

# Airtightness of Dwellings in Ireland: Design, Workmanship and Control

Derek Sinnott<sup>1</sup> and Mark Dyer<sup>2</sup>

<sup>1</sup>Department of Construction and Civil Engineering,  
Waterford Institute of Technology, Waterford,  
Ireland

<sup>2</sup>TrinityHaus,  
Trinity College Dublin, Dublin 2,  
Ireland

*Email: [DSinnott@wit.ie](mailto:DSinnott@wit.ie); [M.Dyer@tcd.ie](mailto:M.Dyer@tcd.ie)*

## **Abstract:**

The residential sector accounts for 25% of Ireland's total energy consumption, of which 60% is used for space heating. As thermal insulation standards increase, building airtightness is playing an increasing role in both building energy performance and indoor environmental quality. This paper reports on the results of air tightness testing carried out on a small number of dwellings. The paper highlights the paucity of dwelling airtightness data for Ireland. The results are compared to past studies and compliance with the existing standards. While the number of houses tested is small they are broadly representative of urban dwellings in Ireland. The study indicates a misconception that newer buildings are more airtight than older buildings. The paper concludes that good design, attention to detail and rigorous controls throughout construction is vital to delivering air-tight dwellings.

## **Keywords:**

Airtightness, Measurements, Standards, Workmanship.

## **1 Introduction**

Twenty five percent of Ireland's total energy consumption is accounted for by the residential sector, 60% being used for space heating (SEI, 2008). In recent years, improving fabric insulation standards, mechanical efficiencies and a greater understanding of energy use in buildings has augmented the importance of airtightness to building energy performance. Technical Guidance Document Part L (2008) - Conservation of Fuel and Energy (Dwellings) refers to Envelope Air Permeability testing of new dwellings, setting a 'reasonable upper limit for air permeability' of  $10\text{m}^3/\text{hr}/\text{m}^2$  at 50Pascals (DEHLG, 2007). This limit is not onerous when compared to standards in other countries, as shown in Table 1 and the increasingly popular PassivHaus standard requiring an n50 of 0.6 air changes per house (ach) (Hodgson and Establishment, 2008). There is a general awareness of the importance of airtightness and Ireland, but inertia to change has left the concept of air-tight dwellings in the doldrums.

Table 1. Airtightness Standards  
(Sourced: Pan, 2010)

	Max air permeability (m <sup>3</sup> /hr/m <sup>2</sup> at 50Pa)	Max air change rate (ach at 50 Pa)
Ireland	10	
Netherlands		6
Switzerland		3.6
Germany		1.8 - 3.6
Denmark		2.8
Estonian		3
Finland		1

Internationally, dwelling airtightness characteristics have been well researched (see (Sherman, 1987; Stephen, 2000; Pan, 2010), and in particular in the USA where over 70,000 fan pressurisation measurements have been collected and analysed, comparing air tightness in terms of age, size, and construction type (Chan *et al.*, 2005).

However, there is a paucity of real data relating to the airtightness characteristics of existing dwellings in Ireland. There is a common perception that newer dwelling airtightness is better than for older buildings, however, in Ireland due to the lack of empirical data this cannot be confirmed.

The paper reports on airtightness test results for two sets of houses; 1) 7 single family dwellings completed in early 2008, during Ireland's building boom, 2) 4 single family dwellings constructed in the 1980's; two of the houses have been retrofitted.

## 2 Dwelling Typology

This study focuses on the quantitative data gathered from 11 occupied single family residential semi-detached houses. All dwellings were of similar construction type; each had two-storeys, three bedrooms and load bearing external cavity walls and was naturally ventilated. Ground floors were slab-on-grade with suspended timber first floors. The attic space was of typical cold roof construction with insulation between ceiling joists. The average floor area and volume of the studied houses was 80m<sup>2</sup> and 217m<sup>3</sup>, respectively. Ventilation was provided by passive wall vents designed with closable hit-and-miss or permanently open louvered vent grilles in each room.

### 2.1 2008 Dwellings

The 2008 dwellings were part of a development of over 60 dwellings. The buildings had brick outer leaf and block inner leaf wall of 100mm cavity wall construction with full fill bonded bead insulation, 200mm of attic insulation, gas fired central heating and double glazing. Mechanical extractor fans were fitted in bathrooms. The houses typically have a draught lobby to the front and WC to the rear of the building.

## 2.2 1980's Dwellings

These identical dwellings were part of a large development. The dwellings which had not retrofitting carried out were typical of houses constructed prior to the implementation of minimum insulation standards in Ireland. The buildings had 100mm masonry cavity walls, with no insulation provided at construction, single glazed windows and no central heating. Nominal 100mm fibre attic insulation placed between the joists had degraded over time, providing little insulation value.

The retrofitted dwelling were identical to the as built dwellings but were retrofitted with double glazed windows and doors, 100mm bonded-bead cavity wall insulation, 200mm glass fibre insulation between and across joists in the attic, and gas fired central heating.

## 3 Test Procedure

In accordance with the requirements of Part L of the building regulations, the air tightness testing was carried out in accordance with the Air Tightness Testing and Measurement Association (ATTMA) Technical Standard, which is based on EN 13829:2000 "Thermal performance of buildings: determination of air permeability of buildings: fan pressurisation method. The test determines the air flow rate required to maintain a pressure differential of 50 Pascal between the inside and outside of the building envelope. External doors and windows were closed, chimneys and flues sealed, trickle vents, smoke vents and all passive ventilation systems closed but not artificially sealed and internal doors open throughout testing.

A Retrotec Q46 Automated Blower-Door was used to carry out the testing. Pressure and flow rate were controlled using a laptop, connected to a DM-2A Automatic Micro-manometer, which controlled the fan. In addition to the DM-2 the test this software continuously logged a number of parameters including fan flow, test pressure and the area measurements. Prior to testing, dwellings were surveyed and the internal envelope area ( $A_E$ ) and volume ( $V$ ) accurately calculated. Software presented the air permeability characteristics in two ways:

- 1) Air Leakage Index - measured as the volume of air passing through each square metre of building envelope in one hour ( $\text{m}^3/\text{hr}/\text{m}^2$ );
- 2) Air Leakage Rate - Air flow rate at a reference envelope pressure difference by the gross internal volume of the dwelling. Unit: air changes per hour (ach)

Both pressurisation and depressurisation were carried out on each house. This takes account for the potential 'value effect' where components may be pushed open during pressurisation and closed down tightly generating a seal during depressurisation. The average of both tests is taken as the air permeability of the house. In addition to the blower-door testing a survey and smoke pencil test was carried out on each dwelling.

## 4 Test Results

The results of the blower door tests are presented in Table 2. The mean air leakage index of the 2008 dwellings ranged from 6.02 – 13.34  $\text{m}^3/\text{hr}/\text{m}^2$ , with a mean of

10.4m<sup>3</sup>/hr/m<sup>2</sup>. Figure 1 graphically demonstrates that 5 from 7 exceeded the Part L ‘reasonable upper limit’ of 10m<sup>3</sup>/hr/m<sup>2</sup>. The average air leakage index for the two retrofitted dwelling was 5.55 m<sup>3</sup>/hr/m<sup>2</sup>, and 12.53m<sup>3</sup>/hr/m<sup>2</sup> for the as built dwellings. This suggests that retrofitting dwellings can reduce air-permeability of dwellings by over 50%. It may be suggested that cavity wall insulation has a two-fold benefit, a) improving thermal properties of the dwelling and b) sealing the array of cracks and penetrations through the masonry building envelope. Comparing all results the 2008 dataset was not as good as expected and does not correlate well with Pan (2010) and Chan *et al.* (2005) who found evidence suggesting that airtightness of newer dwellings has increased compared with older dwellings.

Table 2. Dwelling characteristics and test results

Dwelling	Year of Construction	Retrofit	Envelope Area m <sup>2</sup> (A <sub>E</sub> )	Internal Volume m <sup>3</sup> (V)	Ave Air Changes @ 50Pa (ACH)	Ave. Air perm @ 50Pa (m <sup>3</sup> /hr/m <sup>2</sup> )
A	2008	No	246	224	6.65	6.02
B	2008	No	246	224	9.02	8.60
C	2008	No	246	224	11.58	10.72
D	2008	No	246	224	11.44	10.90
E	2008	No	246	224	11.84	11.36
F	2008	No	246	224	12.19	11.69
G	2008	No	250	221	13.99	13.34
H	1986	Yes	215	205	5.39	5.14
I	1980	Yes	215	205	6.31	5.96
J	1981	No	215	205	11.66	10.64
K	1981	No	215	205	14.9	14.42

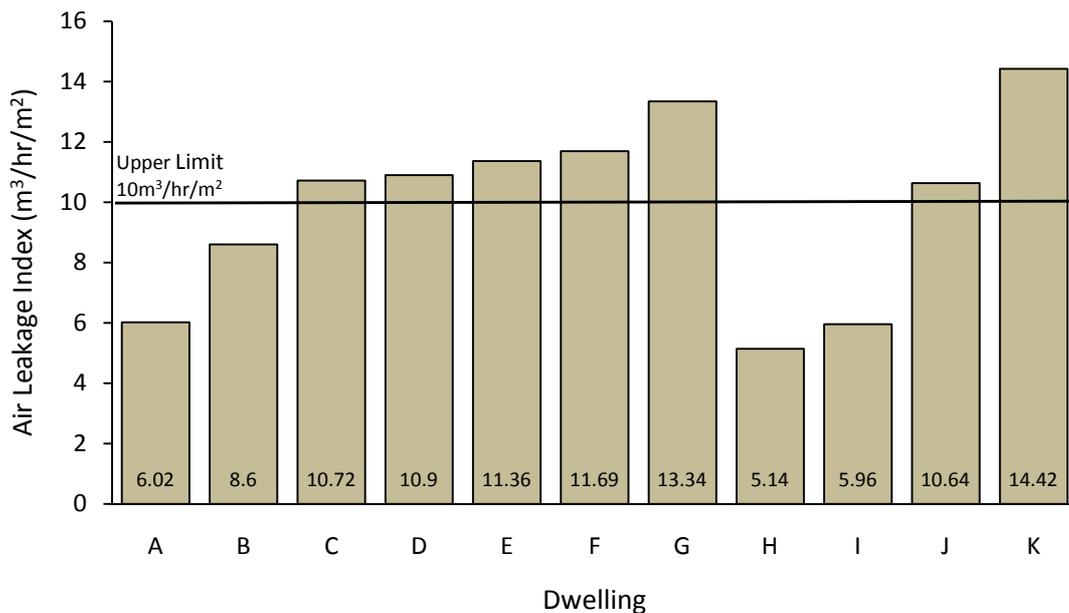


Figure 1. Air Leakage rate comparison with Part L ‘reasonable upper limit’

Smoke pencil test observations correlated well with previous research (Sherman and Chan, 2003; Jaggs and Scivyer, 2006) uncovering an array of different leakage paths. Typical leakage locations were junctions between floor and wall at 1<sup>st</sup> floor level, gaps around attic hatch, letterbox, and leakage through and around windows and doors, penetrations in envelope for plumbing and electrical installations such as light switches and sockets, fire alarms and around waste pipes.

In addition to common leakage paths to all dwelling, the following critical leakage pathways were identified in the 2008 dwellings:

- a) Service ducts concealing the soil vent and waste pipes, located inside the building envelope extending from the ground floor, into the attic space. The duct also concealed the pipes from the toilet and sink in the bathroom. Joints to internal walls were not sealed and thus provided longitudinal leakage pathways into the attic space.
- b) Windows were not sealed correctly to the window openings and in many cases the draught seal was partly detached from the frame, or completely missing.
- c) Many of the wall vent covers were not sealed correctly to the walls, thus leakage pathways remain when vent were closed.

This supports Johnston *et al.* (2004) and Kalamees (2007), findings that workmanship and supervision had a large affect on building airtightness. From the results can clearly be deduced that good design, detailing, specification of materials and construction practice are of fundamental importance when constructing new houses.

## 5 Conclusions

The field study provides a valuable data set of air tightness measurements for 11 new and 1980's single family dwellings. The outcome of the survey that is summarised below highlights the importance of workmanship and construction detailing in order to achieve the air tightness standards set in current Irish Building Regulations. The field measurements indicate that in the case of retrofitted properties there is a direct link between retrofitting and air tightness.

The key findings are summarised as follows:

- The air-permeability of the seven dwellings constructed in 2008 was not as good as expected, with five dwellings exceeding the Part L 'reasonable upper limit' of  $10/m^3/hr/m^2$  at 50 Pascal. Surveys attributed the high leakage rates poor design and construction of the internal service duct concealing the soil vent and waste pipes. Draft stripping was partially detached from window frames and in some cases was completely missing. Windows were installed such that leakage paths remained between the window frame and external walls.
- The results indicate that retrofitting older dwellings can have a significant impact on airtightness. The two retrofitted houses were in excess of 50% more airtight than the two dwellings that had not been altered. The average air leakage

index for retrofitted dwellings was  $5.55 \text{ m}^3/\text{hr}/\text{m}^2$ , far below the  $10\text{m}^3/\text{hr}/\text{m}^2$  target.

- Comparing the 2008 and 1980's dwellings results show that new dwellings cannot automatically assumed to be more airtight than older dwellings.

Over the past number of years building regulations have improved and best practice documentation produced, however, in practice there is a lack of will amongst building professionals to adopt new practices to improve dwelling airtightness. To overcome this problem designers and builders must be educated about the importance of building airtightness and trained in best practice approaches for both new and existing dwellings. Workmanship must also be closely controlled with airtightness testing undertaken during and post construction. This paper highlights the lack of practical research in airtightness for new and retrofitted dwellings in Ireland. The study should provoke policy makers to enhance the control requirements of on-site workmanship, and designers to be vigilant about the effect particular details can have on airtightness.

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