Air Leakage Test Results for St Nicholas Court (Fieldside Place) Development, York

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TABLE OF CONTENTS

Executive Summary

1. This report details the results of air leakage tests carried out on four dwellings on the York Housing Association development at St. Nicholas Court in York (Fieldside Place) during March 2004. The tests showed that none of the houses achieved the initial target air permeability rate of 3 $m^3/hr/m^2$ and failed to meet the requirements of the revised prototype 2008 standard of 5 $m^3/hr/m^2$. The measured permeability ranged from 7.5 $m^3/hr/m^2$ for the most airtight dwelling to 9.5 $m^3/hr/m^2$ for the least airtight.

Introduction

2. This report details the results of pressure tests carried out on 4 dwellings at the York Housing Association development at St Nicholas Court (Fieldside Place), York on 23rd April 2004. The tests were carried out by Dr Jez Wingfield, Dr David Johnston and Dominic Miles-Shenton of the Centre for the Built Environment, Leeds Metropolitan University. Of the 4 tested dwellings, 3 (Plots 16, 17 and 18) had previously been tested by Building Sciences Ltd on 22nd March 2004 (Borland 2004). These further tests were partly conducted to determine what improvement in airtightness had been achieved following any remedial measures to seal the leakage areas identified.

Building Description

3. Fieldside Place is a social housing development of two single-storey cottages and 16 two-storey three-bedroomed terraced houses being built by Wates Construction for York Housing Association. The houses were designed to achieve an enhanced energy performance standard (EPS08) proposed for 2008 (Lowe, Bell & Roberts 2003). The 4 tested dwellings are all two-storey terraces (Plots 4, 16, 17 and 18 as shown in Figures 1 to 4). The units are constructed with a proprietary panelised timber frame system. This utilises a breathable external sheathing board, cellulose insulation and a 'sterling board' internal sheathing. A breather paper is installed over the internal sheathing with battens installed over to form a 'service' void behind the internal plasterboard finish. A further layer of closed cell rigid insulation is installed over the external sheathing with a timber weatherboard external finish. The ground floor is a suspended beam and block with an insulation layer and reinforced screed over. The first floor is of suspended timber construction. The roof is of traditional tiled pitched design with insulation at ceiling level.

Figure 1 - Plot 4

Figure 2 - Plot 16

Figure 3 - Plot 17

Figure 4 - Plot 18

4. The calculated envelope area for each of the four dwellings tested is 254.48m^2 (excluding the sun room at the front of the house).

Air Leakage Standard

5. A new national standard – TM23 Testing buildings for air leakage (CIBSE, 2000) – has been introduced in the UK, which covers the pressure testing of all buildings. This has been adopted as the test standard for Part L1 of the Building Regulations 2000 (England and Wales), which came into force in April 2002 (ODPM, 2001).

6. Traditionally, the airtightness of dwellings has been expressed as an air leakage rate in air changes per hour (ac/h). However, the Approved Document Part L1 2002 (England and Wales) is written in terms of air permeability, and compliance can be demonstrated by pressure-testing to show that the air permeability does not exceed 10 m^3/hr/m^2 @ 50Pa (although for dwellings a pressure test is not mandatory).

7. TM23 (CIBSE, 2000) defines air change rate and air permeability as follows:

Air change rate:

This is the volume flow rate per cubic metre of building internal volume (ac/h) at a test pressure of 50Pa.

Air permeability:

This is the leakage rate per square metre of building envelope ($m^3/hr/m^2$) at a test pressure of 50Pa. The envelope area taken into account in calculating air permeability is the internal surface area of the external façade, and includes the walls, roofs and the total ground floor area. No deductions are made for partitions or the separating walls with adjacent buildings or garages.

Fan Pressurisation System

8. Fan pressurisation systems are used to quantify the air leakage of the envelope of buildings. The leakiness of the envelope is quantified by connecting a single large fan or a series of fans into an external doorway and pressurising the building whilst measuring the airflow rate required to maintain a pressure difference across the building envelope. The leakier the building, the greater the air flow required to maintain a given pressure differential (in almost all cases a differential of 50Pa is used).

9. The fan system used for this test was an Energy Conservatory Minneapolis Model 3 Blower Door equipped with a DG-3 pressure gauge. All other external doors were kept closed during the test.

10. Tests are normally carried out when the outside wind speed is low to minimise any wind induced pressure variations. Air volume flow rate Q (m^3/s) through the fans is measured by calibrated flow grids over a suitable range of building pressure differentials ΔP (Pa). These are then corrected for internal/external temperature difference, in accordance with TM23. A best-fit power-law profile of the form $Q=C_{env}(\Delta P)^n$ is fitted to the data where both the coefficient C_{env} and exponent n are constants. C_{env} is then corrected for the measured barometric pressure to a specified test pressure of 50Pa, providing C_L. The theoretical leakage rate at 50Pa is then calculated from the formula:

    $Q_{50}=C_L(\Delta P)^n$

11. The air change rate can then be calculated by dividing the air volume flow rate (m^3/hr) through the building envelope at a pressure differential of 50Pa (Q_{50}), by the building volume (V). The result is expressed in terms of air changes per hour (ac/h).

12. To compare the envelope leakage characteristics between buildings of different shapes and sizes, air permeability (Q_{50}/S_T) is normally used. S_T is the total internal surface area (m^2). The result is expressed in terms of m^3 leakage per hour per m^2 of envelope area ($m^3/hr/m^2$).

Test Procedure

13. The mean internal and external temperatures were measured and recorded during the tests. The temperature values recorded were used to standardise the airflow rate through the fan systems to commonly agreed conditions. A further parameter assessed was wind speed. If the estimated wind speed had been too high (i.e. > 3 m/s) the test would not have been carried out.

14. The test procedure consisted of pressurising the dwelling to approximately 60Pa then taking a set of measurements of the building pressure differential and flow rate through the fan. The fan speed was then reduced in several steps and the readings repeated at each of the speed settings. The dwelling was then depressurised, and the test procedure repeated. The result is two sets of measurements; one for pressurisation and one for depressurisation.

15. The following temporary seals and measures were in place at the time of the tests:

    a) The mechanical extract system outlets in the bathroom, toilet and the kitchen were closed.

    b) All the trickle vents were adjusted to the closed position (with the exception of a missing trickle vent on one of the Velux windows in dwelling unit 17).

    c) All water traps and U-bends were filled with water.

    d) All external doors were closed (this included the doors between sun-space and living room).

    e) All internal doors were opened.

Results

Air Permeability

16. The air permeability of the dwellings was determined using Q_{50}/S_T. A summary of the test results is illustrated in Table 1.

Plot Number	Pressurisation Test		Depressurisation Test		Mean Permeability ($m^3/hr/m^2$)
	Permeability ($m^3/hr/m^2$)	r^2 coefficient of determination	Permeability ($m^3/hr/m^2$)	r^2 coefficient of determination	
4	7.64	0.998	7.42	0.999	7.53
16	8.58	0.998	8.14	0.996	8.36
17	9.45	0.999	9.46	0.996	9.46
18	7.95	1.0	7.69	0.999	7.82

Table 1 - Air Permeability Results

17. Graphs showing the test data in the form Pressure Difference ΔP (Pa) versus Air Volume Flow Rate (m^3/s), are illustrated in Figures 5 to 12.

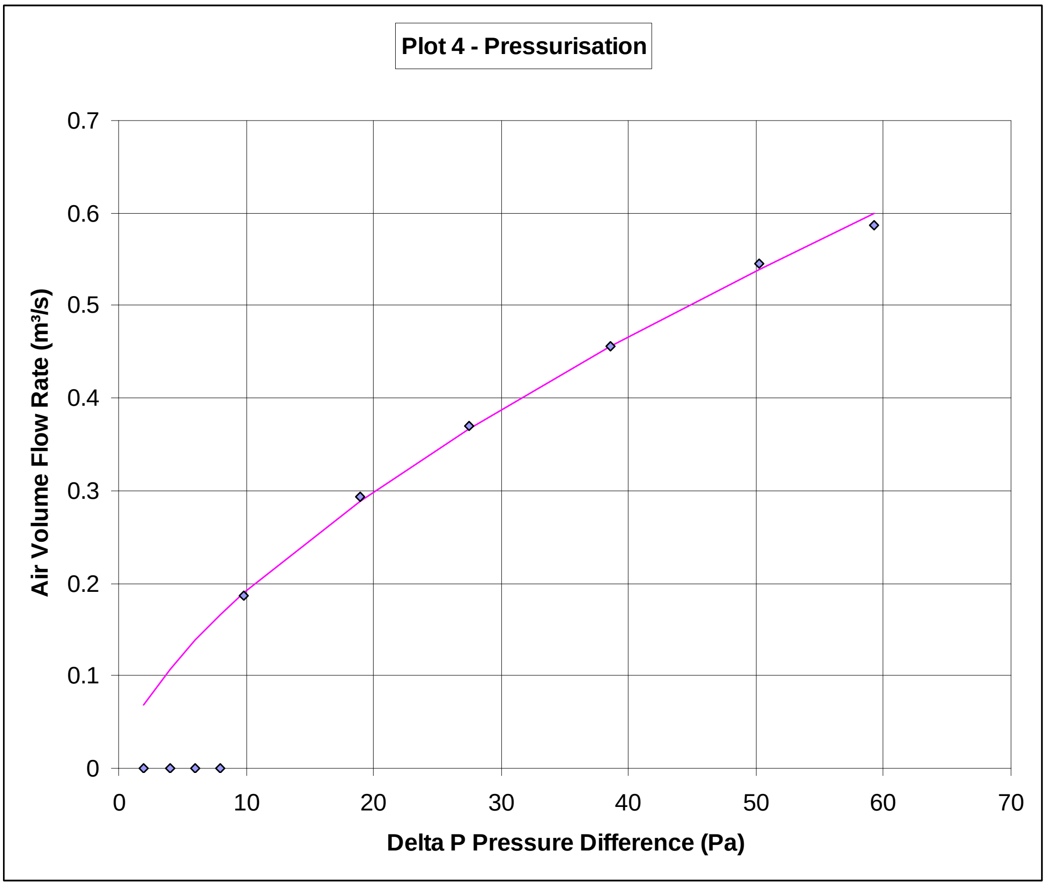

Figure 5 - Plot 4 Pressurisation Graph

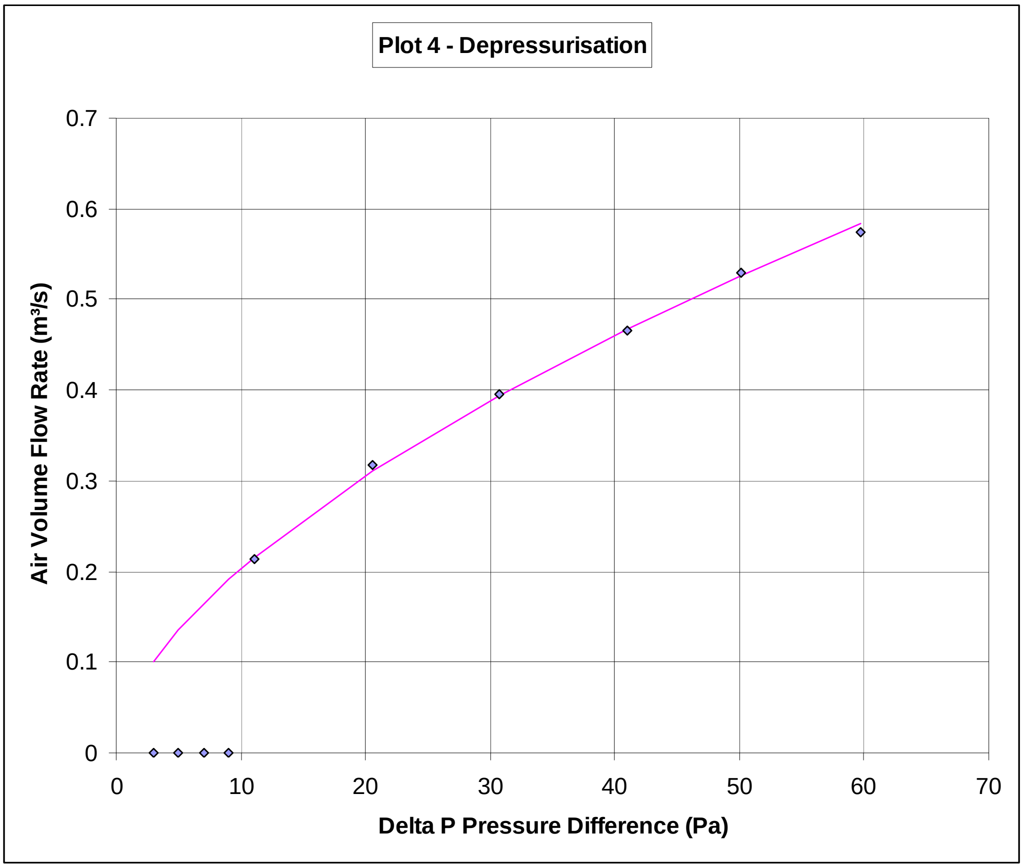

Figure 6 - Plot 4 Depressurisation Graph

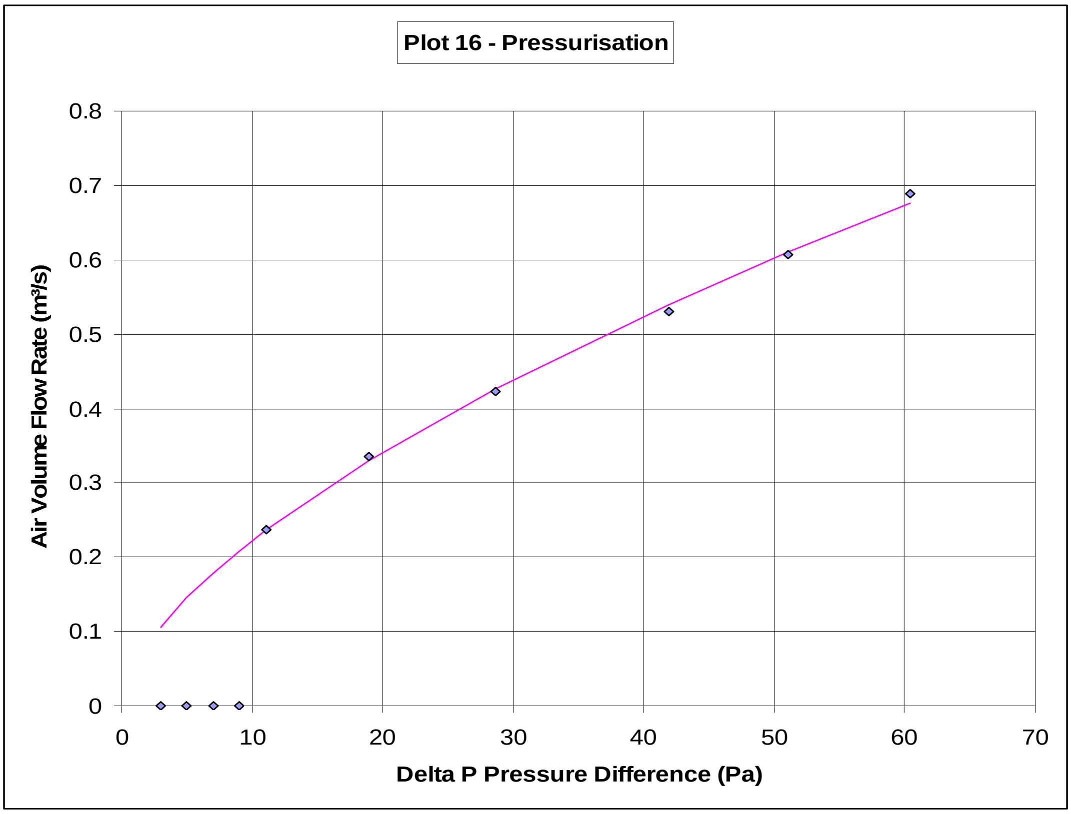

Figure 7 - Plot 16 Pressurisation Graph

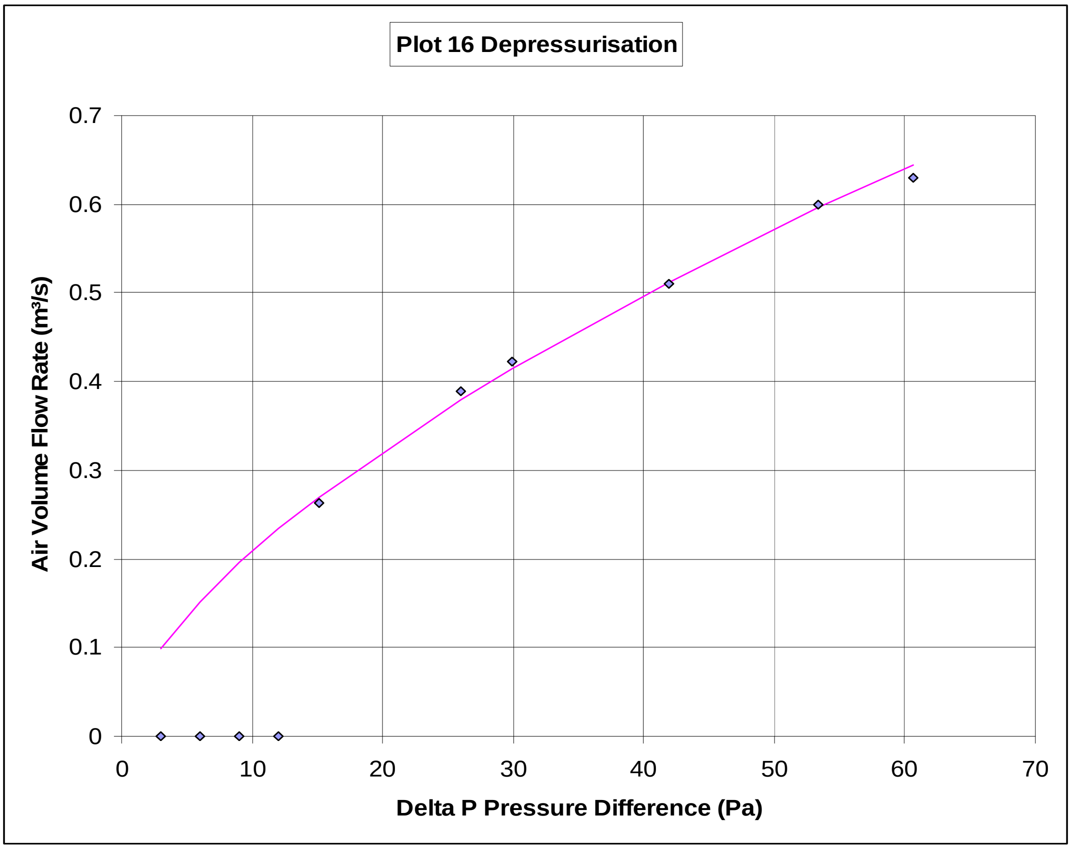

Figure 8 - Plot 16 Depressurisation Graph

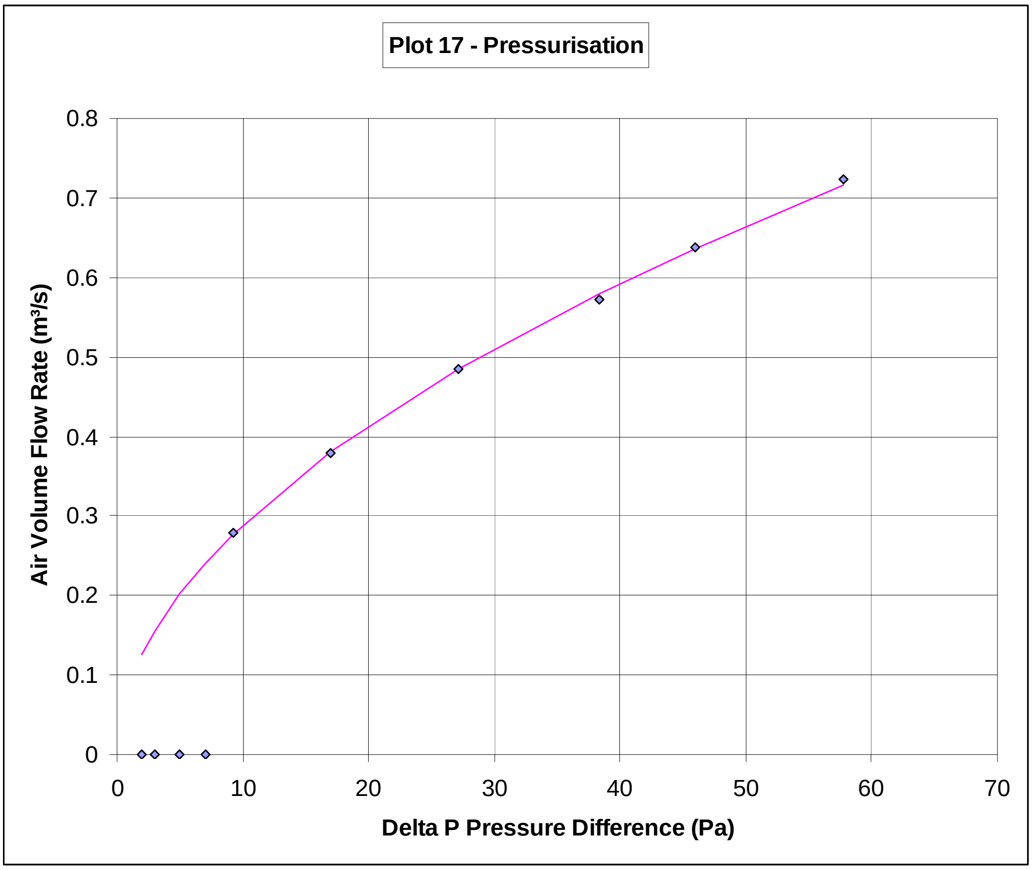

Figure 9 - Plot 17 Pressurisation Graph

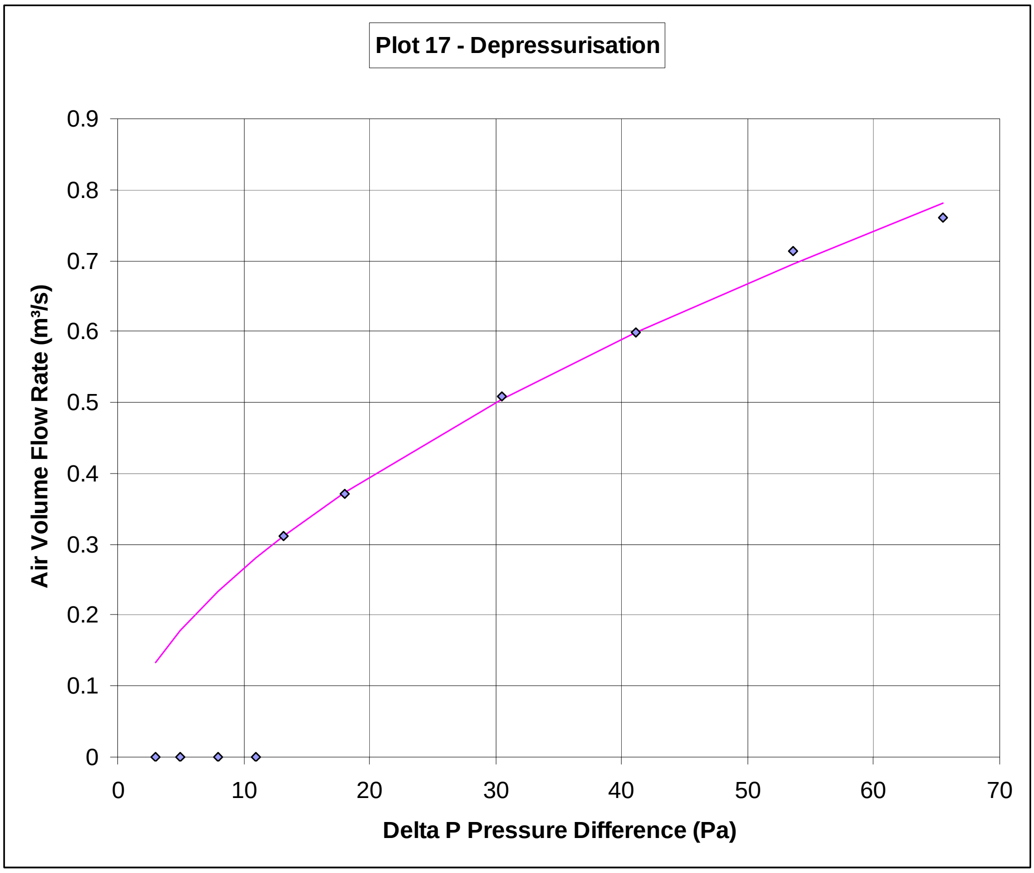

Figure 10 - Plot 17 Depressurisation Graph

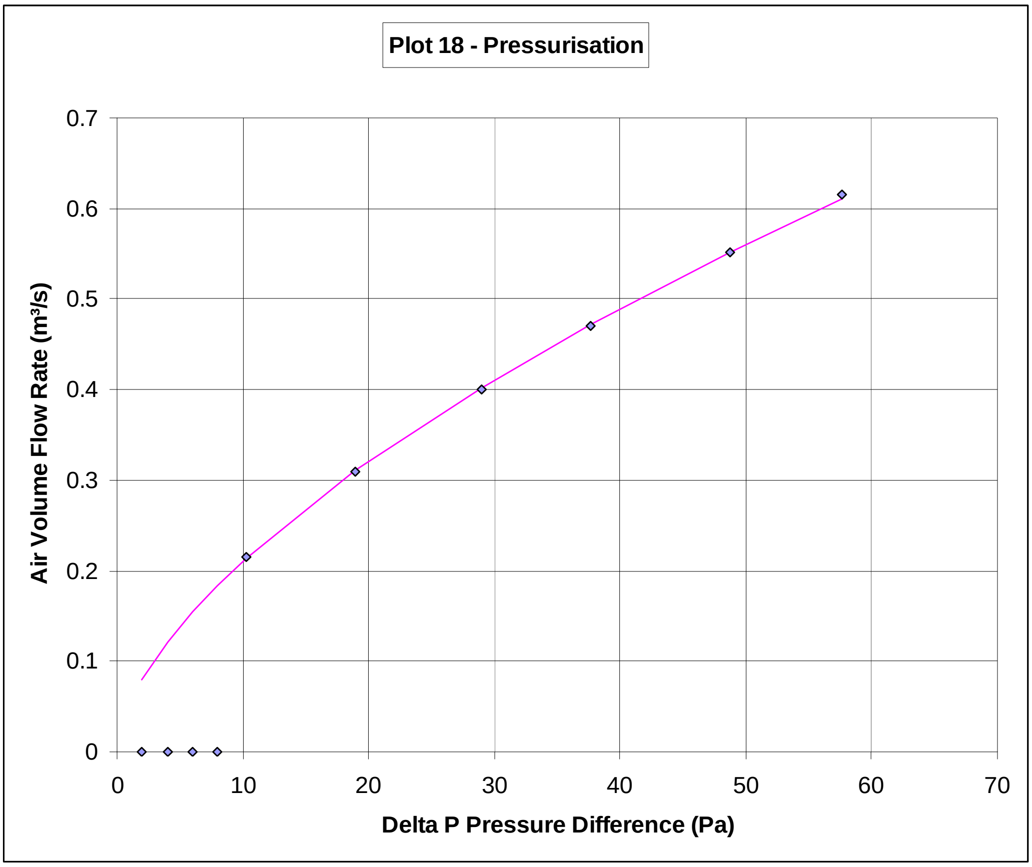

Figure 11 - Plot 18 Pressurisation Graph

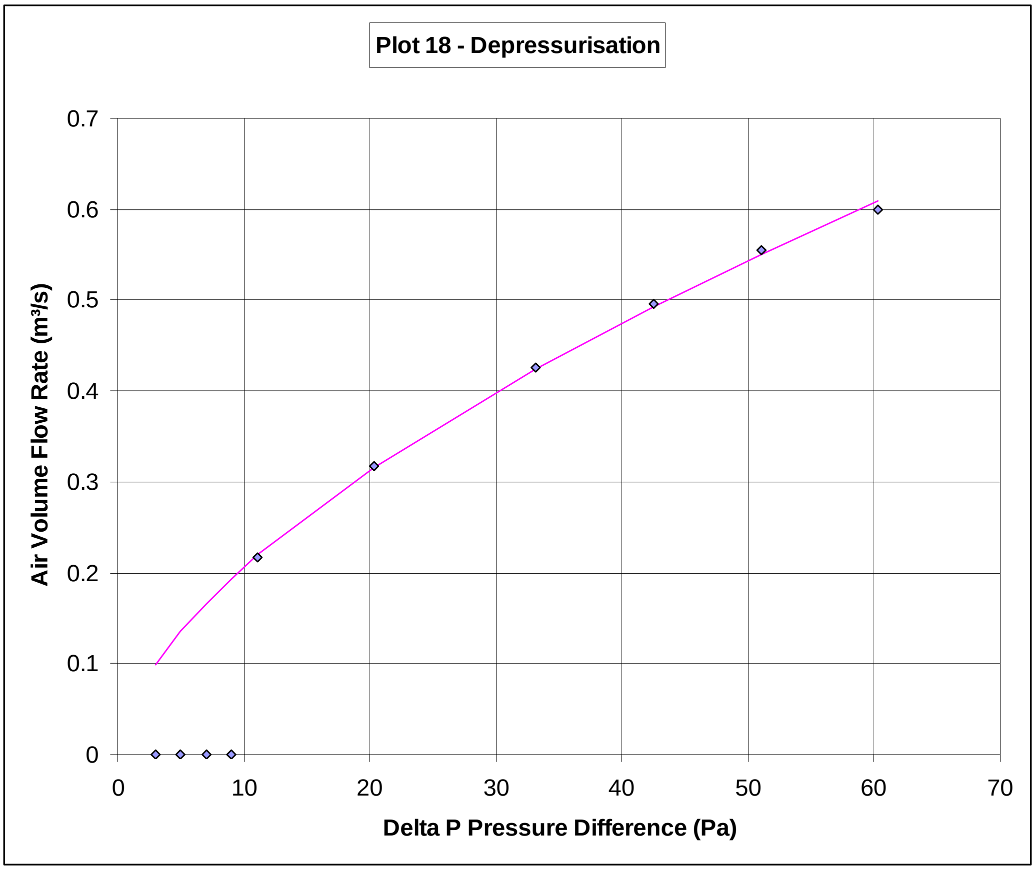

Figure 12 - Plot 18 Depressurisation Graph

Leakage Detection

18. The main air leakage paths within the dwellings were identified by pressurising the building, and locating the main areas of air leakage using hand held smoke generators. All 4 dwellings showed similar leakage paths. It was not possible to quantify the contribution that these leakage paths made to the dwellings overall air leakage. The main air leakage paths observed were as follows:

    a) Service penetrations in kitchen (except plot 4)

Figure 13 - Leak around Sink Outlet Pipe Penetration (Plot 16 kitchen)

b) Service penetrations in downstairs toilet

Figure 14 - Leak around Soil Pipe Penetration in Downstairs Toilet (Plot 17)

c) Service penetrations in bathroom and around bath panel

Figure 15 - Leak around Bath Panel (Plot 16)

d) Joint between Velux window frame and wall

Figure 16 - Leak at Gap between Velux Frame and Wall (Plot 4)

e) Gap between back door and door frame

Figure 17 - Leak around Back Door Frame with Smoke Shown Flowing Outside (Plot 16)

f) Gap between sun-space doors and frame (doors warped)

Figure 18 - Leak at Warped Sun-space Doors (Plot 16)

g) Gap between skirting board and floor

Figure 19 - Leak at Gap between Skirting Board & Floor (Plot 4)

h) Gaps in flooring

Figure 20 - Leak at Gap in Flooring (Plot 4)

i) Around soil vent pipe in boiler cupboard (into floor and into attic)

Figure 21 - Gap around Soil Vent Pipe in Floor of Boiler Cupboard (Plot 17)

j) Through unsealed water pipe penetrations in boiler cupboard

Figure 22 - Unsealed Pipe Penetrations in Boiler Cupboard (Plot 16)

k) Through electrical sockets and cable outlets

Figure 23 - Leak through Electrical Socket (Plot 18)

l) Around loft hatch

Figure 24 - Gap around Loft Hatch (Plot 16)

m) Between frame and window of bedroom window in plot 4

Figure 25 - Leak around Window Frame in Bedroom with Smoke Flowing Outside (Plot 4)

n) Missing trickle vent in Velux window in dwelling 17

Figure 26 - Leak through Missing Velux Trickle Vent/Handle (Plot 17)

o) Gap in mechanical ventilation system pipe work penetration in ceiling

Figure 27 - Leak around Mechanical Ventilation System Pipe Work (Plot 18)

19. Many of the leakage paths had been identified in the previous test (Borland 2004) and have clearly not been remedied. Some attempts were visible in plot 4 (previously untested) to seal some of the problem areas. For example, expanding polyurethane foam had been used to seal around the service penetrations in the kitchen (Figure 28) and sealant had been used to seal the gap between skirting board and floor in the kitchen and downstairs toilet (Figure 29). These factors probably contributed to unit 4 having the lowest air permeability of the dwellings tested.

Figure 28 - Use of Expanding Foam to Seal Service Penetrations in Kitchen of Unit 4

Figure 29 - Sealant used between Skirting and Floor in Kitchen of Unit 4

Discussion

20. The results obtained during this test for units 16, 17 and 18 are contrasted with the results obtained from testing in March 2004 (Borland 2004) as illustrated in Table 2. The results show a reduction in permeability of around 1 $m^3/hr/m^2$ was achieved for each of the dwellings over previous test results. It is probable that this reduction was mostly due to 2^{nd} fix work carried out on the dwellings (such as

replacing sockets and trims) rather than any remedial work (none of which was evident from observation).

Plot Number	Permeability (Pressurisation only) ($m^3/hr/m^2$)	
	BSL Test 22nd March 2004	Leeds Met Test 23rd April 2004
16	9.55	8.58
17	10.86	9.45
18	8.81	7.95

Table 2 - Air Permeability Comparison

21. None of the units tested achieved the target permeability of 3 $m^3/hr/m^2$ which were set for the scheme during the initial design phase or the revised requirements of 5 $m^3/hr/m^2$for the prototype 2008 standard (Lowe and Bell 2001). The failure to meet the target set for the scheme is, perhaps surprising given the considerable attention paid to airtightness in the design process (Lowe et al 2003). This could be due to factors such as:

a) Design changes in the 2-year hiatus between end of the main design phase and actual construction.

b) Cost cutting measures.

c) Lack of awareness on site about the causes of air leakage or training in techniques and control measures for the construction of airtight houses.

d) Lack of site supervision and quality control.

e) No apparent remedial action taken after first set of air leakage tests.

22. In general, there is poor attention to sealing of pipe penetrations. These should be sealed with the use of an appropriate expanding foam or sealant. There are also some significant leaks around door frames and windows (especially Velux) which should be rectified by adjustment, component replacement or sealing. The gap between skirting boards and floor should also be sealed with an appropriate sealant. A sealing strip should be used on the loft hatch and mechanical clips fitted that pull the hatch down onto the seals.

23. Due to the presence of the major leakage paths identified it has not been possible to determine the intrinsic airtightness of the timber frame construction and additional design details used on these dwellings.

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