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

AIRTIGHTNESS OF BUILDINGS — TOWARDS HIGHER PERFORMANCE

Interim Report D5 — Site Assessments and Feedback Material

Dr David Johnston, Centre for the Built Environment, Leeds Metropolitan University

Dominic Miles-Shenton, Centre for the Built Environment, Leeds Metropolitan University

Prof. Malcolm Bell, Centre for the Built Environment, Leeds Metropolitan University

Dr Jez Wingfield, Centre for the Built Environment, Leeds Metropolitan University

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Reference Number: CI 61/6/16 (BD2429)

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Interim Report D5 — Site Assessments and Feedback Material

Report prepared by	Proposal checked by	Proposal approved by
Name: David Johnston, Dominic Miles-Shenton, Malcolm Bell Jez Wingfield	Name: Stuart Borland	Name:
Organisation: Centre for the Built Environment, Leeds Metropolitan University, Northern Terrace, Leeds LS2 8AJ	Organisation: Building Sciences Limited	Faber Maunsell
Project manager: Malcolm Bell	Project Mentor:	Lead Contractor:
Signature	Signature	Signature
Date: October 2004	Date:	Date:

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Executive Summary

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

2 Pressurisation test results show a relatively narrow range of airtightness for all of the tested dwellings, ranging from 9 to 16 $m^3/(h.m^2)$ @ 50Pa. Only three of the 16 tested dwellings had an air permeability that was better than the UK mean of 11.5 $m^3/(h.m^2)$, with the mean for all 16 being 12.8. 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. Only two of the tested dwellings had air leakage values that were lower than the maximum specified level of 10 $m^3/(h.m^2)$ set in Part L1 2002, despite the developer's use of Robust Details as the basis of the application for regulatory approval. This suggests that Robust Details in their current form and implementation are failing to deliver the required level of airtightness in dwellings.

3 Although the small sample size precludes certainty, the airtightness results do appear to show a difference in air permeability between the different types of construction method used for the selected dwellings. The tightest dwellings were those of masonry cavity construction with full fill blown fibre cavity insulation, whilst the leakiest dwellings were those of masonry cavity construction with partial fill cavity insulation. This suggests that full fill blown mineral fibre cavity wall insulation may assist in improving airtightness, perhaps by increasing the resistance to air flow within and along the cavity wall.

4 The data show that the tightest dwellings tested were those constructed by developer B. The leakiest dwelling was constructed by developer D (dwelling D42), which was of steel frame construction. In the case of this dwelling (and to a lesser extent for other dwellings built by the same developer) large gaps were observed between the flooring panels and at the floor/wall junctions, enabling free passage of air to the outside. Therefore, the poor performance of this dwelling was felt to be attributable to factors such as poor tolerances of components, quality of workmanship, site supervision and training, and possibly stemming from unfamiliarity with the steel frame construction technique.

5 The most common air leakage paths were identified as: service penetrations; the junction between the floors and the skirting board; the junctions between intermediate flooring panels; around the bath panel and the shower tray; around the stairs; around kitchen units; through poorly fitting trickle vents; via the loft hatch; through gaps between patio doors and through holes in the ground floor.

6 The types of leakage paths identified suggest that the air permeability of the dwellings could be improved by undertaking a number of relatively simple measures. For instance, sealing the junction between the skirting board and the floors with an appropriate sealant, sealing the kitchen floor, including areas concealed under kitchen units and sealing all service penetrations using an appropriate sealant, including those concealed behind baths and showers.

7 Design assessments have been completed for all 25 selected dwellings and site surveys have commenced on 22 of the 25 selected dwellings. Some of the main points that have been obtained from the site surveys are as follows:

a) Incomplete sealing was found around built-in timber I-beams and joists, sometimes exacerbated by difficult access to the gaps where joists are positioned close to a wall.

b) Incomplete application of scratch coats was observed where applied to cavity walls, especially when applied after the stairs and services had been installed.

c) Plasterboard dry-lining on dabs is not being applied with the required continuous ribbons of adhesive around the perimeter or around services and windows.

d) Gaps and cracks were frequently observed in the external blockwork, and perpends were often not completely filled with mortar.

e) Service penetrations are rarely properly sealed, especially where they are hidden, for example behind cupboards, panels, boxing or radiators. This task is frequently made much more difficult by the excessive size of the holes when compared with the size of pipe or duct.

f) Holes in flooring and gaps between the flooring panels were observed in the intermediate floors of a number of the dwellings.

g) Ground floor concrete slabs were often observed to be incomplete at the corners of a room and in particular around patio doors.

h) In most dwellings the trickle vents in the windows either did not fit tightly in the prepared hole in the window frame, or the closure for the vent would not shut properly.

i) Occasionally, windows or doors were found to be of a poor fit, with a visible gap between the frame and door or window. This was most often seen for patio doors.

j) Large gaps at the floor to wall junction were observed in nearly all dwellings. Some developers had made attempts to seal these gaps, but not consistently throughout the whole dwelling. Some developers had made no attempt to seal these gaps at all.

k) In some cases, loft hatches were incorrectly fitted such that the hatch was not compressing the seal properly, or they were fitted in such a way as to make it impossible to seal the frame to the ceiling.

8 Feedback to the developers from Phase 1 of the project will comprise a workshop for each of the developers, making five workshops in total. The workshops will make use of all of the material that has been gathered during Phase 1 in order to provide information and tailored advice specific to each of the developers. It is intended that the workshops will include presentations from the research team on the site specific results, a discussion of opportunities for improvement and the development of a plan of action to improve airtightness based on the observations and discussions.

Introduction

9 This report is milestone D5: Site Assessments and Feedback Material of Communities and Local Government Project reference CI 61/6/16 (BD2429) *Airtightness of Buildings — Towards Higher Performance* (Borland and Bell, 2003). The report summarises the progress that has been made on the assessment of site data obtained as part of Phase 1 of the project and discusses the material that will be used as feedback to the individual developers (task 2.2.1). The results of completed pressure tests of dwellings from Phase 1 are also illustrated (task 2.1.5).

10 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	Combination of private and social housing.	Dry-lined masonry cavity, partial fill.	• A 2-storey 3 bedroom mid-terrace with an internal floor area of 83 m^2. • A 3-storey 3 bedroom mid-terrace with an internal floor area of 117 m^2. • A 2½-storey 3 bedroom end terrace with an internal floor area of 117 m^2. • A 2-storey 3 bedroom semi-detached with an internal floor area of 81 m^2. • A 2-storey 4 bedroom detached with an internal floor area of 118 m^2.
Developer B	Private housing.	Dry-lined masonry cavity, full fill.	• A 2-storey 4 bedroom detached property with an internal floor area of 129 m^2. • A 2½-storey 5 bedroom detached property with an internal floor area of 164 m^2. • A 2½-storey 3 bedroom detached property with an internal floor area of 149 m^2. • Two 2-storey 3 bedroom detached properties with an internal floor area of 100 m^2.
Developer C	Private housing.	Dry-lined masonry cavity, full fill.	• Two 2-storey semi-detached properties with an internal floor area of 69 m^2. • A 2-storey end terrace 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	Private housing.	Steel frame	• A 2-storey 3 bedroom semi-detached property with an internal floor area of 72 m^2. • Two 2-storey 3 bedroom detached properties with an internal floor area of 91 m^2. • Two 2-storey 3 bedroom detached properties, one with an internal floor area of 84 m^2 and one with an internal floor area of 102 m^2.
Developer E	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. • Two 1 bedroom apartments with an internal floor area of 43 m^2.

Table 1 Details of selected sites and dwelling type.

Summary of Progress to Date

11 Drawings have been received from all five developers. Design assessments have been completed for all of the 25 selected dwellings. Site surveys have commenced on 22 of the 25 selected dwellings (five from developers A, B C and D and two from developer E).

12 In terms of the pressurisation testing, pressure tests have been undertaken on 16 of the 25 selected dwellings (five from developer A, four from developer B, two from developer C and five from developer D). Another dwelling from developer B is also complete (dwelling B86), but due to the very quick completion date requested by the buyer, this dwelling is now occupied and is no longer available for testing. 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.

13 As can be seen from Table 2, it is anticipated that the majority of the selected dwellings will be completed and pressure tested within the programme timescale. The only exception to this relates to the five apartments that are currently being constructed by developer E and three of the dwellings that are being constructed by developer C (C236, C237 and C238). With respect to developer C, market conditions have had a considerable impact upon the construction programme. This has resulted in three of the dwellings remaining at DPC level since June 2004.These dwellings are not expected to be completed and tested until the end of November 2004. The five apartments that are currently being constructed by developer E are also not due to be completed until November 2004. The reasons for the late completion date can be attributed to the much longer build times associated with apartments compared with other housing forms, and the fact that all of the units within a particular block tend to be completed and handed over at the same time.

14 The late testing of the dwellings being constructed by developer C and the apartments being constructed by developer E is not expected to have a major impact on the overall research programme.

Developer	Type of construction	Dwelling type	Current stage of construction	Anticipated completion date
A	Dry-lined masonry cavity, partial fill.	• A9 - 2-storey 3 bedroom mid-terrace. • A11 - 3-storey 3 bedroom mid-terrace. • A12 - 2½-storey 3 bedroom end terrace. • A13 - 2-storey 4 bedroom detached. • A14 - 2-storey 3 bedroom semi-detached.	Completed. Completed. Completed. Completed. Completed.	
B	Dry-lined masonry cavity, full fill.	• B79 - 2-storey 4 bedroom detached. • B80 - 2½-storey 4 bedroom detached. • B81 - 2½-storey 4 bedroom detached. • B82 - 2-storey 3 bedroom detached. • B86 - 2-storey 3 bedroom detached.	Completed. Completed. Completed. Completed. Completed.	
C	Dry-lined masonry cavity, full fill.	• C236 - 2-storey mid-terrace. • C237 - 2-storey mid-terrace. • C238 - 2-storey end terrace. • C239 - 2-storey semi-detached. • C240 - 2-storey semi-detached.	Superstructure. Superstructure. Superstructure. Completed. Completed.	November 2004 November 2004 November 2004
D	Steel frame.	• D39 - 2-storey 3 bedroom semi-detached. • D42 - 2-storey 3 bedroom detached. • D43 - 2-storey 3 bedroom detached. • D44 - 2-storey 3 bedroom detached. • D59 - 2-storey 3 bedroom detached.	Completed. Completed. Completed. Completed. Completed.	
E	Wet-plastered masonry cavity, partial fill.	• CG01 - 2 bedroom apartment. • CG02 - 1 bedroom apartment. • C202 - 2 bedroom apartment. • C301 - 1 bedroom apartment. • C302 - 2 bedroom apartment.	Superstructure. Superstructure. Superstructure. Superstructure. Superstructure.	November 2004 November 2004 November 2004 November 2004 November 2004

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

Results of the Pressurisation Tests

15 Pressurisation tests have so far been undertaken on 16 of the 25 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 3.

Dwelling	Volume (m^3)	Exposed internal surface area (m^2)
A9	193	209
A11	268	257
A12	268	257
A13	273	262
A14	185	209
B79	327	306
B80	420	341
B81	385	323
B82	385	323
C239	162	189
C240	162	189
D39	178	198
D42	225	250
D43	208	218
D44	225	250
D59	237	263

Table 3 Details of the tested dwellings

16 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. All of the pressurisation tests and the air leakage paths associated with each dwelling were video recorded and photographed. The air permeability data and leakage path information will be used at the feedback seminars (see task 2.2.1 of the project proposal) to assist the developers in identifying problems areas and to improve the airtightness performance of their dwellings.

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

Air permeability

18 The results of all the individual air permeability tests are shown in Table 4 and Figure 1. The mean air permeabilities for those dwellings tested to date for each developer and construction type are given in Tables 5 and 6 (no data are available yet for developer E).

Dwelling	Pressurisation test		Depressurisation test		Mean 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	
A9	13.95	0.999	13.86	0.999	13.91
A11	15.46	0.996	14.66	0.997	15.06
A12	12.12	0.990	12.49	0.999	12.31
A13	14.51	0.999	14.16	0.999	14.33
A14	15.33	0.993	15.71	0.994	15.52
B79	8.96	1.000	9.02	0.983	8.99
B80	11.76	0.992	11.20	0.990	11.48
B81	10.11	0.999	9.66	0.993	9.89
B82	12.04	0.996	11.53	0.999	11.79
C239	12.46	0.997	11.90	0.986	12.18
C240	12.11	0.971	11.40	0.981	11.76
D39	12.82	0.992	12.61	0.984	12.72
D42	15.55	1.000	16.37	0.999	15.96
D43	12.10	0.997	11.44	0.999	11.77
D44	14.58	1.000	14.94	1.000	14.76
D59	12.50	0.990	11.76	0.984	12.13

Table 4 Mean air permeability of the tested dwellings.

Developer	Mean permeability of all dwellings tested to date ($m^3/(h.m^2)$)
A	14.2
B	10.5
C	12.0
D	13.5

Table 5 Mean air permeability by developer.

Construction type	Mean permeability of all dwellings tested to date ($m^3/(h.m^2)$)
Dry-lined masonry cavity, full fill (Developers B and C)	11.0
Dry-lined masonry cavity, partial fill (Developer A)	14.2
Steel frame (Developer D)	13.5

Table 6 Mean air permeability by construction type.

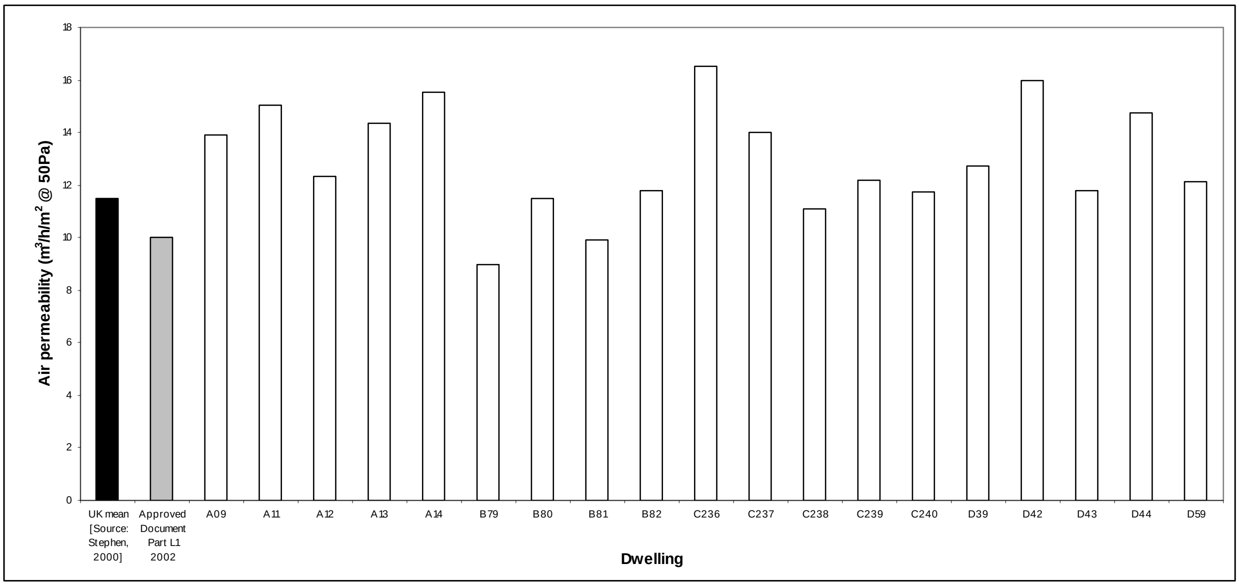

Figure 1 Mean air permeability of the tested dwellings.

19 Figure 1 illustrates the air permeability of the 16 tested dwellings compared with the UK mean[1] and 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). The data show that a relatively narrow range of airtightness was measured for the 16 tested dwellings. The air permeability ranged from 9 to 16 $m^3/(h.m^2)$ @ 50Pa with a mean of 12.8 $m^3/(h.m^2)$and standard deviation of 1.9 $m^3/(h.m^2)$. Only three of the 16 dwellings (dwelling B79, B80 and B81) had an air permeability that was lower than or equal to the UK mean of 11.5 $m^3/(h.m^2)$. The mean of all 16 results (12.8 $m^3/(h.m^2)$ @ 50Pa) suggests that these dwellings are less 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.

20 Perhaps of most importance is that only two of the tested dwellings (dwellings B79 and B81) had air leakage values that were 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). Therefore, the results suggest that only two of the 16 dwellings would satisfy the air leakage criterion set out in Approved Document Part L1. However, given the small sample size and the range of values measured, there is not a statistically significant difference. All five developers were using Robust Details (see DEFRA, 2001) as the basis of the application for regulatory approval. Despite this, the developers were unable to achieve the airtightness target in the majority of cases. This could be due to a lack of on-site quality control relating to the construction of Robust Details, poor communication, poor inherent construction design relating to airtightness, a lack understanding of how Robust Details work or possibly even that the Robust Details themselves may be difficult to achieve in practice, impractical or insufficiently tolerant of site variability — so called 'buildability'. We understand that the impact of Robust Details on whole dwelling air leakage was not subjected to empirical testing when the current catalogue was compiled. This report suggests that empirical testing would be needed as part of a process of developing a catalogue of details capable of reliably delivering an air leakage target.

21 The small sample size of this survey precludes absolute certainty when comparing data either by developer or by construction type. However, ignoring the issue of sample size, the data do show a difference in the air permeability between the different types of construction method covered in this survey (see Table 6). The tightest dwellings were those of masonry cavity construction with full fill blown fibre cavity insulation. The leakiest dwellings were those of masonry cavity construction with partial fill cavity insulation. A somewhat unlikely explanation for this is the better performance of the

[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.

fully filled cavity insulated dwellings, as opposed to the partially filled cavity insulated dwellings, is that the blown mineral fibre will fill some of the cracks and gaps in the construction and will also increase the resistance to air flow within and along the cavity wall, in effect becoming a secondary air barrier. Partially filled cavity walls will not provide a barrier to air movement around the cavity and, as is the case for this particular developer, air movement will be allowed at the joint between rigid insulation boards where the gaps have not been sealed with adhesive tape. Given the small size of the sample, and the high probability of confounding variables, further work (both field tests on whole dwellings and laboratory tests on construction samples) is needed to establish whether this difference is real, or whether it has occurred by chance.

22 The data also show that the tightest dwellings tested were those constructed by developer B (Table 5). We observed no significant differences in the quality of workmanship between the masonry cavity dwellings constructed by developers A, B and C, so we believe that workmanship alone is unlikely to be the cause of difference in performance between these three developers. The difference is likely to be due to a combination of factors such as design, quality control, site supervision and workmanship.

23 The leakiest dwelling was D42 constructed by developer D. All of the dwellings constructed by developer D were of steel frame construction. It is not certain whether the poor performance of the dwellings from developer D is attributable to an intrinsic problem with the airtightness of steel framed construction, the quality of workmanship, or a combination of the two. However, large gaps were observed between a number of the components in dwellings D42 and D44, such as flooring panels and floor/wall junctions. Such gaps in the defined air barrier would enable free passage of air to the outside. This suggests that the poor air leakage of these dwellings may therefore be attributable to factors such as poor tolerances of components, quality of workmanship, site supervision and training, or unfamiliarity with the construction technique.

Leakage identification

24 It was not possible to quantify the contribution that each leakage path made to each of the dwellings overall air leakage, but the smoke tests that were carried out enabled the main leakage paths within each of the dwellings to be identified. All of the dwellings were found to have a number of common air leakage paths. These are identified within Table 7 below.

Elements and junctions	Fixtures and fittings	Service penetrations
Gaps between skirting board and ground floor. Hole in kitchen floor.	Around kitchen units. Around trickle vents. Patio doors. Gaps around the stairs. Around loft hatch. Gaps between skirting board and first floor. Gaps between flooring panels on the first floor. 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. Electrical sockets. Pipework penetrations behind the radiators. Service penetrations in the bathrooms and en-suites. Around extract fans. Service penetrations in the airing cupboard.

Table 7 Main air leakage paths.

25 In addition to a number of common air leakage paths, leakage paths were also identified that were particular to specific dwellings. These were as follows:

a) Holes in the wall for wall-mounted light fittings in dwelling B79.

b) Around the fireplace in dwelling B79.

c) Holes in the ground floor in dwelling B79.

d) Around the window hinge in dwelling B79.

e) Around the door to the integral garage in dwelling B81.

f) Around isolation switch for extract fan in dwelling B82.

g) Gaps between the back door and the door frame in dwellings B79, B80, B81 and B82.

h) Gaps between wall and ceiling in the cupboard under the stairs in dwelling D39.

i) Holes in the ground floor in dwelling D42.

j) Holes in first floor in dwelling D42.

k) Holes at the window/wall junction in dwelling D44.

26 Photographs of all of these leakage paths can be found within the relevant pressurisation test reports for each developer.

27 The leakage identification also highlighted that the air permeability of all of the tested dwellings could be improved by undertaking a number of relatively simple measures. These include:

a) Sealing the junction between the skirting board and the floors with an appropriate sealant.

b) Sealing the kitchen floor, including areas concealed under kitchen units.

c) Sealing all service penetrations, including those concealed beneath baths and showers, using an appropriate sealant.

Interim Results of the Site Assessments

28 This section summarises the progress that has been made to date on the site surveys and presents the interim results.

29 The site surveys were undertaken in three separate stages and information on each particular dwelling on each site was recorded on a site survey protocol (see Johnston, Miles-Shenton and Bell, 2004). The three stages of the site surveys were as follows:

Stage 1: During intermediate floor construction. This will enable inspection of the method of supporting the intermediate floors and enable any potential leakage problems to be identified.

Stage 2: During dry-lining/wet plaster phase. This will enable inspection of the internal leaf of the external walls, the application of the dry-lining, inspection of window/wall junctions, inspection of service penetrations, etc.

Stage 3: Completion. This will enable identification of any potential leakage areas that have not been picked up during the ‘snagging’ process.

30 In addition to completing a site survey protocol, data on each site have also been collected and recorded using photographs, sketches and video tape. To date, Stage 3 site visits have been undertaken on 17 of the 25 selected dwellings and Stage 1 site visits have been undertaken on the remaining eight dwellings. These visits have resulted in the generation of approximately 2000 photographs. The general observations that have been obtained from the site surveys are summarised below.

Built-in Joists

31 For developers A, B and C, the drawings state that the timber I-beams that are used to support the intermediate floors are built into the internal leaf of the external/party wall, sealed with mortar, and then sealed using a mastic sealant. Site observations indicate that in a number of cases, the mastic has only been partially applied around the bottom flange and the web of the timber I-beams (see Figure 2). In addition, since the mastic sealant has been applied after the floor finish has been installed, it is very difficult or impossible to seal the top flange of the timber I-beams. There is a risk that in areas where the mastic sealant has not been applied, the mortar seal will crack as the timber shrinks and the mortar dries out, resulting in a number of air leakage paths from the intermediate floor void to the external/party wall cavity and then to outside.

32 In several cases where built-in joists were used and when observed at the stage prior to final sealing, very large gaps were visible between the joist and blockwork, often with the joist resting at an angle. This would make it much more difficult to properly seal the gaps between block and joist.

33 For developers A, B and C the timber I-beams that are used to support the intermediate floors are offset from the inner leaf of the external/party wall to allow services to be run from one floor to the next. In a number of dwellings this offset is so small that it is not possible to seal the area between the joist and the external/party wall using mortar and mastic sealant. The result is that in a number of the dwellings it is possible to see through the cavity to the external brick skin (see Figure 3). These gaps will enable air within the intermediate floor void to leak through to the external/party wall cavity and then to outside.

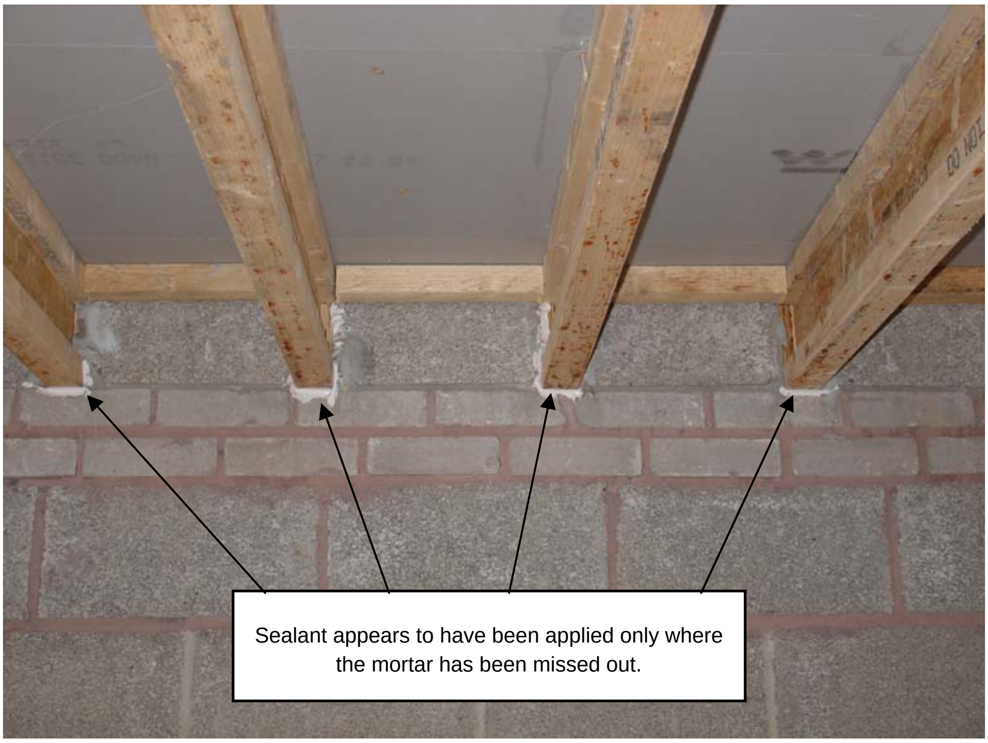

Figure 2 Partial application of mastic sealant (developer B).

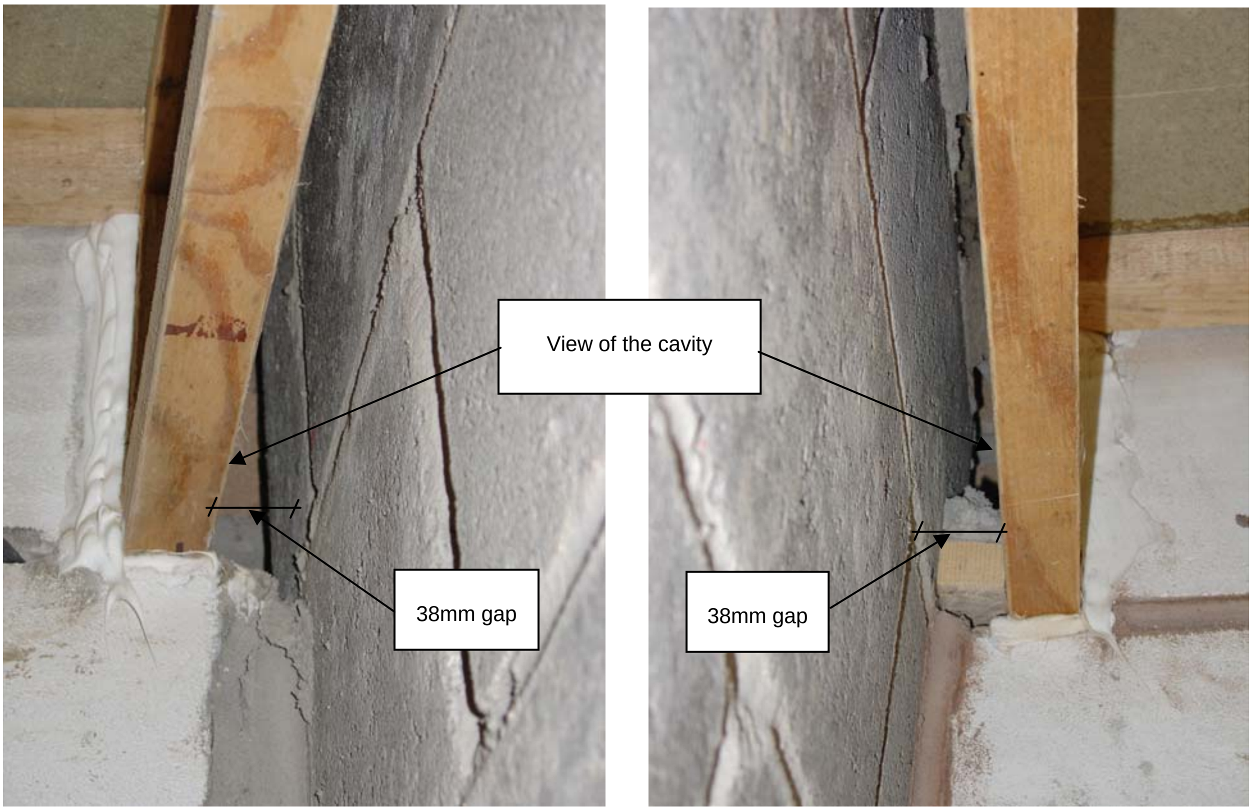

Figure 3 Gaps between the joist and the external/party wall (developer A).

Blockwork

34 Site observations have identified a number of areas where cracks and gaps are visible on the internal blockwork leaf of the external/party wall (see Figure 4), and perpends have not been fully filled (see Figure 5). Any cracks or gaps in the blockwork inner leaf of the external wall could result in air leakage to the external/party wall cavity and then to outside.

Figure 4 Cracks in internal blockwork leaf of external wall.

Figure 5 Perpends not fully filled in internal blockwork leaf of external wall.

Party Walls

35 The drawings for developer C state that a sand and cement scratch coat is to be applied to the party walls. This coat has been applied to improve the acoustic performance of the masonry aggregate block party wall, by sealing the blockwork and covering up any deficiencies in

workmanship, prior to the application of the dry-lining. This coat also has the potential to improve the air permeability of the party wall by acting as an additional air barrier. Site observations indicate that the scratch coat has not been applied across the entire party wall (see Figure 6) in dwellings C239 and C240, and it is also being applied after the stairs and services have been installed (see Figures 6 and 7). The partial application and sequencing of the scratch coat means that it has not been possible to completely seal the blockwork party walls in these dwellings. Consequently, there is a risk that air may leak through badly pointed joints, shrinkage cracks, or gaps in the party wall to the wall cavity and then to outside, in locations where the scratch coat has not been applied.

Figure 6 Incomplete scratch coat applied to party walls around services.

Figure 7 Incomplete scratch coat applied to party walls around stairs.

Plasterboard Dry-lining

36 One of the main air leakage paths within UK dwellings is plasterboard dry-lining (see Stephen, 1998 and 2000). Problems arise with plasterboard dry-lining when air can freely move into the gap between the plasterboard and the masonry wall, especially where the plasterboard is fixed to the wall using adhesive dabs. The air gap between the plasterboard sheet and the masonry wall then acts as a plenum, effectively interconnecting all of the leakage paths within the dwelling. To limit air leakage through plasterboard dry-lining, the report on Robust Construction Details (see DEFRA, 2001) recommends that continuous ribbons of adhesive are used to seal the dry-lining at the perimeter of external walls, openings, and services on external walls. This is illustrated in Figure 8. In our opinion, the process of applying plaster ribbons in such a way as to seal all potential leakage sites is technically difficult to carry out. Observations from site confirm this (see Figures 9 to 11). Figures 10 and 11 also illustrate that the overall thermal performance of these dwellings will be degraded, as the discontinuous ribbons of adhesive will enable air to bypass the internal insulation.

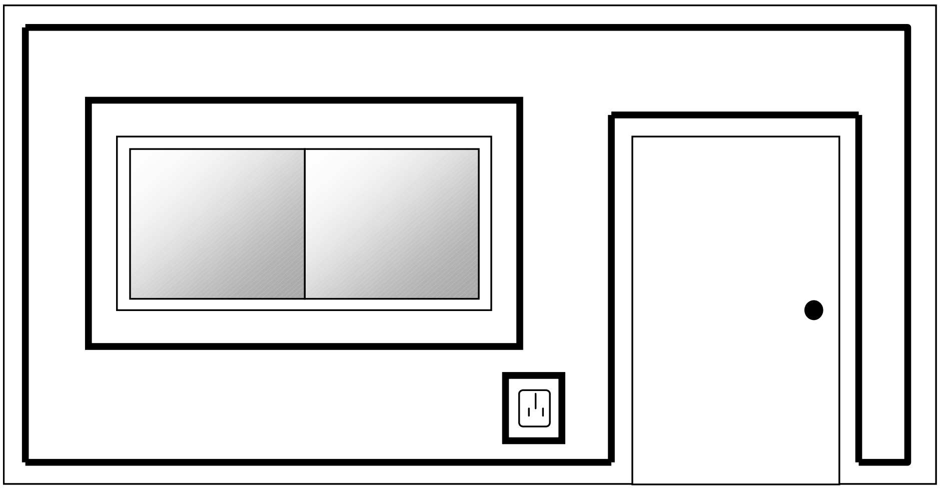

Figure 8 Schematic of continuous sealing of perimeters of a dry-lined wall.

Figure 9 Discontinuous ribbons of adhesive used to seal plasterboard dry-lining.

Figure 10 Discontinuous ribbons of adhesive around window opening.

Figure 11 Discontinuous ribbons of adhesive around door opening.

Service Penetrations

37 Service penetrations are known to be a significant route for air leakage (see Stephen 1998 and 2000). The report on Robust Construction Details (DEFRA, 2001) states that particular care on site should be paid to service penetrations and all service penetrations should be sealed with expanding foam or other suitable sealant, whether in the wall, ground floor, intermediate floor or ceiling (see Figure 12). Where large voids exist, mineral wool or some other backing material should be used to support the sealant. Observations from site illustrate that little attempt has been made to seal the majority of service penetrations through walls, ground floors, intermediate floors and ceilings, and where attempts at sealing have been made, the penetrations are generally inadequately sealed and inappropriate sealants have been used to seal gaps around the service penetrations. These points are illustrated in Figures 13 to 17.

38 In some cases, problems with service penetrations arose due to incorrect sequencing of work. For example, gas pipework which should have been placed in position at an early stage in the build sequence was omitted (due to missing details on drawings) and then had to be added at a later stage, requiring additional penetrations through the fabric that might otherwise have been unnecessary. In many cases, larger holes are made than are strictly necessary for the pipework, in order to allow for positioning (see Figure 13). These large holes are then much more difficult to seal. Another problem is that service penetrations that are subsequently hidden behind boxing or panels (for example the bath panel, shower tray, shower pod, in an under sink unit, in airing cupboard or in an under stairs cupboard) are often left unsealed, whilst visible penetrations in the same dwelling have been sealed. This suggests a lack of understanding of the importance of these areas, with the selection criteria being used when deciding to seal or not being one of cosmetic appearance rather than airtightness.

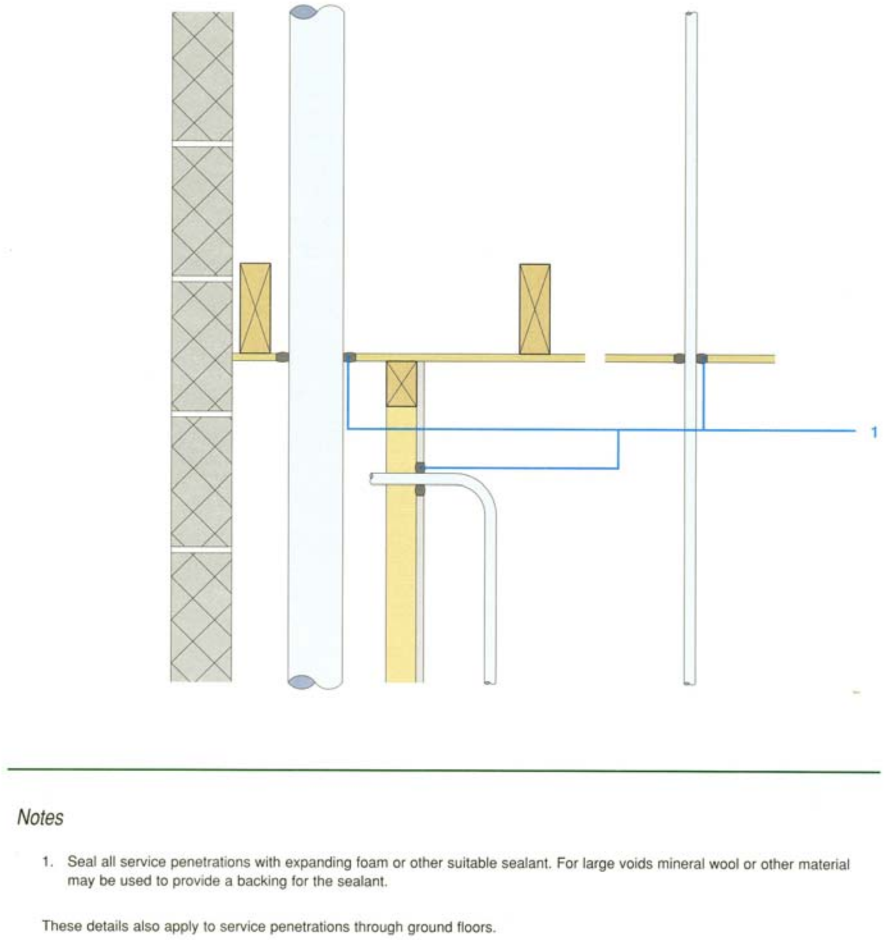

Figure 12 Diagram illustrating sealing of service penetrations [Source: DEFRA, 2001]

Figure 13 Unsealed service penetrations around WC.

Figure 14 Unsealed soil stack penetrating through iIntermediate floor.

Figure 15 Unsealed pipework penetrations behind radiator.

Figure 16 Unsuccessful attempt at sealing around water pipes.

Figure 17 Inappropriate use of sealant to seal service penetrations.

Intermediate Floors

39 Holes in the flooring and gaps between the flooring panels were observed in the intermediate floors of a number of the dwellings (see Figures 18 to 22). In two dwellings (D42 and D44) the gaps in the flooring panels were up to 25 mm wide. Any holes or gaps in the floor will enable air to leak into the intermediate floor void where it may then leak through the external/party walls to outside.

Figure 18 Leaks at the junction between flooring panels.

Figure 19 Leaks at the junction between flooring panels.

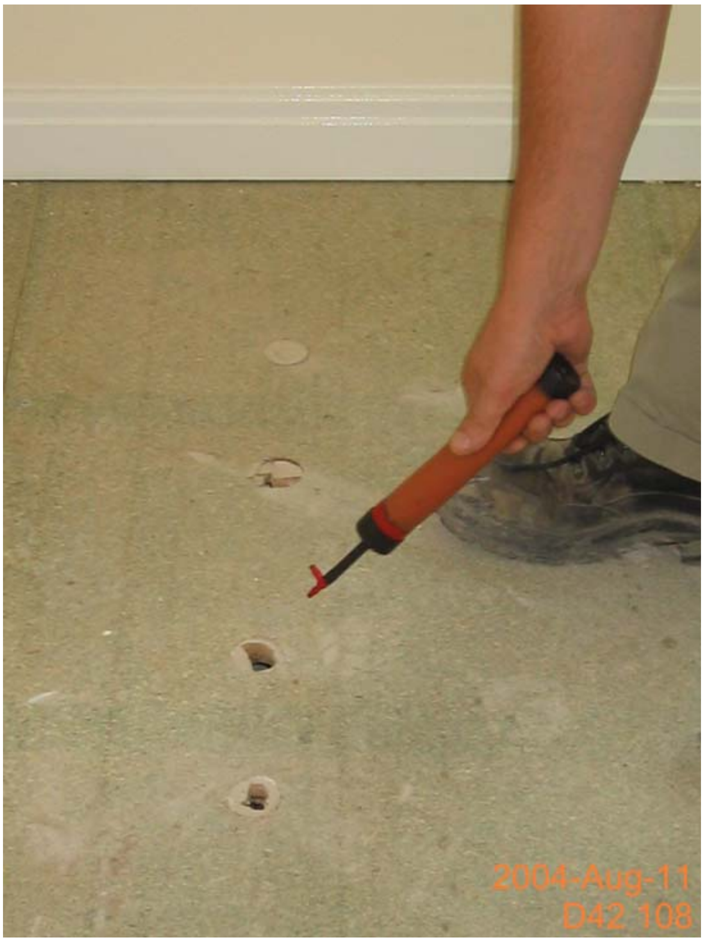

Figure 20 Holes in the flooring panels.

Figure 21 Screw holes in the flooring panels.

Figure 22 Holes in bathroom floor.

Incomplete Ground Floor Slabs

40 The ground floor slabs in a number of the dwellings were observed to be incomplete, particularly around the patio door area, resulting in holes in the ground floor slab (see Figures 23 and 24). Any holes in the ground floor slab will result in an air leakage path from the inside to the outside of the dwelling.

Figure 23 Hole in ground floor slab at patio door.

Figure 24 Hole in ground floor slab hidden by floor covering.

Windows and Doors

41 Windows and doors can be a significant source of air leakage (see Stephen, 1998 and 2000). Any poorly fitting or sealed windows, trickle vents or doors will result in an air leakage path directly from the inside to the outside of the dwelling. It was observed on a number of the dwellings that the trickle vents were either of a poor fit or would not close properly allowing passage of air either through the vent itself (when in the closed position) or through a gap between the vent and window.

42 In several cases the patio doors did not fit correctly such that the seals were uncompressed and in the worst cases there were observable gaps between the external door and the surrounding door frame. These points are illustrated in Figures 25 to 27.

Figure 25 Leakage through poorly fitting trickle vents.

Figure 26 Poorly fitting patio door with visible gap.

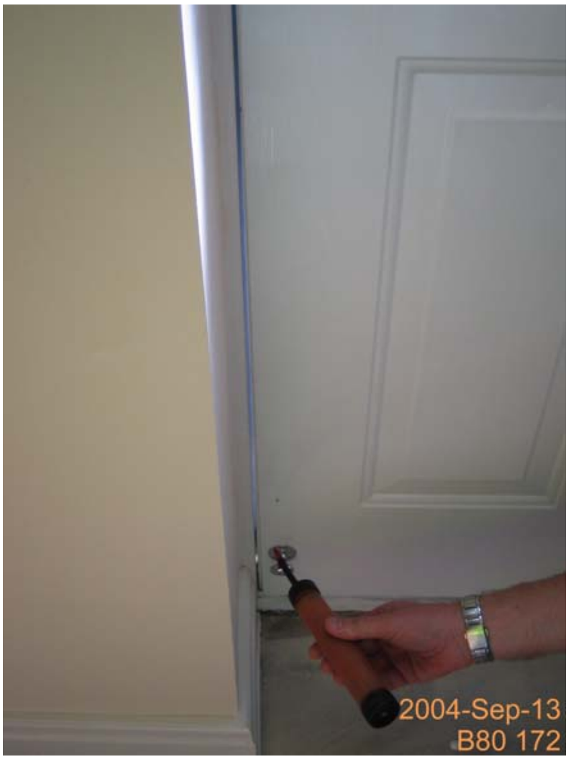

Figure 27 Observable gap between external door and frame.

Wall/floor Junction

43 The report on Robust Construction Details (DEFRA, 2001) states that particular care on site should be paid to joints between structural components, for instance, walls to floors. Observations from site illustrate that a number of gaps exist between the ground floor and the skirting board and the intermediate floor and the skirting board (see Figures 28 to 30). Any gaps will result in an air leakage path. Indeed, in the case of one of the developers (developer D) the air leakage between the wall and intermediate floor was so bad that a flow pattern was observed in the dust on the floor where air had flowed into the building during the depressurisation test (see Figure 29).

Figure 28 Leak at gap between skirting board and ground floor.

Figure 29 Leak at gap between skirting board and ground floor.

Figure 30 Gaps at the junction between the skirting board and the first floor.

Loft Hatch

44 Loft hatches are known to contribute to air leakage. Site observations illustrate that the loft hatches specified by one of the developers (developer D) had been installed in such a way that the hatch was not hinged, it could only be secured on one side and it did not compress the seal fully when it was closed. This was confirmed during a pressurisation test on one of the dwellings where the loft hatch was observed to leak and lift during the test (see Figures 31 and 32). In addition, a number of loft hatches have not been adequately sealed to the ceiling, resulting in air leakage between the loft

hatch frame and ceiling. In one case sealing was made more difficult by the proximity of the loft hatch frame to the wall (see Figure 33).

Figure 31 Leak through poorly sealed loft hatch.

Figure 32 Loft hatch lifting during pressurisation test.

Figure 33 Loft hatch not adequately sealed to the ceiling.

Feedback Material

45 Feedback from Phase 1 of the project will comprise a workshop for each of the developers, making five workshops in total. The workshops will make use of all of the material that has been gathered during Phase 1 of the project to provide information and tailored advice specific to each of the developers.

46 The form of each workshop will be established in conjunction with each developer but, as much as possible, a common pattern will be established. The workshops will be around a half day's duration and will make use of data, notes photographs and video recordings collected during Phase 1 to provide feedback and advice. A two-way dialogue will be facilitated to allow feedback from the developers back to the research team. The workshops will be recorded in note form and a report provided to each developer on the main outcomes.

47 The workshops will take place at the developer's offices. It is proposed that those present will include representatives from senior management, site management and operative supervision. The attendees at each workshop may vary for each developer and will be dependent upon the structure of the organisation and availability of personnel. However, it is expected that the participants will include someone from the design team, the site manager or assistant manager from the site tested, the technical director for design and development or similar, a regional director, and if possible a number of trade supervisors and site operatives.

48 Prior to the workshop, the developer's team will be presented with a copy of the design assessments and the pressurisation test report for their site. This will enable them to gather their thoughts and to investigate any of the issues raised in the reports prior to attendance at the workshop.

49 The workshops will include the following activities:

a) The workshop will begin with a presentation from the research team which will include the following information:

- Details of the pressurisation tests, how they are undertaken, why they are undertaken, their importance with regard to energy performance of dwellings and the airtightness requirements of the current Building Regulations and expected changes to the Building Regulations with respect to airtightness.

- Airtightness results for the developer in question. The results will be compared against those for the rest of the tested cohort, the UK mean and Building Regulation requirements.
- Precise details of the leakage paths and construction issues observed on site will be outlined.

b) A discussion of the results will then follow. This will take the form of directed questioning with opportunities for brainstorming using simple idea generation techniques if thought necessary.

- The developer's team will be asked whether they agree with the findings of the survey and whether what was observed was typical practice for the developer in question.
- The developers team will be asked to identify what changes could be put in place to address the issues raised in specific areas such as dwelling design, availability/completeness of drawings, Robust Details, planning/sequencing, quality of components, quality control, workmanship, site management and training. If considered appropriate, some of these issues could be observed first hand on the site.

c) Finally the developers will be asked to agree to a plan of action that seeks to improve the airtightness performance of their dwellings. It is hoped that this will include the developers agreeing to an informal airtightness target for the dwellings that will be tested as part of Phase 3 of the project.

50 A draft agenda for the workshops can be found within Appendix 1.

Conclusions

51 The failure of the majority of the tested dwellings to achieve the required airtightness target under ADL2002 of 10 $m^3/(h.m^2)$ raises questions about the effectiveness of Robust Details in its current form as a method for achieving compliance with airtightness requirements. The poor performance of the dwellings could be attributable to range of factors. These might include a lack of understanding of Robust Retails, poor quality control of Robust Details on site, poor communication of the importance of Robust Details, poor inherent design for airtightness, a lack of adequate training, lack of necessary details on drawings or difficulties in achieving current Robust Details in practice (so called 'buildability'). Such concerns should feed into the development of Robust Details for the 2005 review of Part L.

52 It may be concluded on the basis of the admittedly small data set, that the airtightness of UK dwellings has not improved since the introduction of ADL2002. If anything, the data suggest that performance has actually worsened when compared with the existing UK housing stock. If these results are a true reflection of the airtightness of UK dwellings currently being built then it could have serious implications for the industry and its preparedness for the proposed changes to Part L. Some of the issues that need to be addressed would include areas such as training, quality control and building design. The next stages of this project will give more focus on these issues.

53 A number of common air leakage paths were observed within the dwellings tested. It is suggested that some relatively simple measures and procedures could be adopted by the developers that would address a number of these leakage paths. Such measures would include sealing all visible and hidden service penetrations using an appropriate sealant, sealing between the skirting board and floor, and ensuring that continuous ribbons of adhesive are used at the perimeter of plasterboard.

54 This report not only reveals a wealth of problems at the level of individual details, but also problems at the strategic and conceptual levels. The latter manifest themselves through sequencing problems that make it difficult or impossible to seal around services and at junctions in construction and through defects that suggest that the workforce does not understand why it is being asked to do certain things. The 'catalogue of details' approach to providing advice on airtightness does not address process or conceptual issues.

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Appendix 1

Workshop agenda

Draft Feedback Workshop Agenda

1. Welcome
2. General Introduction to Airtightness of Dwellings and Testing Procedures
3. Presentation of Airtightness Results for Developer ’x’
4. Presentation of Site Survey Results for Developer ’x’
5. Discussion of Results
6. Brainstorm Solutions
7. Agree Plan of Action
8. Additional Feedback to Research Team and Comments