THE REDUCTION IN AIR INFILTRATION IN DWELLINGS DUE TO WINDOW REPLACEMENT

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ABSTRACT

In the UK, existing dwellings have been traditionally considered as 'leaky' with unnecessary air infiltration resulting in excessive energy use. However, when 'old' windows are replaced, it is likely that the new windows will have a lower air permeability. If most, or all, of the windows in a property are replaced, then the overall reduction in the infiltration rate may be significant. If a dwelling already has a low infiltration rate, then the reduction which will occur upon replacement of the windows may result in an unacceptably low air change rate. Currently, the widely recommended minimum air change rate is 0.5 ach^{-1}. This study set out to investigate if window replacement is likely to reduce infiltration rates to below this level in a significant number of dwellings in the UK. A sample of dwellings was thus pressure tested before and after window replacement and the change in the air infiltration rate determined. If the results are taken as being representative of the UK building stock then the data suggests that approximately 65% of dwellings in the UK could have a predicted heating season mean infiltration rate below 0.5 ach^{-1} after the installation of new windows.

INDEX TERMS

Windows, Replacement, Background, Ventilation, Measurements.

INTRODUCTION

The energy efficient refurbishment of the existing building stock is essential if countries are to meet their commitments to reduce the emissions of CO_2. Replacing existing windows with modern energy efficient windows is one of the measures that can easily be introduced into existing buildings. For this reason, Part L of the 2002 Building Regulations for England and Wales, which covers energy efficiency, brought for the first time, domestic replacement windows under its control. This introduces the problem of getting the correct balance between energy efficiency and providing adequate ventilation to the existing building stock.

In the UK, existing dwellings have been traditionally considered as 'leaky' with unnecessary infiltration resulting in excessive energy use. However, care must be taken that, just as in new buildings, adequate ventilation is provided. This is particularly the case in buildings which *already* have poor indoor air quality. For this reason Part L of the Building Regulations refers to Part F of the regulation, which covers the provision of adequate ventilation. However, there is no explicit mention that Part F always applies to refurbishment, just that after any refurbishment, the building should "not have a worse level of compliance". This has been interpreted by some to mean that if a window had no controllable ventilation before replacement then the new replacement window does not require any. Others have interpreted the regulations to mean that, if replacement windows are likely to significantly reduce a building's air change rate to levels which may result in poor indoor air quality (i.e. below the widely recommended rate of 0.5 ach^{-1}), then controllable ventilation must be introduced at the same time as a window is replaced.

The paper then investigates the impact that replacing windows in the UK domestic building stock is likely to have on the adequate provision of ventilation in the domestic stock. The paper explores whether replacing old windows in a significant proportion of UK dwellings could reduce air change rates below recommended levels unless additional controllable ventilation is installed at the same time as new windows.

The work reported here, which is part of a larger project, set out then:

- To identify a sample of dwellings that were to have complete window replacement,
- To carry out fan pressurisation measurements before and after replacement,
- To assess the impact on the UK building stock as a whole.

RESEARCH METHODS

Pressure testing of houses

The work began with the identification of ten dwellings that were to be the subject of extensive windows replacement. These ten dwellings were then tested to determine air infiltration rates using standard fan pressurisation testing as prescribed by BS EN 13829 – 'Determination of the Airtightness of Building Envelopes by the Fan Depressurisation Method'. In compliance with the Standard, a series of steady state pressure differentials were applied across the dwelling, and at each pressure differential the airflow to maintain the pressure differential is measured. From these values, the leakage characteristics of the tested dwellings were then deduced and reported in terms of both:

- the number of air changes per hour at 50 Pa,
- air infiltration at normal operational pressure.

Note that the air infiltration rate at normal operational pressure is assumed to be adequately represented by the 'divide by twenty' rule (Sherman (1998)). The procedure was then repeated after window replacement had taken place.

Impact on Stock

The results of the testing were then analysed to asses if the sample of houses with replacement windows were significantly more air-tight then the national average, and if they are thus at risk of moisture problems due to under ventilation. In order to estimate the impact on the stock that such experimental results might imply, the work considered the distribution of infiltration rates in UK dwellings. The work used data measured by the Building Research Establishment (BRE) (Stephen 1998).

Assessment of the risk of causing IAQ problems as a result of installing replacement windows by modelling a series of scenarios using Condensation Targeter

To predict the impact that such changes in air infiltration may have on the IAQ, preliminary theoretical modelling has been carried out in this study using 'Condensation Targeter' (Pretlove, 2000). A typical UK dwelling in compliance with the current Building Regulations was modelled.

RESULTS

Pressure testing of houses

A summary of the results of the blower door test before and after replacement of windows results is given in table 1. Note that where any new windows were fitted with trickle vents, the data in table 1 refer to the case where these trickle vents were closed.

Table 1. *Summary of the results of the blower door test before and after window replacement*

Test No.	DWELLING			AIR INFILTRATION ACH^{-1}		
	LOCATION	V [m^3]	% windows replaced	BEFORE (A)	AFTER (B)	(A)-(B)
01/10	Norbury	202	100	0.59	0.36	0.23
02/10	Cudham	393	86	0.57	0.30	0.27
03/10	Mitcham	160	100	0.56	0.22	0.34
04/10	Rotherhithe	108	100	0.37	0.13	0.24
05/10	Rotherhithe	122	70	0.62	0.40	0.22
06/10	Bermondsey	97	100	0.48	0.18	0.30
07/10	Maidstone	171	100	1.86	1.66	0.20
08/10	Mitcham	165	100	0.62	0.56	0.06
09/10	Mitcham	96	100	1.33	1.06	0.27
10/10	Maidstone	227	60	0.70	0.51	0.19

The mean value of the reduction in the predicted heating season mean air infiltration rate after replacement of the windows was 0.23 ach^{-1} (standard deviation of 0.08 ach^{-1}).

Impact on Stock

In order to estimate the potential impact on the stock that such experimental results might imply, we will now consider the distribution of infiltration rates in UK dwellings as measured by the Building Research Establishment (BRE) (Stephen 1998). The average infiltration rate during pressure testing at 50 Pa in that study was found to be 13.1 ach^{-1}. Applying the standard rule of thumb to convert from pressure test results (ACH_{50}) to air infiltration at normal operational pressure (NL), as given by Sherman (1998):

$$NL = \frac{ACH_{50}}{20} \qquad (1)$$

the stock averaged, predicted heating season mean air infiltration rate, of a UK dwelling as measured by the BE study is thus 0.65 ach^{-1}.

Using the experimental data obtained during this current study, which suggest that replacing old leaky windows with modern sealed windows would reduce the stock averaged, predicted heating season mean infiltration rate by 0.23 ach^{-1}; the new predicted heating season mean infiltration rate would be in the region of 0.42 ach^{-1} which is below the widely recommended air change rate of 0.5ach^{-1}. Figure 1 shows the distribution of air infiltration rates, using the BRE pressure test data, before and after the possible effect of the installation of new windows.

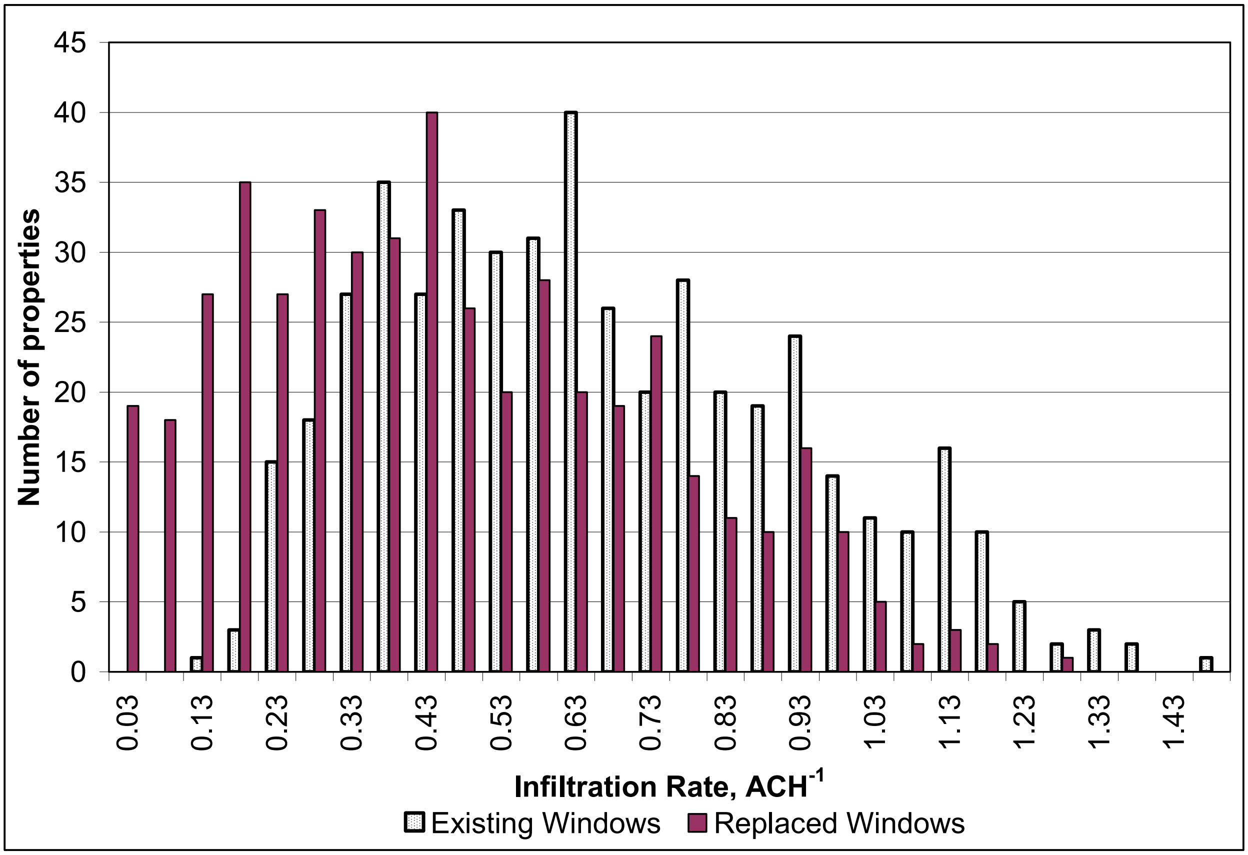

Figure 1. *Distribution of air infiltration rates using BRE pressure test data before and after the possible effect of the installation of new windows,*

If one assumes that the BRE pressure test data applies predominately to dwellings with relatively old, 'leaky' glazing and is typical of the UK building stock, it is possible to use this data to make an estimate of the percentage of UK properties that would have a predicted heating season mean air change rate less than 0.5 ach^{-1} as a result of simply replacing old windows with new, assuming that no additional controllable ventilation is provided at the time of window replacement.

Taking the reduction in the predicted heating season mean air infiltration rate of 0.23 ach^{-1} (i.e. the mean value measured during this project), and applying this to the BRE data set suggests that 65% of dwellings in the UK could have a predicted heating season mean infiltration rate below 0.5 ach^{-1} after the installation of new windows. It appears that some form of controllable ventilation would be beneficial in dwellings with inadequate air infiltration in order to maintain adequate indoor air quality.

Assessment of the risk of causing IAQ problems as a result of installing replacement windows by modelling a series of scenarios using Condensation Targeter

In this modelling exercise the air change rate and moisture production rate were varied to assess how such changes impact on the risk of mould growth in the dwelling. Initial analysis indicates that installing replacement windows, without additional controllable ventilation, may mean - for the average property in the UK - moving from a situation where the risk of mould growth is low (except for cases of very high moisture production) to a situation where there is a high risk of mould growth for all but 'dry' occupancy. The full results will be presented at a later date.

DISCUSSION

It seems clear then that the *potential* does exist for replacement windows to significantly reduce air infiltration rates. However, it is useful to explore some issues that were associated with the experimental work in order to determine how representative a figure the 0.23 ach^{-1} reported here actually is. Firstly, it may be the case that the window installers were 'trying harder' because they knew that the testing was to be undertaken with a resulting better fit. This is certainly possible although the authors feel that this effect is unlikely to be a strong one. The sample size of the tested properties was also relatively small – ten properties. Importantly however, the standard deviation was small and this gives increased confidence in the results.

Note that in three of the properties tested, fewer than 100% of the windows were replaced. The average reduction in infiltration rate if all properties had had all the windows replaced would therefore be expected to have been higher than 0.23 ach^{-1}. A simple extrapolation for the three properties indicates that the average figure may rise to 0.26 ach^{-1}. However, in some cases, doors were replaced at the same time. No information is available as to the isolated impact of these doors but the average change in air infiltration rate due solely to the windows is likely to be reduced because of this. We therefore assume that the 'as measured' reduction of 0.23 ach^{-1} is a reasonable indication of the reduction that would arise if 100% of windows (and no doors) were replaced in all the properties.

CONCLUSION AND IMPLICATIONS

The conclusions of the work undertaken are as follows:

- Analysis of the air infiltration tests undertaken for this study clearly shows that window replacement has reduced the infiltration rate in all the properties tested.
- The predicted heating season mean infiltration rate was reduced on average by 0.23 ach^{-1} with a standard deviation of 0.08 ach^{-1}. In six out of ten dwellings the replacement windows reduced the predicted heating season mean air infiltration rate to below 0.5 ach^{-1}.
- It is important to note that the sample of 10 dwellings may not be representative of the UK stock. However the reduction in predicted heating season mean air infiltration rate was very consistent across the sample with only one property showing a reduction of less than 0.19 ach^{-1}.
- Assuming a reduction in predicted heating season mean air infiltration rate of 0.23 ach^{-1}, i.e. the mean value measured during this project, and applying this to the BRE data set suggests that 65% of dwellings in the UK could have a predicted heating season mean infiltration rate below 0.5 ach^{-1} after the installation of new windows.

- Initial ‘Condensation Targeter’ analysis suggests that installing replacement windows, without additional controllable ventilation, may mean - for the average property in the UK - moving from a situation where the risk of mould growth is low (except for cases of very high moisture production) to a situation where there is a high risk of mould growth for all but ‘dry’ occupancy.
- It would appear that the installation of some form of ventilation introduced at the same time as a window is replaced would be beneficial.

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REFERENCES

BS 6375:Part1: *Performance of windows: Classification for weathertightness*, BSI, UK.
BS 5368: Part 1: *Test Method, Air permeability*. BSI, UK
BS EN 13829 *Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method.)* BSI, UK
Pretlove, S. (2000) *Predicting Relative Humidity in UK dwellings*, PhD Thesis, University of London.
Sherman, M. (1998) *The use of Blower Door Data*, Lawrence Berkley Lab Report 35173. LLBL USA
Stephen, R.K., (1998) *Airtightness in UK dwellings: BRE’s test results and their significance*, Building Research Establishment, *BRE 359*, UK