Ageing and airtightness

How dwelling air permeability changes over time

NHBC Foundation

Housing research in partnership with BRE Trust

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EXECUTIVE SUMMARY

Routine air leakage testing has demonstrated that some new homes designed to achieve high standards of air permeability are actually achieving very high 'as-built' standards – standards at which additional ventilation provision would normally be advisable. NHBC and others share some concerns about the potential consequences of living in highly airtight homes that do not have provision of additional ventilation, although there is little evidence to support these concerns.

In response to suggestions that new homes become leakier as they age because of shrinkage and settlement and that this provides additional adventitious ventilation, this research subjected a small number of dwellings to re-testing one to three years after completion to establish how their air permeability had changed. The research found that, whilst two-thirds of homes did become leakier, the remaining third actually became more airtight. It appears that the type of dwelling, construction, heating and ventilation all have a bearing on the extent to which air permeability changes, although the small sample size means that firm conclusions cannot be drawn.

The re-tests demonstrated that most of the dwellings (83%) remained airtight, achieving a re-test result tighter than 5 $m^3/(h.m^2)$, yet there was little evidence to suggest that the low air permeability without additional ventilation provision was causing a problem in practice. In spite of the fact that good ventilation guidance was widely being disregarded by occupants, only three dwellings showed signs of mould growth and in all cases, it was minor.

This research was intended only to provide an indication of the performance as the sample size was limited. This should be borne in mind when interpreting the results.

ABOUT THE NHBC FOUNDATION

The NHBC Foundation was established in 2006 by the NHBC in partnership with the BRE Trust. Its purpose is to deliver high-quality research and practical guidance to help the industry meet its considerable challenges.

Since its inception, the NHBC Foundation's work has focused primarily on the sustainability agenda and the challenges of the government's 2016 zero carbon homes target. Research has included a review of microgeneration and renewable energy techniques and the groundbreaking research on zero carbon and what it means to homeowners and housebuilders.

The NHBC Foundation is also involved in a programme of positive engagement with government, development agencies, academics and other key stakeholders, focusing on current and pressing issues relevant to the industry.

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Background

Air permeability and pressure testing were introduced into Part L of the Building Regulations in 2006[1] in order to improve the quality of construction and control heat loss through adventitious ventilation. A limit for *design* permeability was set at 10 $m^3/(h.m^2)$ at 50 Pa, although homes are commonly designed to achieve better airtightness as standard. Compliance with Part L is demonstrated by testing a sample of dwellings under construction. NHBC Foundation guidance on achieving airtight dwellings is available in the NHBC Foundation publication *A Practical Guide to Building Airtight Dwellings.*[2]

Up until the end of 2009, NHBC's Air Leakage Testing Services team had undertaken over 5500 tests. Results from these tests indicated that air permeability results far better than 10 $m^3/(h.m^2)$ were being achieved on a regular basis and that there is an improving trend. Figure 1 shows the NHBC test results.

Due to the natural variability in housing construction, it is to be expected that a small proportion of homes will achieve better as-built air permeability than they were designed to. However, as can be seen from Figure 1, very high levels are being obtained in a substantial proportion of homes tested. This is of concern because, if homes are more airtight than they were designed to be and do not have additional ventilation provision, the indoor environment may not be satisfactory – in particular, the air quality may suffer and humidity levels may be too high, increasing the risk of mould growth. The topic of indoor air quality is discussed in the NHBC Foundation publication *Indoor Air Quality in Highly Energy Efficient Homes – A Review.*[3]

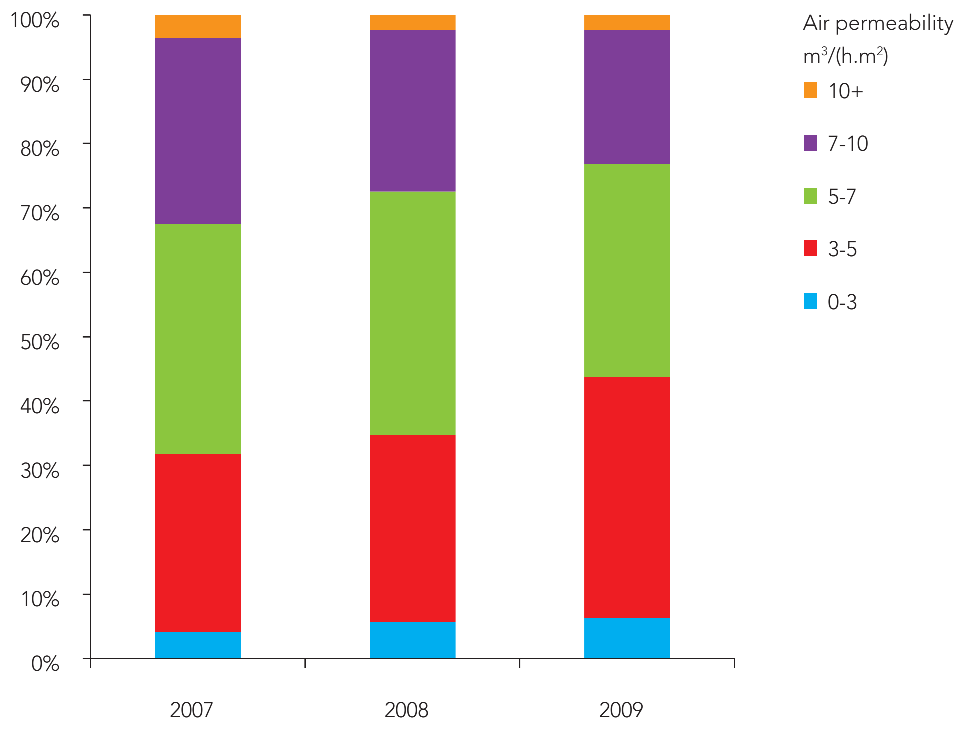

Figure 1 NHBC Air Leakage Testing Services pressure test results for new homes.

The study

Based on the results of these air permeability tests, NHBC has become concerned that some homes – probably a small proportion – are likely to be under-ventilated, although there is no evidence to suggest that this is causing a problem in practice. It has been suggested that this may be because within the first months and years after completion small gaps and cracks open up in the building fabric, causing the air permeability to increase and thus providing more adventitious ventilation.

This study aimed to test this hypothesis by re-testing 25 homes that were reasonably airtight at completion (ie they achieved a low level of air permeability). The re-tests took place one to three years after the original test and the opportunity was taken to inspect the homes for signs of condensation and mould growth and to make enquiries to establish the occupants' behaviour in terms of use of trickle vents, extractor fans, etc.

The site work was accompanied by a desk study to establish and evaluate previous related work in this area.

Previous research and studies

Air leakage performance has been the subject of previous research, eg see *Airtightness of Buildings – Towards Higher Performance. Final Report – Domestic Sector Airtightness.*[4] However, minimal work has previously been undertaken to specifically investigate the change in air permeability of the same dwelling between testing at the end of construction and after a period of occupation.

Investigations by Elmroth and Logdberg[5] on Swedish dwellings and by Warren and Webb[6] in the UK are somewhat dated. These investigations recorded a decrease in performance, with air permeability increasing by 70% and 83% respectively. Both studies highlighted that a significant decrease in performance occurred within the first 12 months.

Investigations on the performance of 17 properties constructed to PassivHaus standards were undertaken by Peper, Kah and Feist[7] at the PassivHaus Institute. The results indicated a similar performance in the later tests, although the true change in some properties would have been affected by work undertaken to improve performance between the tests. These investigations were accompanied by a literature search, which included reference to tests on six properties in Denmark by Saxof and Nielson.[8] Tests undertaken two years after the initial tests indicated only a slight change in performance, considered to be within measuring accuracy.

A more extensive survey of timber frame dwellings in Canada was undertaken between 1986 and 1990 by Proskiw.[9] These investigations included testing at different times of the year and identified that dwellings initially achieving a better air permeability performance suffered less from seasonal variations. Taking account of seasonal variation and measuring accuracy, overall results of the Canadian research indicated a close correlation in performance between initial and subsequent test results.

As noted earlier, NHBC Foundation Report NF18[1] reviews the literature on indoor air quality in homes.

Preparatory work

- Approximately 160 dwellings were selected from the NHBC Air Leakage Testing Services results database for which the measured air permeability was <4 $m^3/(h.m^2)$ and for which postal addresses and homeowner details were available. A mix of types, including attached and detached dwellings of both masonry and timber frame, was targeted.
- The dwellings' registered builders were contacted to confirm that they would be happy for us to contact the homeowner directly for the purposes of this study.
- Letters were sent to the homeowners seeking their participation in the study.
- Due to the limited response, the introductory letters were followed up by an offer of a £20 gift voucher to encourage participation and this resulted in 25 responses.
- Checks were made with participants to confirm that no relevant alterations had been made to their homes since the original test. Appointments were arranged to re-visit the properties and conduct re-tests. For logistical reasons it was not possible to test two homes and so the total number of homes actually re-tested was 23.
- Before attending site, the test engineer obtained the original test result and site notes for reference, including, importantly, determining the envelope area measured and used for the original test (for re-use).

Site work

- Before undertaking any works the test engineer briefed the homeowner on the test process and visually inspected the condition of the property, using a predetermined set of questions and notes, and recorded their findings. The test equipment was then set up and mechanical ventilation systems (such as extract fans and cooker hoods) temporarily sealed.
- The test was carried out in accordance with ATTMA (the Air Tightness Testing and Measurement Association) Technical Standard[10] and the result recorded. (ATTMA TS1 is based on BS EN 13829:2001 *Thermal Performance of Buildings – Determination of Air Permeability of Buildings – Fan Pressurisation Method*.)[11]
- A smoke pencil was used to identify the key air leakage points.
- The homeowner was then asked a series of predetermined questions about how they use their home and their experiences of living in it. Their responses were recorded by the test engineer on the question sheet.

Results

Table 1 in the Appendix shows 23 test results, carried out between 10 March and 27 May 2010.

It is to be noted that the overall total number of dwellings studied was limited so caution should be exercised in drawing conclusions. It should be emphasised that the sub-sets of dwelling, construction, heating and ventilation type, are particularly limited and not statistically significant.

The mix of homes tested is shown in Figure 2.

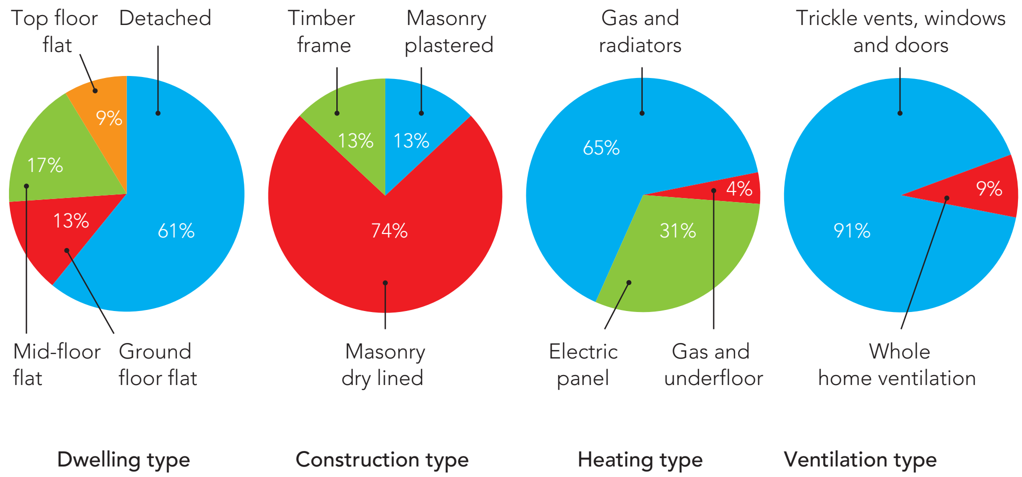

Figure 2 Profile of resultant dataset.

The sample datasets did not include any attached (terraced or semi-detached) homes. This is because owners of these types of home did not accept the invitation to participate.

Figure 3 is a graphical representation of the differences in tested air permeability between the original tests and re-tests.

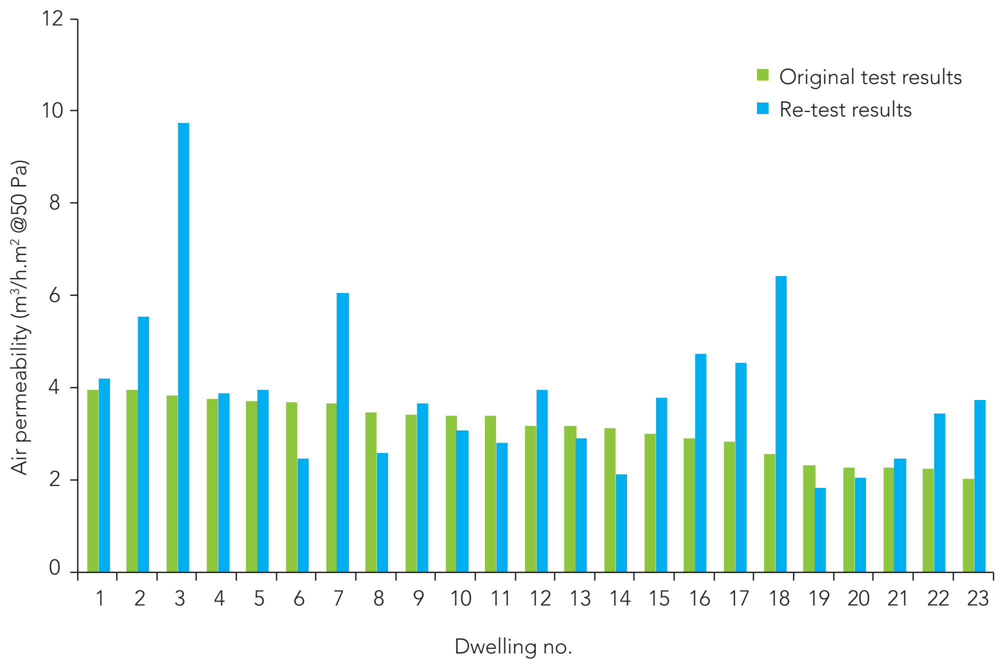

Figure 3 Air leakage test results.

Observations

- 23 dwellings (100%) achieved a re-test result tighter than 10 $m^3/(h.m^2)$
- 19 dwellings (83%) achieved a re-test result tighter than 5 $m^3/(h.m^2)$
- 16 dwellings (70%) achieved a re-test result better than 4 $m^3/(h.m^2)$
- 8 dwellings (35%) achieved a re-test result better than 3 $m^3/(h.m^2)$.

The changes in performance between the original test and the re-test were as follows:

- 15 dwellings (65%) became leakier, on average by 1.5 $m^3/(h.m^2)$ although the range of change is wide
- 8 dwellings (35%) got tighter, on average by 0.63 $m^3/(h.m^2)$.

During the re-tests, the following features on the properties with the most significant leakage were recorded: loft hatches, recessed lighting, around front doors, through window and patio door seals, radiator pipe penetrations, behind kitchen units, around the boxing to soil and vent pipes, and around bath panels and shower trays.

Types of dwelling

The detached houses generally became leakier than the flats (Figure 4). This may be simply explained by the fact that houses are normally larger and therefore have larger areas of wall, ceiling and floor than flats.

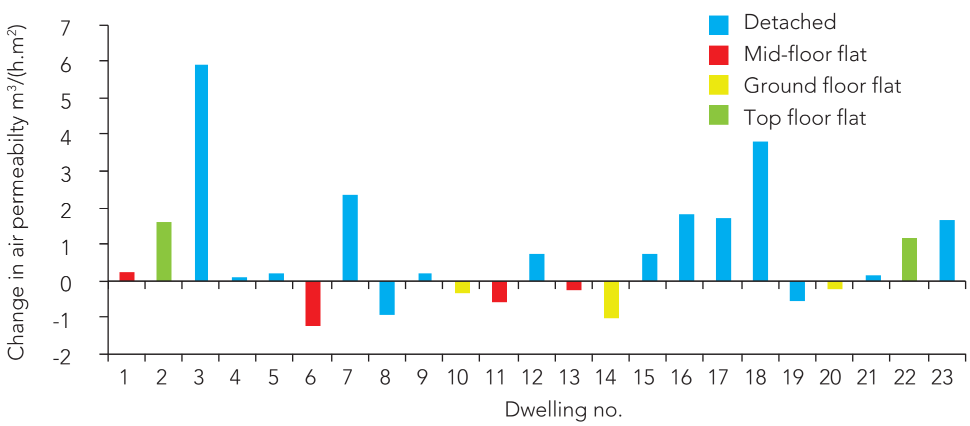

Figure 4 Dwelling type.

Types of construction

Timber frame dwellings showed the largest change in airtightness and plastered masonry the lowest.

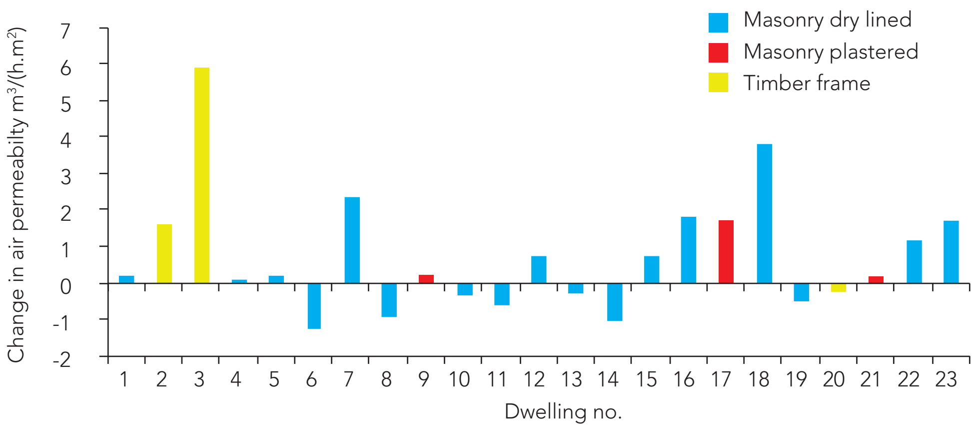

Figure 5 Construction type.

Types of heating system

Six of the eight results that achieved a performance improvement were heated with electric panels rather than a gas and radiator system (Figure 6). This may be due to the reduced number of service penetrations.

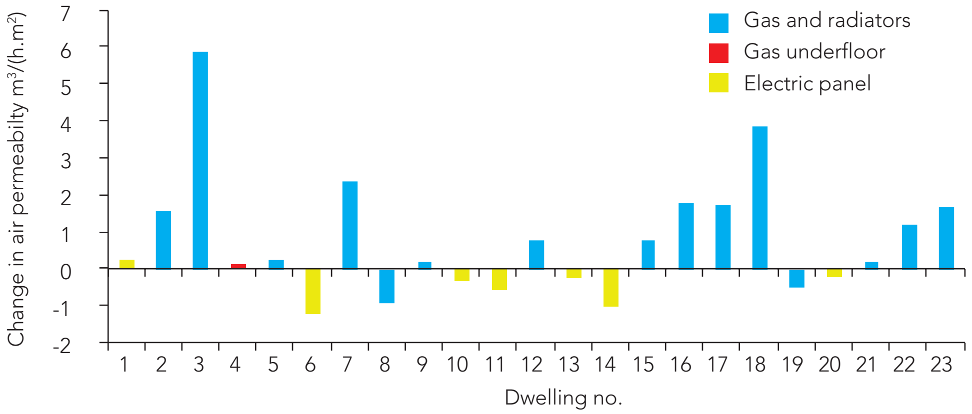

Figure 6 Heating type.

Types of ventilation

The change in air permeability for dwellings with a whole home ventilation system was particularly low (Figure 7).

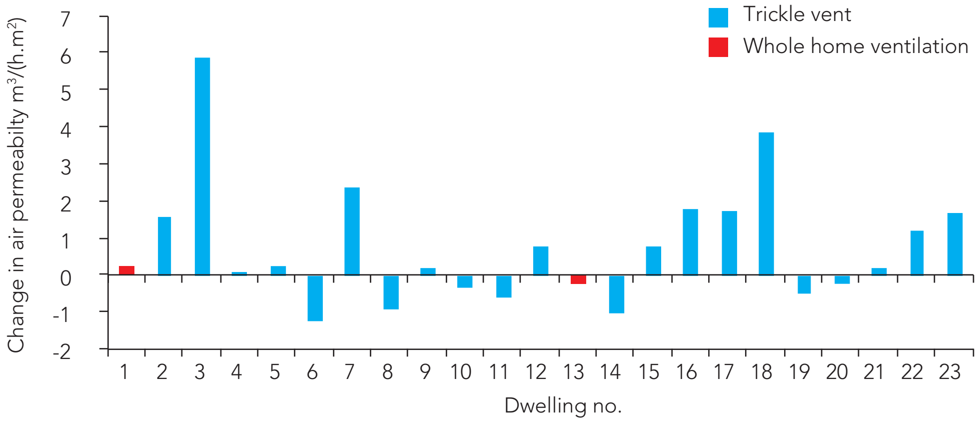

Figure 7 Ventilation type.

Questionnaire and visual observation

A summary of the findings from the questionnaire and visual observations is presented in Figure 8.

It is interesting to note the extent to which occupants fail to comply with good ventilation practice widely accepted as being necessary to reduce condensation and mould growth.

When asked, 65% of the occupants said that they used trickle vents always or sometimes. However, in 10 of the 23 homes (44%) with trickle vents, these were recorded as being set in the closed position. Only five were recorded as open (22%), eight having a mix of open and closed (35%).

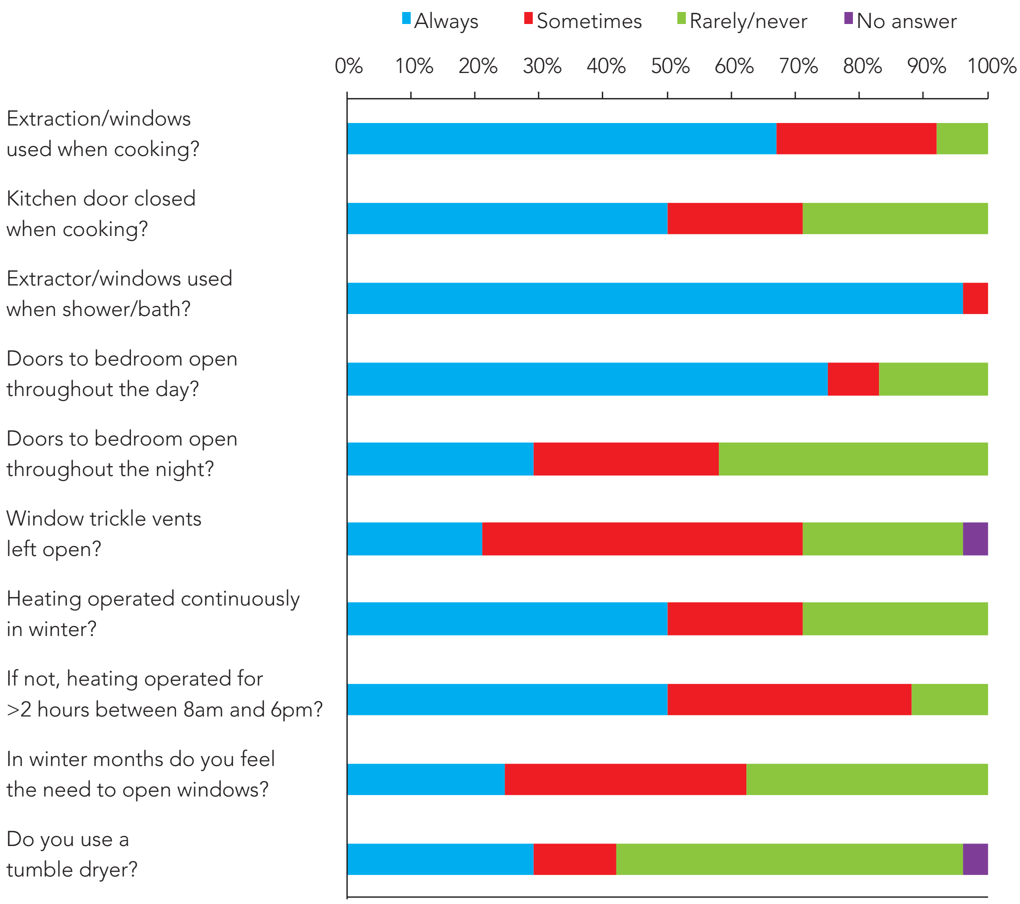

Figure 8 Summary from questionnaire and visual observations.

Mould growth

Mould growth was present in the habitable areas of three homes included in the study (13%) although in all cases the mould growth was minor.

Dwelling 4

Minor mould growth in an en-suite bathroom to the master bedroom around the wall and ceiling junction near the window. In this dwelling it was noted that trickle vents were set in the closed position and the homeowner indicated that they were rarely/never used (re-test result 3.88 $m^3/(h.m^2)$, detached, masonry dry lined, gas and underfloor heating, and trickle vents).

Dwelling 9

Evidence of some mould around junctions of external walls, wall/ceiling junctions, window reveals. It was noted that trickle vents were set in the closed position, although the homeowner indicated that trickle vents were sometimes used (re-test result 3.66 $m^3/(h.m^2)$, detached, masonry plastered, gas and radiators, and trickle vents).

Dwelling 21

A small amount of mould was evident behind and around the sanitary ware in the bathroom. The homeowner indicated that trickle vents were always used, although a mixture of open and closed vents was noted at the time of the visit (re-test result 2.46 $m^3/(h.m^2)$, detached, masonry plastered, gas and radiators, and trickle vents).

Discussion

When tested one to three years after completion, the air permeability of two thirds of the dwellings tested had increased (ie had become leakier). The specific reason is not known but it is assumed that this is due to normal settlement and shrinkage.

Perhaps surprisingly, the air permeability of the remaining third had decreased. Again the reason is not known, but it could be the result of settlement, the installation of carpets and floor finishes after the original test, and the presence of plugs in electrical sockets, etc.

The features causing the most significant leakage were loft hatches, recessed lighting, around front doors, through window and patio door seals, radiator pipe penetrations, behind kitchen units, around the boxing to soil and vent pipes, and around bath panels and shower trays.

Although many of the homes were very airtight and did not have special ventilation provision, this did not appear to be causing problems in practice, despite the fact that good advice on reducing condensation was routinely being ignored. Only minor mould growth was observed, and this was in only three dwellings.

Conclusions

Research into changes in air permeability as dwellings age is limited, particularly on new homes in the UK.

Evidence from this programme of re-testing of 23 homes up to three years after construction does not support the hypothesis that the air permeability of new homes increases during the first months and years after completion. These tests showed that a substantial minority of the homes tested actually became more airtight over the period since completion.

With the exception of three homes that showed signs of minor mould growth, there was no evidence of under-ventilation in the homes. Given that good ventilation practice was not being followed by the majority of occupants, it is surprising that there was not more evidence of under-ventilation problems.

It should be noted that the total number of dwellings in this study was limited and so caution should be exercised in drawing conclusions. It should be emphasised that the sub-sets of dwelling, construction, heating and ventilation type, are particularly limited and not statistically significant. To confirm the results of this study, further research involving a larger sample of all dwelling types, constructions, and heating and ventilation types would be needed.

APPENDIX

Test results

Table 1 Air permeability test results ($m^3/h.m^2$ at 50 Pa)

Dwelling number	Dwelling type	Wall construction	Heating	Ventilation	Original test result	Re-test result	Increase/decrease (original vs re-test)
1	Mid-floor flat	Masonry dry lined	Electric panel	Whole home ventilation	3.96	4.20	0.24
2	Top floor flat	Timber frame	Gas and radiators	Trickle, windows and doors	3.95	5.56	1.61
3	Detached	Timber frame	Gas and radiators	Trickle, windows and doors	3.84	9.75	5.91
4	Detached	Masonry dry lined	Gas and underfloor	Trickle, windows and doors	3.76	3.88	0.12
5	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	3.72	3.96	0.24
6	Mid-floor flat	Masonry dry lined	Electric panel	Trickle, windows and doors	3.7	2.48	-1.22
7	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	3.67	6.07	2.40
8	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	3.48	2.59	-0.89
9	Detached	Masonry plastered	Gas and radiators	Trickle, windows and doors	3.43	3.66	0.23
10	Ground floor flat	Masonry dry lined	Electric panel	Trickle, windows and doors	3.41	3.08	-0.33
11	Mid-floor flat	Masonry dry lined	Electric panel	Trickle, windows and doors	3.39	2.81	-0.58
12	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	3.18	3.96	0.78
13	Mid-floor flat	Masonry dry lined	Electric panel	Whole home ventilation	3.17	2.92	-0.25
14	Ground floor flat	Masonry dry lined	Electric panel	Trickle, windows and doors	3.14	2.12	-1.02
15	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	3.01	3.78	0.77
16	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	2.92	4.74	1.82
17	Detached	Masonry plastered	Gas and radiators	Trickle, windows and doors	2.83	4.56	1.73
18	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	2.58	6.43	3.85
19	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	2.33	1.83	-0.50
20	Ground floor flat	Timber frame	Electric panel	Trickle, windows and doors	2.28	2.05	-0.23
21	Detached	Masonry plastered	Gas and radiators	Trickle, windows and doors	2.27	2.46	0.19
22	Top floor flat	Masonry dry lined	Gas and radiators	Trickle, windows and doors	2.25	3.44	1.19
23	Detached	Masonry dry lined	Gas and radiators	Trickle, windows and doors	2.04	3.75	1.71

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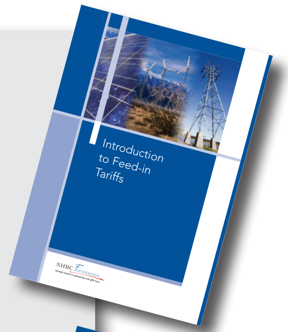

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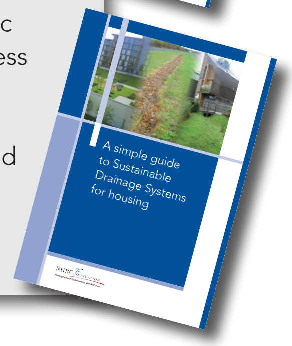

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The requirement for air permeability and pressure testing was introduced into the building regulations in 2006. As housebuilders have become familiar with the factors affecting airtightness and the attention to detail needed, their ability to achieve high standards of airtightness has improved significantly. Indeed, a very high standard for many homes is being demonstrated by the testing at completion. But is that standard maintained over the life of the home or do factors such as shrinkage and normal settlement reduce airtightness?

This NHBC Foundation research seeks to answer that question by re-testing a sample of homes one to three years after completion. It finds that, although most homes do become less airtight as they age, a substantial minority of one third actually became more airtight. Another interesting finding is that, although good ventilation practice was routinely not being followed by occupants, there was limited evidence of condensation and mould growth.

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