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AIRTIGHTNESS IN UK DWELLINGS: A REVIEW OF SOME RECENT MEASUREMENTS.

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ABSTRACT

The objectives of this paper are to review measurements of airtightness in two domestic refurbishment projects in England, and to attempt to determine the effects of basic construction method and approach to refurbishment on airtightness. Both refurbishment projects involved groups of two storey dwellings, constructed in load bearing cavity masonry.

While the total number of houses involved in the work reported here is small, the results suggest that a substantial fraction of the existing UK dwelling stock could, in principle be made air-tight enough to justify the use of continuous mechanical ventilation on energy grounds. However, this may be significantly more difficult to achieve in dwellings built since 1970 due to changes in the method of wall construction.

1 INTRODUCTION

For a number of reasons, to do with traditionally plentiful fuel supplies and comparatively mild climate, dwellings in the UK tend to be less airtight than those in some other high latitude countries. If anything, this difference has grown over the last twenty years following the adoption, initially in Sweden, of airtightness standards for new dwellings [1][2][3]. Recent measurements show essentially no age-related gradient of airtightness in the UK stock, suggesting that dwellings constructed now are no more airtight than those constructed at the beginning of the century [4].

Airtightness is connected in a complex way with both occupant health and energy efficiency. There is some evidence that controlled ventilation in airtight dwellings may lead to lower concentrations of contaminants in internal air [5]. The optimum ventilation strategy depends on the level of airtightness achieved.

Mechanical ventilation with heat recovery (MVHR) was introduced in Sweden together with an airtightness standard of 3 ac/h at 50 Pa. Liddament [6] suggests that the current consensus is that balanced MVHR requires a leakage of 1 ac/h or lower, with dwellings in the range 1-3 ac/h being more suited to a strategy of continuous extraction. These leakage rates are between 5 and 15 times lower than the current UK average. Unless it can be shown that there is a reasonable possibility of achieving much greater airtightness in the existing UK stock, the scope for energy conservation by reducing ventilation heat loss and the market for continuous mechanical ventilation are likely to remain small.

2 METHOD

The method used to measure air leakage was fan pressurisation using a Minneapolis blower door. Under good conditions measurements have an error band of perhaps ±10%. Blower door measurements were supplemented by photographic and video documentation.

3 AIRTIGHTNESS IN EXISTING HOUSING AT YORK

The York Energy Demonstration Project provided an opportunity to investigate the effects of refurbishment on the airtightness of existing, low rise, load bearing masonry housing in the North of England. Fuller descriptions of the York Project have been presented by Bell & Lowe [7][8]. We will note here that the houses were built in the 1930s and 1950s using traditional construction techniques, including wet-plastered walls. In 1992 they were comprehensively renovated, with replacement double glazed windows, new doors and 200 mm of loft insulation. Fan de-pressurisation tests were carried out in three of the houses. The wall cavity of one of the houses, Chapelfield B, was filled with blown mineral fibre, while the wall cavities of the other two houses, Bell Farm A & B were filled with in-situ foamed polyurethane. The tests were undertaken in January 1992, before, and in March and April 1992, after improvement work. In January it was possible to test only two of the houses under near perfect weather conditions, while in the spring it was possible to test all three of the houses, but under adverse wind conditions. The results are shown in table 1 and figure 1 below.

Table 1 Leakage rates at York. (ac/h at 50 Pa)

Dwelling	before	after
Chapelfield B	19.3	7.5
Bell Farm B		6.8
Bell Farm A	16.9	4.9

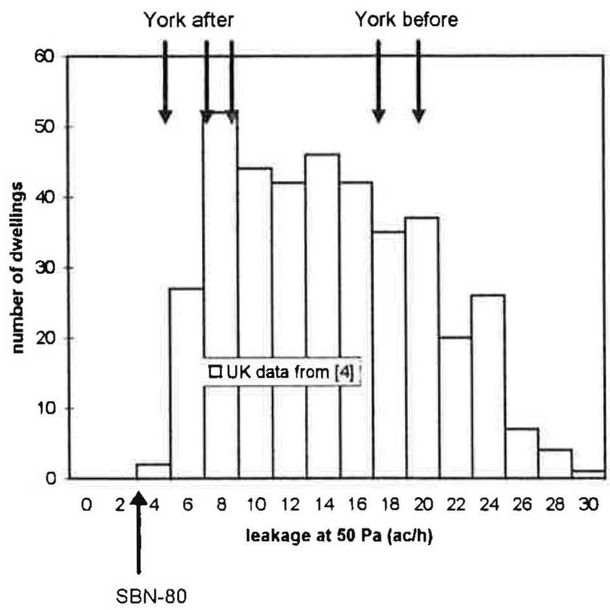

Figure 1. York retrofit in UK and European context.

These results show a 2.5 - 3 fold improvement in air tightness in both sets of houses. This was brought about by a combination of measures, including draughtstripped replacement windows and doors, covering of tongued and grooved floors with 3 mm plywood sheeting (not sealed around skirting boards), and repair of obvious damage to plasterwork around doors and windows.

Leakage rates before improvements were higher than the UK average, although by no means extreme. The leakage rates after improvements are in the bottom quartile of a BRE database of 385 UK dwellings [4]. The estimate for Bell Farm A is below 5 air changes per hour[1]. This figure was exceeded, in 1992, by just two in the BRE database, and it approaches the 1980 Swedish 3 ac/h standard for new housing [1]. It was achieved without significant attention to detail or workmanship or supervision. Moreover, a number of design and construction defects were evident at the time of testing. The most important of these were:

the new external timber panel doors on all three houses were poorly sealed;

[1] In this house, after refurbishment, it was only possible to measure directly the leakage rate with the mechanical ventilation system unsealed. The effect of sealing this system was estimated from measurements on the adjoining house.

draught sealing around new opening windows in all houses was discontinuous; and

in Bell Farm A, a 200 mm section of skirting board on the chimney breast was missing, exposing a gap between floor boards and wall of some 0.01 m^2 - this gap almost certainly continued behind the electric fire.

The significance of these measurements is that they suggest the possibility of achieving air leakage rates of 3 ac/h or less in existing masonry houses in the UK, with the application of modest additional effort. At this level, mechanical ventilation with heat recovery would be a viable option on energy efficiency grounds, even in gas heated dwellings, and significant reductions in ventilation heat loss would be possible.

The fact Bell Farm A&B achieved somewhat lower leakages than Chapelfield B, suggests that that use of high density polyurethane foam as a cavity fill may be a reliable and effective way of reducing air leakage in traditionally constructed masonry houses, probably by reducing leakage through joist spaces in suspended timber upper floors.

4 AIRTIGHTNESS IN REFURBISHED DWELLINGS AT ESHWINNING

The results presented here are based on a field trial which was set up to explore the feasibility of incorporating mechanical ventilation with heat recovery (MVHR) into traditional low-rise housing. The field trial is based on a group of 12 local authority houses, constructed in the 1960s at Eshwinning in County Durham. The houses have been divided into an experimental group with MVHR, and a control group without. The houses are currently being monitored with the objective of measuring differences in internal air quality, energy use and acceptability to tenants.

When the field trial was first proposed, the intention was to undertake a programme of airtightness improvements on the houses before monitoring began. Work at York, reported above, suggested that a leakage rate of 3 ac/h at 50 Pa would be a challenging but not unobtainable target for dwellings of traditional construction, and if achieved, would provide a good chance of enabling the research team to observe significant energy benefits from MVHR.

The houses selected for the field trial are sited on the western edge of the village of Eshwinning, in County Durham. The village is in a valley at about 145 m above sea level. The two-storey houses were constructed in the 1960s in short staggered terraces, with low pitched trussed rafter roofs. External walls are of brick-block or block-block cavity construction, lined internally with plasterboard-on-dabs. Internal load-bearing walls are of blockwork, lined on both sides with plasterboard-on-dabs. Ground floors are ground-bearing concrete slabs finished with thermoplastic tiles. First floors consist of structural timber joists supported on gable, party, and internal load-bearing walls and finished with chipboard. The soil stack runs within the inner block leaf of the external wall, and connections to it are made through the plasterboard lining. Small single storey flat-roofed extensions house WCs, entrance lobbies and coal stores. These extensions were constructed with two walls of brick-block construction, with the third wall being timber clad.

At the start of the field trial the houses were in a poor state of repair. An initial pressurisation test on one house (not subsequently included in the field trial) showed a very high leakage rate (28.9 ac/h). This led to the field trial leakage target being revised upward to 8 ac/h at 50 Pa.

Programmes of general and targeted airtightness work were undertaken by a team from Leeds, in conjunction with a partial refurbishment of the dwellings carried out by Derwentside District Council. The most important step in the general airtightness programme was the injection of expanding polyurethane foam into the cavity between the structural concrete block inner leaf and the plasterboard skin of the walls. This required the drilling of 9 mm diameter holes at approximately 100 mm centres around the edges of each continuous sheet of plasterboard on all external and party walls, and around windows and external doors. The objective was to form continuous ribbons of foam, which would prevent air movement into this cavity from interior partitions and the first floor void.

Targeted airtightness work was carried out after the general airtightness programme had been completed. This targeted work involved depressurising each house, and identifying leaks by feeling for draughts, and by using smoke pencils. These leaks were then sealed where possible using polyurethane foam or silicone mastic. Draughtproofing was also carried out on areas of the dwellings such as the external doors and loft hatch. In one house, pressure tests were undertaken at 5 stages through the programme of work, giving an indication of the relative importance of each step.

The pressure tests show that before refurbishment, the air leakage rates of the dwellings at Eshwinning lay between 24-26 ac/h at 50 Pa, substantially in excess of the UK mean of 14 ac/h [4] and a factor of 8 greater than the original airtightness target for houses fitted with MVHR. The mean leakage rate after refurbishment and airtightness work was 10.9 ac/h, a reduction of 56%. This represents a considerable improvement, but still leaves the field trial dwellings leakier than had originally been hoped.

The majority of the improvement is accounted for by a combination of the general airtightness work and the effects of the refurbishment. Data from one house, which received only the refurbishment and no airtightness work, suggests that refurbishment work carried out by Derwentside District Council and the total package of airtightness work carried out by Leeds Metropolitan University, made similar contributions to the overall reduction in leakage.

Data from another of the houses suggests that the most important general airtightness measure to be undertaken was the sealing of the external walls. This reduced the air leakage rate of this dwelling by more than 8 ac/h at 50 Pa. Next in importance was the sealing of the tops and bottoms of the party walls which resulted in an improvement of $\approx$1.5 ac/h at 50 Pa. Sealing the external doors and windows resulted in a total improvement of $\approx$1 ac/h at 50 Pa.

The total time required for general airtightness work was reduced with practice and by the end of the period was of the order of 3 man days per house. The time required for the targeted airtightness work and the pressurisation testing was approximately 1½ man days per house. During the general airtightness work, approximately 40 kg of expanding polyurethane foam was required per house, at a cost of some £180. Material costs for the targeted airtightness work were minimal, with the greatest cost incurred being for labour.

It is clear that the airtightness of the field trial houses fell short of what had originally been hoped for. Technically the most important factor that contributed to air leakage in these houses was the method used to construct the walls. The use of plasterboard-on-dabs effectively interconnects all the leakage paths in the house. Geometrically the house, rather than being a simple cuboid consisting of a roof, external walls and a ground floor, becomes a complex network of inter-penetrating voids. Many of the junctions between these voids are hard to access, and even where access can be gained, there is little possibility of a visual check on the continuity of retrofitted seals. The construction method interacted adversely with the partial nature of the refurbishment carried out on the field trial houses, which meant that significant parts of the external walls could not be accessed from the inside of the dwelling. The arrangement of the houses in staggered terraces meant that cavities within party walls were continuous with those in external walls, and communicated freely into attic spaces and first floor voids.

There had been little attempt, during the original construction process, to seal around connections into soil stacks. Many of these connections took place behind kitchen units and WC's and were inaccessible. The existence of leaks at these points was attested to by discovery of cavity fill in kitchen units following the filling of wall cavities. Attempts were made to seal connections between to the soil stack with polyurethane foam, but this was made more difficult by presence of mineral fibre cavity fill in this space.

Wear-and-tear over the life of the dwellings contributed to air leakage. Damage to the plasterboard linings had occurred in a number of places, most importantly at the edges of walls, around doors and windows, and behind sink units. Much of this damage was not repaired during the refurbishment. This was particularly the case behind kitchen units, and behind baths, which were not replaced during the refurbishment process. Such damage made it difficult to undertake the general air-tightening work, as this depended on plasterboard being sound.

A check on this proposition was provided, in July 1995, by a pressure test that was undertaken in a house on the field trial estate., that had previously been gutted by fire. All internal fittings had been removed and replaced, and the plasterboard linings on all walls had been replaced by a conventional coat of plaster. No additional airtightness measures were undertaken in this house, but in most other respects it resembled the field trial houses following their refurbishment. The leakage rate in this house was 9.4 ac/h. This result is in line with measurements presented earlier for other refurbished houses of traditional wet-plastered construction at York [7]. If allowance is made for the effects of the open-flued gas fire in the living room in this house, it would have been the most airtight of all those tested. It appears likely that, had the field trial houses been constructed in this way, much lower final leakage rates could have been achieved following a revised airtightness programme.

5 CONCLUSIONS

The tentative conclusions from the work are:

- air leakage through the external envelopes of dwellings of load-bearing masonry construction can be reduced by between a factor of 2 and 3 by relatively simple measures;

- wet-plastered dwellings are significantly more airtight than dwellings with a plasterboard finish; measurements at York suggest that air leakage rates of 3 ac/h at 50 Pa might be achieved in such dwellings with modest additional effort;

- reducing leakage in plasterboarded dwellings appears to be more costly than in dwellings of conventional construction.

These tentative conclusions assume significance in the light of the fact that a large proportion of new domestic load bearing masonry construction in the UK is now dry-lined. Experience outside the UK with timber framed dwellings shows that with the right techniques [3][9], such a construction can be made airtight. However, in the absence of routine post-construction pressurisation testing, there is no incentive to apply these techniques to dry-lined load-bearing masonry constructions in the UK.

The work on which these conclusions have been based was undertaken opportunistically, and is not definitive. Neither of the field trials described above was established with the primary objective of investigating or demonstrating low leakage rates (3 ac/h at 50 Pa or less) in existing UK housing. The authors suggest that such a programme might yield results of considerable significance and should be established without delay.

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