AIR LEAKINESS OF NON-STANDARD HOUSING: IMPACT OF UPGRADING MEASURES

S. Sharples[1] and C. Goodacre[2]

[1] Sheffield Hallam University, Centre for the Built Environment, Unit 9
Science Park, Howard Street, Sheffield S1 1WB, UK
[2] Sheffield City Council, P.O. Box 1918, Sheffield S1 2XX, UK

ABSTRACT

Sheffield City Council in the UK identified some dwellings of non-standard construction that needed to be refurbished. The refurbishment mainly involved applying insulation and rendering to the exterior surfaces of external walls and replacing old windows. The main aims of the refurbishment for the Council were to improve the condition and appearance of the dwellings and reduce conductive heat loss through the fabric. Although no specific measures were taken to improve the air tightness of the houses it was thought to be interesting to see if an improvement in air tightness could be achieved as a by-product of the general refurbishment. This study performed a series of blower door air tightness tests on three dwellings, each of different non-standard construction, before and after refurbishment. The three houses displayed a wide range of air leakiness values prior to refurbishment. The worst house had nearly twice the leakage of the best house and all the houses were above the recommended good practice air tightness value for UK housing. After refurbishment the leakiness of each house had been reduced, although the improvements were of not of equal magnitude. Two of the three houses did meet the good practice air tightness as an additional benefit of the general refurbishment.

KEYWORDS

Air tightness, energy, housing, refurbishment

INTRODUCTION

Adequate ventilation is obviously required in buildings to provide fresh air for respiration and to dilute and remove pollutants and combustion by-products. However, excessive ventilation can results in thermal discomfort (particularly draughts) and excessive energy consumption. Although UK thermal building regulations for housing have required progressively higher levels of insulation to reduce fabric energy losses there has not been an equivalent requirement for air tightness. Indeed, there is still no regulatory maximum air leakiness target for new or refurbished UK housing. A recent survey of the air tightness of UK dwellings by the Building Research Establishment (Stephen, 1998; Stephen, 2000) concluded that UK dwellings were leakier than in many other countries and that there was significant room for improvement in the air tightness of the UK housing stock. This improvement is particularly important for existing older housing since they are likely to be quite leaky, quite poorly insulated and to represent the vast majority of the housing stock (given the low rate of new house construction in the UK). Local authorities in the UK often have estates of houses that need refurbishment to improve the condition, appearance and thermal performance. This refurbishment will often involve increasing fabric insulation levels and replacing old single glazed windows. However, it is not usually the case that specific steps are taken to reduce the air leakiness of the properties (for example, sealing around service ducts and at constructional joins such as where walls meet floors and ceilings). Sheffield City Council had identified a number of houses that it wished to refurbish, but no actual target to reduce air leakiness was required as part of the project brief. This study sort to investigate what improvements in air tightness resulted as a by-product of this general programme of refurbishment.

THE HOUSES TESTED IN THE STUDY

The houses chosen for refurbishment by Sheffield City Council were all of non-standard construction (in terms of the combinations of materials used). General pre-refurbishment construction details are given in Table 1 while Table 2 describes the general refurbishment actions.

TABLE 1

Existing construction / materials data for the tested houses

House No.	Pre-Refurbishment Details	Before	After
House A	Ground floor: brick cavity wall 220mm thick. First floor: plasterboard interior on wooden studs with 25mm thick horizontal timber boards. Solid concrete floor. Envelope area: 205.25 m^2 Volume: 225.79 m^3		
House B	External walls of 250mm no-fines concrete, rendered externally and plastered internally. Solid load bearing panels (150mm thick) with infill of 180mm thick breeze block, plastered internally. Solid concrete floor. Envelope area: 190.97 m^2 Volume: 210.95 m^3		
House C	External walls of pre-cast concrete load bearing panels (150mm thick) with infill of 180mm thick breeze block, plastered internally. First floor wall is tiles fixed to battens with 25mm insulation board, 100 x 50 softwood frame with 12.5mm plasterboard. Solid concrete floor. Envelope area: 196.38 m^2 Volume: 220.15 m^3		

TABLE 2

Refurbishment construction / materials data for the tested houses

House No.	Post-Refurbishment Construction Details
House A	External timber cladding removed to allow voids between studs to be filled with 75mm insulation board, recover with vapour barrier and new timber cladding. Existing timber window replaced with upvc double glazed windows with Pilkington low E glass. Replacement of front and rear doors with upvc and fibreglass high performance doors.
House B	50mm insulation boards fixed to the external elevations and covered with a Permarock render system, all windows replaced with upvc double glazed windows as above, Renewal of soffit, fascia and rainwater system.
House C	1st floor tiles removed and 50mm insulation boards fixed to the external elevations and covered with a Permarock render system, all windows replaced with upvc double glazed windows as above, renewal of soffit, fascia and rainwater system.

METHODOLOGY

The air leakiness characteristics of each property were established using the blower door technique described in the Chartered Institution of Building Services Engineers publication TM23 (CIBSE, 2000) and prEN 13829 (2000). Two panels in to which calibrated fans were placed replaced an external door. All internal doors were opened and all purpose-made openings (trickle vents, flues, air bricks etc.) were sealed. The fans were used to depressurise the house to create indoor-outdoor pressure differences from approximately 25 to 55 Pascal (in approximately 6 equal steps) . The airflow through the fan, Q, at each pressure differential, ΔP, was determined and a graph of Q versus ΔP was plotted to show the air leakage characteristic curve for each dwelling. The data were fitted to a power law equation

$$Q = C (\Delta P)^n \quad (1)$$

where Q is the measured air volume flow rate in (m^3h^{-1}); C and n relate to the specific building under test and ΔP is the internal/external pressure difference (Pascal). Work by Walker et al (1998) has tested the validity of using this power law equation for low pressure envelope leakage testing. Figure 1 shows an internal and external view of the blower door in place.

Figure 1: Internal and external view of blower door

RESULTS

i) Air tightness results before refurbishment

Figure 2 show the Q-ΔP curves for the three houses before refurbishment.

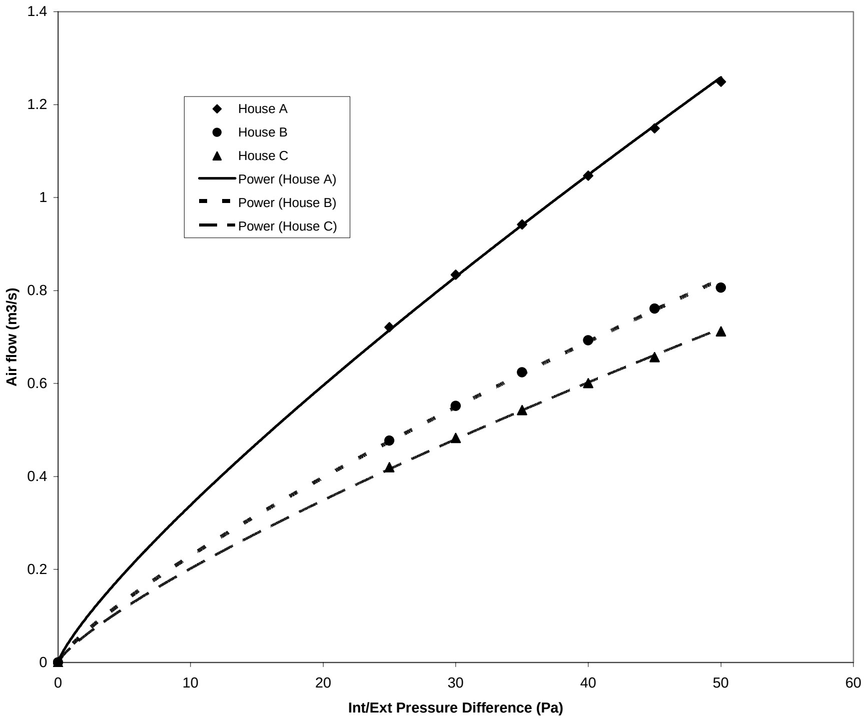

Figure 2: Q-ΔP curves for the three houses before any refurbishment

There are several ways of expressing air leakiness to give a value that can be used to compare the performance of different buildings. Air permeability is defined as the air leakage rate (m^3/hour) at an indoor-outdoor pressure difference of 50 Pascal, Q_{50}, divided by the total building envelope surface area (including the ground floor area) S. In the UK a naturally ventilated dwelling built to a 'good practice' standard would be expected to have a Q_{50}/S value of 10.0 $m^3/h/m^2$ at 50 Pa and a 'best practice' standard would be expected to have a Q_{50}/S value of 5.0 $m^3/h/m^2$. An air leakage test does not explicitly give a value for the air infiltration rate of a dwelling. However, from a large number of measurements on dwellings it has been possible to develop a 'rule of thumb' that the air infiltration rate per hour (ACH) is approximately $1/20^{th}$ of the Q_{50} air flow divided by the volume of the house. Table 3 shows a comparison of the air permeability values for the three houses before refurbishment and estimated ACH values based on the $1/20^{th}$ rule.

TABLE 3

Air permeability values of houses before refurbishment

House	**Q_{50}/S measured ($m^3/h/m^2$)**	**Q_{50}/S good practice ($m^3/h/m^2$)**	**Air Infiltration Rate (ACH)**
House A	21.9	10.0	0.99
House B	15.2	10.0	0.69
House C	13.1	10.0	0.58

It is apparent from Table 3 that, prior to refurbishment all of the houses were a long way from even the 'good practice' value and that there was a large range of leakiness values between the three houses.

ii) Air tightness results after refurbishment

Figure 3 show the Q-ΔP curves for the three houses after refurbishment.

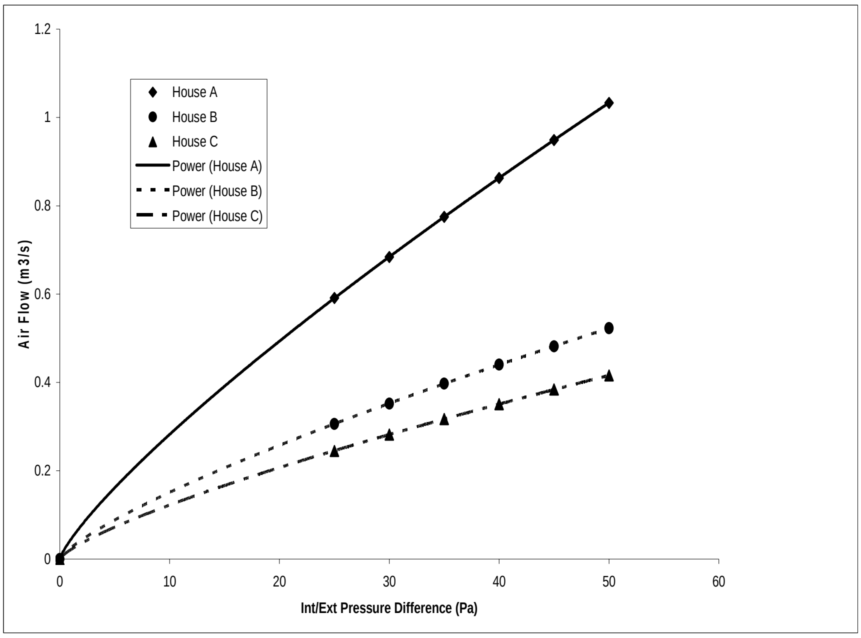

Figure 3: Q-ΔP curves for the three houses after refurbishment

The before and after refurbishment air permeabilities and air changes per hour are shown in Table 4.

TABLE 4
Air permeability values of houses after refurbishment

House	**Q_{50}/S before ($m^3/h/m^2$)**	**Q_{50}/S after ($m^3/h/m^2$)**	**% change**	**ACH before**	**ACH after**	**% change**
House A	21.9	18.1	21 %	0.99	0.82	21 %
House B	15.2	9.9	54 %	0.69	0.45	53 %
House C	13.1	7.6	72 %	0.58	0.34	71 %

DISCUSSION

Table 4 demonstrates that the general refurbishment of all three of the houses did produce, as an added benefit, an improved level of air tightness. However, the improvements were not uniform; the leakiest house before refurbishment, House A, was still the leakiest after refurbishment and was still a long way from meeting the recommended UK ‘good practice’ air permeability for dwellings of 10 $m^3/h/m^2$. The other two house did meet the value after refurbishment. The non standard construction details of House A were still contributing to a high leakiness and the general refurbishment had produced a moderate improvement. The timber boards on the front of House A were replaced after refurbishment and these remained as a potential leakage path. It would be necessary to apply specialist sealing techniques to significantly improve House A's performance. Houses B and C experienced relatively much bigger improvements in air tightness after general refurbishment. House B had solid concrete panels and it might be expected that the applied insulated and rendered panels would not have a big effect. It is probable that the installation of new double glazing in House B and the covering of some old gas fire flue outlets by the rendered panels were the biggest cause for the observed improvement. The hung tiles on the first floor of House C were replaced by insulated and rendered panels. This, together with the new glazing, probably accounts for the very large observed improvement in the air tightness of House C.

The residents of the three houses were all asked for their opinion on the thermal performance / thermal comfort after refurbishment. They all felt that there was a significant and noticeable improvement in terms of reduced need for heating to obtain comfort.

The largest survey of air tightness of UK dwellings, carried out by the Building Research Establishment (Stephen, 1998) examined 471 properties of various ages. The BRE survey found the mean air permeability to be 11.5 $m^3/h/m^2$. Comparison with the values in Table 4 for the three houses from this study indicate that prior to refurbishment all the houses had above UK average leakiness but that after refurbishment only House A was still above the national average.

CONCLUSION

Sheffield City Council undertook to improve the appearance and insulation levels of some unusually constructed dwellings. The cost of refurbishment was high (typically €30,000 per dwelling) because of the non-standard constructional details that had to be worked around. However, this study has shown that as well as reducing fabric heat losses the refurbishment has had the added benefit of reducing ventilation energy losses due to the unplanned improvement in air tightness.

REFERENCES

CIBSE (2000). *Testing buildings for air leakage,* Chartered Institution of Building Services Engineers Technical Memorandum TM23

prEN 13829 (2000) *Thermal performance of buildings - determination of air permeability of buildings - fan pressurisation method* (ISO 9972:1996, modified), European Committee for Standardisation, Brussels

Stephen, R. (1998). *Airtightness in UK dwellings: BRE test results and their significance,* Building Research Establishment Information Report BR 359

Stephen, R. (2000). *Airtightness in UK dwellings,* Building Research Establishment Information Paper IP 1/00

Walker, I.S., Wilson, D.J. and Sherman, M.H. (1998). A comparison of the power law to quadratic formulations for air infiltration calculations. *Energy and Buildings* **27**, 293-299