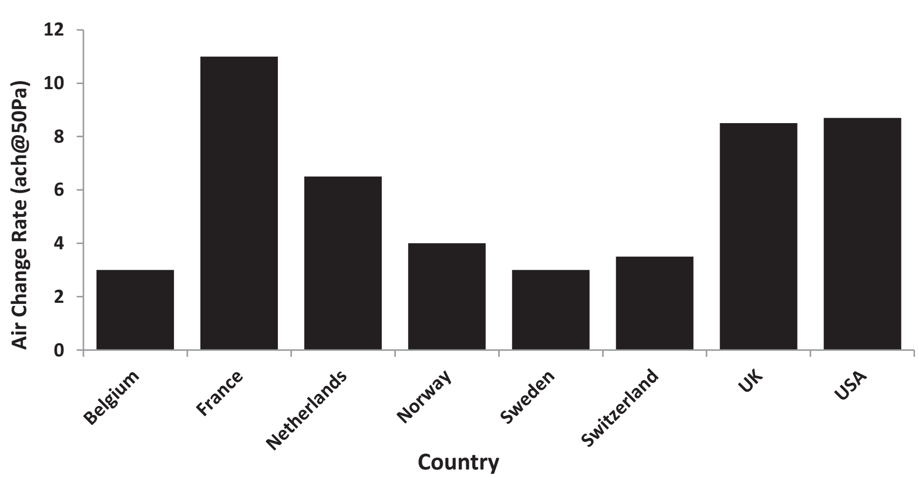

Fig. 1. Comparison of national data for normalised maximum air leakage criteria in dwellings [8].

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