Interim Report to Communities and Local Government Building Regulations Division under the Building Operational Performance Framework

AIRTIGHTNESS OF BUILDINGS — TOWARDS HIGHER PERFORMANCE

Interim Report D8 — Site Assessments and Test Results

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Interim Report D8 — Site Assessments and Test Results

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Executive Summary

1 This report details the results of pressurisation tests on dwellings constructed by the participating developers as part of Phase 3 of the project. The report also reviews the progress on the assessment of site survey data that have been obtained for the selected sites.

2 Drawings have been received from all five developers. Design assessments have been completed for all 26 selected dwellings and site surveys have commenced on 24 of these dwellings. Eleven of the 26 selected dwellings (five from developer B, one from developer C and five from developer D) have been completed and pressure tested.

3 A number of different approaches have been adopted by the developers for Phase 3 of the project. Two of the developers have concentrated efforts on the existing detailed design (developers A & E), whilst the other three (developers B, C and D) have adopted a staged approach, enabling the effects of a range of different airtightness measures to be compared.

4 Phase 3 site observations indicate that all the developers have reacted to information supplied in the Phase 2 feedback sessions, to varying degrees. The two-way dialogue established between the research team and the developers throughout Phase 3 has assisted in ensuring that the intended measures have been successfully introduced, and has also raised further issues which in many cases have resulted in the adoption of additional modifications. The result is that a number of issues from Phase 1 have been resolved. However, certain other issues remain unresolved; most notably those which require major revisions to detail design drawings or which may incur other significant expense.

5 In terms of the pressurisation testing, the results undertaken to date show a relatively wide range of airtightness, ranging from 5.6 to 15.0 $m^3/(h.m^2)$ @ 50Pa and with a mean of 9.7 $m^3/(h.m^2)$ @ 50Pa. Only three of the 11 dwellings tested to date achieved an air permeability that was higher than or equal to the UK mean of 11.5 $m^3/(h.m^2)$ @ 50Pa. This suggests that the dwellings tested are more airtight than the average for the stock as a whole. However, more importantly, only six of the 11 dwellings tested had air leakage values that were lower than the maximum specified level of 10 $m^3/(h.m^2)$ @ 50Pa set in Part L1 2002. This was despite each developer receiving detailed and targeted feedback on airtightness from the Leeds Met research team during the dwellings' construction and the use of Robust Details as the basis of the application for regulatory approval.

6 The data also show that in the majority of cases, the dwellings tested during Phase 3 of the project were more airtight than those tested during Phase 1. This suggests that the combination of the measures undertaken by the developers coupled with feedback from the Leeds Met research team has had a positive impact on the airtightness of the dwellings that have been tested.

7 The scale of the reductions in air leakage that has been achieved by each of the developers has varied and is dependent upon the measures undertaken. The greatest reductions in air leakage to date have been achieved by developer B, who achieved a 50% reduction in air leakage from the Phase 1 mean in two of the tested dwellings (B16 and B17). These reductions were achieved by pointing all of the joints and apertures prior to the application of the dry-lining in B16 and parging all of the external walls prior to dry-lining in B17. This suggests that pointing and parging can make sizeable contributions to the overall reduction in air leakage rate. Developer B is also the only developer to date where all Phase 3 dwellings tested achieved an air permeability of less than 10 $m^3/(h.m^2)$ @ 50Pa.

8 A number of common air leakage paths were identified within the Phase 3 tested dwellings. These relate to:

a) Junctions of the ground floor and external walls.

b) Junctions of intermediate floors and walls.

c) Thresholds.

d) Stairs.

e) Trickle vents.

f) Patio/French doors.

g) Bath panels and shower trays.

h) Around kitchen units.

i) Kitchen and bathroom service penetrations.

j) Service penetrations around the hot water cylinder.

9 All the above paths were also identified during Phase 1 of the project. The improved air permeability results obtained in Phase 3 to date indicate that as many of the air paths noted in Phase 1 still remain, there must be a reduction in the amount of infiltration through at least some of these critical areas. In the cases of stairs, trickle vents and patio doors none of the developers has made any changes in specification between Phase 1 and Phase 3, suggesting that improvements to the actual construction of the building envelope rather than material/supply changes are responsible for the increased airtightness in Phase 3.

Introduction

10 This report is milestone D8 — Site Assessments and Test Results of Communities and Local Government Project reference CI 61/6/16 (BD2429) *Airtightness of Buildings — Towards Higher Performance* (Borland and Bell, 2003).

11 The aim of this report is to summarise the progress that has been made on the assessment of the site data that has obtained as part of Phase 3 of the project (tasks 2.3.1 and 2.3.2 of the project proposal). It also presents the results of the pressurisation tests that have been undertaken to date.

12 Details of the developers, the sites and the dwellings that are participating in this phase of the project are set out in Table 1.

Developer	Type of development	Type of construction	Selected dwelling types
Developer A (5 dwellings)	Combination of private and social housing. 	Dry-lined masonry cavity, partial fill. 	• A 3-storey 3 bedroom end terrace with an internal floor area of 117 m^2. • Two 2-storey 3 bedroom mid-terraces with an internal floor area of 113 m^2. • A 2½-storey 3 bedroom end terrace with an internal floor area of 116 m^2. • A 2-storey 3 bedroom end terrace with an internal floor area of 113 m^2.
Developer B (5 dwellings)	Private housing. 	Dry-lined masonry cavity, full fill. 	• Four 3-storey 3 bedroom semi-detached properties with an internal floor area of 132 m^2. • A 2½-storey 4 bedroom detached property with an internal floor area of 164 m^2.
Developer C (5 dwellings)	Private housing. 	Dry-lined masonry cavity, full fill. 	• A 2-storey 4 bedroom detached property with an internal floor area of 106 m^2. • Two 2-storey end terraces with an internal floor area of 61 m^2. • Two 2-storey mid-terraces with an internal floor area of 71 m^2.
Developer D (5 dwellings)	Private housing.  	Steel frame 	• Four 2-storey 4 bedroom detached properties with internal floor areas of 85, 108, 117 and 124 m^2. • A 2-storey 3 bedroom detached property with an internal floor area of 93 m^2.
Developer E (6 dwellings)	Social housing. 	Wet-plastered masonry cavity, partial fill.	• A 2 bedroom apartment with an internal floor area of 58 m^2. • Two 2 bedroom apartments with an internal floor area of 57 m^2. • Three 1 bedroom apartments with an internal floor area of 43 m^2.

Table 1 Details of selected dwelling types for Phase 3 of the project.

Summary of Progress to Date

13 Drawings have been received from all five developers. Design assessments have been completed for all of the 26 selected dwellings (five from developers A, B, C and D and six from developer E). Site surveys have commenced on 24 of the 26 selected dwellings, the remaining two are due to commence construction in November 2005.

14 In terms of the pressurisation testing, pressure tests have been undertaken on 11 of the 26 selected dwellings (five from developer B, one from developer C and five from developer D). Details of the current stage of construction and anticipated completion dates for all of the dwellings that are participating in this phase of the project are set out in Table 2.

15 As can be seen from Table 2, it is anticipated that the selected dwellings will be completed and pressure tested within the project timescale. Two dwellings being constructed by developer A (A79 and A80) may encompass additional design alterations dependent upon the pressure test results of the three plots that are currently being observed, and have an expected completion date of February 2006. The apartments being constructed by developer E are not expected to be completed until March 2006 as a result of inclement weather experienced during Phase 1 of the project. This issue has been the subject of a programme revision which was approved in April 2005, and is not expected to have any additional impact on the timing of remainder of this project. However, any further delays in the build programmes for either of these developers may necessitate a further programme revision to allow the results of these dwellings to be included in the final report on domestic airtightness.

Developer	**Type of construction**	**Dwelling type**	**Current stage of construction**	**Anticipated completion date**
A	Dry-lined masonry cavity, partial fill.	• A64 — 2-storey 3 bed mid-terrace. • A65 — 2-storey 3 bed mid-terrace. • A66 — 2-storey 3 bed end terrace. • A79 — 2½-storey 3 bed mid-terrace. • A80 — 3-storey 3 bed end terrace.	1st fix. 1st fix. 1st fix. Sub-structure. Sub-structure.	November 2005. November 2005. November 2005. February 2006. February 2006.
B	Dry-lined masonry cavity, full fill.	• B14 — 2½-storey 4 bed detached. • B16 — 3-storey 4 bed semi-detached. • B17 — 3-storey 4 bed semi-detached. • B21 — 3-storey 4 bed semi-detached. • B22 — 3-storey 4 bed semi-detached.	Completed. Completed. Completed. Completed. Completed.	
C	Dry-lined masonry cavity, full fill.	• C17 — 2-storey end terrace. • C18 — 2-storey mid-terrace. • C19 — 2-storey mid-terrace. • C20 — 2-storey end terrace. • C194 — 2-storey 4 bed detached.	1st fix. 1st fix. 1st fix. 1st fix. Completed.	December 2005. December 2005. December 2005. December 2005.
D	Steel frame.	• D73 — 4 bed detached. • D74 — 3 bed detached. • D75 — 4 bed detached. • D76 — 4 bed detached. • D96 — 4 bed detached.	Completed. Completed. Completed. Completed. Completed.	
E	Wet-plastered masonry cavity, partial fill.	• AG01— 2 bedroom ground floor apartment. • AG02 — 1 bedroom ground floor apartment. • A201 — 2 bedroom 2nd floor apartment. • A202 — 1 bedroom 2nd floor apartment. • A301 — 2 bedroom top floor apartment. • A302 — 1 bedroom top floor apartment.	Superstructure. Superstructure. Superstructure. Superstructure. Superstructure. Superstructure.	March 2006. March 2006. March 2006. March 2006. March 2006.. March 2006.

Table 2 Details of the selected dwellings, their current stage of construction and anticipated completion date.

Interim Results of the Site Assessments

16 This section summarises the progress that has been made to date on the site surveys undertaken during Phase 3 of the project and presents the interim results.

17 As with Phase 1 of the project, the site surveys were undertaken in three separate stages (see Johnston, Miles-Shenton, Bell and Wingfield, 2005) and information on each of the selected dwellings was recorded on a site survey protocol. Details of the site survey protocol can be found within Johnston, Miles-Shenton and Bell (2004). To date, Stage 3 site visits have been undertaken on 11 of the 26 selected dwellings and Stage 1 site visits have been undertaken on 13 of the remaining 15 dwellings.

18 A two-way dialogue has been facilitated between the research team and the developers, during Phase 3 of the project. This approach has been adopted to enable any observations from site on

the airtightness performance of each of the selected dwellings to be fed back to the developers. In practice, the feedback has taken the form of a short written report, supplemented by photographs, highlighting any potential areas or issues that may have an influence on the eventual airtightness performance of the dwellings in question. An example of such a report for each developer can be found within the Appendix. The report has also been supplemented with a discussion with the site team prior to the next site visit. By providing such feedback to the developers, it gives them the opportunity to identify and rectify any issues relating to airtightness on site, prior to the dwellings being completed and tested.

19 The approach adopted by the research team during this phase of the project contrasts with the approach adopted during Phase 1. During Phase 1 the research team's role was purely observational and no advice or guidance was given to the developers on airtightness.

20 Details of the approach undertaken by each developer and the general observations that have been obtained from the site surveys to date are summarised below for each developer. The results have been presented by individual developer to reflect the fact that each developer has taken a different approach to airtightness during this phase of the project.

Developer A

21 The general approach taken by this developer has been to tighten up the existing detailed design where possible, by placing a focus on workmanship and training the operatives in airtightness awareness. Three of the dwellings (A64, A65 and A66) have been constructed using this approach, making only minor adaptations without incurring any significant additional costs. Depending upon the air leakage results from these three dwellings, additional work may be undertaken on the remaining 2 dwellings (A79 and A80) with extra-over costs.

22 Observations from site are summarised below, with some illustrated examples contained in Table 3.

- Increased attention to detail has been paid to the ground floor construction, where incorrectly positioned service penetrations are no longer a problem.
- There were no observed examples of damaged blocks or unfilled perpends in the current phase of building, problems which were regularly observed in Phase 1.
- External wall penetrations have been made more accurately in the current phase, enabling sealing around them to be done more successfully. All small penetrations observed have been sealed using mastic prior to dry-lining, this was not always the case in Phase 1. Examples of both are shown in Table 3.
- Built-in joists in close proximity to parallel walls were a problem in Phase 1 (Table 3). This problem has been addressed by ensuring that these gaps are being filled during construction, rather than relying on retrospective sealing where access is limited.
- Intermediate floor penetrations have been made more accurately in the current phase, with neat holes being created more suited to the size of the respected penetration.
- Potential air leakage into the loft-space through the metal studwork and around plasterboard ceilings is an 'as yet' unaddressed problem. The Leeds Met research team have brought this to the attention of the developer.
- Thresholds are now being sealed using proprietary cavity closers during construction (Table 3). The retro-filling of the cavity after dry-lining in Phase 1 did not produce an airtight detail.
- Window sill boards and jamb liners are to be fixed with solid layers of mortar and plasterboard adhesive, respectively; this should prevent the movement of air between the cavity around the opening and the void behind the plasterboard dry-lining. The same potential air path through the perforated metal lintels has been prevented by taping over the perforations prior to dry-lining.
- The positioning of the shower tray creates a potential air leakage path from beneath the shower tray, through the metal stud partitioning, directly into the ventilated loft-space as illustrated in Table 3. This was a potential path observed in Phase 1 and still remains in Phase 3.

Detail	**Phase 1 Observations**	**Phase 3 Observations**
External Wall Service Penetrations	  Larger penetrations smashed through blockwork retrospectively (example shows a cooker hood extract duct). Many smaller penetrations remaining unsealed at dry-lining stage.	  Larger penetrations have purpose made gaps left (as above for a cooker hood extract duct) or suitably sized holes bored. Smaller penetrations all sealed at pre-plaster stage.
Built-In Joists	  Gaps through to cavity observed at a number of instances where joists are in close proximity to walls.	  No corresponding gaps observed at these junctions, although mastic is rarely applied to these less accessible areas.
Threshold	 Threshold not sealed until after dry-lining, creating potential air paths from behind the dry-lining into the cavity.	 Proprietary cavity closers used to seal the cavity at the threshold prior to dry-lining.
Shower	  Air paths exist from underneath the shower tray, through the metal stud partitioning, into the ventilated loft-space.	 The same possible air paths still exist in this phase, as the site staff are continuing to build to the design drawings unless formally instructed otherwise.

Table 3 Selected alterations to detailing between Phase 1 and Phase 3 adopted by developer A.

Developer B

23 This developer has undertaken a staged approach. One dwelling (B14) has been built as standard, taking on board the feedback that was given to the developer at the end of Phase 1 of the project. One dwelling (B21) has been built as B14, with the developer acting upon the on-site feedback from Leeds Met research team where applicable. One dwelling (B22) has been built as B21, plus all of the light fitting cables have been installed through pattress boxes and all electrical and radiator pattress boxes have been sealed. Another dwelling (B16) has been built as B21, plus all of the apertures in the external walls have been sealed at pre-plaster stage. The remaining dwelling (B17) has been built as B21, plus all of the external walls have been parged.

24 Observations from site indicate that some of the issues raised from Phase 1 have been addressed in Phase 3. Further issues diagnosed in Phase 3 have also been acted upon, as a result of the continued feedback given during Phase 3. These issues are listed below, with examples illustrated in Table 4.

- Incorrectly positioned ground floor service penetrations continue to be a problem, although in Phase 3 awareness of this problem has resulted in attempts to seal around these prior to boxing in.
- The issue of unfilled perpends, again a problem which was regularly observed in Phase 1, was also observed in Phase 3 albeit at a reduced severity. This was due in part to a more informed site management team and was further reduced as all separating walls were rendered for Part E compliance. In addition, specific measures to counteract this issue were taken in B16 and B17 as shown in Table 4.
- Sealing around external wall penetrations appears to have been done more successfully in Phase 3, by sealing penetrations at an earlier stage of construction. Sealing around these penetrations has, in most cases in Phase 3, been attempted at the pre-plaster stage; which was seldom the case in Phase 1.
- A number of issues relating to the built-in joists in Phase 1 have also been addressed. Gaps around I-beam web stiffeners still exist, but in general spaces around the joists have been pointed around more successfully, mastic has been applied more thoroughly and fewer spaces are left where joists are fitted in close proximity to walls.
- Intermediate floor penetrations have been made with far more attention to detail than in Phase 1, with holes being created more suited to the size of the respected penetration and more accurately positioned for the location of the penetration (Table 4).
- Potential for air leakage into the loft-space through service penetrations has been reduced as with intermediate floor penetrations, by more careful positioning of penetrations and more suitably sized holes. However, this is still an issue around the perimeter of the plasterboard ceilings particularly whilst continuous ribbons of plasterboard adhesive are not being used at the wall/ceiling junctions.
- Thresholds are now being partially sealed at an earlier stage of construction. The retro-filling of the cavity after dry-lining in Phase 1 did not produce an airtight detail (Table 4). The loose-fill then screed methods adopted in Phase 3 have substantially reduced this problem but not eliminated it completely.
- Window sills and jambs are now being pointed before dry-lining to help prevent the movement of air directly into the cavity and mastic sealant is applied around the closers, as shown in Table 4. The jamb/head junctions are no longer relying on mineral wool to plug the gaps between the tops of the closers and the lintels, a number of methods have been adopted to solve this problem.

Detail	Phase 1 Observations	Phase 3 Observations
External Wall Blockwork	  Gaps observed in blockwork and unfilled perpends which often remain unsealed, hidden in floor voids and behind the ‘dot and dab’ dry-lining.	  Parging applied to party walls between floor and ceiling levels, visible apertures pointed up in B16, all external walls parged (including between joists) in B17.
Intermediate Floor Service Penetrations	  Excessively sized and incorrectly located holes for penetrations commonplace.	  More suitably sized holes. Incorrectly positioned holes have been repaired.
Threshold	  Threshold not sealed until after dry-lining, creating potential air paths from behind the dry-lining into the cavity.	  Cavity below thresholds filled prior to dry-lining, making it possible to seal the junction at pre-plaster stage.
Jambs and Jamb/Head Junctions	  Potential leakage paths from behind the dry=lining and jamb liners into the cavity, with jamb/head junctions often relying on mineral wool as the plugging material.	  All gaps around closers sealed with mineral wool and mastic, expanding foam and mastic, or fully parged (B17).

Table 4 Selected alterations to detailing between Phase 1 and Phase 3 adopted by developer B.

Developer C

25 This developer has also undertaken a staged approach. One dwelling (C194) has been built as standard in order to compare this dwelling, which is detached, to the semi-detached and terraced dwellings constructed during Phase 1 of the project. Two of the dwellings (C19 and C20) are being built as C194 with the party walls parged only and the site management are looking out for any potential airtightness issues as raised in the feedback session at the end of Phase 1. The remaining two dwellings (C17 and C18) are being built as C194, plus all of the external walls are being parged.

26 Observations from site indicate that little change has so far been made to the way the superstructure has been constructed between Phase 1 and Phase 3. On-going feedback from the Leeds Met research team to the developers has resulted in a review of certain aspects of the detailed design. This is currently being undertaken, and may mean further measures being adopted for the remaining four properties in this phase.

Developer D

27 This developer has also undertaken a staged approach. Two of the dwellings (D73 and D74) have been built as standard, both of which have been constructed to new designs that have been developed to comply with Part L1 2002. The performance of these two dwellings will be compared with the dwellings constructed during Phase 1, which were constructed to old designs that were adapted to comply with Part L1 2002. Two dwellings (D75 and D96) have been built as D73 and D74 with greater care being taken to seal around the primary air barrier (in these dwellings the Kingspan insulation). The remaining dwelling (D76) has incorporated a number of design changes that have not incurred significant cost. Such changes have included: taping tops of metal studwork at first floor ceilings, taping insulation at intermediate floor level, taping around windows and service penetrations, sealing the external wall/floor junction, plus on-going changes as discussed with site management and the Leeds Met research team.

28 Site observations for Phase 3 indicate that there is little difference in the airtightness of the designs adapted for 2002 compliance and the new designs made specifically for this purpose, with regards to airtightness. Table 5 contains selected illustrated examples of the observations summarised below.

- Phase 3 amendments to the ground floor slab construction have been introduced to improve the airtightness of the junction of slab and wall, using sacrificial blockwork as a former for the slab edge rather than polystyrene. This solved some problems (i.e. misplaced slab extensions at thresholds) but not others such as the horizontal misalignment of frame and slab shown in Table 5.
- In D76 the gaps under the steel frame sole plate, between shims used for levelling, were sealed internally using a mastic sealant prior to dry-lining.
- Phase 3 alterations to intermediate floor construction, applying the flooring after frame construction rather than having chipboard pre-attached to flooring cassettes, eliminated the problem of gaps in the intermediate floor.
- On D76, gaps around the cavity tray at the intermediate floor perimeter were sealed with tape. Where possible the cavity tray was omitted to allow the ground and first floor insulation panels to be taped together as in Table 5.
- Tears and punctures to the outer foil surface of the wall insulation (the primary air barrier) were sealed with tape in D75, D76 and D96, a practice not observed during Phase 1 or on D73 and D74.
- In D76 and D96, intermediate floor service penetrations for soil stacks were drilled with some precision, rather than smashed through as observed elsewhere on site.
- At all openings in D76 tape was applied to return the air barrier in to the steel frame as in Table 5.
- At window jambs in D76 tape was used to link the window frames to the air barrier.
- In D76 at the loft/ceiling interface, the holes in the top of the internal partitioning were taped over and all gaps around the plasterboard ceilings were sealed using expanding foam.

Detail	**Site Observations**	
Ground Floor Slab Perimeter	  Phase 1 slab construction, with slab extensions at thresholds often misplaced leaving gaps into the cavity.	  Phase 3 potential air paths from the wall void into the retrospective sealed cavity and around the slab perimeter
Intermediate Floor Perimeter	  Gaps around the intermediate floor cavity tray in both Phase 1 and 3, creating a break in the primary air barrier.	  D76, where continuity of the air barrier at this junction is achieved by taping to both sides of the cavity tray or by omission of the cavity tray and taping.
Openings	  The airtightness around openings relies on the plasterboard lining linking the steel frame to the window or door frame, not a continuation of the air barrier.	  For D76, the air barrier is returned inward to the steel frame and extended outward to meet the window frame using tape.
Loft Boundary	  Holes linking the internal partitioning voids directly to the ventilated loft-space.	  D76, with ceilings and service penetrations into the loft sealed around.

Table 5 Selected alterations to detailing adopted by developer D.

Developer E

29 The general approach taken by this developer has been to tighten up the existing detailed design, by concentrating effort on a number of areas that contributed to air leakage during Phase 1 of the project. For instance, in all of the plots increased attention (initially by site management) will be paid to soil stack risers and window/door jambs, sills and thresholds. In apartments EA301 and EA302 (top-floor apartments) additional attention will also be paid to loft-space junctions, particularly around the mezzanine storage deck.

30 Initial observations from site for Phase 3 indicate that the high quality of construction observed throughout Phase 1 is being maintained. Construction on site is currently at the superstructure stage and the potential airtightness issues raised during Phase 1 relate to details which are expected to be constructed between November 2005 and February 2006.

Results of the Pressurisation Tests

31 Pressurisation tests have so far been undertaken on 11 of the 26 selected dwellings. All of these tests were carried out by Leeds Metropolitan University using an Energy Conservatory Minneapolis Model 3 Blower Door. The internal volumes and exposed external areas of the tested dwellings are listed in Table 6.

Dwelling	Volume (m^3)	Exposed internal surface area (m^2)
B14	398	364
B16	338	296
B17	338	296
B21	338	296
B22	338	296
C194	264	268
D73	283	296
D74	231	232
D75	295	309
D76	308	296
D96	252	267

Table 6 Details of the tested dwellings

32 In addition to the pressurisation tests, the main air leakage paths within each of the dwellings were identified by pressurising the building, and locating the main areas of air leakage using hand held smoke generators. However, quantifying exactly what contribution each leakage path made to each dwelling's overall air leakage was not possible. Determination of major and minor leakage paths contained within this reports rely upon the experience of the researchers carrying out the leakage detection; by using a standard procedure for the leakage detection, comparative flow rates of smoke escaping from the building envelope were used.

33 All of the pressurisation tests and the air leakage paths associated with each dwelling were photographed and in many cases video recorded. The air permeability data and leakage path information was also fed back to each of the developers (see task 2.3.3 of the project proposal) to assist the developers in identifying problems areas and to improve the airtightness performance of their future dwellings.

34 Detailed pressurisation reports relating to each of the developers are available on request.

Air permeability

35 The results of all the individual air permeability tests are shown in Table 7 and Figure 1.

Dwelling	Pressurisation test		Depressurisation test		Mean air permeability ($m^3/(h.m^2)$)
	Permeability ($m^3/(h.m^2)$)	r^2 coefficient of determination	Permeability ($m^3/(h.m^2)$)	r^2 coefficient of determination	
B14	9.33	0.996	8.15	0.980	8.74
B16	5.50	0.987	5.69	0.993	5.59
B17	5.61	0.990	5.76	0.991	5.69
B21	7.31	0.996	7.27	0.997	7.29
B22	7.44	0.995	7.31	0.991	7.37
C194	15.90	0.996	14.02	0.992	14.96
D73	13.39	0.991	13.22	0.991	13.31
D74	12.62	0.970	12.80	0.949	12.71
D75	10.97	0.979	10.22	0.990	10.60
D76	9.23	0.982	8.56	1.000	8.89
D96	11.52	0.995	10.77	0.999	11.14

Table 7 Mean air permeability of the tested dwellings.

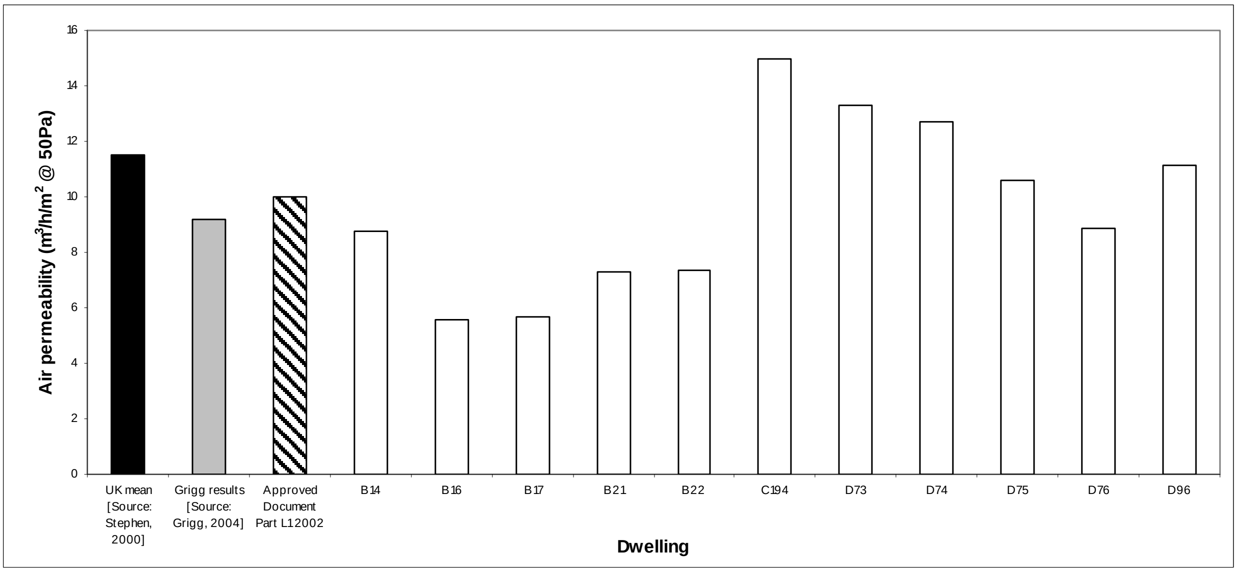

Figure 1 Mean air permeability of the tested dwellings.

36 Figure 1 illustrates the air permeability of the 11 tested dwellings compared with the UK mean,[1] the recommended maximum level set in the 2002 edition of the Building Regulations Approved Document Part L1 of 10 $m^3/(h.m^2)$ @ 50Pa (ODPM, 2001) and some recent measurement

[1] The UK mean has been derived from the Building Research Establishment's (BRE's) air leakage database, which is the largest and most comprehensive source of information on the airtightness of UK dwellings (see Stephen, 1998 and 2000). This database contains information on some 471 dwellings of different age, size, type and construction. However, despite its size, this database is not the result of random sampling and cannot claim to be unequivocally representative of the UK housing stock.

undertaken by Grigg (2004).[2] The data show that a relatively wide range of airtightness was measured for the tested dwellings. The air permeability of the dwellings ranged from 5.6 to 15.0 $m^3/(h.m^2)$ @ 50Pa, with a mean of 9.7 $m^3/(h.m^2)$and standard deviation of 3.1 $m^3/(h.m^2)$. Although the range of air permeability that was measured within the tested dwellings is consistent the work undertaken by Grigg (2004), the mean for the dwellings tested in this project is slightly higher (9.7 as opposed to Grigg's $m^3/(h.m^2)$ @ 50Pa). This may be a result of the inclusion of large proportion of apartments[3] (36%) in the sample tested by Grigg (2004) compared with our sample (to date, no apartments have been included in our sample). Only three of the 11 dwellings (27%) had an air permeability that was higher than or equal to the UK mean of 11.5 $m^3/(h.m^2)$. The mean of all 11 results (9.7 $m^3/(h.m^2)$ @ 50Pa) suggests that these dwellings are more airtight than the average for the UK stock as a whole (11.5 $m^3/(h.m^2)$ @ 50Pa). However, given the number of dwellings tested and the range of values measured, there is not a statistically significant difference between the sample and the UK mean.

37 Perhaps of most importance is that only six of the 11 dwellings tested to date have achieved air leakage values that are lower than the maximum specified level of 10 $m^3/(h.m^2)$ @ 50Pa set in the 2002 edition of the Approved Document Part L1 (ODPM¸ 2001). As in Phase 1 of the project, all of the dwellings that have been tested to date were using Part L Robust Details (see DEFRA, 2001) as the basis of the application for regulatory approval. In addition to this, each developer also received detailed and targeted feedback from the Leeds Met research team on any potential areas or issues that may have an influence on the eventual airtightness performance of the selected dwellings.

38 The data also show that the tightest dwellings tested were those constructed by developer B. All of the dwellings constructed by this developer achieved air leakage values less than the target of 10 $m^3/(h.m^2)$ @ 50Pa that is specified within ADL1 2002. The leakiest dwelling tested to date was constructed by developer C, which was built as per their standard Phase 1 construction. Only one of the five dwellings constructed by developer D achieved an air leakage rate of less than 10 $m^3/(h.m^2)$ @ 50Pa.

39 The air permeability of the 11 tested dwellings has also been compared against the air permeability results that were achieved during Phase 1 of the project. The results of this are shown in Figure 2.

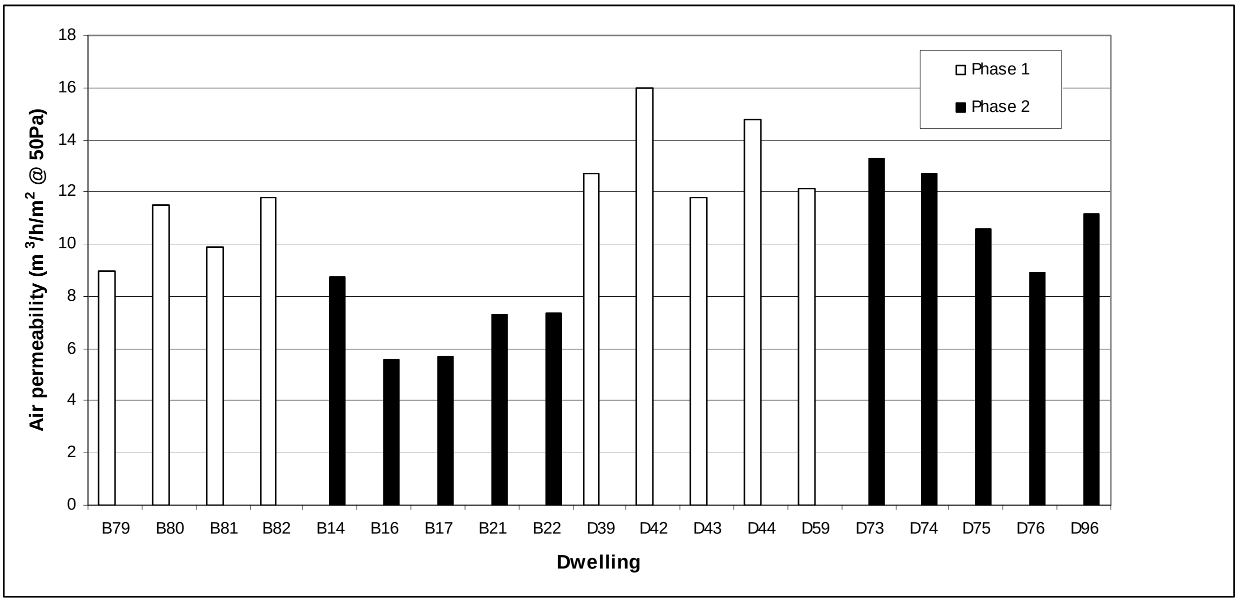

Figure 2 Mean air permeability of the tested Phase 1 and Phase 3 dwellings.

[2] The measurements undertaken by Grigg (2004) are based upon a non-random sample of 99 dwellings that were constructed to the provisions contained within the 2002 edition of the Building Regulations Approved Document Part L1.

[3] Apartments tend to be more airtight than other dwelling forms of equivalent area as they are more likely to have solid intermediate floors, fewer door and window openings and fewer service penetrations.

40 Figure 2 illustrates that in the majority of cases, the dwellings that have been tested during Phase 3 of the project are more airtight that than the corresponding dwellings that were tested during Phase 1. This suggests that the combination of feedback from the Leeds Met research team coupled with the various approaches adopted by the developers has had a positive impact on the airtightness of the dwellings tested.

41 In order to establish the scale of the reductions that have been achieved by undertaking various airtightness measures and acting upon the feedback from the Leeds Met research team, the air permeability results have been analysed for each individual developer. The results of this analysis are set out below:

Developer B

42 A summary of the Phase 3 air permeability test results and measures that were undertaken on the dwellings constructed by this developer are contained within Table 8 and Figure 3.

Dwelling	Measures undertaken	Air permeability ($m^3/(h.m^2)$)
B14	Built as standard, taking on board the feedback from Phase 1.	8.74
B16	As B21, plus pointing to all joints and apertures prior to dry-lining.	5.59
B17	As B21, plus the application of a parging layer to all external walls.	5.69
B21	Built as B14, plus acting upon the on-site feedback from Leeds Met research team where applicable.	7.29
B22	As B21, plus all of the light fittings, radiator and electrical pattress boxes have been sealed to the plasterboard dry-lining.	7.37

Table 8 Air permeability of the dwellings tested for developer B.

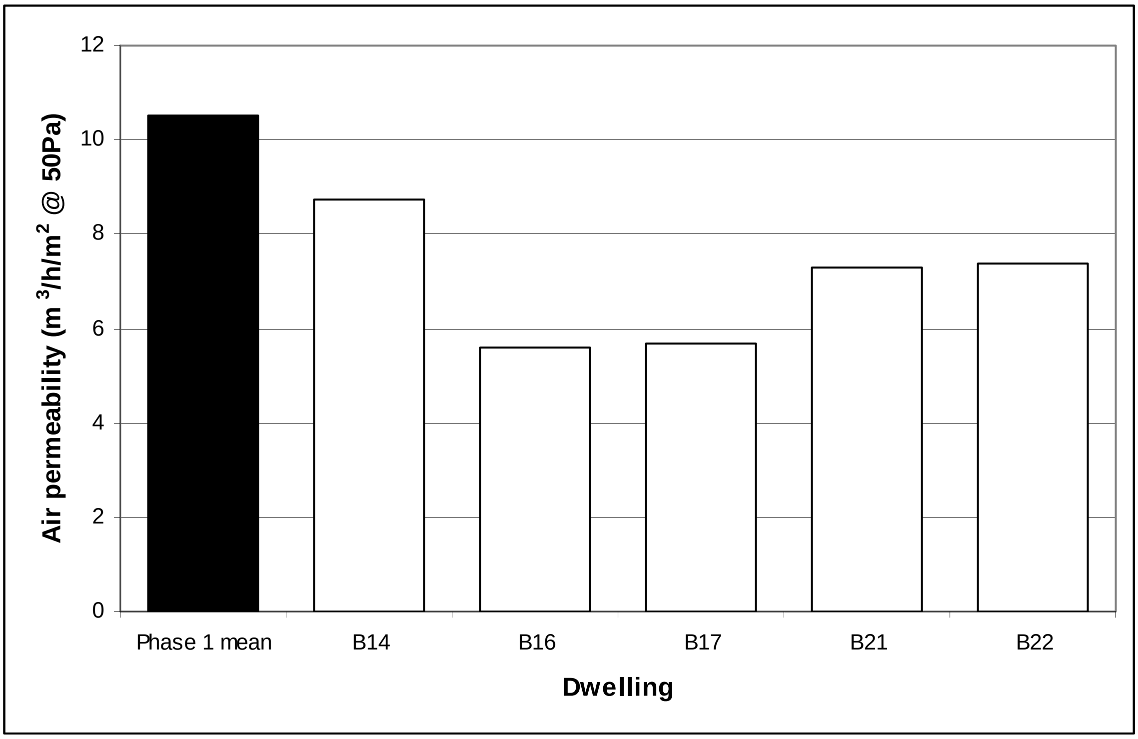

Figure 3 Air permeability of the dwellings tested for developer B.

43 Given the small sample size the results for developer B cannot provide absolute certainty of the success of each measure taken in this staged approach. However, this initial sample would suggest that the most important measures undertaken by this developer during Phase 3 of the project involved pointing all of the joints and apertures prior to the application of the dry-lining (B16)

and parging all of the external walls prior to dry-lining (B17). Both of these measures reduced the air leakage rate of the dwellings constructed by this developer, from a mean of 10.5 $m^3/(h.m^2)$ @ 50Pa during Phase 1, to 5.6 and 5.7 $m^3/(h.m^2)$ @ 50Pa, respectively in Phase 3. This represents a reduction in air leakage of almost 50% from the Phase 1 mean. In addition, these results also suggest that pointing and parging can have a similar impact on the overall reduction in air leakage rate.

44 Next in importance would appear to be acting upon the on-site feedback from the Leeds Met research team where applicable (B21), which resulted in a reduction in the mean air leakage rate of around 3 mh^{-1} @ 50Pa (a 30% improvement from the Phase 1 mean). Sealing all of the light fittings, radiator and electrical pattress boxes (B22) appeared to have little additional effect on air leakage and gave a similar reduction to acting upon the on-site feedback from the Leeds Met research team. Finally, the least effective measure was to build the dwellings as standard and only taking on board the feedback from Phase 1 of the project (B14), although the sample size of 1 once again prevents accurate statistical analysis. Nevertheless, this still resulted in a reduction in the air permeability by around 2 mh^{-1} @ 50Pa (a 17% improvement from the Phase 1 mean).

45 In terms of leakage identification, all of the dwellings were found to have a number of common air leakage paths. These are identified within Table 9 below.

Elements and junctions	Fixtures and fittings	Service penetrations
Between the skirting board and ground floor. Around thresholds. Around the stairs. Between the skirting board and intermediate floors.	Around kitchen units. Around trickle vents. Around bath panels and shower trays.	Service penetrations in the kitchen and utility room. Service penetrations in downstairs toilet. Pipe-work penetrations behind the radiators. Service penetrations in the bathrooms and en-suites. Service penetrations below the CPSU.

Table 9 Main air leakage paths associated with developer B.

46 In addition the common air leakage paths listed in Table 9, leakage paths were also identified that were particular to specific dwellings. These were as follows:

a) Around extract fans in dwellings B14, B16 and B21.

b) Through TV aerial and electrical sockets in dwellings B14, B16.

c) Around internal door frames in dwellings B14, B21 and B22.

d) Around rooflight in dwelling B14.

e) Around loft hatch in dwellings B14, B16 and B22.

f) Around rear door in dwellings B16, B17 and B21.

g) Around fireplace in dwellings B16 and B21.

h) Around window casement in dwellings B17 and B21.

i) Hole in intermediate floor in dwelling B17.

47 Most of the leakage paths are common to a number of dwellings. Leakage detection performed during the pressurisation tests provided observational data that the amount of smoke escaping through these gaps varied considerably between dwellings, unfortunately no method of measuring this quantitatively was available. An example being the significantly reduced flow of smoke observed through the junctions of intermediate floors and walls in both B16 and B17, and through the ground floor/external wall junction in B17. Also the treatment of certain details was not common throughout this site, for example dwellings B21 and B22 had boiler flue pipes which were fully sealed around and no leakage detected, whereas this appeared to be a major direct source of air leakage detected in all of the other three dwellings constructed by developer B.

48 Photographs of all of these leakage paths can be found within the relevant pressurisation test reports.

Developer C

49 The Phase 3 air permeability test results for developer C indicate that plot C194 achieved an air leakage rate of 15.0 $m^3/(h.m^2)$ @ 50Pa, which is comparable to the leakage rates achieved for the two worst performing dwellings constructed during Phase 1 (Plots C236 and C237 which achieved air leakage rates of 16.5 $m^3/(h.m^2)$and 14.0 $m^3/(h.m^2)$ @ 50Pa, respectively), both of which were mid-terraced properties where the intermediate floor void continued across an alleyway. This floor void was identified as a potentially significant source of air leakage within both of these dwellings. The performance of the two mid-terraced dwellings was around 3 to 4 $m^3/(h.m^2)$ @ 50Pa higher than the air leakage rates measured in the end-terraced (Plot C238) and the semi-detached dwellings (Plots C239 & C240) constructed during Phase 1. The relatively poor air leakage performance of C194 may be attributable to a number of complex details that are contained within the dwelling, such as an integral garage and ventilated roof void between the ground floor and first floor bay windows (the latter also an issue on the mid-terraced dwellings), where the continuity of the primary air barrier was disrupted.

50 In terms of leakage identification, the main air leakage paths associated with dwelling C194 are identified within Table 10 below.

Elements and junctions	Fixtures and fittings	Service penetrations
Between the skirting board and ground floor. Around the stairs. Between the skirting board and intermediate floor. At French door threshold. Through holes in cylinder cupboard floor.	Around kitchen units. Through and around trickle vents. Through French doors. Around bath panel. Around bay window head. Around internal door frames. Around loft hatch.	Service penetrations in the kitchen. Service penetrations in the downstairs toilet. TV aerial and electrical sockets. Service penetrations in the bathroom. Around central light fittings. Service penetrations in the cylinder cupboard.

Table 10 Main air leakage paths for dwelling C194.

51 No specific measures were taken to increase the airtightness of dwelling C194 over the standard construction in Phase 1. This suggests that the more complex design issues affecting the detached and mid-terrace dwellings, which are absent on the semi-detached and end-terrace dwellings, have a detrimental effect on the airtightness of the dwellings from developer C; although the small sample size prevents accurate statistical analysis.

52 Photographs of all of these leakage paths can be found within the relevant pressurisation test report.

Developer D

53 A summary of the Phase 3 air permeability results and measures that were undertaken on the dwellings constructed by this developer are contained within Table 11 and Figure 4.

Dwelling	Measures undertaken	Air permeability ($m^3/(h.m^2)$)
D73	Built as standard to new design.	13.31
D74	Built as standard to new design.	12.71
D75	As D73 and D74 with greater care being taken to seal around the primary air barrier.	10.60
D76	As D73 and D74 plus the incorporation of a number of design changes that have not incurred significant costs.	8.89
D96	As D73 and D74 with greater care being taken to seal around the primary air barrier.	11.14

Table 11 Air permeability of the dwellings tested for developer D.

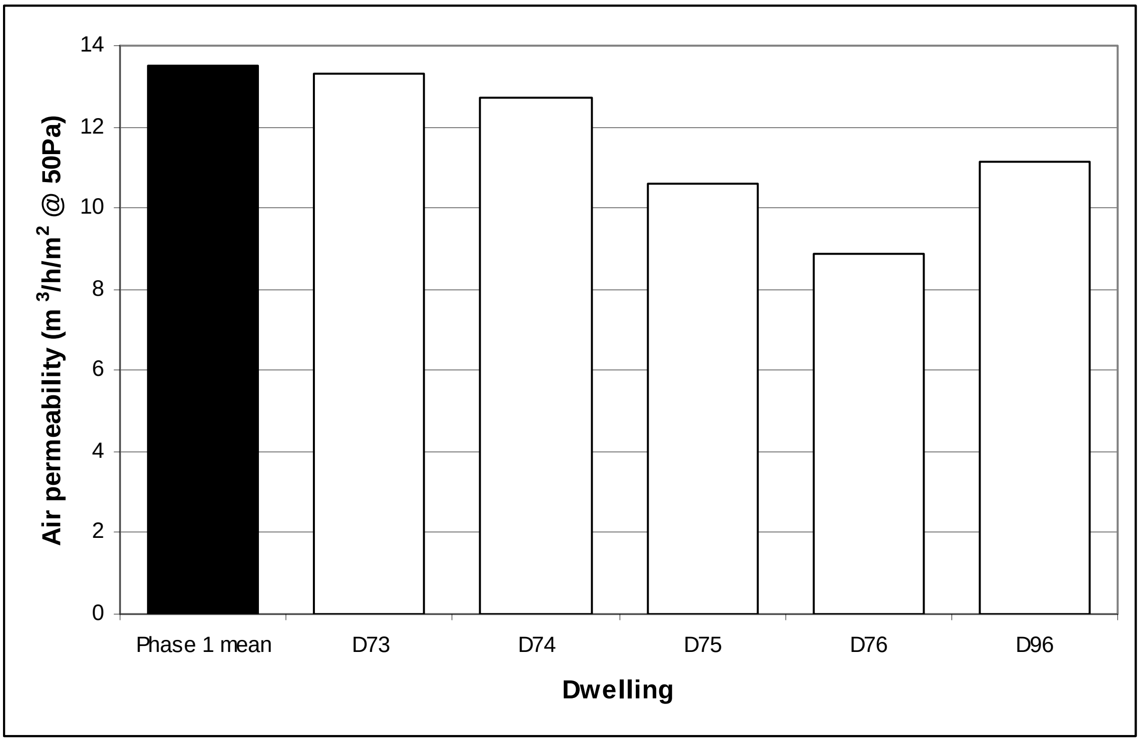

Figure 4 Air permeability of the dwellings tested for developer D.

54 The results for developer D indicate that in those dwellings that were built as standard using the new designs, and where no additional measures were undertaken to improve the airtightness of the dwellings (plots D73 and D74), the air leakage rates obtained were 13.3 $m^3/(h.m^2)$and 12.7 $m^3/(h.m^2)$ @ 50Pa, respectively. These rates are comparable to those obtained during Phase 1 of the project, where the mean air leakage rate for developer D was 13.5 $m^3/(h.m^2)$ @ 50Pa. This suggests that in terms of airtightness, the new dwelling designs do not perform significantly better than the old dwelling designs. In those dwellings where more care was taken to seal around the primary air barrier (Plots D75 and D96), the air leakage rate reduced to 11.1 and 10.6 $m^3/(h.m^2)$ @ 50Pa, respectively. This represents a reduction in air leakage from Phase 1 of around 20%. The tightest dwelling constructed by developer D was Plot D76, where considerable effort was made by the construction team to make the dwelling airtight. The air leakage rate measured for this dwelling was 8.9 $m^3/(h.m^2)$ @ 50Pa, resulting in a reduction in the mean air leakage rate of 34%. Dwelling D76 was also the only dwelling constructed by developer D to achieve an air leakage rate lower than the target of 10 $m^3/(h.m^2)$ @ 50Pa that is specified within ADL1 2002.

55 The light steel frame method of construction adopted by developer D uses the outer foil coating of the polyurethane foam insulation as the primary air barrier, with a reliance on the use of a metallic tape to ensure continuity of this air barrier. The site assessments and on-site feedback from the

Leeds Met research team give an indication of the comparative fragility of this air barrier, which would appear to be reinforced by the test results obtained. Where increased attention was given to this air barrier (D75 and D96) airtightness performance was increased; where further consideration to the air barrier was introduced the dwelling air permeability was reduced further. Once again the small sample size precludes certainty.

56 In terms of leakage identification, all of the dwellings were found to have a number of common air leakage paths. These are identified within Table 12 below.

Elements and junctions	Fixtures and fittings	Service penetrations
Gaps between skirting board and ground floor. Gaps between skirting board and first floor. Leakage around all thresholds. Gaps around the stairs.	Around kitchen units. Around trickle vents. Patio doors. Around loft hatch. Gaps around the bath panel and the shower tray.	Service penetrations in the kitchen and utility room. Service penetrations in downstairs toilet. Around electrical fuse box and electrical sockets. Pipework penetrations behind the radiators. Service penetrations in the bathrooms, en-suites and cylinder cupboards Around extract fans.

Table 12 Main air leakage paths.

57 In addition the common air leakage paths listed in Table 12, leakage paths were also identified that were particular to specific dwellings. These were as follows:

j) Hole at the junction between the wall and the ceiling in dwelling D73.

k) At the window sill/wall junction in dwelling D73.

l) Around the rear doors in dwellings D73, D74 and D96.

m) At the window head in dwellings D75 and D76.

n) Around window casements in dwellings D76 and D96.

58 Photographs of all of these leakage paths can be found within the relevant pressurisation test reports.

Conclusions

59 This report presents the progress that has been made in assessing the site survey data that have been collated for Phase 3 and presents the interim results of the Phase 3 pressurisation tests performed to date.

60 During Phase 3 of this project a number of different approaches have been adopted by the participating developers. Developer A is concentrating efforts on existing detailed design, with a possible review for the final two dwellings dependent upon the interim pressurisation results obtained for the initial three dwellings. Developer E is also concentrating efforts on existing detailed design as discussed in their Phase 2 feedback session, and will introduce the agreed measures when construction reaches that stage. Developers B, C and D, on the other hand, have adopted a staged approach enabling some general comparisons between different airtightness measures to be made, with developer C currently reviewing their strategy as a direct result of feedback from the Leeds Met research team following the initial Phase 3 site surveys.

61 An analysis of the site observations indicates that all of the developers have acted upon the feedback from Phase 1 of the project and have actively participated in a two-way dialogue with the Leeds Met research team. The observations obtained from site have illustrated the variety of approaches that have been adopted by the developers for Phase 3 of the project, ranging from the

tightening up of the existing detailed design approach and addressing supervision and workmanship issues to design amendments such as the application of a parging layer to all external walls. The observations also indicate that the feedback from the Leeds Met research team coupled with the approach undertaken by each developer has resulted in the majority of the airtightness issues identified during Phase 1 of the project being addressed. However, other measures that tend to require design changes or are perceived to incur significant costs, remain unaddressed and are likely to contribute to air leakage within the selected dwellings. For instance, significant modifications to the loft/ceiling junctions have only been attempted on one dwelling in Phase 3 (dwelling D76); as this is presumed to either require extra labour and material costs or require new design drawings being created which is even more costly. In none of the participating sites has a specific budget been introduced to increase the airtightness performance of the dwellings, but this may change for developer A, subject to the outcome of pressurisation tests for Plots A64, A65 and A66.

62 Results from both developers B and D would suggest that the maximum specified air permeability of 10 $m^3/(h.m^2)$ @ 50Pa set in Part L1 2002 is not unrealistic for either of these two different construction methods, and in the case of developer B substantially lower levels of infiltration are achievable with relatively little extra cost incurred. The results from developer B indicate that investing efforts into the primary air barrier in full fill masonry cavity construction, by pointing up or parging the external walls prior to dry-lining, provided the most noticeable improvements in airtightness of the dwellings, and air permeabilities of less than 6 $m^3/(h.m^2)$ @ 50Pa are genuinely achievable. However, the very small data set precludes certainty. With the light steel frame construction used by developer D, increased awareness of airtightness issues by site supervisors improved the airtightness of the dwellings but design changes (predominantly to the primary air barrier) were necessary for the air permeability of the dwelling to be reduced below the target figure of 10 $m^3/(h.m^2)$ @ 50Pa.

63 A number of common air leakage paths were observed in all 11 dwellings tested, all of which were also detected in Phase 1. However, although many of these observed points of entry detected under pressurisation exist, their individual contribution to overall dwelling leakage is less obvious, as the point of entry rarely relates directly to the actual point of leakage from the building envelope. The sealing of all wall, ceiling and floor penetrations through the primary air barrier at any earlier stage of construction was highlighted to all developers in the Phase 1 feedback sessions, to prevent subsequent building work obstructing any sealing to be carried out at a later date. These sequencing issues, coupled with certain specific design changes adopted, have been reflected by some of the initial improvements seen in the Phase 3 air permeability test results. The two-way dialogue established between the Leeds Met research team and the developers in Phase 3 has ensured that all involved personnel, particularly site management, are gaining an increasing awareness of airtightness issues, and are able to make advancements in the reduction of the air permeability of their respective dwellings.

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Appendix

Phase 3 - Site observations and developer feedback

Airtightness of buildings – towards higher performance

Site A

Visit date: 28-Sep-2005

Observations:

Site Overview

A64 and A65 currently in pre-plaster stage and yet to undergo final pre-plaster check.
A66 currently being dry lined
A79 and A80 yet to commence ground floor construction.

General Observations
There continues to be a marked improvement in these plots over those observed in Phase 1 in terms of expected airtightness of the dwellings. As well as the previously mentioned general improvements in quality and workmanship, additional specific measures have also been taken. These actions will have a positive effect on the airtightness of the dwellings. However, whether this is enough to reliably reduce the air permeability from the average 14.2 mh^{-1}@50Pa achieved in Phase 1 to the target of below 10 mh^{-1}@50Pa, or whether further measures need to be taken, remains to be seen.

A64

2-Storey, 3-bedroom, mid-terrace dwelling.
Partial-fill cavity-masonry, standard build to completion.

Currently in pre-plaster stage and yet to undergo final pre-plaster check.

Openings
The taping of perforations in the lintels should reduce air leakage. At the jambs plasterboard adhesive for the lining will be used to seal any small gaps around the closers, similarly a mortar bedding for sill boards should ensure that air leakage through this detail is minimised.

Service Penetrations – External Walls

Some service penetrations through the external walls have already been sealed effectively (gas pipe), others (boiler flue) have neat, suitably-sized holes bored which will simplify sealing after installation. The hole for the cooker hood extract duct, which was observed on the previous visit, has been loosely packed with mineral wool; this will get compacted and sealed with either mortar or expanding foam prior to the plasterboard ceiling being fitted.

Service Penetrations – Intermediate Floor

Although air will not escape directly to outside the building envelope through these penetrations, they allow air to move more freely throughout the dwelling generating ‘hidden’ leakage paths. Some penetrations through the intermediate floor are larger than necessary and will take more time and effort to seal; if penetrations through the cylinder cupboard floor are to be sealed effectively this will require doing so before the tank is positioned and access is restricted.

Built-In Joists

All the joists built in to the external walls have been successfully sealed around using mortar and mastic, with the exception of those where the close proximity of an adjacent wall has made access to the junction difficult. If necessary, additional work could be done to seal these awkward joints but would incur extra time and costs, efforts which may be better spent elsewhere in the dwelling.

A3

Loft/Ceiling Junction
An unaddressed cause of air leakage; air movement into the ventilated loft-space through holes in the top of the metal studwork for internal partition walls. Loft insulation will be placed over the top of these holes, but will have very little effect in reducing the amount of air movement through them.

Bathroom Boxing & Soil Stack
Both the boxing-in of the pipe-work and the soil stack have penetrations directly into the ventilated loft-space. These will be filled with mineral wool which will reduce smoke spread, but will still allow air to move between the void behind the boxing and the loft-space.
In both cases, air may be able to enter the boxing void from other voids. In the bathroom the void behind the boxing may be linked to voids behind the dry-lining and under the bath; in the case of the soil stack the boxing void is also linked to the intermediate floor void.
With air able to move throughout the dwelling due to these interconnected voids, complex ‘hidden’ air-leakage paths are created. A leakage path where air enters one void and escapes the building envelope via a different one may not only be difficult to identify and detect, but equally awkward to seal; particularly if the sealing is required to be done retrospectively.

A4

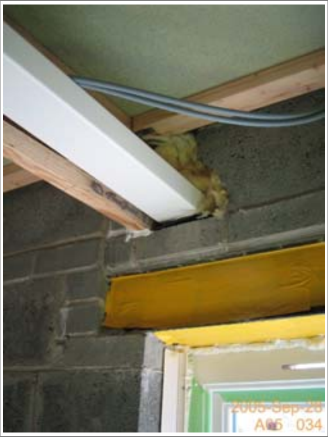
A65

2-Storey, 3-bedroom, mid-terrace dwelling.
Partial-fill cavity-masonry, standard build to completion.

Currently in pre-plaster stage and yet to undergo final pre-plaster check.

Openings
As in A64, the small gaps around the closers at the jambs will be sealed using plasterboard adhesive as the lining is positioned. The gaps at the tops of the closers have been sealed with mastic, and the perforations in the lintels sealed with tape.

Service Penetrations – External Walls
As in A64 service penetrations through the external walls have neat, suitably-sized holes which be easily sealed around after installation. The cooker hood extract duct and electrical consumer unit penetrations will again be plugged with compacted mineral wool and sealed with either mortar or expanding foam prior to dry-lining.



Service Penetrations - Intermediate Floor

Holes made in the intermediate floor are more appropriately sized for the penetrations than in A64, which will prove either easier to seal or may restrict the air flow around them. As in A64, if services to the cylinder cupboard are to be sealed, this needs doing so before access is limited.

Built-In Joists

As in the previous plot, all the joists built in to external walls have been well sealed with mortar and then mastic wherever possible.

Steel Studwork

Apertures in the steel studwork allow air to circulate throughout internal partitions and, when fitted on the first floor, directly into the loft-space. When grommets are fitted to prevent abrasion to cables these gaps are reduced but will still allow air movement.

The shower is typically an area where air leakage through this path occurs. Air can enter the void beneath the shower tray from around the flexible plastic front panel (or via intermediate floor penetrations) and move directly into the ventilated loft-space through gaps in the steel studwork. Mineral wool placed in these voids for acoustic purposes may impede the air flow to some degree but will not stop air movement through this partitioning.

A6

Connected voids

As in A64, the boxing-in of pipe-work in the bathroom links a number of voids (including voids in the partition wall, beneath the bath, behind the dry-lining, etc.) directly to the loft-space creating increasingly complex 'hidden' air leakage paths.

The voids around the stairs also link together various other voids which, although not leaking directly to outside of the building envelope, allow air to circulate more freely throughout the dwelling.

A66

2-Storey, 3-bedroom, end-terrace dwelling.
Partial-fill cavity-masonry, standard build to completion.

Currently in initial stages of dry-lining.

Openings

All gaps previously observed around openings have been successfully filled. The use of propriety cavity closers at thresholds, taping of lintel perforations and mastic sealing of junctions will minimise leakage at these details. Ribbons of plasterboard adhesive running the full length of the jambs are to be used to ensure that they are also made as airtight as possible.

A7

Service Penetrations – External Walls
Small penetrations for cables have been sealed around using mastic. The hole for the boiler flue is not excessively large and will be filled with expanding foam where it penetrates the blockwork once the boiler is installed. The mineral wool surrounding the cables to the electrical consumer unit is to be compacted and sealed using expanding foam prior to dry-lining.

Cylinder Cupboard
Penetrations beneath the cylinder cupboard floor link various voids and may help create hidden leakage paths. As mentioned previously, penetrations through the cylinder cupboard floor will require sealing around prior to the tank being positioned.

Loft-space junction
Some possible air leakage paths may remain after dry lining. Holes in the top of the steel studwork will allow air to move between the void in the partitioning and the loft. Gaps around the edges of the first floor ceiling and gaps at the ends of the wall plate may both allow air from behind the plasterboard on the walls to move into the loft, if continuous ribbons of plasterboard adhesive are not used at this junction.

Shower
As mentioned in A65, the shower is an area where air moving through the steel studwork may be a major source of air leakage, as air entering the void under the shower tray (form around the panel, from the intermediate floor and through adjacent studwork voids) may move relatively freely into the loft-space.

Bathroom Boxing and Soil Stack
As described for A64, the dual problem of inter-linked voids and possible air-paths directly into the loft-space are apparent at both these details. These details have been constructed 'as designed', and it would appear that the issue of airtightness of these details is an issue of design rather than one of workmanship or supervision.

A9

Airtightness of buildings – towards higher performance

Site B

Visit date: 05-Aug-2005

Observations and comments:

B16

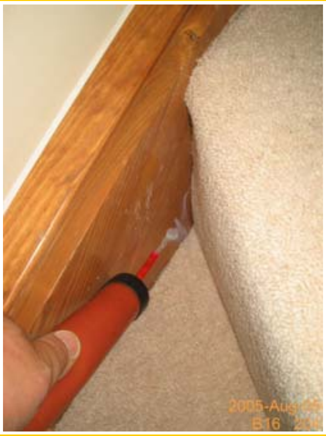
Full-fill cavity masonry, 3-storey, 3-bed, semi-detached dwelling.
Standard build – plus parge party walls and fill apertures to all external walls.

Pressure Test Result:

Air permeability	**5.60 $m^3/(h.m^2)$ @ 50Pa**
Air permeability – depressurisation only	5.69 $m^3/(h.m^2)$ @ 50Pa
Air permeability – pressurisation only	5.50 $m^3/(h.m^2)$ @ 50Pa

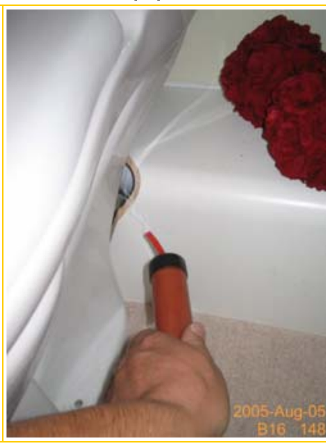
Hall, stairs and landings

- Air leakage through an unfinished pattress box in the hallway.
- Various points of leakage through and around both sets of stairs.
- Leakage into some junctions of door frames and intermediate floors.
- Slight air movement around the loft-hatch and its housing.

Downstairs closet

- Air leakage around the extraction fan housing.
- More significant air movement into the open-ended boxing around the soil pipe.

Dining room

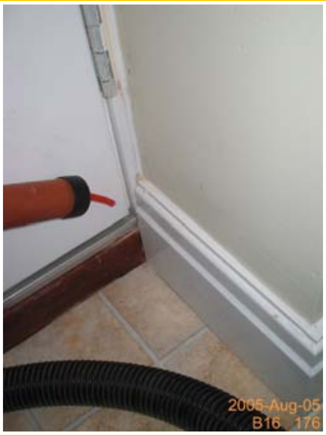
- Air leakage at the junction of ground floor/party wall/external wall.
- Leakage around the electrical socket on the party wall.

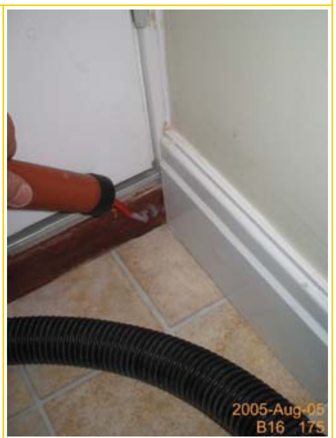
Kitchen

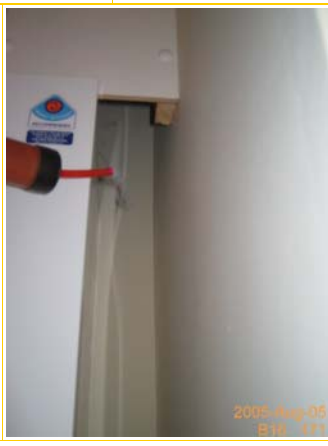
- Leakage along the ground floor/wall junctions, most severe in the corners.
- Significant air movement over the plinth into the void beneath the kitchen units through the gap observed under the corner unit.
- Air leakage into the space behind the wall units along the party wall.
- Significant air movement into the void beneath the kitchen units around the dishwasher.
- Inside the unit under the sink, significant leakage detected around the service penetrations and over the back of the unit.


Utility room

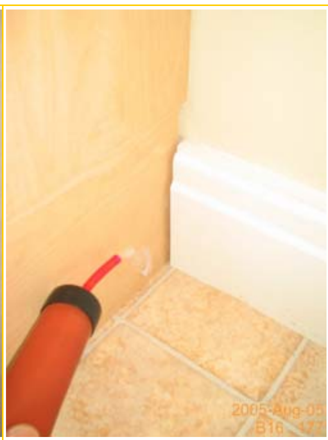
- Air movement around both sides of the threshold and bottom of the back door, and through the keyhole.
- Leakage detected around the boiler.
- As in the kitchen, air movement was observed around the base of the units, over the unit back under the sink and through service penetrations.





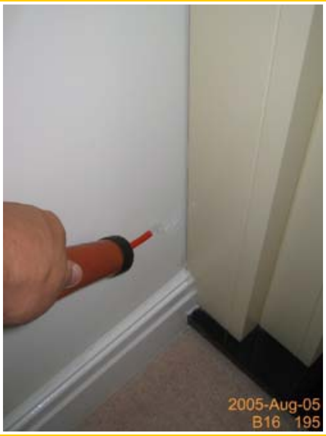



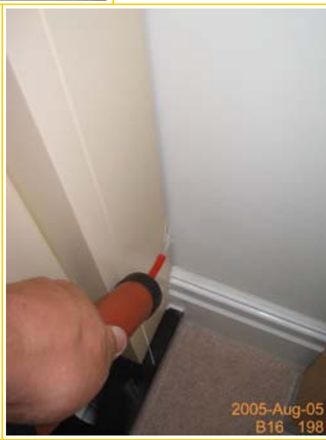
A14

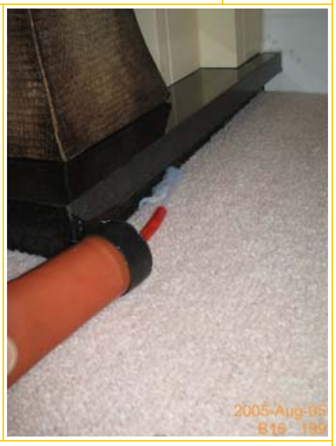


Lounge

- Air movement was detected all around the fireplace surround.







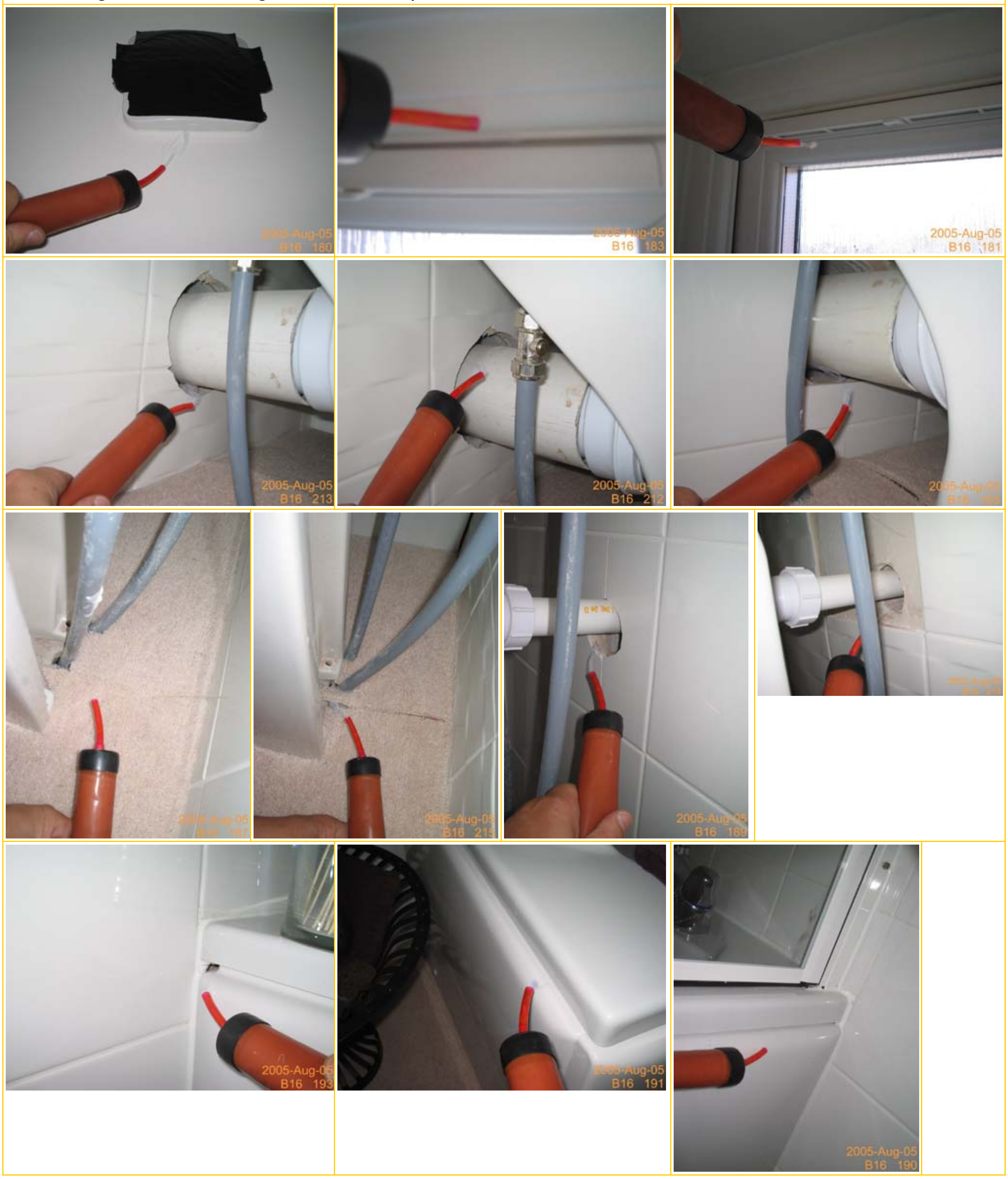
Bathrooms

- Air movement around extraction and trickle vents, and through poorly closing trickle vents.
- Significant leakage around soil pipes in both bathrooms.
- Leakage into both intermediate floors around the water supply pipe-work to wash basins, and into

A15

the external wall around both waste pipes.

- Leakage around all edges of the bath panels.



A16


CPSU cupboard

- Significant air movement around both sides of the water storage unit, and through gaps in the skirting board placed in front of it.

B17

Full-fill cavity masonry, 3-storey, 3-bed, semi-detached dwelling. Standard build – plus parging to all external walls prior to dot and dab plastering.

Ground floor

Gaps observed under the skirting, particularly at the corners of room. Where penetrations into the ground floor existed, these are hidden by units or boxing so may well remain unsealed and provide potential leakage paths – as observed in B16.

A17

Thresholds
This was another area of air leakage in B16, and it would appear that this is likely to also provide potential leakage paths at both front and back door in this dwelling.

Back door/window frame
Although it is envisaged that this gap will be sealed where visible it is the part of this gap hidden below sill level that may remain, linking the void behind the plasterboard directly with the cavity and allowing unrestricted air movement between the two.

Intermediate floor
Slices have been made into both intermediate floors, presumably for access after the ceilings have been fitted. These may leave gaps allowing air to move into the floor void if not sealed.

Intermediate floor/wall junction
Some gaps were observed around the intermediate floor perimeter, enabling movement of air into the floor and wall voids. Behind the bath, where no skirting board is applied and the wall/floor junction is not finished-off, any air movement around the bath panel will be able to travel directly into these voids.

Stairs
Gaps observed around the base of the newel post and in many places around both sets of stairs.

Bathroom service penetrations
Both bathrooms suffered from the same problems, with unsealed service penetrations through both external walls and intermediate floors, often with much larger holes than necessary made for pipes.



Kitchen/Utility room
Gaps observed similarly to where leakage occurred in B16 around units and service penetrations.


Other heating and plumbing penetrations
Potential leakage paths again exist at; radiator pattresses, where excessively large holes have been made in the intermediate floor beneath the water storage unit and where pipe-work runs from the CPSU directly into the ventilated loft-space.

A20

B21

Full-fill cavity masonry, 3-storey, 3-bed, semi-detached dwelling.
Standard build to completion.

Ground floor

Without continuous ribbons of plasterboard adhesive, air may well be able to move directly into the void behind the plasterboard dry-lining from under the skirting board. The service penetrations through the ground floor situated extremely close to the walls may also cause both similar and added difficulties, as observations in previous plots have indicated.

Thresholds

Possible leakage paths at both front and rear thresholds, as previously noted.

Intermediate floor

As in previous plots, slits can be seen cut into the intermediate floors that provide potential leakage paths. At the floor perimeter air leakage may also occur under the skirting into the wall and floor voids, which are linked due to dabs of plasterboard adhesive (rather than continuous ribbons) being applied.

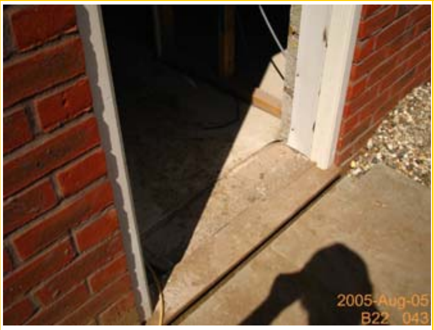
Service penetrations
Potential for air leakage around the radiator pattress boxes exists as in previous plots. Penetrations for the boiler and electrical sockets/switches appear to have reduced gaps around them compared with previous dwellings, but it is around plumbing penetrations through the intermediate floor where this improvement is most noticeable, with little or no air-gap surrounding most of the pipe-work.

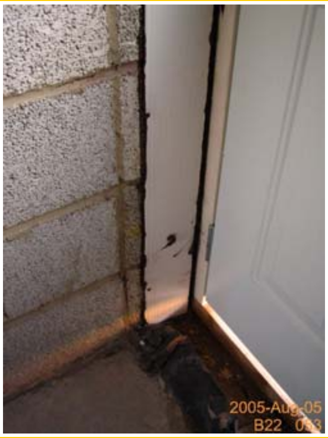

B22

Full-fill cavity masonry, 3-storey, 3-bed, semi-detached dwelling.
Standard build plus parge party wall, light fitting cables through pattresses, switch boxes and heating cable boxes sealed at plaster stage, all pipes penetrating external walls to be sealed.

Thresholds
At both front and rear these have the potential to be far more airtight than in previous dwellings, with

the few small gaps around the closers generally effectively sealed with mastic at both jambs and thresholds.





Windows

Similar to the treatment of door jambs, heads and thresholds in this plot, the treatment around the windows shows a marked improvement for airtightness. No gaps were observed around the cavity closers at the sills or jambs. At the jamb/head junctions most previously observed gaps had been filled with expanding foam or mastic, with only very small amounts of non-airtight mineral fibre stuffing remaining visible.

Built-in joists

At party walls mastic sealant had been applied around all built-in joists increasing their airtightness, except those so close to the walls that access was seriously impeded. It is assumed this was done for acoustic purposes rather than for airtightness, as only occasional examples were observed of mastic sealant being applied around joists built into the external walls.

Loft/ceiling junction

Gaps around the perimeter of the plasterboard ceiling will allow air to move directly from the void behind the dry-lining on the walls directly into the ventilated loft-space; unless they are adequately sealed or continuous ribbons of plasterboard adhesive are applied along this junction.

Service penetrations – external walls

At the penetrations through the external wall for both gas and electricity, the holes had been plugged using mortar and a mastic sealant applied. This should provide a far more airtight seal than the mineral wool alone which had been observed in previous plots.

Service penetrations – intermediate floor

A mastic sealant had been used to seal unnecessary holes made in the intermediate floor, and to seal around most of the plumbing penetrations. Where no mastic had been applied, the holes bored for the pipe-work were of a suitable size with little space around them.

Service penetrations – pattress boxes

Mastic sealant has been applied to all electrical pattresses where cables pass into them; however, many gaps remain around the junctions of these pattress boxes and the plasterboard dry-lining, allowing air movement into the dry-lining void if they are not sealed effectively.

A24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B22 062
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B22 065
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B22 077
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B22 076
2005-Aug-05
B22 074

Airtightness of buildings – towards higher performance

Site C

Visit date: 16-Sep-2005

Observations:

C17

Masonry cavity, full-fill blown-fibre insulation, 2-storey, 2-bedroom, semi-detached dwelling.
Standard build to completion, parging layer to be applied to party wall only.

Ground floor
Potential for leakage into the floor void around penetrations. If mineral wool is used as a packing material to fill gaps it will reduce air flow, but will not make the penetration airtight.



Patio door
Possible leakage path at the threshold, particularly as the patio door frames are fitted in-line with the external brickwork rather than over the cavity. If the cavity is not sealed prior to dry-lining an air path from behind the reveal lining directly into the cavity remains. The blocked-in reveals may not be in accordance with Robust Details, but should provide a relatively airtight jamb/head junction.


Bay window
The bay wall provides a more complex detail which may provide potential leakage paths at the jamb/sill junction and at the angles of the bay where the perpends are not completely filled through the whole thickness of the wall.


Built-in joists
A mixture of good and bad examples. In some cases the joints around the joists have been completely filled with mortar which will assist in airtightness and the potential problem areas where joists are fitted closely parallel to walls have been well constructed. However, in some cases there are gaps around and between joists large enough to make the external brickwork visible, these may prove difficult to seal with mastic and could contribute to the leakiness of the dwelling.



C18

Masonry cavity, full-fill blown-fibre insulation, 2-storey, 2-bedroom, mid-terraced dwelling.
Standard build to completion, parging layer to be applied to party walls only.

Ground floor
As previously mentioned for ground floor penetrations and the patio door threshold. At the front door a propriety cavity closer has been fixed at the threshold, which should assist in reducing any air leakage at this detail.

Openings
At door, window and patio door heads only small gaps exist which should easily be sealed with a suitable sealant.

Steelwork
Gaps exist between the RSJs and between the joist and the steelwork, both of which may provide potential leakage paths if left unsealed.


Built-in joists
Again, some joists are fully mortared in whilst others have gaps around, these gaps may get filled in when the party walls are rendered. A more complex detail, and potentially serious problem, occurs above the ginnel; where there is uncertainty over what constitutes the primary air barrier. Here the intermediate floor void extends over the ginnel underneath the bathroom, the drawings suggest the top of this wall is sealed by pushing in the 200mm mineral wool quilt placed in the floor void above the ginnel, this is not regarded as a satisfactorily airtight seal and further consideration of this detail is suggested before further construction work restricts access.


C19

Masonry cavity, full-fill blown-fibre insulation, 2-storey, 2-bedroom, mid-terraced dwelling.
Standard build to completion plus parging layer to be applied to all external and party walls.

Ground floor
Potential problems as mentioned in previous plots.

Openings
Small gaps at the sills and jambs should get filled by the parging layer. At the jamb/head junction the gaps are small enough to be filled easily with a suitable sealant.

Blockwork
The application of the parging layer should seal gaps such as these, which otherwise would allow air to move directly between the void behind the plasterboard dry-lining and the cavity.

Steelwork
As with C18, there are concerns that air might be able to move from behind the plasterboard fixed on dabs up into the cavity between the RSJs if it is not effectively sealed.


Built-in joists
As with C18, there are concerns where the intermediate floor extends over the ginnel.


C20

Masonry cavity, full-fill blown-fibre insulation, 2-storey, 2-bedroom, semi-detached dwelling.
Standard build to completion plus parging layer to be applied to all external and party walls.

Ground floor
As mentioned for previous plots.

Blockwork

As with C19, unfilled perpends and gaps in bedding layers should not be a problem as they will be filled when the walls are parged.

Built-in joists

Once again, some gaps have been effectively sealed (in the 1st example using a facing brick) and others not. Providing that the parging layer extends throughout the intermediate floor void, and right up to the joists, this should not cause a problem.

Airtightness of buildings – towards higher performance

Site D

Visit date: 05-May-2005

Observations and comments:

D73

Threshold & cylinder cupboard

Continuing potential leakage paths at thresholds, particularly where cavity-fill may not extend fully into base of reveal, allowing a direct air path from the wall void into the cavity.
Roof of cylinder cupboard still a potential problem due to service penetrations and non-airtight seals at junctions.


Integral garage

The intermediate floor and wall voids of the main house are linked directly to the wall voids of the garage, allowing free movement of air between the two.
Unsealed holes in the structural steelwork allow air leakage directly from the intermediate floor void into the roof-space above the garage.



D74

Ground floor

Potential leakage paths where service penetrations are hidden (e.g. behind kitchen units) and where shrinkage of filling materials may occur.


Threshold & boxed-in pipe-work
As previously mentioned, at thresholds, concerns over the treatment of reveal bases and shrinkage of filling material.
Unsealed ends of boxing-in of pipe-work allow unrestricted air leakage (via soil pipe stack).

Window heads
Apparently unresolved potential leakage path at the window heads, with small holes in the corners allowing direct passage of air from inside the building into the cavity. These holes are only small, but do have a cumulative effect on the overall air leakage of the dwelling.

Boiler
Access to the boiler flue, to seal the air barrier around it, is becoming increasingly limited as construction progresses. Our initial concerns that this will only get sealed at the plasterboard and externally still apply, and there is a very distinct possibility that the substantial hole in the air barrier caused here will remain inadequately sealed at the insulation (air barrier) layer.


D75

Ground floor
Concerns in the kitchen with service penetrations through ground floor that are yet to

be sealed; also the junction between floor and wall presents an increased risk behind the units where it is more likely to remain unfinished/unsealed.
Service penetration in downstairs WC may provide path to unsealed area behind boxing-in of pipe-work.



Thresholds

Potential risks as mentioned for both previous plots. Concerns over air leakage at both front door and at rear patio doors, due to air movement around base of reveals and potential leakage paths through joints and cracks caused by shrinkage of the filler material.



Boiler

As mentioned with previous plot, sealing at the air barrier becomes increasingly difficult (and more likely to get omitted) as further work is carried out.


Pipe-work & cylinder cupboard

Gaps at the top of the boxing and in the cylinder cupboard roof; both providing potentially serious air leakage paths; via the soil pipe void and loft space, respectively.


Bath

Service penetrations through the intermediate floor are likely to remain unsealed as they will soon be hidden behind the bath panel; similarly the wall floor junction is also likely to remain unfinished.

 

Shower
The problems noted for the bath are increased here as there is no facing on the partition walls beneath the shower tray. Air movement from underneath the tray, via the partition wall, to the loft space can be expected.

 

D76

Ground floor
Caulking of the ground floor junction with the external walls reduces the likelihood of air leakage under the steel frame, where shims have been used for levelling. Generally this was done very effectively, some minor points: an opportunity has been missed to seal between vertical gaps in plasterboard, some missed areas at the ground floor service penetrations and access to some junctions with internal walls was impeded due to the build sequence.

  

Threshold
As previously mentioned for all external doors

  

Insulation

A36

Damage to insulation (and hence, air barrier) has been repaired successfully in most cases.
Problems still exist where the tape appears to be losing its adhesion, particularly at internal corners and where wall-tie channels are close to joints between insulation boards.



Service penetrations
Externally and internally, penetrations are still being created larger than necessary and rarely sealed by the trades creating them.
Areas illustrated here are penetrations which are more likely to remain unsealed (covered by the meter box and by kitchen units, respectively).


Windows – continuation of air barrier
Valiant attempts made to continue the air barrier between the insulation and the window frames using tape – to varying degrees of success.





Window heads
Small gaps are again common at the window heads.


Pipe-work & cylinder cupboard
As mentioned for previous plots.



Bath & shower
As mentioned for previous plots.



Loft hatch
Hinges are not fitted in the loft hatch where spaces are provided for them. Resulting in gaps at the end opposite the catch, and a lack of compression of the draught-stripping at that end.
Small gaps also exist around the loft hatch framing.


D96

Ground floor
Potential for air leakage exists around the ground floor service penetrations, particularly where these lie in close proximity to external walls and access to sealing around them is limited.

Insulation
Some damage caused to the insulation by scaffolding during the roof construction. Noticeable lack of care taken when puncturing the insulation for services.

Airtightness of buildings – towards higher performance

Site E

Visit date: 17-Aug-2005

Observations:

Phase 3 – Site Overview

4-Storey apartment block, 8 apartments per floor, mix of 1 and 2 bedroom apartments.
Masonry cavity, partial-fill insulation; concrete intermediate floors, solid party walls, wet plastered throughout.

General Comments:
On initial inspection there appear to be no obvious differences in quality of both materials and workmanship from those observed in Phase 1; the taping of insulation joints is maintained and blockwork is to an equally high quality throughout.
However, due to problems caused by moisture infiltration during the construction of Phase 1, plastering and fitting of internal fixtures of this block is not due to commence until the roof construction is complete and each section is made weather-tight.

EAG01

Ground floor, 2-bed apartment

Service Penetrations
Noted as a potential leakage path in Phase 1, penetrations here have been cut neatly, square and not excessively large, so they should prove easier to make airtight.



Wall/Floor Junctions
Possible slight gaps around the ground floor/wall junctions which should become airtight once the screed and plaster are applied. The intermediate floor/wall junction has been pointed up around the balcony supports, but nowhere else as yet. This junction is more likely to be a source of air leakage unless it is sealed before the suspended ceiling is fitted.



Balcony Door
Gaps exist between the cavity closer and lintel at the jamb/head junction, which may allow air to escape into the cavity if not sealed. Perforations in the lintel itself may also allow infiltration if not sealed (or sealed around). At the jambs, any gaps around the closers should be sealed when plastering except for the small gap at the threshold where the plaster may not be applied right down to the floor. At the thresholds, air was observed escaping into the cavity in Phase 1, this may again be the case here if the frame/floor junction is not effectively sealed.

Windows

Potential problems at heads, jambs and sills as described above.

EAG02

Ground floor, 1-bedroom apartment.

Service Penetrations

Larger than necessary holes for service penetrations requiring more effort to seal to an airtight standard at a later date, so increasing the likelihood of air paths remaining on completion. Mineral wool packing required around penetrations through intermediate floors (at min.10 Kg/m^3 as specified in the design drawings) for acoustics purposes will not make it airtight, and air may still move between storeys and into the holes running through the concrete planks.

Wall/Floor Junction

Again, concerns over the intermediate floor/wall junctions, which will be hidden by the suspended ceiling. Any air coming through the ceiling (e.g. through recessed light fixings and through partition walls) will rely on this junction being sealed to maintain the airtightness of the apartment.


Wall/Wall Junction
It is expected that these junctions will get pointed up and then made airtight by plastering. The slight concern is the treatment at the very tops and bottoms of these junctions which will not be plastered over, and are hidden by the suspended ceiling and by skirting boards respectively.

Balcony Door
As discussed for EAG01.


Window
As discussed for EAG01.

EA201

2[nd] floor, 2-bedroom apartment

Service Penetrations

As with EAG01, the holes made for service penetrations are suitably small and should result in more effective sealing around than when larger holes are made. Again, packing/plugging with a minimum density 10 Kg/m^3 mineral wool will reduce the air flow through these penetrations but will not make them airtight.

Balcony Door

Possible leakage paths around the brackets and through the blockwork should get sealed when the floor is screeded.

EA202

2nd floor, 1-bedroom apartment

Service Penetration
As observed for previous plots.

Balcony Door
As observed for previous plots.