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

AIRTIGHTNESS OF BUILDINGS — TOWARDS HIGHER PERFORMANCE

Interim Report D7 — Design Assessments

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

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Interim Report D7 — Design Assessments

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Executive Summary

1 This report reviews the progress that has been made on assessing the design drawings and the site survey data that have been obtained for the selected sites that are participating in Phase 3 of the project and reports on the interim results.

2 Drawings for Phase 3 of the project have been received from all five developers. Design assessments have been undertaken for all of the 26 selected dwellings and site surveys have commenced on 11 of these dwellings. Four of the dwellings selected from developer D have been completed and pressure tested.

3 The main points that have been obtained from the drawing assessments are as follows:

a) All of the developers have made design changes to the dwellings that are participating in Phase 3 of the project, following feedback from the research team.

b) The developers did not feel able to make significant design changes to the house types and the design drawings that are participating in Phase 3 of the project, the time and cost of this process being the prohibitive factors. Consequently, the submitted drawings suffer from the same limitations as those that were assessed during Phase 1 of the project (see Johnston, Miles Shenton and Bell, 2004). For instance, the way in which information on air leakage is presented on the drawings varies considerably between the developers, the drawings do not contain an explicit air leakage target, none of the drawings makes reference to a higher air leakage rate than that which is contained within Approved Document Part L1, the drawings do not identifies the location of the air barrier, there is no continuity of the air barrier, none of the drawings identify the construction principle that will be used to achieve an airtight building envelope and although some of the drawings identify areas where attention to detail is required to achieve airtightness, they do not state how this will be achieved on site.

c) It appears that due to the small number of dwellings involved in this phase of the project, any changes to the dwelling designs appear to have been communicated to the site via informal means, predominantly verbally or in note/memorandum form. Although appropriate for this project, such an approach is unlikely to be successful if various airtightness measures are to be replicated on a national scale.

Introduction

4 This report is milestone D7 — Design Assessments of Communities and Local Government Project reference CI 61/6/16 (BD2429) *Airtightness of Buildings — Towards Higher Performance* (Borland and Bell, 2003). The aim of this report is to summarise the progress that has been made on assessing the design modifications that have been made for the dwellings to be studied during Phase 3 of the project (task 2.3.1 of the project proposal). It also presents the results of the pressurisation tests and the feedback seminars that were outstanding from milestone D6 — Seminars and Developer Feedback (Johnston, Miles-Shenton and Bell, 2005).

Summary of Progress to Date

5 Site surveys for Phase 1 of the project have been completed for all 25 of the selected dwellings (four from developer B, five from developers A, C and D and six from developer E).

6 All of the dwellings selected for Phase 1 of the project have been pressure tested.

7 Feedback and guidance seminars reporting on Phase 1 of the project have been undertaken with all five developers.

8 Five dwellings have been selected from developers A, B, C and D, and six from developer E (26 dwellings in total) to participate in Phase 3 of the project. Drawings have been received from the developers for all but one of the dwellings.[1]

9 Design assessments have been completed for all of the selected dwellings. Site surveys have been commenced on 11 of the 26 selected dwellings (five from developers C and D and one from developer B).

10 Pressurisation tests have been completed on four of the Phase 3 dwellings from developer D.

Update on the Pressurisation Test Results

11 This section presents the results of the two remaining pressurisation tests from developer E (dwellings EC301 and EC302) that were not previously reported in milestone D6 — Seminars and Developer Feedback (Johnston, Miles-Shenton and Bell, 2005).

12 The air permeability results for dwellings C301 and C302 are shown in Table 1. The mean air permeability results for all of the dwellings that participated in Phase 1 of the project are illustrated in Figures 1 and 2 and Tables 2 and 3.

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	
EC301	5.53	0.999	4.97	0.995	5.25
EC302	7.46	0.995	7.38	0.997	7.42

Table 1 Mean air permeability of the dwellings EC301 and EC302.

[1] New drawings have only been submitted for those dwelling types that had not previously been assessed during Phase 1 of the project. The remaining dwellings have been assessed using the drawings submitted for Phase 1.

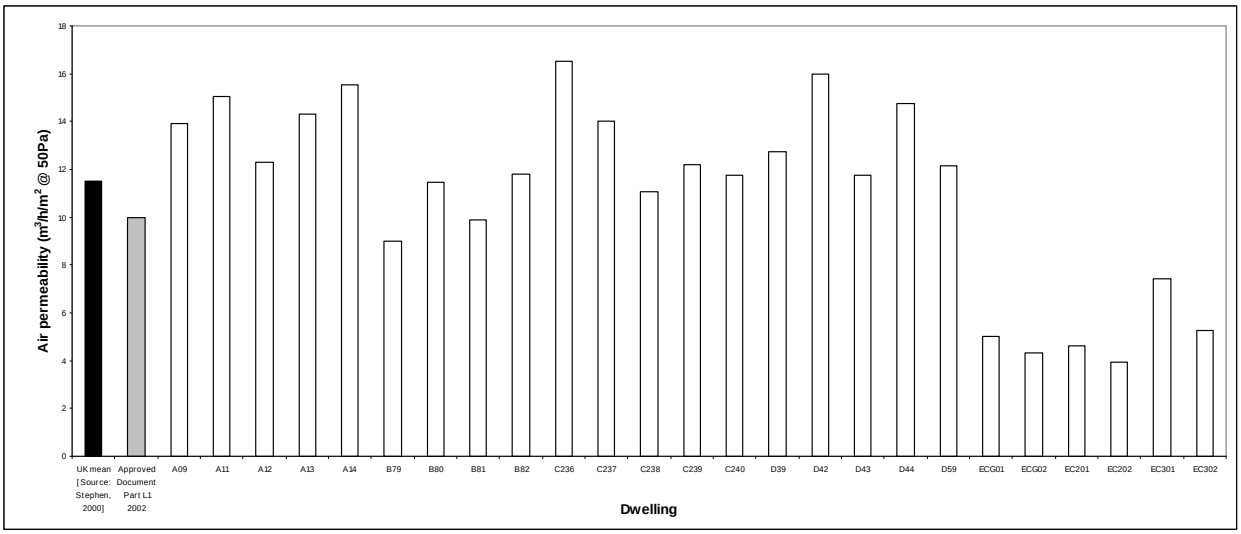

Figure 1 Mean air permeability of the tested dwellings.

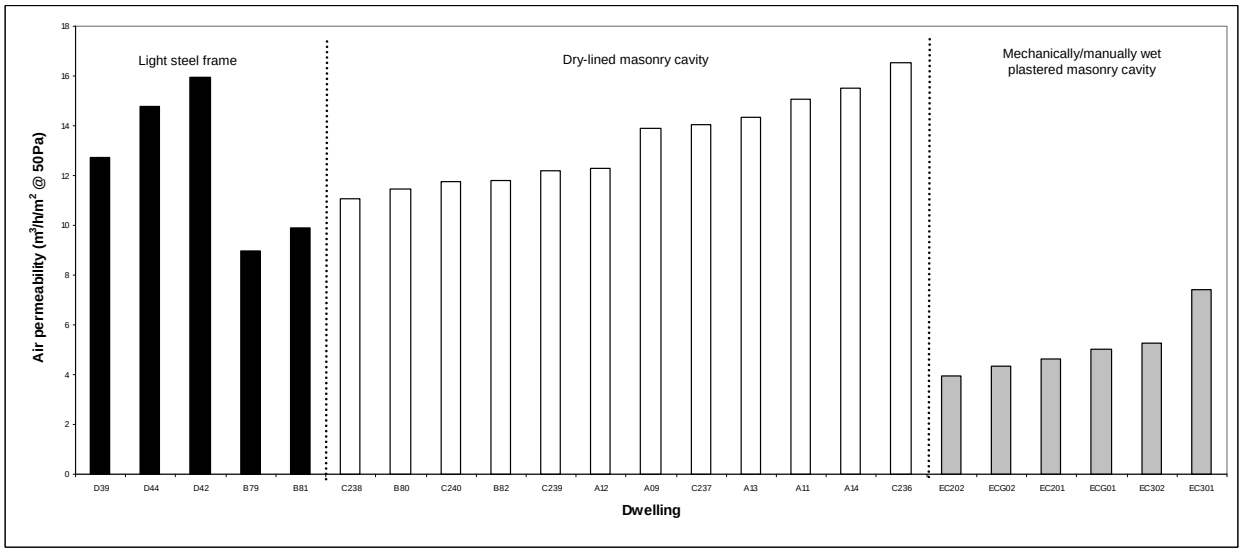

Figure 2 Mean air permeability of the tested dwellings by construction type.

Developer	Mean permeability of all dwellings tested to date ($m^3/(h.m^2)$)
A	14.2
B	10.5
C	13.1
D	13.5
E	5.1

Table 2 Mean air permeability by developer.

Construction type	Mean permeability of all dwellings tested to date ($m^3/(h.m^2)$)
Wet plastered masonry cavity (Developer E)	5.1
Dry-lined masonry cavity (Developers A, B and C)	12.6
Light steel-frame (Developer D)	13.5

Table 3 Mean air permeability by construction type.

13 The air permeability results for dwellings EC301 and EC302 are slightly higher than those that were recorded for the other apartments constructed by developer E. The reasons for the slightly higher air leakage can be attributed to a number of air leakage paths that were particular to these apartments. As top-floor apartments, both had a traditional ventilated timber roof construction rather than a concrete intermediate floor above; leakage particular to these dwellings was observed through and around the mezzanine storage deck and increased air movement through the wall/floor junctions and ceiling service penetrations was also detected. The net effect of these two results is an increase in the mean air permeability for developer E from 4.5 $m^3/(h.m^2)$to 5.1 $m^3/(h.m^2)$ @ 50Pa.

Update on the Feedback Seminars

14 This section reports the results of the feedback seminars undertaken with developers C and E that were not previously reported in milestone D6 — Seminars and Developer Feedback (Johnston, Miles-Shenton and Bell, 2005).

15 Feedback and guidance seminars have been undertaken with the two remaining developers (developers C and E). The developers' response to these seminars was very positive. The main points arising from these seminars are summarised as follows:

d) Both developers displayed only a notional understanding of airtightness, with a lack of in-depth knowledge in a number of areas:
   - The importance that airtightness has with regard to the energy performance of buildings.
   - How air permeability is measured.
   - The difference between air infiltration and natural ventilation.
   - Many of the factors known to influence airtightness.
   - The location of the main air leakage paths within UK dwellings.
   - The difference between direct and indirect air leakage paths.
   - How air leakage paths can be detected.

e) Both developers agreed with the findings of the site observations, the pressurisation tests and the leakage identification work. They also agreed that what had been observed on site was generally typical of their construction practice nationally.

f) Observations from site highlighted a number of construction issues that could potentially affect the eventual airtightness performance of the selected dwellings. For developer C, these issues related to the dry-lining; the built-in joists; the blockwork; the wall, floor and roof junctions; the ground and intermediate floors; the windows and doors; the loft hatches and service penetrations. For developer E, significantly fewer construction issues were observed on site, even though they appeared to have a similar level of understanding of airtightness issues as all of the other developers. The reasons for the difference were felt to be attributable to a higher build quality coupled with the adoption of an intrinsically more airtight method of construction, namely: the use of a mechanical/wet plaster internal finish and pre-cast concrete intermediate floor slabs. The construction issues that were observed for developer E related to the intermediate floor/wall junction; patio doors; the mezzanine storage deck; the loft hatches and service penetrations.

g) Developer E was particularly pleased with the results of the pressurisation tests, as all of the dwellings that were tested achieved an air permeability significantly lower than the maximum specified level of 10 $m^3/(h.m^2)$ @ 50Pa that is contained within the 2002 edition of the Approved Document Part L1 (ODPM¸ 2001). The dwellings constructed by developer E were also

significantly more airtight than the dwellings constructed by all of the other developers.[2] Although developer E was constructing relatively airtight dwellings by UK standards, they did not seem to understand why their dwellings were performing so well.

h) Neither of the developers had any real understanding of the concept of an air barrier, they were unaware of the construction principle that they were using to achieve an airtight envelope and neither of them had explicitly identified the position of the air barrier on their drawings.

i) Although none of the dwellings tested had an explicit air barrier, both developers were adopting the internal airtight barrier approach by default (developer C was using the dry-lining whilst developer E was using the mechanical/wet plaster finish). The fact that all of the mechanically/wet plastered apartments constructed by developer E achieved air leakage values less than 10 $m^3/(h.m^2)$ @ 50Pa appeared to be due to a high build quality and the method of internal finish and intermediate floor construction that was chosen, rather than the developers making any conscious effort to build airtight dwellings.

j) Developer C agreed that quality of workmanship and inadequate site inspection were issues that were influencing the level of airtightness obtained on site and both of these issues could and should be improved on site.

16 Both developers were also asked to identify measures that they would undertake during Phase 3 of the project to improve the airtightness performance of their dwellings and to agree to an informal air leakage target. The measures identified and the targets agreed by each developer are illustrated within Table 4. Table 4 also identifies the measures that plan to be undertaken by developer B, which were not previously reported in milestone D6 — Seminars and Developer Feedback (Johnston, Miles-Shenton and Bell, 2005).

Developer	Measures identified	Air leakage target ($m^3/(h.m^2)$ @ 50Pa)
B	Staged approach adopted. Four identical semi-detached dwellings chosen. Various measures undertaken on each dwelling for comparison: - One to be built as standard.[3] - One to be built as standard with all apertures to external walls filled. - One to be built as standard with all light fitting cables through pattresses and all switch boxes, heating cable boxes and pipes penetrating external walls sealed at plaster stage. - One to be built as standard with all external walls parged prior to them being dry-lined.	To be confirmed.
C	Staged approach adopted. Block of four terraced dwellings chosen. Various measures undertaken on each dwelling for comparison: - Parging coat to be applied to one mid- and one end-terrace. - Other mid- and end-terrace to be built as standard. Greater attention to workmanship on all dwellings.	To be confirmed.
E	Address a number of detailing issues, namely: around the patio doors; the mezzanine decking in the top-floor flats; the cylinder tank ceiling and look at measures to reduce air leakage around/through the service risers.	To be confirmed.

Table 4 Measures identified and agreed air leakage targets for developers B, C and E.

[2] Part of this difference may be attributable to the built form of the dwellings that were being constructed by developer E. Developer E was the only developer constructing apartments. Apartments tend to be more airtight than other dwelling forms of equivalent area as they are more likely to have solid intermediate floors, fewer doors and window openings and fewer service penetrations.

[3] In this case, 'as standard' refers to the same specification as those dwellings that participated in Phase 1 of the project.

Design Assessments

17 This section summarises the progress that has been made to date on the design assessments and presents the interim results. Details of the dwellings that are participating in this phase of the project are set out in Table 5

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 2-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 	• A 2-storey 4 bedroom detached property with an internal floor area of 85 m^2. • A 2-storey 4 bedroom detached property with an internal floor area of 124 m^2. • A 2-storey 4 bedroom detached property with an internal floor area of 108 m^2. • A 2-storey 3 bedroom detached property with an internal floor area of 93 m^2. • A 2-storey 4 bedroom detached property with an internal floor area of 117 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 5 Details of selected dwelling types for Phase 3 of the project.

18 As previously mentioned, drawings have been received from all five developers and design assessments have been undertaken on all of the 26 selected dwellings.

19 The main points that have been obtained from the completed design assessments can be summarised as follows:

a) Following detailed feedback from Phase 1 of the project, all of the developers have made design changes to the dwellings that are participating in Phase 3 of the project.

b) A variety of approaches to improving the airtightness of the dwellings participating in Phase 3 of the projected have been adopted by the developers. Due to the design costs involved, no substantial design changes have been made to the design documentation used on site. Consequently, the submitted drawings suffer from the same limitations as those that were assessed during Phase 1 of the project (see Johnston, Miles-Shenton and Bell, 2004). These were as follows:

- Considerable variation in the way in which the information relating to air leakage is presented.
- None of the drawings contains an explicit air leakage target.
- None of the drawings makes reference to a higher air leakage rate than that which is contained within Approved Document Part L1.
- None of the drawings identifies the location of the air barrier or states that it should be continuous around the envelope.
- None of the drawings identifies the construction principle that will be used to achieve an airtight building envelope.
- Although some of the drawings identify areas where attention to detail is required to achieve airtightness, they do not state how this is to be achieved on site.

c) Despite cost limitations, the developers have adopted a number of different approaches to improve the airtightness of their dwellings. Two of the developers have tightened up the existing detailed design approach, whilst the remaining three developers have adopted a staged approach to integrating various airtightness measures enabling a comparison to be made between different airtightness measures at minimal cost. The approach undertaken by each developer is summarised as follows:

- Developer A — Tightening up the existing detailed design approach by placing a focus on workmanship. This will include: holding workshops for key trades; Toolbox training talks aimed at management and subcontractors supervisors; a pre-test inspection checklist; displaying a gallery of unacceptable work in the canteen; regular inspections of work; and addressing sequencing issues.
- Developer B — Staged approach. One of the dwellings to have all the external walls parged based upon some recent results of paring at Stamford Brook in Altrincham (Lowe and Bell, 2001). Remaining dwellings to incorporate a range of measures such as filling all apertures in external walls, installing light fitting cables through pattress boxes and sealing all boxes and pipes that penetrate external walls at plaster stage.
- Developer C — Staged approach. Two dwellings to have all the external walls parged based upon the parging results at Stamford Brook. Remaining dwellings to be built as standard. Greater attention to be given to workmanship on all of the dwellings.
- Developer D — Staged approach coupled with the introduction of new dwelling designs, which should address the issues associated with the slab/wall junction, and the application of the chipboard flooring on site. Greater attention given to workmanship on one dwelling and attempts made to create a continuous air barrier at the external wall and ceiling level on another dwelling.
- Developer E — Tightening up the existing detailed design approach by concentrating effort on a number of areas that contributed to air leakage during Phase 1 of the project. For instance, around the patio doors; the mezzanine decking in the top-floor flats; the cylinder tank ceiling and look at measures to reduce air leakage around/through the service risers.

d) Due to the small number of dwellings involved per developer, any changes to the dwellings design appear to have been communicated to the site via informal means. Although such an approach may be appropriate for this project, it is unlikely to be successful if various airtightness measures are to be adopted on a much larger scale to improve performance overall.

Conclusions

20 This report reviews the progress that has been made in assessing the design drawings that have been submitted for Phase 3 of the project and presents the interim results.

21 An analysis of the design assessments indicates that due to the costs involved, only minor changes have been made to the house types that are participating in Phase 3 of the project. This, coupled with the fact that only small numbers of dwellings are involved in the project, has resulted in the developers choosing not to amend the design drawings associated with these dwellings. The consequence of this is that the drawings submitted for assessment suffer from the same limitations as those that were submitted for Phase 1 of the project. Therefore, any changes to the dwellings design have been communicated to the site via informal means. Although this approach may be appropriate for the small numbers of dwellings selected to participate in this project, this approach is unlikely to be successful if such measures are to be adopted on a much larger scale to improve performance overall.

22 Despite the cost limitations, a number of different approaches have been adopted by the developers for Phase 3. Two of the developers are concentrating efforts on the existing detailed design, whilst the other two are adopting a staged approach which will enable the effect of different airtightness measures to be compared.

References

BORLAND, S. and BELL, M. (2003) *Airtightness of Buildings — Towards Higher Performance.* A Project Proposal to Communities and Local Government Building Regulations Division Under the Building Operational Performance Framework. Project Reference Number CI 61/6/16 (BD2429), Building Sciences Limited, Ardington.

JOHNSTON, D. MILES-SHENTON, D. and BELL, M. (2005) *Airtightness of Buildings — Towards Higher Performance. Interim Report D6 — Seminars and Developer Feedback.* A Report to Communities and Local Government Building Regulations Division Under the Building Operational Performance Framework. Project Reference Number CI 61/6/16 (BD2429), Leeds Metropolitan University, Leeds.

JOHNSTON, D. MILES-SHENTON, D. and BELL, M. (2005) *Airtightness of Buildings — Towards Higher Performance. Interim Report D3 — Assessments of Design and Pilot Site Data.* A Report to Communities and Local Government Building Regulations Division Under the Building Operational Performance Framework. Project Reference Number CI 61/6/16 (BD2429), Leeds Metropolitan University, Leeds.

LOWE, R. and BELL, M. (2001) *Evaluating the Impact of an Enhanced Energy Performance Standard on Load-Bearing Masonry Domestic Construction.* Partners in Innovation — Focus Full Proposal, Leeds Metropolitan University, Leeds.

ODPM (2001) *The Building Regulations 2000 Approved Document Part L1: Conservation of Fuel and Power in Dwellings. 2002 Edition.* Office of the Deputy Prime Minister, London, HMSO.